Reconciling two views of information

Meaning of Information working group

IN 1948 CLAUDE SHANNON, motivated by the engineering challenge of encoding, transmitting, and decoding electronic signals, took the radical step of defining “information” in a way that completely disregarded whatever meaning a transmitted signal might contain. For Shannon, the statistical properties of signals sent from sender to receiver were the engineering challenge of encoding, transmitting, and decoding electronic signals. His ideas have since been widely applied in the physical, biological, and social sciences.

Meanwhile, over in linguistics and philosophy, scholars continued to wrestle with definitions of information that were all about meaning and its interpretation — and focused almost exclusively on human minds and language. “They’ve been thinking primarily in terms of language, and of the semantics of true sentences — what they call propositions,” says philosopher of mind SFI External Professor Dan Dennett (Tufts). “Propositions have distracted philosophers for a century.”

“Shannon’s theory and its emphasis on the statistical properties of information have been useful in many scientific and engineering contexts,” says SFI External Professor Chris Wood. “But in other contexts, and not just those involving humans, information without meaning seems limiting and unproductive.”

Is extracting meaning from the world the provenance of human minds? Could a machine generate meaning from its inputs? To help address the 30-year divide between Shannon’s information and semantic information, Dennett and Wood are organizing a January SFI working group, “The Meaning of Information,” that brings together perspectives from physics, engineering, evolutionary biology, linguistics, philosophy, and neuroscience.

Their approach is to identify the most fundamental cases of semantic meaning and explore their properties and consequences. One such example, offered by Harvard biologist David Haig in a recent essay, is a simple binary system that strikes a spark. If only oxygen is present, nothing happens, but if hydrogen is present, an explosion occurs. Next, consider the same system but with a key difference: a hydrogen sensor. If no hydrogen is detected, the system strikes a spark, but if hydrogen is detected, it does not. The system with the sensor acts differently based on its environment.

Can the system be said to interpret the environment? If so, does that interpretation contain meaning? The participants will start with Haig’s essay, “Making Sense: Information as Meaning,” which proposes that meaning “be considered the output of the interpretive process of which information is the input.”

“We’re hoping Haig’s ideas may be the basis for getting us all the way from molecules to poets and scientists and philosophers while keeping the same definitions of information, interpretation, and meaning throughout,” says Dennett.

McKinnons give $3m to expand science at SFI

In one of the largest gifts in the nonprofit’s history, Ian and Sonnet McKinnon have donated $3 million to expand fundamental research at the Santa Fe Institute.

The gift, to be deposited in a single installment, will support core science activities, in particular the highly diverse working groups and workshops that are the hallmark of SFI’s collaborative approach to the challenges of complexity — looking for emergent patterns across physical, biological, technological, and social systems.

Following an extended dialogue with SFI President David Krakauer about the Institute’s scientific impact, the McKinnons announced their gift to SFI.

“Twas delighted by their decision to support core collaborative activities and the generosity of their gift,” Krakauer says. “Ian and Sonnet are scrupulous philanthropists who want to make every dollar count. Their willingness to support creative, independent research affirms the societal benefit of investigating fundamental questions about the nature of the complex world.”

While SFI researchers are generally motivated by curiosity rather than immediate applications, techniques pioneered at SFI have facilitated advances in drug discovery, ecological conservation, epidemiology, urban planning, and new forms of artificial intelligence.

“The academic freedom and collaborative culture of the Santa Fe Institute draws hundreds of world-class researchers to SFI every year,” says Jennifer Dunne, SFI’s Vice President for Science. “That kind of convening power wouldn’t be possible without support from individuals like the McKinnons.” Dunne also notes that for every dollar spent, the Institute leverages more than four additional dollars from federal grants, foundations, and strategic partners.

SFI hosts more than 50 scientific meetings annually and welcomes over 800 visiting scientists. Over the course of 224 years — from hundreds of technologies to hundreds of thousands — there’s much territory to explore.

“Part of what makes SFI’s approach unique, and what makes this working group unique, is that SFI researchers want to go beyond talking about analyzing the streams of output from the patent office,” Strumsky explains. “This working group calls for a much deeper look into production of information and how it affects our understanding of our world.”

The patent system’s detailed and precise descriptions of inventions, including data on the inventors, where they worked and when they were working, offers researchers a way to understand technological change in terms of selection, obsolescence, adaptation, and diffusion processes. But the system is also human-powered, and humans are flawed. Can AI help?

Some countries are already using AI to help patent examiners. The strategy seems to be working. AI has been able to replace redundant searches, freeing patent examiners to work with clients and be more responsive to their needs. Examiners can get overwhelmed, but AI never gets tired.

“We need to understand the nature of the patenting system as an information processing and generating system before we can assess how AI can make the patenting system better,” Lobo says. “More generally, before a diagnosis of the system is truly meaningful, made and a solution proposed, we need to understand the fundamental nature of the system.”

To understand that fundamental nature, Strumsky says researchers need to study the patent system as an evolving system that generates enormous amounts of new information on a daily basis. “We need to understand how the type of information generated enables and constrains our ability to study technology and understand how we interact with it.”

> MORE ON PAGE 4
Can lookahead optimization help us make better decisions?

When NASA scientists equip the Orion spacecraft with medical supplies for its manned mission to Mars, they will choose what to send in light of their best predictions of what the environment will be like. Yet some of the most difficult scenarios for scientists to predict are those in which agents enter into unknown territories. Can scientists develop methods that will allow NASA to make better choices for equipping their missions? A forthcoming SFI working group, “Lookahead optimization in artificial and natural systems,” will bring together scientists from diverse fields to develop better quantitative models of optimal decision making. The interdisciplinary working group was conceived by SFI President David Wolpert, SFI Professor Amy Bogaard, and SFI Professor Mirta Galesic, who is Cowan Chair in the Social Dynamics of an Idea, and is funded by the John Templeton Foundation.

Lookahead optimization allows scientists to account for the duration of a given experiment. Galesic became involved in the workshop when she recognized that lookahead optimization might help us understand some seemingly odd patterns in individual and social decision making. “It can be hard for us to see how a decision might actually be optimal for a set of actors. Sometimes what does not look optimal—say, delaying an important decision rather than choosing what seems like a good solution right now—might actually make sense in a look-ahead framework, which accounts for the long-term consequences of immediate choices.” While Galesic hopes that the workshop will help her see where lookahead optimization might be used to understand and predict human decisions, Tracey and Wolpert hope to learn more from Galesic about how heuristics that humans and other animals use relate to engineering design. For Tracey, the working group is an occasion to clarify the “meeting ground between mathematical decision models and patterns in biological, social, and artificial systems.” The workshop will take place at the Santa Fe Institute from February 21-22, 2018.

In January 2015, NASA scientists released an balloon in Antarctica to better understand and provide forecasts for weather in space. (Image: NASA Goddard via flickr)
Finding meaning in big data

Big data gets a lot of attention. Fields ranging from cybersecurity to cancer biology to social networks increasingly use behemoth datasets, which can be seen as vast networks. Researchers search those networks for patterns and connections that could help solve problems. Stop hackers, lengthen survival, improve communication.

But there’s a challenge. The noise in high-dimensional datasets can obscure real correlations—and give rise to illusory patterns that don’t mean anything.

In the case of biology, for example, a researcher may sequence the genomes of 100 mice and analyze tens of thousands of genes. That’s a lot of data, but the amount of information per gene—the number of mice—is relatively small. When researchers analyze that data, they may find correlations or connections that occur by chance, between genes and disease risk.

“Humans are very good at seeing patterns, even when they’re not there,” says Christopher Moore, Professor at SFI. “We have a strong tendency toward false positives. Our algorithms do, too.”

To better understand the limits of finding meaningful patterns in big data, Moore has organized a working group, to be held at the SFI April 15-16. He’s invited an interdisciplinary group of mathematicians, physicists, and theoretical computer scientists to address the problem and devise new algorithms that can succeed all the way up to the limits that arise from not having enough data, or not knowing if the data is accurate.

Moore suggests that networks can undergo a phase transition of sorts, shifting from order to disorder, similar to how ice melts or iron de-magnetizes. At low temperatures, the magnetic field of the atoms in a block of iron mostly lines up in the same direction. Raise the temperature enough, and the iron’s magnetic strength abruptly drops to zero.

The analogy extends to networks. With enough information about each node—for instance, when a node has links to similar nodes—a network can readily be classified into groups of similar nodes. But when you add noise by adding nodes with incomplete information or unexpected connections, eventually the noise overwhelms the signal: it becomes impossible or unfeasible to find meaningful patterns.

Recognizing the inherent limits of finding meaning, says Moore, can help researchers map out the difference between real patterns and illusory ones. (Image: Michael Glim)
What are humans good for?

Members of SFI’s Applied Complexity Network (ACtioN) confronted this question again and again over the course of the November symposium on natural and artificial intelligence.

In the most pessimistic interpretation, the answer is not much. Machines best us in chess in 1997 and now, in 2017, in the notoriously complex game of Go. Algorithms are producing nostalgic playlists, tweetering prolifically, designing fonts, and co-authoring scientific papers. And although their sonnets remain still for now, robots’ weather and sports reports have their own bite, the norm, we realize it or not.

Of course, there are also algorithms that spend their days managing car photos into the form of a loaf of bread. But even these are a fertile breeding ground for machine learning, suggesting Y Combinator’s Michael Nielsen. The real question isn’t what computers can do, but rather what computers are for. Are they simply machines for answering questions — what Nielsen terms “cognitive outsourcing?” Or can machines actually change the range of thoughts that we can think? Can they transform our cognition?

Since long before the days of dune caps, we have associated intelligence with computation: far more than with kinesthetic or emotional abilities. But SFI President David Krakauer offered an alternative definition: “Intelligence,” he declared, “is making hard problems easy.”

Action-ABLE INSIGHTS FROM ATTENDEES

“How the common language of complexity is key for articulating, sharing, and identifying problems, even on a small scale.” —Visual artist Lynne Baillie

“Algorithms are sexy, but insight actually comes from as many iterations (of neural networks) as possible.” —Mark Johnson of Descartes Labs

“In robotics, you’re regularly humbled by the real world. We were managing complexity and we didn’t even know we were.” —Philip Heermann of Sandia National Labs

The simple act of walking across a room without thinking about each step represents a form of intelligence, according to SFI Professor Håkan Håkansson, who chaired the application-driven task group building a theoretical framework for understanding “embodied intelligence,” which could one day be used to create natural movement in robots. For humans, this form of intelligence emerges from a learning process — a self-organized interplay between brain, body, and environment. Robotics, by contrast, is still dominated by the paradigm of pre-programmed control from a central computer. Machines do not experience the open-endedness of childhood — a developmental period which, arguably, is responsible for making us human. Machine learning leverages human-generated datasets. Even AlphaGo, which was not trained using human data, still operates entirely within the game’s rigid parameters.

As External Professor Melanie Mitchell (Portland State University) pointed out, babies spend all their time simply discovering the physical world around them — touching, drooling, biting, and developing common sense. AI can beat us at Go, but it can’t tell us “whether Michael Phelps’ hair was wet when he got out of the pool.”

“In robotics, you get regularly humbled by the real world,” says Philip Heermann, who attended with Sandia National Labs. Things that come naturally to humans — sitting, walking — are often comically difficult to replicate. But should we be replicating them? Or splitting our tasks? If humans were only ever good for playing Go, tweeting, and recognizing voices, there wouldn’t be much use for us anymore. The key now, it seems, is to play to our strengths: problem-solving, innovation, and play. Esther Dyson (Way to Wellville), a former SFI Trustee, remarked, “I would like to see all of those truck drivers become gym teachers and soccer coaches, and pay gym teachers and soccer coaches more. Technically, we’ve been commandeering ‘other’ — if not ‘artificial’ — intelligence for millennia. We took a hard problem — traveling fast, carrying heavy goods — and recognized that it was not our strong suit. We domesticated the horse. And here we are today.”

MORE ABOUT THE McKINNONS

Ian and Sonne McKinnon both grew up in Albuquerque, New Mexico. Sonne attended the UNM Anderson and graduated with a BBA, Ian graduated summa cum laude and Phi Beta Kappa from Occidental College with a BA in Public Policy and received an MBA from Harvard Business School as a Baker Scholar. Ian is the Founding Partner of Sandia Holdings, LLC, the primary investment vehicle for the McKinnon family and related entities. Prior to founding Sandia, Ian spent nearly twenty years at Ziff Brothers Investments, from which he retired as a Managing Partner. Outside of the office, Ian serves as a trustee of the Brunswick School in Greenwich, Connecticut, where he also chairs the Investment Committee. He is a trustee of the Albuquerque Academy and the Santa Fe Institute and serves on the Advisory Board of HighVista Partners, a money management firm in Boston. Finally, he is one of the founding members of TEAM8, a sports management company.

Sonne served as National Vice-Chair for the UNM Foundation Board of Directors from 2006-2010. She was also a mentor and board member for REACH Prep, an organization that provides academic and other forms of assistance for underprivileged students who are applying to and matriculating in private preparatory schools. She has served on the board of Greenwich Academy since 2013 and has acted as President of the Board of the Roger Federer Charitable Fund Inc. since 2014. Ian and Sonne live in Greenwich, CT with their two children, two dogs, rabbit, and fish.

The McKinnons give $3 million (cont. from page 0)
Researchers turn to complexity science to improve assessment of scientific value

It’s difficult to put a value on scientific research. In the last two or three decades, universities and other institutions have increasingly turned to quantitative metrics to gauge the impact of research. An individual’s h-index, for example, reports that a scholar with an index of h has published h number of papers each of which has been cited at least h times. Google Scholar also reports an h index, which shows how many publications have been cited at least 10 times. Journals have a citation-based metric, too — the impact factor (IF). Yet another, Altmetrics, uses social media shares and likes, together with citations, to assess the reach of a published paper. Importantly, decisions may turn on these measures.

They influence how an individual is promoted or evaluated for tenure within a university, for example, or whether or not a project gets funding. Laubichler and SFI President David Krakauer, a biologist at Arizona State University and an SFI External Professor, the increased reliance on these metrics is a worrying trend. That dependence risks collapsing judgment and impact. “We have basically outsourced what is the core activity of science, namely to judge the future direction of science,” he says. These metrics may fail to recognize novel ideas or innovative approaches, especially in interdisciplinary fields that aren’t easily categorized.

Laubichler and SFI President David Krakauer suspect that the tools of complexity science can help. They’ve organized a workshop, scheduled for early April at SFI, designed to explore questions about scientific value. “The goal is to basically first get some clarity about what we actually mean by impact, and what judgment means, in the context of the type of science we are pursuing at the SFI,” Laubichler says. The workshop will bring together researchers in complexity science with institutional leaders to start a conversation about reframing the problem of measuring impact. Laubichler says the group will look to the tools of complexity for insights into how to improve judgment. Laubichler hopes the discussion will spur ideas about new ways of measuring value. “We’ll be attempting to create new metrics that actually represent the values we advocate for in the kind of work we’re doing,” he says.

Complexity postdocs reconvene in March

The Santa Fe Institute and James S. McDonnell Foundation (SIIJM) are reconvening their postdoctoral fellows for the third bi-annual Postdocs in Complexity Conference on March 27-30 in Santa Fe. The conference is generously funded by SIIJM.

During the four-day postdoc conference, early-career complexity scientists share ideas and collaborate on projects, and learn from researchers from within the SFI and SIIJM communities and the corporate world.

This year’s talks will revisit several themes from previous conferences and introduce new topics, like SFI External Professor Michael Hochberg’s talk on academic publishing. “Although early-career scientists may already have authorship experience, it can be highly challenging to navigate the world of scientific publishing,” says Hochberg, who is also the founding editor of Ecology Letters. His talk will explore what scientific journals are looking for and how to use them to better disseminate research work, published, the use of social media, and what to expect in the future of publishing.

The postdocs will also meet for four research jam sessions, working in small groups to tackle research questions. But unlike previous meetings, where groups rotated through different topics, this year’s groups will each focus on a single topic.

“There was a desire to have more goal-oriented research exercises,” says Hilary Skolnik, SFI’s Postdoctoral Fellows Program Manager. The goal for this year’s research jam sessions will be to work toward producing something substantial, like papers for publication or proposals for funding.

Two new trustees elected to SFI’s Board

The Santa Fe Institute’s Board of Trustees has welcomed two new members. Bill Gurley of Benchmark Capital and James Pallotta of Raptor Group were elected to the Board during the Institute’s annual Applied Complexity Network and Trustees Symposium on November 5, 2017.

A long-time venture capitalist, Gurley has drawn inspiration from complexity science throughout his career. “As early as 1995, I was fortunate enough to begin a career on Wall Street and was seated near Michael Mauboussin, now the chair of the Board of Trustees at the Institute. We both shared a fascination with learning, and shortly after we met we both consumed Mitchell Waldrop’s Complexity, a book about the rise of the Santa Fe Institute. SFI External Professor Brian Arthur’s work on increasing returns and his essay in Harvard Business Review, edited by Cormac McCarthy, were mind-blowing,” Gurley recounts. “I often tell people that this single book has had a bigger impact on how I think about the world than anything else I have ever read. The concept of ‘networks borrowed’ from Complexity and SFI have been alongside me for my entire venture career, and have played a key role in how I think about markets, strategies, and competitive advantage. I couldn’t be more excited about joining SFI as a trustee.”

Gurley has spent 18 years as a general partner at Benchmark, joining in 1999. Over his venture career, he has invested in and served on the boards of such companies as jpmorgan (JPM), MDT, Aig, byEAI, CrutchHub (IPG/GRUB), Nexxstax, OpenTable (IPG/IPEN, Aig byPrinceton), StitchFix, Uber, and Zillow.com (ZPO). Before entering the venture capital business, Gurley spent four years on Wall Street as an "Institutional Investor"-ranked research analyst, including three years at CS First Boston. He also worked as the lead analyst on Amazon’s IPO.

Pallotta is founder, chairman, and managing director of the Boston-based Raptor Group, a diversified financial services firm that provides investment management and advisory services. In his portfolio management role at Raptor Capital Management LP, he manages individual, institutional, and his own personal capital.

He is President and Chairman of the professional Italian football club AS Roma, as well as co-owner and executive board member of the Boston Celtics. He is known for his philanthropy, giving millions each year through his charitable trust. “It is a pleasure to formally welcome Bill and Jim to the SFI community,” says Michael Mauboussin, Chair of SFI’s Board of Trustees and Director of Research at BlueMountain Capital. “These are legendary investors with deep intellectual curiosity. They appreciate the importance of rigorous research in complex systems that defies disciplinary boundaries. We are very excited to have them on the board.”

The Santa Fe Institute’s Board of Trustees, which has fiduciary responsibility for the Institute, oversees SFI’s operations through its biannual jam sessions, working in small groups to tackle research questions. But unlike previous meetings, where groups rotated through different topics, this year’s groups will each focus on a single topic.

“Laubichler hopes the discussion will spur ideas about new ways of measuring value. “We’ll be attempting to create new metrics that actually represent the values we advocate for in the kind of work we’re doing,” he says.”

Research NEWs Briefs

RESEARCH NEWS BRIEFS

A map of London, colored to show the distortion of travel the routes through a central point. (Image: Hugo Serrano (University of Rochester), co-author of “ Morphology of travel routes and the organisation of cities” with Hyphen Yuang)

THE CITY CENTRAL

How can we tell if a city is centralized? Hyejin Youn (Northeastern University), a former SFI Postdoctoral Fellow, and her co-authors on a new paper in Nature Communications offer a way to quantify city centralization by looking at geometric shapes of travel routes. That geometric shape can give you insight into whether there is a positive force at the center to attract the edges, it curves outward if a negative force at the center repels. It’s an example of social physics, says Youn — like observing the deflection of sunlight by gravity to prove the general relativity theory, we can observe human mobility as it responds to a force, or positive externality, revealed by infrastructure, like roads.

VIVE l’INNOVATION

As the first parliament of the French Revolution navigated its way into a new democratic system of governance and out of monarchy, more than one thousand speakers debated how to reinvent the relationship between individuals and the state. In a paper published in October on the arXiv pre-print server, SFI External Professor Simon DeDeo (Carnegie Mellon University) and co-authors analyzed reconstructed transcripts from the 40,000-plus speeches made in early years of that parliament. Using new techniques in information theory that draw on social science, the authors tracked how new speech pattern and novel ideas arose while old patterns faded from the discussion. The paper was listed in MIT Technology Review’s “Best of the Physics arXiv” for the week of October 26, 2017.

NEW TOOLS FOR STUDYING ANIMAL SOCiALITY

Somewhere between million-node social media networks and the dozen nodes of a wolf pack, there’s a little-explored sphere of social experience. In their recent Animal Behaviour paper, SFI-ASU Postdoctoral Fellow Elizabeth Hobson and co-author David McDonald (University of Wyoming) developed network analysis tools to explore how relationship strengths vary across micro, meso, and macro levels of animal sociality — for example, between an individual and its community, or between a community of individuals and the social network of the entire group. The new tools, adapted from population genetics, could allow researchers to understand whether differences in social environments experienced by a particular animal are the result of individual quirks or are general characteristics of the social organization. The authors successfully applied their metrics to data from three known animal social networks and discussed how their innovation offers a quantitative method to study disease transmission, social complexity, and the flow of information in animal social networks.

COUNTER-INTUITIVE COARSE-GRAINING

The Blackwell order in information theory considers two channels that convey the same information — for example, two phone lines — and states that if one channel’s output is a garbled, or noisy, version of another, then that channel is a “Blackwell inferior,” and therefore typically less capable. There have been some known exceptions to this rule, but in their entry paper, SFI Professor David Wolpert and co-authors present an even more surprising one. They show that pre-garbling a signal through coarse-graining — a process of simplifying a signal that usually results in a loss of information — can actually lead to a superior channel. This discovery offers important new insights for the development of measures of scientific impact.
The 2018 SFI Alumni Fiesta

Calling all former SFI postdoctoral fellows, REUs, Santa Fe School students, and faculty! We’re hosting a reunion, and we hope you can come.

Thirty years ago, in the summer of 1988, the first Complex Systems Summer School was held at the base of the Sangre de Cristo Mountains, marking the beginning of SFI Education. In the three decades since, roughly 4,000 aspiring scientists have gained experience through SFI’s fellowships and face-to-face educational programs.

To celebrate, we’re planning the first SFI Alumni Fiesta, July 6-8. It will be a chance to reconnect in Santa Fe, meet people from other programs, and share some big and creative ideas.

“It’s a combination reunion, conference, networking event, and collaboration space,” says Paul Hooper, Director of Education, a former Omidyar Fellow and summer school alum. “It’s an opportunity for SFI to check in with our alumni and take stock of the impact our programs have had.”

We’ll kick off the Fiesta with a reception at SFI and continue with two days of talks, exchange, and collaborative events in Santa Fe. Hooper hopes these interactions will offer opportunities for alumni to share current work, brainstorm nascent ideas, and spur new collaborations.

“This event is really about connecting people and supporting the community of folks interested in complexity sciences,” says Hooper. The Fiesta will follow immediately on the heels of the 2018 Complex Systems Summer School, and participating students are encouraged to stick around for the fun.

Alumni can watch for a Save-the-Date invitation and a link to pre-register for the Fiesta — if we don’t have your current email address, just reach out to us at santafe.edu/alumni!

The first annual InterPlanetary Festival

Santa Fe Institute’s first annual InterPlanetary Festival will draw space enthusiasts from around the world for a two-day celebration of human ingenuity June 7-8, 2018, in Santa Fe, NM. The festival will transform the Railyard District in downtown Santa Fe with an expo showcasing innovation and technology for space exploration.

Concurrent with the expo, participants can enjoy open-air concerts, maker spaces, lectures, panel discussions, food, beer, and citizen science projects and games centered around InterPlanetary topics.

“This is a festival where we’re asking people to come and have fun, but also to contribute towards a global challenge of becoming an InterPlanetary civilization,” says SFI President David Krakauer.

As a global destination for both the arts and sciences, Santa Fe is the ideal location for a festival that celebrates innovation across these domains. The InterPlanetary Festival coincides with the opening of the CURRENTS New Media art installation and the inaugural National Maker’s Conference (NOMCON) in Santa Fe.

“The arts — visual arts, cinematic, literary, musical — expand our imaginations and they explore convictions that we don’t even know exist,” Ark, he says, plays a critical role in the InterPlanetary Project.

“We now as researchers need to reach out to a broader base in order to address complex issues such as resource use, economic inequality, and climate change,” Krakauer says. “One way to bring people together is to make the science very aspirational. Posing an InterPlanetary challenge brings the best minds to the table and also has the virtue of potentially producing an InterPlanetary civilization.”

If you or your organization would like to support or be involved in the 2018 inaugural InterPlanetary Festival, please contact Carlin McKee or carlin.mckee@santafe.edu or call 505.946.3651.