Big Data meets big theory at annual symposium

As our abilities to acquire, store, and analyze mountains of data have grown in recent years, so too have questions about Big Data’s true abilities and limits. Proponents tout Big Data as a means to improve the quality of almost any process we can measure. But data alone, without accompanying theory, may not lead to the best questions and hence may not be generating the best answers.

SFI’s annual Business Network and Board of Trustees Symposium will explore both the promise and the limits of Big Data, as well as the value of theory in the Big Data context.

“The fundamental hope of Big Data proponents is that it can provide a tool to help them substantially answer their questions,” says Symposium organizer, neuroscientist, and SFI Business Network Director Chris Wood. “But perhaps the biggest misconception is that we can answer all our scientific, business, government, or political questions if we only have the right data.”

Often the true usefulness of Big Data is uncertain, Wood points out. Social scientists are now using data from social networks such as Twitter and Facebook to make inferences about social interactions in general. Whether or not the conclusions from online network data generalize to other forms of interaction is an important empirical question, he says, but that question cannot be answered from the online data alone.

Sometimes Big Data can be the right resource. Symposium speaker Dan Wagner’s analytics during the 2012 Obama campaign used a variety of commercial and political data to identify those voters likely to favor Obama’s messages, then helped find ways to reach them electronically or face-to-face. The strategy contrasts markedly with more traditional “voting bloc” techniques.

Problems with the digital economy – particularly people’s willingness to give away data to improve their user experience or even crime reduction – might be answered from the online data alone. In any case, it is essential to question and test assumptions about Big Data and its applications, Wood says. A familiar example is the use of search histories to target online advertising. Are all search terms equally valuable to advertisers? Such questions are part of the “arms race” between companies providing online services and seeking to deliver the best “eyes” to their advertisers.

The invitation-only Symposium runs October 31-November 2 in Santa Fe.

Workshop: How far can Big Data about cities really take us?

Big Data’s potential to provide a quantitative basis for addressing familiar urban problems has prompted several universities and corporations to launch programs dedicated to urban informatics and policy. But the use of extensive data in urban management is not new, which poses questions about what specific qualitative leaps are achievable in the near future, and what data those advances require.

For a few days in September, urban researchers, city planners, and representatives from international organizations and major corporations are meeting at SFI to explore how Big Data can help them better understand, plan, and manage cities.

Some Big Data enthusiasts believe “if we can measure everything we can solve everything, without knowing or caring about underlying constraints,” says meeting co-organizer and SFI Distinguished Professor Geoffrey West. The workshop will explore under which specific conditions this may be true.

In that view’s favor, some pressing urban problems – such as effective public transportation or even crime reduction – might be tackled using relatively simple approaches enabled by more and better data. But “we still don’t know how such solutions play out.”

For many of the complex systems we care about, “simply relying on the fact that computers are bigger and faster isn’t enough,” says SFI Professor Cris Moore.

Intel co-founder Gordon Moore’s law about the doubling of computing power every few years is of little significance compared to the astronomically greater improvement in computing power achieved through smarter algorithms, Cris says.

An SFI workshop in early August for physicists and computer scientists sought to prompt collaboration on new algorithms for solving problems and modeling nature.

A primary source of smarter algorithms is statistical physics. Physicists use their insights into a system’s structure to design algorithms and collect empirical evidence of their validity. Of particular interest are algorithms that “skip over the steps that nature takes,” as Cris puts it, bypassing what’s called the “critical slowing down.”

RESEARCH NEWS

Searching for smarter algorithms

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RESEARCH NEWS

Building a theory for ‘sustainability’

It’s a word being attached to products, businesses, fisheries, farms, and more – but what does “sustainable” really mean? And if you can find a definition that everyone agrees on, how do you know whether you are attaining it?

“The problem is that the term has been used in many ways,” says SFI Professor Luis Bettencourt. “To some it means quick fixes to crop yield or water quality problems, with little consideration of the ecosystems services that support those fixes or the shifts they require in other human demand or consumption. To others it’s a useful, but general, aspiration.”
This phenomenon occurs in many natural systems near phase transitions: it takes water, for example, a long time to boil even though applying heat gets the water to the boiling temperature relatively quickly. “So the challenge for theoretical computer scientists,” says Cris, “is to analyze the physicists’ algorithms rigorously, understand why they are so much faster than traditional algorithms – and if possible, prove that they are – or delineate under which circumstances these algorithms work.”

During the workshop, that challenge made for an intense two-way flow of ideas between the physicists with their intuition and algorithmic experience and the computer scientists who would like to prove theorems about these smarter algorithms. “We’re trying to strengthen the bridges between physicists and computer scientists and have them learn as much from one another as possible,” says Cris. “If the Participants walked out of here both with new algorithms to try and new conjectures to prove.”
This fall, the Institute welcomes four new postdoctoral researchers to SFI's Omidyar Fellowship program. Omidyar Fellows spend up to three years in residence in Santa Fe, where they pursue their own research interests. For more information and to meet the fellows, visit www.santafe.edu/omidyar-fellows.

**People**

Physicist Sid Redner to join SFI in 2014

External Professor Sidney Redner will join the Institute’s resident faculty next summer, SFI Chair of Faculty Jennifer Dunne announced on August 13. Redner now chairs the Department of Physics at Boston University.

Redner says he’s looking forward to the working style and academic freedom SFI affords, noting that opportunities he says are hard to come by. He first visited SFI during visits in 2004 and 2005, when he was an IBM Scholar at Los Alamos National Laboratory working on opinion formation.

He hopes to continue work on quantitative social science, but “I couldn’t even predict what I’d be doing six months from now. It really like to reinvent myself at SFI,” he says.

Redner earned an A.B. in physics from UC Berkeley in 1972 before moving to MIT with plans for a career in high-energy experimental physics. Following a few years studying high-energy theory and mathematics, Redner began working on statistical physics, focusing on phase transitions and renormalization theory, with advisor H. Eugene Stanley.

After earning his Ph.D. in 1977, Redner spent a year at the University of Toronto before joining BU’s physics department in 1978. Over the past three and a half decades, he has worked on a variety of topics related to statistical physics, including polymer physics and the theory of random walks, in addition to more recent work on complex networks and on social dynamics such as voting and opinion formation. He has been chair of BU’s physics department since 2011 and joined SFI as an external professor in 1997. He is the author of more than 200 academic papers and books chapters as well as two books on statistical physics.

“Redner is an outstanding addition to the resident faculty,” says Dunne. “His rigorous and creative approaches to a wide range of research topics complement ongoing work at SFI, and he will add new dimensions to the intellectual and institutional life here.”

SFI welcomes four new Omidyar Fellows for 2014, says goodbye to seven postdocs

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**Achievements**

At its 2013 commencement ceremonies, Harvard University bestowed an honorary degree on SFI Science Board member Robert May, Baron May of Oxford. May’s citation reads: “A prodigious polymath and peerless peer whose mind conceives models that sustain life and whose voice rings in support of enlightened inquiry.”

The “Village Ecosystems Project (VEP) in the American Southwest,” a research program directed by SFI Science Board member and External Professor Tim Kohler, was honored by the 2013 Shanghai Archaeology Forum Selection Program for individuals and organizations that have achieved distinction in innovative, creative, and rigorous works with significant relevance to the contemporary world. SFI Omidyar Fellow alum Scott Ortman is a senior researcher on the project.

A recent paper by Anargyros Papageorgiou and SFI External Professor Joseph Traub, “Measures of quantum computing speedups” (also published as an SFI working paper), has been selected as an “Editors’ Suggestion” by Physical Review A.

SFI External Professor Brian Arthur’s book The Nature of Technology: What It Is and How It Evolves was selected as one of Nature’s top reads for summer 2013.

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SFI External Professor Ole Peters is co-founder and fellow of The London Mathematical Laboratory (LML), an independent institute for basic science, located in Central London and funded by charitable donations. LML’s three fellows have backgrounds in mathematical physics and, with their network of collaborators, currently do work in ergodic theory, stochastic processes, extreme value theory, economics, and the history of science.

**Inside SFI**

The application period for the 2014 SFI Omidyar Fellowship is open. Interested postdoctoral researchers should apply before October 25, 2013. For eligibility requirements and to apply, visit www.santafe.edu/omidyar-fellowship. Please email questions to ofellowship@santafe.edu.
As a relatively recent branch of science, the study of complex systems is nearly nonexis-
tent in K-12 science curricula. Yet complex-
ity today touches nearly every other scientific
discipline and has informed many recent
innovations, says Irene Lee, a longtime edu-
cation researcher in SFI’s Education and Out-
reach group.

In August, Lee was named director of SFI’s new Learning Lab, created this summer to
support an important component of the
Institute’s mission: inspiring the next genera-
tion of scientists. The Learning Lab will help
translate SFI’s research for the general public,
with an emphasis on students in kindergar-
ten through 12th grade.

“The problems our world is facing – hunger,
climate change, conflict – are going to be
best addressed and solved by people who
understand complexity,” Lee says. “The abil-
ity to consider all the interrelated factors that
contribute to these problems will be a critical
skill needed in designing solutions.”

Until now, SFI has addressed the community’s
need for complexity science education with
programs targeted for specific audiences. The
Learning Lab will create a more global and
strategic approach to sharing SFI research
outcomes, conducting research on best prac-
tices in teaching complexity science, evaluat-
ing current education efforts, and creating
new models for complex systems education.

Significantly and symbolically, its staff now
resides under one roof, having recently
moved to SFI’s Gatehouse near the entrance
to the Cowan Campus.

The ability to effectively disseminate out-
comes is an important component of all SFI
research. The Learning Lab will maintain
close relationships with local schools and uni-
versities that provide students access to this
science, and work closely with researchers to
make sure their research is accurately pre-
vented and the pedagogy is age-appropriate.

The Learning Lab encompasses all of SFI’s
current and future educational programs for
local students in kindergarten through 12th
grade, including Project GUTS (Growing Up
Thinking Scientifically), GUTS y Girls, and the
New Mexico Computer Science for All pro-
gram, as well as professional development
programs for teachers.

The goal, says Lee, is to share the excite-
ment and relevance of complexity science
with a new generation of young scientists
and, ultimately, support efforts to encour-
age students to pursue careers in STEM
(science, technology, engineering, and
math) disciplines.

Now seeking applications/nominations
for SFI’s Cowan Chair

The Institute is seeking nominations for and applications from individuals
conducting research in the social and behavioral sciences for the SFI Cowan
Chair in Human Social Dynamics. This is a full-time resident faculty posi-
tion at the equivalent of the assistant or associate professor level. Applica-
tions are due by November 1, 2013. More at www.santafe.edu/cowan.

Sound is vibration. Rhythms have ratios. Octaves are fractions of one another. For cen-
turies, musicians have used the mathematical relationships among scales and harmonies to
pluck our emotions. Composers fill us with patterns and then surprise us with asymme-
tries. Even the planets play unheard songs in revolutions and orbits.

On Saturday evening, November 2, SFI and The Santa Fe Symphony present a unique
symphony of science. The event features an expansive multimedia presentation and re-
marks by SFI Professor Cris Moore, a mathe-
matician and computer scientist, interspersed with musical selections by The Symphony.

“Mathematics can help us understand why we love the music we love and how to create
new music that no one has ever heard be-
fore,” says Moore.

November 4 special concert
brings math and music to area students

On Monday, November 4, several
hundred northern New Mexico 7th-9th-
grade students will attend a version of
the “Majesty of Music and Mathematics”
event designed just for them. SFI VP
for Education and Outreach Ginger
Richardson says the field trip/concert at
The Lensis will form the basis of an ongo-
ing educational website with learning
tools for teachers and students, to be
available at SFI’s Complexity Explorer
(www.complexityexplorer.org).

“It’s time for transdisciplinary
electric power grid science

As climate change increases weather distur-
bances, as increasing demand tests power
supplies, as smart grid and renewable energy
technologies make the grid more complex
distributed, and as planners improve re-
sponses to inevitable power failures, a trans-
disciplinary understanding of power grid reli-
ability and complexity informed by modeling
becomes more critical, according to a July
23 opinion piece in PNAS co-authored by SFI
Professor Cris Moore, SFI External Professor
Raissa D’Souza, and collaborators.

“Validated models enable the next grand challenge: improve and transform power
grids to meet 21st century pressures. Reli-
able electricity must reach more people
demanding more energy in more places...
These challenges span engineering, physics,
complex networks, computational science,
economics, and social sciences,” plus ecol-
y, they conclude.

Hierarchy in networks could
have emerged at random

From river systems to electrical grids, most
networks exhibit some degree of hierarchy,
but researchers have been slow to under-
stand why. In a July 6 paper in PNAS, SFI Ex-
ternal Professor Ricard Solé and colleagues
at Pompeu Fabra University argue that much
of the hierarchy in the world could have
emerged at random.

The team began by constructing three mea-
ures of hierarchy: how clear the “chain of command” is, how prevalent circular
circles are, and how high up the network those
circles are. Using those measures, they iden-
tified four distinct types of hierarchy, corre-
sponding to software and electronic circuits;
language, metabolic, and neural networks;
genome regulation networks; and food webs.

Simulations showed all but gene regula-
tion networks and food webs shared similar struc-
tures with random networks, suggest-
ing hierarchical networks can form without
anything guiding them there.

How network theory is inform-
ing cognitive science

Networks have long played a key role in
cognitive science, from studies of artificial
neural networks to modeling of semantic
memory. Today, the inclusion of network
theory in the cognitive sciences and the ex-
pansion of complex-systems science promise
to significantly change how the organiza-
tion and dynamics of cognitive and behav-
ioral processes are understood, according
to a recent paper co-authored by SFI External
Professor Morten Christiansen. The paper
was published May 30 in Trends in Cogni-
tive Science.

Learning Lab coalesces K–12 ed programs

Greg Helman, The Symphony’s Founder and
General Director, says: “Throughout history
there has been much conjecture on the com-
monality of music and mathematics, and
this project is an effort to explore through
the language of mathematics the nature of
rhythm, symmetry, and harmony.”

The program takes the audience on a jour-
ney, from the rhythms of molecules and
planets to the harmonies of dolphins and
the dissimilarities of the “devil’s interval,” from
the music of Strauss to the theme song of
The Simpsons, from the earliest bone flutes
40,000 years ago to the soundtracks of
modern cinema.

The Symphony’s performances span the musi-
cal spectrum, from demonstrations on the harp
and flute to movements from Strauss, Brahms,
Prokofiev, Handel, Holst, Wagner, Bach,
Adams, and more.

The November 2 concert, “Voyages of
Discovery IV: The Majesty of Music and
Mathematics,” takes place at 7:30 p.m. at
the Lensic Performing Arts Center. Tickets range
from $22 to $76 and are available through
The Symphony box office at (505) 988-1414
or (800) 480-1319, and through The Lensic
Box Office at (505) 988-1234. Tickets are also
available online. Visit www.santafesymphony.
or www.lensic.org.

“The Majesty of Music and Mathematics”
is the fourth in a series of “Voyages of Dis-
coveray” events co-organized by SFI and
The Symphony.

This year’s Voyages is generously underwrit-
en by the Andrew and Sydney Davis
Foundation.