Delays in networking yield rapid super-connection

Water can suddenly freeze into a sheet of ice similarly to how a network of points can suddenly achieve super-connectivity. (Image: Brandon Keim)

Delaying an emerging network's overall connectivity can last for only so long, and can make for a cataclysmic shift when it finally happens, according to recent research by a team of scientists that includes SFI External Professor Raissa D'Souza.

Dubbed “explosive percolation,” the phenomenon challenges conventional understanding of network formation and opens a new door for studies of connectivity when the greater subgroup of points to join is chosen. “It’s surprising that a small change could impact the fundamental nature of the process,” says Raissa.

The usual pattern of emerging connectivity follows what is known as the Erdös-Rényi random graph process. In it, linking randomly chosen pairs of points one at a time eventually yields a rapid but smooth transition between little and great connectivity. Every attempt to adjust the onset of connectivity has generated a continuous transition — until now.

Raissa, an associate professor in the Department of Mechanical and Aeronautical Engineering at UC Davis, and colleagues applied an algorithm that exploits the randomness of the links. They randomly generated two candidate pairs of points to join — rather than one — and chose to connect the pair that creates the smaller subgroup (the pair of points having the fewest existing connections).

As with Erdös-Rényi, the level of connectivity stays low until a critical point but then shoots up to covering more than half the network nearly instantaneously. The team’s method also hastens the onset of superconnectivity when the greater subgroup option is chosen. “It’s surprising that a small change could impact the fundamental nature of the process,” says Raissa.

The team has shown the pattern computationally, but a mathematical proof of the behavior has yet to be worked out.

Explosive percolation offers applications both in fields that wish to build connections quickly, such as online or transportation networks, or destroy them, such as disease modeling, she says.

The work appeared in the March 13 issue of Science and has caught the interest of researchers in areas from basic science to counterterrorism.

RESEARCH NEWS
First map of scientific curiosity reveals surprises

A Los Alamos National Laboratory research team that includes SFI External Professor Luis Bettencourt has created maps that for the first time portray the private usage behavior of consumers of scientific scholarship.

Using “clickstream” data — detailed records of the sequences of articles scientists download as they chase their curiosities on the World Wide Web — the researchers created maps that yield insights about the dynamics of scholarship and relationships among scientific fields. The researchers believe their visualizations can help funding agencies detect emerging trends and point scientists to interdisciplinary hot spots. The research, led by LANL’s Johan Bollen, appeared recently in PLoS One (http://is.gd/mtQH). “This will be a crucial component of future efforts to study and predict scientific innovation, as well as novel methods to determine the true impact of articles and journals,” Bollen says.

Previous visualizations of scientific activity typically based on citation data, like early world navigation charts, useful but not fully representative of the terrain being mapped, the researchers say. Existing citation data: more on page 2

RESEARCH NEWS
Constants in language change

Eight researchers spanning the linguistic disciplines met at SFI for two days in March to find common ground and address big questions about how human language changes.

The workshop, called “Models of Innovation and Propagation in Language Change,” was organized by SFI Postdoctoral Fellow Dan Hruschka and External Professor Morten Christensen (Cornell University). It builds on a related meeting held last year.

“Discovering the pressures that lead people to adopt new words and ways of saying things helps us understand the nature of social interaction and the human condition more broadly,” Morten says.

Rather than the typical series of talks followed by discussions, the researchers explored:

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Neutral network sizes of biological RNA molecules can be computed and are not atypically small; Jorg, T.; Martin, O.C.; Vermaat, J.E.; Dunne, Jennifer; Sailer, Constantino [External Professor]; Tsallis, Constantino [External Professor]; Physical Review Letters 79 (4), January 2009, pp. 577-603

Condensate-induced transitions between topologically ordered phases; Bais, Sander (F.A.) [External Professor]; Stenkula, Jan H.; Physical Review B 79 (4), January 2009, pp. 577-603

Major dimensions in food-web structure properties; Vermaat, J.E.; Dunne, Jennifer [External Professor]; PloS One 4 (1), January 2009, pp. 278-292

On the robustness of q expectation values and Renyi entropy; Hanr, R.; Thurner, Stefan [SFI External Professor]; Tsallis, Constantino [SFI External Professor]; Physical Review E 78 (2), January 2009, pp. 37-32

Protein material costs: Single atoms can make an evolutionary difference; Bragg, J.G.; Wagner, Andreas [SFI External Professor]; Physical Review Letters 102 (3), January 23, 2009, pp. 302-305


How many species have mass M? Clastor, Auren [SFI Postdoctoral Fellow]; Schwabl, D.J.; Redner, Sidney [SFI External Professor]; American Naturalist 173 (2), February 2009, pp. 256-263

Cancer research meets evolutionary biology; Pepper, John [SFI External Professor]; Findlay, C.B.; Kassen, R.; Spencer, S.L.; Maly, C.C.; Evolutionary Applications 2 (1), February 2009, pp. 60-70

Evolutionary model of species body mass diversification; Clastor, Auren [SFI Postdoctoral Fellow]; Redner, Sidney [SFI External Professor]; Physical Review Letters 102 (3), January 23, 2009, pp. 302-305

Since Darwin’s time, for example, math- ematical models and genetic principles have been developed to describe evolutionary mechanisms that in many ways undermine Darwin’s theory as it was conceived. And yet, David says, Darwin’s theory was essential for progress in those areas.

Four other SFI faculty members explored both the influence and the limitations of Darwinian thought in modern science: Professor Tamney Bhattacharya on disease and health, Research Professor Jennifer Dunne on ecosystems, Research Professor Jessica Flack on society, and Professor Eric Smith on economics.

SFI’s upcoming public lectures include:

“The Computer, the Brain, and the Internet,” May 27 – The Internet, not the computer, may now be our best current model for understanding how the brain works. Thought may be nothing more than a search in the space of ideas. Those talks will explore a new hybrid world where the brain, the computer, and the Internet are progressively merging and the implications for the intellectual future of our species.

“What will it cost the Earth to save the planet?” July 16

“Stalin’s Ulam Memorial Lecture Series: Adventures in the simple and the complex: A tribute to Murray Gell-Mann,” September 15, 16, and 17

Watch the update for more SFI’s upcoming public lectures. To receive email notification about lectures, subscribe to lecture-subscribe@santafe.edu.

Online behavior of scientists, with colors representing the scientific discipline of each journal and lines reflecting the more stringent criteria involved in citations.”

“Whereas maps based on citations favor the natural sciences, our maps showed a prominent and central position for the humanities and social sciences, which, in many places, acted like interdisciplinary bridges connecting various other scientific domains,” says Luis. “In this sense the creation of scientific knowledge is a fundamentally interdisciplinary activity, though certain connections appear as a multitude of weak links that were hard to observe before the more stringent criteria involved in citations.”

Future work will focus on developing models of scholarly search. The researchers also will continue to develop real time data-management systems and models that allow emerging trends in scientific innovation to be identified and encouraged.


Recent news coverage of the work appeared in Nature (March 9), the New York Times (March 16), Wired magazine (March 20 and April 14), and Wired (March 11).

RESERCH NEWS

Seminar series to explore dynamics of construction

Descriptions of how high-level, often unexpect ed structures arise from small-scale properties or individual behaviors (in ant colonies, for example) have recently been applied in fields far from their origin fields of physics and biology. Less well understood are the processes by which such structures are built from the ground up.

A series of seminars at SFI this summer will begin to share ideas from a variety of SFI research threads, and may prompt work toward a common theoretical framework for the building of structure across many scales, from viruses to societies.

The “Construction Dynamics Seminar Series” organized by SFI Research Professor Jessica Flack will explore, among other topics, the computational processes underlying construc tion, how structural feedback influences lower level behaviors, and how principles and rules governing construction evolve.

“Of particular interest is whether cells or organisms, or individuals in social groups, by building their ecological and social environments, reduce uncertainty about the cost of social interactions or the availability of resources, and are therefore able better to develop appropriate strategies for competing,” she says.

The seminar series is broad enough to include much ongoing research within the Institute’s community: the major transitions in evolution, levels of selection, evolution of development, evolution of signaling systems, animal behavior, cognitive science, niche construction, the origins of individuality, rebelliousness and innovation, scaling, information theory, and theories of computation and emergence, to name a few.

The series kicks off May 7 with a presentation by SFI Sabbatical Visitor John Odling-Smee (University of Oxford), a leading researcher in animal learning, its role in evolution, and niche construction.

For more information, www.santafe.edu/events/
INSIDE SFI

iTunes U to make SFI educational programs available for download

Podcasting of digital audio and video files over the Internet, not long ago, was an almost entirely new phenomenon, has ushered in an era of mobile learning.

This spring SFI is making digital media available for download from the Institute’s website via Apple’s iTunes U system. SFI will join Harvard, Stanford, MIT, and many other major universities in making educational materials available to the public via iTunes U. According to SFI project manager Atty Mullins, the new SFI iTunes U site will allow public access to select Institute public lectures, colloquia, seminars, and workshops. He expects the project to go live in May.

Conceived and executed with the help of content developer Luke Washburn, iTunes U will allow both Mac and Windows users to view videos via the iTunes application or download them to video iPods or Phones. “We believe iTunes U will further SFI’s education and outreach goals by making the Institute’s unique content available to a much larger audience than ever before,” Atty says.  

INSIDE SFI

Busy season approaches for SFI education programs

This summer young scientists from the second- ary through the graduate level are converging on the Institute to better understand complex systems.

The Institute’s educational programs have several broad impacts, says SFI Education and Outreach VP Ginger Richardson. “First, we’re training the upcoming generation of complexity science scholars who will become practitio- 
ners within this new paradigm here at SFI and elsewhere,” she says. “Second, our students become very real ambassadors for SFI and complexity science as they move forward in their careers. Finally, good science education simply benefits society at large.”  

The Institute is one of the sites for the annual Research Experiences for Undergraduates program funded by the National Science Foundation. Undergraduate students work with faculty mentors on individual research projects focused on some aspect of complex systems. Each project may be based on a suggestion from the SFI mentor, an idea from the student, a combination of the two. This summer nine outstanding undergraduate scholars from the U.S. and Latin America are participating; the students live at nearby St. John’s College and spend their days at SFI.

The 15th annual Graduate Workshop on Computational Social Science Modeling and Complexity takes place June 21 through July 4. Co-directed by SFI Professor John Miller (Carnegie Mellon University) and SFI Education & Professor Scott Page (University of Michigan, Ann Arbor), the workshop includes faculty lectures, special topic seminars by SFI researchers, and presentations of work in progress by the advanced graduate student participants.

“Our vision is to create an idyllic two-week graduate experience — an environment in which students can do good science, explore ideas without feeling shackled by disciplinary constraints, and pursue those ideas to their logical endpoints,” Scott says. “The interactions between our students and our faculty mentors on individual research projects is the interplay between computer scientists, econo- 

ists, and sociologists is always fun.”

The two programs are part of a wide variety of year-round educational outreach offerings from SFI. Annual schools provide students with an introduction into and collaborative research experience in different complexity science topics. The Institute also supports residential and international internships and fellowships through the postdoctoral level. And Project GUTS (“Growing Up Thinking Scientifically”), supported by SFI, is a free, one-year after school program for motivated New Mexico-area middle schoolers who share an interest in scientific inquiry, problem solving, and investigating topics of interest to their local communities.  

Language change

themes based on five paper positions written by 
participants and circulated before they met.

Issues included models of random and constrained change in language, condi- 
tions of creating change, and how social forces like population structure and context act as mechanisms for changes to spread and stay in languages. First, though, they had to decide how each discipline, from cognitive linguistics to historical linguistics, defines ideas like variance and innovation.

“Every time we say a new sentence, that’s prob- 
ably a new way of saying something,” says Dan. “Is that entire utterance an innovation? What counts as an outcome?”

Morton called the workshop a success. “We were able to put together a number of ways of looking at language change across the different perspectives of participants.”

They outlined a paper that covers their findings, tentatively titled “toward a cognitive science ap- proach to language change,” and plan to submit it to a journal later this year.  

Mitchell book offers accessible, guided tour of complexity science

A new book by SFI External Professor Melanie Mitchell (Portland State University) offers an accessible, illustrated overview of the founda- tions of complexity research and a survey of recent developments in the field.

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For their 2007 CSSS collaborative project, biologist Ryan Chisholm and physicist Elise Filotas examined “critical slowing down” (CSD), a phenomenon whereby a disturbed ecosystem takes increasingly longer to recover from small perturbations as it nears a transition to another stable state.

The pair took an analytical approach to two two-species models. They found that CSD gives greater advance warning of a transition in a predator-prey model when predation is high or the prey population grows slowly. In a computerized model, it works when the rare species’ population grows slowly.

Their findings add support to earlier numerical work and suggest factors to consider when investigating transitions in disturbed systems, from eutrophic lakes to rangeland.

Since the school, Chisholm has been pursuing a PhD in ecology and evolutionary biology at Princeton University. Filotas is finishing her multi-disciplinary PhD thesis in physics and ecology at the University of Montreal.

CSSS, an annual month-long program for graduate students and postdocs, combines lectures on techniques and applications of complex adaptive systems with interdisciplinary collaboration. The 2009 Santa Fe CSSS starts in June.

Two participants in SFI’s Complex Systems Summer School (CSSS) are publishing collaborative work they began during the 2007 CSSS session. Their paper, accepted by the Journal of Theoretical Biology, is available online at doi:10.1016/j.jtbi.2008.11.008.

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