June 9-14, 2002 Nashua, NH

New England Complex Systems Institute

International Conference on Complex Systems

Chairman: Yaneer Bar-Yam, NECSI

Executive Committee:
Dan Braha, Helen Harte, Ali Minai,
Larry Rudolph, Temple Smith, Gunter Wagner

Program Committee:
Philippe Binder, Dan Braha, Helen Harte,
Sui Huang, Michael Jacobson, Mark Klein, Seth Lloyd,
David Meyer, Ali Minai, Lael Parrott, David Sloan Wilson, Jeff Stock

Logistics and coordination:
Sageet Braha, Cherry Ogata, Russell Luke Evans, Matthew McClellan

Partial Support by the

National Science Foundation
National Institute for General Medical Sciences, NIH

Additional support:

American Institute of Physics, Perseus Press,
University of Chicago Press, World Scientific

http://necsi.org

New England Complex Systems Institute
24 Mt Auburn St., Cambridge MA 02138

International Conference on Complex Systems

June 9, 2002

Dear Conference Participant,

I would like to welcome you on behalf of the New England Complex Systems Institute and the executive committee to this conference on the unity of the study of complex systems. A dramatic change has occurred in the last few years with a much more widespread appreciation for the exciting opportunities that the unified study of complex systems provides. There are many factors contributing to this development including the previous conferences in this series. This conference continues the tradition of solidifying the foundations of the study of complex systems, and demonstrates the excitement of new results in our field.

The Sheraton Nashua in which we are holding this conference is a well designed conference facility and the staff has been very helpful in all the arrangements. A hotel map is attached which indicates the names of rooms:

Wentworth Ballroom - for the main sessions,
Amherst, Bedford, Chesterfield, Hollis Rooms - for some of the breakout sessions
Ashwood Court - for food during breaks
Nashua South Ballroom - for daily lunches
A message board will be placed just outside the Ashwood Court.

We look forward to your participation in future events and activities of NECSI.

Best wishes for a fruitful week,

Yaneer Bar-Yam
President
New England Complex Systems Institute

ADDITIONAL CONFERENCE INFORMATION

Poster Session:

The poster session will be held in the Wentworth Ballroom Conference Center. Posters should be set up during the Monday lunch break (which is 1 hour and 40 min), or session breaks. Posters will be arranged alphabetically by author's last name. A list of abstracts will be posted. Please attend your poster during the opening poster session on Monday evening.

Electronic Mail / Web access:

We are arranging for access to the WWW near the main hotel lobby in the Bristol room, which is in the executive office area. Additional and presumably higher speed access is possible at Kinkos. Ask at the Hotel desk for directions. Coordinate with colleagues for transportation.

Press conferences:

There will be press conferences everyday between 1:20PM and 1:50PM in the Bedford room. Conference participants are invited to participate in these meetings and to be interviewed.

Cell phones, computers, video and audiotaping of the sessions:

Please remember to turn off cell phones, and to limit the use of computers during sessions (if computer use becomes distracting it will be prohibited). The conference sessions will be recorded for the proceedings by the organizers. No other video or audio recording is allowed.

Wednesday Banquet Information:

The banquet is self-supporting and is not included in the registration fee. Please make reservations at the ICCS registration desk as early as possible to ensure seating. The hotel requires 3 days advance notice for seat reservation, which would require notification by Sunday. We will try to fit you in with later notice but cannot guarantee it.

Attendance to the banquet session (Marvin Minsky speaker) is possible without attending the banquet. Please arrive at the stated time to be seated.

Conference tables:

Conference sponsors have been allocated tables in Ashwood Court to display information relevant to their activities. Publishers have books on display for purchase. Please visit these tables for further information.

GENERAL CUISINE

D.B. COOPERS
4 Spit Brook Rd
Nashua
603-888-7746

CHARLEY'S
Pheasant Lane Mall
Nashua
603-891-2060

"99"
10 St. Laurent St.
Nashua
603-883-8781

APPLEBEES
379 Amherst St.
Nashua
603-886-9292

RUBY TUESDAY
275 Amherst St
Nashua
603-882-0099

MARTHA'S
185 Main St.
Nashua
603-883-8781

MICHAEL TIMOTHY'S
212 Main Street
Nashua
603-595-9334

STEAKHOUSE

OUTBACK
440 Middlesex Rd
Tyngsboro, MA
603-649-8700

CHICAGO STEAK ROOM
2 Somerset Pkwy
Nashua
(603) 595-4155

Silo's Steakhouse
641 D.W. Highway
Merrimack
(603) 429-2210

ITALIAN

LUI LUI'S
259 D.W. Highway
Nashua
603-888-2588

VILLA BANCA
194 Main Street
Nashua
603-598-0500

YA MAMA'S
75 D.W. Highway
Merrimack
603-578-9201

SEAFOOD

WEATHERVANE
174 D.W. Highway
Nashua
603-891-1776

AMERICAN LOBSTER
290 Main Street
Nashua
Tel: 603-880-3526

NEWICK'S SEAFOOD
696 D.W. Highway
Merrimack
(603) 429-0262

STEVIE P'S YACHT CLUB
49 Lowell Rd
Hudson
(603) 886-5191

PIZZA

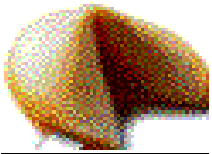
BERTUCCI'S PIZZA HUT
406 Amherst St.
Nashua
603-595-7244

PIZZA HUT
199 D.W. Highway
Nashua
603-888-3553

PIZZERIA UNO
304 D.W. Highway
Nashua
603-888-6980

PAPA GINO
South Gate Plaza
Nashua
603-888-7662

CHINESE



HALUWA
326 Nashua Mall
Nashua
603-883-6662

MING GARDEN
197 D.W. Highway
Nashua
603-888-7228

LILAC BLOSSOM
650 Amherst St.
Nashua
603-886-8420

JAPANESE

TOKYO STEAKHOUSE
166 D.W. Highway
Nashua
603-888-8200

OSAKA TEA GARDEN
295 D.W. Highway
Nashua
603-888-9090

MEXICAN

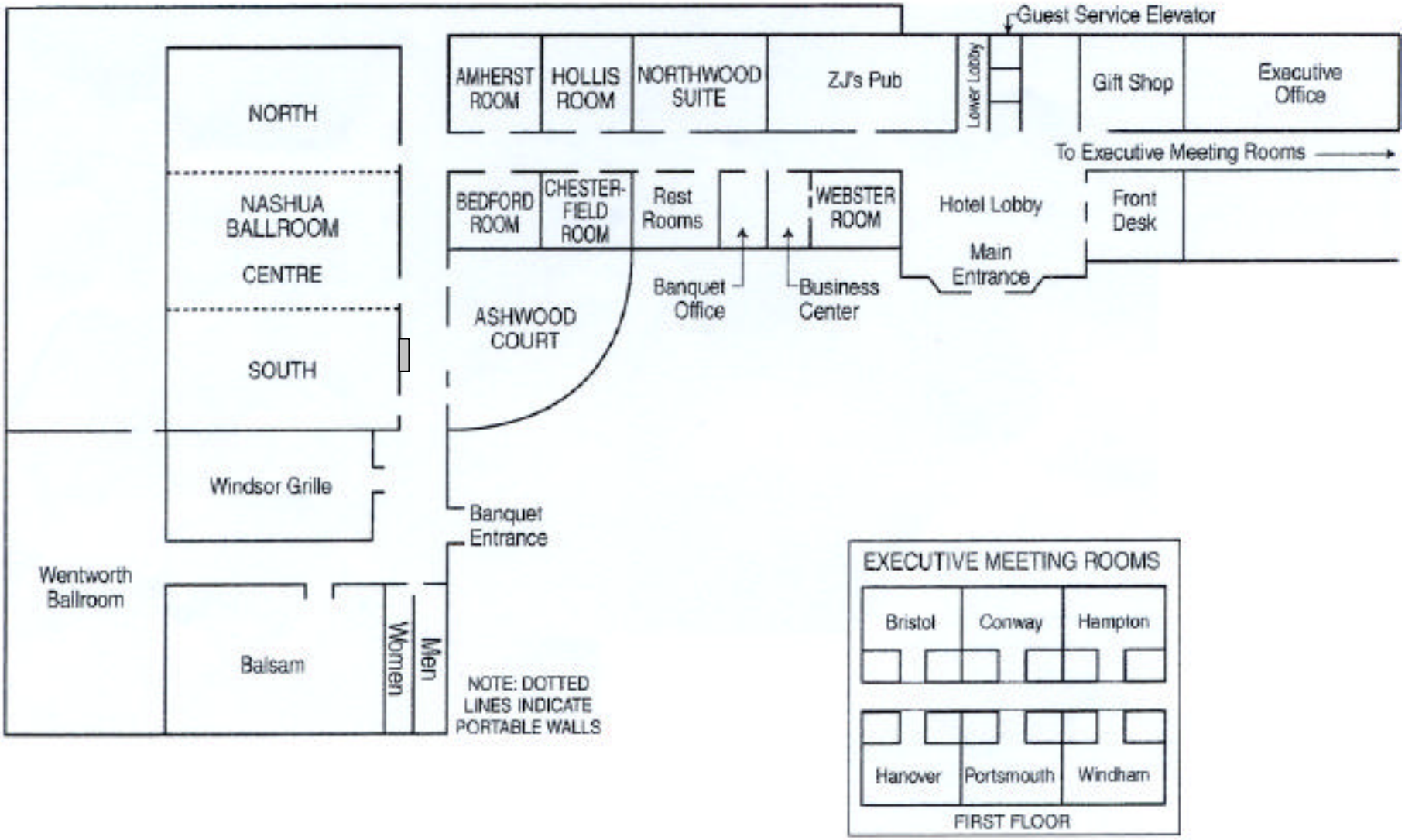
MARGARITAS
1 Nashua Dr.
Nashua
603-883-0996

LA HACIENDA DEL RIO
4 Taggart Drive
D.W. Highway
Nashua
603-888-3353

Shorty's Mexican Road House
328 Nashua Mall
Nashua, New Hampshire 03063-3261
603-882-4070

Reservations recommended for most restaurants

Sheraton Nashua Hotel, 11 Tara Boulevard, Nashua, NH
Phone: (603)888-9970



THIS PAGE INTENTIONALLY LEFT BLANK
PROGRAM BEGINS ON NEXT PAGE

New England Complex Systems Institute

International Conference on Complex Systems (ICCS)

June 9-14, 2002 in Nashua, NH

Conference Program

SUNDAY, June 9

9:00AM-5:00PM PEDAGOGICAL SESSIONS

*ALI MINAI – Pedagogical sessions

StarLogo and SIMP/STEP
*MARK SMITH – Application to Medical Management
*ERIC HELLER – Quantum chaos
*CHARLES BENNETT – Quantum Information Processing
Lunch break
*GREG CHAITIN - Algorithmic complexity
*BUD MISHRA – Biomedical systems
*USAMA FAYYAD - Data Mining
*DAN SCHRAG – Climate Change

5:30PM-6:15PM Reception

6:15PM-7:15PM Special Memorial and Award Session in honor of
Herbert A. Simon and Claude E. Shannon

MONDAY, June 10

8:10AM Continental breakfast

9:00AM-12:20PM EMERGENCE

*IRV EPSTEIN - Welcome / Emergence

*PHILIP ANDERSON - Emergence of Complex Systems
*JOHN STERMAN - Social systems
Break
*DWIGHT READ – Cultural Anthropology
*RITA COLWELL – Biocomplexity

12:20PM Lunch

2:00PM-5:20PM DESCRIPTION AND MODELING

*LARRY RUDOLPH - Description and Modeling

*JOHN CASTI - Agent based modeling
*JEFFREY KEPHART – Agent economies
Break
*SETH LLOYD - Networks
*MITCHELL FEIGENBAUM - Universality and the dynamics of chaos

6:30PM-9:30PM PARALLEL SESSIONS

Thread A:

Biological systems

Molecular and Cellular systems

*BELINDA ORME
*JAIME LAGUNEZ OTERO
*JOSE M. BORREGUERO

Medical

*PARTHA P. KANJILAL, RICHARD R. GONZALEZ & DANIEL S. MORAN
*M.SHIN, A. GOEL & H.LIM

Neural systems

*MICHAL ZOCHOWSKI & L. B. COHEN
*MATTHEW T. DEARING & HAROLD G. CRAIGHEAD
*V. ANNE SMITH

Ecology

*J. C. SPROTT
*JANINE BOLLIGER & *JULIEN C. SPROTT
*LAEL PARROTT

Human environment interactions

*MADHUR ANAND, KE-MING MA, BRIAN TUCKER & RACHELLE DESROCHERS
*NOAH C. GOLDSTEIN

Thread B:

Multiscale ecology & evolution

*ARTURO H. ARIÑO
*NELLI AJABYAN
*IRAKLI LOLADZE
*ROBERT MELAMEDE

Evolution

*ELIN WHITNEY-SMITH
*GUY A. HOELZER
*JOSH MITTELDORF
*KLAUS JAFFE
*BORIS MITAVSKIY

Psychology

*ROBERT K. LOGAN
*OLGA MITINA
*IGOR YEVIN
*CHRIS PHOENIX

Thread C:

Social Systems

Terrorism

*BRUCE SKARIN
*CZESLAW MESJASZ
*PETER A. FLEMMING

Social interactions and Management

*FLAVIO DA SILVA
*ZHANGANG HAN
*RUBEN R. PUENTEDURA
*KWANG WOO PARK
*N. OZTAS, T. HUERTA, R. C. MYRTLE & P. J. ROBERTSON

Economics

*IRINA MANOLESCU & CLAUDIA CIORASCU

Other social

*RAM MAHALINGAM & KANCHANA RAMACHANDRAN
*COLBY BROWN
*DOUG SMITH
*HAJIME YAMAUCHI

Thread D:

Engineering & Management

Data Mining

*SEMIH ONUT & H.IBRAHIM ERDEM
*AUROOP R GANGULY
*VLADIMIR GUDKOV

Intelligent systems

*CELESTINE A. NTUEN
*JACOB BEAL

Networks

*VINOD SUBRAMANIAN, RAJKUMAR ARUMUGAM & ALI A. MINAI
*ROBERT GHANEA-HERCOCK
*ERNEST BARANY
*RON COTTAM, WILLY RANSON & ROGER VOUNCKX
*CHANG-YONG LEE

Thread E:

Physical systems and Formal methods

*ARIEL BALTER
*ARIEL BALTER
*CHRISTOF AEGERTER
*ING-REN TSANG & ING-JYH TSANG
*NATASHA LEPORE
*PAWEL SIWAK
*JOHN MAWEU

Complexity

*ALAN BAKER
*MICHAEL BRETZ
*DOMINIQUE GROSS
*CHRIS DAVIA

9:30PM-10:00PM INITIAL POSTER SESSION

Biological systems

*HIROKI SAYAMA
*CHRIS PHOENIX
*CHRIS DAVIA
*YI ZHOU, ARCHISMAN RUDRA, SALVATORE PAXIA & BUD MISHRA
*ERICH SCHMIDT & STEVEN KLEINSTEIN
*GALINA BUSHUEVA, NADIA KABACHI AND ARNOLD KIV
*CRAIG VAN HORNE
*JUAN CARLOS CHIMAL EGUIA
*JOHN MAYFIELD

Social systems

*ROBERT TINKER, AMY PALLANT & *QIAN XIE
*H. F. CHAU & *F. K. CHOW
*CZESLAW MESJASZ
*WILLIA HARDIN GLOVER
*M. MARKO, *A. PROBST & *A. DAS
*T. R. HUERTA , N. OZTAS, P. J. ROBERTSON
*M. J. NAIDOO
*KONSTANTIN KOVALCHUK
*N. OZTAS, *T. HUERTA, & P. J. ROBERTSON

Engineering

*A. DAS, M. MARKO, *A. PROBST & M. A. PORTER
*C. GERSHENSON, M. A. PORTER, A. PROBST & M. MARKO

Complexity

*CARLOS E. PUENTE
*CARLOS GERSHENSON
*KONSTANTIN L KOUPTSOV

Physical systems & Formal Methods

*MARK R. TINSLEY & *RICHARD J. FIELD
*CARLOS E. PUENTE
*PIERRE SENER
*MD. SHAH ALAM
*JOHN MAWEU
*H. N. MHASKAR

Tools

*EDWARD A BACH

Arts

*MARNE RIZIKA

TUESDAY, June 11

8:20AM Continental breakfast

9:00AM-12:20PM

*JIM KAPUT – Education

*ROBERT DEVANEY – Chaos in the Classroom
*RICARDO NEMIROVSKY – Complexity for Students
Break
*JERRY SUSSMAN - Formalizing Science
*ROBERT SAVIT – Minority game

12:20PM Lunch

2:00PM-5:00PM AFTERNOON PARALLEL BREAKOUT SESSIONS

*MARK KON - Learning Theory

*HRUSHIKESH MHASKAR
*ART WERSCHULZ
*ALAN WAXMAN
*GEORGE CYBENKO
*LEE JONES
*HILLOL KARGUPTA
*MARC PARHAM

*DAVID SLOAN WILSON – Altruism & Modular Systems

*SANJAY JAIN
*JEFF CARPENTER
*GREGORY VELICER
*JOCHEN TRIESCH
*JENNIFER HALLINAN
*RICHARD A. WATSON

- Market and Industry Dynamics

*JEHO LEE
*YURI YEGOROV
*PIERPAOLO ANDRIANI
*DAVID W. PETERSON
*D. CHISTILIN

*NANCY SCHON / DAVE BRITTON - Arts

*PAULA MATTHUSEN
*PHILIP GALANTER
*ELLEN LEVY
*IVAR HAGENDOORN

*RICHARD P. TAYLOR, BRANKA SPEHAR, COLIN W. G. CLIFFORD & BEN R. NEWELL

7:00PM-10:00PM EVENING PARALLEL BREAKOUT SESSIONS

*JEFF CARES, Military Systems

*ALFRED BRANDSTEIN
*RAY CHRISTIAN
*GARY HORNE
*JOHN Q. DICKMANN

*HELEN HARTE – Management

*EVE MITLETON-KELLY
*HAROLD E. KLEIN
*MARY ANN ALLISON
*BRIGITTE FLEEMAN

*SUI HUANG - Bio-medical

*BUD MISHRA
*I. ROUZINE & J. M. COFFIN
*SOLOMON GILBERT DIAMOND
*D. E. CREANGA, E. LOZNEANU & *J. C. SPROTT
*CHRISTOPHER A. SHAW
JAMES HOLLAND JONES

*BRUCE BOGHOSIAN - Patterns in Physical Systems

*EUGENIO DEGROOTE
*JACQUES LEWALLE
*MASAHARU KURODA & FRANCIS C. MOON
*XIANG SAN LIANG & ALLAN R. ROBINSON
*BENJAMIN SKELLETT

WEDNESDAY, June 12

8:20AM Continental breakfast

9:00AM-12:20PM NATURAL AND ENGINEERED SYSTEMS

*ALI MINAI - Natural and Engineered Systems

*RODNEY BROOKS - Robots and beyond
*WILLIAM COTTON – Air Traffic Control
Break
EDWARD LORENZ – Meteorological prediction
*ALLAN R. ROBINSON - Multiscale interactions in the sea

12:20PM Lunch

2:00PM-3:20PM SPECIAL PARALLEL SESSIONS

Session A:
Special talk
*YU-CHI HO - No-Free-Lunch theorem and computer security
Funding
*SUSAN M. FITZPATRICK - McDonnell Foundation
Session B:
Education and Psychology
*IRIS STAMMBERGER
*LEN TRONCALE

*STEVE HASSAN – Mind control

Session C:

Organizations

*ERIC BONABEAU

*EDGAR PETERS - Complexity and Efficient Markets

*KEN O'BRIEN - Organizations

3:30PM-5:00PM AFTERNOON PARALLEL SESSIONS

Thread A:

Education

*MICHAEL J. JACOBSON

*MICHAEL CONNELL

*VAL BYKOSKI

*LEN TRONCALE

*BROCK DUBBELS

Thread B:

Cellular Automata & Dynamical Systems

*ARNOLD SMITH & STEPHANIE PEREIRA

*MATHIEU CAPCARRERE

*HOWARD A. BLAIR

*DOUGLAS E. NORTON

*H. SABELLI, L. KAUFFMAN, M. PATEL & A. SUGERMAN

*ATIN DAS

Thread C:

Urban and Global Change

*ITZHAK BENENSON & EREZ HATNA

*ERIC ALLISON

Networks

*FABRICE SAFFRE

*LASZLO GULYAS

*XUENAN LI

Thread D:

Multi-agent systems

*FRED M. DISCENZO

*IQBAL ADJALI, DAVID COLLINGS & PAUL MARROW

Knowledge Management

*RAJKUMAR ARUMUGAM, VINOD SUBRAMANIAN & ALI MINAI

*JOHN TRIMBLE & HARRY KEELING

*ZANN GILL

6:15PM-7:45PM BANQUET

7:45PM-9:30PM BANQUET SESSION

*MARVIN MINSKY – Society of mind

THURSDAY, June 13

8:20AM Continental breakfast

9:00AM-11:40AM BIOCOMPLEXITY

*TEMPLE SMITH Biocomplexity

*CHRIS JOHNSON - Visualizing biological systems

*BRAD SMITH - NMR Imaging of biological dynamics

Break

*GEOFFREY WEST - Scaling in biology

*ALBERT-LÁSZLÓ BARABÁSI - Scale free networks

12:20PM Lunch

2:00PM-5:00PM AFTERNOON PARALLEL BREAKOUT SESSIONS

*DAN FREY – Complexity in Engineering

*MYLES WALTON
*MARK KLEIN, PEYMAN FARATIN, HIROKI SAYAMA, Y. BAR-YAM
*DAVID WALLACE
*DAVID L. DARMOFAL,
*CARROL V. SIDWELL

*DWIGHT READ - Social Interactions

*ROBERT L. GOLDSTONE & BENJAMIN ASHPOLE
*PEYMAN FARATIN
*KEITH WARREN, ELENA IRWIN, BRIAN ROE & WILLIAM SEAN NEWSOME
*GEORGE J. GUMERMAN, ALAN SWEDLUND, JEFFERY S. DEAN, JOSHUA EPSTEIN & ROBERT AXTELL
*COREY LOFDAHL
*THOMAS J. WHEELER & MARY DOLAN
*JEFFREY C. SCHANK

*ALBERT-LÁSZLÓ BARABÁSI - Games on Networks

*SUI HUANG
*BENJAMIN SHARGEL
*K. JOSEF, J. SARANAK & K. W. FOSTER
*ADRIAN LI MOW CHING, VENUS SHUM & LIONEL SACKS
*DEREK RAINE

7:00PM-10:00PM EVENING PARALLEL BREAKOUT SESSIONS

*ITZHAK BENENSON -- Urban systems

*TAKESHI ARAI & TETSUYA AKIYAMA
*JOANA BARROS & FABIANO J. A. SOBREIRA
*LASZLO GULYAS & YURI MANSURY
*GARY G. NELSON & PETER M. ALLEN
*D. BORRI, G. CONCILIO & E. CONTE
*GULIE BENGUIGUI & DANNY CZAMANSKI

*JASON REDI - Distributed Robots and Computing

*RADHIKA NAGPAL
*MICHAEL HOWARD, REGINA ESTKOWSKI & DAVID PAYTON
*IAN W. MARSHALL, CHRIS ROADKNIGHT & LIONEL SACKS
*SANJAY SARMA
THEODOROS MICHALAREAS

*HIROKI SAYAMA - Evolution

*JANET WILES, JAMES WATSON, BRADLEY TONKES & TERRENCE DEACON
*ERIK RAUCH, HIROKI SAYAMA, CHARLES GOODNIGHT & Y. BAR-YAM
*JOSH MITTELDORF, S. CHANDU RAVELA, ROBERT BELL, DOMINIC L. BOCCELLI, *DAVID H. CROLL & DEVA SEETHARAM
*BURTON VOORHEES
*LUIS MATEUS ROCHA
*DANIEL W. MILLER

*JAMES KAPUT - Complex systems curriculum open discussion

SAINT JOSEPH COLLEGE (Ronald DeGray, Shyamala Raman)
UNIVERSITY OF ALASKA (Cheryl Wright, Kim Peterson, Jerzy Maselko, and Jim Liszka)

FRIDAY, June 14

8:20AM Continental breakfast

9:00AM-5:20PM SPECIAL DAY ON EVOLUTION

*LES KAUFMAN – Evolution

*TERRENCE DEACON - Evolution and mind
*DAVID SLOAN WILSON – Darwin's Cathedral
Break
*JOEL PECK – Sex and altruism
*RAFFAELE CALABRETTA – Modularity
Break and continue over lunch

*CHARLES GOODNIGHT – Evolution

*MIKE WADE: - Gene interactions
*JASON WOLF - Maternal effects
Break
*LISA MEFFERT – Evolutionary bottlenecks
*HIROKI SAYAMA – Beyond the gene centered view

List of presentations [keys in brackets indicate day, time and session]:

ADJALI **[W-Aft-MultiASys] IQBAL ADJALI, DAVID COLLINGS & PAUL MARROW** - Modelling Third Generation Mobile Spectrum Auctions

AEGERTER **[M-Phys] CHRISTOF AEGERTER** - Two-Dimensional Rough Surfaces: Experiments on Superconductors and Rice-Piles

AJABYAN **[M-MultiEcolEvol] NELLI AJABYAN** - Global Stability and Oscillations in the Mathematical Models of Population Interactions With Spatial Heterogenity

ALAM **[P-Phys] MD. SHAH ALAM** - Algebra of Mixded Number

ALLISON **[W-Aft-Urb] ERIC ALLISON** - Self Organization in Cities: Case Studies in Neighborhood Historic Preservation

ALLISON **[Tu-Eve-Mgmt] MARY ANN ALLISON** – On Going Collaborative Feedback

ANAND **[M-HumEnvInt] MADHUR ANAND, KE-MING MA, BRIAN TUCKER & RACHELLE DESROCHERS** - The Evolution of Complexity in Natural and Reconstructed Ecological Assemblages

ANDRIANI **[Tu-Aft-MktIndDyn] PIERPAOLO ANDRIANI**

ARAI **[Th-Eve-UrbSys] TAKESHI ARAI & TETSUYA AKIYAMA** - A CA Based Two-Stage Model of Land Use Dynamics in Urban Fringe Area

ARIÑO **[M-MultiEcolEvol] ARTURO H. ARIÑO** - Optimal Sampling For Complexity In Soil Ecosystems

BACH **[P-Tools] EDWARD A BACH** - SIMP/STEP: A Platform for Fine-Grained Lattice Computing

BAKER **[M-Cx] ALAN BAKER** - Philosophy and Complexity

BALTER **[M-Phys] ARIEL BALTER** - Levy Flights in Climate Data

BARANY **[M-Net] ERNEST BARANY** - Dynamics of Ethernet Protocol

BEAL **[M-IntelSys] JACOB BEAL** - Themes: Emergence, Self-Organization; System Categories: Psychological, Engineered

BLAIR **[W-Aft-CADynSys] HOWARD A. BLAIR** - Unifying Discrete and Continuous Dynamical Systems

BOLLIGER **[M-Ecol] JANINE BOLLIGER & JULIEN C. SPROTT** - A Case Study for Self-Organized Criticality in Landscape Ecology

BONABEAU **[W-Spec-Org] ERIC BONABEAU** - Co-Evolving Business Models

BORREGUERO **[M-MoleCelSys] JOSE M. BORREGUERO** - Fluctuation Analysis in the Transition State Ensemble of the SH3 Domain

BORRI **[Th-Eve-UrbSys] D. BORRI, G. CONCILIO & E. CONTE** - Managing Urban Traffic Dynamics by a Multi-Agent DSS

BRANDSTEIN **[Tu-Eve-MilSys] ALFRED BRANDSTEIN** - The Role of Analysis in the Brave New World

BRETZ **[M-Cx] MICHAEL BRETZ** - Emergent Probability Lonergan's Genetic Model of Knowledge Growth, Development and Decline

BROWN **[M-Soc] COLBY BROWN** - A Graph-Dynamical Model of Transportation Development

BUSHUEVA **[P-BioSys] GALINA BUSHUEVA, NADIA KABACHI & ARNOLD KIV** - Psychology-Physiological Approach for the Analysis of the states Pathology

BYKOSKI **[W-Aft-Edu] VAL BYKOSKI** - Complex Models and Model-Building Automation

CALABRETTA **[Fri-Evol] RAFFAELE CALABRETTA** - An Evo-Devo Approach to Modularity of Mind

CAPCARRERE **[W-Aft-CADynSys] MATHIEU CAPCARRERE** - Emergent Computation in CA: A Matter of Visual Efficiency

CHAU **[P-SocSys] H. F. CHAU & F. K. CHOW** - How To Avoid Fooling Around In Minority Game

CHIMAL EGUIA **[P-BioSys] JUAN CARLOS CHIMAL EGUIA** - Some Further Analogies Between the Bak-Sneppen Model for Biologcal Evolution and the Spring-block Earthquake Model

CHING **[Th-Aft-GamesNet] ADRIAN LI MOW CHING, VENUS SHUM & LIONEL SACKS** - User and Service Interaction Dynamics

CHISTILIN **[Tu-Aft-MktIndDyn] D. CHISTILIN** - Development and Self-Organization of Complex System. Case of World Economy

CONNELL **[W-Aft-Edu] MICHAEL CONNELL** - Neuroscience and Education--Bridging the Gap

COTTAM **[M-Net] RON COTTAM, WILLY RANSON & ROGER VOUNCKX** - Self-Organization and Complexity in Large Networked Information-processing Systems

CREANGA **[Tu-Eve-BioMed] D. E. CREANGA, E. LOZNEANU & J. C. SPROTT** - Computational Analysis in Temporal Series Describing Kidney Excretory Function

DA SILVA **[M-SocMgmt] FLÁVIO MESQUITA DA SILVA** - Positive Feedback Loops and tracking Principles Applied to Sustainable Community Building: A Case Study

DAS **[P-Eng] A. DAS, M. MARKO, A. PROBST & M. A. PORTER** - Neural Net Model for Featured Word Extraction

DAS **[W-Aft-CADynSys] ATIN DAS** - Nonlinear Data Analysis of Experimental [EEG] data and Comparison with Theoretical [ANN] Data

DAVIA **[M-Cx] CHRISTOPHER J. DAVIA** - Biology, Brains and Catalysis

DEARING **[M-NeuralSys] MATTHEW T. DEARING & HAROLD G. CRAIGHEAD** - Digitally Mapping Cultured Neuron Networks

DEGRAY **[Th-Eve-CxOpen] RONALD DEGRAY & SHYAMALA RAMAN** - Developing a Web-based Interactive Syllabus for an Undergraduate Course in Systems Thinking and Complexity

DEGROOTE **[Tu-Eve-PhysPat] EUGENIO DEGROOTE** - Flame Spreading Over Liquid Fuels: A General Model

DIAMOND **[Tu-Eve-BioMed] SOLOMON GILBERT DIAMOND** - Measuring Hypnosis: Relating Mental State to Systematic Physiological Changes

DICKMANN **[Tu-Eve-MilSys] JOHN Q. DICKMANN** - Complex Systems Research and Information Age Warfare

DISCENZO **[W-Aft-MultiASys] FRED M. DISCENZO** - Managed Complexity in An Agent-based Vent Fan Control System Based on Dynamic Re-configuration

DUBBELS **[W-Aft-Edu] BROCK DUBBELS** - Building a Network to the People

FARATIN **[Th-Aft-SocInt] PEYMAN FARATIN** - A Multiagent Simulation Model of the Emergence and Dynamics of Negotiation in Complex Contracting Games

FLEEMAN **[Tu-Eve-Mgmt] BRIGITTE FLEEMAN** - Sensemaking of a Change Intervention With Insights From Complexity Science

FLEMMING **[M-Terror] PETER A. FLEMMING** - Understanding Patterns of Cyber Terrorism: An Evaluation Research Framework

GALANTER **[Tu-Aft-Arts] PHILIP GALANTER & ELLEN LEVY** - On four modes of artistic engagement with complexity

GANGULY **[M-DataMin] AUROOP R GANGULY** - Hybrid Statistical and Data Mining Approaches for Forecasting Complex Systems

GERSHENSON **[P-Cx] CARLOS GERSHENSON** - Complex Philosophy

GHANEA-HERCOCK **[M-Net] ROBERT GHANEA-HERCOCK** - Co-operative Agents in Network Defence

GILL **[W-Aft-KnowMgmt] ZANN GILL** - Webtank

GLOVER **[P-SocSys] WILLIA HARDIN GLOVER** - An Exploratory Study of Key Factors of Self-Organization in Organizational Systems

GOLDSTEIN **[M-HumEnvInt] NOAH C. GOLDSTEIN** - Co-evolution in Coupled Human-Natural Systems

GOLDSTONE **[Th-Aft-SocInt] ROBERT L. GOLDSTONE & BENJAMIN ASHPOLE** - The Allocation of Agents to Resources in a Networked Multi-Player Environment

GROSS **[M-Cx] DOMINIQUE GROSS**

GUDKOV **[M-DataMin] VLADIMIR GUDKOV** - Multidimensional Network Monitoring for Intrusion Detectio

GUMERMAN **[Th-Aft-SocInt] GEORGE J. GUMERMAN, ALAN SWEDLUND, JEFFERY S. DEAN, JOSHUA EPSTEIN & ROBERT AXTELL** - Evolving Social Complexity in the Prehistoric American Southwest

HAGENDOORN **[Tu-Aft-Arts] IVAR HAGENDOORN** - Emergent Patterns in Dance Improvisation How Complexity Theory Inspires Choreography and Vice Versa

HALLINAN **[Tu-Aft-AltModSys] JENNIFER HALLINAN** - Iterative Diffusion of Vectors for the Detection of Modularity in Complex Networks

HAN **[M-SocMgmt] ZHANGANG HAN** - Evolution of Labor Division For Coopertive Agents With Learnig Abilibty

HASSAN **[W-Spec-EduPsych] STEVEN HASSAN** - A Complex Systems Approach to Countering Brainwashing, Mind Control, and Terrorism

HO **[W-Spec-Special] YU-CHI HO** - The No-Free-Lunch Theorem, Complexity and Computer Security

HOELZER **[M-Evol] GUY A. HOELZER** - On the Relationship Between Natural Selection and Self-Organization

HOWARD **[Th-Eve-RobotComp] MICHAEL HOWARD, REGINA ESTKOWSKI & DAVID PAYTON** - Amorphous Predictive Nets

HUANG **[Th-Aft-GamesNet] SUI HUANG** - Gene network topology and dynamics in mammalian cell fate regulation

HUERTA **[P-SocSys] T. R. HUERTA, N. OZTAS, P. J. ROBERTSON** - Complexity as a unifying paradigm for Organization and Management

JACOBSON **[W-Aft-Edu] MICHAEL J. JACOBSON** - Complex Systems in Education: Integrative Conceptual Tools and Techniques for Understanding the Education System Itself

JAFFE **[M-Evol] KLAUS JAFFE** - On the Modulation of Variance in the Evolution of Complex Systems: Sex in Artificial Life

JAIN **[Tu-Aft-AltModSys] SANJAY JAIN** - Emergence, Growth and Collapse of Cooperative Organizational Structure in Evolving Networks

JONES **[Tu-Eve-BioMed] JAMES HOLLAND JONES**

JOSEF **[Th-Aft-GamesNet] K. JOSEF, J. SARANAK & K. W. FOSTER** - Laboratory Controlled Model System for Study of Complexity Models that Apply to the Signaling Network of a Single Biological Cell

KANJILAL **[M-Med] PARTHA P. KANJILAL, RICHARD R. GONZALEZ & DANIEL S. MORAN** - Characterization of Heat Intolerance Response Through Orthogonal Transformation Based Analysis of Heart Beat Interval Series

KLEIN **[Tu-Eve-Mgmt] HAROLD E. KLEIN** - Designing Organizations to be Responsive to the Complex Changing Environment

KLEIN **[Th-Aft-CxEng] MARK KLEIN, PEYMAN FARATIN, HIROKI SAYAMA & Y. BAR-YAM** - A Complex Systems Perspective on Collaborative Design

KON **[Tu-Aft-Learn] MARK KON**

KOUPTSOV **[P-Cx] KONSTANTIN L KOUPTSOV** - Using a Complex Systems approach to undo Brainwashing and Mind Control

KOVALCHUK **[P-SocSys] KONSTANTIN KOVALCHUK**

KURODA **[Tu-Eve-PhysPat] MASAHARU KURODA & FRANCIS C. MOON** - Local Complexity and Global Nonlinear Modes in Large Arrays of Fluid Elastic Oscillators

LEE **[M-Net] CHANG-YONG LEE** - A Stochastic Dynamics for the Popularity of Websites

LEE **[Tu-Aft-MktIndDyn] JEHO LEE** - Reconsideration of the Winner-Take-All Hypothesis

LEPORE **[M-Phys] NATASHA LEPORE** - Unified Framework for Finding the Eigenstates of Helmholtz Equation Using Boudary Methods

LEVY **[Tu-Aft-Arts] ELLEN LEVY** - Initial Conditions to Final Results in the Complex Systemsof Art and Science

LEWALLE **[Tu-Eve-PhysPat] JACQUES LEWALLE** - In What Sense is Fluid Turbulence a Complex Physical System?

LI **[W-Aft-Net] XUENAN LI** - The Complexity of the Growing Network

LIANG **[Tu-Eve-PhysPat] XIANG SAN LIANG & ALLAN R. ROBINSON** - A Multiscale Interactive Dynamical Analysis for Oceanic Flows Intermittent in Space and Time

LLOYD **[M-Aft-Net] SETH LLOYD** - Bits and Bucks: Modeling Complex Systems by Information Flow

LOFDAHL **[Th-Aft-SocInt] COREY LOFDAHL** - On Trade and the Environment as a Complex System

LOGAN **[M-Psych] ROBERT K. LOGAN** - What the Evolution of Notated Language Teaches Us about the Origin of Speech

LOLADZE **[M-MultiEcolEvol] IRAKLI LOLADZE** - Biological Systems From the Perspective of Chemical Elements: The Simplicity and Rigor of Stoichiometric Approach

LOZNEANU **[M-Phys] E. LOZNEANU & M. SANDULOVICIU** - Cell-Like Space Charge Configurations Formed by Self-Organization in L aboratory

MAHALINGAM **[M-Soc] RAM MAHALINGAM & KANCHANA RAMACHANDRAN** - The Fate of the Girl Child: A Systems Approach to the Evolutionary and Cultural Psychology of Female Infanticide

MANOLESCU **[M-Econ] IRINA MANOLESCU & CLAUDIA CIORASCU** - The Accuracy of Auto-Adaptive Models for Estimating Romanian Firm's Cost of Equity

MARKO **[P-SocSys] M. MARKO, A. PROBST & A. DAS** - Transforming the World Wide Web into a Complexity-Based Semantic Network

MARSHALL **[Th-Eve-RobotComp] IAN W. MARSHALL, CHRIS ROADKNIGHT & LIONEL SACKS** - The Role of Complex Systems in the Management of Pervasive Computing

MATTHUSEN **[Tu-Aft-Arts] PAULA MATTHUSEN** - In Memory of an Anthill: Complexity Theory and Compositional Processes

MAWEU **[M-Phys] JOHN MAWEU** - Self Organized Criticality in State Transition Systems

MAYFIELD **[P-BioSys] JOHN MAYFIELD** - Evolution as Computation

MELAMEDE **[M-MultiEcolEvol] ROBERT MELAMEDE** - Dissipative Structure Based Perspectives on the Origins of the Genetic Code

MESJASZ **[P-SocSys] CZESLAW MESJASZ** - Changing Images of Organization and Development of Information Society

MESJASZ **[P-SocSys] CZESLAW MESJASZ** - How Complex Systems Studies Could Help in Identification and Prevention of Threats of Terrorism

MHASKAR **[P-Phys] H. N. MHASKAR** - When is approximation by Gaussian networks necessarily a linear process?

MILLER **[Th-Eve-Evol] DANIEL W. MILLER** - The Complexity of Homeodynamic Psychophysiological Systems

MITAVSKIY **[M-Evol] BORIS MITAVSKIY** - The Universality of a Slightly Generalized Binary Genetic Algorithm

MITINA **[M-Psych] OLGA MITINA** - The Perception of Fractals: The Construction of Psychometric Function of Complexity and Correlation With Personal Traits

MITLETON-KELLY **[Tu-Eve-Mgmt] EVE MITLETON-KELLY** - Organizational Complexity

MITTELDORF **[M-Evol] JOSH MITTELDORF** - Demographic Homeostasis and the Evolution of Senescence

MITTELDORF **[Th-Eve-Evol] JOSH MITTELDORF, CHANDU RAVELA, ROBERT BELL, DOMINIC L. BOCCELLI, DAVID H. CROLL & DEVA SEETHARAM** - On The Prudent Predator

NAGPAL **[Th-Eve-RobotComp] RADHIKA NAGPAL** - Programmable Self-Assembly and Scale-Independence

NAIDOO **[P-SocSys] M. J. NAIDOO**

NORTON **[W-Aft-CADynSys] DOUGLAS E. NORTON** - Epsilon-Pseudo-Orbits and Applications

NTUEN **[M-IntelSys] CELESTINE A. NTUEN** - Human Interaction With Complex Automation: A Summary of Symposia Outcomes

O'BRIEN **[W-Spec-Org] KENNETH C. O'BRIEN** - Common Sense and Complexity: Harnessing the Science of Complexity for Your Business

ONUT **[M-DataMin] SEMIH ONUT & H. IBRAHIM ERDEM** - Customer Relationship Management in Banking Sector and A Model Design for Banking Performance Enhancement

ORME **[M-MoleCelSys] BELINDA ORME** - Chaos and Mixing in Biological Fluids

OTERO **[M-MoleCelSys] JAIME LAGUNEZ OTERO** - From Physics to Economy via Biology

OZTAS **[M-SocMgmt] N. OZTAS, T. HUERTA, R. C. MYRTLE & P. J. ROBERTSON** - Mapping the Field: Complexity Sciences in Organization and Management

PARK **[M-SocMgmt] KWANG WOO PARK** - Income Distribution Dynamics: Marriage and Informational Cascades

PARROTT **[M-Ecol] LAEL PARROTT** - Can Self-Organisation be Used as a Measure of Ecological Integrity?

PECK **[Fri-Evol] JOEL PECK** - Sex and Altruism

PETERSON **[Tu-Aft-MktIndDyn] DAVID W. PETERSON** - An Adaptive Endogenous Theory of Technological and Economic Growth

PHOENIX **[M-Psy] CHRISTOPHER J. PHOENIX** - A Multi-Level Synthesis of Dyslexia

PHOENIX **[P-Bio] CHRISTOPHER J. PHOENIX** - Control and Complexity Issues in a Proposed Nanomedical Device

POPESCU **[M-Phys] S. POPESCU, E. LOZNEANU & M. SANDULOVICIU** - On the Mystery of the Differential Negative Resistance

PUENTE **[P-Cx] CARLOS E. PUENTE** - More Lessons From Complexity. The Origin: The Root of Peace

PUENTE **[P-Phys] CARLOS E. PUENTE** - Treasures Inside the Bell

PUENTEDURA **[M-SocMgmt] RUBEN R. PUENTEDURA** - Slow and Steady: Deliberately Computationally Inefficient Genetic Algorithms and Hard Problems

RAINE **[Th-Aft-GamesNet] DEREK RAINE** - The Complexity Of Canonical Power Law Networks

RAUCH **[Th-Eve-Evol] ERIK RAUCH, HIROKI SAYAMA, CHARLES GOODNIGHT & YANEER BAR-YAM** - The Relationship Between Measures of Fitness and Time Scale in Evolution

ROBINSON **[Wed-AM-NatEngSys] ALLAN R. ROBINSON** - Data Assimilation for Modeling and Predicting Multiscale Coupled Physical-Biological Dynamical Interactions in the Sea

ROCHA **[Th-Eve-Evol] LUIS MATEUS ROCHA** - Indirect Encoding of Phenotypes in Evolutionary Agents

ROUZINE **[Tu-Eve-BioMed] I. ROUZINE & J. M. COFFIN** - Realistic Model of Cellular Immune Response Against Human Immunodeficiency Virus

SABELLI **[W-Aft-CADynSys] H. SABELLI, L. KAUFFMAN, M. PATEL & A. SUGERMAN** - Bios: Mathematical, Cardiac, Economic and Meteorological Creative Processes Beyond Chaos

SAFFRE **[W-Aft-Net] FABRICE SAFFRE** - RAn (Robustness Analyser)

SAYAMA **[P-Bio] HIROKI SAYAMA, MARCUS A. M. DE AGUIAR, YANEER BAR-YAM & MICHEL BARANGER** - Spontaneous Formation of Isolated Groups and its Effects on Genetic Invasion in Locally Mating and Competing Populations

SCHANK **[Th-Aft-SocInt] JEFFREY C. SCHANK** - Cycle Variability, Follicle Competition, and Female Mate Choice

SCHMIDT **[P-BioSys] ERICH SCHMIDT & STEVEN KLEINSTEIN** - Evaluating Affinity Maturation on NK Landscapes

SENER **[P-Phys] PIERRE SENER**

SHARGEL **[Th-Aft-GamesNet] BENJAMIN SHARGEL** - Optimization of Robustness and Connectivity in Complex Networks

SHAW **[Tu-Eve-BioMed] CHRISTOPHER A. SHAW** - Reverse Engineering Neurological Diseases

SHIN **[M-Med] M.SHIN, A. GOEL & H.LIM** - Radial Basis Function Classification of Microarray Data Using Shin-Goel Algorithm

SIWAK **[M-Phys] PAWEL SIWAK** - Iterons: the Emergent Coherent Structures of IAMs

SKARIN **[M-Terror] BRUCE SKARIN** - A System Dynamics Approach to Understanding Terrorism

SKELLETT **[Tu-Eve-PhysPat] BENJAMIN SKELLETT** - Classical Dynamics of Magnetically Coupled Spins

SMITH **[W-Aft-CADynSys] ARNOLD SMITH & STEPHANIE PEREIRA** - Continuous and Discrete Properties in Self-Replicating Systems

SMITH **[M-Soc] DOUG SMITH** - Order (for free) in the Courtroom: Law as a Complex Adaptive System

SMITH **[M-NeuralSys] V. ANNE SMITH** - Using Bayesian Networks to Reverse Engineer Simulated Songbird Brains

SOBREIRA **[Th-Eve-UrbSys] FABIANO J. A. SOBREIRA & JOANA BARROS** - City of Slums: Self-Organisation Across Scales

SPROTT **[M-Ecol] J. C. SPROTT** - Predator-Prey Dynamics for Rabbits, Trees, and Romance

STAMMBERGER **[W-Spec-EduPsych] IRIS STAMMBERGER** - Contemporary Models of Creative Cognition: an Ethnographic Review of the Impact of Complexity, Evolutionary and Computational Theories

SUBRAMANIAN **[M-Net] VINOD SUBRAMANIAN, RAJKUMAR ARUMUGAM & ALI A. MINAI** - Intelligent Broadcast in Random Large-Scale Sensor Networks

SUBRAMANIAN **[M-Net] VINOD SUBRAMANIAN, RAJKUMAR ARUMUGAM & ALI A. MINAI** - Intelligent Broadcast in Random Large-Scale Sensor Networks

TAYLOR **[Tu-Aft-Arts] RICHARD P. TAYLOR, BRANKA SPEHAR, COLIN W. G. CLIFFORD & BEN R. NEWELL** - The Discovery of Fractals in Jackson Pollock's Paintings: Implications for the Visual Sciences

TINKER **[P-SocSys] ROBERT TINKER, AMY PALLANT & QIAN XIE** - Complex Molecular Simulations in Science Education

TINSLEY **[P-Phys] MARK R. TINSLEY & RICHARD J. FIELD** - Dynamic Instability in Tropospheric Photochemistry: An Excitability Threshold

TRIESCH **[Tu-Aft-AltModSys] JOCHEN TRIESCH** - Towards Understanding Self-organized Information Flow in the Cortex

TRIMBLE **[W-Aft-KnowMgmt] JOHN TRIMBLE & HARRY KEELING** - Coping with Complexity in Knowledge Management

TRONCALE **[W-Aft-Edu] LEN TRONCALE** - Stealth Studies in Complex Systems that Completes Science GE Requirements at Most Universities

TRONCALE **[W-Aft-Edu] LEN TRONCALE** - An Open Source Computer-Based Tool for Research and Education in the Systems Sciences

TSANG **[M-Phys] ING-REN TSANG & ING-JYH TSANG** - Diversity, Cluster Entropy and Complexity on Randomly Occupied Lattices

VAN HORNE **[P-BioSys] CRAIG VAN HORNE** - The Principles of Connectivity, Self-organized Criticality, and Complex Adaptive Systems May Further Our Understanding of the Symptoms and Treatment of Parkinson's Disease

VELICER **[Tu-Aft-AltModSys] GREGORY J. VELICER** - Altruism and Social Conflict in the Bacterium Myxococcus Xanthus

VOORHEES **[Th-Eve-Evol] BURTON VOORHEES** - Virtual Stability as a Conceptual Principle Underlying the Directionality of Evolutionary Processes

WADE **[Fri-Evol] MICHAEL J. WADE** - Gene Interactions

WARREN **[Th-Aft-SocInt] KEITH WARREN, ELENA IRWIN, BRIAN ROE & WILLIAM SEAN NEWSOME** - The Sum of the Parts: Two Studies of Interpersonal Influence on Aggressive Behaviors in Small Group Settings

WATSON **[Tu-Aft-AltModSys] RICHARD A. WATSON** - Compositional Evolution: Evolvability, Modularity, and Symbiosis

WHEELER **[Th-Aft-SocInt] THOMAS J. WHEELER & MARY DOLAN** - Interdisciplinary Conceptual Model Blending

WHITNEY-SMITH **[M-Evol] ELIN WHITNEY-SMITH** - Extinctions and the Evolution of Ecosystems: Systems Dynamics and the end of the Pleistocene

WILES **[Th-Eve-Evol] JANET WILES, JAMES WATSON, BRADLEY TONKES & TERRENCE DEACON** - Evolving Complex Integrated Behaviour by Masking and Unmasking Selection Pressures

YAMAUCHI **[M-Soc] HAJIME YAMAUCHI** - Evolution of Language Universals under Baldwinian Niche Construction

YEGOROV **[Tu-Aft-MktIndDyn] YURI YEGOROV** - The Transitions in Industry, Research and Society: Dynamic Equilibrium Approach

YEVIN **[M-Psych] IGOR YEVIN** - Criticality of the Brain and Criticality of the Art

ZHOU **[P-BioSys] YI ZHOU, ARCHISMAN RUDRA, SALVATORE PAXIA & BUD MISHRA** - Detecting and Modeling Long Range Correlation in Genomic Sequences

ZOCHOWSKI **[M-NeuralSys] MICHAL ZOCHOWSKI & L. B. COHEN** - Optical Imaging of Spatio-Temporal Properties of Odor Evoked Oscillations in the Turtle Olfactory Bulb

ICCS ABSTRACTS: Alphabetically by first author

Iqbal Adjali - *BTexact Technologies*

Modelling Third Generation Mobile Spectrum Auctions. Iqbal Adjali, David Collings and Paul Marrow

Licences for Third Generation Mobile (3GM) spectrum have been auctioned in the UK and other countries around the world. An understanding of the dynamics of the auction design used, and the likely strategies which bidders might have to adopt, was of vital importance to telecom operators who wished to win a licence in these spectrum auctions. There is also increasing interest in auctions in general, born out of the burgeoning Internet-based auction business and the potential use of auctions to sell telecoms bandwidth on the wholesale and even retail markets. Research into auction theory will therefore be of increasing importance to providers of telecommunication services. The UK 3GM Auction used a structure based on simultaneous compulsory bidding in a form of multi-unit ascending auction. The structure is based upon the type of auction used successfully by the US Federal Communications Commission in selling radio spectrum in the United States, but introduces a number of new features which are thought to improve the effectiveness of the auction mechanism. A team from BT with expertise in game theory and complex system modelling applied two techniques to aid the understanding of the UK 3GM Auction. First, they constructed a simulation tool which allowed the modelling of entire auctions, and the analysis of the different outcomes produced by an ensemble of auctions. In this paper results from the simulation tool are presented and compared with the actual auction. The second analysis technique used was the construction of a mock auction tool which could be used to facilitate practise auctions, in order to learn bidding strategies interactively. This tool was used in practise for the auction in training the teams involved in bidding. Here results of the mock auctions are discussed and their effectiveness in preparing for the real auction is analysed. In the final section of the paper the likely role of auctions in telecommunications in a wider context are discussed.

Christof Aegerter - *Vrihe Universiteit Amsterdam*

Two-Dimensional Rough Surfaces: Experiments on Superconductors and Rice-Piles.

The study of the kinetic roughening of interfaces has long been studied in e.g. imbibition systems. These studies were however up to now restricted to a single spatial dimension. We present two new experimental systems, where the roughening process can be studied in two spatial dimensions. In the first case, the surface of a 2d pile of rice is studied and in the second case the magnetic fluxscape in a type-II superconductor is investigated. Furthermore, we discuss some questions arising in the analysis of the structure of such surfaces.

Nelli Ajabyan - *Institute Hydroecology&Ichthyology, NAS Armenia*

Global Stability and Oscillations in the Mathematical Models of Population Interactions With Spatial Heterogenity

This paper presents the investigation of oscillations and nonlinear dynamics of models of ecological systems with spatial heterogeneity. The dynamics of coupled oscillators is proved to be relevant in the study of pattern generation of a biological system. Patterns of Hopf bifurcation, started with Turing model, have been an active subject of research in recent years [1]. The processes of pattern generation in biological systems exhibit universal geometric properties in one hand and a high sensitivity with respect of external parameters on the other hand. The contrast between general geometric properties of generated patterns and their strong dependence on the parameters of a particular process make them a very attractive subject of

theoretical and experimental research. The recognition that the coupling network acts as a filter suggests that it is possible to alter bifurcation scenarios by using different filters in the coupling. It is well acknowledged that the presence of symmetry in a dynamical system will change the generic behavior of that system. This provided credence to the idea of using approximate maps and the concepts of symmetry breaking bifurcation of chaotic attractors in physical experiments [2]. In this paper some global bifurcation phenomena associated with networks of identical oscillators will be reviewed. As an application global bifurcation of phase locked oscillators are applied to the study of migratory affects in predator-prey system. The model of n systems connected with migration flows was studied by Svirezhev Yu M.[3]The study of nonlinear phenomena has applied motivation in providing the concept for some generations of ecological models. To obtain the models that based on more realistic hypotheses about natural system behavior it is possible to lean up on well-known mathematical concepts. A trophic chain with nonlinear functions describing prey-predator interaction is one of the examples of such generalization. The application of the ecological stability concept allows gaining model explanation of some observations and effects that had not interpretation in the frame of existing mathematical theory. Literature cited1. Ashwin P., King C.P., W. Swift. Three identical oscillators with symmetric coupling. Nonlinearity, 3,1990, p581-601. Priented in UK.2. J.C. Alexander G Auchmuty Global Bifurcations of Phase-Locked oscillators . Archive for rational meachanics and Analysis Springer_Verl. Berlin, v. 93, N 3, 1988, p 253-2703. Svirezhev Yu. M. Nonlinear waves dissipative structures and catastrophes in ecology. Moscow, 1987.

Shah Alam - *Shahjalal University of Science and Technology*

Algebra of Mixded Number

Mixed number is the sum of a scalar and and vector like quaternion but the algebra of mixed number is different from that of quaternion. In this paper the details algebra (math tools) of mixed number is explained.

Eric Allison - *Pratt Institute*

Self Organization in Cities: Case Studies in Neighborhood Historic Preservation

While the theory of cities as self organizing entities is documented and acknowledged in both academic and popular writing (Jacobs, 1993; Johnson 2001; Portugali, 2000; Bar-Yam, 1977, nd), there are relatively few case studies documenting actual examples of emergent self organization in cities. This paper describes the self organization which took place in New York City to effect the designation of multiple neighborhoods as historic districts in the last third of the twentieth century. This unexpected emergent behavior is continuing and spreading via formal and informal networks to other cities. In 1965, the Mayor of New York signed into law a bill creating a Landmarks Preservation Commission charged with designating and protecting historic structures in New York City. The newly-created Landmark Preservation Commission could designate both individual buildings and historic districts. The New York City law was the first of its kind in the United States. The Landmarks Preservation Commission, after public hearings, could designate a building or district administratively. The designations took place immediately. They were then submitted to the local legislature to preserve due process. The legislative body originally the Board of Estimate, now the City Council were required to give a yes or no vote within sixty days. The intent was that the Commission, staffed by experts, would survey the city, select appropriate buildings, hold hearings, and designate those found worthy, via a top-down hierarchical process. At the hearing for the bill creating the Commission, the future Executive Director of the Commission who had helped write the bill testified that he anticipated eventually designating approximately 1,000 individual landmarks and two or three historic districts. These initial conditions led to a very different result than anticipated. Thirty-seven years later, New York City has some 1,300 individual landmarks not far off the original estimate but it also has over seventy historic districts, encompassing more than 22,000 buildings. Among other factors, this unanticipated result emerged from the responses of

individual agents (city dwellers) to changing environment conditions, including:* changes in the funding and personnel time and emotional energy available to support the goals;* changes in the goals, themselves, as a result of the need to solve a host of complex social problems; * increased competition for desirable, affordable places to live; and* immersion in the phase change occurring throughout human civilization from hierarchical to hybrid and networked control structures (Bar-Yam, nd). Space permitting, I will develop four case studies. Three cases will describe different instances of self organizing neighborhoods and citizens (the Fort Greene Historic District in Brooklyn and the Tribeca Historic District and the Ladies Mile Historic District both in Manhattan). The fourth will document how New York City's Historic Districts Council created to garner support in the city's historic districts for increasing the budget of the Landmarks Preservation Commission re-organized itself as a network node among the various independent neighborhood groups.

Madhur Anand - *Laurentian University*

The Evolution of Complexity in Natural and Reconstructed Ecological Assemblages. Madhur Anand, Ke-Ming Ma, Brian Tucker and Rachelle Desrochers

We study the complexity of ecological assemblages that have been severely damaged by man-made perturbation (mainly air pollution) and ask the question: how is complexity affected and how well can we alter recovery trajectories by intervention? We use data from both field and laboratory experiments in Sudbury, Ontario that documented plant and microbial assemblage dynamics after varying degrees of perturbation and rehabilitation in 2001. Assemblage-level patterns are modelled using two approaches. The first attempts to summarize taxa-interactions either using information-theoretical measures or a reduced multivariate space. The second attempts to fit a stationary Markov model to assemblage dynamics. Assemblage-level dynamics was effectively summarized using Principal Components Analysis (> 80% variation captured in first two axes); however spatiotemporal structure was not very well captured. The Markov models provide an excellent fit to observed dynamics ($p<0.001$). The results show that in all treatments the microbial assemblages reach equilibrium quickly but have different recovery pathways under different treatments and that initial state matters. Information theoretical measures reveal that the assemblage dynamics cannot be attributed to any single or dominant taxon but is rather an emergent property of the system.

James J. Anderson - *Center for Computational Biology and Bioinformatics NIGMS*

NIGMS Funding Opportunities for Complex Biomedical Systems Research and Training

The National Institute of General Medical Sciences (NIGMS: a component of the U.S. National Institutes of Health) announces a new Center for Bioinformatics and Computational Biology. This Center will promote advances in cross-disciplinary research, education, and training involving quantitative approaches to complex biological and biomedical problems, and allied bioinformatics. NIGMS has issued a number of program announcements (PA) and requests for applications (RFA) that will provide support for these areas. The suite of initiatives have as their foci: 1. The understanding of system principles and dynamics in processes involving large numbers of interacting components, at all levels of biologicalorganization within the scope of the NIGMS mission; 2. The development of analytical methodologies to discover the genetic architecture of complex genetic traits; 3. The study of the evolutionary dynamics of pathogens and their hosts with their environments; 4. The development of enabling technologies useful for the study of metabolic processes and metabolic engineering; 5. The development of basic mathematical concepts and algorithms that have the potential for significantly advancing the state of the art inbiomedical research. The initiatives comprise mechanisms to fund research projects (traditional research project grants (R01) and program project grants (P01)), to fund establishment of integrative research efforts ("glue grants," R24), to fund extensive programs

of research related activities (Center grants(P50)), to provide support for short courses and workshops (R25 education grants) for both biologists and non-biologists, and to provide trainingat both pre- and postdoctoral level (T32 and T33 Training Grants). Detailed information on these programs will be available, and can also be found at the following URL:http://www.nih.gov/nigms/funding

Pierpaolo Andriani - *University of Durham Business School*

Self-organised criticality, Kauffman's laws and industrial clusters

The work presented in this paper aims at providing an empirical validation to some aspects of Kauffman's laws of complex systems (Investigations, 2000).
"...On a coevolutionary timescale, coevolving autonomous agents as a community attain a self-organised critical state by tuning landscape structure and couplings between landscapes, yielding a global power law distribution of extinction and speciation events and a power law distribution of species lifetimes" and "...As an average trend, biospheres and the universe create novelty and diversity as fast as they can manage to do so without destroying the accumulated propagating organisation that is the basis and nexus from which further novelty is discovered and incorporated into the propagating organisation"

The work examines Italian industrial clusters (ICs). ICs are geographic concentrations of interconnected companies and institutions in a particular field, encompassing an array of linked industries and other entities important to competition. Individual firms tend to be flexibly specialised in a particular production phase, through relationships of both competition and co-operation.

The work takes as unit of analysis self-contained socio-economic areas known as travel-to-work areas (self-contained areas of home-work commuting), classified in a range spanning from ICs to low industrial activity areas. A statistical analysis based on complexity theory frameworks shows:

1. ICs are closer to self organised critical (SOC) systems than other types of geographic agglomerates. SOC is explored in terms of nodal properties (rank-size rule)
2. ICs seem to explore the space of diversity within the envelope of their extended value chain maintaining the 'propagating organisation' at a higher rate than non ICs.
3. The product of internal diversity (industrial species) times internal connectivity is higher for a community of autonomous agents than for an aggregate.

This work defines diversity as composed of three elements: variety (roughly number of categories necessary to classify species), disparity (distance between categories) and balance (apportionment of species per category) and applies distance metrics ideas to measure diversity. The propagating organisation is measured by a proxy, that is the internal connectivity of the system.

This work arrives at the following conclusions:

1. The frameworks of complexity theory used in this work, namely self-organised criticality and exploration of diversity at the subcritical-supracritical boundary, are useful to interpret socio-economic structural and dynamical properties of geographic agglomerations of firms.
2. SOC and diversity can be used as tools to discriminate between (industrial) aggregate and system of autonomous agents, thereby suggesting a phase transition between the two.
3. The structure of interdependence among agents (organisations) in a local agglomerate is related to the closeness to a power law (SOC behaviour) of the local aggregate's structural and behavioural properties, thereby confirming Kauffman's intuition.
4. The preliminary exploration of the structural properties of Italian industrial agglomerations confirms some aspects of Kauffman's fourth laws, specifically the fact that communities of autonomous agents explore the phase space of diversity (adjacent possible) at a rate superior to that of aggregates of autonomous agents.

Takeshi Arai - *Tokyo University of Science*

A CA Based Two-Stage Model of Land Use Dynamics in Urban Fringe Area - Takeshi Arai and Tetsuya Akiyama

To develop a more practical simulation model applicable to the planning process at local governments, we tried to create a CA(Cellular automata) based land use model which precisely describe the transition between the land use states of each 10 metres square cell. We applied our model to two suburban cities in the Tokyo metropolitan region and we used a set of data with the title "Detailed Digital Information (10 m Grid Land Use) Metropolitan Area" to calibrate the model. As the factors which may affect the transition potential, we picked out the aggregated land use state in the neighbourhood, the accessibility to transport services and land use zoning. To estimate the parameters of the equations in the model, we used the multivariate analysis, such as discriminant analysis and logistic regression. Although performance of the model is not sufficiently good, this is a valuable step to make a more practical simulation tool for planning.

Arturo H. Ariño - *University of Navarra*

Optimal Sampling For Complexity In Soil Ecosystems

Soil ecosystems are inherently complex: space, time and biological diversity interact giving way to emergence of dynamic, complex features such as distribution patterns, abundance profiles, nutrient paths, etc. Specifically, sampling for soil diversity is fraught with problems that arise form the very different spatial scales that involve biological populations' aggregates and subpopulations. Typical sampling techniques tend either to be ineffective for complexity assessment (i.e. too small to capture a representative subset of most populations and their distributions) or overshot their target with very large samples that can be cost-ineffective. Optimized sampling techniques that use the species-area curves may be inadequate for the purpose of measuring diversity, as they typically focus on the species accumulation rather than on the measurement of structure. Also, species-area curves are sensitive to the accumulation mechanism: the order in which subsamples accumulate matters. We propose an algorithmic method that tries to capture enough data for a cost-effective diversity (complexity) assessment while statistically ensuring consistency. Tests have been done with actual, species-level soil mesofauna fauna data. A C program implements the algorithm.

Rajkumar Arumugam - *Department of Electrical & Computer Engineering and Computer Science University of Cincinnati*

Intelligent Broadcast in Random Large-Scale Sensor Networks Rajkumar Arumugam, Vinod Subramanian, Ali A. Minai

With advances in miniaturization, wireless communication, and the theory of self-organizing systems, it has become possible to consider scenarios where a very large number of networkable sensors are deployed randomly over an extended environment and organize themselves into a network. Such networks --- which we term large-scale sensor networks (LSSN's) --- can be useful in many situations, including military surveillance, environmental monitoring, disaster relief, etc. The idea is that, by deploying a LSSN, an extended environment can be rendered observable for an external user (e.g., amonitoring station) or for users within the system (e.g., persons walking around with palm-sized devices). Unlike custom-designed networks, these randomly deployed networks need no pre-design and configure themselves through a process of self-organization. The sensor nodes themselves are typically anonymous, and information is addressed by location or attribute rather than by node ID. This approach provides several advantages, including: 1) Scalability; 2) Robustness; 3) Flexibility; 4) Expandability; and5) Versatility. Indeed, this abstraction is implicit in such ideas as smart paint, smart dust, and smart matter. The purpose of our research is to explore how a system comprising a very large number of randomly distributed nodes can organize itself to communicate information between designated geographical locations. To keep the system realistic, we

assume that each node has only limited reliability, energy resources, wireless communication capabilities, and computational capacity. Thus, direct long-range communication between nodes is not possible, and most messaging involves a large number of ``hops"between neighboring nodes. In particular, we are interested in obtaining reliable communication at the system level from simple, unreliable nodes. Wireless networks that operate without fixed infrastructure are called ad-hoc networks, and are a very active focus of research by the wireless community. However, most of the work focuses on networks with tens or hundreds of nodes, where most message paths are only a few hops long. All data messages in such a system are unicast, i.e., they are between specific pairs of nodes. There are two major formulations for this. In some message routing algorithms, a path discovery process is used to first find a route between the source and destination nodes (or locations), and the message is then sent along this path. This is clearly a top-down approach with limited scalability. Other routing protocols use next-hop routing, where each node, knowing the destination of an incoming message, only determines the next node to forward the message to. These protocols scale much better, but at the cost of maintaining and updating extensive amounts of information about network topology. This can be expensive in terms of energy, and can often lead to problems if the individual nodes are unreliable, causing broken links and lost messages. From a complex systems viewpoint, the problem with unicast-based next-hop methods is that they do not exploit the inherent parallellism of the system to achieve robustness. This is the issue we consider in our research. Rather than using directed unicast between nodes, we study the possibilities of broadcast. In the simplest case, this corresponds to flooding, where every message received by a non-destination node is ``flooded" to all the node's neighbors. While this is a simple apprach, it is extremely wasteful of bandwidth and creates a lot of collisions --- the simultaneous use of the wireless channel by multiple messages, all of which are lost as a consequence. To overcome the problems of flooding while retaining its inherent parallellism, we explore the method of intelligent broadcast. In this approach, each node receiving a message decides whether to re-broadcast it to all its neighbors or to ignore it. Note that the decision does not involve selecting which neighbor the message is forwarded to, but only whether to forward the message. The latter is a much simpler decision, and can be made on the basis of the information carried by the message incombination with that available within the potential forwarding node. This approach leads to a self-organized communication process where local decisions by the nodes produce global availability of information. In the paper, we present a well-developed paradigm for random LSSN's, including a model for the nodes and viable broadcast-based protocols for channel access and network organization. We evaluate the performance of the network in the case of simple flooding, and then study the effect of a simple decision heuristic that allows nodes to limit messagere-broadcast based on how many hops the message has already travelled. We show that this heuristic leads to a dramatic improvement in performance, making the broadcast-based system a viable --- and more robust --- alternative to more complicated systems under some conditions. We also characterize how network parameters such as size, node density, messaging rate and node reliability affect the performance of the heuristic.

Edward A Bach - *Boston University*

SIMP/STEP: A Platform for Fine-Grained Lattice Computing.

SIMP/STEP, is a platform for fine-grained lattice computing such as that of cellular automata (CA), lattice gases/partitioned CA (LG/PCA), and pixel-level image processing (IP) operators. The SIMP programming environment targets the needs of complexity experimenters, physical modelers, and IP programmers who want to quickly write efficient and readable massively-parallel programs without worrying about the underlying implementation. The STEP abstract machine interface is a set of fine-grained lattice computing primitives into which SIMP programs are compiled.

Through some specific examples, we demonstrate how to program CA and LG/PCA in SIMP. We also describe a few complex-system modeling approaches such as using LG/PCA to make an invertible global dynamics out of an invertible local dynamics and using a fine-grained, discrete, microscopic dynamics to synthesize a system that obeys some macroscopic continuous differential equation.

Finally, we highlight some implementation and performance aspects of STEP. In particular, we discuss PC-STEP, a software STEP kernel and a STEP hardware accelerator design styled after the CAM-8 of Toffoli and Margolus.

Alan Baker - *Xavier University*

Philosophy and Complexity

Complexity theory has largely ignored – and been ignored by mainstream philosophy. This is unfortunate and also surprising, for both fields are by nature wide-ranging in their score and interdisciplinary in their impact. My aim in this paper is to sketch some possible paths for fruitful interaction between these two fields. I shall argue that each has conceptual tools which are of potential benefit to the other.

For the purposes of this paper I shall concentrate primarily on the philosophy of science, since it is here that the most immediate connections with complexity theory are to be found. Contemporary analytic philosophy has largely abandoned to the natural sciences the detailed work of explaining and predicting physical phenomena (a task which used to fall under the heading of natural philosophy). This is especially true for physical phenomena that are complex. Identifying, experimenting upon, analyzing, and modeling such phenomena is most effectively accomplished by those with expertise in the broad range of mathematical, scientific, and social scientific fields which fall under the broad heading of complexity theory or complexity science. Philosophy, by contrast, is a meta-discipline, focusing not so much on the nature of the world itself as on our various ways of engaging with the world. Philosophical expertise may play a valuable role, especially with respect to the following two topics;

(i) Complexity theory, considered as an object of study in its own right. Is complexity theory methodologically distinct from traditional science? Is it revolutionary in the sense articulated by Thomas Kuhn?

(ii) Complexity, considered as an abstract concept. Is it a unitary concept or a cluster of related but distinct concepts? Can complexity be adequately defined? How does it relate to other notions such as disorder, randomness, etc.?

My particular focus in what follows concerns the methodology of theory choice in science. Philosophers of science have long been interested in the criteria by which
scientists evaluate and choose between competing theories. There are many factors influencing these decisions which have little if anything to do with the content of the theory itself, factors such as the reputation of the theory's authors, the place and manner of its publication, and the likelihood of future funding. Other factors are internal to the theory itself. One important such factor is simplicity. The preference for simple theories is often referred to as Occam's Razor. An area of ongoing debate among philosophers of science concerns how to define simplicity. There has been a parallel debate going on among complexity theorists concerning how to define a satisfactory notion of complexity. There has been little, if any, feedback between these two debates, yet each has the potential to inform the other. Below I list some of the main points I shall discuss in the body of the paper;

(a) Philosophers tend to analyze simplicity as a property of theories or hypotheses, whereas complexity theorists typically analyze complexity as a property of phenomena. This links back to my earlier point that philosophy is by nature a meta-discipline.

(b) Philosophers distinguish between syntactic simplicity (or elegance), which is a measure of a theory's conciseness, and ontological simplicity (or parsimony),
which is a measure of how many things, or kinds of things, a theory claims exist. Parallel concepts of syntactic and ontological complexity may be defined.

(c) Philosophers have focused on defining comparative but non-quantitative notions of simplicity. By contrast, complexity theorists have generally aimed to
define quantitative measures of complexity.

(d) What, if any, rational justification can be provided for Occam's Razor? Why should we value simple theories, or expect them to be more likely to be true, especially in a world apparently full of chaotic and complex phenomena? Ought Occam's Razor to be a methodological principle of complexity theory? One of the goals of complexity theory has been to identify general features common to complex phenomena in different contexts such as the human brain, patterns of earthquakes, or the stock market and to identify patterns and regularities they have in common. This is one sort of higher-level simplicity.

Ariel Balter - *Indiana University*

Levy Flights in Climate Data

Inovations in high frequency (> 1/day) climate variables appear to be Levy Stable random variables. Many climate variables show strongly Gaussian behavior (such as directional wind) and many (such as temperature) do not. However, the inovations (i.e. differences) are strongly non-Gaussian. Instead, they can be fit extremely well byLevy Stable distributions. We have examined this phenomenon for a large number of climate variables representing a wide range of years, geographies, climatologies and sampling frequencies. The effect appears highly universal. We believe this effect emerges from nonlinearities which can be modeled as multiplicative noise. By establishing the ubiquitous manifestation of this effect we hope to provide a tool for climate modelling. Most stochastic climate models use white Gaussian noise for inovations. Switching to Levy Stable noise will undoubtably improve the usefulness of these models.

Ernerst Barany - *New Mexico Tech*

Dynamics of Ethernet Protocol

The critical output bandwidth needed to ensure that a CSMA/CD based LAN does not accumulate packets unboundedly in its queues is computed. This is an emergent property of the network that follows from decentralized microscopic laws. The result follows from the stationary distribution property of ergodic Markov chains

Joana Barros - *Centre for Advanced Spatial Analysis - University College London*

City of Slums: Self-Organisation Across Scales. Joana Barros and Fabiano Sobreira

Third World cities are known for their inherent chaotic and discontinuous spatial patterns and rapid and unorganised development process. Due to the very same characteristics, in the present paper, these cities are seen as excellent objects for the study of complex systems. We argue that the morphological structure of these cities can be analysed by the interplay of two different urban processes across scales: the local process of formation of inner-city squatter settlements and the global process of "peripherization" (typical growth process of Third World cities). The basic aim of this paper is to analyse the interrelationship between these two processes. This issue is explored through 'City-of-slums', an agent-based model that focuses on the process of consolidation of inner-city squatter settlements within a peripherization process. The paper presents briefly two previous studies on these topics where the dynamics of these two urban processes are examined as two isolated complex systems through heuristic agent-based models and their morphologies are discussed. We then combine aspects of these two dynamics to compose City-of-slums, in an attempt to discuss the role of self-organisation in the spatial dynamics of Third World cities. It is suggested that the resulting urban morphology, although related to distinct scales, present similar degree of fragmentation (fractal pattern). Preliminary observations also suggest that these complex processes are involved in a spatial logic in which resistance is the cause, consolidation is the process and fragmentation is the result.

Jacob Beal - *MIT AI Lab*

Themes: Emergence, Self-Organization; System Categories: Psychological, Engineered

In a distributed model of intelligence, peer components need to communicate with one another. I present a system which enables two agents connected by a thick twisted bundle of wires to bootstrap a simple communication system from observations of a shared environment. The agents learn a large vocabulary of symbols, as well as inflections on those symbols which allow thematic role-frames to be transmitted. Language acquisition time is rapid and linear in the number of symbols and inflections. The final communication system is robust and performance degrades gradually in the face of problems.

Itzhak Benenson - *University Tel Aviv*

Dynamic consequences of human choice behavior in the City, Itzhak Benenson and Erez Hatna

Inherently spatial relationships between the elementary objects - land units, households, householders, cars, firms, and public institutions - make City different from the other complex systems. For example, householder choice depends not only on the properties of the real estate and the family's economic abilities, but also on the properties of the physical and human environments at current and potential locations. For landowner, the vicinity and wider neighborhoods of the location are important for making commercial decision, which defines the price and the usage of the land units. The behavior of human elementary objects defines the characteristics of urban objects of all kinds. However, as opposed to non-living objects, the standard reaction of humans to unsatisfactory conditions is a decision to relocate themselves or their activity. The spatial (as well as non-spatial) choice of humans does not follow assumptions of chemical dynamics and is intensively discussed in the psychological literature (Gigerenzer, Goldstein, 1996). Serious experimental and analytic arguments in favor of the bounded rationality and satisfycing behavior (Simon, 1956, 1982) have been provided. We propose the agent-based model of urban development, which is based on this principle. The analysis of the several versions of the model demonstrates, that satisficing spatial behavior of human agents both enables likely simulation of the real-world population dynamics and makes the model results robust to infrastructure changes. It is shown that "human" urban system exhibits long periods of stable development interrupted by abrupt changes, caused by essential qualitative changes in the infrastructure, such as new building construction over extended areas, major changes

Howard A. Blair - *Syracuse University*

Unifying Discrete and Continuous Dynamical Systems

We analyze the structure of dynamical systems (DS) in such a way as to reveal a structural parameter that differentiates among the kinds of DSs that frequently arise. This structural parameter is present in each of four components of nearly all DSs, including those that arise in the context of quantum computing. The four components are (1) the computation space, (2) the temporal structure, (3) the local state space, and (4) the differential state space. Each of these four components can be varied independently, and can be chosen to have either a discrete structure in the sense of data-structures, or a continuous structure in a strong topological sense. There are a variety of product operations that enable the crafting of hybrid structures.

The desired structure for each of the DS's components is obtained in a principled fashion by specifying the structural parameter: a field of filter families that satisfy certain closure properties to yield a so-called convergence space. The field of filter families is to a convergence space as a topology is to a topological space.

The notion of a convergence space is stronger than that of a topological space. The virtue of the convergence space notion is that directed graphs are convergence spaces, and continuity specializes in the case of directed graphs to graph homomorphisms.The convergence space components of the DS can be built out of limits of directed graphs.

In particular this provides a natural way to combine discrete data-structures with topological spaces. The trajectories of familiar DSs are the continuous solutions of constraints on the convergence space components of those systems.

An ordinary differential equation in several variables, or in countably infinitely many variables, as in a Fermi-Pasta-Ulam continuous-valued cellular automaton, is a DS that fits cleanly into our analysis, once it is realized that the phase space is not the computation space, rather the phase space is the (implied global) state space. The computation space is the underlying cellular automaton structure. One novel aspect is that various approximating solutions, as would be given by Euler and Runge-Kutta methods, are obtained by altering the field of filter families on the temporal structure.

The utility of the convergence space analysis provides for efficiently describing combinations of, for example, cellular automata in which the state of a cell C evolves in discrete time steps while cells in the neighborhood of C evolves differentially in continuous time in a manner dependent in part on the evolution of the state of C. In the end, the distinction between, say, an ODE and a Turing machine, comes down to the field of filter families on the four components of the systems.

REFERENCES

1. Fermi, E., J. Pasta and S. Ulam, Studies of Nonlinear Problems, S. Ulam, Sets, Numbers and Universes, MIT Press: Cambridge, 1974, pp. 491-501

2. Heckmann, R. A Non-topological View of dcpo's as Convergence Spaces. First Irish Conference on the Mathematical Foundations of Computer Science and Information Technology (MFCSIT 2000) July, 2000.

Janine Bolliger - *Swiss Federal Research Institute*

A Case Study for Self-Organized Criticality in Landscape Ecology Janine Bolliger and Julien C. Sprott

In ecology, the phenomenon of self-organized criticality may provide a powerful approach to complete current theoretical frameworks (e.g., metapopulation theory) with a profound understanding of how ecological feedback, interaction, and historical coincidence act together so that biotic units co-occur at their present locations. This study investigates the self-organized critical state and the complexity of the historical landscape of southern Wisconsin (60,000 km2). The landscape was classified into 27 discrete forest types using statistical cluster analysis. The data for classification was derived from the United States General Land Office Surveys that were conducted during the 19th century prior to Euro-American settlement. We applied a two-dimensional cellular automaton model with a single adjustable parameter. The model evolves by replacing a cell that dies out at random times by a cell chosen randomly within a circular radius r (neighborhood), where r takes values between 1 (local) and 10 units (regional). Cluster probability measures the degree of organization. Good agreement is found when comparing the simulated to the observed landscape using fractal dimension (spatial), fluctuations in cluster probability (temporal), and algorithmic complexity (interaction characteristics). All results are robust to a variety of perturbations. In our example, the self-organized state is scale-invariant in both time and space and depends on the neighborhood size chosen for the model runs. Small neighborhoods (r = 1 or 4 cells), representing low connectivity across landscapes, over-organize. Adjacent cells are likely to exhibit similar properties and are thus likelier to organize, however, too small fractions of the overall forest-type diversity are accounted for. Large neighborhoods (r = 10 or 314 cells) representing high connection among the forest types do not organize, indicating that the likelihood of cells interacting with cells exhibiting similar properties in large neighborhoods are rare. Intermediate neighborhood sizes (r = 3 or 28 cells) representing intermediate levels of connectivity in forests, where many local, but some longer distance interactions occur, give rise to self-

organization to the level of the observed forest landscape. Such ‘small-world’ phenomena studied by Watts and Strogatz (1998) have been observed for many systems that typically range somewhere between regular and random. We view the self-organized critical state as a measure of connectivity of the forest landscape, since the functional significance of scale invariance is, among others, a description of how system elements interact across the system. With this example of self-organized criticality, we show that simple models may suffice to replicate the forest landscapes originating from complex spatial and temporal interactions.

Eric Bonabeau - *Icosystem Corporation*

Co-Evolving Business Models

Trying to predict the future structure of an industry is a key ingredient when it comes to defining a company's strategy. Scenario planning is a popular method to aggregate the knowledge of industry specialists into possible scenarios using special brainstorming sessions. Another route consists of putting that knowledge into a model of the industry and let the industrys players co-evolve their business strategies or business models. Existing industry knowledge is first transformed into relevant strategic building blocks (value proposition components, operational components, revenue components) that serve as the basic units for evolutionary recombination. The initial state of the simulation reflects the current industry structure with respect to both business models and market shares. The weakest players disappear and are replaced by new players that borrow building blocks from the strongest players. After a number of generations, the industry may or may not converge toward a stationary structure. This approach has been applied the evolution of the Internet Service Provider (ISP) industry. In this context, a number of runs showed the emergence and later disappearance of the free ISP business model, reflecting the actual dynamics of the ISP industry in Europe. In order to obtain reliable results regarding the industry's stationary structure, one thousand co-evolutionary simulations were run for 500 generations. For each simulation, the endpoint population was analysed to try to answer the following questions: are there stationary industry states, stationary business models, what are the winning business models, what are the most likely endpoints for the industry? Surprisingly, in most runs the ISP industry converged to a monochromatic industry structure, that is, one where all business models are similar. Furthermore, 60% of the runs converged toward the same color, that is, the same business model, suggesting that the industry has a very robust evolutionary attractor. Many more statistical measurements can be extracted out of the simulations, allowing us to understand how and why the industry converged toward a particular structure. This outcome can then be used to define an ISP's strategy.

D. Borri - *Polytechnic of Bari*

Managing Urban Traffic Dynamics By A Multi-Agent DS - D. Borri, G. Concilio, E. Conte

Complexity of urban environments is severely challenging science and technology, making Information Technology (IT) tools strongly significant for enabling innovative and more appropriate decisions. Concerning urban environments, the paper deals with the important issue of the traffic dynamics proposing a tool for managing and controlling traffic air pollution, since its effects on human health are recognised as widely relevant. The design of the proposed tool is based on the belief that IT systems can support decision making processes reducing routine tasks thus enlarging substantive and problem oriented decision activities, through improving man-machine interaction. Basing on a local case study, the paper reports about a two-years research work of the authors, studying traffic problems in a middle-sized city of Southern Italy, starting from daily monitored data about air quality conditions. The research was aimed at developing the architecture of a Decision Support System (DSS) assisting decision makers of municipal offices to implement strategic actions for controlling traffic air pollution. The DSS is designed as a multi-agent system

in order to replicate the single and autonomous tasks of the decision makers, at the same time saving and strengthening the interaction among those tasks and fuelling dialogue among different data sources and receivers. The paper describes the development of the DSS architecture which was carried out starting from the real structure of both the decision making process and its main activities and focusing on the use and the production of knowledge within the process itself. In the DSS design, a special attention was given to three main tasks of the decision process: validation of data from pollution measurement stations, assessment of measurement stations functioning, and production of short term traffic actions. A neural network approach and an expert system environment represent the main technological basis for the implementation of the DSS. Further research perspectives are finally investigated with regards to the development of medium-long term traffic strategies and to its possible support in IT environment.

Jose M. Borreguero - *Center For Polymer Studies, Boston University*

Fluctuation Analysis in the Transition State Ensemble of the SH3 Domain

We perform a detailed analysis of the thermodynamics and folding kinetics of the SH3 domain fold with discrete molecular dynamic simulations. We propose a protein model that reproduces the cooperative folding transition experimentally observed in globular proteins. We use our model to study the transition state ensemble (TSE) of SH3 fold proteins --- specifically, we study a set of unstable conformations that fold to the protein native state with a probability close to 1/2. We analyze the participation of each secondary structure element in the formation of the TSE and we find good agreement with xperimental results of Src SH3 domain and alpha-Spectrin SH3 domain proteins. We also identify the folding nucleus of the SH3 --- a set of specific amino acid contacts that determine whether a conformation belonging to the TSE will fold. We predict that a set of contacts between the secondary structure elements RT--loop and distal hairpinare the critical folding nucleus of the SH3 fold, and we propose a hypothesis that explains this result.

Alfred Brandstein - *US Marine Corps*

The Role of Analysis in the Brave New World

Recent advances in science, especially computer science, have made dramatic changes in our approach to the role of analysis. Our faith in the capabilities of modeling to support decision making has been severely shaken. In the complex world of non-linearities and co-evolution, we are struggling to find the proper role for modeling and analysis. The approach we are taking to define this role is discussed.

Michael Bretz - *Dept. of Physics, Univ. of Michigan*

Emergent Probability Lonergan's Genetic Model of Knowledge Growth, Development and Decline.

A little known but intriguing heuristic model of knowledge growth and structural change was conceived many decades ago[1]. In his treatise, Lonergan successfully disentangled the dynamic elements surrounding the scientific intellectual process and modeled how explanatory knowledge is generated. He extended this model to knowledge growth itself and to the dynamics underlying all development - be it chemical, evolutionary, historical, environmental, economical, psychological, organizational or ethical. Lonergan characterized generic growth as the successive appearance of conditioned Recurrent Schemes(RS), each of which come into existence probabilistically once all required prior conditions (selected earlier schemes) are in place. When formed, a new dynamic recurrent scheme becomes locked into long term stability (some examples of RS networks are resource cycles, motor skills and habits). He envisioned the overall concrete

growth process of recurrent schemes to be highly dynamic, convoluted, non-linear and genetic in form, so appropriately designated it "Emergent Probability" (EP). Although developed qualitatively, EP constitutes a complex dynamic system that is ripe for computer exploration. In this talk I will present first results from a MATLAB toy model for state space growth and evolution of EP as simulated by a scale-free, directed growing network (nodes as RS?s, links as conditions). The appearance of RS clusters and their interplay with each other, competition for scare resources, and dependence of clusters on the underlying ecological situation will be emphasized. Aspects of EP appear to have been reinvented as key elements in present day hypercycle, neuronal group and bioinformatics models, making EP a potential vantage point for unification between, and fertilization among, the disparate calculational approaches and interdisciplinary fields (as mentioned above). Lonergan?s stated global EP features extend beyond the properties usually attributed to complex genetic systems, so central questions must be addressed in the further study of Emergent Probability.

1. Insight, A Study of Human Understanding by Bernard J. F. Lonergan (Longman, Greens & Co., London, 1957; Collected Works(3), edit. F.E.Crowe and R.M. Doran, Toronto Press, 1992)

Colby Brown - *Sociology, Wesleyan University*

A Graph-Dynamical Model of Transportation Development

Charles Horton Cooley described conversation and transportation as subsets of the larger social phenomenon of general communication. (Cooley, 1894) Cooley's classification system seems particularly useful when Shannon's information theoretic-concept of uncertainty and the institutional economic concept of transactions costs are compared. (Shannon, 1949, and perhaps Pitelis, 1993) Transportation and social networks also share the potential application of methodologies based in graph theory. Noting these precedents, we suggest that transportation development can be analyzed as an iterative graph dynamical process in which changes in a society's structural networks effect changes in that society's transportation infrastructure, effecting changes in social structure, etc. Within this model, the American urban expressway development process of the mid-20th century presents an interesting puzzle. If the social networks most relevant to interstate highway development were locally limited to the urban areas in which development occurred, then the well-documented destructive effects of development appear paradoxical. Theories of power or asymmetrical information might explain this state of affairs, yet, it is more likely that the pattern of development of urban expressways depended heavily upon linkages to dispersed (state- and national-level) institutions and actors. In that case the behavior of either "articulation points" or "articulation groups," (i.e. groups of people who, if removed, would leave a network cut into two or more disconnected cliques), would have been crucial to the exact pattern of development experienced in a given locality.

We examine mid-century changes in the structure of urban social networks in America, socio-economic phenomena governing transportation development through that time period, and construct a multi-layer graph dynamical model of transportation development based on historical and statistical evidence. In the process, we consider the emergence of what Manuel Castells (1983) has called "information age" urban social networks; a self-organized critical phase transition from locally-based communications to more dispersed, though not necessarily less communal, relations.

Galina Bushueva- *Institute of Eye Diseases and Tissue Therapy, Odessa, Ukraine*

Psychology-Physiological Approach for the Analysis of the states Pathology.

Galina Bushueva, Nadia Kabachi and Arnold Kiv

All pathologies are complex disturbances of physiological processes and deep changes in their psychological state. In our presentation we would like to put forward a conception of complex diagnostics of different diseases based on analysis of patients' physiological and psychological characteristics. In [1] it was

found correlations between the states of people cardio-vegetative system and their creative thinking characteristics. These correlations are caused in particular by disturbances of relaxation time of spasmodic state (RTSS) of organism. The results obtained in [1] opened a possibility to study relaxation processes in the vegetative nervous system using a special device (computer pupillograph), which gives quantitative characteristics of accommodation – convergence pupillary (ACP) system of eye.

In this work we studied patients with symptoms of disturbances in vegetative nervous system. We investigated RTSS by measurement ACP system of eye at different stages from beginning until the end of illness. At the same time we performed computer testing of creative thinking. The method of testing programs development is described for example in [2].By computer pupillograph we obtained data about pupillary size, reaction to illumination, accommodation and other parameters of eye. We measured visual acuity, reserves of accommodation and the pupillary sizes at convergence. Measurements of the vegetative nervous system tonus were fulfilled by method described in [3]. Parameters of creative thinking, which were measured, are: I (Intuition), L (Logic), VTS (Volume of thinking space).

It was found in this study that in the process of treatment of patients an improvement of creative thinking parameters mostly forestalls an appearance of usual signs of recovery, which are used in medical practices. So it may be concluded that a complex psychology – physiological diagnostics allows to define more precisely the end of recovery and the necessary time of treatment of patients for an illness. We continued our research by trying to exploit the data obtained previously (results) to predict the patients psychological behavior after their cure. For that, we are using generally the Data Mining techniques [4] and in particular the Bayesian networks (probabilistic networks) which combine probability theory with a graphical representation of domain models. The first results obtained we seemed promising. The results can be used as an element in decisions of organizational and economic problems in public health.

REFERENCES

1. N. Bushueva, A. Kiv, V. Orischenko, E. Ushan, G. Finn and Sue Holmes. Psychological limitation of creative activity. Computer Modeling&New
Technologies 3 (1999) 135-137

2. A. E. Kiv, V.G.Orischenko et al. Computer Modeling of Learning Organization. In Advances in Agile Manufacturing. Eds.P.T.Kidd, W.Karwowski. Amsterdam (1994) 553-556

3. A.M. Kluev. The State of Vegetative Nervous System of People with Accommodation Spasm. Journ. of Ophtalm. 6 (1976) 443-45

4. N. Kabachi, S. Levionnois, A. Happe, F. Le Duff, M. Bremond. Data Mining Techniques for Patient Care Pathway. In Third International Conference on Data Mining Methods and Databases for Engineering, Finance and Other Fields, 25 - 27 September 2002 Bologna, Italy (subdued).

Val Bykoski - *Boston University*

Complex Models and Model-Building Automation

A model-building framework (MBF) is proposed to automate building complex models. The framework is designed to combine dynamically model components, analyze dependencies, construct a model code, build it, connect the model to the input and output data, run the model, evaluate it, and, if necessary, modify it. A construction environment and its control and configuration logic, a basic component of the proposed framework, isdescribed. A generic model-building logic is presented and discussed as well as building techniques and tools. Complex models such as business/enterprise models, geographical sites such as cities, traffic systems (including air traffic), bioinformatics gene expression models, and similar ones contain hundreds parameters, adaptive components, interdependencies. Initially, the framework is a highly generic medium/space whichis being shaped and customized by the data into a specific medium/space reflecting a structure and dynamics built into the data. The goal of a model-building activity is to generalize the original data into equivalent _model form_ and to use the model then to generate (_predict_) new data for a new context. This in fact is the goal of any scientific framework, a _theory_. The architecture of a model used to

be fixed, that is, equations, functions involved (such as propagation functions, nonlinearity elements), dependencies, network architecture, kernels, etc. Also, building a model used to be separated from the model running, evaluation, and model modifying phase, a sort of offline data/model exploration pipeline. The MBF makes those elements and phases highly dynamic. Construction tools_ are necessary since complex models cannot be hand-built. Since they cannot be solved _analytically_, in terms of symbols, the data-driven technology to build a model is the only choice, indeed. The first step is a generic model prototype with highly flexible/adaptive structural and functional components. It could be, for example, a cellular neural networks (NN). Data as well as certain fundamental criteria/constraints are used to incrementally build and customize the prototype making it a data container, a generating database which can absorb new data and also to generate new data for new contexts. The data used to drive the model-building process have to have a format ofinput-output (or if/then) pairs. So, the model-building process is _supervised_ or driven by the output data. As an example, the NN models structure, their building rules, interdependencies are discussed as well as integration of the (training) data into the framework. What makes the MBF approach different is that the model is being built _on-the-fly_ based on a meta-description, and therefore various models can be built _to order_ as a highly dedicated tool. The MBF may as well generate the testing, visualization, and other appropriate tools for that model. A prototype of a MBF is designed and developed, and versions of NN models have been generated automatically using a generic core. Results will be presented and discussed.

Raffaele Calabretta - *Institute of Cognitive Sciences and Technologies National Research Council, Rome, Italy*

An Evo-Devo Approach to Modularity of Mind

A module can be defined as a specialized, encapsulated organ that has evolved to handle specific information types of enormous relevance to the species. Given their extremely general nature modular systems can be found in different aspects and levels of reality, from genomes to nervous systems, from cognitive and linguistic systems to social systems, and they are an object of study for a variety of scientific disciplines, from genetics and developmental biology to evolutionary biology, from the cognitive sciences to the neuro-sciences. Modules can emerge during the life of an individual organism as part of the biological development of the individual. Biological development is controlled by both genetically inherited information and the environment in which the individual develops. The two sources of information do not simply add linearly but there is a strong nonlinear interaction between them. Genetic expression is environmentally constrained in that the external environment (even in utero) and the already produced phenotype at any stage of development have a crucial role in determining the further developmental stages of the phenotype. And, conversely, learning, experience, and the environment external to the organism's body can influence the phenotype only in ways that are, more broadly or more stringently in different cases, genetically fixed. In any case it is clear that the modular structure of the brain is strongly influenced by the species-specific information contained in the DNA of all individuals of the same species. This poses two important research questions: How information relating to the modular structure of the brain is encoded in the genotype? How is this genetically encoded information acquired during an evolutionary process taking place in a succession of generations of individuals? With respect to the first question we have to consider that the genotype itself is a modular system. The DNA molecule can be analyzed as made up of modules at different levels: bases, aminoacids, genes. If we consider genes as the genetic modules, we know that genes map in complex ways into phenotypical traits. The mapping rarely is one-to-one but more frequently is many-to-many. Many genes enter into the determination of a single phenotypical trait and at the same time a single gene tends to influence many different phenotypical traits. Hence, we cannot in general assume that one gene entirely controls the development of a single neural module but, more probably, many genes control the development of one and the same module and one and the same gene controls the development of many different modules. The second research question concerns the evolutionary origin of the genetic modularity of the genotype which underlies the development of neural modules. For example, one can

hypothesize that at first a segment of the genotype controls the development of some particular neural module; then, this segment of the genotype is duplicated as a result of some mutation; and finally, the duplicated genetic module changes its function as a result of some further mutation and it becomes responsible for a new neural module with a different function. For the purpose of answering the two questions described above, it is obviously necessary to consider in the chosen model of study both the process of organism development and organism phylogenetic history. However, it is surprising to notice that the developmental and evolutionary integrated study of organism modularity is a quite recent conquest even in biology. Traditionally, the process of organism development and that of phylogenetic evolution were considered as being very different and thus have been studied separately in two different research fields (i.e., developmental biology and evolutionary biology). In order to achieve a better comprehension of reality, the importance of considering them at the same time it has instead been recently pointed out (consider, for example, the recent symposium on Modularity in development and evolution, Delmenhorst, Germany, May 11-14, 2000). The combined approach - now known as an "evo-devo" approach - to studying the meaning of biological is very innovative and is therefore not yet widespread in biology research, but it is showing itself to be plausible from a biological point of view and therefore very useful from an heuristic point of view. Unfortunately also in the cognitive sciences, development and evolution have not been considered as being two very important processes to be studied together in order to get a better understanding of the modular nature of mind. On the contrary, they are often considered as being two opposed processes that are incompatible for explaining the acquisition of brain competence. On the one side, developmental psychology, while admitting the modular nature of mind, claims that this is most of all the product of a process of development. On the other side, nativists and evolutionary psychologists maintain the view that humans born already furnished with hardwired cognitive modules. Without wanting to take a part in this controversy, which remains nevertheless one of central interest in the cognitive sciences (i.e., the nature-nurture debate), we suggest a way to reconcile different position in a new way of studying the evolution of modularity of mind, i.e., an evo-devo approach.

REFERENCES

Calabretta, R., Di Ferdinando, A., Wagner, G. P. and Parisi, D. (In press). What does it take to evolve behaviorally complex organisms? BioSystemsCalabretta, R. & Parisi, D. (In press). Evolutionary Connectionism and Mind/Brain Modularity. In W. Callabaut & D. Rasskin-Gutman (Eds.), Modularity. Understanding the development and evolution of complex natural systems. The MIT Press, Cambridge, MA. [draft: doc, pdf; updated June 4, 2001] Calabretta, R., Nolfi, S., Parisi, D. and Wagner, G. P. (2000). An artificial life model for investigating the evolution of modularity. In Y. Bar-Yam, (ed.), Unifying Themes in Complex Systems. Perseus Books, Cambridge, MA.Di Ferdinando, A., Calabretta, R., and Parisi, D. (2001). Evolving modular architectures for neural networks. In R. French & J. SougnÈ (Eds.), Proceedings of the Sixth Neural Computation and Psychology Workshop Evolution, Learning, and Development, Springer Verlag, London. [pdf, ps, abstract]Fodor, J. (1983). The modularity of mind. The MIT Press, Cambridge, MA. Karmiloff-Smith, A. (1999). Modularity of mind. In R. A. Wilson and F. C. Keil (Eds.), The MIT encyclopedia of the cognitive sciences. The MIT Press, Cambridge, MA. [html]Keil, F. C. (2000). Nativism. In R. A. Wilson and F. C. Keil (Eds.), The MIT encyclopedia of the cognitive sciences, The MIT Press, Cambridge, MA [html]Simon, H. A. (2000). Can there be a science of complex systems? In Y. Bar-Yam, (ed.), Unifying Themes in Complex Systems. Perseus Books, Cambridge, MA.Wagner, G. P., Mezey, J. & Calabretta, R. (In press). Natural Selection and the origin of modules. In W. Callabaut & D. Rasskin-Gutman (Eds.), Modularity. Understanding the development and evolution of complex natural systems. The MIT Press, Cambridge, MA [draft: doc, pdf; updated March 13, 2001]Wallace, A. (2002). The emerging conceptual framework of evolutionary developmental biology. Nature 415, 757-764.

Mathieu Capcarrere - *Logic Systems Laboratory. Swiss Federal Institute of Technology, Lausanne*

Emergent Computation in CA: A Matter of Visual Efficiency

Cellular Automata as a computational tool have been the subject of interest from the computing community for many years now. More precisely, the development of the Artificial Life field led many to wonder on how to do computation with such tools. Artificial Evolution which gave good results on specific tasks, like density or synchronization was often given as an answer. However, it appeared that the limitations of such an approach were severe and really the question of WHAT meant computation with cellular automata became pregnant. The answer to this question is far from obvious. Mitchell, Crutchfield, Hanson et al proposed an analysis of "particles" as a partial answer. Wuensche more recently developed the Z parameter as a paraphernalia to treating this question. Before this question appeared in its full-blown form in the A-life/Computer scientist community,there were already propositions going this way with Wolfram's class III and, related, Langton's computing at the edge of chaos. In this presentation/paper, I will argue that computation of CAs is a matter of visual efficiency. Basing our argument on past, recent and also previously unpublished results (ours and others) mainly but not only on the density and the synchronization task, I will propose a definition of what is computation by means of CAs. This will be the occasion to (re)define emergent behavior, in a limited scope, but also to envisage differently the whole question of what may be sought in computing research in CAs. The practical consequences of this approach will alter the HOW question answer, and most notably how to evolve computing CAs. Though the talk will be centered around the density task, will encompass a much bigger chunk of the CA field. However, the claim is NOT a redefinition of the whole computation by means of CAs, but rather a tentative definition in the limited scope of emergent computation.

Giuseppe Castagnoli - *Elsag, IT Division*

The Quantum Computer: A Complex System Irreducible to Classical Models

All devices created by man to support his everyday life, from the stone age to modern engineering, are functionally representable in classical physics. The quantum computer might make the first exception. Its operations essentially call for a quantum mechanical representation (Mahler 2001). They fully draw on a richness of quantum physics that vanishes in classical physics. Being a complex and purposeful (problem-solving) system strictly based on non-classical laws, the quantum computer as a model might enrich the vision of Complex Systems. We provide here a pedagogical presentation. By omitting technicalities, the special way of working of the quantum computer can be explained in a conceptually complete fashion to an interdisciplinary audience. We start by explaining the special quantum effects used in to-day quantum computation: quantum mode superposition (through the metaphor of the parallel-possible universes), parallel non interfering and interfering histories, the exponential explosion of the number of modes/histories of a compound object with the number of its parts, quantum togetherness (entanglement), quantum measurement as filtering. Pictorial aids illustrating possible histories and their quantum transformations substitute mathematical formulation. Then we show in conceptual detail how the above special effects yield the quantum speed-up of Shor’s (1994) and Grover’s (1997) algorithms. Speed-up can mean solving in less then a second problems whose solutions by to-day classical computers would in principle require billions of billions of years. Long-standing computational notions become deeply altered in quantum computing, starting from the very notion of algorithm as a procedure for dynamically constructing the solution of a problem. In quantum computation, the implicit definition of the solution, inherent in the statement of the problem, directly determines the solution in a non procedural way, through an extra-dynamical quantum transition. Such a transition is jointly influenced by the initial and the final selection (Castagnoli and Finkelstein, 2001). This is unlike classical computation which is the dynamical development of the initial selection (i.e. condition) alone. We discuss how the current approach to quantum computation might hold a classical vestige, being still algorithmic in character, although enriched with some special quantum effects. We introduce at a conceptual level a non-algorithmic, non-dynamical approach to quantum computation (Jones, 2000, Castagnoli and Finkelstein, 2002). This can be based on the same quantum relaxation processes

and symmetries (due to identical particle indistinguishability) that govern the formation of atomic and molecular structure. This latter approach naturally raises the question whether biological processes and molecular evolution draw on the richness of the quantum level.
REFERENCES:
G. Castagnoli and D.R. Finkelstein (2002) Quantum-statistical computation arXiv:quant-ph /0111120 v4 30 Jan 2002. G. Castagnoli and D.R. Finkelstein (2001) Theory of the quantum speed-up Proc. R. Soc. Lond. A 457, 1799.L. Grover , (1996) In Proc. 28th A. ACM Symp. On Theory of Computing, P. 212. Philadelphia, PA: ACM Press. J. A. Jones, V. Vedral, A. Ekert, G. Castagnoli (2000), Nature 403, 869.G. Mahler (2001) Science 292, 57.P. Shore (1994) In Proc. 35th A. Symp. of the Foundation of Computer Science, Los Alamitos, CA, P. 124. Los Alamitos, CA: IEEE Computer Society Press.

H. F. Chau - *University of Hong Kong*

How To Avoid Fooling Around In Minority Game H. F. Chau and F. K. Chow

Minority game (MG) [1][2] is a simple model of heterogeneous players who think inductively. It plays a dominant role in the study of the global collective behavior in free market economy in econophysics since it is a powerful tool to study the detailed pattern of fluctuations. In MG, there are three important parameters: the number of players N, the number of each player’s strategies S and the length of histories M. Maximal cooperation of players is observed in MG whenever 2^M » NS. However, is it possible to keep optimal cooperation amongst the players for any fixed values of N, S and M? We report a simple and elegant way to alter the complexity of each strategy in MG with fixed N, S and M so that the system can always be locked in a global cooperative phase. Indeed, our investigation concludes that player cooperation is the result of a suitable sampling in the available strategy space.
[1] D. Challet and Y.-C. Zhang, Physica A 246, 407 (1997).
[2] Y.-C. Zhang, Europhys. News 29, 51 (1998).

Adrian Li Mow Ching - *University College London*

User and Service Interaction Dynamics. Adrian Li Mow Ching, Venus Shum and Lionel Sacks

Active networks enable a faster deployment of services in a telecommunications network. To develop autonomous management systems for such a network requires understanding the emergent behaviour arising from the interactions between the underlying users and the network services. In this paper we use complex systems modelling to perform service engineering analysis on a generalised telecommunications service network abstracted from an ANDROID network. This work aims to develop ideas and issues regarding service engineering for future networks. In particular, we analyse the interactions between users and the network and study the affects of load balancing on the service platform. As a result we see a self-limiting characteristic that prevents the load on the communications network increasing beyond its capacity. However, the resulting effects on the users are an increase in the volatility of the response time for each service request, which is highly undesirable. We find that load balancing has significant improvements on resource utilisation and load management.

D. Chistilin - *Institute World Economy and International relation*

Development and Self-Organization of Complex System. Case of World Economy

This work is an intermediate result of a research of the process of development and self-organization of world economy; this research was begun in 1998 and it uses a complex systematic approach (the theory of complex systems).

Some elements of the work were presented at scientific forums of NECS (ICCS-98, ICCS-2000).

The objective of the work is to reveal and define phenomena which are characteristic to the behavior of complex systems in the process of their development on the basis of factual material of the world economy development during the period of 1825-2000.

The following methods are used in the research: complex-systematic analysis, historical and interdisciplinary methods and method of simulation in verbal-logical form.

Social system - "the world economy" - is considered as a complex system consisting of two global subsystems: economic and political.

Common agents for both subsystems are national economies, which interact in economic and political spheres and form connections and structure of social system of world economy.

The principal functional purpose of social system "the world economy" is an achievement of self-regulation of relations between the agents in economic system through political system which results in the state of dynamic equilibrium, i.e. economic growth of world economy.

The functioning of world economy means an implementation of economic and political relations in the process of international exchange of resources on the basis of international division of labour with the aim of the most effective distribution of valuable resources for production of valuable benefits for consumption.

Development of social system means a process of increasing its stability under the influence of outside environment (maintenance of stability in the given limits - homeostasis) by means of accumulation of structural information changing the quantity of organization (effectiveness) of the system and making its structure more complicated.

Increasing of stability is expressed in accumulation of economic effectiveness and formation of more complicated structure of society.

Development of world economy means a co-evolution of economic and political subsystem development resulted in gradual complication of social order, which increases the system stability under environment influence, pressure of population growth and resources limits.

Development means a change of equilibrium states with different macro-economic characteristics. Each state is expressed in structural and quantitative characteristics. For world economy we will consider as the system of international monetary relations (IMR) as a structural characteristic. The growth rate of the gross national product of the countries-members of international economic relations we will consider as a quantitative characteristic.

On the basis of historical material we distinguish three structural characteristics of IMR type and, correspondingly, three periods of time and three states of world economy (gold standard, system of Á›åòîí-Bóäñ, Jamaika system). On the basis of statistical data we calculate the quantitative characteristics for each state. Then we bring all data together into the table forms.

On the basis of distinguished states we build verbal-logical model of the world economy (figure). As an specimen we take the ‹.Àâäååâ's model, which is based on the idea that phenomenon of development can be considered as a struggle of two opposite trends - organization and disorganization. The process of development, which is begun from the maximum of disorganization, can be described as a process of accumulation of structural information, which is calculated as the difference between the real and maximum values of entropy.

The model allows to make the following conclusions:

1. Each consequent distinguished state of world economy has more complicated organization of political system and international monetary relations. And this fact demonstrates the tendency of complication of world community structure.
2. Each consequent state is more effective from economic point of view and has the higher rate of economic growth. This allows world economy to develop steadily in conditions of grown population of the planet and limited resources. A tendency of growth of economic effectiveness of the whole system is observed in the long-lasting interval of time.
3. The process of formation of consequent structures of both political and economic organization of the world economy took place in condition of strong non-equilibrium environment resulted in numerous military and civil conflicts and economic crises.

4. All stated above allows to conclude that:
system of the world economy possesses the property of the complex systems - self-organization.
the Îêñàíãå›à-Ï›èãîæèíà's principle of minimum of energy dissipation is realized in the process of development. Each consequent organization of world economy produces less entropy than the previous one.
The category of energy in physical system corresponds to category of resources in social system. Thus, principle of minimum of dissipation of limited resources acts in social systems. The model reflects realization of this phenomenon in the process of development and self-organization of the world economy.
Direction of development of the system "world economy" is defined by the law of conservation of accumulated effectiveness and this allows to say that the model has predicted potential for realization of prognosis of future organization of the world economy.

Claudia Ciorascu - *University, Iasi, Romania*

The Accuracy of Auto-Adaptive Models for Estimating Romanian Firm's Cost of Equity.

Claudia Ciorascu & Irina Manolescu

In the paper the mutations of the Romanian firms capital structures and the relations with the cost of equity capital are analyzed. The validity of leverage effect of capital structure to financial return is also tested. We consider in this analysis the public data of more than one hundred Romanian firms listed at Bucharest Stock Market and on RASDAQ, between 1997 and 2000.

The initial hypotheses in this research are: the relation of leverage effect is not validated for Romanian firms; using auto-adaptive models for the estimation of firm’s cost of equity the results are better than the classical techniques (as CAPM or auto-regressive models).

Because of their adaptation to the specific of the input data, the self-adapting models can be successfully used in real problems with large data sets. We are studying the quality of this approach in the case of estimating firm’s cost of equity. This also defines the pre-requisites for considering new instances of the problem: share valuation, investment decision-making, etc.

The presence of the determinant factors of capital structure (bankruptcy and monitoring costs, motivation of the managers, institutional restrictions, transaction costs, taxes) represents an argument for the validation of the first hypothesis, but their incidence is exceeded by the low liquidity of the Romanian capital market.

All this elements have opposed effects on the cost of capital and the resulted conclusion is the impossibility to obtain an optimal capital structure, especially on Romanian capital market.

The existence on Romanian stock market of the listed firms with a debt ratio (debt / equity capital) higher than 500%, but sometimes reaching incredible values like 10000%, raises serious questions over the admittance criterions on stock market quotation. These highly indebt firms have descending trends in activity and profits and the questions about financing policy can be raised both firm and financial institutes level.

Michael Connell - *Harvard*

Neuroscience and Education--Bridging the Gap

Many researchers, educators, and laypersons are excited about the prospect that neuroscience can fruitfully inform educational research and practice, ultimately leading to significant improvements in curriculum design, pedagogical techniques, and overall efficacy of educational institutions. Despite the enormous amount of hype surrounding these issues, however, to date there have been few tangible, rigorous results demonstrating how findings from neuroscience can actually be brought to bear on educationally relevant problems such as mechanisms of knowledge transfer.

In this presentation, I argue that computational neuroscience offers tools that can provide a theoretical bridge for applying neuroscience findings to educational issues. The approach I describe involves identifying key constraints at the neurological level (i.e. that structural changes to synapses are implicated in

long-term storage of information encoded in the nervous system, whereas dynamic functional activation patterns seem to be the basis for thought and action), incorporating these assumptions into a computational neuroscience model (a connectionist or other kind of artificial neural network), and then tracing the effect of these (biologically plausible) low-level constraints on higher-order patterns (at the level of cognitive processes), attempting to filter out model characteristics and behaviors that are mere artifacts of the model and its more ad hoc assumptions. This complex systems approach provides a straightforward way to link two levels of analysis (neural structure and cognitive function) that is complementary to the more common reductionist approach of building detailed models of specific phenomena (such as language acquisition or concept formation), and may be particularly attractive at the present time for people interested in exploring qualitative properties of higher order cognitive functions involving neural structures that are far removed from the sensory periphery. I describe how computational neuroscience offers a non-intuitive (and biologically informed) paradigm for understanding human knowledge organization and conceptual structure (in terms of a semi-parametric representational substrate), and I describe how it can shed new light on some educationally relevant issues. In particular, I discuss how this model provides insight into the nature of representation in the mammalian nervous system, I argue that this analysis suggests a set of meaningful conceptual categories that can inform meta-theoretic reasoning about classes of psychological theories, and I describe the mechanism of stimulus generalization (near transfer) that is revealed by this model.

Emilia Conte - *Polytechnic of Bari*

Managing Urban Traffic Dynamics by a Multi-Agent DSS

Complexity of urban environments is severely challenging science and technology, making Information Technology (IT) tools strongly significant for enabling innovative and more appropriate decisions. Concerning urban environments, the paper deals with the important issue of the traffic dynamics proposing a tool for managing and controlling traffic air pollution, since its effects on human health are recognized as widely relevant. The design of the proposed tool is based on the belief that IT systems can support decision making processes reducing routine tasks thus enlarging substantive and problem oriented decision activities, through improving man-machine interaction.

Basing on a local case study, the paper reports about a two-years research work of the authors, studying traffic problems in a middle-sized city of Southern Italy, starting from daily monitored data about air quality conditions. The research was aimed at developing the architecture of a Decision Support System (DSS) assisting decision makers of municipal offices to implement strategic actions for controlling traffic air pollution. The DSS is designed as a multi-agent system in order to replicate the single and autonomous tasks of the decision makers, at the same time saving and strengthening the interaction among those tasks and fuelling dialogue among different data sources and receivers. The paper describes the development of the DSS architecture which was carried out starting from the real structure of both the decision making process and its main activities and focusing on the use and the production of knowledge within the process itself. In the DSS design, a special attention was given to three main tasks of the decision process: validation of data from pollution measurement stations, assessment of measurement stations functioning, and production of short term traffic actions. A neural network approach and an expert system environment represent the main technological basis for the implementation of the DSS.

Further research perspectives are finally investigated in the wider dimension of medium/long term traffic control, where strategies can benefit by the multi-agent interactive approach, which can lead to gradually shift to different, higher, levels of organization in problem management. Some considerations are made with regards to knowledge representation tasks within DSSs devoted to complex problem management, to the use of machine learning as a form of knowledge representation, and to organizational learning within the decision making environments facing air quality problems.

Ron Cottam - *Brussels Free University*

Self-Organization and Complexity in Large Networked Information-processing Systems. Ron Cottam, Willy Ranson & Roger Vounckx

Classical analysis of large networked information-processing systems from a _quasi-external_ point of view begins to create problems as the range of hierarchical structural scales is extended. Most particularly, the viability of deterministic distributed control becomes questionable in extended-scale temporally-dynamic (i.e. interesting!) networks. The _traditional_ split between _body_ and _mind_ appears to be most particularlyrelated to our mental incapacity to relate to large systems whose character is primarily distributed but whose characteristics collapse to those of a synchronous deterministic network when reduced to a unified perspective. The major problem in forming such a representation is the necessarily irrational coupling across multiple scales of a large disparate complex organization such as the brain and our consequent inability toformulate correctly a causal tree for the system. We investigate the implications of these difficulties beyond simply the establishment of an upper systemic scaling limit, and relate them to a recently recorded Windows Local Area Network browser election breakdown.

D.E.Creanga - *Univ. Al.I. Cuza*

Computational Analysis in Temporal Series Describing Kidney Excretory Function. D.E. Creanga, E.Lozneanu, J.C.Sprott

Semi-quantitative analysis was carried out on the excretory function of human kidney. Health and pathological kidney are investigated by means of nuclear medicine using radio-pharmaceutical technique based on radio-isotopeTc99m and a gamma-camera device assisted by a specialized computer. The amount of Tc99m physiological solution in every kidney is given by a temporal series computationally which we processed using the analysis strategy based on linear and non-linear tests. Fast Fourier transform, auto-correlation function, the portrait in the phase space and the corresponding fractal dimension present similarities as well as differences when the health kidney is compared to the pathological one. The histogram of probability distribution is presenting a repetitive character for the normal kidney while for the non-functional kidney the strong asymmetry of the probability distribution is the dominant feature of the histogram shape. Fast Fourier transform does not present significant differences nor in the lin-log representation neither in the log-log representation but the wavelet transform seems to be marked by some qualitative differences. The portrait in the state space reconstructed using the first derivative of the raw data graph shows a higher dispersion of the points corresponding to the ill kidney than for the health one (while the reconstruction using the delay coordinates appears in the same form for both cases). The most important difference between the two cases is offered by the correlation dimension which is significantly higher for the health kidney in comparison to the ill one.

David L. Darmofal - *MIT*

Probabilistic Aerothermal Design of Gas Turbine Engines

Atin Das

Nonlinear Data Analysis of Experimental [EEG] data and Comparison with Theoretical [ANN] Data

In this paper, nonlinear dynamical tools like largest Lyapunov exponents (LE), fractal dimension, correlation dimension, pointwise correlation dimension will be employed to analyze electroencephalogram

[EEG] data obtained from healthy young subjects with eyes open and eyes closed condition with the view to compare brain complexity under this two condition. Results of similar calculations from some earlier works will be produced for comparison with present results. Also, a brief report on difference of opinion among coworkers regarding such tools will be reported; particularly applicability of LE will be reviewed. The issue of nonlinearity will be addressed by using surrogate data technique. We have extracted another data set which represented chaotic state of the system considered in our earlier work of mathematical modeling of artificial neural network. We further attempt to compare results to find nature of chaos arising from such theoretical models.

Neural Net Model for Featured Word Extraction A Das, M.Marko, A. Probst

Existing search engines have many drawbacks while situations demand more refined operations. We have shown with examples that two of the mostpopular conventional search engines return out-of-context results. Our group is actively engaged in developing new algorithms for this purposewhich are different in understanding the topology of searching.
There are two main independent approaches to achieve this tasking. The first one, using the concepts of semantics, has been implemented partially.(For more details see another paper presented by at the conference: Transforming the World Wide Web into a Complexity-Based Semantic NetworkM.Marko, A.Probst, A.Das.)
The second approach is reported in this paper. It is a theoretical model based on using Neural Network (NN) learning features. Instead of usingkeywords or reading mechanically words from the first few lines from papers/articles, the present model gives emphasis on extracting 'featuredwords' from an article. We call those words as 'featured words' that occur most frequently. Obviously we have to exclude English words like "of,the, are, so, therefore" etc. from the list of featured word. To form such a word list, an article is read first. To read a full paper as input tothe model would be a heavy load of computation, so a choice of the first few hundred words can serve the purpose -also because beyond this limit,generally technical or scientific notations appear which are not relevant for the present purpose. These words are raw data and will be used asthe input to the model. The NN model will chose from N such words (raw data) to find M featured words (refined data). This output is then fed tothe search engine to produce more accurate words. Working of the proposed NN model is based on Principal Component Analysis (PCA).
Another important feature of the proposed model is an association of words so that when related words combine to form a meaningful word which maynot be in the user-supplied list of search terms- is also included in the featured word and hence in the search result. We also propose to giveweights to the exact place of occurrence of a word. For example those in the headline or as "key word" are more important than those in the bodyof the text. Finally, a scheme is proposed to train such a network to accomplish the entire scheme outlined above. This will be implemented by managing theweight matrix of the proposed model.

Christopher J. Davia - *Carnegie Mellon Univ*

Biology, Brains and Catalysis

In this talk, I examine the hypothesis that living processes, from the smallest to the largest (including the brain), are catalytic processes, and hence, that life is a fractal catalytic process. Although a physical thermodynamic process, I suggest that catalysis is not confined to enzymatic biochemistry; rather, enzyme catalysis is a microscopic example of a general process. It is suggested that rather than characterizing biological processes in terms of 'functions,' they are better characterized in terms of their property of persistence. The persistence of a living process, which may be chemical, neural, perceptual or behavioral, is a direct consequence of the catalytic process that makes 'explicit' the orders and relationships that are 'implicit' in the environment.

Because catalysts, and therefore processes of catalysis, emerge unchanged from the reactions that they mediate, there is a relation between catalysis and persistence; this relation is most evident in living processes. Moreover, the persistence of a catalyst may be a consequence of the way in which it mediates the chemical/thermodynamic tendencies in its environment. This process may involve the order (or structure, possibly related to the entropy) of the system.

In the domain of enzyme catalysis, several researchers have theorized that the principle agent of catalysis is a type of wave called a soliton (e.g., Caspi & Ben-Jacob, 2002; Sataric et al., 1991). Solitons are waves that can travel large distances without significant loss of energy or structure. It is argued that this property is consequent on the relationship between the soliton and the structure (or boundary conditions) of the medium. In the case of enzyme catalysis, the soliton is expressed as a vibrational mode involving the molecules that comprise the enzyme. It will be argued that the persistence of the soliton and the persistence of the enzyme are necessarily related. A soliton may provide a path between the 'before' and 'after' energy states via points of ambiguity or'fixed points' (i.e. points that do not change), which may be related to the 'order' (or structure) in the environment. I will discuss how the soliton wave has been implicated in several levels of biological process including enzymes, DNA, microtubules, heart function, muscle function and nerve impulses, evidence that lends support for the fractal catalytic theory. The fractal catalytic hypothesis is consistent with (but more specific than) the 'order from order' principle of Schrodinger (1979), who suggested that living systems maintain their order by utilizing the order in their environments. At the same time, the present hypothesis contrasts with the 'emergentism' of chaos theory, which fails to address the relationship between far-from-equilibrium dynamic systems, as may be observed at the level of the brain, and the other systems (both internal to the organism and external) with which it must interface. Finally, the hypothesis of an abstract but unifying process, such as catalysis, that characterizes all of life challenges the implicit assumption of theoretical biology that the strategies and processes that characterize a species are completely contingent upon the chance evolution of a process that reproduces and mutates.

Matthew T. Dearing - *Cornell University*

Digitally Mapping Cultured Neuron Networks Matthew T. Dearing , Harold G. Craighead

An understanding of structural and functional characteristics in a complex network requires a detailed map of the network's components and interconnections. Data sets representing the Internet, World-Wide-Web, scientific collaboration networks, and biological processes have been used to analyze these systems' network characteristics. However, there has been a lack of sufficient architectural data for another interesting complex network system: interconnected neurons. We present a method of automated digital image analysis to extract critical network properties from a cultured neuron network. Our data collection software will provide needed information for mapping cultured neuron systems, which will later be systematically compared to the functional characteristics of neuron devices with similar network structures.

Ronald DeGray - *Saint Joseph College*

Developing a Web-based Interactive Syllabus for an Undergraduate Course in Systems Thinking and Complexity

We will demonstrate a web-based interactive syllabus for a one semester course in systems thinking and complexity that is suitable for acapstone course in an undergraduate curriculum in information technology.

We also report our pedagogical and epistemological experiences in developing the course content. We wanted to provide students with a cognitiveframework beyond the technical aspects that they would acquire from a text based Information Technology curriculum. We also wanted to takeadvantage of technology and the rich source of materials available on the Internet.

This will be a joint presentation by Saint Joseph College professors: Dr. Ronald DeGray, Associate Professor of Mathematics and Dr. ShyamalaRaman, Associate Professor of Economics and Director of International Programs

Eugenio Degroote - *Universidad Plitecnica de Madrid*

Flame Spreading Over Liquid Fuels: A General Model

Understanding flame spreading over liquid fuels is a matter of both fundamental interest and crucial practical importance, mainly for its relevance to safety issues, as it is the base for the knowledge and ultimate control of fire propagation/suppression mechanisms.In this work, a complete overview of the problem is shown. A complete set of experiments have been carried out; they show that, depending on the initial surface fuel temperature, at least five different spreading regimes have been found. The appearance of all these regimes is directly related with the existence of a preheated zone (in the liquid phase) in front of the flame, that contributes in some way to its spreading. Our last experimental results suggest that the different mechanisms involved in this process are also directly related with the thermal transfer between the liquid phase (Liquid fuel) and the gas phase (fuel+air); this interaction between both phases seems to be the main responsible of the existence of so many differente spreading regimes. Finally, considering flame spreading as a dynamical system, the different transition temperatures observed have been observed and characterised as well. A numerical model is being proposed, that fits well with our experimental results. A dimensionless variable has been defined too, that results to be very similar for al the fuels and exerimental geometries used in our experiments, for one of the critical temperatures observed.

Tessaleno C. Devezas - *Los Alamos National Laboratory*

Aggregate Output Model Describing the Limit-Cycle Behavior of a Logistic Growing Process in Socioeconomic Systems

A socioeconomic system is an evolving complex adaptive system with many kinds of participants, which interact in intricate ways that continually reshape their collective future. During the ongoing evolutionary process the system self-organizes and learns
configuring and reconfiguring itself toward greater efficiency among greater complexity. Each stage of the evolutionary process corresponds to a given structure that encompasses previous self-organization, learning and current limitations. This is to say that self-organization and learning are embodied in the system’s structure and the learning rate is an overall system’s property. Such stages of the evolutionary path of a socioeconomic system are well described by simple logistic curves that to some extent conceal the complexity of mechanisms involved In this paper a cybernetic framework is proposed which, using a chaos based approach, may help to unveil some hidden properties of the logistic learning collective dynamics. From the relationship between the differential and the discrete logistic equations, it is demonstrated that the unfolding of a logistic (learning) process is constrained by two control parameters: the aggregate learning rate  and a generation-related characteristic time tG, whose product maintained in the interval tG<4 (deterministic chaos) grants the enduring evolutionary process. Describing the socioeconomic system discretely as a logistic growing number of interactorsadopting a new set of ideas (new learning) and using the logistic function as the probabilistic distribution of individuals exchanging and processing information in a finite niche of available information, it is demonstrated that the rate of information entropy change (K-entropy) exhibits a four-phased limit-cycle behavior. Implications of this modeling on reducing logical uncertainties in predicting the behavior of social systems are discussed.

Solomon Gilbert Diamond - *Harvard University*

Measuring Hypnosis: Relating Mental State to Systematic Physiological Changes

A fundamental problem in hypnosis research is to quantitatively assess the hypnotic depth of subjects because the subjective experience of patients during hypnosis cannot be measured directly. Prior evidence exists that systematic physiological changes during hypnosis may be reflected in heart rate variability (HRV). A novel method is presented for estimating HRV parameters that change dynamically on the time scale of seconds. The estimated parameters are combined into a single normalized HRV dynamic parameter (nHRVdp). This parameter was found to increase systematically across 10 subjects during the hypnotic state when compared with a commensurate control condition ($p<0.000001$). Significant correlations were found between the number of subjective hypnotic phenomena experienced by subjects and mean nHRVdp ($p=0.043$). Dynamic self-rating of hypnotic depth during hypnosis was also found to correlate significantly with nHRVdp ($p=0.0497$). These results suggest that an ECG monitor together with the proposed algorithm can objectively measure hypnotic depth. This "hypnometer" could have broad applications in clinical hypnosis and in research to better understand the physiology of the hypnotic state.

Commander John Q. Dickmann - *US Navy*

Complex Systems Research and Information Age Warfare

Defense community innovators have proposed concepts for using cutting-edge technologies to solve long standing military challenges, including destruction of time-critical targets, theater-wide surveillance, power projection and access to littorals. These concepts assume great benefits from networking that will enable military advantage by use of distributed systems. However, the advantages of networking as well as the implications of engineering distributed systems have not been fully articulated. This paper defines and describes how distributed, networked forces provide advantage; translates the advantage to engineering aspects of distributed system characteristics, functionality and design goals; and introduces a method of developing the engineering competencies required to design effective distributed, networked military forces.

Fred M. Discenzo - *Rockwell Automation*

Managed Complexity in An Agent-based Vent Fan Control System Based on Dynamic Re-configuration

New developments in advanced control techniques are occurring in parallel with advances in sensors, algorithms, and architectures Dubbelsthat support next-generation condition-based maintenance systems. The emergence of Multi-agent Systems in the Distributed Artificial Intelligence arena has shifted control system research into a very challenging and complex domain.

A multi-agent system approach enable us to encapsulate the fundamental behavior of intelligent devices as autonomous components that exhibit primitive attitudes to act on behalf of equipment or complex processes. Based on this approach, we have implemented an initial set of systems that validate this methodology to manage the inherent complexity of highly distributed systems to provide a consistent and aggregated system behavior. There are three essential aspects of this new paradigm that suggest the significant potential of intelligent, self-organizing distributed architectures; these are:

· The complexity of solutions of highly monolithic control systems is now understood as an aggregated family of well-delimited primitives. This aspect exposes the new systems as hybrid solutions that area made of well-connected hardware and software de-coupled units

· The primitive components represent an emergent infinitesimal behavior in which each primitive is only programmed with complete rules to satisfy local pursuits. Primitives are programmed with incomplete (or none) rules to describe the relationship with other primitives. Each primitive uses an agent language and is capable ofcommunicating peer primitives (e.g. Agents, Holons, or Cellular Automata).

· The system is then initially exposed to chaotic interactions among the primitives. The chaotic interactions are defined as a highly intense capability matching task (association). It is also postulated that the overall behavior will progressively converge to temporal clustering of primitives. This is what we refer to as managed complexity.

The concepts above and new engineering developments have helped achieve new and important capabilities for integrating CBM technologies including diagnostics and prognostics with predictive and compensating control techniques. Integrated prognostics and control systems provide unique opportunities for optimizing system operation such as maximizing revenue generated for capital assets, maximizing component lifetime, or minimizing total life-cycle costs.

We have defined and implemented an integrated diagnostic / prognostic / controller system in the context of an agent-based representation. This integrated agent-based system has been implemented in a variable frequency drive (VFD) and in a programmable logic controller (PLC). The VFD agent has been demonstrated operating an axial vent fan system. During operation the system dynamically adjusts system operation based on the collaboration with other agents operating in related parts of a chiller system.

This paper will describe the foundation technologies that are essential to realizing an adaptive, re-configurable automation system. These technologies include diagnostic and prognostic algorithms, advanced control techniques, agent-based framework for real-time automation systems, and system integration / modeling techniques. We will describe a demonstration system we have developed for HVAC applications that utilize these technologies. We will also cite the important, unprecedented capabilities this new system can provide along with open issues and research challenges associated with the wide-scale deployment of robust integrated prognostics and control systems in an agent framework.

Brock Dubbels - *The Norwegian University of Science and Technology*

Building a Network to the People

In consideration of the goals of the New England Complex Systems Institute to educate the population of complex systems in awareness, perspective, and methods, it is important to consider ways to create a learning web for the distribution of NECSI's most valuable resource: knowledge. Let it be made clear form the beginning, beyond the knowledge and methods, the most valuable resource that this community has is the individuals who are interested in Complex Systems work. These individuals could, through their training at NECSI, become mentors and trainers to local community schools for a limited time. This might enable NECSI to apply for educational dollars from local and federal sources and provide much needed support for young people, broadening awareness of complex systems for young people, their teachers, and a deeper learning for the students affiliated with NECSI in their training. The issue becomes one of vision and method. In order to make this work, one might suggest that we use any methods possible, but in consideration of the importance of practicing what we preach, it might be best to offer education about complex systems through a complex systems approach. There is a wide variety of method in teaching and learning, and many of the methods compliment if not endorse a complex systems approach to the world. The goal of this paper is to put forward suggestions for teaching methodologies that are representative of the complex systems approach to problem solving, i.e., it might be easy to have one person stand in front of a group and lecture, but does this represent a movement away from centralized control or the processes of group interaction. In the body of this paper, a review of approaches to curriculum and learning promotion will be organized to present different modes of instruction from either a traditional, or complex systems approach; recommendations will be made to offer an approach that not only serves to educate the populace about complex systems, but also does so from a complex systems approach in curriculum in form and substance. A review of the ideas of the K-16 education initiative and the session on education at the ICCS3 conference will be included with current ideas in education and learning. recommendations will be made for enacting this curriculum with members of NECSI, and future members.

Juan Carlos Chimal Eguia - *ESCOM-IPN*

Some Further Analogies Between the Bak-Sneppen Model for Biologcal Evolution and the Spring-block Earthquake Model

Along recent years a lot of attention has been devoted to the so-called self-organized critical systems: Which are open,extended systems, that organized themselves into steady metastable states, without any temporal or spacial predominant scale (except those impose by the finite size of the system). The SOC concept has been used to describe statistical properties of several physical systems by means of numerical models based on cellular automata. In particular, Bak and Sneppen proposed a SOC-model for biological evolution at the level of entire species or faunas, that exhibits punctuated equilibrium behavior. On the other hand, Olami., Feder and Christensen, have suggested that the two-dimensional spring-block earthquake model can explain some properties of real seismicity. In the present work we show that there exists several interesting analogies between these SOC-models. Both of them exhibit punctuated equilibrium in the long term, which leads us to suggest an equivalent characterization of seismic and "evolutionary" provinces through the long term slopes of the stair-shaped graphs of cumulative activity in the courseof time.

Ibrahim Erdem - *Yildiz Technical University*

Customer Relationship Management in Banking Sector and A Model Design for Banking Performance Enhancement

Huge growth of Customer Relationship Management (CRM) is predicted in the banking sector over the next few years. Banks are aiming to increase customer profitability with any customer retention. This paper deals with the role of Customer Relationship Management in banking sector and the need for Customer Relationship Management to increase customer value by using some analitycal methods in CRM applications.

CRM is a sound business strategy to identify the bank’s most profitable customers and prospects, and devotes time and attention to expanding account relationships with those customers through individualized marketing, repricing, discretionary decision making, and customized service-all delivered through the various sales channels that the bank uses. In banking sector, relationship management could be defined as having and acting upon deeper knowledge about the customer such as how to find the customer, get to know the customer, keep in touch with the customer, ensure that the customer gets what she/he wishes from service provider, and understand when they are not satisfied and might leave the service provider and act accordingly. This study will underline CRM objectives such as growth, retention and cost reduction. Increasing customers’ product cross-holdings, maximizing the contribution from each customer through time and increasing efficiency are couple of those objectives, which this study will cover.

Under this case study, a campaign management in a bank is conducted using data mining tasks such as dependency analysis, cluster profile analysis, concept description, deviation detection, and data visualization. Crucial business decisions with this campaign are made by extracting valid, previously unknown and ultimately comprehensible and actionable knowledge from large databases. The model developed here answers what the different customer segments are, who more likely to respond to a given offer is, which customers are the bank likely to lose, who most likely to default on credit cards is, what the risk associated with this loan applicant is.

Finally, a cluster profile analysis is used for revealing the distinct characteristics of each cluster, and for modeling product propensity, which should be implemented in order to increase the sales.

Peyman Faratin - *MIT*

A Multiagent Simulation Model of the Emergence and Dynamics of Negotiation in Complex Contracting Games

Complex systems are often characterized by the emergence of global behaviors that are often difficult to anticipate simply by inspection of the system's components. In this paper we present some interesting emergent properties that arise in the context of negotiation over contracts with multiple interdependent issues. In particular, we show that a concessionary strategy is actually superior if adopted by both parties, but the possibility of allowing agents to adopt a non-conessinary strategy introduces a prisoner's dilemma. These results, derived from multi-agent system simulations, are potentially relevant to human contexts such as collaborative design.

Brigitte Fleeman - *University of Texas at Austin*

Sensemaking of a Change Intervention With Insights From Complexity Science

Using Weick's (1995) framework of sensemaking and the insights gained from research on complex-adaptive systems, I am interested in empirically investigating the question of whether and how differences among agents affect the sensemaking processes of small groups as complex-adaptive systems. In general, diversity is a requisite and hallmark of complex adaptive systems. In the organization literature, diversity is seen more as a liability than an asset. On the one hand, diversity can hinder organizational performance when multiple interpretations must be understood and different cues integrated from a confusing array of possibilities. On the other hand, diversity often leads to surprising and unique inputs giving rise to novel and comprehensive considerations. In applying these perspectives to the interactions and relationships in diverse groups, an interesting tension emerges: How can diverse inputs be used in group sensemaking? The focus of this research project is the influence of functional diversity on the processes of sensemaking in small groups as complex adaptive systems and the consequences in terms of group understandings.

Using a naturalistic inquiry, the processes of sensemaking in weekly operational meetings of a functionally diverse small manager group at a startup site of a hospital network were followed for 7 months. The healthcare network had identified that clinical professionals have difficulty to move into the responsibilities as managers. A volunteer unpaid consultant developed an on the job trainingeffort and guided this leadership development project. Although these managers had extensive clinical experience, business and financial experience was limited. In addition to the 31 weekly operational meetings, several other meetings were observed and audiotaped. Various interviews with managers and the volunteer consultant complement the group sensemaking by following up on the individuals sensemaking.

The data analysis is in progress. Specific attention has been given to two surprising turn of events during the data collection: (1) an interesting interpretation of the nursing managers with regard to the leadership development project and (2) the surprising leaving of the group leader, the site manager. At the core are the different contributions to topic streams and understandings during the group meetings by the managers from different backgrounds. Insights from complexity science will contribute to the analysis and modeling of relationships and the group sensemaking processes. For instance, ideas derived from Axelrod's (1997) modeling of dissemination of culture can be applied to thinking about the development of ideas and crystallization of two or three main topics; Kauffman's (1995) conflicting constraints in the NK model can serve as a source for interpretation ideas regarding the connection to other hospital sites. Although these computer simulations consider individual traits or connectivity, hierarchical influences (e.g., power) are not included, which seem to be quite influential on the sensemaking of the group in this hospital setting.

Axelrod, R. (1997). The complexity of cooperation: Agent-based models of competition and collaboration. Princeton, NJ: Princeton University Press.
Kauffman, S. A. (1995). At home in the universe. New York, NY: Oxford University Press.
Weick, K. E. (1995). Sensemaking in organizations. Thousand Oaks, CA: Sage Publications.

Peter A. Flemming - *Vinyard Software*

Understanding Patterns of Cyber Terrorism: An Evaluation Research Framework

The proposed study develops an improved approach to understanding cyber terrorism by investigating the complexities inherent in conventional terrorism. It begins by illustrating weaknesses in contemporary research and develops a theoretical framework of international terrorism based on those variables which are noted for having the greatest impact on influencing terrorist group behavior. In the first phase of the study, emphasis is placed on establishing the role these variables play in shaping the dynamics of terrorist events. In the second stage, the relationship between terrorist group structure and behavior is reexamined to understand the nature of cyber terrorism.

The overall research strategy incorporates both qualitative and quantitative analyses as a means of furthering our understanding of terrorist group behavior. A comparative analysis offers insight into how the characteristics of various terrorist groups are reflected in their activity and how these are then reflected in cyber terrorist activity. An extensive statistical analysis using ITERATE data that covers the 1968-2000 period is also employed. This analysis performs a dual function of identifying/ highlighting the extent of international terrorism over the last three decades and testing several hypotheses of terrorist group behavior in the cyber environment. In sum, this study advances a research framework that identifies a key set of elements that shape cyber terrorism.

The comprehensive research strategy developed in this study addresses inter alia a number of salient concerns. These are:

1) clarification of the importance of terrorist group attributes in relation to conventional and cyber behavior;
2) empirical evidence that refutes the many myths surrounding terrorism, its evolution and outcomes;
3) establishment of recognized bench-marks of terrorist activity; and
4) identification of the cyber terrorist threat as it relates to various classes of terrorist groups and their victims.

In conclusion, this study offers both theorists and policy makers the opportunity to reevaluate contemporary thinking on cyber terrorism and the initial building blocks that are essential for future, informed research, as well as the amelioration of the cyber terrorist threat.

Aaron Fritz - *Utah State University*

Publication in the mainstream scientific literature is essential for the credibility and dispersal of our research. Publication of agent-based simulation often presents special challenges. Some of these challenges are because agent-based simulation is a new approach: convincing editors and reviewers that research results are of general applicability, overcoming objections to models with too many parameters, justifying selection of methods and inputs, satisfying the need for "validation". Other challenges are more technical: how to adequately document a model within a journal article's size limitations, how to present results derived from graphical interfaces. In this panel discussion, researchers who have attempted and sometimes succeeded in publishing agent-based research will identify such challenges and ways in which they can be overcome or circumvented. We hope to include the perspectives and advice of journal editors who have managed the review of agent-based papers.

Philip Galanter - *New York University*

On four modes of artistic engagement with complexity. Philip Galanter and Ellen Levy

Scientific complexity is not the basis for an art movement or style. But just as the Copernican revolution, the theory of evolution, and the innovations of Freudian psychology had implications beyond science, we feel complexity compels reconsideration of traditional themes in art, criticism, and philosophy.

The author and artist Ellen Levy have organized a show called "Complexity" that will take place at the Samuel Dorsky Museum in the fall of 2002 at SUNY New Paltz. In our research for this show we have found that artists engage complexity on four modes:

Portraiture - Artists can create realistic presentations of natural complex phenomena that transcend typical scientific visualization, evoking both a visual understanding and an emotive response in the viewer (e.g., Andreas Gursky and Harold Edgarton).

Descriptive Systems - Artists also experiment at various levels of conceptual abstraction. Artists will often invent innovative, possibly idiosyncratic, systems, which describe complex phenomena in a way that does not occur in the sciences (e.g., Mark Lombardi).

Commentary - Just as artists have commented on scientific and technical paradigms such as computers, genetics, and the like, they have also offered critiques of physical and social systems (e.g. Hans Haacke).

Technical Application - The study of complexity offers a new rich toolbox for artists who create works via generative systems. Such techniques include: genetic algorithms, swarming behavior, parallel computational agents, neural networks, cellular automata, L-systems, chaos, fractals, a-life, and other forms of emergent behavior (e.g., Karl Sims. John Simon Jr., and Woody and Steina Vasulka).

This talk will include examples such as the above and more, discuss the work and the ideas behind the work, and offer some speculative remarks as to how notions from complexity may help to progress beyond the postmodernist dead-end that dominates mainstream art criticism and theory today.

Auroop R Ganguly - *MIT*

Hybrid Statistical and Data Mining Approaches for Forecasting Complex Systems

Complex natural and built systems typically exhibit limited predictability. However, even a marginal increase in forecast accuracy often translates to significant benefits. Recent advances in data dictated forecasting tools, the physics of natural and built systems, and the enabling information technologies, have opened up new windows of opportunity. The modern forecaster has a more difficult task than her predecessors, owing to the ever increasing complexity of built systems or the need to incorporate the latest domain knowledge and measurements available from natural systems. However, she also has access to more and better information. The challenge is to be able to efficiently assimilate and reconcile the information to generate better forecasts. Approaches for data dictated forecasting of complex systems could be categorized into two classes. The first approach could be called

Traditional Statistics (TS), which includes correlation and spectral analyses, Bayesian approaches, time series and regression models like MARIMA, TAR and GARCH for the conditional mean and the variance, as well as methods for detection of outliers, interventions, trends, causal indicators and seasonal or other pulses. These techniques are statistically rigorous, but often need to make prior assumptions about the data or the underlying data generation mechanisms. However, the domain knowledge needed to make the assumptions might not always be readily available. The second approach could be termed Data Mining (DM), which include methods like K-means, Gaussian mixtures, Artificial Neural Networks (ANN) and Decision Trees. DM sometimes lack thorough statistical interpretations or the ability to weed out spurious trends, but might be able to discern patterns that are not obvious to TS. This article hypothesizes that optimal hybrid forecasting approaches could be designed that combines TS and DM tools, which could maximize the possibility of discovering interesting patterns while retaining statistical rigor. Arguably the most commonly used TS and DM tools for forecasting are MARIMA and ANN respectively. A simple forecasting algorithm is proposed that attempts to combine these tools in an optimal fashion. The power of this new algorithm is demonstrated using real data, through two example applications in disparate domains.

The first example is space time forecasting of high resolution rainfall amount. The governing equations of weather are nonlinear and often exhibit chaos, while rainfall physics at high resolutions is not well understood and exhibit high variability. Relevant data are available from remote sensors like radar and satellites, ground measurements, and numerical weather m dels. Forecast improvements are rather difficult to

obtain, however even relatively small gain in accuracy could translate to reduced flood hazards. The second example is sales and demand forecasting in the industry.

The inherent variability in these systems are a caused by human or extraneous factors, which are difficult to quantify. Data are available from corporate data repositories, syndicated data providers, and third party sources. Dynamic markets and changing corporate and competitive policies make the forecasting process complicated. However, relatively small gains in the accuracy of demand forecasts could lead to better management of inventory, and better tactical, operational and strategic plans.

Carlos Gershenson - *Univerity of Sussex*

Complex Philosophy

We present several philosophical ideas emerging from the studies of complex systems. We make a brief introduction to the basic concepts of complex systems, for then defining abstraction levels. These are useful for representing regularities in nature. We define absolute being (observer independent, infinite) and relative being(observer dependent, finite), and notice the differences between them. We draw issues on relative causality and absolute causality among abstraction levels. We also make reflections on determinism. We reject the search for any absolute truth (because of their infinity), and promote the idea that all comprehensible truths are relative, since they were created in finite contexts. This leads us to suggest to search the less-incompleteness of ideas and contexts instead of their truths.

A Study on the Relevance of Information in Discriminative and Non-Discriminative Media - C. Gershenson, M. A. Porter, A. Probst, and M. Marko

In this poster we compare the relevance of information obtained from "discriminative media" and from "non-discriminative media". Discriminative media are the ones which accumulate information with an heuristic selection of information. This can be made by humans (editors), or by artificial intelligent systems, exhibiting some form of "knowledge". Non-discriminative media just collect information without any distinction. This collection can also be made by humans or by artificial systems, but there is no "knowledge" involved in the process. We ranked the words occurring in an edited electronic publication specialized in complex systems research, and we found that they approximate a modified Zipf distribution. We compared occurrences of representative words from the distribution with the occurrences in non-discriminative media. We found that a non-discriminative medium (Google) resembles much less the order of our original distribution than a semi-discriminative one (NEC Research Index), even when both appear to have their own modified Zipf distribution. We conclude that discriminative media will have a higher efficiency rating in the area they specialize in than non-discriminative media. Using the same search method, the discriminative media should deliver more relevant information. This relevancy also depends on the skills of the user, but non-discriminative media are more sensitive to poor searching skills, since there is a higher probability of delivering irrelevant information. This leads us to suggest the incorporation of intelligent classifications in different media (such as semantic webs), in order to increase the relevance of the delivered information.

Robert Ghanea-Hercock - *BTexact Laboratories*

Co-operative Agents in Network Defence

The question addressed in this paper is how can complex information networks survive hostile attacks. In particular we seek to understandsurvivability and defence in large-scale computing networks. An integrated network of software agents has been constructed which provides adynamic immunological and automated defence mechanism within a computing network. As recent evidence indicates, firms, governments and

otherorganisation urgently require better defensive strategies in cyberspace, (Anderson et al 1999, and Briney 2000). In particular, the ability of anentity to maintain itself in the face of continuous perturbation raises many issues related to metabolism, network topology, inter-agent bindingforces and assimilation by external agencies. Using a collective formation of smart software agents we aimed to create a form of adaptive immune-response structure within a computing network.Some preliminary work in this field has already demonstrated the effectiveness of such methods using software agents, (Crosbie M. & Spafford 1995,Filman & Linden 1996, Yialelis, Lupo & Sloman 1996).

In order to investigate these processes a multi-agent simulation model has been developed which demonstrates spontaneous group formation and themaintenance of group integrity. These system aspects are proposed as integral components of survivability. Each agent is susceptible to virusinfections, passed between each agent and social assimilation by its local neighbours. From this model we observe a wide range of complex socialbehaviours that could be selected from a few critical interaction parameters. We then introduced an artificial immune system to each agent, whichallows learned 'antibody' solutions to be exchanged between the agents within a social group. This mechanism reduced the infection level to asmall percentage of the non-cooperative state.

The interest in this behaviour stems from the concept that by linking together the sensory and intelligence capabilities of a large number ofagents distributed across a network we can amplify the ability of the network to resist attacks or intrusion. Specifically through socialco-operation, agents can benefit from the combined defensive capabilities of their particular group.

The present global computing and communications network is a highly dynamic structure on an immense scale. Future attempts to defend Intranet ortelecommunication networks will require equally dynamic and adaptive processes. This work indicates that a cohesive network of sociallyinteracting agents can create a highly robust and adaptive defence system for information networks. The agent simulation we have developeddemonstrates that it is possible to create a population of autonomous agents, which form self-healing social groups with greater resistance toattacks and perturbation than isolated agents.

Zann Gill - *RIACS, NASA Ames Research Center*

Webtank

Webtank (think tank on the web)and the management of organizational complexityIn this talk I'll give a mini-tour through the webtank mock-up and discuss plans to use it to support think tank knowledge management throughself-organization as the webtank evolves.

I'll describe how this pilot experiment in web-supported learning lays the foundation for a web-based "greenhouse" designed to address thecomplexity of knowledge management as this interactive web environment scales up. The webtank will document process events linked to an assessmentplan that can inform human/agent decisions about how to modify the documentation strategy and guide website evolution.

The operative principle of the webtank is to encourage individual differences as the key to effective collaborative problem-solving andinnovation, reflecting the principle of alife simulations where heterogeneous actors collaborate to solve problems. As individual webtank modulesare uploaded, their location in the sitemap is fluid and is gradually specified as they evolve their links to other entries. As the site graduallyscales up, the small number of low connectivity links grows into a networked modular, structure that evolves toward increasing coherence.

Willia Hardin Glover - *Fielding Graduate Institute*

An Exploratory Study of Key Factors of Self-Organization in Organizational Systems

This research is an exploratory investigation of self-organization in complex organizational systems. Self-organization is a process of transformation that culminates in the spontaneous structural reorganization of

complex social systems. An instrumental case study methodology was employed to explore this social phenomenon in 2 Dallas-based organizations. A combination of archival data and interviews revealed 2 important observations: a) Self-organizing behavior is inherent in organization transformation and b) image, mission, and values, the organization's core elements are key factors that contribute to self-organization in organizational systems.

Amrit Goel - *Syracuse University*

Radial Basis Function Classification of Microarray Data Using Shin-Goel Algorithm. Amrit Goel and Miyoung Shin

Golub et.al. (1) introduced a generic approach to cancer classification based on gene expression monitoring by DNA microarrays. Their class discovery procedure automatically distinguishes between two types of cancer, acute myeloid leukemia (AML) and acute lymphoblastic leukemia (ALL), without class knowledge. They state that it should be feasible to develop cancer classifiers based solely on gene expression monitoring independent of previous biological knowledge. Here, we develop radial basis function (RBF) classifiers for distinguishing between ALL and AML based on gene expressions.

RBF classifiers have been used in a wide range of disciplines from engineering to medical sciences and economics to astronomy. However, current algorithms for determining RBF model tend to produce inconsistent designs due to their ad-hoc nature. Recently, Shin and Goel (2,3) introduced a new approach for the design and analysis of radial basis function classification models. In general, there exists a conflict between model complexity and performance, the so-called bias-variance dilemma. The Shin-Goel (SG) algorithm selects the lowest complexity model with the “best” compromise between training and test errors via a user-specified complexity control parameter. Their approach provides an objective and systematic design methodology due to its origins in the mathematical properties of the interpolation and design matrices associated with the RBF model. This algorithm involves no randomness in classifier development and can be almost totally automated. Finally, the SG algorithm is computationally fast since it involves matrix computations as opposed to iterative search employed in current algorithms.

In this paper we use the SG algorithm to develop Gaussian radial basis function classifiers for the microarray data of Golub et.al.(1). We consider two data sets. The first uses 7129 and the second 50 gene expressions. In both sets, 38 patients are used for classification model development and 34 for testing. Our results are summarized below.

7129 gene data set

For training data of 38 patients, the SG algorithm produced an RBF design with twenty nine Gaussian basis functions and classified all patients correctly. For test data, 29 of the 34 patients were classified correctly by the RBF classifier.

50 gene data set

For training data, the SG algorithm produced an RBF classifier with five Gaussian basis functions in the hidden layer and classified all 38 patients correctly. For test data, 33 of the 34 patients were correctly classified by the RBF classifier.

In this paper we also report on the sensitivity analyses of the developed classifiers. These analyses show that the training and test errors for both data sets are relatively robust to global basis function width as well as to model complexity (number of basis functions).

REFERENCES

[1] T. R. Golub, D. K. Slonim, P. Tamayo, C. Huard, M. Gaasenbeek, J. P. Mesirov, H. Coller, M. L. Loh, J. R. Downing, M. A. Caligiuri, C. D. Bloomfield, E. S. Lander. Molecular Classification of Cancer: Class Discovery and Class Prediction by Gene Expression Monitoring. *Science*, 286:531-537, 1999.

[2] M.Shin and A. L. Goel. Empirical Data Modeling in Software Engineering Using Radial Basis Functions. IEEE Transactions on Software Engineering, 26:567-576, 2000.

[3] M. Shin, and A. L. Goel. Radial Basis Function Model Development and Analysis Using the SG Algorithm (Revised), Technical Report, Department of Electrical and Computer Science, Syracuse University, Syracuse, NY, 2002.

Noah C. Goldstein - *UCSB Geography*

Co-evolution in Coupled Human-Natural Systems

Coupled human-natural systems interact in many dimensions, including the cultural, the physical, and the biological. Over time, coupled human-natural systems interact and develop to exhibit coevolved behaviors. These behaviors are promoted by feedbacks between the two systems as well as the dynamics inherent to each individual system. Many inter-system feedbacks occur in cycles, based on biophysical drivers or cultural characteristics. This paper has two goals. First, this paper will present the behavioral relationship of a coupled human-natural system and discuss if it can indeed be called one of "coevolution". This is challenging, as different types of evolution are at play in each individual system; Human systems by cultural (Lamarckian) evolution, Natural systems by both biological (Darwinian) evolution, and physical evolution of the landscape. The coupled system complex provides a novel locus of coevolution, one that can be challenging to understand and describe. Comparisons to purely biological examples will be made and a definition of coevolution for complex systems will be proposed. Second, this paper will describe examples of coupled human-natural systems, and characteristic behaviors that make them unique and similar. These include agriculture as well as river flooding and other natural disasters. What is important in examining specific coupled human-natural systems are historical events and trends that can then be used to understand where the systems are linked, and over which spatial and temporal scales the linkages occur. A case study of urban growth and wildfires in Santa Barbara, California will be used as an example. The coastal city is the home to a growing population, along with an extensive urban-wildland interface with the fire-adapted chaparral of the Los Padres National Forest. In recent decades, wildfires have caused millions of dollars of damage to homes and structures within the urban fabric. In addition people have contributed to large alterations in fire regime, and fire spread. Recent developments in the historical and forecasting simulation modeling of the urban-wildfire coevolution in Santa Barbara will be presented along with a framework to study the potential risks that the growing urban area may foresee in the future.

Robert L. Goldstone - *Indiana University*

The Allocation of Agents to Resources in a Networked Multi-Player Environment. *Robert L. Goldstone & Benjamin Ashpole*

Our goal in this research is to collect a large volume of time-evolving data from a system composed of human agents vying for resources in a common environment, with the eventual aim of guiding the development of computational models of human resource allocation. We have developed an experimental platform that allows a large number (more than 30) of human participants to interact in real-time within a common virtual world. We recorded the instant-by-instant actions of each individual within this environment. Two resource pools were created with different rates of replenishment. The participants' task was to obtain as many resource tokens as possible during an experiment. An agent obtained a token by being the first to move on top of it. In addition to varying the relative replenishment rate for the two resources (50-50, 65-35, 80-20), we manipulated whether agents could see each other and the entire food distribution, or had their vision restricted to food in their own location.

As a collective, the agents would optimally harvest the resources if they distribute themselves proportionally to the distribution of resources. Several empirical violations of global optimality were found in the 8 sessions of 20+ participants that were tested. One observed suboptimality was an underutilization of resources that occurred because of frequent pool-switching by individual agents. Agents did not mimic the

distribution of agents' resource allocations by their individual distribution of allocations. Nevertheless, they did alternate resources frequently enough to introduce collective inefficiencies in harvesting.

Second, there was a systematic underutilization of the more preponderant resource. For example, agents distributed themselves approximately 70% and 30% to resources pools that had relative replenishment rates of 80% and 20%, respectively. The expected pay-off per agent was larger for pools with relatively high replenishment rates.

Third, there were oscillations in the harvesting rates of the resources across time. Perceived underutilization of a resource resulted in an influx of agents to that resource. This sudden influx, in turn, resulted in a glut of agents, which then led to a trend for agents to depart from the resource region. This cyclic activity in the collective data was revealed by a Fourier analysis showing prominent power in the range of 30 seconds per cycle.

Fourth, agents were more dispersed within a resource pool than optimal. The distributions of both agents and resources were well fit by Gaussian functions, and the means of the agent and resource distributions closely matched. However, the variances for the agent distributions were much larger than for the resource distributions, particularly when agents' vision was restricted and for agents in pools with relatively low replenishment rates.

These results are discussed in terms of optimal foraging behavior, K-armed bandit problems, frequency dependent selection, and resource allocation strategies. In addition to providing practical suggestions on how to improve the utilization rate of a set of resources by a decentralized collection of agents, the current data highly constrain models of agent and resource allocation.

Dominique Gross - *Dublin City University*

Currently the science of complexity lacks a generally accepted formal definition of complexity. However, especially among modellers of complex natural systems, the notion of CAS slowly seems to emerge as a widely adopted working definition of complexity. We want to suggest that the notion of CAS lacks at least two crucial features in order to suit as a framework for understanding real complex systems. These features are "radical openness" and "contextuality". The former describes the property of real complex systems to lack clear boundaries and the latter describes the fact that components of real complex systems typically fulfill multiple functions simultaneously.

Vladimir Gudkov - *University of South Carolina*

Multidimensional Network Monitoring for Intrusion Detectio

An approach for real-time network monitoring in terms of numerical time-dependant functions of protocol parameters is suggested. Applying complex systems theory for information flow analysis of networks, the information traffic is described as a trajectory in multi-dimensional parameter-time space with about 10-12 dimensions. The network traffic description is synthesized by applying methods of theoretical physics and complex system theory, to provide a robust approach for network monitoring that detects known intrusions, and supports developing real systems for detection of unknown intrusions. The methods of data analysis and pattern recognition presented are the basis of a technology study for an automatic intrusion detection system that detects the attack in the reconnaissance stage.

Laszlo Gulyas - Harvard University

A Model of Dynamic Small World Networks by Random Walks

Recent years have seen an increased interest in the properties of complex real-world networks, e.g., the World-Wide Web, human acquaintance networks, food webs, etc. It has been shown that these networks

exhibit a number of important properties. The most known of these is the so-called small-world property implying that the average path length in the network is small relative to the system size. Another important feature of such complex networks is clustering, i.e., the increased probability that pairs of nodes with a common neighbour are connected themselves. Recently, increased efforts have been dedicated to the study of degree distributions in real-world networks. It has been shown that in a number of cases it follows a power law. While a number of models have been proposed to generate networks with some combination of the three properties above, virtually each of these describes a process that ends with a network having the desired properties. Less effort has been devoted to the design of a dynamic system that would generate and maintain such a network. While there are a few such models, most of them assume that the system size or the number of links increases monotonically. In this paper I propose a novel model that generates and maintains a small-world network with high level of clustering, where links dynamically change between a fixed number of nodes. In this model, nodes are represented as agents performing random walks on a lattice. During their walk they create links to agents in their vicinity. These links, however, wear out by time unless reinforced by repeated encounters. An important property of the networks generated by this model is that the degree distribution remains virtually constant over time. A preliminary analysis of the key factors contributing to these findings is presented, together with the discussion of a possible extension that may produce arbitrary degree distributions.

Patterns of Firm Agglomeration: An Autonomous Agent-Based Model of City Formation, Laszlo Gulyas and Yuri Mansury

This paper proposes an agent-based model of city formation in which firms behave as true „autonomous‰ agents. More specifically, agents (i.e., virtual firms) migrate from one location to the other, in so doing often create agglomerations (i.e., formation of virtual cities), based on a local decision-making process that is internal to individual agents. It is these changes at the microscopic level that subsequently lead to the large-scale macro-patterns of city formation. Our modeling approach is thus „bottom-up‰ rather than based on an ad-hoc „top-down‰ rule commonly adopted in previous studies. A special feature of the model developed in this paper is the agents, capability to search both globally and locally. At each period, in its search for a better place to reside an agent learns the information content of a region in two stages, the global and the local. In the global stage, agents see the whole world (i.e., have „unlimited vision‰ spatially) but can only extract limited information from each location in the world (i.e., agents have unlimited breadth but limited depth of knowledge). Specifically, in the global stage an agent learns only the population density of all regions and then employs that knowledge to evaluate every region. Once an agent has identified which region is the „best‰ in the global stage, the agent proceeds to the second stage in which it performs a local search on that region,s neighborhood. In this local stage, agents see only the neighborhood of a location selected in the global stage (i.e., have „limited vision‰ spatially) but are capable of extracting the full-depth of information from every location in that neighborhood. Only in this latter stage does an agent discover the specific characteristics of that neighborhood and then uses that information to select the particular location to which it will ultimately migrate. Our paper aims to (1) replicate the rank-size rule ˆ known as Zipf,s Law in spatial economics ˆ that American cities exhibited, (2) provide microeconomics foundations to the migratory behavior of firms, and (3) compare the structure of agglomeration in our model with the stylized spatial pattern of city formation in the US. We found an emerging pattern of city formation in which firms ultimately agglomerate in clusters even though locations have no inherent distinctions. Under a certain (robust) set of parameter values, the rank-size distribution of these clusters of firms (i.e., cities) exhibits the power-law relationship that resembles the empirical artifact exhibited by American cities.

George J. Gumerman - *University of Arizona & Santa Fe Institute*

Evolving Social Complexity in the Prehistoric American Southwest. George J. Gumerman , Alan Swedlund , Jeffery S. Dean ,Joshua Epstein , and Robert Axtell

The Anasazi (ancestors of the present day Pueblo peoples) of the American four corners area were a technologically simple agricultural society, dependent on maize agriculture. Ethnographic, historical, and archaeological accounts document a culture with complex social, religious, and economic systems. Detailed reconstruction of the past environment from A.D. 200 to A.D. 1450 permits an understanding of the coupled natural and cultural landscape of the region. Changes in Anasazi social complexity are closely linked with perturbations in environmental conditions.

An agent-based model has been developed in order to test the relationship of a number of physical and cultural attributes to changes in Anasazi social complexity. The changing landscape of Long House Valley in northern Arizona and the location and size of prehistoric settlements on an annual basis has been digitized. In contrast to the actual cultural situation, agents, or artificial Anasazi, evolve on the same digitized landscape according to rules derived from the ethnographic and historic data and inferences from archaeological research. The artificial Anasazi are then compared to the actual situation to determine if inferences made about the role of demography and environment in the changing social complexity are correct.

The modeling effort has demonstrated that nutritional, demographic, and environmental conditions have had a greater impact on the Anasazi evolutionary trajectory than previously suspected. In addition, the models have indicated that certain strategies that were not implemented by the Anasazi might have buffered the society from collapsing into simpler forms and even permitted them to stay in the area they abandoned at approximately A.D. 1300. The great environmental and cultural detail and the relatively simple technological society of the Anasazi make the four corners region of the southwest an excellent natural laboratory in which to test hypotheses about evolving social complexity.

1 Arizona State Museum, University of Arizona, Santa Fe Institute
2 University of Massachusetts - Amherst
3 Arizona State Museum, University of Arizona
4 Brookings Institution, Santa Fe Institute
5 Brookings Institution

Ivar Hagendoorn

Emergent Patterns in Dance Improvisation How Complexity Theory Inspires Choreography and Vice Versa

In a traditional choreography a choreographer determines the motions of a dancer or a group of dancers. Information theory shows that there is a limit on the complexity that can be created in a given amount of time. This is true even when building on previous work, since movements and their interactions have to be communicated to the dancers. When creating a group work, choreographers circumvent this problem by either focusing on the movements of individual dancers (giving rise to intricate movements but within a simple spatiotemporal organization) or on the overall structure (intricate patterns but simple movements). Complexity theory offers a different paradigm towards the generation of enticing patterns. Flocks of birds or schools of fish are generally considered Œbeautiful_ but lack a central governing agent. Computer simulations of individual based models show that a few simple rules can give rise to the emergence of the kind of patterns seen in flocks or swarms. In these models individual agents are represented by dots or equivalent shapes. For this and other reasons, which will be discussed, to be of use to choreography and to be implemented on or rather with dancers, some additional rules will have to be introduced. I will present a number of possible rules, which emerged from Œreal life_experiments with dancers and the considerations that shaped them. I will also extend the individual based model framework, which is based on local interactions between single agents, to include the interaction with a group of agents acting as a single agent. Dancers may perceive the global structure they form, e.g. a line or a cluster, and then put that knowledge to

creative use according to some pre-established rules, e.g. if there is a line, form a circle or if there is a cluster spread out in all directions. Some of the rules presented here may be applied back to other complex systems. The present paper is also an invitation to complexity theorists working in different fields to contribute additional rules and ideas.

Jennifer Hallinan - *University of Queensland*

Iterative Diffusion of Vectors for the Detection of Modularity in Complex Networks

Systems biology offers the prospect of new insights into the emergentproperties of complex biological systems such as cells, tissues, whole organisms and ecosystems. However, the data which has been collected to date is incomplete, raising concerns that attempts to model biological systems at a systems level are premature. We contend that incomplete data sets are not necessarily a problem if the data which does exist is organized into structural modules characterized by relatively high connectivity within the nodule and lower connectivity between modules.

Modularity appears to be widespread in biological systems ranging from subcellular networks to ecosystems, and is important to both the functionality and the evolution of the system concerned.

The ability to identify modules within largely uncharacterized biological networks would be valuable in several ways. It would assist with the characterization of uninvestigated nodes based upon their module membership and it would permit assessment of the extent to which analysis of the already characterized nodes of an incompletely studied network is feasible. If the well understood nodes form a largely independent module within the network, the fact that much of the rest of the network is uncharacterized becomes less relevant.

In this paper we describe an algorithm for the objective identification of modules within a network.. Each node of the network is assigned a binary vector n bits long, where n is the number of nodes in the network. The initial vector for node i consists of a 1 in position i and 0 in every other position. The system then undergoes an iterative process of vector modification, as follows:

.At each time step an edge in the graph is selected at random..The vectors representing the nodes at each end of the edge are compared.At any position i in the vector at which the entry is not equal to 0 an amount delta is added to the larger of the two entries and subtracted from the smaller

This process is iterated until each node in the network has been modified on average p times, where p is a tunable parameter of the system. The final set of vectors is then subjected to a standard clustering method (we have used k-means and Kohonen's Self-OrganizingMap) in order to assign cluster membership to each node in the network.. Each cluster can be interpreted as a structural module within the original network.

Using artificially generated networks composed of modules of known degree of clustering, the iterative vector diffusion algorithm performs robustly. We have also applied the algorithm to the network of protein-protein interactions in the yeast Saccharomyces cerevisiae.In this network the nodes are proteins and the links are protein-protein interactions detected using a yeast two-hybrid screen. Details of the nature, function and subcellular location of the protein are unknown for more than half of the proteins in S. cerevisiae. The characterization of the modules detected, and the potential utility of the IVD algorithm for the detection of functional modules in a network such as this is discussed.

Zhangang Han - *Beijing Normal University*

Evolution of Labor Division For Coopertive Agents With Learnig Abilibty

This paper studies the dynamics of how cooperation in a multi-agent system is evolved. A multi-agent system usually has many self-interested individuals; each makes decisions based on environment and their own states at the current time. Information is usually localized, and the ability for each individual to move is confined. The evolution of the multi-agent system may lead to collective behaviors due to mutual

interactions among individuals. Specialization increases productivity in an economy that will result in labor division. This paper simulates a specialization evolution process by introducing one kind of agents that each can take two kinds of tasks: search for resources and mine the already found resources. Agents search resources by random walk. An agent can decide whether to mine the resource found by itself or trade the resource to other agents nearby through a market-like mechanism. There are no global planning mechanisms. The agentssearching and mining capabilities can be adjusted through learning-by-doing with maximum value constrains for the capabilities. An agent's specialization degree is measured by the ratio of profits made by searching to all the profits made. Initially, agents are evenly partitioned in the specialization degree space. Evolution leads to a pattern that agents tend to specialize in their works. There are some of the agents make benefits only through searching for resources and trading them to others and some of the agents make benefits only through accepting trades from others and mining the resources. Only through cooperation, can the individuals that specialize in searching survive. This paper also studies the effect of parameters on division of labor, as trading range, trading price, searching range, mining speed, population density, and resource density. At certain areas of the parameter space division of labor does not emerge. This paper locates the phase transition point.

Steven Hassan - *Freedom of Mind Resource Center Inc.*

A Complex Systems Approach to Countering Brainwashing, Mind Control, and Terrorism

Destructive mind control is a systematic social influence process that typically includes deception, hypnosis and behavior modification techniques to subvert an individual1s identity in order to create a new pseudo-identity in the image of the leader.

A mind control model will be presented that demonstrates how the control of: behavior; information; thoughts and emotions are used by destructive cults (pyramid structured, authoritarian regimes) to make cloned identities, obedient and dependent to its authority.

Furthermore, the presentation will include how a complex system model called the Strategic Interaction Approach can be used to mobilize social networks to empower impacted individuals to reassert their own identity and independence and break free from the pseudo-identity.
http://www.freedomofmind.com

Yu-Chi Ho - *Harvard*

The No-Free-Lunch Theorem, Complexity and Computer Security

Using a simple explanation of the No Free Lunch Theorem and the reasonable assumption that P(NP, we derive certain general conclusions regarding the limiting behavior of complex systems and network security.

Guy A. Hoelzer – *University of Nevada Reno*

On the Relationship Between Natural Selection and Self-Organization

Biological evolution is often cited as an example of self-organization in a dynamical complex system, which is consistent with the notion that self-organization continually optimizes structures in response to unpredictable perturbations. Some authors have even suggested that this model of adaptive evolution should be considered as an alternative to Darwin's model of adapation through natural selection. There is, however, no reason to think that these are mutually exclusive processes. In this talk, life will be described as a self-organized engine that reduces an energy gradient created by the earths shadow; the constraints of birth/reproduction/death increase the "coarseness of the grains" of the system, permit better optimization of energy flow, and provide the foundation for natural selection among phenotypic variants to occur. This self-

organizing engine can then take advantage of natural selection as a means of further optimizing energy flow. Indeed, data recently compiled by Brown, West and colleagues show strong and predictable relationships between energy processing and fitness in many taxanomic groups. In this view, natural selection is both distinct from the general self-organizing process and used as a tool for self-organization, thus placing Darwin's theory into a more general framework.

Craig van Horne - *Harvard Medical School*

The Principles of Connectivity, Self-organized Criticality, and Complex Adaptive Systems May Further Our Understanding of the Symptoms and Treatment of Parkinson's Disease

Parkinson's disease has been identified as a progressive loss of dopaminergic neurons within the substantia nigra, a small nucleus deep within the midbrain. The symptoms of the disease, tremor, rigidity and hypokinesia, begin to develop once there has been a loss of 70-80% of this neuronal population and worsen to an incapacitating condition as the degeneration continues. Two substantial issues regarding the disease are that the underlying etiology of the dopaminergic cell loss remains unknown and that despite the availability of medications and procedures that provide temporary relief of symptoms there are no treatments or interventions that halt the progressive neuronal death. As the disease progresses, the treatments lose efficacy and are often complicated by disabling side effects. A potential limitation has been the consideration of the disease as being due to either a loss of dopamine or to the loss of the cells themselves. While both play a role, I propose that it may

In terms of complex adaptive systems and self-organized criticality there are several assertions. It is reasonable to identify the basal ganglia as a complex adaptive system comprised of several sub-cortical nuclei composed of highly interconnected neuronal populations. The connections allow for multiple areas of input, output, and feedback loops. In addition, there are functional and structural features that allow for adaptive changes to occur in response to external and internal changes. The basal ganglia may also be considered to be a self-organized system demonstrating a dynamic function that is positioned in the sub-critical state at the edge of chaos. In this sense, the critical state represents the flow and propagation of signaling through and within the interconnected nuclei. This dynamic function allows smooth and accurate motor activity to occur at the level of the organism. In this system the underlying feature of self-organized criticality is the many degrees of free

Michael Howard - *HRL Laboratories*

Amorphous Predictive Nets. Michael Howard, Regina Estkowski and David Payton

This paper describes our work on the development of biologically inspired approaches to achieve coordinated action from extremely large numbers of distributed, loosely connected, embedded computing elements. In such networks, centralized control and information processing is impractical. If control and processing can be decentralized, the communications bottleneck is removed and the system can become more robust. Since conventional computing paradigms provide limited insight into such decentralized control, we look to biology for inspiration.

With the recent progress in the miniaturization of sensors and computing elements and in the development of necessary power sources, large arrays of networked wireless sensor elements may soon be realizable. The challenge will be to develop software that enables such amorphous arrays to self-organize in ways that enable the sensing capabilities of the whole to exceed that of any individual sensor.

Our goal has been to devise local rules of interaction that cause useful computational structures to emerge out of an otherwise amorphous array of distributed sensor nodes. These distributed logical structures appear in the form of local differences in sensor node function, and local differences in node-to-node connectivity. These local differences serve to form distributed circuits among nodes that allow a group of nodes to perform

cooperative sensing and computing functions that are not possible at any single node. Further, since the local differences emerge and are not pre-programmed, there is never a need to assign specific functions to specific nodes. We can start out with a completely amorphous array of sensor nodes, running the same software, and have them all automatically differentiate into the necessary computational structures.

In this paper, we describe two methods, each using only local interactions between nodes, to detect the presence and heading of an intruder moving through a distributed sensor network. In one method, nodes do not differentiate, but they rely on temporal derivatives of signals produced by neighboring sensors. While this method is capable of detecting motion, it cannot discern the direction of motion within less than a 180-degree cone. In the second method, nodes differentiate along parallel spatial bands. This results in a pattern state within individual nodes that either sensitizes or desensitizes the nodes to particular activation/inhibition signals from neighboring nodes. Activation/inhibition rules are designed such that messages signaling the presence of an intruder are inhibited along bands of the same type, but are propagated into bands of a different type. This, in effect, leads to a form of moving edge detection for objects moving across the sensor array from one spatial band to another.

These methods provide a purely distributed means of computing the direction and likely destination of a sensed movement, with no need for centralized data analysis or explicit sensor data fusion. As with any approach to amorphous computing, it is impractical to try to extract information from the network, such as a global map of node activation. We present options for exploiting the results of the distributed computation performed by the network.

Sui Huang - *Children's Hospital, Harvard Medical School*

Gene network topology and dynamics in mammalian cell fate regulation

The advent of large-scale genomic technology opens a new window to the old riddle of genome-to-phenome mapping. A first step towards an integrative ?bottom-up? understanding of living systems based on genomic information is to study as an entity the network of interactions between the genes and proteins. Recent work has revealed interesting characteristics of the topology of genomic (gene/protein/metabolite) interaction networks, such as the power-law distribution of connectivity between the genes. However, it remains largely unknown how the global network topology translates into ?emergent? phenotypic behavior. A first level of emergence in the multi-level, hierarchical organization of living system is the global cell behavior which can bee seen as the ?macroscopic biological observable? that is determined by the underlying gene regulatory network, the ?microscopic? level. Cell fate regulation, i.e. the switch between a finite set of discrete phenotypic cell states, such as proliferation, differentiation and apoptosis, represents such a robust, emergent cell behavior. First, we used conventional cell biology experiments to measure cell state transition dynamics in human cells and show that at the macro-level cell fate dynamics is compatible with the idea that cell differentiation states are attractor states, as proposed by Kauffman and others. We then used DNA microarray-based dynamic gene expression profiling to analyze a cell fate switch and present preliminary data demonstrating that also at the micro-level the notion of cell fates being attractor states of the high-dimensional system of interacting genes is consistent with experiments. These findings suggest that the observed dynamics of cell behavior is a direct manifestation rather of the structure of the state space (e.g. phase singularities) of the network rather than of its topology. Therefore, we studied how topological features found in real gene networks affects the dynamics, i.e., the ?attractor landscape? in simulated, generic networks. We show that power-law distribution of connectivity, a topology found in all cellular networks studied, exhibits a state space structure that might be more favorable for biologically meaningful cell fate regulation. Implications of this finding for fundamental biological properties of cells, such as the coexistence of stability and flexibility (adaptation), as well as applications in cancer research and drug discovery are discussed.

Alfred W. Hubler - *University of Illinois*

Experimental Appoaches to Complex Systems. Alfred W. Hubler and Paul Melby

We study adaptation to the edge of chaos in high dimensional experimental system. We investigate experimentally high dimensional Chua circuits with low pass filtered feedback. We find that Chua oscillators adapt to edge of periodic regimes, which a larger than a certain minimum size. The minimum size of the period windows depends on the size of the feedback. We also find that in the chaotic regime, adaptive Chua circuts with external control tend to disentrain from the target dynamics and tend to adapt to the edge of chaos. These finding may explain why chaos is rarely
observed in complicted chemical systems and other complicated systems.

Tim Huerta - *University of Southern California Los Angeles*

Complexity as a unifying paradigm for Organization and Management

The literature on the philosophy of science is undergoing a transformational change that challenges academics with the inadequacies of the positivist perspective. The traditional focus on empirically identifiable linear relationships and an historical foundation based on idealized associations have misconstrued simplification as truth. Critical social scientists and post-modernists claim there is no hope for generalizing our understanding of social phenomena, and phenomenologists claim there is no expectation that such an understanding of organizations will ever develop. Yet complexity theory may offer an effective paradigm to handle this seeming contradiction between the advocates of the rational/empirical perspective and the challenges of post-positivists. In short, the complexity movement in the social sciences has the potential to account for all of these perspectives in a holistic and unifying theoretical framework that embraces the seeming paradox through a deeper understanding of causal networks.

Philosophical arguments made by phenomenologists, critical social scientists, and postmodern academicians offer a number of critiques of positivism. These post-positivist challenges have, in part, come from the arguments articulated at the beginning of the quantum movement in physics. Rather than offer a foundation for future scientific discourse, however, these critiques have only offered a patchwork perspective with future promises of greater understanding. Fox and Miller's discourse theory, for example, provides no basis for inquiry consistent with the scientific method. Tom Cook's *Quasi-Experimentation* attempts to use a traditional empirical paradigm, but then argues that positivist research is impossible because academics can't distinguish between a causal or corollary relationship. By calling positivists epistemologically bankrupt, these perspectives have destroyed any basis for generalizable academic research.

Complexity theory offers a means to address the challenges posed by these competing perspectives and thereby provides a basis for epistemological discourse in the study of organizations. Complexity acknowledges the role of empirical research and embraces parsimony ideologically situated with traditional positivism while at the same time provides a mathematical framework for understanding complex behaviors. At the same time, it recognizes non-linear and recursive causality, sensitivity to initial conditions, and the importance of context implicit in the post-positivist arguments. By affirming both perspectives, complexity has been used to leverage a greater understanding of why simplifications may not adequately describe interactions, while at the same time allowing for the construction of general theory to describe interactions. In essence, complexity has the potential to become an interdisciplinary paradigm that addresses the concerns of both sides of the epistemological debate. Complexity may constitute a unifying paradigm to address simultaneously the concerns of the post-positivist in the empirical framework of the positivist consistent with traditional positivist philosophy.

This paper identifies a roadmap to understanding social systems and their organization by using complexity science's reconciliation potential. By revisiting both sides of the epistemological debate between positivist and post-positivist perspectives, complexity is identified as a suitable candidate for unifying the underlying

philosophy of social inquiry. The implications for organization of a complexity perspective are also identified.

Michael J. Jacobson - *The Distributed Learning Workshop*

Complex Systems in Education: Integrative Conceptual Tools and Techniques for Understanding the Education System Itself

This session will discuss the results of planning meetings held as part of a New England Complex Systems Institute project on Complex Systems and K-16 Education that was funded by the National Science Foundation. The project involved a diverse group of scientists (physicists, chemists, biologists, psychologists, sociologists, mathematicians, computer scientists) and educational researchers in meetings to consider common ground that could be used to generate researchable ideas for integrating the field of educational research with advances in the study of complex systems in other disciplines. The session will provide an overview of ideas that were generated in the meetings in areas such as the potential implications of complex systems for education in terms of content, teaching, learning and cognition, and for understanding from a fresh perspective the complex system of education itself. The final report and working papers are available at: http://necsi.org/events/cxedk16/cxedk16.html.

Klaus Jaffe - *Instituto Venezolano de Investigaciones Científicas*

On the Modulation of Variance in the Evolution of Complex Systems: Sex in Artificial Life

Using computer simulations I studied the conditions under which diverse degrees of ploidy, mutation rates, hermaphroditism and sex (recombination) were evolutionary stable. The parameters that showed relevance to the stability of sex were: variable environments, mutation rates, ploidy, number of loci subject to evolution, mate selection strategy and reproductive systems. The simulations showed that mutants for sex and recombination are evolutionarily stable, displacing alleles for monosexuality in diploid populations mating assortatively when four conditions were fulfilled simultaneously: selection pressure was variable, mate selection was not random, ploydy was two or the reproductive strategy was haplo-dipoid or hermaphroditic, and the complexity of the genome was large (more than 4 loci suffered adaptation). The results suggest that at least three phenomena, related to sex, have convergent adaptive values: Diploidy, sexual reproduction (recombination) and the segregation of sexes. The results suggest that the emergence of sex had to be preceded by the emergence of diploid monosexual organisms and provide a explanation for the emergence and maintenance of sex among diploids and for the scarcity of sex among haploid organisms. The divergence of the evolutionary adaptation of the sexes is a derived consequence of the emergence of sex. The simulation results allow to postulate a taxonomy of mechanisms regulation

Sanjay Jain - *University of Delhi, Indian Institute of Science, and Santa Fe Institute*

Emergence, Growth and Collapse of Cooperative Organizational Structure in Evolving Networks

A mathematical model of an evolving network, motivated by the origin of life problem, will be discussed. The evolution exhibits an initial phase of no cooperation until a small cooperative structure, an autocatalytic set, appears by chance. Because of its cooperative property and consequent stability, it turns out that evolution gets the opportunity to build upon this structure, and the autocatalytic set expands. This is the phase in which cooperation emerges and grows. The success of this organization and its dominance of the environment leads eventually to the emergence of a new kind of competition among its members. This can

cause the robust cooperative organization to become fragile and collapse. The underlying mechanisms and time scales for these processes will be discussed.

James Holland Jones - *University of Washington*

Compartmental models for the transmission of infectious diseases have become part of the standard toolkit in epidemiology. However, assumptions relating to proportional mixing employed in these models severely limit their applicability with respect tosexually-transmitted diseases. Several methods have been developed torelax the assumption of proportional mixing. I use a loglinearmodeling approach to estimate (nonproportional) mixing preferencesfrom clinic data to create a compartmental model for Chlamydiadynamics in Seattle/King County. Such clinic data are clearly biasedin terms of their representation of a number of important featuresincluding race, sex, and age distribution. Using a Bayesian model, Iextend the loglinear modeling framework of Morris (1991) so that I caninclude prior information on the structure of the population whichfeeds the clinic. This framework also proves useful for incorporatinguncertainty into estimates of biological parameters in the model. Ishow that race- and sex-differentials in prevalence can arise simplyas a function of (1) differential mixing as a function of race andsex, and (2) different latent periods in men and women. Following theapproach of Raftery and Poole (2000), I reconcile uncertainty withmodel inputs with the observed (deterministic) model outputs, andcalculate posterior predictive distributions for both biological andsocial parameters which can then be confronted with additional datacollected in this ongoing work.

Keith Josef - *Syracuse University*

Laboratory Controlled Model System for Study of Complexity Models that Apply to the Signaling Network of a Single Biological Cell. K. Josef, J. Saranak, And K. W. Foster

The unicellular alga Chlamydomonas is a free-living multi-input multi-output nonlinear signal transduction network. This organism is 10 mm in diameter with two anterior cilia, each 15 mm in length and 0.24 mm in diameter. The cell has an ?eye? with a rhodopsin photoreceptor. The cell also has chlorophyll-based photoreceptors, flavoproteins, a phytochrome (730 nm) receptor, and probably other photoreceptors.This alga swims about 120 mm/s with the cilia beating (20-80 Hz) in a breaststroke .The stroke frequency is modulated by changes in external environmental factors such as light levels, temperature, and chemical composition of the immersing medium. The cells also rotate at 2 Hz, scanning their environment producing a signal for tracking light sources. Based on multiple environmental inputs the cell decides whether to go towards, away or orthogonal to the light direction, presumably to optimize its survival. We specifically study the real-time events of the signaling network with emphasis on the pathway from rhodopsin to ciliary motion.

An electro-optical method monitors the cell?s ciliary beating. Suctioned onto the tip of a micropipette, the cell?s magnified image is focused onto a quadrant photodiode array. Two independently-random light patterns stimulate the cell and the variations in light scattered from the two cilia passing into and out of each photodiode quadrant are recorded. One stimulus at 543 nm excites the light tracking receptor and the other at 660 nm excites chlorophyll. The response of each cilium during the power stroke and recovery stage of the stroke is determined. The stroke frequency, power stroke amplitude, and phase relationship between the two cilia are presently assayed. The three responses of the cilia to the stimuli are correlated with the input stimuli to determine the linear and nonlinear dynamics of the phototransduction network of the cell. The well-regulated experimental conditions provide real laboratory data with strict control of the environment suitable for extensive model analysis. A parallel cascade method of system identification is used, approximating the system response by a linear dynamic element followed by a static nonlinear element. The output of this linear-nonlinear approximation is tested to see if the mean square error is reduced. If so, this approximation is added to other parallel linear-nonlinear cascades and the residual of this approximation is used as the

successive input. Cascades are added until the mean square error of the model is reduced to an acceptable level. This analysis yields first and higher order x-y and x-x kernels.

The stroke frequency, power stroke amplitude, and relative phase between the cilia all exhibit highly nonlinear properties with different delays and characteristics. Each cilium also possesses unique characteristic responses. In addition to light stimuli, chemicals may be used to stimulate Chlamydomonas. Mutations at known points of the signaling pathway and mutants with defects in the ciliary mechanisms and photoreceptor can be assayed to elucidate the mechanisms of the cells? signaling network. Questions of the precise nonlinear control of the cilia as well as the fractal nature of the control and signal processing are being addressed.

Partha P. Kanjilal - *US Army Research Institute of Environmental Medicine, Heller Institute of Medical Research*

Characterization of Heat Intolerance Response Through Orthogonal Transformation Based Analysis of Heart Beat Interval Series. Partha P. Kanjilal, Richard R. Gonzalez, And Daniel S. Moran

This study examines the heart beat interval (R-R interval) series obtained from a database of military subjects who had suffered heat stroke. The data are collected following a heat tolerance test (HTT) in which treadmill exercise (1.34m.s-1,2%grade for 2h) is performed in a climatic chamber with ambient conditions of 40fC/40%RH. The HTT is conventionally performed whenever a person is presumed to be heat intolerant (HI). In HI individuals, the presence of inherent non-stationarity in the cardiac R-R intervals series renders conventional spectral approaches unusable. Since wavelet transform is not influenced by the non-stationarity, it is used to preprocess the data. We arranged the database from a cohort of individuals who were HI and heat tolerant based on the HTT. The data were arranged into a series of matrices up to row lengths n=30. Each data matrix was singular value decomposed. The set of singular values (si, (1£i£ n)) obtained for each configuration were then mapped to a set of 30 singular values (SV) preserving the overall energy, and a mean distribution of the set of singular values is formed. Subsequently, a normalized and weighted (by i2) SV profile was generated. The {i2si} distribution was scaled by (i2si)max and is plotted against i. It is observed that for healthy heat-tolerance individuals undergoing HTT, the normalized and weighted singular value distribution profiles tend to collapse together. In the present context, the distributions for the heat-tolerant group tend to be quite close to each other, whereas the distributions for the heat-intolerant group were highly dispersed. It is suggested that the dispersion of the profiles of the weighted singular value distribution may be a useful analytical prognosticator of possible heat-intolerance in otherwise healthy humans. Further studies are underway to validate this finding.

Hillol Kargupta - *University of Maryland*

Decision Trees, Fourier Spectrum, and Learning Complex Models from Data Streams

Many real-life environments deal with data streams. Communication Networks, stock market, process control, and sensor networks are some examples. Learning functions from continuously flowing in data streams offers many challenges. This talk will consider the problem of learning complex decision tree ensembles from data streams. It will offer a perspective of decision trees in Fourier domain and note several interesting properties of the spectrum of decision trees. The talk will also present several applications of the proposed approach.

Eve Mitleton-Kelly - *London School of Economics*

Organizational Complexity

Work-in-progress will be presented on a research project looking at the conditions that facilitate the emergence of new organisational forms (or ways of organising) after a merger, restructuring or the spinning off of a new business. This is a 3-year collaborative action research project with 5 business partners: British Telecom's Brightstar (an incubator of new businesses), Norwich Union Life and Rolls-Royce Marine (both recent mergers), Shell Internet Works (spinning off new businesses leveraging the Shell brand and global presence)and BTA consulting who will help with the dissemination.

The project will use the principles and logic of complexity to study:

- the integration of national, business, cultural and technical systems in the emergent organisational forms;
- the role of ICTs in facilitating connectivity and the exchange of knowledge;
- the tension between globalisation and local cultures and requirements.

We have a research team of 12 including an artist, a modelling expert, two psychologists and a business liaison manager, as well as an international team of business and academic advisors.

The paper will outline the complexity logic being used in the methodology and present some initial findings, including a short study on virtual teams when one of the business partners set up a new business in another continent. The issues raised include 'management at a distance' when the head office is still in London; knowledge generation and sharing; the use of ICTs to enable communication and knowledge processes.

Learning from the four pilot studies, both by the parent organisation and by the other business partners is a key element of success and the project is using various methods to facilitate interchange and learning.

The Complexity Research Programme at the London School of Economics was awarded the largest research grant given to the School for social science research, by that particular Research Council and the examining Panel gave the project the highest priority.

Mark Klein - *MIT*

A Complex Systems Perspective on Collaborative Design

Collaborative design is challenging because strong interdependencies between design issues make it difficult to converge on a singledesign that satisfies these dependencies and is acceptable to all participants. Complex systems research has much to offer to the understanding ofthis process. This paper describes some insights derived from this novel perspective.

Harold E. Klein - *Temple University*

Designing Organizations to be Responsive to the Complex Changing Environment

Organizations cannot seem to change fast enough in response to the deconstruction of conventional industries within which they compete - let alone, to the potential structural changes that can only be conjectured. In response, industries are consolidating. Through acquisition and merger, corporate organizations are reaching such size and internal complexity as never before experienced. And this trend is sure to continue!

The problem isn't confined to corporate organization. While the post war geopolitic has disintegrated during the last decade, national governmental institutions (here and abroad) designed to interface with the rest of the world have remained essentially unchanged. The problem is made frighteningly clear in the USG's organizational response to 9-11: the creation of the Office of Homeland Security (OHS), an organization that is supposed to coordinate (?) the efforts (or Programs or...?) of some 126 governmental entities. The organizational chart distributed by the OHS soon after its creation showing its sphere of responsibility crystallized the difficulty - an obtuse, confusing and unintelligible layout of existing interrelationships among

the 126 agencies that are relevant in some way to the national anti-terrorism effort. New challenges are being met with administrative infrastructures that evolved to cope with environments that no longer exist.

The issue is how to evoke representations of prospective environments that can assist decision makers in reconfiguring their internal organizational arrangements so as to be responsive to changing conditions - to provide the answers to such questions as:

Which strategic decisions/activities/organization units need to take action? What is the sequence in which these decisions//.../ to be addressed or act?

Which organization units/decisions/tasks need to be coordinated in response to a prospective environment? Given alternate views/forecasts/scenarios, what changes are necessary from the current infrastructure?

How can organization actions alter the prospective environment? Where are the most appropriate intervention points? And which organization units/activities/ tasks are involved?

In a previous NECSI conference, I presented both the conceptual foundations of the SPIRE methodology for representing the organization's relevant environment in a unique causal mapping format that can be helpful to strategic decision-makers. I also summarized the results of an actual application of the approach in a large corporation, focusing on one of several revelatory causal maps generated from inputs from the corporation's own environmental scanning task. Here, I will focus on the organizational design implications, i.e., the answers to the questions posed above. I will contrast these with the original organization structure and show what changes are indicated. The SPIRE approach, data availability permitting, will be applied to published OHS organization data in order to show how a complex systems methodology could assist in implementation of the OHS mandate, such as it is understood.

The SPIRE approach (Systematic Procedure for Identifying Relevant Environments) is based on a heuristic program that creates causal map representations of the organization environment closely analogous to neural networks, both in appearance and behavior. To my knowledge, it is the only operational tool currently available for strategic decision-making.

Mark Kon - *Boston University*

Learning theory now underlies much of what we as a society are trying to accomplish technologically. This field subsumes a number of areas of inference, including neural network theory, nonparametric statistics, statistical learning theory, and classic machine learning.

Its importance stems from the fact that most human endeavors with well-defined objectives can be encoded in input-output or stimulus-response terminology. This in turn is best representable mathematically as a function f from a space of possible stimuli (inputs) to the space of possible responses (outputs). Such a function may for example:

- map a picture to a correct parsing of its contents
- map visual inputs of biological system to correct behavioral responses
- map a pattern of object characteristics to a correct indentification of the object
- map a sequence of amino acids to a protein's structure or its chemical behavior
- map values of a function to the estimate value of its integral
- map values of a function to a an estimate of the entire function

The basic learning problem is that of learning (identifying) f. To do this, an individual or machine must see examples of it. In natural and artificial learning, this is accomplished through observation of correct outputs f(x_i) to given inputs x_i . This paradigm began in classical statistics (e.g., learning a linear regression function from data points). It continued into the more complex domain of nonparameteric statistics (e.g., learning a nonlinear function from data points). Nonparametrics then diversified into feedforward neural network models, which have been included in parts of continuous (or statistical) learning theory. Meanwhile, the discrete version of continuous learning theory has long been studied in (machine) learning theory, a field which had primarily resided in computer science. Data mining encompasses all these areas with a paradigm of ever-increasing complexity of databases and models. Fortunately, a re-integration of these sub-areas is now occuring.

This special session is devoted to various areas of current research in learning theory, with the sub-text of emphasizing the ever-increasing complexity of both the tasks handled by these methodologies, and of the methodologies themselves. The learning problem being dealt with by this spiraling complex of approaches now appears in many different formulations, and yet has not lost its simple basic nature.

Konstantin L Kouptsov - *New York University*

Using a Complex Systems approach to undo Brainwashing and Mind Control

An L-system is the way to describe or to generate the complex object by a set of production rules. In this case the algorithmic complexity is eazily calculated. In the case when the exact rules are not known an algorithm to search for production rules is proposed. If the object admits only an approximate L-description, the algorithm can be modified to use heuristic match.

Konstantin Kovalchuk - National Metallurgikal Academy of Ukraine

Description of a Subjective Position of a Decision-Maker in Human Organization

It counts traditionally, that the decision maker's (DM's) subjectivism decreases the quality of decisions and that it is important to get rid of it. But in our point of view it is in conformity with the practice of economic management, too; the subjectivism of a DM not only does not decrease the quality of economic decisions, but also increases their flexibility, makes them more stable against the various kinds of influences, provides the practical use of decisions and responsibility for executing them due to the opportunity to express the DM's position or interest The decision-making problem consists of approximating the binary relation over the set of the feasible alternatives (decisions), using the information about DM's preferences. Let be a fuzzy binary reflexive relation For the formal description of a subjective position of a DM let us introduce the monotonously increasing reflection function as estimation of each alternative

The DM stands by the position of neutrality, if his reflection function is the identity- the position of pessimism, if the position of optimism, if Except three basic positions (optimism-neutrality-pessimism) it is important to single out two combined positions, too, the positions of centrism and extremism.

The DM stands by the position of centrism if his reflection function fulfills the condition:

And - the position of extremism if his reflection function fulfills the condition:

Classification of the DM's positions allows to understand the dialectics between the objective estimate of an alternative and the subjective position of a DM: "A subject appreciates more precisely the alternatives, which objective estimates are opposed (contrary) against his own position." So the pessimist estimates more precisely the best alternatives, the optimist the worst ones, the centrist the extreme (best and worst) ones, and the extremist the average ones. Thus it is so important to count the subjective position of a DM depending upon the specific of the problem economic situation.

The reflection function of the concrete DM is obtained by the expert way. This process can be simplified considerably if the DM's subjective position is known a priori. To select the kind of the function we can use the power function, which is concave when, but is convex on the interval for. Realizing the group expert analysis, the additional requirement is placed upon the team of experts the aggregate neutrality, which we can formally describe, by condition:

Where the coefficient of competence of -the exper the reflection function of -th expert's position.

Conclusion. The model of abstracting and retrieving the DM's subjective position, which increases the realizing or the economic decisions has been developed. For that the subjective 'positions of a DM, based upon the scales "pessimist-neutral-optimist" and "extremist-neutral-centrist" are formally defined arid described.

It is shown formally, that the opponent estimates more exactly the alternatives, which are correspondent to the opposite position, specifically, the pessimist the best alternatives, the optimist the worst ones, the extremist the average quality of alternatives, the centrist the extreme ones. Practically it motivates the objective requirement to form the team of experts among the people with various subjective positions.

Masaharu Kuroda - *Applied Complexity Engineering Group, AIST*

Local Complexity and Global Nonlinear Modes in Large Arrays of Fluid Elastic Oscillators.

Masaharu Kuroda, Francis C. Moon

Process from local complexity to global spatio-temporal dynamics, especially the generation mechanism of a traveling 2D-wave is investigated in a group of nonlinear oscillators such as arrays of cantilevered elastic rods in a wind tunnel. Generally speaking, the soliton theory tells us that only a soliton-like wave can exist in systems with dissipation. A solitary wave can appear even in real engineering systems with energy dissipation only if a nonlinear effect and an energy-input compensating the energy-loss by damping exist. This prediction is now being proved experimentally.From 90 to 1000 steel and polycarbonate rods with gap ratios ranging from 1.0 to 2.5 are used. As the Reynolds number (based on rod diameter) increases from 200 to 900, a pattern with characteristics of spatio-temporal chaos emerges in global behavior of the elastic rod array. There are local and global patterns. Local patterns are composed of transient rest, linear motion, and elliptical motion. In the 90-rod experiments, a cluster-pattern entropy measure is introduced based on these three patterns as a quantitative measure of local complexity.Below a threshold wind velocity, no significant dynamics appear. Video images reveal that, at first, each rod moves individually, then clusters consisting of several rods emerge and, finally, global wave-like motion takes place at higher flow velocities. Spatial patterns in the rod-density distribution appear as more rods suffer impacts with nearest neighbors. Furthermore, these collective nonlinear motions of rods are observed and categorized into several global modes. Using accelerometer data, the rod impact rate versus flow velocity shows a power-law scaling relation. This phenomenon may have application to plant-wind dynamics and damage as well as fluid-structure heat exchange systems. This experiment may also be a two dimensional analog of impact dynamics of granular materials in a flow.

Chang-Yong Lee - *Kongju National University*

A Stochastic Dynamics for the Popularity of Websites

As the Internet plays an important role in our present society, research on the Internet becomes more and more active. In particular, study of the characteristics of websites and their dynamical phenomena has become recognized as a new field of research. Aside from the technical understandings of the Internet and the web, this new field can be regarded as an artificial ecological system of which many interacting agents, or websites are composed. As is true for most complex systems, size and dynamical variations make it impractical to develop characteristics of the web deterministically. Despite the fact that the web is a very complex system, seemingly an unstructured collection of electronic information, it is found that there exists a simple and comprehensible law: the power law distribution. It is known that the number of visitors to websites also exhibits a power law distribution. This finding suggests that most of data traffic in the web is diverted to a few popular websites. This power law distribution of the popularity for websites is one of the characteristics of the Internet web market. In this paper, we have studied a dynamic model to explain the observed characteristics of websites in the WWW. The dynamic model consists of the self growth term for each website and the external force term acting on the website. With numerical simulations of the model, we can explain most of the important characteristics of websites. These characteristics include a power law distribution of the number of visitors to websites, fluctuation in the fractional growth of individual websites, and the relationship between the age and the popularity of the websites. We also investigated a few variants of the model and showed that the ingredients included in the model adequately explain the behavior of the websites.

Jeho Lee - *KAIST*

Reconsideration of the Winner-Take-All Hypothesis

Recently, the winner-take-all hypothesis has been popular not only in academia but also in industries. This hypothesis has been drawn from prior research on network externalities, which showed that competition between incompatible technologies would make the market tip toward a single dominant technology or firm. Prior work stressed the importance of a large installed base by implicitly assuming that consumer benefits arise globally from all the adopters in a network. Our study is based on a different assumption: Each consumer's benefit from adopting a technology is primarily affected by her close acquaintances. We found that market dynamics do not always lead to winner-take-all. The results depend on the assumptions on kinds of network topologies. Our results can potentially address the question of why incompatibilities sometimes persist.

Natasha Lepore - *Harvard University*

Unified Framework for Finding the Eigenstates of Helmholtz Equation Using Boudary Methods

The powerful plane wave decomposition method (PWDM) for finding the eigenstates of the Helmholtz equation can be regarded as a variant of the mathematically well-established boundary integral method (BIM). The capabilities of the BIM and the PWDM are discussed using a unifiedframework. This opens the way to further improvements.

Ellen Levy - *School of Visual Arts, NYC*

Initial Conditions to Final Results in the Complex Systemsof Art and Science

Systematic approaches to making art share certain methodologies with conducting scientific experiments, such as establishing a set of parameters and constraints to set a process in motion. Approaches may also include replication, creative tinkering Despite these similarities, the evaluation criteria of these two activities encompass different aims and modes of address; in fact, different languages. In contrast to science, where reproducibility of results is valued, qualia are often evoked in the arts. But this begs the difficulty of assigning consistent, shared values used in assessing art since for art, the intention as well as the end result is what counts especially where replication occurs (e.g. appropriative visual strategies). In certain ways, complexity approaches help erode this presumed subjective vs. objective distinction for the arts and sciences. Cultural models of innovation and learning bear particularly meaningful analogy to complex adaptive systems in biology (e.g., processes of biological mutation and adaptation). Artists as well as scientists can portray how novel innovative or adaptive utilizations may lead to a breakup of constraints, yielding unpredictable results. The morphologist D'Arcy Thompson is relevant to this discussion as are others, including scientists and artists, who have modeled dynamic change over time. Artistic approaches both with and without extensive technology can focus insightfully on evolutionary processes. Along with other artists who have work experience in science, I have found ways to adapt generative and visualization techniques to topics of biological and cultural evolution. With our greatly expanded technological means to simulate outcomes, the real has at times become co-extensive with the artificial. Complexity theory plays a role in mediating these changing conceptions of nature and culture.

Jacques Lewalle - *Syracuse University*

In What Sense is Fluid Turbulence a Complex Physical System?

Fluid turbulence is a familiar fluid phenomenon, from the billowing wind to the mixing of creamer in coffee. It has long fascinated artists (da Vinci's sketches, van Gogh's Starry Night, Hokusai's crashing waves), and challenged physicists, mathematicians and engineers. Turbulence is still, with various attributions, the biggest unsolved problem of classical physics. It is a perennial attractor of the latest theories and concepts, such as statistical mechanics, stochastic modeling, catastrophe theory, renormalization,chaos, and self-organized criticality, to name only a few. The difficulty resides in finding the proper interface between these ideas, the rich physics of the phenomenon and the Navier-Stokes equations (NSE), which are the fluid-mechanical version of F=ma. In their standard form, NSE are a nonlinear system of partial-differential and nonlocal equations; known since 1823, they have yielded only a few exact solutions, none relevant to the understanding of turbulence. Noteworthy alternative formulations include the Fourier version of NSE and the use of vorticity instead of Newton's momentum. In spite of partial successes, none of these approaches has captured the emergence of eddies in three-dimensionalfields (although they appear in numerical solutions), or the statistical scaling laws that connect eddies of different sizes. In this paper, a promising new approach is presented, making use of wavelet transforms. The spatial-spectral wavelet representation of the velocity field corresponds to the addition of one independentvariable, which modifies the mathematical structure of NSE. Relevantto the emergence of structures, nonlinear algebraic interaction rules are identified; their symmetries and spectral content will be presented and differences between two- and three-dimensional turbulence will be discussed.

Xuenan Li - *University of Massachusetts*

The Complexity of the Growing Network

Growing network models of the web and other complex system produce pparently complex networks from simple growth rules in which nodes are added one at a time to the network. The probability that a new node links to an existing node of the network scales as a power \gamma of the degree of the existing node. When \gamma=1, the growing network self-organizes to a power law degree distribution in qualitative agreement with complex networks found in the real world. We show, however, that these growing network models, though they seem to require that nodes are added one at a time, lack the true history dependence. We exhibit an efficient parallel algorithm for generating these networks for the case \gamma=1. The running time of the algorithm is polylogarithmic in the size of the network showing that the model is not complex in the sense of parallel computational complexity. The cases \gamma \neq 1 are also studied using a Monte Carlo algorithms.

Xiang San Liang - *Harvard University*

A Multiscale Interactive Dynamical Analysis for Oceanic Flows Intermittent in Space and Time. Xiang San Liang and Allan R. Robinson

A new methodology, Multiscale Energy and Vorticity Analysis (MS-EVA), has been developed to investigate sub-mesoscale, mesoscale, and large-scale dynamical interactions in oceanic free jets. MS-EVA is based on a new device called a multiscale window transform (MWT). This is a local, orthonormal, and self-similar functional analysis tool which is windowed on scales, with location resolution maximized in the phase space. With this transform, multiscale features are represented in distinct scale windows. The energetics and enstrophy for these windows are then defined and their governing equations derived. For each window, the resulting equations show a balance of terms representing processes which can be categorized into three classes: transport, transfer, and dissipation. Among the transfer processes, of particular interest are those perfect transfer processes, which, for every location in the physical space, act to re-distribute the energy over the phase space, but with the energy sum over the scales preserved. The perfect transfer processes can be further decomposed through interaction analysis to describe the energy source information.

When properly combined, these perfect transfer interaction analyses are shown to correspond to important processes in geophysical fluid dynamics. Barotropic and baroclinic instabilities are two such examples. Two classical models, each representing one of these instabilities, are chosen to validate the MS-EVA.

As a real ocean application, the MS-EVA is used to diagnose the dynamics of the Iceland-Faeroe Front (IFF). An MS-EVA-ready dataset is first generated, from a hindcast with the Harvard Ocean Prediction System (HOPS), using the hydrographic data obtained during a 1993 survey in that region. The observed mesoscale meander provides an ideal testing ground of the MS-EVA capability. The calculated energetics, when locally averaged, reveal that the formation of the meander is a result of both a baroclinic instability and a barotropic instability, with the former dominant in the western region at mid-depths, while the latter is more active in surface layers.

Seth Lloyd - *MIT*

Bits and Bucks: Modeling Complex Systems by Information Flow

This talk presents a general method for modeling and characterizing complex systems in terms of flows of information together with flows of conserved or quasi-conserved quantities such as energy or money. Using mathematical techniques borrowed from statistical mechanics and from physics of computation, a framework is constructed that allows general systems to be modeled in terms of how information, energy, money, etc. flow between subsystems. Physical, chemical, biological, engineering, and commercial systems can all be analyzed within this framework. Take, for example, trading over the internet. Each flow of information (measured in bits per second) is associated with a flow of energy (measured in watts). The energy per bit -- effectively, a form of temperature -- is a crucial quantity in characterizing the communications performance of the network in the presence of noise and loss. But each bit can also be associated with a monetary value (bucks), as when the title to some commodity is transferred electronically to a buyer and an electronic draft to pay for the commodity is transferred to the seller. The bucks per bit -- again, a form of temperature -- is a crucial quantity in deciding whether to buy or sell. Clearly, some bits are worth more than others! This paper shows that in complex systems that can be accurately described by such a modeling framework, different structures for interconnects and protocols for exchange can lead to qualitative and quantitative differences in behavior. In some cases, such as thermodynamic systems, stable behavioral equilibria exist and exhibit gaussian fluctuations. In other cases, such as phase transitions and systems of economic exchange, quasi-stable or unstable equilibria exist and exhibit power-law fluctuations. Finally, some types of flows yield no equilibrium at all. The framework makes quantitative predictions for the efficacy, flexibility, stability, and robustness of complex systems characterized by flows of information together with energy, money, etc.

Corey Lofdahl - *SAIC*

On Trade and the Environment as a Complex System

Issues regarding trade and the environment have gained increased policy salience as highlighted by the 1999 World Trade Organization (WTO) ministerial in Seattle. Economists maintain that trade helps the environment citing numerous empirical studies that correlate international trade with increased national wealth and national wealth with cleaner natural environments. Environmentalists, in contrast, maintain that the opposite as environmental degradation is historically coincident with industrialization and trade. Lofdahl (2002) argues that trade hurts rather than helps the environment using a range of computer-based techniques including data visualization, statistics, and system dynamics. This study highlights the complex system concepts that underlie this work.

Robert K. Logan - *U of Toronto*

What the Evolution of Notated Language Teaches Us about the Origin of Speech

The origin and evolution of human language which has puzzled scholars for hundreds of years, has been difficult to address is because the events took place hundreds of thousands of years ago and hence no documentary data exists to shed light on what happened. Nevertheless many attempts to probe the origins of speech have been made from a variety of different disciplines and data sets. The aim of this study is to juxtapose, compare and synthesize this large body of work with a model I developed to describe the evolution of notated language in The Sixth Language (Logan, 2000) where it was shown that speech, writing, mathematics, science, computing and the Internet form an evolutionary chain of languages. I believe that these two bodies of work can inform each other. The thesis that will be developed in this paper is that historic data relating to the evolution of language after the advent of speech and beginning with the emergence of writing can shed light on the origin and evolution of human language and resolve some of the controversies and differences of opinion on a number of issues. At the same time the origin of speech body of work can enrich our understanding of the evolution of notated language.

Irakli Loladze - *Princeton University*

Biological Systems From the Perspective of Chemical Elements: The Simplicity and Rigor of Stoichiometric Approach

Biological systems exhibit enormous complexity, yet the number of chemical elements in all life is only a few dozens. Life cannot create or destroy chemical elements, nor can it convert one element into another. These fundamental constraints are true for all scales of life from cells to biosphere. Stoichiometric theory takes full advantage of these scale invariant constraints and provides simplifying framework for studying biological dynamics. I will give examples of how stoichiometric approach can provide qualitatively new insights: from ecological theory of predator-prey interactions to links between elevating CO2 and human nutrition.

Ram Mahalingam - *University of Michigan*

The Fate of the Girl Child: A Systems Approach to the Evolutionary and Cultural Psychology of Female Infanticide. Ram Mahalingam & Kanchana Ramachandran

Son preference and female neglect have been common among many Asian cultures, particularly India and China. Several theoretical perspectives attempt to explain why such extreme forms of female neglect and infanticide exist in these cultures. Behavioral ecologists have argued that peer competition and female explain why such extreme forms of female neglect and infanticide exist in these cultures. Behavioral ecologists have argued that peer competition and female strategies for maximizing reproductive success account for differential investments in sons and daughters. Cultural and ethnographic explanations focus on the religious and cultural reasons for son preference, such as sons will take care of them when they get old. However, female infanticide is a complex phenomenon. Preliminary data seems to indicate that in spite of development interventions for womens empowerment through education and increased opportunities for employment, female infanticide continues to grow in specific societies. Mahalingam and Low suggest that a confluence of structural, cultural and ecological factors shape the history, current and future practice of female infanticide. Using the interdisciplinary perspectives suggested by Mahalingam and Low, we propose a complex systems perspective which incorporates the interaction among individual and family level factors (gender socialization), caste identity (honor culture),and structural factors (social ability, and developmental programs). We have identified one such caste group- the Thevars amongst whom female infanticide is prevalent. Thevar, a warrior caste believes that caste honor needs to be protected by marrying their daughters

into higher status males of the same caste. Failure to do so will be hurt the honor of the self and the primary goal of the caste is to protect honor at all cost.

We argue that the social mobility of Thevar women and Dalits (former untouchables) result in confrontation between the two caste groups. State sponsored educational empowerment programs targeted toward Dalits and Thevar women result in the mobility of Thevar women and Dalit male and females. Thevar males feel threatened by the social advancement of Dalit men who are in competition to become attractive choices for marriage. As a result there are several attacks on Dalits by Thevars resulting in inter caste conflict. We argue that empowerment and the disparities in social
mobility between Thevar men, women and Dalits contribute to the increasing cost of marrying off Thevar women. This results in a negative attitude toward having daughters. Thevars also feel that they need sons; to stand up for their caste. We make the case that this complex interaction among structural factors such as caste hierarchy and social development is emergent from and determines family dynamics in this caste. Thevar women are socialized towards increasing femininity to prove their loyalty to their caste and their peers. This explain one of the paradoxes in demographic findings that in this caste group, the more educated women are more likely to invest heavily on their sons not on their daughters.

The compliance of Thevar women to be more traditional even after access to higher education attests to these complex interactions among gender dynamics, cultural expectations and shifts in caste hierarchies. Using systems and exploratory modeling techniques we hope to delineate and study these dynamics (1) from a micro systems perspective at the level of family and individual interaction, (2) understand the non linear impacts of globalization and development on female infanticide at the macro societal level and (3) and explore optimal leverage points that can reverse current trends of increasing female infanticide in this community.

M. Marko - *Comenius University, Slovakia*

Transforming the World Wide Web into a Complexity-Based Semantic Network. M.Marko, A. Probst, A. Das.

Tim Berners-Lee_s term "Semantic Web" denotes the next evolutionary step of the Web, which establishes a new machine-understandable layer of datafor automated agents, sophisticated search engines, information integration and interoperability services. The main aim of this paper is to examine available tools and current standards to outline a practical roadmap to transform this vision into avisible benefit. We hope that our example will inspire similar activities within the complexity community to achieve a synergistic effect of the_Web_s full potential_.

We begin with a task to overcome existing drawbacks of keyword-based search engines ignoring the variable semantic context of query keywords. Anexample of such semantic confusion could arise from a search for the keyword _ontology_. The problem is that the word has different meanings indifferent communities. The philosophy community views it as (1) a 'science of being_. The AI and Semantic Web communities view it as (2) a 'systemof shared meanings'.A standard search result would likely yield a mixture of these two meanings. Hence, many of the search results would not pertain in the givensituation.

Ontology(2) does not only contain metadata i.e. data about the data such as word definitions or instances, it also contains relationships amongthe concepts defined. A large space for various inference algorithms is being created. In this manner, a semantic search for "ontologyconstruction language" (or even a Natural language query _What is the language to construct ontologies?) could point to DAML+OIL related articles,although they would not contain any of the search keywords. It would be because the application could access metadata in which DAML+OIL isdescribed as a language used to construct ontologies. The application would be able to infer this relationship thanks to the machine-readableformat of the embedded metadata.

It is clear that the development of consistent ontologies will play a crucial role in further Semantic Web application. We focus our attention toNeural net models (see: Neural Net Model for Featured Word

Extraction, A.Das, M.Marko, A. Probst, M. A. Porter) and internet-based communitycollaboration as potential means to speed up the creation of ontologies. Finally, we present a practical application of a semantic search withinan existing electronic news provider.

Ian W Marshall - *BT exact*

The Role of Complex Systems in the Management of Pervasive Computing. Ian W Marshall, Chris Roadknight and Lionel Sacks

Extrapolation of current trends for ownership of microprocessors [1] suggests that within 10 years it is possible that many individuals will ownin excess of a thousand microcontrollers. If, as seems increasingly likely, pervasive computing on this scale is realized, users will be facedwith a major investment of time and money in configuration and maintenance activities. To minimize this impact it is important to investigate waysof automating low level management processes and enabling many pervasive computing devices to self-configure and operate almost autonomously [2].At the same time it is vital to ensure that the management processes are able to adapt to new requirements and applications, since it is likelythat developments will be extremely rapid and unpredictable [3].

Clearly any management system that can meet these requirements is going to exhibit dissipative structures, and long range dependency (leading toscale free properties and fractal dimension), much like many natural systems. We have simulated the operation of a management system (inspired bya simple model of biofilm colonies) that autonomously configures and maintains a network of up to 5000 heterogeneous devices. A key feature is theability of nodes in the system to perform unsupervised in-situ learning by exchanging policies with one another. This was achieved by combiningpolicy based management [4] with an evolutionary algorithm derived from prokaryote biology [5]. The algorithm combines rapid learning (plasmidexchange), automated configuration (limited motility of individuals) and evolutionary learning via a conventional mutation based GA. New policiescan be evolved internally. In addition users are able to distribute new policies to subsets of the devices that they control, using a weaklyconsistent gossip protocol derived from fireflies [6]. Simulations have shown the system is able to create and maintain an organisation thatperforms at least as well as conventional designs such as caching systems, whilst requiring no human input or intervention. In particular thesystem copes extremely well with multifractal load derived from real Internet traffic logs, once it has self-organized into a metastable criticalstate. To provide a practical verification of the simulation results we have embodied the algorithm in an ad-hoc network consisting of 20 nodes,where the nodes are intended to emulate distributed sensor controllers. Each node consists of 3 sensors, 3 actuators, a 16 bit microprocessor andan infra-red transceiver. Initial results are encouraging.

Generalising and proving the capabilities of this system will require complex system models. We are attempting to extend the reaction-transportmodels of Ortoleva et al [7], since they are a good fit with the capabilities of our current system. We also hope that improved understanding ofbiogeochemical processes will provide inspiration for extending the functionality of our system.

This work was partly funded by the Royal Society, London

[1] L Gerstner, keynote speech at telecom 99, http://www.ibm.com/news/1999/10/11.phtml[2] http://www.research.ibm.com/autonomic/manifesto/autonomic_computing.pdf[3] R Saracco, J.R.Harrow and R.Weihmayer _The disappearance of telecommunications_ IEEE 2000[4] M Sloman., "Policy Driven Management for Distributed Systems", Plenum press Journal of Network and Systems Management, Plenum Press[5] I.W.Marshall and C.M.Roadknight, "Emergent organisation in colonies of simple automata." 6th European Conference on artificial life. 2001[6] I.Wokoma et al "Weakly consistent sychronisition" Policy 2002[7] P.Ortoleva, "Geochemical self-organization" OUP 1994

Paula Matthusen - *NYU*

In Memory of an Anthill: Complexity Theory and Compositional Processes

In memory of an anthill, is a composition for string quartet based on ideas from cellular automata theory. The score is organized around the choices that individual musicians make to begin, interrupt, and restart the composition at any time. Since each individual musician makes these choices in the context of the choices of the surrounding musicians in the quartet, the composition self-organizes from their interactions. The composition can move along several possible musical;routes with each route leading to its own, unique ending. Musical routes are not predetermined, but occur naturally as players react to each other's interpretations during the piece. If a performer does not like a particular way the piece is heading, he or she can "restart" the performance, thereby directing it away from an unwanted ending. The string quartet would likely consider some of these possible endings, such as those that instruct the performers to break their instruments or throw their bows across the room, to be undesirable. The presence of these endings enhances the dramatic nature of the piece and encourages the quartet to self-organize and cooperate as they redirect the course of the piece away from possible unwanted results. Within much western and non-western music, the direction and identity of pieces are often determined by carefully arranged and established hierarchies between members of an ensemble and/or with a particular dominance of a tonal area or musical line. in memory of an anthill bypasses these hierarchies by relying on the tensions between improvisation and pre-composed music while the 77 rules for performance ensure that each player has an equal voice in the ensemble. This balance results in an unpredictable work that is never performed the same way twice and yet always remains sonically recognizable and distinct. For the conference, I would present two separate recordings of the piece and discuss its conceptual and structural aspects. The use of cellular automata theory as a foundation for in memory of an anthill results in an exploration of existing musical hierarchies, their fragility, and ability to change.

John Maweu - *Syracuse Univ*

Self Organized Criticality in State Transition Systems

The presence of self-organized criticality in a specific kind of state-transition system is demonstrated by the presence of a power law distribution obtained by empirical evolution to convergence.

The state-transition systems under investigation are monotonic and thus are guaranteed to reach a fixed point. In order to produce the power law distribution as seen in the sandpile effect, a fortuitous resemblance between raising programs in the lattice of monotonic state-transition systems and associated marginal increases in fixed point size and dropping sand grains on a sand pile and avalanches observed at the surface of the sandpile was seen by my advisor. Not every program investigated gave rise to an observable power law distribution, so a search for a program on the edge of chaos was indicated.

The monotonic state-transition systems under consideration are positive logic programs over a finite signature Σ. That is, functions $p: \Sigma \to 2^{2^\Sigma}$ which describe the evolution of interpretations of Σ by the cumulative one step iteration operator $\hat{T}_p(I) = I \cup \{ x \in \Sigma \mid \exists y \in p(x) [y \subseteq I] \}$ are investigated. For any p, $\hat{T}_p$ has a fixed point. A wider goal of these investigations is to determine just how these fixed points depend on p. We know, for example, that positive logic programs exist as points in a lattice and that raising a program, p, in this lattice also raises the fixed point of $\hat{T}_p$ in the lattice of subsets of Σ.

Raising p may, however, leave the fixed point of $\hat{T}_p$ fixed, just as adding a grain to a pile of sand may not cause an avalanche. This resemblance of our transition system to Bak-Sneppen models of evolution was reinforced by considering the difference in the size of fixed points as the size of an avalanche. The log of the frequency of avalanches was plotted against the log of the sizes of the avalanches and it is clear that the plot is evidence of a power law distribution.

Gottfried Mayer - *Penn State Univ.*

Timescales Aspects Of Internet Access With Emphasis On The Situation In Developing Countries. Gottfried J. Mayer, Atin Das, Carlos Gershenson, Mason Porter, Matus Marko, Andrej Probst

Many examples of complex systems show some form of self-reference in the form of internal feedback, auto-catalysis, etc. One might even assume that it is one of the defining properties of complex adaptive systems because without any form of self-reference or self-reflection it is unlikely that learning and adaptation can be achieved at any level of efficiency. In the context of human social interaction this principle is also known in a more general sense as “practicing what one ispreaching.”. On the other hand there are a number of historical examples that seem to suggest that this principle does not enhance the individual’s or the organization’s evolutionary fitness: Successful pop singers who protest against social injustice become millionaires exploiting their workers, conferences researching the impact of the Internet provide no Internet access to their participants and publish their results in printed proceedings without Internet distribution. In this paper we try to give some semi-quantitative account of conditions that lead to self-referential behavior within the complex systems community and provide an estimate as to when an adoption of principles and methods of complex adaptive systems research can make the transition to becoming evolutionary advantageous in the competition among complex systems agents.

Our conceptual and more philosophical discussions will be supplemented with some rudimentary empirical data from our experience in publishing the Complexity Digest (www.comdig.org) since 1999. We also propose and initiate a polling process to establish increasingly more accurate information about the level at which complexity methods are applied within the complexity community. The empirical results will be archived and updated on www.comdig.org/selfref.

In the second part of our contribution we will discuss universal features that are common to biological brains and social organizations in general, a structure that has recently been named “Global Brain”. The formation of cell-assemblies in the biological brain is believed to be associated with cognitive events and feature binding in perception and learning. In the context of a global brain we interpret gatherings of intelligent agents with the objective to communicate intensively on a common topic –such as a scientific conference- as an event analogous to the binding event of cell assemblies. We know from biological brains characteristic time-scales of about 25ms are established. We know that in human communication there exist similar "universal" time-scales that facilitate constructive interaction and the emergence of collective, self-organized behavior. One of the shortest time-scales is that of synchronous interaction (e.g. 300ms in conversation etc) but other time-scales determined by biological factors ("how long can a person sit and listen to a speaker") can be of similar importance. Current mega-conferences with the order of 10^4 participants push the limits of the concept of "face-to-face" interactions among participants. We argue that there exists a critical time-scale after which the efficiency of communicating the conference content sharply decreases. From our experience with conference web-casts arranged by Complexity Digest we estimate that such a critical timescale lies within one week after the end of the conference.

John Mayfield - *Iowa State University*

Evolution as Computation

The existence of genetic and evolutionary computer algorithms and the obvious importance of information to life processes when considered together suggest that the formalisms of computation can provide significant insight into the evolutionary process. A useful computational theory of evolution must include life and also non-living processes that change over time in a manner similar to that observed for life. It is argued that when the evolution of life is partitioned into a DNA part and a soma or phenotype part, that the DNA part may be properly treated as a computation. A specific class of computations that exhibit biology-like evolution is identified to be the iterated probabilistic computations with selection when selection is based on interactions among evolving entities. When selection is not based on interaction with other evolving entities,

the term optimization seems more appropriate than does evolution. One implication of the view presented is that evolution is an emergent property of certain information systems. Another consequence is that the mathematics of computation apply directly to the evolution of DNA. The paper introduces an information like measure of complexity, transcript depth, which incorporates the minimal computational effort invested in the organization of discrete objects. Because organisms are based on information stored in their DNA, organism complexity is constrained in a fundamental way by DNA transcript depth.

Robert Melamede - *UCCS*

Dissipative Structure Based Perspectives on the Origins of the Genetic Code

Modern open system thermodynamics, as pioneered by Prigogine, provides a new framework for examining living systems. This paper presents a variety of novel hypotheses that integrate opens system, far from equilibrium physical principles with many of the layers of biological complexity. An abstract conceptual development will provide a unifying perspective that starts with pre biotic evolution, the origins of the genetic code, and the origins of life itself. A physical understanding of the nature of health and disease will lead to thermodynamic interpretations of the basic living processes of cell division and cell death. These underlying processes will be reiterated to provide new definitions of speciation and individuality. Considerations of man's place in an evolving biosphere will also be examined.

Yasmin Merali - *Warwick Business School*

The Concept of Emergent Ecologies and Persistence in Cyberspace

Summary
This paper focuses on the persistence of firms in the Internet-enabled, inter-connected world, deploying the information lens to look at the shaping of competitive domains in the emergent socio-economic context. We conceptualise the potential competitive space as a multidimensional information space and explore the dynamics of its structuring as firms interact, creating dynamic networks of networks with emergent competitive characteristics. We introduce a classification of types of networks emerging in cyberspace, and suggest that in complex dynamic environments, networks of networks give rise to persistent ecologies. The argument is illustrated by tracing, on a time-line, the co-evolution of a long-lived technology company and its ecology. Using the concepts of emergence and self-organisation derived from complexity theory, it is argued that it is at the level of the ecology and through the emergent properties of the collective that cyberspace is structured, and that the persistence of firms is intimately coupled with sustaining the ecology.
Overview
We begin by outlining the context for competition in the information space. Much of the popular new economy literature focuses on exploitation of the Internet for competing in, and reshaping, existing competitive spaces. The focus of this paper is on the emergence of new competitive spaces and the dynamics of persistent firms shaping and being shaped by the context, and affecting and being affected by discontinuities of the context.
The information lens is deployed to explore how organisational existence and interaction can shape and be shaped by the information space that the Internet has opened up. It highlights the contemporaneous emergence of new competitive spaces and the organisational development of ecological niches in the information space.
We set out defining characteristics of organisation in the information space, establishing the co-dependence of firm-level organisation in the information space and the emergent macro-level organisation of the information space. Arguing that the ubiquitous connectivity afforded by the Internet effectively opens up an unbounded, multidimensional space for competition, we proceed to examine emergence of organisational characteristics, capabilities and interactions through colonisationof this space. The process of colonisation is

seen as one entailing changes in the characteristics of both, the colonising organisations and the territory being colonised. The example of a long-lived technology company to show how collective interactions give rise to the emergence of a viable ecology that sustains, and is sustained by, co-evolution its inhabitants.

Drawing on analogies from biological systems, the paper explores requisite organisational forms and characteristics for competing in the Internet enabled economy. It concludes that the dynamic network offers the most resilient organisational form for this context, and that evolution, adaptation and transformation are all important for generating the requisite diversity of capabilities for defining and exploiting new competitive spaces. The final discussion reflects on implications of this view for the theory the firm, suggesting that the emergence and evolution of dynamic information networks in the information space will challenge traditional views of the boundary of the firm and the articulation of inter-firm transactional value propositions.

Czeslaw Mesjasz - *Cracow University of Economics*

Changing Images of Organization and Development of Information Society

In the early stages of development of management theory, a mechanistic metaphor had been used. Later it was replaced with a metaphor of organism (biological system). A significant breakthrough in applications of metaphors in management theory was caused by development of systems thinking and cybernetics (the latter is viewed as a part of the former). Metaphors and analogies rooted in systems thinking, and later, in complex systems studies, have become an important instrument of studies of organizations.

The following analogies and metaphors have been most useful in management theory and practice: machine, biological system (living system), open system (related with the previous concept), complex adaptive system, learning system, autopoietic system.

In the evolution of metaphors of organization an interesting phenomenon could be observed. The source fields of the first metaphors - machine and organism were "external" to the organization. The source fields of open system, complex adaptive system, autopoietic system and learning organization are overlapping with the concepts of organization itself (the target field). The metaphors of organization can be then divided into two groups, following specificity of their source fields - external (machine and biological system) and overlapping - the remaining ones with varying level of the overlap.

It is commonly agreed that the ability of self-observation and knowledge about itself is an important part of an organization. For the "external" metaphors, the self-referential mechanism is easier to identify. For the "overlapping" metaphors this phenomenon has been studied predominantly for "second order cyberneticsand for autopoiesis of social systems proposed by Niklas Luhmann.

The main aim of the paper, which is an introduction to further research, is to study how the evolution of application of metaphors has influenced the theory organization. The following interpretations of analogies and metaphors will be applied: descriptive, explanatory, predictive, normative, prescriptive and regulatory. Specific features of all metaphors of organization will be described. It will be studied how "overlap" of the source field of metaphor with the target field (organization itself) influences each of those approaches.

For the more "overlapping" metaphors a specific impact of development of the Information Society can be observed. From many facets of the Information Society the following one will be exposed. The IS will be characterized as a system with growing capability of mapping itself onto itself. This general observation will be preliminary developed in the paper.

Initial results of research referring to theory of organization and some consequences of the phenomenon of "overlapping" of metaphors of organization for contemporary microeconomics will be presented. The hypothesis will be put before that the proposed approach can be helpful in introducing into the methodology of neoclassical economics the cognitive aspects, which in turn, may prove helpful in deepened understanding of the "New Economy". The concepts of utility and contractual approach in microeconomics will be the subject of introductory studies.

How Complex Systems Studies Could Help in Identification and Prevention of Threats of Terrorism

The most dangerous threats were usually unpredictable, not because of objective barriers of their predictability, but because of the social context which contributed to distortions of perceptions and predictions by most of the actors involved.

The main aim of the paper is to present a survey of possibilities how complex systems studies can even partly contribute to identification and prevention of the threat of terrorism.

A broadly defined prediction is the core issue in any security discussions. Identification of a threat should make possible subsequent future actions. Therefore attention will be paid how complex systems studies can help in identification and subsequent prevention of threats.

In order to develop analytical properties of the concept of security, an eclectic approach will be proposed. Its purpose is to combine objective value of widened neorealist broadened security concept with the constructivist and at the same time deepened idea of security viewed as an;act of speech (Buzan et al. 1998). (References will be provided in the paper)

In the eclectic approach security is referred to the following sectors: military, economic, political, environmental and societal and the concepts of existential threat, securitization and desecuritization are used - Buzan et al. (1998).

Some of the founders of systems thinking were also involved in security-related studies - peace research (Anatol Rapoport, Kenneth Boulding), international relations - Karl W. Deutsch (1964), Morton Kaplan (1957). Similarly many modern works on security expose the links with systems thinking and complexity studies - direct references - (Rosenau 1990, 1997), (Snyder & Jervis 1993), and indirect introductory references (Kauffman 1993, 1995). Other, more specific applications can be also found, e.g. a book edited by Alberts and Czerwinski (1999), works by RAND Corporation (RAND Workshop 2000).

In searching the links between complex systems studies and threats of terrorism the following problems seem most important:

1. Effective identification of threats of terrorism.
2. Securitization and desecuritization of threats of terrorism.
3. Methods of prediction of terrorism - strategic and operational, day-to-day basis.

The survey of potential applications of complex systems studies in identification and prevention of terrorism will include two levels:

First, applications of analogies and metaphors deriving from systems thinking and complexity studies in the language of security theory and policy. In applications of models, analogies and metaphors the following approaches can be identified: descriptive, explanatory, predictive, normative, prescriptive and regulatory. Since it can be agreed that security is a product of the social discourse (securitization), it is necessary to answer how the ideas drawn from systems thinking and complexity studies can be used in all aspects of securitization - identification of threats of terrorism and in their prevention.

Second, assessment of possibilities to build mathematical models helpful in identification and prevention of threats, especially including threat of terrorism. In this point an attempt will be made to provide and answer to the question if some areas of complex systems studies could prospectively become similar as game theory for conflict studies.

H. N. Mhaskar - *California State University, Los Angeles.*

When is approximation by Gaussian networks necessarily a linear process?

An important characteristics of a Gaussian network is the minimal separation among its centers. For example, the stability of interpolation and the degree of approximation is often estimated in terms of this minimal separation. We prove that for a target function decaying at a polynomial rate near infinity, the degree of approximation of the function by Gaussian networks decays polynomially in terms of the minimal

separation if and only if linear approximation processes from the theory of weighted polynomial approximation provide a comparable degree of approximation. We describe constructions of Gaussian networks with an optimal degree of approximation measured in terms of the minimal separation as well as the number of neurons, where the coefficients are linear functionals of the target function and the centers are fixed, independent of the target function. The coefficients can also be constructed using samples of the function at randomly selected sites.

Daniel W. Miller - *Greenwich Univesity*

The Complexity of Homeodynamic Psychophysiological Systems

Mind and body, as well as the external environment, are homeodynamic, complex systems. The homeodynamic aspect is vital to the maintenance of connectivity and optimal functioning in non-equilibrium states. Mind and body are each in a continual state of flux and change. They areenergetically different mechanisms interacting within the necessities of survival dynamics. The homeodynamic concept demonstrates clearly that without its interactions the organism could not survive. It is functionally inherited with DNA and operates through cellular, hormonal and neural processes such as stem cells and the neuroimmunological system. There also are many reports of primitive bacteria as well as higher organisms that depend on homeodynamic processes for survival. These indicate that homeodynamic processes are participants in evolutionary development. The position is taken that the effectiveness of random mutation in evolution is secondary to the more powerful intervention of directed evolution. Furthermore, in conjunction with directed evolution, support can be found for the development of neural consciousness from primitive structures to the complexity of human capabilities. Vital questions need to be discussed, such as how might body and mind interact in the human organism if they are energetically different mechanisms and how can dysfunctional states of body and mind be clarified through homeodynamic explanations? Is there a need to include spiritual systems in scientific theory? An attempt will be made to answer these and other issues.

Boris Mitavskiy - *University of Michigan in Ann Arbor*

The Universality of a Slightly Generalized Binary Genetic Algorithm

I will set up a mathematical framework to invastigate the structure of invariant sets under the family of the crossover operators for a genetic algorithm. Then I shall demonstrate how this machinary allows us to prove that, in a certain sence, under surprisingly weak equirements, every heuristic search algorithm is isomorphic to a binary genetic algorithm with possibly a nonuniform distribution on the family of mutation operators. I'll also show a number of other facts such as how to modify a genetic algorithm so as to minimize the role of mutation while preserving the ergodicity of the algorithm.

Olga Mitina - *Moscow State University*

The Perception of Fractals: The Construction of Psychometric Function of Complexity and Correlation With Personal Traits.

The experimental research for construction of functional relation between objective parameters of fractals' complexity (fractal dimension and Lyapunov exponent) and subjective perception of their complexity was conducted. As stimulus material we used the program created by F.Abraham, based on Sprott's algorithms of generation of fractals and calculation of their mathematical characteristics. For the research 20 fractals were selected which had different fractal dimensions in a range from 1 up to 2. We conducted 3 series of experiments.

1. 20 fractals were showed to subjects (100 persons). The pictures of the fractals were formed on the screen of the computer during randomly chosen time interval in the definite range (from 5 till 20 sec). For every fractal the subject should give the answers about his (her) opinion about the complexity and attractiveness of the fractal using ten-point scale. Each subject also answered the questions of some personality tests (Kettel and other). The main purpose of this series was the analysis of correlation between personal characteristics of respondents and their subjective perception of complexity, attractiveness and time of fractal's presentation.
2. The same 20 fractals were showed to subjects (50 persons), but they were forming on the screen of the computer during the same time interval (for all fractals and all subjects). Subjects also estimated subjective complexity and attractiveness of fractals. The given series was necessary for revealing what depends on concrete fractal when a subject answers the questions about the complexity and attractiveness in the fixed time interval of presentation.
3. The same 20 fractals were showed to subjects (30 persons), but in the random order and ten times for each. Thus each experiment included 200 presentations. For every fractal psychometric functions of objective parameters of complexity and it's subjective value by each respondent were constructed.

On the basis of the conducted research at the department of psychology of Moscow State University the special practical course was developed where students learn about fractals and do practical work on evaluating specific fractals and construct psychometric curves of time and complexity perception.

Josh Mitteldorf - *U of Pennsylvania*

Demographic Homeostasis and the Evolution of Senescence

Evolution of senescence has been explained in terms of pleiotropy and tradeoffs between longevity and reproduction. Such theories fit comfortably within a population genetic framework where individual reproductive potential is assumed to be optimized under natural selection.

We have speculated that demographic homeostasis may be a driving force in evolution that rivals reproductive potential in its force and ubiquity. This hypothesis may support very different theories for the evolution of senescence.

Diverse experimental evidence from field studies and genetics laboratories suggests that senescence is broadly regulated under genetic control. Only the strength of population genetic theory has prevented the inference that senescence is an evolutionary adaptation. A broader theoretical framework, in which fitness of populations and ecosystems is regarded as a substantial counterweight to individual fitness, permits this inference and suggests mechanisms by which senescence may be selected for its own sake.

We summarize three models in which senescence may evolve based on benefits to the population that outweigh its cost to the individual. The first model is based simply on logistic growth. Iteration of the logistic equation was, historically, one of the earliest examples through which the mathematical notion of chaos was studied. When the logistic equation is iterated with too large a timestep, chaotic population dynamics ensue. We show how lifespan can act like a finite timestep, delaying the feedback of crowding on population growth; thus limits on lifespan may evolve for the purpose of suppressing demographic chaos. The second model illustrates coevolution, in which predator/prey population dynamics are stabilized by the difference in vulnerability between old and young prey.

In these two cases, senescence contributes directly to demographic stability; but we have observed other models (and other parameter sets within these same models) in which this is not the case. Indeed, senescence may be stabilizing or destabilizing to population dynamics. Nevertheless, a context in which individual reproductive potential is not maximized profoundly alters the landscape in which senescence must evolve, enhancing the plausibility of other mechanisms by which senescence may be selected for its own sake.

The third model illustrates the possibility that senescence may evolve based upon benefits to the population which are not directly related to demographic stability. These benefits include population diversity and a shorter effective generation cycle. In a context dominated by selection pressure for optimal reproductive potential, these benefits are insufficient to overcome the individual costs; however once individual

reproductive potential is subject to stabilizing selection (for reasons unrelated to senescence) a window opens for senescence to evolve in association with enhanced fertility.

This third mechanism may be easily confused with pleiotropy. The difference is that in pleiotropy, reproductive potential alone is maximized, but some genes with a benefit for fertility impose an incidental cost, identified with senescence. In the new concept, fertility and longevity are governed by independent genes, but they are constrained to evolve together because the combination of high fertility with long lifespan leads to demographic chaos.

On The Prudent Predator. Josh Mitteldorf, Chandu Ravela, Robert Bell, Dominic L. Boccelli, David H. Croll, Deva Seetharam

Reproductive restraint can dampen demographic oscillations that might otherwise be lethal to a population. In the past, Wynne-Edwards (among others) surveyed many natural examples of this phenomenon, and speculated that population regulation might be a ubiquitous evolutionary adaptation. However, a commonly held view is premised on the maximization of individual fitness (as measured by reproductive value) and, thus, the theoretical question of whether populations may moderate their fertility in order to stabilize growth of the food species on which they depend was thought to have been settled in the negative three decades ago. We present a surprisingly simple, individual-based evolutionary model in defiance of this conventional wisdom. Predator and prey populations occupy sites on a viscous grid. Probabilities for reproduction and death of individual predators and prey are derived from a dampened Lotka-Volterra dynamic. Predators evolve with a single gene ("alpha-gene") that governs their propensity both to consume prey, and to reproduce. We have identified a range of parameter values for which predators evolve to a moderate level of alpha-gene which may persist indefinitely within a narrow range. The evolutionary mechanism seems to be that grid sites in which the alpha-gene evolves too high a level experience chaotic population dynamics which drive the prey, and hence the predators, to local extinction. The site is then re-colonized by migrants from neighboring sites where the alpha-gene has not yet achieved such a high value. We speculate that if further investigation reveals this result to be as general as Wynne-Edwards once supposed, then the consequences for the theoretical science of evolution may be profound. We may come to think of fitness not in terms of individual reproductive potential, but of stable ecosystems.

Mihnea Moldoveanu - *University of Toronto*

How Does the Mind Economize on Complexity Costs? A Principal-Agent Model of Affect and Cognition ?

The 'complexity' of a phenomenon is modeled as the result of an interaction between a cognitive schema and a set of observations that corroborate or refute predictions deductively derived from the schema. The paper attempts to provide an economic model of the process by which various schemata are chosen. the model is based on a partitioning between a cognitive function or agency (supplying theories, models, predictions and ascertaining their degree of corroboration) and an affective function (supplying selective rewards (such as brain blood glucose levels) to the cognitive function on the basis of the relative success of the predictions in question). Affect rewards cognition in proportion to the accuracy of the predictions in question. The model is shown to have a unique optimal contracting solution. This solution corresponds precisely to a propensity of decision makers to minimize uncertainty, defined in the sense of Shannon entropy. The model is used to (a) explain well-known results from cognitive psychology regarding cognitive 'biases' and 'fallacies' and to link these results to the neurophysiology of fear, anxiety and responses to anomaly (which are interpreted as failed predictions).

The Economics of Cognition

Dealing with complexity is informationally and computationally intensive. Cognitive pragmatism often requires that decision making agents make choices not only about choosable options, but also about the models that they use in order to represent a certain situation. The paper builds a model of the ways in which cognitive pragmatists choose among various models, and presents applications to the understanding of complex organizational phenomena and industry dynamics. The model is based on a categorization of different representations and models in terms of the computational complexity of the algorithms required to competently simulate a phenomenon or make predictions about using a partiucular model. The utility of a model to the decision maker is measured in terms of (a) the value of precision in a problem-solving scenario, (b) the cost to the decision maker of performing additional computations, and (c) the information produced by each iteration of an algorithm based on the decision maker's model. The paper arrives at a model of cognitive pragmatism that makes predictions about which models (of organizations, industries, individuals) are most likely to propagate forward in different market or social niches.

Mark Musolino - *University of Pittsburgh*

Complexity of Musical Measures and its Effect on Time Perception

Radhika Nagpal - *MIT*

Programmable Self-Assembly and Scale-Independence

Cells cooperate to form complex structures, such as ourselves, with incredible reliability and precision in the face of constantly dying and replacing parts. Emerging technologies, such as MEMs, are making it possible to embed millions of tiny computing and sensing devices into materials and the environment. We would like to be able to build novel applications from these technologies, such as smart materials and reconfigurable robots, that achieve the kind of complexity and reliability that cells achieve. These new environments pose significant challenges: a) How does one achieve a particular global goal from the purely local interactions of vast numbers of parts? b) What are the appropriate local and global programming paradigms for engineering such systems?

In this talk, I will present an example of how programmable self-assembly can be achieved, from the local interactions of identically-programmed agents ("cells") connected in a sheet. The approach is significantly different from current approaches to emergent systems: the desired global shape is described at an "abstract" level, using a language based on a set of geometry axioms, which is then {\em automatically compiled} into a program run by individual cells. The cell program itself is composed from a small set of local organization primitives, inspired by studies of developmental biology. The resulting process is extremely reliable in the face of random cell distributions, varying cell numbers, and random cell death, without relying on global coordinates or centralized control. A wide variety of folded shapes and 2D patterns can be specified at an abstract level, and then synthesized from the collective behavior of identically-programmed cells.

The programmable self-assembly provides many robust mechanisms that are applicable to programming smart matter applications. The process also exhibits several structural traits that have strong parallels to those seen in biological systems. In this talk, I will focus on one particular property, called {\em scale-independence}. Scale-independence implies that a cell program can create the same shape/pattern at many different scales, without any modification. The shape scales automatically with the size of the sheet and the total number of cells. The shape even scales asymmetrically with the initial shape of the sheet, allowing a single program to generate many related shapes, such as D'Arcy Thompson's famous coordinate transformations which he used to explain shape differences in related species (in ``On Growth and Form''). Scale-independence is common in biology; sea urchin and hydra embryos develop normally over ten-fold size differences, and morphologically distinct species of Drosophila exist with practically identical DNA. Genetic analysis is unlikely to reveal much information in such cases. Our artificial system gives us insights into how such shapes could be produced at the cell level by a single program, and we plan to exploit these

insights to design biological experiments. We believe that the results from this research will have an impact on our engineering principles for robust design as well as our understanding of biological morphogenesis.

MJ Naidoo - *Kingshill Research*

Many health service users and providers are set in their ways. Approaching the task of implementing service improvements in Dementia Services using creativity and complexity science the team at Kingshill were able to demonstrate that by trusting in the process of change and allowing the experience of emergent and novel behaviour to form new perceptions and a greater dynamic in quality improvement was established. This involved a more coherent integrated service that challenges much of the old behaviour and relationships among all stakeholders. By facilitating all groups in the process and encouraging emergent behaviour using techniques derived from the creative arts the team at Kingshill witnessed transitional phases involved in the development of novel behaviour and new team led dynamics that focussed on implementing improved quality systems and more meaningful relationships between service users and providers. Using practical creative exercises and storytelling also demonstrated the powerful contribution made by carers and patients in treatment of this disease. By enhancing the quality of communication and understanding that emerged from the use of creative storytelling techniques, decisions relating to care, both clinical and non clinical, contributed to the implementation of an integrated service for patients. For all the stakeholders involved in the project the process of continual transformation and development had begun, a key feature of complexity science, and a meaningful exemplar for other teams and organisations a

Gary G. Nelson - *Mitretek Systems*

Self-Organizing Geography Contrasted with Regional Planning in the U.S - Gary G. Nelson, Mitretek Systems, Peter M. Allen, Cranfield University

In the 1970,s, the U.S. Department of Transportation, inspired by Ilya Prigogine, sponsored work on self-organizing models of cities and regions. These nonequilibrium, evolutionary, models addressed the need to integrate land use and transport for long range, regional-scale planning. Since that time, the „science of complexity‰ has further endorsed the self-organizing approach as pursued by some countries for regional and environmental planning. Yet despite the increasing challenges to conventional (non-integrated, deterministic, quasi-equilibrium) regional planning models, the self-organizing models have been rejected in the U.S. A reason for this divergence of praxis and theory is the expectation of confident outcome-analysis for large public works even though that contradicts the uncertainty inherent in their scale. This contradiction can be resolved only through a complete scale hierarchy of objects that emerge from planned projects to evolutionary geography. This scale hierarchy is articulated by self-organizing models that focus on the evolutionary dynamics of geography appropriate at the large scale. But besides the conventional dichotomizing of land use from transport, essentially as a way of creating artificially a quasi-equilibrium context for linear causality, there is also a dichotomy of planning from policy, in order to define an "objective" technical process within the larger social process. This begs the question of why there is any credibility to planning under the social ideology of market democracies. The self-organization paradigm, associated with the limits to control posed by complexity, offers a useful perspective on the technical issues of planning models within the institutional issues of regional planning in the U.S.

Kenneth C. O'Brien - *OPEN Strategies*

Common Sense and Complexity: Harnessing the Science of Complexity for Your Business

The scientific community is continuing to explore the implications of the science of complexity and complex systems. While there is much yet to be done, concepts are emerging that appear to have immediate application to organizations and business. Some members of the consulting community have started integrating selected elements of their interpretation of the science in their work with clients. It is crucial that the scientific and consulting communities maintain a robust dialog during this developmental period to insure there is continuity between the efforts. To that end, this presentation provides an overview of the work being done by one consultant to communicate the significance of the science and how it can be applied to business. To frame it another way, it's about "how the world works according to the science of complexity and what it might mean to a business". The presentation will cover the concept of organizational fitness as a strategic planning framework/context to integrate the implications of the science into an organization's planning process. This consulting approach has been used with a number of clients including energy utilities, governmental entities and the University of Washington Medical Center.

Belinda Orme - *Icosystem*

Chaos and Mixing in Biological Fluids

The motion of particles and feeding currents created by micro-organisms due to a beating flagellum are considered. The calculations are pertinent to a range of sessile organisms, but we concentrate on a particular organism, Salpingoeca Amphoridium (SA)(a choanoflagellate); due to the availability of experimental data, Pettitt (2000).

These flow fields are characterised as having very small Reynolds numbers, implying viscous forces dominate over inertial ones consistent with the Stokes flow limit. The flow generated by the flagella is initially modelled via consideration of a point force known as a stokeslet. The interaction between the boundary to which the organism is attached and its flagellum leads to toroidal eddies, which serve to transport particles towards the micro-organism; promoting filtering of nutrients by SA.

It is our conjecture that the interaction of multiple toroidal eddies will lead to chaotic advection and hence enhance the domain of feeding for these organisms. We illustrate the degree of mixing in the region around SA using chaotic measures to study the influence the flagellum has on the surrounding fluid. Poincare sections illustrate a sense of chaotic mixing whilst Lyapunov exponents characterize how well mixed the fluid becomes. Further, three-dimensional particle paths around such an organism are considered using Greens functions. Comparisons of flow patterns from numerical data with both experimental and theoretical work suggest agreement.

Jaime Lagunez Otero - *UNAM*

From Physics to Economy via Biology

The cell is behaves has several emergent cognitive properties, in a way of a higher level than that of simple CNS. We would like to present some examples and discuss the possibility of evaluating such capacities. The systems that we study are in the process of cell growth and death, subjects relevant in the study of oncogenic processes and aging. Our page requiring maintainance is at 132.248.11.4 interests: As you may remember, as I have attended NECSI events several times, I am PI for genetic and proteic networks. We have explored several computational paradigms such as agent based programing in order to search for emergent capacities within the signal transduction system of the cell.

N. Oztas - *University of Southern California*

Mapping the Field: Complexity Sciences in Organization and Management. N. Oztas, T. Huerta, R.C. Myrtle, P. J. Robertson1

The purpose of this paper is to provide an overview of the application of complexity sciences to the organization and management theory literature. To address this issue, we searched the ABI/INFORM online database, which provides access to over 1,000 premier worldwide business and management periodicals, using self-organization chaos theory and complexity sciences as key words. Our initial search showed 519 pieces published between 1980 and 2000. After eliminating the non-management and non-complexity sciences articles, our final sample consisted of 178 papers published in 105 different magazines and journals between 1985 and 2000. To analyze these articles, we used Barley, Meyer, and Gash's (1988) original triple clustering of types of academic literature -- descriptive, practice, and theory. We also added a fourth group of studies from popular magazines and compared them to the former three clusters of scholarly work.

Our initial review of the application of complexity in these four clusters found that emerging sciences of complexity have received an important amount of attention in both theory and practice of organizational life. A characteristic common to all four groups of studies is that, because the new sciences originate from the physical and natural sciences and still are evolving even in those fields, the literature and the techniques are not yet fully developed or institutionalized either in academia or professional life.

We initially observed that, while one group of studies approached the topic as an extension and refinement of existing theories, another group of studies has already started proposing theoretical and empirical foundations for a completely new approach to organizational life, not only by showing the applicability of complexity science approaches to organizational life as a new paradigm, but also by establishing links with existing organizational literature. Additionally, a group of professional managers and consultants has already started experimenting in their organizations with novel approaches emerging from the new sciences of complexity.

Despite these optimistic findings, our preliminary results also support concerns regarding complexity theory's susceptibility to becoming another fad in management practice (McKelvey, 1999; Maguire and McKelvey, 1999). In order to establish a firm foundation for institutionalizing complexity sciences in the organization and management field, there is an urgent need for additional conceptual clarification, theory development, and empirical research.

This paper constitutes the first step in analyzing these four groups of studies in an attempt to map and aggregate the arguments of the emerging literature in the organization and management field. In this initial analysis, we focus on the descriptive qualities of the publications to map the field and leave the detailed focus on content for a subsequent paper.

1. School of Policy, Planning, and Development University of Southern California, Los Angeles, California.

Lael Parrott - *Université de Montréal*

Can Self-Organisation be Used as a Measure of Ecological Integrity?

Self-organisation is a cardinal feature of all living systems, and, as early as the 1940's, E. Shrödinger suggested that the phenomena might be a defining characteristic that distinguishes living systems from non-living systems. Since then, numerous measures of self-organisation have been introduced and been applied to all types of living systems. Most recently, self-organisation has been proposed as a possible indicator of ecological integrity, with the hypothesis being that undisturbed ecosystems should be more effective at utilising available energy, and should, therefore, have higher measures of self-organisation. This hypothesis, as well as the general usefulness of measures of self-organisation to characterise an ecosystem's state, is explored using an individual-oriented model of a materially closed ecosystem. Results based on relatively simple ecosystem configurations show marked differences in self-organisation between systems with different community structures. We conclude, therefore, that measures of self-organisation may be useful indicators of ecological integrity. The idea will be pursued further with field data from a Laurentian ecosystem.

Joel Peck – *University of Sussex*

Sex and Altruism

The evolution of sexual reproduction is one of the long standing mysteries in evolutionary biology. The evolution of "altruistic" behaviour has also been a focus of much research. In this talk some of the difficulties surrounding the theories of sex and altruism will be explained. A solution will then be proposed that may help to resolve the mysteries surrounding both sexual reproduction, and the evolution of altruistic behaviour.

David W. Peterson - *Ventana Systems, Inc.*

An Adaptive Endogenous Theory of Technological and Economic Growth

Long-term per capita real economic growth is driven by technological progress, which is exogenous to most theories. A new agent-based model shows that the empirically observed patterns of economic growth of nations emerge naturally from the coevolution of many mutually interacting firms. The model includes simple rules for the founding of firms, their strategic decisions for allocating internal resources, their acquisition of external resources, their competitive interaction in the market, their decisions of when and how much to change their policies, and their shutdown, acquisition, or breakup in case of failure. Simulations of the model reveal long-term trends qualitatively matching the observed data, both in growth trends and in observed patterns of size-convergence and "glass ceiling" effects seen in developing nations. The model also suggests some new root causes of the observed differences in economic growth rates among nations. Finally, the model suggests that the growth patterns observed to be stable over the last 200 years are in fact only metastable. With the right kind of perturbation, the patterns of economic growth could bifurcate suddenly into a new, dynamically stable, mode.

Christopher J. Phoenix

A Multi-Level Synthesis of Dyslexia

Dyslexia has been studied from many angles. Researchers have obtained seemingly contradictory results and created widely varying theories and treatments. A complete understanding of dyslexia requires recognition of neurological and psychological components and their interaction, and could therefore benefit from a complex systems approach. This paper surveys and synthesizes results from many theoretical, experimental, and clinical approaches to dyslexia, including Tallal, Davis, Geiger, and Merzenich. The magnocellular hypothesis combined with the Davis theory of "triggers" appear to explain nearly every experimental result, observation, and successful treatment of which the author is aware. Dyslexia can be understood as an accretion of simple symptoms in multiple sensory modalities, each symptom having the same neurological basis; each individual has a different combination of symptoms, and the symptoms are created and maintained through mental/psychological interaction with the individual's efforts to perform. There is strong observational evidence, confirmed by pilot studies carried out by the author, that the symptoms can change momentarily. Although such rapid change is not recognized by many dyslexia researchers, it has been demonstrated with PET scans in the case of stuttering; this finding is crucial to a full understanding of the interaction between neural function and mental state. The recognition of the diversity of symptoms, their common neurological basis, and their extreme plasticity in response to high-level mental state, may help to focus research and to develop increasingly effective and rapid treatments.

Control and Complexity Issues in a Proposed Nanomedical Device

This paper addresses control and complexity issues in a proposed medical device performing a straightforward yet extremely complex function. In a few decades, devices may become far more intricate than software is today; the science of complexity will become as necessary to successful design as the science of materials. This proposal supplies a preview of the problems that complexity scientists may be called upon to solve. The purpose of the proposed device is to replace blood by lining blood vessels and performing transport functions. Molecular nanotechnology (MNT) promises the capability of building such a device; however, its design is far beyond our present abilities. The device contains 3x10^14 cooperating machines, with over 2x10^11 MIPS of distributed computing. It must maintain appropriate concentrations of all chemicals in all areas of the body, and support the immune system by delivering white cells as necessary. Although incredibly aggressive by today's standards, the medical benefits could make it a desirable product if the design problems can be solved. Such a project seems fantastic, but it should not be viewed in isolation--several proposed products of MNT are equally complex. MNT promises access to unprecedented capability and complexity of devices, and product designers will surely push the envelope. Successful designs will require significant advances in distributed computing, medical systems, fault detection and recovery, and control of complex feedback loops. The present proposal may serve to inspire or focus efforts on a typical near-future design problem.

Carlos E. Puente - *University of California, Davis*

More Lessons From Complexity. The Origin: The Root of Peace

The last few decades have witnessed the development of a host of ideas aimed at understanding and predicting nature's ever present complexity. It is shown that such a work provides, through its detailed study of order and disorder, a suitable framework for visualizing the dynamics and consequences of mankind's ever present divisive traits. Specifically, this work explains how recent universal results pertaining to the transition from order to chaos via a cascade of bifurcations point us to a serene state of unselfish love, symbolized by the convergence to the origin in the root of a Feigenbaum's tree, in which we all may achieve our inherently desired condition of justice, peace and joy. The implications of these ideas regarding forgiveness and freedom are discussed.

Treasures Inside the Bell

Universal constructions of univariate and bivariate Gaussian distributions, as transformations of diffuse probability distributions via, respectively, plane- and space-filling fractal interpolating functions, are reviewed. It is illustrated that the construction for the bivariate Gaussian distribution yields infinite exotic kaleidoscopic decompositions of the bell in terms of beautiful "mandalas" having arbitrary n-fold symmetry, for any n>2.It is argued that these ideas yield a new paradigm for the emergence of order, for a host of natural patterns, such as snow crystals and biochemical rosettes (including life's own DNA), are found inside the bell.

Ruben R. Puentedura - *Bennington College*

Slow and Steady: Deliberately Computationally Inefficient Genetic Algorithms and Hard Problems

It is known from the work of Axelrod, Miller, Lindgren and others that the application of genetic algorithmic (GA) strategies to the Iterated Prisoner's Dilemma yields varying results, depending upon the encoding used. In this paper I explore the results of using a new, "deliberately inefficient" encoding for the GA that allows for the slow evolution of strategies of varying complexity, and develop a quantification scheme to determine the degree of altruism of a given strategy. I find that, in general, altruistic strategies do not carry the day;

furthermore, the exact mix of strategies in the long-term evolution of the system proves to be quite sensitive to both the error rate in the system (as expected), as well as to the mutation rate in the GA. The results of this work indicate promising possibilities for future applications of this encoding strategy to "hard" problems, such as protein folding.

Derek Raine - *University of Leicester*

The Complexity Of Canonical Power Law Networks

In the small-worlds networks (SW) of Watts and Strogatz the ratio of cliquishness to network diameter C/L plays the role of a complexity parameter as a function of the rewiring probability of the network p. The ratio C/L is small at the two extremes of order and randomness and large for intermediate configurations. Networks that follow the node distribution of the standard canonical law (SCL) of Mandelbrot have node frequency proportional to (n + m)b as a function of rank n, and interpolate between the uniform random networks of Erdos and Renyi and the SW networks. In this paper we show how SCL networks arise by maximising the information entropy subject to a fixed geometric mean node class, and we investigate the extension of the complexity measure to these networks. We look at two examples of the evolution of SLC networks. The first example is development during cell division. The second is the fission-fusion scenario for the origin of life in which catalysis of polymerisation is non-specific. We comment finally that these two examples can be distinguished in terms of the ‘languages’ recognised by the systems considered as automata.

Erik Rauch - *MIT, NECSI*

The Relationship Between Measures of Fitness and Time Scale in Evolution. Erik Rauch, Hiroki Sayama, Charles Goodnight and Yaneer Bar-Yam

The notion of fitness is central in evolutionary biology. It is widely assumed that the instantaneous rate of change in frequency of a type is a valid measure of evolutionary fitness. We use a simple spatially-extended predator-prey or host-pathogen model to show an important generic case where this characterization fails. In the model, the evolutionarily stable type is out-competed in the short term by seemingly fitter mutants. These mutants enjoy high reproduction ratios for many generations, but go extinct in the long term (e.g. after 200 generations). The rapidly-reproducing types modify their local environment in a way that is detrimental to their survival, but this environmental modification and its feedback to population growth requires many generations. The distinct fates of the different types are made possible by self-organized spatial segregation. The results imply that averages over space or time should not always be assumed to adequately describe the evolutionary dynamics of spatially-distributed ecological systems. We propose general quantitative measures of fitness that reflect the importance of time scale in evolutionary processes, and also show how the results can be understood using the notion of heritability of the environment.

Allan R. Robinson - *Harvard University*

Data Assimilation for Modeling and Predicting Multiscale Coupled Physical-Biological Dynamical Interactions in the Sea

Data assimilation is now being extended to interdisciplinary oceanography from physical oceanography which has derived and extended methodologies from meteorology and engineering for over a decade and a half. There is considerable potential for data assimilation to contribute powerfully to understanding, modeling and predicting biological-physical interactions in the sea over the multiple scales in time and space involved. However, the complexity and scope of the problem will require substantial computational

resources, adequate data sets, biological model developments and dedicated novel assimilation algorithms. Interdisciplinary interactive processes, multiple temporal and spatial scales, data and models of varied accuracies and simple to complex methods are discussed. The powerful potential of dedicated compatible data sets is emphasized. Assimilation concepts and research issues are overviewed and illustrated for both deep sea and coastal regions. Progress and prospectus in the areas of parameter estimation, field estimation, models, data, errors and system evaluation arealso summarized.

Luis Mateus Rocha - *Los Alamos National Laboratory*

Indirect Encoding of Phenotypes in Evolutionary Agents

In this paper we present a simulation study of the evolutionary behavior of two different kinds of agents. The first type of agents evolve via phenotypic variation or (Lamarkian) self-inspection, and the second via genetic variation. Both types of agents possess self-organizing phenotypes, modeled by Fuzzy Development Programs (FDP) [Rocha, 2001], which are procedures for combining fuzzy sets in such a way as to model several characteristics of self-organizing development processes. The objective of the simulation is to study the advantages of coded (genetic) reproduction over hypothetical, purely dynamical alternatives, thus increasing our understanding of the origin of life problem. We show that agents with genotypes tend to take over the environment in most conditions, except when high genotype variation is present.

We also discuss in detail the indirect encoding algorithm employed by the agents with genotypes. These agents indirectly encode phenotypes by constructing them from available dynamics building blocks given genetically encoded initial conditions for configurations of these building blocks. This indirect encoding scheme models the process of development of phenotypes via self-organization in real biology. Unlike traditional genetic algorithms, and the most radical theories of neo-Darwinian evolution, genetic descriptions do not directly represent particular traits of phenotypes. Rather, the final phenotypes are a result of non-linear self-organization, which is irreversible and produces epistatic dependencies on phenotypic traits. The agents of the simulations here presented possess these traits, which furthermore prove to be advantageous in applications of genetic algorithms which we discuss.

REFERENCES:

Rocha, Luis M. [2001]. "Evolution with material symbol systems". Biosystems. Vol. 60, pp. 95-121.

I.M.Rouzine - *Tufts University*

Realistic Model of Cellular Immune Response Against Human Immunodeficiency Virus. I. Rouzine and J.M. Coffin.

Background. Although many elements of immune system are well-studied experimentally, it is not known how they are connected on the systemic level. Mathematical modeling of immune system as a network of interacting cell compartments is an efficient way to obtain this information, and to design therapeutic vaccines against viruses which persist in human body and are associated with high mortality, such as HIV, hepatitis B and C. To choose the best model among the enormous number of biologically plausible models, its predictions have to be compared with multiple quantities measured, at different time points, for several experimental systems. In this work, we consider immune kinetics of HIV/SIV and the lymphocytic choreomeningitis virus infecting mice (LCMV). Although virologically unrelated, the two viruses show similarities at the systemic level of host-virus interaction. They both (i) persist in the host at detectable levels, (ii) depend strongly on the presence of CD8 T cells, (iii) cause premature depletion of antigen-specific CD8 T cells, and (iv) replicate in the lymphoid tissue cells. The difference between the two viruses is that all the strains of HIV/SIV persist in vivo, while LCMV may or may not persist depending on the strain and the initial doze. Development of efficient therapies against such infections depends on understanding, on the systemic level, the scheme of interaction of different cell types involved in the CTL response.

Methods. Our starting hypothesis is that the mechanism of the (impaired) CTL response is the same, on the systemic level, for HIV/SIV and LCMV and that the differences between the two viruses and between LCMV strains are due to quantitative variation of system parameters. We checked several dozen of models of primary CTL response (4 weeks) against data on 8 time-dependent immunological quantities obtained for SIV (Kuroda et al., 1999) and two strains of LCMV with different behavior, Armstrong (Murali-Krishna et al., 1998) and Docile at low and high infecting dozes (Moskophidis et al, 1993).

Results. The simplest model we found which fits these data with a good accuracy includes 8 different subtypes of immune cells and has 15 constant parameters. It postulates that effector and dividing cells, after depletion of helper cells, become "transient effector" cells which can differentiate into either anergic or memory cells or die. The model specifies how these processes are controlled by the antigen and innate (non-CD4) helper cells. The viruses which can infect helper cells and get them killed by CTL can persist.

Conclusion. Testing mathematical model against several time-dependent parameters measured for similar systems provides us with much more information about the immune response than both empiric methods and traditional heurisitic modeling are capable of. Most small modifications of our model lower the quality of fitting dramatically. This indicates that the model is very specific and worthy of additional experimental tests proposed in our work.

Hector Sabelli - *University of Illinois at Chicago.*

Bios: Mathematical, Cardiac, Economic and Meteorological Creative Processes Beyond Chaos. H. Sabelli, L. Kauffman, M. Patel, and A. Sugerman

Bios is a newly found form of organization that resembles chaos in its aperiodic pattern and its extreme sensitivity to initial conditions, but has additional properties (diversification, novelty, nonrandom complexity, episodic patterning, 1/f power spectrum) found in natural creative processes, and absent in chaos. New methods have been developed to measure the properties that differentiate bios from simpler chaos. Global diversification is the increase in variance with duration of the time series; local diversification is the increase in variance with increase in embedding [Sabelli and Abouzeid, Nonlinear Dynamics, in press]. Diversification differentiates three types of processes: (a) mechanical processes and random series conserve variance; (b) processes that converge to equilibrium or periodic or chaotic attractors initially decrease variance; (c) creative processes increase variance. Novelty is defined as the increase in recurrence isometry with shuffling of the data [Sabelli, Nonlinear Dynamics, 2001]. Heartbeat intervals, most economic series, meteorological data, colored noise, and mathematical bios display novelty. Periodic series are recurrent (higher isometry than their shuffled copy). Chaotic attractors are neither novel nor recurrent; they have the same number of isometries as their shuffled copies. Nonrandom complexity is characterized by the production of multiple episodic patterns ("complexes"), as contrasted to the uniformity of periodic, chaotic and random trajectories; arrangement (the ratio of consecutive to total recurrence) measures nonrandom complexity [Sabelli, J. Applied Systems Studies, in press]. The process equation $A_{t+1} = A_t + k * t * \sin(A_t)$ generates convergence to π, a cascade of bifurcations (including a "unifurcation"), chaos (with prominent period 4), bios and infinitation, as the value of the feedback gain k * t increases [Kauffman and Sabelli, Cybernetics and Systems, 1998; Sabelli and Kauffman, Cybernetics and Systems, 1999]. When t is given a negative sign, biotic series show irreversibility while chaotic series show only hysteresis. Bios is composed of multiple chaotic complexes, and change their range and sequence with minor changes in initial conditions (global sensitivity); chaotic trajectories are bounded within one basin of attraction (local sensitivity to initial conditions). The generation of bios requires bipolar feedback. When the bipolar feedback provided by the trigonometric function is biased, the equation produces a time series that culminates in chaos with prominent period 3 similar to that observed with the logistic equation. Conservation is required for bios, which is replaced by chaos in $A_{t+1} = k * t * \sin(A_t)$. The series $A_{t+1} - A_t$ of a biotic time series is chaotic; differentiating an empirical series prior to analysis may transform a biotic pattern into a chaotic one. Mathematical bios and heartbeats show $1/f^N$ power spectra; the time series of differences shows a direct relation between frequency

and power. Empirical and mathematical biotic series show asymmetry, positive autocorrelation, and extended partial autocorrelation. Random, chaotic and stochastic series show symmetric statistical distributions, and no partial autocorrelation. (Supported by SACP).

Fabrice Saffre - *BTexact Technologies*

RAn (Robustness Analyser)

Robustness of complex networks has been extensively discussed in the scientific literature for the last few years. Several authors have pointed out that different topologies would react differently to node failure and/or broken links (see e.g. Albert et al., 2000; Cohen et al., 2000) and that mathematical techniques used in statistical physics could effectively be used to describe their behaviour (see e.g. Callaway et al., 2000). It has also been demonstrated that most artificial networks, including the Internet and the World Wide Web, can be described as complex systems, often featuring "scale-free" properties (see e.g. Albert et al., 1999; Faloutsos et al., 1999; Tadic, 2001).

In this context, it is becoming increasingly obvious that the robustness of a wide variety of real distributed architectures (telecommunication and transportation networks, power grids etc.) is essentially a function of their topology, and could therefore be evaluated on the basis of their blueprint. Similarly, several alternative designs could be compared before their actual implementation, in order, for example, to balance redundancy costs against increased resilience.

RAn is the software embodiment of a mathematical framework developed to quantify complex networks' behaviour when submitted to cumulative node failure. It is designed to test the robustness of any given network topology in an automated fashion, computing the values for a set of global variables after performing a statistical analysis of simulation results. Those variables, characterising the decay of the network's largest component, effectively summarise the system's resilience to this form of stress.

Hiroki Sayama - *NECSI*

Spontaneous Formation of Isolated Groups and its Effects on Genetic Invasion in Locally Mating and Competing Populations. Hiroki Sayama, Marcus A. M. de Aguiar, Yaneer Bar-Yam, and Michel Baranger

We present a theoretical model of evolution of spatially distributed populations in which organisms mate with and compete against each other only locally. We show using both analysis and numerical simulation that the typical dynamics of population density variation is spontaneous formation of isolated groups due to competition for resources within neighborhoods that are local but range over several spatial sites. Such population gaps strongly affect the process of genetic invasion by local reproductive mixing, and even non-homogeneous genetic distribution is possible as a final state. We then particularly consider a specific version of this model in the presence of disruptive selection, favoring two fittest types against their intermediates. This case can be simplified to a system that involves just two non-conserved order parameters: population density and type difference. Since the co-existence of two fittest types is unstable in this case, symmetry breaking and coarsening occur in type difference, implying eventual dominance by one type over another for finite populations. However, such coarsening behavior may be pinned by the spontaneously generated population gaps between isolated groups. The long-term evolution of genetic composition is sensitive to the ratio of the mating range and the competition range among other parameters. Our model may provide a theoretical framework for consideration of various properties of spatially extended evolutionary processes, including spontaneous formation of subpopulations and lateral invasion of different types.

Jeffrey C. Schank - *University of California, Davis*

Cycle Variability, Follicle Competition, and Female Mate Choice

It has long been thought that at least some female mammals (including women and Norway rats) synchronize their ovarian cycles when in close proximity. However, re-analyses of these studies has revealed serious and systematic methodological errors. In retrospect, this is exactly what should have been expected given that female mammals exhibit considerable variability in the lengths of their ovarian cycles and cycle variability prevents synchrony. Moreover, despite the ubiquity of cycle variability in cycling mammals, no attention has been paid to possible adaptive functions of cycling and cycle variability. I present a mathematical model of follicular competition on the ovary that displays (i) species typical cycle variability distributions, (ii) species typical ovulation rates, and (iii) compensatory ovulation for biologically realistic parameter values. There are also plausible parameter values that produce a high degree of cycle regularity. But, apart from artificial selection on some domestic mammals, wild mammals, in general, do not have highly regular cycles. I then argue that cyclic ovulation together with cycle variability in some mating systems may enhance a female's ability to choose phenotypically high quality mates while minimizing competition for quality mates with other females.

Erich Schmidt – *Princeton University*

Evaluating Affinity Maturation on NK Landscapes. Erich Schmidt Steven Kleinstein

Individual lymphocytes make response decisions based on signals received from their environment. These cells coordinate with other cells of the immune system to produce an effective response. We present a framework to study this decision making process along with an example of its application.

We use a simple neural network to represent the internal decision making process of a cell. Signals from cell surface receptors are translated into probabilities of actions such as division or apoptosis. The network is evaluated by determining how well the cell performs in a simulated environment. We then search the parameter space to determine the;best; cell program, within a set of biological constraints. As an example, this approach is applied to study the process of affinity maturation in germinal centers. Specifically, we evaluate the ability of a clonal opulation of B cells to efficiently find the highest affinity points on a fitness landscape. In this case, the environmental signal is the B cell receptor affinity for antigen, and one decision the B cell can make is whether or not to mutate its receptor. We use an NK model for the landscape, with parameters adjusted to produce a realistic affinity landscape.

Pierre Sener - *Iridia*

The Connections Between the Frustrated Chaos and the Intermittency Chaos in Small Hopfield Network. Hugues Bersini and Pierre Sener

Frustrated chaos is a dynamical regime which appears in a network when the global structure is such that local connectivity patterns responsible for stable oscillatory behaviours are intertwined, leading to mutually competing attractors and unpredictable itinerancy among brief appearance of these attractors. In this paper, through a detailed study of the bifurcation diagram given for some connection weights, we will show that this frustrated chaos belongs to the family of intermittency type of chaos. The transition to chaos is a critical one, and all along the bifurcation diagram, in any chaotic window, the duration of the intermittent cycles, between two chaotic bursts, grows as an invert ratio of the connection weight. We will more specifically show that anywhere in the bifurcation diagram, a chaotic window always lies between two oscillatory regimes, and that the resulting chaos is a merging of, among others, the cycles at both ends. Since in our study, the bifurcation diagram concerns the same connection weights responsible for the learning mechanism of the Hopfield network, we will discuss the relations existing between bifurcation, learning and control of chaos. We will show that, in some cases, the addition of a slower Hebbian learning mechanism onto the

Hopfield networks makes the resulting global dynamics to drive the network into a stable oscillatory regime, through a succession of intermittent and quasiperiodic regimes.

Benjamin Shargel - *NECSI / Icosystem Corporation*

Optimization of Robustness and Connectivity in Complex Networks

It has recently been shown that many complex biological, social and engineered systems can be modeled as inhomogeneous networks, whose connectivity distributions follow a power-law, implying no characteristic scale. Such scale-free networks possess a great degree of interconnectedness due to the efficient use of a relatively few number of highly connected nodes. Scale-free networks are often contrasted with exponential, or purely random networks that are less interconnected but retain a greater robustness to attack. In this paper we present a general framework of complex networks, of which both of these network types are special cases, by parameterizing two aspects of network construction: growth and preferential attachment. We find that the growth and preferential attachment parameters tune the attack tolerance and interconnectedness of the network in a largely independent manner, enabling the construction of a new type of network that has the interconnectedness and failure tolerance of a scale-free network but a robustness to attack closer to that of an exponential network.

Christopher A. Shaw - *Univ. British Columbia*

Reverse Engineering Neurological Diseases

The causes of the 'age-related' neurological disorders (Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis (ALS)) remain unknown. These disorders cannot be currently detected until irreparable damage has been done to the nervous system. Largely for this reason, these disorders are incurable and likely to remain so for a variety of theoretical reasons. Without knowing causal mechanisms, no targeted pharmacological strategy can be employed. The costs associated with the palliative care for victims is enormous. Current hypotheses tend to focus on either genetic abnormalities or environmnetal neurotoxins as causal. As most cases of such disorders are 'sporadic' rather than 'familial', a purely genetic origin seems unlikely. Environmental factors seem much more likely to play a dominant role, albeit possibly acted upon by genetic 'propensities'. This conclusion, while helpful, still leaves a vast number of potential environmental factors to consider, many of which alone, or in synergy, could cause neuropathological outcomes mimicking the various human disorders. We have approached the problem using a model system designed to mimic conditions of an unusual neurological disorder that combines many of the features of Alzheimer's, Parkinson's, and ALS. This disorder is termed ALS-parkinsonism dementia complex and was once a major cause of death on Guam. Epidemiological evidence linked the disorder to consumption of the seed of the cycad palm: incidence of the disorder reached almost 25% of the adult population when cycad seed consumption was high; 'Americanization' of the Guamanian diet led to a dramatic decline in ALS-PDC. Our animal model involves mice fed cycad flour similar to that consumed on Guam. The mice are subjected to a battery of behavioral tests for motor, olfactory, and cognitive function and are sacrificed at various stages after the onset of cycad exposure. Behaviorally, cycad-fed mice show significant declines in motor abilities followed by losses in learning and memory. Olfactory function is disturbed. Histological analysis of the central nervous systems of these animals reveal widespead neurodegeneration associated with areas controlling motor, olfactory, and cognitive functions. Biochemical analyses show significant changes in various second messenger pathways (e.g., protein kinases), in ionotropic receptor numbers and distributions, decreases in the level of glutamate transporter proteins, and abnormal expression of various cytosolic proteins such as heat shock and tau. Our current goal is to put these changes into sequence with a view to establishing a time line of pathological events from first exposure to cycad neurotoxins all the way to cell death and behavioral loss of function. Given the extremely large numbers of molecules that could be

involved in cell death 'cascades', we are attempting to 'reverse engineer' the various stages in our model. We believe that the likely neurotoxin begins to impact neuronal health by causing excessive glutamate release leading to excitotoxic actions. Subsequent events include loss of glutmate transporters and hyperactivation of regulatory protein kinases. 'Downstream' events seem to include tau protein abnormalities. Experiments now in progress seek to fill in details leading to each of these stages by selectively examining molecules that are part of specific biochemical pathways. The ultimate goal remains that of providing a complete sequence of events leading to neuronal cell death.

Bob Sheldon - *Emergent-IT, Inc.*

Comparing the Results of a Non-Linear Agent-Based Model to Lanchester'sLinearModel:Intuitive Guidelines for Analyzing SOCRATES Output

The basic mathematical models used by the military to analyze combat operations have changed little in the last one hundred years, despite the fact that military technology has changed dramatically in the Information Age. "Project Albert" is a research and development effort by the Marine Corps Combat Development Command to assess the general applicability of the study of complex systems research to warfare and to provide candidate models for the study of Information Age military operations. This presentation discusses a comparison of a Project Albert research effort, the Simulation of Cooperative Realistic Autonomous Transparent Entities (SOCRATES), with a traditional mathematical combat model

Carrol V. Sidwell - *Pratt & Whitney*

Monte Carlo Simulations for Tolerance Design of Secondary Flow Systems

Flávio Mesquita da Silva - *Compahnia Energetica de Brasilia*

Positive Feedback Loops and tracking Principles Applied to Sustainable Community Building: A Case Study

Premise

One of the patterns observed in the tracking tradition is that all animals, but human beings love visiting the 'transition zone', which is a place where environments meet (i.e. prairie and forest, water and sand, etc.) In other words, diversity is an integral part of nature, and as such animals naturally accept it. As natural beings, humans can be affected in ways that they may re-discover (or uncover) how to operate in a diverse social environment.

Context

The experience took place within the sole distributor of electric power in the cosmopolitan area of Brasilia, Brazil, the Companhia Energetica de Brasilia - CEB.

Most employees were busy trying to understand the new organizational architecture, which had been previously designed by a group of consultants, and were uncertain about what would happen to the 'good old niches', held mostly by well-educated male engineers, who were immersed in a well-defined hierarchical structure.

There was a culture of doers with stiff postures, who had been following specific rules to accomplish specific tasks. The new architecture was process-oriented while the former was goal-oriented. There were scattered evidences of a culture of collaboration. Consequently, the system was not conducive to the generation of feedback loops throughout the company, especially positive ones. Negative feedback happened as a result of a controlling posture derived from the framework established within the company, and it was restricted to the scope of those departments that were directly related to each other.

On the other hand, the new model yielded solidarity. It encouraged collaboration, shared responsibility and, thus, it demanded a radical shift on the power relationship, from top down to bottom up. The major obstacle, however, was that there was no way to work on a strategic, shared planning without aligning it to the company's new design. The complexity resided in aligning people who had distinct levels of perception, and were at different stages of integration of the already on-going process in the company.

Method

The overcoming of this challenge required a paradigm shift of major degree. Principles of positive feedback loops and Permaculture, and the foundation of tracking (people, in this case) were utilized to design practices that brought people together to deal with the issue of cultural change in this complex environment.

The key insight was to observe people's behaviors, including their avoidances, and map them, as it is done in the tracking tradition. As a result, two distinct patterns, which expressed, respectively people's likes and dislikes, preferences and non-preferences were woven together.

As the mapping activity progressed, the level of intangibles decreased. Conversely, the level of certainty increased in terms of what could be expected from the partakers. The next step was to generate new, creative impulses into the system, which took in consideration the patterns revealed by the partakers, so that they could act in new, proactive ways. Their responses to these inputs generated a sequence of new ways of conversations and actions, which gradually created the following: a) need for nexus; b) sense of purpose; and c) shared focus.

The turning point came with the emergence of a comprehensive program with several interesting and intertwined projects in social accountability called *CEB Solidary and Sustainable.* This program was created to integrate all once scattered actions on social accountability, connecting one another, as well as creating new projects. The coordinators of this program became the link between all parts involved – the company, employees, stakeholders, government, society and environment, and the systematization of these multi-leveled relationships made the building of a sustainable community possible.

Barry G. Silverman - *University of Pennsylvania*

I offer a framework for representing and simulating alternative social psychological theories of crowd behavior and guerilla organizations and for studying their properties in artificial societies. This framework is based on utility theory, however, each agent in the artificial world contains a cognitive model with four layers that help it to sense the nearby environment and other agents actions and to decide its next course of action. Layer one includes physiological stressors modeled as reservoirs (energy level, noise tolerance, crowd proximity, etc) that cause decision functioning and performance to increase or degrade as the reservoirs are replenished or depleted. Layer two uses world value ontologies containing the agent's standards, preferences, and goals to construe the activation and decay of emotions in reaction to world events. Layer three summarizes the emotional construals into a somatic marker, or utility score, and uses that to select the best response (maximin) or action in the (Markov) chain of possible next states for that agent. Layer four runs the agent procedures for manipulating the world to carry out its intentions. In this fashion macro behavior emerges from the micro-decisions of (bounded rationality) agents.

The near term goal in creating this framework is to support the analysis of alternative violence mitigation strategies, though a longer term goal is to interactively support security force training in immersive worlds. In the current prototype implementation, crowd equilibrium is modeled at a political protest where agents are variously observing and picketing. An agent provocateur attempts to taunt the security forces, and if these forces use doctrines that cause them to manage the crowds poorly and react inappropriately to the taunting, a tipping occurs and a violent rampage emerges where various unemployed males begin opportunistic looting. The result serves as an initial test of the theories of several well-known crowd modelers, of how guerilla organizations might be attempting to destabilize events, and of the effectivity (or not) of various peace-keeping practices. We are further using this as a testbed to study the role of cellular automata (and genetic evolution) for population reactions to crowd events and for the study of how best to integrate artificial life and cognitive agents into a larger simulation of a terrorism campaign.

SPONSOR: Pentagon, Defense Modeling and Simulation Office.

Pawel Siwak - *Poznan University of Technology*

Iterons: the Emergent Coherent Structures of IAMs

Iterons of automata [14] are periodic coherent propagating structures-patterns of symbols- that emerge in cellular nets of automata. In a sense, they are like fractal objects; they owe their existence to iterated automata maps (IAMs) performed over a string of symbols. The iterons comprise of particles and filtrons. The particles, or signals, are well known [2, 5] in classical cellular automata (CAs) model where iterated parallel processing of strings occurs. They spread and carry local results, synchronize various events, combine information, transform data, and carry out many other actions necessary to perform a computation or to complete a global pattern formation process in extended dynamical systems. The filtrons form another class of coherent objects supported by IAMs. They emerge in iterated serial string processing which is a sort of recursive filtering (IIR filtering) [11]. In many aspects the filtrons are like solitons known from nonlinear physics; e.g. they pass through one another, demonstrate elastic collisions, undergo fusion, fission and annihilation, and form breathers as well as other complex entities. The first observation of filtron type binary objects has been done by Park, Steiglitz and Thurston [10]. They introduced a special ST-window sequential operator and a parity update function - the model called parity rule filter CA, and showed that it is capable of supporting coherent periodic substrings with soliton-like behavior. Now, a number of particular models exist that support filtrons. These are iterating automata nets [3], filter CAs [1, 7, 9], soliton CAs [6, 17], higher order CAs, sequentially updated CAs [3], integrable CAs [4], iterated arrays [5], IIR digital filters or filter automata [11-14], discrete versions of classical soliton equations (KdV, KP, L-V) [4, 16, 19], and fast rules [1, 9]. Some new models like box-ball systems [16, 19], crystal systems [8] and quantum affine Lie algebras were introduced quite recently. All these models that support discrete coherent structures, indicate at deep and relevant connections between the computational processes occurring within the nets of automata (represented by IAMs), the equations of motion of nonlinear dynamical systems, and the behavior of discrete complex systems. In the paper we present a unified automaton approach to discrete coherent structures. The aim is to expose the idea and the generic role of IAMs in supporting coherent structures. The very beginning of this idea comes form the paper [18]. We start with the particles known from classical CAs, and show how they are related to some paths on the associated de Bruijn's graphs. Then, we show the automata nets where the symbols of evolving strings are separated from the symbols of automata states. In such nets the strings flow throughout automata, thus the iterated serial processing of strings is performed in a natural way; filtrons can be observed and analyzed. Again, they are represented by some paths (sequences) of operations. We show the automata that are equivalent to all known serial string processing models (mentioned earlier), and we present the filtrons supported by these automata. Also we show how the filtrons can be analyzed in some associated computations [11, 13].

Bruce Skarin - *Worcester Polytechnic Institute*

A System Dynamics Approach to Understanding Terrorism

After the events of September 11th, 2001 it is clear that terrorism is perhaps one of the largest complex problems facing modern society in how it affects the entire population in some form. The first step in trying to solve other large social problems such as racism and gender discrimination began with creating a general public awareness and understanding. Once a problem has been clearly defined within the public, new policies tend to receive wider support and more effective implementation.

Problems such as terrorism have grown to a complexity that reaches far beyond the limits of individual understanding. It has been demonstrated that the human mind's ability to comprehend relationships decreases with every added causal factor. This leads to weaker decision making strategies that either have a

diminishing impact or tend to enlarge the problem. A lack of knowledge and understanding can also create debilitating fear and uncertainty in the general public. This can lead to many other economic, social, and political problems.

Terrorism is not new to the world, but its progression has reached a point that indicates that better understanding needs to be developed. With terrorism's global reach, these strategies must be understandable and acceptable to many different groups with conflicting backgrounds. We believe that the use of system dynamics can play a significant role in this process.

The goal of this project (to be completed by 4/30/02) is to develop and test an additional tool for improving public understanding about the dynamics of religious terrorist organizations. This includes building a detailed and calibrated system dynamics model of religious terrorist group formation. We will specifically explore the growth of the Al-Qa'ida terrorist network and the trend of declining incidents and increasing severity. In addition we will sample the general public's understanding of terrorism dynamics and evaluate the effects of learning from the model.

Benjamin Skellett - *University of Queensland*

Classical Dynamics of Magnetically Coupled Spins

This paper investigates the dynamics of a Hamiltonian system comprising of two coupled spins. This system can be considered as a model for two interacting magnetic molecules coupled via their magnetic moments using superconducting loops. Such a system has recently been proposed as a realisation of quantum bits for use in quantum computing. This system is interesting because without the coupling, motion is totally linear; the spins exhibit uniform precession. The simple nonlinear interaction is responsible for generating complex dynamics which we aim to understand and explain.The Hamiltonian for the system can be written in terms of the components of angular momentum yielding a set of six coupled differential equations. With the total angular momentum of each spin constant, the motion is confined to the surfaces of two spheres. In this paper we make use of a stereographic projection to transform coordinates and reduce the dimension of the phase space before proceeding to analyse the stability and bifurcation of the equilibrium solutions. Equilibrium occurs when there is no movement in the system, resulting in a fixed spatial configuration where the forces on each spin are in balance. Since the total energy in the system remains constant, these fixed configurations will occur only for extreme initial energy values.

We discover that the system is robust to weak coupling and identify a critical value of the coupling parameter, above which the system undergoes a bifurcation. This bifurcation causes the equilibrium configurations to move away from the poles, resulting in qualitatively different dynamics. Trajectories remain regular and localised close to the extreme energy configuration, although the system displays sensitive dependence on initial conditions and chaotic motion in other regions of the phase space. Investigating the topology of the constant-energy hypersurfaces allows us to understand the constrained phase space available for trajectories to explore and is a good indicator of whether to expect a near-integrable or chaotic regime.

By taking Poincare sections we are able to sample the motion while reducing the dimension of the phase space. This allows us to numerically investigate the integrability of the system. It also allows us to identify regions of chaotic and regular motion, as well as verify the analytic results. The correspondence between the Poincare sections and the higher dimensional dynamics is further established by visualising the motion of each spin on the original spherical surfaces. The complexity of the motion is clearly visible in the angular momentum coordinate system.

V. Anne Smith - *Duke University Medical Center*

Using Bayesian Networks to Reverse Engineer Simulated Songbird Brains

Biological systems are inherently complex, consisting of multiple levels of organization and interactions. To decipher how biological systems work, one needs to integrate information across these multiple levels. The songbird vocal communication system is ideal for such integration due to a long history of ethological investigation and a discrete dedicated brain network. We believe integration can be accomplished by reverse engineering using functional bioinformatic algorithms. One major limitation of reverse engineering of biological systems is that there are no current high-throughput intervention methods to test the accuracy of the generated solution. In anticipation of this limitation, I created an artificial songbird brain system algorithm, called BrainSim, where I make and know all the rules. I sample data from this simulated system as one would sample data from a real biological system, and plug the sampled data into reverse engineering algorithms to recover my rules. Such an approach enables improvement of the algorithms for better recovery as well as guidance for data collection in later biological experiments. I began by testing Bayesian networks as a method of reverse engineering. I found that Bayesian networks are capable of recovering with over 50% fidelity the rules of the simulated system, and thus show promise for being able to integrate the multiple levels of analysis necessary for understanding a complex system such as the songbird brain.

Arnold Smith - *National Research Council (Canada)*

Continuous and Discrete Properties in Self-Replicating Systems

Since von Neumann's seminal investigations in the 1940s, cellular automata have played a central role in the computational study of self-replication. In this paper we will argue that simulations that are closer to certain kinds of artificial chemistry, using cellular (or atomic) elements with a combination of discrete and continuous attributes, which are free to move in a continuous Euclidean space, can offer significant advantages over discrete cellular automata. We will show examples of populations in which structures similar to those in comparable cellular automata not only self-replicate, but whose elements self-organize to create some of those structures in the first place. This latter property is not characteristic of living systems, but demonstrating it increases the sharpness of the questions we can ask about such systems. We also argue that the underlying complexity of these partially continuous systems is less than for analogous cellular automata, in terms of the initial information required to seed the systems and define their rules. In our experiments, we start with a population of particles randomly distributed and with random initial velocities inside a two-dimensional container. For these experiments, the number of types of particle is small --- two to five. Particles move and orient themselves with respect to a field that can be thought of as electrical. All particles have a net charge of zero, but most have a dielectric polarization which gives them an orientation and causes them to locally attract each other, supporting the formation of simple molecular structures. Several mechanisms for catalyzing replication are investigated, in some cases involving a special transcription agent, and in other cases spontaneous cell mitosis under specific conditions. These experiments lead to a discussion of informational content and complexity in each of the regimes. By varying the binding parameters, we can vary the robustness and stability of the structures that are created, and we will discuss some initial experiments on structural competition and evolution. In passing, we describe a mechanism for temporally and spatially adaptive computational resolution which allows a relatively large population of freely-moving particles and their interactions to be simulated without enormous computational cost. This is still exploratory work, but it is expected to have application in due course to nanotechnology, where very simple structures interacting in a Euclidean space will need to be able to reproduce, and where robustness, resilience, and population dynamics will need to be carefully modeled.

Doug Smith - *University of Denver College of Law*

Order (for free) in the Courtroom: Law as a Complex Adaptive System

The American jurist O.W. Holmes defined law, roughly, as the prediction of how a trial judge would react to a situation. Yet, in their more honest moments, lawyers concede that law on the books bears a less- than - perfect relationship to what trial courts do. Still legal commentators uniformly ignore trial courts in favor of examination of the written decisions of appellate courts, which represent less that one per cent of all legal decisionmaking. Law is often described as the examplar of hierarchical control of a social system. Indeed the bulk of legal writing assumes away trial court discretion and proceeds as if trial courts' decisions are perfectly deteremined by directives and review of courts of appeal. Those few writers who have tried to apply the insights of chaos theory and complexity science to law have, for the most part, been solely concerned with legal doctrine in the forms of the written decisions of appellate court judges and the statutory enactments of legislatures. Past efforts to systematize the decisions of trial court judges have faltered at the point of locating any source of patterns or predictability in trial court rulings. This paper locates the source of patterns in law by treating law as a complex adaptive system. It proposes a simplified model of a legal system comprised of two lawyers and a single judge with no a priori decisions or statutes to guide her. It posits that this simplified system would lead inevitably to an kind of ordered state as the judge is constrained to choose among the arguments made by our two lawyers who will in turn utilize judge's feedback to (re) formulate thier arguments. Building from this model, and upon the recent works of Kauffmann, Holland, Simon, Bruner, Maturana and Varela and Giddens, as well as Luhmann, Teubner, Stephen Winter and George Soros, this paper examines law from a systems perspective. It describes how a coherent legal system could emerge, without hierarchical controls, based upon shared cognitive structures (especially as developed in law schools and in the professioal socialization process)economic and institutional considerations and interrelationships among repeat players and outsiders within courts. Thus the articles places a premium on the role of attorneys as active agents in constructing and maintaining the system. This paper argues that the day-to- day workings of court systems better describes law than examination of statutes or written decisions of appellate courts. In support three sources of evidence are examined: the difference between judicial decisions in civil and common law countries, the practice of landlord-tenant laws in states with statutes that are protective of tenants andstates that are not and the results of decisions in an emerging area of law, atttacks on predatory lending. The theory of this paper predicts that legal argumentation and decision-making would be more similar in civil and common law countries than traditional legal scholarship describes, that landlord-tenant law would be reach results far more simlar than the differences in landlord-tenant statutes would suggest and that law of predatory lending, which has largely arisen in the past six or seven years, would differ among jurisdictions despite largely uniform statutes and common law bearing on the practice.

The paper concludes that legal scholars ignore the systems effects of law at their peril, and that a close examination of the day-to-day workings of local courts describes law at a greater level of generality than legal doctrine or treatises on law.

J. C. Sprott - *University of Wisconsin - Madison*

Predator-Prey Dynamics for Rabbits, Trees, and Romance

The Lotka-Volterra equations represent a simple nonlinear model for the dynamic interation between two biological species in which one species (the predator) benefits at the expense the other (the prey). With a change in signs, the same model can apply to two species that compete for resources or that symbiotically interact. However, the model is not structurally stable, since persistent time-dependent (oscillatory) solutions occur for only a single value of the parameters.

This paper considers structurally stable variants of the Lotka-Volterra equations with arbitrarily many species solved on a homogeneous two-dimensional grid with coupling between neighboring cells. Interesting, biologically-realistic, spatio-temporal patterns are produced. These patterns emerge from random initial conditions and thus exhibit self-organization. The extent to which the patterns are self-organized critical (spatial and temporal scale-invariant) and chaotic (positive Lyapunov exponent) will be examined.

The same equations, without the spatial interactions, can be used to model romantic relationships between individuals. Different romantic styles lead to different dynamics and ultimate fates. Love affairs involving more than two individuals can lead to chaos. Strange attractors resulting from such examples will be shown.

Iris Stammberger - *Tufts University*

Contemporary Models of Creative Cognition: an Ethnographic Review of the Impact of Complexity, Evolutionary and Computational Theories.

Using an ethnographic methodology, I review a selected sample of models of creative cognition. The review shows that despite the fact that the literature in creative cognition is as diverse and fragmented as is the disciplinary background of researchers interested on the phenomenon, contemporary models tend to rely on concepts and constructs borrowed from complexity, evolutionary and computational theories. To explore the possible ways in which seemly irreconcilable models could inform each other, I identify the computational models as top-down models while the evolutionary models are identified as bottom-up models. This is based on the distinction offered in Dennett's "Darwin Dangerous Idea" (1995) that computational and evolutionary approaches in cognitive science can be seen as top-down and bottom-up analysis, respectively, of the same phenomenon. Dennett distinction also includes complexity theory as offering a map of the patterns identified by top-down and bottom-up analysis; in such a framework, interpretations of creative cognition offered by computationalism, evolution and complexity theory could be seen as complementary.

Models of creative cognition tend to borrow from only one explanatory framework - complexity theory, for instance - simply ignoring models nested on a different explanatory framework, and therefore contributing to generate what seem to be irreconcilable views of the phenomenon under study. In those cases in which theorists recognize the differential impact of their chosen theoretical framework, they do not tend to elaborate on the possible cross-fertilization among frameworks, and therefore fail to identify what constructs create the divergence among views or what different conceptualizations could lead to a more coherent understanding of creative cognition.

Once the research question is clear, the ethnographic lens helps validate the selected sample, forces systematic data analysis, reveals how the process of construction of concepts and categories in each model is impacted by the chosen nesting framework: complexity, computation or evolution, and illuminate ways in which theorizing could be cohesive. The selected sample is the collection of essays included in the following edited publications: 1. Dimensions of creativity (Boden, 1996), 2. Handbook of Creativity Research (Sternberg, 1999), 3. Creative Thought (Ward et al, 1997), 4. Technological Innovation as an Evolutionary Process (Ziman, 2000), 5. Changing the world (Feldman et al, 1994), 6. Scientific Discovery (Langley, 1987), 7. The Nature of Insight (1995). In the paper I discuss the criteria that validate the sample.

What emerges from this exercise is a fresh look to models of creative cognition with the potential of contributing to a unified theory of the phenomenon.

Vinod Subramanian - *University of Cincinnati*

Intelligent Broadcast in Random Large-Scale Sensor Networks

With advances in miniaturization, wireless communication, and the theory of self-organizing systems, it has become possible to consider scenarios where a very large number of networkable sensors are deployed randomly over an extended environment and organize themselves into a network. Such networks --- which we term large-scale sensor networks (LSSN's) --- can be useful in many situations, including military surveillance, environmental monitoring, disaster relief, etc. The idea is that, by deploying a LSSN, an extended environment can be rendered observable for an external user (e.g., a monitoring station) or for users within the system (e.g., persons walking around with palm-sized devices). Unlike custom-designed networks,

these randomly deployed networks need no pre-design and configure themselves through a process of self-organization. The sensor nodes themselves are typically anonymous, and information is addressed by location or attribute rather than by node ID. This approach provides several advantages, including: 1) Scalability; 2) Robustness; 3) Flexibility; 4) Expandability; and 5) Versatility. Indeed, this abstraction is implicit in such ideas as smart paint, smart dust, and smart matter.

The purpose of our research is to explore how a system comprising a very large number of randomly distributed nodes can organize itself to communicate information between designated geographical locations. To keep the system realistic, we assume that each node has only limited reliability, energy resources, wireless communication capabilities, and computational capacity. Thus, direct long-range communication between nodes is not possible, and most messaging involves a large number of ``hops" between neighboring nodes. In particular, we are interested in obtaining reliable communication at the system level from simple, unreliable nodes.

Wireless networks that operate without fixed infrastructure are called ad-hoc networks, and are a very active focus of research by the wireless community. However, most of the work focuses on networks with tens or hundreds of nodes, where most message paths are only a few hops long. All data messages in such a system are unicast, i.e., they are between specific pairs of nodes. There are two major formulations for this. In some message routing algorithms, a path discovery process is used to first find a route between the source and destination nodes (or locations), and the message is then sent along this path. This is clearly a top-down approach with limited scalability. Other routing protocols use next-hop routing, where each node, knowing the destination of an incoming message, only determines the next node to forward the message to. These protocols scale much better, but at the cost of maintaining and updating extensive amounts of information about network topology. This can be expensive in terms of energy, and can often lead to problems if the individual nodes are unreliable, causing broken links and lost messages. From a complex systems viewpoint, the problem with unicast-based next-hop methods is that they do not exploit the inherent parallellism of the system to achieve robustness. This is the issue we consider in our research.

Rather than using directed unicast between nodes, we study the possibilities of broadcast. In the simplest case, this corresponds to flooding, where every message received by a non-destination node is ``flooded" to all the node's neighbors. While this is a simple apprach, it is extremely wasteful of bandwidth and creates a lot of collisions --- the simultaneous use of the wireless channel by multiple messages, all of which are lost as a consequence. To overcome the problems of flooding while retaining its inherent parallellism, we explore the method of intelligent broadcast. In this approach, each node receiving a message decides whether to re-broadcast it to all its neighbors or to ignore it. Note that the decision does not involve selecting which neighbor the message is forwarded to, but only whether to forward the message. The latter is a much simpler decision, and can be made on the basis of the information carried by the message in combination with that available within the potential forwarding node. This approach leads to a self-organized communication process where local decisions by the nodes produce global availability of information.

In the paper, we present a well-developed paradigm for random LSSN's, including a model for the nodes and viable broadcast-based protocols for channel access and network organization. We evaluate the performance of the network in the case of simple flooding, and then study the effect of a simple decision heuristic that allows nodes to limit message re-broadcast based on how many hops the message has already travelled. We show that this heuristic leads to a dramatic improvement in performance, making the broadcast-based system a viable --- and more robust --- alternative to more complicated systems under some conditions. We also characterize how network parameters such as size, node density, messaging rate and node reliability affect the performance of the heuristic.

John Symons - *University of Texas, El Paso*

Emergence and Reflexive Downward Causation

Richard P. Taylor - *University of Oregon*

The Discovery of Fractals in Jackson Pollock's Paintings: Implications for the Visual Sciences. Richard P. Taylor, Branka Spehar, Colin W. G. Clifford and Ben R. Newell

It is well known that natural processes and computer mathematics can generate fractals (patterns that repeat at many magnifications). Our recent fractal analysis of Jackson Pollock's dripped paintings demonstrate that humans can also generate fractals (1). This discovery has renewed interest in the human visual system's response to fractals and, in particular, to the complexity generated by their repeating patterns. This complexity can be quantified using the fractal dimension D. We show that humans display a 'universal' aesthetic preference for a specific range of complexity (D = 1.3 to 1.5), regardless of whether the fractals are generated by nature's processes, by mathematics, or by Pollock (2). We will discuss practical applications of this result (2). Having revolutionized art of the Twentieth Century, Pollock's work may be destined to have an even broader impact in the Twenty-first Century.

1. R.P. Taylor et al, Nature 399, 1999, 422.
2. R.P. Taylor, Nature, 410, 2001, 18.

Robert Tinker

Complex Molecular Simulations in Science Education. Robert Tinker, Amy Pallant and Qian Xie

The growing understanding among scientists of the central role of complex systems and emergent properties has not been matched by any significant changes in the K-14 math and science curriculum. One of the problems is that there is no room in the curriculum for new topics; any additions must either displace other topics or realize efficiencies in teaching required topics. We have developed a piece of sophisticated molecular simulation software called Molecular Workbench 2D, and are experimenting with using this tool to teach a wide range of traditional topics in physics, chemistry, and biology that represent emergent properties including thermal phenomena, physical properties of materials, reactions, and biochemical processes. Our preliminary results indicate that, using complex simulations, these topics are easily taught at least as early as the eighth grade and that the focus on macroscopic properties that emerge from atomic-scale models results in improved learning of important science topics.

Mark R. Tinsley - *The University of Montana*

Dynamic Instability in Tropospheric Photochemistry: An Excitability Threshold. Mark R. Tinsley and Richard J. Field

Dynamic equations describing photoxidation of tropospheric chemical pollutants are nonlinear,containing complex feedback loops. Such nonlinearity is known to give rise to variousdynamical instabilities including multiple steady states, oscillation, and even chaos. A relatedtype of instability, excitability, is demonstrated here using a two-variable (reduced from six) model of methane photoxidation in which perturbation of a stable but excitable steady statebeyond a threshold is dramatically amplified before the steady state is reapproached. Suchswitching/amplification responses may have important implications for atmospheric/climaticmodeling. A phase-plane analysis describes the origin of this excitability and suggests that itmay be a relatively common phenomenon in environmental models.

Jochen Triesch - *UC San Diego*

Towards Understanding Self-organized Information Flow in the Cortex

One of the most fundamental questions in the neuro- and cognitive sciencesis how the flow of information through the brain is organized(1). For example,the same visual stimulus may have very different consequences and may leadto very different perceptual and behavioral reactions when occurring indifferent contexts or behavioral states. The brain must somehow manage toroute the right pieces of information to the right places at the right time.In this light, the problem of behavior organization can be seen as essentiallyan information routing problem. It seems unlikelythat there is an "overseer" brain structure that has global control of whatinformation is passed from where to where but it seems more likely theinformation flow is self-organized to a large extent. We are studyingsimple networks of modules which can adapt the information routing betweenmodules on roughly the same time scale as processing within modules takesplace(2). To this end a functional coupling variable is defined between modulesthat is subject to fast dynamics resulting in dynamic information routingthrough the network. The dynamic information routing is driven by a completelydistributed process adapting the functional coupling between modulesbased only on locally available information and is essentiallyHebbian(3) in nature.

We study simple network models with different module topologies withreciprocal connectivity: strictly hierarchical, fully connected, and mixedparallel/hierarchical topologies as found in the primate cortex.We analyze the resulting dynamics using simulations. As a result of the dynamicself-organized information routing, networks can quickly form cliques ofstrongly interacting modules that are relatively isolated from other cliques.These emergent network dynamics bear an interesting resemblance to a numberof phenomena in human and animal perception including sensory integration andsegmentation, attention, rivalry and ambiguity, automaticity ofprocessing, and dual task performance. From the viewpoint of dynamicinformation routing these issues bear interesting similarities, suggestingthat similar neural mechanisms might play a role.We discuss candidate mechanisms for the implementation ofthe dynamic self-organized information routing in the brain and theirbiological plausibility.

(1) E Salinas and TJ Sejnowski (2001), Nature Reviews Neuroscience, vol 2,p 539-550.(2) C vd Malsburg (1981), "The correlation theory of brain function".Internal Report 81-2, Max Planck Institute for Biophyscial Chemistry,Goettingen, Germany.(3) DO Hebb (1949), "The Organization of Behavior", New York: Wiley.

John Trimble - *Howard University*

Coping with Complexity in Knowledge Management

Knowledge management systems have experienced increased complexity due largely to the exponential growth in information technology. The increasedavailability of information and increased communication among stakeholders are central aspects of the formation of complex knowledge managementsystems. These systems are multifaceted and consist of both implicit and explicit components.

Coping with this increased complexity requires effectively dealing with the knowledge acquisition process and the knowledge representationapproaches necessary in transforming individual mental models into computational models and collective conceptual models that form the basis of aneffective knowledge management system.

This project builds on knowledge acquisition techniques and approaches developed in the study of expert systems, systems management and cognitivescience. In particular, it draws on previous work by the authors involving knowledge acquisition in system dynamics, intelligent tutoring systemsand software development projects. Knowledge elicitation, and group techniques are the primary focus since they facilitate the progression fromindividual mental models to collective conceptual and computer based models. The identification of implicit knowledge management components andimplicit knowledge is the most serious challenge to knowledge acquisition processes.

Knowledge representations render complex knowledge repository problems manageable by the appropriate stakeholders. An ontology is the naturalextension of a knowledge representation . It allows a more broadly shared formal conceptualization of a particular domain. Ontologies allow bothcomputer agents to navigate knowledge repositories and humans to confront knowledge management system complexity. A major issue

concerningontology development is _how broad of a domain should the ontology address?_. Different ontological paradigms are examined. They are approached astwo broad categories : 1) compositional and static relationships and 2) dynamic and causal relationships. These two broad categories mirror thestructural and temporal complexity of knowledge management systems. Structural paradigms examined include object oriented languages, semanticnetworks and frames. Dynamic system paradigms include event-based dynamics, process-based dynamics, dialectical change and system dynamics.

The general knowledge management system under study is the University academic system. The particular system under study is academic knowledge atHoward University. This effort is part of a larger project that involves the study of intelligent knowledge engineering and management . Thispaper will report on the application of select knowledge acquisition techniques, within the Systems and Computer science Department at HowardUniversity, to determine the best ontological approaches and artifacts to navigate the complexity of the department_s knowledge management system.

Len Troncale – *Cal Poly University*

Stealth Studies in Complex Systems that Completes Science GE Requirements at Most Universities

Systems science research, and its application to specific domains such as systems biology, is expanding very rapidly. While basicresearch activity occurs at graduate-level centers at major universities, there are increasing commercial applications. The future health of bothendeavors depends, in part, on the existence of a healthy pipeline that feeds and directs pre-college and undergraduate studentsinto these new, unconventional fields. Yet many of the systems education programs of the past three decades failed to survive, even as newprograms were being initiated. What can we learn from the early failures and how can we push awareness of complex systems to earlier grades toensure a healthy feeder pipeline? This presentation will contrast successful and unsuccessful past programs in a search for guidelines, and willcall for the NSF to support comprehensive studies or conferences specifically on the health of and progress in systems education. The presentation will describe a NSF-supported program that will soon be ready for adaptation to other campuses as an extended example. This newprogram essentially is stealthsystems science education for every university. It would allow undergraduates from any major tofulfill the universal science general education requirement by taking a yearlong course centered on systems mechanisms. These processes aresimilar in many natural science phenomena, so are used as Integrative Themes to synthesize and simplify the knowledge base of seven sciences(astronomy, physics, chemistry, geology, computer science, and mathematics). Students are first taught how to recognize a specific systems process(like cycling, duality, hierarchy, chaos, feedback, etc.) in new material, and then are sequentially presented with dozens of case studies in thephysical, biological, and symbolic sciences that illustrate how the process is common to all of these sciences. This approach gives students acommon, repeating framework for the many new terms and relationships for each case study. Students learn considerably greateramounts of science, and learn systems science simultaneously. The exact same processes are then shown in social and technology systems, even inthe arts and humanities. Students leave the course with a feeling of the unity of science, and the utility of science and systems science in theirdaily lives. Course methods are as integrated and interdisciplinary as the pre-integrated material. They use the advantages of a hybrid approachbalancing the technological with the human. Students attend weekly discussion sessions, skill-training sessions, and team-completedinterdisciplinary labs, on the same topics as the multimedia modules. The computer-based courseware has 15 special multimedia aids to learningembedded within it, as well as a dozen special learning aids. The result, shown in nine test offerings of the course on two CSU campuses, isincreased efficacy of learning even for science phobic students. Data will be presented indicating how much the students learn, howwell they learn it, and how they judge the hybrid e-learning/collaborative learning methodology compared to conventional lectures.Perhaps the most important aspect of this example is its potential for widespread dissemination as a Systems Integrated Science text, and as aGeneral Education alternative for

many of our 2,500 universities, including training teachers for a multiplier effect on K-12. Such stealthstudies in systems science could contribute significantly to the long-term health of the complex systems worker pipeline.

An Open Source Computer-Based Tool for Research and Education in the Systems Sciences

XML-Java has been used effectively by several different communities of scholars to improve their communication, speed introduction of new workersto the field, and as a mechanism to spread the use of standards, or its opposite, the juxtaposition of alternative schools ofthought to enable faster development. A well-developed example of XML serving these functions is the building and use of CHML for the fieldof chemistry. This special interest workshop will call together anyone at ICCS02 interested in initiating an;open-source programming effort using XML-Java to build a similar tool for the systems sciences or sciences of complexity. We would call this new commons database SYSML, an enhancement tool about systems science and systems scientists, built by systems scientists, for systemsscience advancement. The field of systems studies has a fairly long, but unusually disconnected history. Personalities are overtly and overly dominant in such periodsof early development, sometimes to the detriment of the field. Many promising new avenues of approach have appeared, many new conference series,new book series, new journals, and many new application domains. But these tend to compete rather than complement and inform each other. The mostdominant feature of such historical and recent developments is incredible diversity. Strategies of approach range from basic theoretical research,to work on methodological tools, to work in the natural sciences, to applications in every conceivable domain of the social sciences, to evenvirtual worlds. What holds such a diverse field together? How can these domains be linked to and inform each other? SYSML would be one approach tohelp different schools of thought to learn about and integrate with each other, rather than compete and promote unintentional fragmentation of thefield. Graphics developed in the NSF-ISGE project will be used to provide a metaphor of the integration that is needed. SYSML would focus onincorporating standards for and hotlinks to presentations of very comprehensive, and interconnected lists of topics such as: Types of Systems,Alternative Taxonomies of Systems, Systems Research Workers, Systems Research Institutions, Systems Journals, Systems Book Series, Key FutureQuestions, Systems Conference Series, Consensus Systems Mechanisms/Processes, their Identifying Features, Identifying Functions, Discinyms,Transdisciplinary Testing and Verification, Examples and Exemplars, and any others this self-appointed team of SYSML builders can brainstorm intoexistence. We would expect thorough debate and discussion to occur during this planning session on whether such a tool would be useful or damagingto the development of the field, and how it can be kept as neutral as possible, and as useful as possible for both experienced workers and novicessimultaneously.

Ing-Jyh Tsang - *Alcatel Bell N.V.*

Diversity, Cluster Entropy and Complexity on Randomly Occupied Lattices. I.R. Tsang and I.J. Tsang

Diversity is an important characteristic of nature and have been used to describe the complexity of different systems. The term ``complexity'' hasbeen associated with the diversity in the length scales that the clusterscan assume in the randomly occupied lattices model [1]. Moreover, diversitycan refer to different properties of the system, such as the size orconfiguration assumed by the clusters. Thus, ``cluster diversity'' isdefined as the differentiation of clusters in respect to their size orLattice Animals (LA). Entropy is a fundamental concept in physics. It is related with theinformation content and order/disorder of a system. Here, we consider``cluster entropy'', which is defined using the probability that an occupiedsite belongs to a cluster of size s, or being part of a specific free orfixed LA [2]. This definition can be associated to the information entropyand the configurational or local porosity entropy defined in [3]. However,these entropies are based on the information content of a sliding m X msquare region, thus being basically a local or short-

range measurement.Conversely, our definition of entropy depends on the structure of theclusters, which are not limited to a local region and are capable ofspanning over the whole lattice. We analyse the cluster diversity and cluster entropy of the system, whichleads to the determination of probabilities associated with the maximum ofthese functions. We show that these critical probabilities are associatedwith the percolation transition and to the complexity of the system.

[1] I. R. Tsang and I. J. Tsang, Phys. Rev. E 60, 2684 (1999). I. R. Tsang and I. J. Tsang, J. Phys. A: Math. Gen. 30, L239(1997). I.J. Tsang and I.R. Tsang. Unifying Themes in Complex Systems: Proc. of the First NESCI Inter. Conf. on Complex Systems edited by Yaneer Bar-Yam (Perseus Book, Reading, MA, 1999)
[2] I.J. Tsang, I.R. Tsang and D. Van Dyck, Phys. Rev. E 62, 6004 (2000).
[3] C. D. Van Siclen,Phys. Rev. E 56, 5211 (1997); F. Borger, J. Feder, T. Jossang and R. Hilfer, Physica A 187, 55 (1992); C. Andraud, A. Beghdadi and J. Lafait, ibid. 207, 208 (1994); C. Andraud, A. Beghdadi, E. Haslund, R. Hilfer, J. Lafait and B. Virgin ibid. 235, 307 (1997).

Jiri Vanicek - *Harvard University*

Replacement Manifolds: A Method to Uniformize Semiclassical Wavefunctions. Jiri Vanicek and Eric J. Heller

We present a new semiclassical technique which relies on replacingcomplicated classical manifold structure with simpler manifolds, which arethen evaluated by the usual semiclassical rules. Under circumstances wherethe original manifold structure gives poor or useless resultssemiclassically the replacement manifolds can yield remarkable accuracy. We show how the method can be used to uniformize cusp singularities in amodel of a 2D electron flow if complex replacement manifolds are takeninto account.

Gregory J. Velicer - *Max-Planck Institute for Developmental Biology*

Altruism and Social Conflict in the Bacterium Myxococcus Xanthus

The myxobacteria are a group of primarily soil-dwelling bacteria that exhibit social migration, multicellular development of fruiting structures, and social predation on other microbes. Upon starvation, local populations of Myxococcus xanthus aggregate and initiate a cascade of intercellular communication that guides fruiting body development and sporulation. During this social developmental process, a minority transforms into stress-resistant spores, while a majority of each aggregated population appears to perish, and thus appears to exhibit a dramatic instance of altruism at the level of individual microorganisms. Some laboratory-generated genotypes that are defective at development in isolation are able to cheat on a developmentally-proficient wild-type in mixed populations during development, thus showing exploitation of a complex cooperative system at the genetic, as well as individual, level. When rare, these cheaters produce spores more efficiently than the wild-type during development of mixed populations, despite being much poorer than the wild-type during development in separate, isogenic populations. When allowed to compete with the wild-type over several cycles of development and growth, distinct cheater genotypes show a variety of competitive fates and effects on total population dynamics. The ease of generating cheater genotypes in the laboratory (via both experimental evolution and genetic manipulation) raises questions about the prevalence of cheating in natural populations and the selective forces, population structures, and potential policing mechanisms that act to maintain altruistic genotypes in the wild.

Burton Voorhees - *Athabasca University*

Virtual Stability as a Conceptual Principle Underlying the Directionality of Evolutionary Processes

A system will be said to be virtually stable when it is employing self-monitoring in order to maintain itself in a state that would otherwise be unstable. Since such operation requires energy expenditure, there must be a corresponding benefit that justifies this expenditure. This benefit is greater flexibility in response to environmental perturbations. At a minimum, the capacity for vitural stabilityrequires that a system be able to monitor its states with a frequency great enough that only small corrections are necessary to maintain itself in the virtually stable state. In essence, an ongoing small energy expenditure is used in order to avoid the need for occasional major energy expenditures, and an ongoing high frequency of self-monitoring purchases the capacity for more rapid episodic reactions to environmental changes. This provides an evolutionary advantage favoring organisms with sensory and motor systems capable of maintaining virtually stable states. In this paper we providea number of examples of various aspects of vitural stability, and based on these carry out an analysis of the concept as it relates to other general evolutionary principles, including requsite variety, edge-of-chaos, and the distinction made by Crutchfield and his collaborators between fittness barriers and entropy barriers.

Michael J. Wade - *Indiana University*

Gene Interactions

The genetic architecture of a phenotype consists of the genes, the interactions among them (epistasis), and the interactions among genes and environments (G x E) that affect the phenotype's expression. For a phenotype with a 'complex' genetic architecture, epistasis and G x E play significant roles as opposed to a phenotype with a 'simple' architecture, in which interactions of any sort are relatively unimportant. Epistasis contributes to inbreeding depression, developmental homeostasis, plasticity, evolution of sex and recombination, mating system evolution, speciation, and interdemic selection, because all of these topics involve phenotypes with a complex genetic architecture. For example, in speciation, epistasis contributes to reproductive isolation because genes that function well in the genetic background of conspecifics function poorly in the genetic background of inter-specific hybrids, decreasing their fertility and viability. Such a change in the sign of a gene's effect from positive to negative can only be caused by interactions with other genes or with the environment. In metapopulations with migration, interactions function like constraints in that they limit the rate of adaptive evolution. When migration is halted, however, the constraint is removed and the rate of adaptive evolution is accelerated. Thus, interactions are extremely important to the origin of biodiversity.

David Wallace - *MIT*

Integrated Simulation as a Tool for Collaborative design

Myles Walton - *MIT*

Managing Uncertainty in Space Systems Conceptual Design Using Portfolio Theory

Keith Warren - *Ohio State University*

The Sum of the Parts: Two Studies of Interpersonal Influence on Aggressive Behaviors in Small Group Settings. Keith Warren, Elena Irwin, Brian Roe, William Sean Newsome

Economists and other social scientists have recently shown considerable interest in interactions-based models that address the question of how often and when an individual's choices depend on those of peers (Brock & Durlauf, 2000; Manski, 1995). Most of these studies have focused on neighborhoods and schools as the units of analysis, in an attempt to understand interactions among large numbers of individuals. However, most social interventions occur in classrooms, small groups or dyads, and there is a need to model interactions in these smaller-scale settings.

This paper describes studies that attempt to model the effect of interpersonal interactions on aggressive behavior in two different settings, the first a sample of elementary school classrooms and the second a group home for developmentally disabled adults. In each case we argue that the value of aggressive behavior will depend on whether others are behaving aggressively; aggression will, therefore, tend to breed aggression.

In the first study, we employ a logistic regression model and find that the average level of aggression in elementary school classrooms, measured by the teacher, is positively correlated with clinically significant levels of aggression in individual children, measured by their parents, both concurrently and at one and two year follow-up. This correlation remains statistically significant when controlling for family and neighborhood poverty, family conflict, gender, academic achievement and level of aggression in the previous time period. This suggests that early classroom-based interventions might have a lasting effect on aggressive behaviors in children.

In the second study, we use multivariate nonlinear time series analysis to study the interactions of two individuals, one male and one female, living together in a group home. We find evidence of correlated volatility in their aggressive behaviors. In this case, the volatility of the female resident's behavior is negatively correlated with that of the male resident on the next time lag. The volatility of the male resident's behavior is positively correlated with that of the female resident. This mix of positive and negative correlation implies that staff interventions can have unexpected iatrogenic effects at times of resident behavioral volatility.

This presentation has methodological as well as substantive implications. It emphasizes the critical importance of choosing the correct unit of analysis, whether it is neighborhood, classroom, or peer group, if we wish to find evidence of interpersonal interactions. Further, some types of interactions, such as correlated volatility between individuals, may only be possible to document in a nonlinear time series framework.

Brock, W. & Durlauf, S. (2000). Interactions-based models. In Heckman, J. & Leamer, E. (eds) Handbook of Econometrics, 5th Edition. Amsterdam: North Holland.

Manski, C. (1995). Identification Problems in the Social Sciences. Cambridge, MA: Harvard University Press.

Richard A. Watson - *Brandeis University*

Compositional Evolution: Evolvability, Modularity, and Symbiosis

Certain kinds of complex systems, considered unevolvable under normal accretive change, are, in principle and under certain circumstances, easily evolvable under compositional change. We use the term ‘compositional’ to refer to mechanisms that combine together systems or subsystems of genetic material that have been semi-independently pre-adapted in different lineages. Examplesinclude: sexual recombination (in subdivided populations), naturalhybridization, horizontal gene transfer, and endosymbiosis. In contrast, we use the term ‘accretive’ to refer to variation mechanisms that accumulate random variations in genetic material, (i.e. the new genetic material introduced by such changes has not been pre-adapted elsewhere as a set). Thus accretive evolution is driven predominantly by ‘successive slight modifications’, and underlies our common understanding of evolutionary change and evolutionary difficulty. Examples include: genetic mutation, and sexual recombination (inpanmictic populations).We provide two highly abstract computational models to illustrate a sufficient set of mechanisms and conditions for compositional change. The first is based on sexual recombination; the second is based on hierarchical encapsulation of symbiotic groups

inspired by serial endosymbiosis and the major evolutionary transitions. We discuss the likelihood of evolving particular kinds of complex adaptations under compositional and accretive mechanisms. In particular, we define a class of adaptive landscape, arising from a highly epistatic butmodular substructure, which typifies characteristics that are difficult for accretive evolution yet easy for compositional mechanisms. Specifically, this landscape is highly rugged, has many local optima with broad fitness saddles, and it includes complex adaptations that appear irreducibly complex, and cannot be reached by paths of small changes with monotonically increasing fitness. Nonetheless, we show that, under particular conditions, complex adaptations of this kind are easily evolvable under compositional mechanisms. Our results emphasize the importance of understanding the qualitative structure of an adaptive landscape and that certain mechanisms in some circumstances cannot be appropriately characterized as merely a different source of accretive change.

Allen Waxman - *Boston University*

ARTMAP Learning for Multisensor Fused Image Mining

We have developed methods for fused visualization and interactive data mining of multisensor and multispectral imagery, based on neural network models of visual processing, learning and recognition. These methods have now been integrated into a commercial image exploitation environment widely used by the defense and intelligence communities. This presentation
will quickly review the visual processing methods for image fusion (center-surround shunting dynamics, opponent-color processing, boundary contour and texture processing) and then focus on the rapid interactive data mining based on Adaptive Resonance Theory (Fuzzy ARTMAP) in the
fast-learning limit, and its extension to include discovery of subspace projections from high-dimensional feature space. If time permits, a laptop demo will be given of interactive training of search agents to mine for targets in fused imagery embedded in 20 and 200 dimensional feature space.

Arthur G. Werschulz - *Fordham University / Columbia University*

An Overview of Information-Based Complexity

Computational complexity has two goals: finding the inherent cost of some problem, and finding optimal algorithms for solving this problem. Information-based complexity (IBC) studies the complexity of problems for which the available information is partial, contaminated by error, and priced. Examples of such problems include integration, approximation, ordinary and partial differential equations, integral equations, and the solution of nonlinear problems such as root-finding and optimization. In this talk, we give a brief overview of IBC. We focus mainly on the integration problem (which is a simple, yet important, problem that can be used to illustrate the main ideas of IBC) and the approximation problem (which will be of most interest to specialists in learning theory). One important issue that we discuss is the "curse of dimension"---the depressing fact that the worst case complexity of many problems depends exponentially on dimension, rendering them intractable. We explore IBC-based techniques for vanquishing the curse of dimension, finding (for example) that randomization beats intractability for the integration problem but not for the approximation problem, but that both these problems are tractable in the average case setting under a Wiener sheet measure.

Thomas J Wheeler - *University of Maine*

Interdisciplinary Conceptual Model Blending. Thomas J Wheeler and Mary Dolan

It is becomming common that research and system's development effortsare being undertaken by multidisciplinary teams, for several reasons. The first is that insights from several points of view provide a richer understanding of issues and more opportunities for problem solutions. The second is related; often, an insight in one disciplinecomes from a thought pattern from another discipline. Third, in many disciplines the research in parts of the domain has reached the stage where exploring issues and advances in adjoining parts and in the interaction of parts is warrented. Lastly, a special case of this comes from the hierarchical nature of systems, especially life, wherein research at individual levels is different in kind from research at others and integration across levels has become possible and desirable.

While this presents a marvelous opportunity, there are serious problems. In multidisciplinary research, merging of the disciplines' conceptualizations must occur, at least in the (separate)minds of the collaborators, but also in the resulting or supporting systems.

Increasing use of computer databases for organizing research and its results leads to data integrations problems for multidisciplinary research/systems. Each database is designed independently, in accordance with a domain's conceptual model specialized to a particular research effort, then encoded using general purpose data models. Because of the independence of development, the differing cultures of the fields, and other reasons, incompatibilities occur at interfaces between models and systems. Because of the general purpose nature of the data models, domain insight and intuition, which is clear in each domain's natural illustrations and explanations of its key models, is lost.This paper explores a mechanism and a methodology for integration of separate discipline's models, based on distilling the inherent structure of each model and blending them to create the structure for the integrated domain. It delineates a number of incompatibility dimensions, and addresses integration issues at the terminology, semantics, pragmatic and activity levels.The approach has four aspects. The first consists of integrating the "natural" graphic depictions and explanations each discipline makes of its core concepts, with the general purpose models of their systems. The second extracts the underlying structure of the natural models based on analysis of the metaphorical underpinnings of those models. The third creates a blend of the models' structures, using the character of one to underlie the semantics composed from elements of other models mapped onto slots of the core model. The fourth creates a framework for visualization of the blended domain by creating natural depictions and explanations of the blended domain, from the blended structure and its underlying metaphors. This technique provides a framework for understanding, organizing and supporting interdisciplinary work, while improving the conceptual modeling process by integrating more domain insight into the modeling process. We will illustrate the mechanisms and the methodology with cases from interdisciplinary projects in molecular biology and ecology.

Elin Whitney-Smith - *George Washington Univ*

Extinctions and the Evolution of Ecosystems: Systems Dynamics and the end of the Pleistocene

At the end of the Pleistocene, there were significant climate changes and, following the appearance of Homo Sapiens on each major continent, significant megafaunal extinctions.

The leading extinction theories, climate change and overkill, are inadequate. Neither explains why: (1) browsers, mixed feeders and non-ruminant grazer species suffered most, while ruminant grazers generally survived, (2) many surviving mammal species were sharply diminished in size; and (3) vegetative environments shifted from plaid to striped (Guthrie, 1980.)

Nor do climate change theories explain why mammoths and other megaherbivores survived changes of similar magnitude. Although flawed, the simple overkill hypothesis does link the extinctions and the arrival of H. sapiens. Mosimann & Martin(1975) and Whittington & Dyke(1984) quantitatively model the impact of H. Sapiens hunting on prey. However, they omit the reciprocal impact of prey decline on H. Sapiens; standard predator-prey models, which include this effect, demonstrate that predators cannot hunt their prey to extinction without themselves succumbing to starvation.I propose the Second-Order Predation Hypothesis , a

boom/bust scenario: upon entering the New World, H. sapiens reduced predator populations, generating a megaherbivore boom, then over-consumption of trees and grass, and, finally, environmental exhaustion and the extinctions.

The systems dynamic model developed in this work (available from http://quaternary.net/extinct2000/) specifies interrelationships between high and low quality grass, small and large trees, browsers, mixed feeders, ruminant grazers and non-ruminant grazers, carnivores, and H. sapiens driven by three inputs: H. sapiens in-migration, H. sapiens predator kill rates, and H. sapiens food requirements It permits comparison of the two hypotheses, through the setting of H. sapiens predator kill rates. For low levels of the inputs, no extinctions occur. For certain reasonable values of the inputs, model behavior consistent with Second-Order-Predation: carnivore killing generates herbivore overpopulation, then habitat destruction, and ultimately differential extinction of herbivores. Without predator killing, extinctions occur only at unreasonable levels of in-migration. Thus, Second-Order-Predation appears to provide a better explanation.

Further, the boom-bust cycles suggest we over-interpret the fossil record when we infer that the populations decreased steadily, monotonically to extinction.

Robert L. Wiebe - *Boeing; Air Traffic Mangement*

Questions from Complexity Science to develop new perspectives on Air Traffic Management

The Air Traffic Management system has manylevels of Complexity within any national airspace, and becomes even more complex as harmonization of worldwide ATM services is considered for aglobal ATM system. Questions will be asked such as, can delay be used as a measure of complexity for ATM, is delay an emergent property of thesystem, are there a few persistent patterns among world airports that can be used to simplify airspace design, are there sets of minimal rulesthat define behavior (e.g. the manner in which aircraft are "collected" prior to approach), and can self-organization be a part of an ATM system.

The intent is to present some information that has been collected about the U.S. ATM system, address these questions with my thoughts, and thenhear from the participants about their thoughts and answers to those same questions.

Janet Wiles - *The University of Queensland*

Evolving Complex Integrated Behaviour by Masking and Unmasking Selection Pressures.

Janet Wiles, James Watson, Bradley Tonkes and Terrence Deacon

The evolution of vitamin C dependency in humans has an interestingevolutionary history. Many animals have the ability to endogenouslysynthesize ascorbic acid (vitamin C). The crucial gene in this synthetic pathway is for an enzyme (LGO) that catalyses the last stage of synthesis of vitamin C. Anthropoid primates (monkeys, apes, and humans) don't synthesize their own vitamin C, and the question that arises is why not, when it seems so useful. It turns out that primates including humans do indeed have the wasted hulk of such a gene that is no longer expressed and has accumulated irreparable mutational damage (it is now a "pseudogene" and was identified by Japanese researchers in 1994 using a probe gene from rat). The loss appears to have happened about 40 Mya, which is the time that some primates became diurnal, with consequent changes in lifestyle, including a diet including significant amounts of fruit. A neat just-so-story is that the increased fruit in the animals' diets provided ample regularly available vitamin C, reducing the selection pressure to maintain the function of the vitamin C producing gene. Once the gene was corrupted in this lineage, the animals were effectively addicted to fruit, and trapped in the fruit-eating lifestyle: obligate frugivores. At this point, all the abilities that had incidentally supported the acquisition of Vitamin C through diet were then placed under a much stronger selection pressure, causing many to evolve in such a way as to better insure the ubiquitous availability of this now essential nutrient. In recent work, Deacon hypothesized that this kind of secondarily distributed selection pressure is a major force in evolution, integrating what were

initially a diverse set of potentially unrelated skills (e.g. colour vision, tooth structure, taste preferences, etc. in this case) into a metastable multilocus multiphenotype adaptive complex.

This distributed selection pressure acts as a "reverse Baldwin effect" in that abilities specified directly in the genome may become masked by both internal and external sources, including flexible behavioral abilities, and over time their genetic specification is lost (a complexity catastrophe in Kauffman's terms). When this occurs, the individual becomes dependent on the external source or whatever else has provided the masking effect, and any phenotypic capacities that support this masking (e.g. by providing an externally redundant nutrient) become increasingly elaborated and integrated through positive selection pressure. Deacon's terms are "masking" and "unmasking" of selection, to describe these two effects, respectively--the former related to the Baldwin effect in reverse, the latter to Waddington's "genetic assimilation"—and "redistribution" of the substrate of adaptation, to describe the result.

We extended Hinton and Nowlan's (1986) simulation of the Baldwin effect to explore how masking and unmasking can transfer dependence from one gene to many and thereby integrate whole complexes of genes. Hinton and Nowlan used a chromosome of 20 genes to simulate a needle in a haystack task, such that the individual received a payoff only when all alleles were set to '1'. The analogy in the above scenario is that setting all alleles to '1' corresponds to the ability (a0) to endogenously synthesize vitamin C. Their model was extended by adding k additional gene complexes (a1, a2, ak), each assumed to code for other abilities based on the coordinated action of 20 genes (totalling 20k genes in the chromosome). The k other abilities each benefit the individual, but individually, their benefits are significantly less than that from the first ability. However, together, the k abilities duplicate the function of the first ability. The time course of the simulations demonstrate the initial advantage of the endogenously synthesized vitamin C, followed by a transfer of the ability to the complex of genes that mask the effect.

The Baldwin effect has been hypothesized as a potential mechanism for developing language-specific adaptations like innate Universal grammar or an innate modular "language faculty" or in fact any other highly modular capacities. These simulations support Deacon's argument that the process is likely the inverse, and that the extensive neural and other anatomical consequences would not be in the form of specific innate adaptations that make the acquisition process more innate. Instead, the power of symbolic communication as a masking agent should unmask selection on an extensive and highly distributed constellation of capacities that would collectively come under selection for their fractional contributions to the acquisition and use of language.

Kwang Woo Park - *Claremont Graduate University*

Income Distribution Dynamics: Marriage and Informational Cascades

This paper investigates the role of household formation on income distribution dynamics. This is accomplished by building an age-structured general equilibrium model in which agents are endowed with physical and psychological attributes that affect marriage and fertility decisions. Personal characteristics are transmitted from parents to children resulting in intergenerational persistence of marriage patterns and household income. Further, psychological factors allow fads and fashions to impact distributional dynamics. After calibrating the model, the dynamics of several variants of the model are simulated and tested against the data. We find that psychological factors affecting marriage explain a substantial proportion of income distribution dynamics.

Hajime Yamauchi - *U of Edinburgh*

Evolution of Language Universals under Baldwinian Niche Construction

While considerable superficial differences exist among human languages, it has been noticed for long time that a non-trivial level of commonality exists in human languages. The generative grammar led by Noam

Chomsky has attributed such structural (i.e. grammatical) universals to a special innate specification of language learning. More precisely, it assumes that all human infants come into the world with a linguistic prespecification of the form of possible human grammars. Together with the ìLanguage Acquisition Device,î which refers to childís strategy for acquiring a grammar, children are capable of learning any existing languages regardless of their ethical groups and birthplaces (i.e. UG). Under the theory, the existence of language universals is somewhat truism as UG encompasses possible human languages. This is the major difference from other quantitative research (e.g. Greenberg 1966). The elegance of this theory is not only it provides an unconventional view of language univers

Recently, it becomes increasingly popular that evolution of UG is explained by a Baldwinian process (Pinker & Bloom 1990, Turkel 1996, Dor & Jablonka 2001). However, it is often the case that in such studies, explanation of the precise mechanism of the Baldwin effect is often compromised. Based on the study of Yamauchi (2000), in this paper I argue that evolution of UG is aided not by the conventional Baldwin effect (e.g. Waddington 1975, Hinton and Nowlan 1987), but a new type of the Baldwin effect (Deacon 1997, Godfrey-Smith 2001). Under this type of the Baldwin effect, a population produces its own linguistic niche. Such a niche is defined only by internally (i.e. external environmental pressure is minimum), and is constructed by agentsí co-operative activity. This co-operative activity is characteristic to language evolution as keeping ìparityî among agentsí individual communication systems is a crucial factor of adaptation. As a new niche is constructed, initially not adaptive gen

Yuri Yegorov - *Central European University*

The Transitions in Industry, Research and Society: Dynamic Equilibrium Approach

Evolution of industry, science and society exhibit periods of slow development followed by fast revolutionary changes. The paper is an attempt to model this complex dynamics using the principle of aggregation of individual optimizing behaviour. Since the subject area represents a mix of equilibrium and evolution, it calls for new mathematical tools for its modeling. A framework of competition of two nonconvex technologies (IRS-DRS type) born in different periods allows for possibility to have periods of their peaceful coexistence with periods of rapid shifts (cascades). A continuum of overlapping generations allows for external force, which drives temporary equilibrium away if there is an asymmetry in technologies. The model is formally written for the shift of labor across two sectors. Its results may be also applied for modeling scientific and ideological revolutions in society. The emergence of new superior scientific branch may have difficulties in its initial period, caused by impossibilities to cooperate and possibility to block the superior path by the coalition in the old school. The equilibrium demand for teaching particular science is also derived: it has endogeneous form of the integral equation.

Igor Yevin - *International Association of Empirical Aesthetics*

Criticality of the Brain and Criticality of the Art

Theory of complex system revealed that brain is acting close to instability point and therefore our brain can respond to any small perturbation, whether intrinsic or extrinsic. This paper aims to show that art as a complex system also operates near critical point. Using different notions of instability, borrowed from natural sciences, it will be shown that great many artworks, including well-known masterpieces, exist near unstable points. For instance, balance - the most important principle of compositional design in painting, sculpture, and architecture - means creation of unstable states. The presence of long-range correlations in human writing, painting, and music also indicate that appropriate works of art are at critical points. Synaesthesia as "intersensory association"(colored hearing synesthesia is association musical tonalities and colors) could be explained as an ability of input acoustic signals to access visual part of the brain. It is easy to show that amount of Shannon information processing between the artwork and the brain riches a maximum

magnitude when both the art and the brain are at critical states. The relationship between "arousal potential" of artworks and "hedonic value" well known as the Wundt curve (which looks like inverse U) is explained using Ginzburg-Landau theory of phase transition. The "arousal potential" in this model is the order parameter and "hedonic value" plays the role of control parameter. The main conclusion of this paper: the art might be treated as a tool for supporting human brain near criticality.

Yi Zhou - *NYU*

Detecting and Modeling Long Range Correlation in Genomic Sequences. Yi Zhou, Archisman Rudra, Salvatore Paxia and Bud Mishra

A genome encodes information that is needed to create complex machineries combining DNA, RNA and proteins. However, this structure has evolved by certain basic biological processes that modify the genome in a specific but stochastic manner, and has been shaped by selection pressure.

With complete sequences of many genomes available, it is now possible to question whether all such genome evolution processes are adequately understood. In particular, we measure the long-range correlation (LRC) of DNA sequences in the hope of distinguishing between different models of DNA evolution.

In order to study DNA sequence LRC, we view the DNA sequences as being generated from a random walk model. We map a whole genomic sequence using a purine-pyrimidine binary rule. This creates a `DNA walk' along the genome. The degree of LRC in the sequence is characterized by the Hurst exponent (H), which can be estimated using various methods. (For infinite length: H=0.5, no LRC; H>0.5, positive LRC; H<0.5, negative LRC.)

We have analyzed various genomes using VALIS: bacteria, invertebrate and vertebrate. We observe a consistently higher H value in the non-coding regions compared to the coding regions. Thus, the DNA walks down the non-coding region sequences possess stronger positive LRC than those in the coding regions. In addition, the H values in different regions increase with the evolutionary positions of the corresponding organisms. This suggests that some cellular events tend to make DNA sequences more positively correlated as evolution proceeds.

Based on our observations, we hypothesize that the differences in the strengths of LRC in DNA sequences are caused by a spectrum of events affecting DNA evolution. Those include DNA polymerase stuttering, transposons and recombination, which tend to add deletions and insertions, and natural selection and DNA repair mechanisms, which try to eliminate the changes in the sequences. The differences in the distribution of such spectrum in coding and non-coding regions and in different organisms cause the differences in the degree of LRC in DNA sequences.

The hypothesis can be tested *'in silico'* using Polya's Urn model. In our model, each basic DNA sequence change is modeled using several probability distribution functions. The functions can decide the insertion/deletion positions of the DNA fragments, the copy number of the inserted fragments and the sequence of the inserted/deleted pieces. Moreover, those functions can be interdependent. The combination of those basic DNA sequence changes can represent most of the natural DNA evolution events: deletion, insertion, point mutation, tandem repeats, transposition, etc.

Our analysis and simulation were carried out on two novel computational tools: VALIS, a bioinformatics environment for genome analysis and `Genome Grammar', a system for simulating genome evolution. Our `Genome Grammar' can handle stochastic grammars and primitives for many kinds of mathematical probability distributions. It allows one to apply hypothesized processes on sequences from different sources. In particular, it enables us to conduct our experiments on DNA evolution based on Polya's Urn model. Finally, the '*in silico*' experimental results can be verified '*in vivo*' using microbial mutants in the corresponding cellular processes.

Michal Zochowski - *University of Michigan*

Optical Imaging of Spatio-Temporal Properties of Odor Evoked Oscillations in the Turtle Olfactory Bulb. Michal Zochowski LB Cohen

We made voltage-sensitive dye measurements of the response to several odorants in an in vivo turtle preparation, using the styryl dye (RH414) and a 464-element photo-diode array (NeuroPlex) to measure optical signals from the bulb.

Four different population signals were detected to odorant stimuli: a slow depolarization and three oscillations (rostral, middle and caudal). The oscillations had different spatio-temporal properties - location, frequency and latency.

We also applied multiple odorant presentations with different inter-stimulus intervals, odorant concentrations and odorant combinations. Two of oscillatory responses change their character dramatically if the second odorant pulse is applied within 1-20 sec. The rostral oscillation either does not appear or is much smaller in the response to the second pulse. The caudal oscillation on the other hand, may be partially suppressed and/or not undergo its period doubling, exhibiting often only a fast 14 Hz frequency. The changes in middle oscillation depend on the history of odor presentation. If the same odor is presented on the following odorant pulses as on the first one the middle oscillation is significantly enhanced. On the other hand if the odorant is different on the following odorant presentations than on the first one this oscillation is reduced or doesn't appear at all. These changes in the olfactory bulb responses do not correlate with the changes of magnitude of receptor cell signal, measured by monitoring calcium concentration in the synapses of the receptor neurons.

New England Complex Systems Institute
24 Mt Auburn St., Cambridge MA 02138

Conference Participant
International Conference on Complex Systems

June 9. 2002

Dear Conference Participant,

The New England Complex Systems Institute (NECSI) is an independent research and educational institution dedicated to advancing the study of Complex Systems. By developing and coordinating interdisciplinary and interinstitutional research and educational programs, NECSI is building local, national, and international communities to promote the application of Complex Systems concepts and methodologies.

Information about NECSI's programs and activities can be found at our web site http://necsi.org.

As a member of the NECSI community we welcome your involvement and contributions in furthering existing activities and developing new ones. We feel that there is a great opportunity for us to make important contributions to the advancement of our understanding of the world and to the goals of society.

Yours truly,

Yaneer Bar-Yam

International Conference on Complex Systems

Subject Areas: Unifying Themes in Complex Systems

Sessions will be structured around both themes and systems.

The Themes Are:

EMERGENCE, STRUCTURE AND FUNCTION: substructure, the relationship of component to collective behavior, the relationship of internal structure to external influence, multiscale structure and dynamics.

INFORMATICS: structuring, storing, accessing, and distributing information describing complex systems.

COMPLEXITY: characterizing the amount of information necessary to describe complex systems, and the dynamics of this information.

DYNAMICS: time series analysis and prediction, chaos, temporal correlations, the time scale of dynamic processes.

SELF-ORGANIZATION: pattern formation, evolution, development and adaptation.

The System Categories Are:

FUNDAMENTALS, PHYSICAL & CHEMICAL SYSTEMS: spatio-temporal patterns and chaos, fractals, dynamic scaling, non-equilibrium processes, hydrodynamics, glasses, non-linear chemical dynamics, complex fluids, molecular self-organization, information and computation in physical systems.

BIO-MOLECULAR & CELLULAR SYSTEMS: protein and DNA folding, bio-molecular informatics, membranes, cellular response and communication, genetic regulation, gene-cytoplasm interactions, development, cellular differentiation, primitive multicellular organisms, the immune system.

PHYSIOLOGICAL SYSTEMS: nervous system, neuro-muscular control, neural network models of brain, cognition, psychofunction, pattern recognition, man-machine interactions.

ORGANISMS AND POPULATIONS: population biology, ecosystems, ecology

HUMAN SOCIAL AND ECONOMIC SYSTEMS: corporate and social structures, markets, the global economy, the Internet

ENGINEERED SYSTEMS: product and product manufacturing, nano-technology, modified and hybrid biological organisms, computer based interactive systems, agents, artificial life, artificial intelligence, and robots.

Founding Organizing Committee

Philip W. Anderson - Princeton University
Kenneth J. Arrow - Stanford University
Michel Baranger - MIT
Per Bak - Niels Bohr Institute
Charles H. Bennett - IBM
William A. Brock - University of Wisconsin
Charles R. Cantor - Boston University
Noam A. Chomsky - MIT
Leon Cooper - Brown University
Daniel Dennett - Tufts University
Irving Epstein - Brandeis University
Michael S. Gazzaniga - Dartmouth College
William Gelbart - Harvard University
Murray Gell-Mann - CalTech / Santa Fe Institute
Pierre-Gilles de Gennes - ESPCI
Stephen Grossberg - Boston University
Michael Hammer - Hammer & Co
John Holland - University of Michigan
John Hopfield - Princeton University
Jerome Kagan - Harvard University
Stuart A. Kauffman - Santa Fe Institute
Chris Langton - Santa Fe Institute
Roger Lewin - Harvard University
Richard C. Lewontin - Harvard University
Albert J. Libchaber - Rockefeller University
Seth Lloyd - MIT
Andrew W. Lo - MIT
Daniel W. McShea - Duke University
Marvin Minsky - MIT
Harold J. Morowitz - George Mason University
Alan Perelson - Los Alamos National Lab
Claudio Rebbi - Boston Unversity
Herbert A. Simon - Carnegie-Mellon University
Temple F. Smith - Boston University
H. Eugene Stanley - Boston University
John Sterman - MIT
James H. Stock - Harvard University
Gerald J. Sussman - MIT
Edward O. Wilson - Harvard University
Shuguang Zhang - MIT