Insights from examining multiple ecosystem datasets

Ecological studies typically have focused on a given habitat, such as the food web of “who eats whom” in a forest or coral reef. While this approach offers insights into how each ecosystem is organized, singular datasets can’t answer questions about how the structure, dynamics, and functioning of a given food web vary across changing conditions. Now, advances in data handling that can examine hundreds of instances of particular types of food webs are providing a new way to study how species resist or adjust to changes in the ecological context.

One such study examines the aquatic ecosystem within a pitcher plant—a carnivorous plant that lures insects to nectar at the bottom of a long, jug-like leaf and traps them. The pitcher plant food web includes detritus (dead insects), midges, mosquito and fly larvae, bacteria, mites, rotifers, and protozoa. A database of 780 pitcher plant food webs, sampled in clusters at sites along the eastern U.S. and Canadian coastline, reveals trends in how the communities within these plants change in relation to environmental factors.

“By understanding how these tiny ecosystems are structured, we can start to see how ecosystem organization changes, or doesn’t change, across latitude and climate,” explains Jennifer Dunne, SFI’s Chair of the Faculty and an expert in ecological network structure and dynamics.

Study: Homer’s *The Iliad* dates to 762 BCE, give or take

One of literature’s oldest mysteries is a step closer to being solved after a recent study that dates *The Iliad* to 762 BCE and adds a quantitative means of testing ideas about history by analyzing the evolution of language.

The epic poem *The Iliad*, set amid the final year of the Trojan War, is attributed to the ancient Greek poet Homer and is foundational to Western literature, but scholars have not reached a consensus about whether it was written shortly after the war or much later. Archaeological and historical evidence have placed the text’s origins in the 7th or 8th century BCE, but such records are sparse and often have an uncertain validity.

SFI External Professor Mark Pagel, an evolutionary biologist at Reading University (UK), and colleagues decided to ask what scholars refer to as “The Homeric Question” using a quantitative approach borrowed from the study of evolution.

In determining when species emerged and gauging their relatedness to others, biologists compare genetic and physical traits along with novel adaptations. Similarly, linguists compare words that share an ancestor (e.g., *water* in English and *wasser* in German both come from the proto-Germanic *wasser*), as well as words that supplant earlier terms (the modern English *dog*, for example, largely replaced the Old English *hund*), to pinpoint when a lexicon or language was in fashion.

Pagel’s team compared the Greek vocabulary in Homer’s Iliad to modern Greek, relying on a 200-word lexicon found in every language and contrasting the distinctly related *Hittite* as an indicator of divergence. Their methods date Homer’s language in *The Iliad* to 762 BCE. The statistical model, says Pagel, “is completely ignorant of history—it doesn’t know who Homer is and it doesn’t know Greek.” Accordingly, the potential date ranges from the improbable extremes of 376 to 762 BCE.
According to the New Mexican on February 21, a recent talk at SFI by noted climate scientist James Hansen, who told an overflow crowd that efforts to stem climate change will be ineffective as long as fossil fuels remain the cheapest form of energy. On February 1, the Atlantic’s Richard Florida takes a look at innovation and its relationships with public and private, citing views of SFI External Professor W. Brian Arthur, who has suggested that the U.S. is poised for an era of innovation and growth. Florida also mentions frequent SFI collaborator Deborah Strumsky and Jose Lebo, who are part of a new research team by the Brookings Institution that examines historic patent data in relation to cities of origin.

In a lengthy feature article in TheMudis (Madison, Wisconsin) on January 30, SFI External Professor David Krakauer, director of the Wisconsin Institute for Discovery at the University of Wisconsin-Madison, outlines the critical need to rethink and remake the university education system. In a January 25 article in The Chronicle of Higher Education, SFI External Professor Jon Wilkins discusses his Romin Institute, which is providing a platform for unaffiliated academics to contribute to scholarly progress. The Technologist on January 22 describes a new SFI research project led by SFI Professor Luis Bettencourt, in collaboration with the nonprofit Slum Dwellers International and backed by the Bill & Melinda Gates Foundation.

In the real world, Thurner says, it can be much less frequently, and respond quite quickly to female friendship initiatives. “The big result is that the Wikipedia behavior is what we call non-finite state,” DeDeo says. “It’s constantly generating new patterns of behavior that haven’t been seen before.”

One possibility, he says, is that the unboundarized source for these behavior patterns in Wikipedia is shared between people – it’s the people interacting that create that. “What’s very exciting,” he says, “is why the results are different.”

DeDeo’s study is published online at http://arxiv.org/abs/1212.0018.

### How men and women organize their (online) social networks differently

A new quantitative study of how men and women manage social relationships in the online multiplayer game Parus finds that gender differences observed in the real world tend to be mirrored in the online society.

“It is fascinating that we maybe see traces of a million years of social evolution in a computer game,” says SFI External Professor Stefan Thurner (Medical University of Vienna), who co-wrote the paper with Michael Szell (MIT).

Females have more communication partners, engage in economic activities to a greater degree, attract positive behavior, organize in clusters, reciprocate friendships, take fewer risks than men, and show a preference for stability in local networks. Males try to talk most often with those who talk with many, reciprocate friendships with other males much less frequently, and respond quite quickly to female friendship initiatives.

In the real world, Thurner says, it can be difficult to study social networks of a set of people at the same time with the same resolution. Online multiplayer games like Parus, with their detailed data about players’ social interactions and networks, allow researchers to quantify interactions on a systemic level.

Their paper was published February 7 in Scientific Reports.

Wikipedia’s remarkable accuracy and usefulness comes from something larger than the sum of its written contributions, a study by SFI Research Fellow Simon DeDeo finds. The free, anonymously written and edited online encyclopedia was widely expected to fail prey to cranks and partisans. Instead, it has proven no less accurate than the venerable Encyclopaedia Britannica, according to several analyses of the quality of its information.

“The question is how?” asks DeDeo, who has studied the 11-year-old online knowledge repository as the product of a particularly cooperative human social system. “Wikipedia is an extremely high-functioning system. How do people create societies that have extremely high cooperation?”

A great example of this cooperative nature is Wikipedia’s article on former U.S. President George W. Bush – a contested piece of Wiki real estate that has been edited some 45,000 times.

“Show me a place on the internet where people agree about George W. Bush,” says DeDeo. “But the Wikipedia article reads as if it was written by everyone who knows about Bush – although we know it was written by people who cared a lot.”

Just how Wikipedia manages this collective balance is something DeDeo was able to study in detail because, unlike most other social systems, every Wikipedia edit is recorded.

“It’s almost like you had closed circuit cameras running as a society is creating itself,” he says, “so every move could be studied and watched.”

All these sequences of behaviors create what can be viewed as a historical grammar, like that of a language or even bird song. A human language, for example, has very simple grammar, with few elements and combinations possible – what’s called a finite-state system. The historical language that creates and maintains Wikipedia might be expected to follow a rather limited grammar as well, but that’s not what DeDeo discovered.

“The big result is that the Wikipedia behavior is what we call non-finite state,” DeDeo says. “It’s constantly generating new patterns of behavior that haven’t been seen before.”

One possibility, he says, is that the unboundarized source for these behavior patterns in Wikipedia is shared between people – it’s the people interacting that create that. “What’s very exciting,” he says, “is why the results are different.”

DeDeo’s study is published online at http://arxiv.org/abs/1212.0018.

### Optimizing optimization

Complex data-rich endeavors like predicting climate change or developing a new heavy-duty material involves running many simulations and comparing their results with observations such as field data or experiments, an “information source” whose use has its own pros and cons.

“In trying to optimize something using many sources of information, each source has a different way of storing time and resources, and a different accuracy,” says SFI External Professor David Wolpert, an algorithm designer at Los Alamos National Laboratory.

Traditionally, scientists use their intuitions to choose from information sources on the fly. Wolpert wants to let machines do it instead. “Humans aren’t designed for this,” he says, “statistical techniques may be far more powerful.”

A dozen researchers representing MIT, Stanford, Sandia National Labs, and the Air Force geospatial intelligence office (AFGEO) convened to consider new directions for “Multiple Information Source Optimization (MISO).” As part of the working group, they explored means of finding statistical relationships between cheap but inaccurate sources and accurate but expensive sources.

“The right knowledge allows you to use cheap, less accurate sources knowing how they complement the others,” says Wolpert, who held a similar working group in July 2012, during which organizers introduced standard MISO procedures – what had so far been used in aerospace engineering – to other research communities.

At the follow-up meeting in November they introduced a supercomputer machine learning approach to optimize the optimization process by explicitly comparing an information source’s contribution to the MISO design.

The advances are poised to make a tremendous difference in fields requiring massive simulations, say Wolpert, such as determining the human impact of climate change, fuel of algal farms, magnitude of climate change, and severity of extreme weather.

Participants recently presented their findings at the Society for Industrial and Applied Mathematics (SIAM) meeting in Boston.

The advances are poised to make a tremendous difference in fields requiring massive simulations, say Wolpert, such as determining the human impact of climate change, fuel of algal farms, magnitude of climate change, and severity of extreme weather.

Participants recently presented their findings at the Society for Industrial and Applied Mathematics (SIAM) meeting in Boston.

### Homeric dating

Recent study has dated the Iliad from 762 BCE to 1157 BCE. But the estimate attaches a robust likelihood to the date, and it ties nicely to Nestor’s Cup, a clay vase dated to 723 BCE that is thought to carry an inscription from The Iliad.

The study reveals an “astonishing regularity in the way languages evolve,” notes Pagel. “That we can blindly apply rates of language change to Homeric and modern Greek and come up with 762 BCE tells us language is behaving in a regular and predictable way.”

Their study was published in the online edition of BioSays on February 18.

### Nonlinearities

What’s the special sauce that makes the Wikipedia such a good place to do science? I believe it has something to do with how its intellectual context shifts continuously. The steady flow of people and the diverse interests of their disciplines and thought styles mean today I might overhear a discussion between a biologist, an economist, a lawyer, and an archaeologist. Tomorrow it might be a physicist bouting ideas off of a philosopher, a physician, and an ecologist. I’ve met a myriad biologist, historian, sociologist, actors, authors, poets, diplomats, bankers, even a tribal leader from Afghanistan – and to all those I’ve met, forgive me. When any discussion can lead in so many directions, how could this not be productive, energizing setting for science? As long as they snowball, everyday at SFI is an original.

Evolution seems to play at least a supporting role in most of the discussions here. In this issue, for example, there’s an article about a fascinating paper by Mark Pagel and colleagues in which they used an evolution-inspired analysis of language change to date languages. I find it fascinating how the field of literature’s longest-running mysteries – no easy task given historians can’t even agree that Shakespeare wrote all of Shakespeare. If you like to think about evolution, don’t miss the new online video by Dan Rockmore and colleagues. The 46-minute documentary, Darwin’s Extra Sense, explores how mathematics-assisted evolutionary theory is opening doors to astonishing insights into the living history of our ability to population genetics, healthcare, neuroscience, and other fields. It’s available through the “Videos” link on SFI homepage.

Juniper Losato and I were, the other day, trying to think of all the pop culture mentions of the character. The icon标签 by, played by Jeff Goldblum in Jurassic Park, was, of course, a pop culture icon. In the ) (and ) finds a way” ). At least two episodes of the X Files include SFI characters. Rumor has it the window dressing in the TV series Members was inspired by a visit to SFI. There are many more. Please let us know. Go to SFI’s Facebook page and give us the list of pop culture mentions, verified or unverified. We’ll check it out and post a complete list. If you don’t use Facebook, just send me an email with as many details as you can muster.

John German, jgd@santafe.edu

The SFI Update is published by the Institute six times a year to keep its community informed. Please send comments or questions to John German at jgd@santafe.edu.

Follow SFI online at www.santafe.edu

SFI Bulletin

States of Complexity

SFI Bulletin: subscribe to receive email notification of each new issue, visit www.santafe.edu and look for the “Follow Us” menu.

SFI in the News

The Santa Fe New Mexican on February 21 covered a recent talk at SFI by noted climate scientist James Hansen, who told an overflow crowd that efforts to stem climate change will be ineffective as long as fossil fuels remain the cheapest form of energy. On February 1, the Atlantic’s Richard Florida takes a look at innovation and its relationships with public and private, citing views of SFI External Professor W. Brian Arthur, who has suggested that the U.S. is poised for an era of innovation and growth. Florida also mentions frequent SFI collaborator Deborah Strumsky and Jose Lebo, who are part of a new research team by the Brookings Institution that examines historic patent data in relation to cities of origin.

In a lengthy feature article in TheMudis (Madison, Wisconsin) on January 30, SFI External Professor David Krakauer, director of the Wisconsin Institute for Discovery at the University of Wisconsin-Madison, outlines the critical need to rethink and remake the university education system. In a January 25 article in The Chronicle of Higher Education, SFI External Professor Jon Wilkins discusses his Romin Institute, which is providing a platform for unaffiliated academics to contribute to scholarly progress. The Technologist on January 22 describes a new SFI research project led by SFI Professor Luis Bettencourt, in collaboration with the nonprofit Slum Dwellers International and backed by the Bill & Melinda Gates Foundation, that seeks to expand the scientific study of urban slums worldwide.

On January 22, NPR’s Robert Krulwich reviews a landmark 2007 paper by SFI Distinguished Professor Geoffrey West and colleagues at the University of Auckland, which at the species level, a relatively simple formula – a power law – seems to describe the life spans of all living creatures. Krulwich notes that although the conclusions remain controversial among biologists, the paper has been cited more than 1,500 times since its publication.

On January 8 corresponded a study by SFI collaborator Tobias Galla and External Professor Doyle Farmer in which they ran thousands of simulations of two-person
economic games, concluding that equilib- rium might not be relevant in a complex “game” with many players such as a financial market.

The Santa Fe New Mexican on December 29 covers the recent gift to SFI by Eugene and Claire Thaw of their former Tesuque, 29 covers the recent gift to SFI by Eugene

On December 17, BBC.com blogger Gau Vince reviews the sustainability benefits of dense urban living and cites research by SFI’s cities and urbanization team.

In a December 2012 interview in Alliance magazine, SFI Director and External Professor Geoffrey West appeals for a broader, networks-oriented view of problem solving and philanthropy.

School Board member Lord Robert May in a November 19 Albuquerque Journal interview.

Pore’s Nanyang Technological University and Clare Thaw of their former Tesuque, 29 covers the recent gift to SFI by Eugene

The pore’s Nanyang Technological University and Clare Thaw of their former Tesuque, 29 covers the recent gift to SFI by Eugene

Managing identity on the Internet

Much of what we do on the Internet – purchasing books and music, banking, interacting with the IRS – requires trusted mechanisms for establishing and protecting our identities. Other Internet interactions are better supported through anonymity. How do we square these seemingly incom-

Members of SFI’s Business Network will focus on identity and trust on the Internet at the Network’s next topical meeting on April 17 at Fidelity Investments in Boston. Speak-

The core of the NSTIC’s vision is the “Identity Ecosystem,” a process for authenticating the digital identities of individuals, organizations, and devices in the online environment. Like an ecosystem that exists in nature, the Identity Ecosystem will involve a network of interactions among organizations and indi-

NSTIC’s approach is not without its critics; other speakers will challenge some of NSTIC’s assumptions and proposed strategies and recommend improvements.

The challenge of developing strategies for a trusted, secure identity in cyberspace is related to SFI’s work on novel forms of computation and computer security inspired by biology,” says Chris Wood, SFI Director of the Business Network.

Applying the lessons of biology and natural systems to computers and other human-creat-

ed systems is a recurring theme at SFI. External Professor Stephanie Forrest and her colleagues, for example, have used the immune system to develop an important new perspective on computer security, one with quite different assumptions and organizing principles than those of conventional computer security.

For more, visit www.santafe.edu/network/.

PATTERNS IN INFORMATION

Bailey criminal court in England look to patterns in trials that led to guilty verdicts.

“You can look at the available trial evidence and the predictability of their outcomes, the researchers found evidence for different distinct trial patterns in other words, more than one pathway to a guilty verdict.

“The system is not just processing informa-

tion, but doing so in a structured fashion,” he says, “with separate and non-overlapping pathways through the decision process.”

In a second case they studied five years of WikiLeaks-published military reports about insurgent attacks in Afghanistan – data about locations, durations, combattants, and more. “Insurgency is not just about violence,” says DeDeo, “but also about signaling and coordina-

tion with rivals.”

An insurgent group’s attack is a message to rival insurgent groups, to NATO forces, or to the civilian population.

...and Cosmology, as well as his mentorship of scientists, his leadership in the scientific community, and his service to the coral reef, according to SFI Science Board member Lord Robert May in a November 19 Albuquerque Journal interview.

The porcine’s Nanyang Technological University and Clare Thaw of their former Tesuque, 29 covers the recent gift to SFI by Eugene

A new center is an effort to harness the vast amounts of data ubiquitous in today’s digital age.

The center will be a focal point for advancing online identity management and will serve as a highly visible example of “someone making the most of big data.”

For more information, visit www.santafe.edu/network/.

The Antenna Physical Society has awarded SFI Di-

tutored by great students, he added, and led to him having an “extra-

ordinary body of literary work” that has "inspired a generation of writers, film-

makers, and theatre practitioners the world over.”

Managing identity on the Internet

Much of what we do on the Internet – purchasing books and music, banking, interacting with the IRS – requires trusted mechanisms for establishing and protecting our identities. Other Internet interactions are better supported through anonymity. How do we square these seemingly incom-

Members of SFI’s Business Network will focus on identity and trust on the Internet at the Network’s next topical meeting on April 17 at Fidelity Investments in Boston. Speak-

The core of the NSTIC’s vision is the “Identity Ecosystem,” a process for authenticating the digital identities of individuals, organizations, and devices in the online environment. Like an ecosystem that exists in nature, the Identity Ecosystem will involve a network of interactions among organizations and indi-

NSTIC’s approach is not without its critics; other speakers will challenge some of NSTIC’s assumptions and proposed strategies and recommend improvements.

The challenge of developing strategies for a trusted, secure identity in cyberspace is related to SFI’s work on novel forms of computation and computer security inspired by biology,” says Chris Wood, SFI Director of the Business Network.

Applying the lessons of biology and natural systems to computers and other human-creat-

ed systems is a recurring theme at SFI. External Professor Stephanie Forrest and her colleagues, for example, have used the immune system to develop an important new perspective on computer security, one with quite different assumptions and organizing principles than those of conventional computer security.

For more, visit www.santafe.edu/network/.

PATTERNS IN INFORMATION

Bailey criminal court in England look to patterns in trials that led to guilty verdicts.

“You can look at the available trial evidence and the predictability of their outcomes, the researchers found evidence for different distinct trial patterns in other words, more than one pathway to a guilty verdict.

“The system is not just processing informa-

tion, but doing so in a structured fashion,” he says, “with separate and non-overlapping pathways through the decision process.”

In a second case they studied five years of WikiLeaks-published military reports about insurgent attacks in Afghanistan – data about locations, durations, combattants, and more. “Insurgency is not just about violence,” says DeDeo, “but also about signaling and coordina-

tion with rivals.”

An insurgent group’s attack is a message to rival insurgent groups, to NATO forces, or to the civilian population.

...and Cosmology, as well as his mentorship of scientists, his leadership in the scientific community, and his service to the coral reef, according to SFI Science Board member Lord Robert May in a November 19 Albuquerque Journal interview.
Spin Glasses and Complexity (January 2013), by SFI Science Board member Daniel Stein and co-author Charles Newman, offers an accessible introduction to spin glasses, why they are important, and how they are opening up new ways of thinking about complexity. It then explores how spin-glass concepts have found applications in areas as diverse as computational complexity, neural networks, protein folding, immune response, and social network modeling. The book is the latest in the “Primers in Complex Systems” series, a collaboration between SFI and Princeton University Press.

In Decision Making and Imperfection (Springer, 2012), co-authors Tatiana Guy, Mirislav Karny, and SFI External Professor David Wolpert explore how decisions made in both natural and artificial systems often differ from those recommended by the axiomatically well-grounded normative Bayesian decision theory. The book identifies sources of imperfection and ways to decrease discrepancies between the prescriptive theory and real-life decision making. And it considers such questions as how a crowd of imperfect decision makers outperforms expert decisions; how to decrease the decision maker’s imperfection by reducing knowledge available; how a human’s limited willingness to master available decision-support tools is an additional source of imperfection; and how the decision maker’s emotional state influences rationality.

Although animals may have first appeared nearly 700 million years ago with the earliest sponges, their initial diversifications appear to have been modest until a richly diverse fossil fauna appeared 170 million years later. In The Cambrian Explosion: The Construction of Animal Biodiversity (Roberts and Company, 2013), Doug Erwin and James Valentine synthesize research from many fields to explain why this period witnessed such remarkable novelty of animal forms. Erwin completed the book while serving as SFI’s Chair of the Faculty.

* Ecosystems continued from page 1

In early March, Dunne convened the first of two SFI working groups on “Gradient-based Ecological Network Research.” The meeting brought together ecosystem modelers with researchers who recently have compiled or initially analyzed datasets for mangrove islets, intertidal communities, rock pools, and pitcher plants. Together they began to explore the richness of the data and how best to learn from them.

“We make the most progress when we use data to develop and test theory, and use models and theories to shape new questions and find new ways forward in data collection,” she says. “With this group of outstanding empiricists and theoreticians, we are asking questions like: How do trophic organization, species roles, and feeding motives vary with changing conditions? Are these characteristics the same across time and space or do they shift — and if so, how, and why?”

* Networks and inequality continued from page 1

Hooper, who is collecting ethnographic data from the Tuamaga, a group of Amazonian hunters and horticulturalists, models the structure of their social networks. Then he compares the results with real-world data on the distribution of wealth in those societies. So far the data are consistent with the models, but there is still work to be done to improve the theory so it better represents observed reality, says Hooper.

“The more you can get your models informed by data, the more you can leverage the models to ask what’s going on,” says Hooper. “There’s a back-and-forth that’s really productive.”

The February NSF-funded workshop was part of SFI’s Dynamics of Wealth Inequality project led by Bowles and UC Davis anthropologist Monique Borgerhoff Mulder.

Upcoming events

Science on Screen series returns to Santa Fe March 13

The popular Science On Screen series continues Wednesday, March 13, at 7:00 p.m., with Paula Sabolí’s talk on Never Cry Wolf. Dropped alone into the Arctic Circle to study the hunting patterns of wolves, a biologist discovers the deeper mysteries of the wild. Sabolí, an SFI Professor and anthropologist, brings a natural science perspective, gleaned from years of field work, to Carroll Ballard’s 1983 Oscar-nominated classic.

Next screening: Wednesday, May 8 (note revised date), 7:00 p.m., SFI Research Fellow Simon DeDeo presents Sneakers.

The Science on Screen series is a joint collaboration of SFI and the Center for Contemporary Arts in Santa Fe. Advance tickets are recommended; for tickets and prices, call the CCA Box Office at 505-982-1338. All showings take place at the CCA (1050 Old Pecos Trail) in Santa Fe.

SFI’s 2013 Community Lecture series debuts March 14

When a wildfire, earthquake or hurricane strikes, people typically seek information from authorities. Today, through social computing and networking technology, citizens, observers, even “citizen-responders,” are innovating ways they can participate in disaster response. On Thursday, March 14, at 7:30 p.m. at the Greereson Theater (1600 St. Michael’s Drive) in Santa Fe, Lesia Palen will describe these emergent socio-technical phenomena and, using examples from events over the past few years, will discuss the implications for emergency response and society at large. Palen is an associate professor of computer science and project director for the Connectiv tyLab at the University of Colorado, Boulder.

Next Lecture: Thursday, May 9, 7:30 p.m., James A. Little, “The Minds of Children,” Alison Gopnik, professor of psychology and affiliate professor of philosophy, UC Berkeley, and author.

SFI Community Lectures are free and open to the public, but seating is limited. Visit www.santafe.edu for a schedule of SFI’s 2013 lecture series.