SOCIETY OF ACTUARIES

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Complexity Sciences—Simplified!

By Dave Snell

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What do deterministic chaos, behavioral economics, fractal geometry and genetic algorithms have in common? Aside from their potentially high scores on a Scrabble board, they are all (arguably) part of the fascinating set of topics some of us have chosen to include under the heading of complexity sciences. Along with other multisyllabic mouthfuls such as predictive modeling, network theory and cellular automata, these topics were discussed in a very popular two-part presentation on complexity science tools at the SOA Annual Meeting in New York City last October.

The Actuary of the Future, Forecasting and Futurism, and Health Sections joined forces to sponsor two sessions: "Complexity Science: What It Is and Why You Want to Know About It," which was followed by "Solving Actuarial Problems with Complexity Science."

Why would three sections wish to go in together for two sessions at the annual meeting? I think we all saw the potential for a set of tools that may be very useful supplements to our classical set of actuarial forecasting and modeling techniques.

Dave Snell

Jennifer McGinnis moderated the first session, and I was honored to be the presenter. We covered the ideas behind the names and briefly summarized what they were and how they might be useful to actuaries. Naturally, we did not have time to go into a lot of depth on any one topic in the limited time. For example, Stephen Wolfram wrote a 1,200-page book on cellular automata (*A New Kind of Science*), which he described as an introduction to that topic; and in the first session my presentation on cellular automata was only five minutes long. However, attendee feedback suggests that we did demystify at least the majority of topics and we piqued the interest of many actuaries to pursue further study of them.

A gross oversimplification of the difference between these tools and our more familiar modeling tools would be that classical actuarial models employ deterministic methods, while complexity science tools seem to be more oriented toward inductive methods. For example, actuaries build sophisticated theoretical models and then we assume that the world will conform to them. That may seem to happen for a while, and then we are rudely surprised when an outlier event (à la Nassim Taleb, *The Black Swan*) occurs that seems to cascade the tails of our probability curves over one another like a set of dominoes. As Yogi Berra so aptly said, "It's tough to make predictions, especially about the future." He is also known for his comment that "[t]he future ain't what it used to be."

Well friends, the future is not what it used to be; and the tools we used to use to model it may be necessary but not sufficient to continue to model it and manage risk to the degree we as actuaries have thought we could manage it in the past.

I don't know how to squeeze two 90-minute sessions into a newsletter article, but I do have some good news for those who missed the presentations and would like another chance at them. We were asked to repeat them at the Life & Annuity Symposium in New Orleans, May 16–17, and at the Health Meeting in Boston, June 13–15; and these sessions were videotaped. They are available for purchase at *http://www.soa.org/recordings*. We are also repeating the first session at the 2011 Annual Meeting in Chicago. If you can make it, we would love to be able to spread the word to you.

In the meantime, here is a very simplified explanation of the fancy phrases I mentioned at the beginning of this article:

Deterministic Chaos—Many seemingly simple equations and models are highly dependent upon starting assump-

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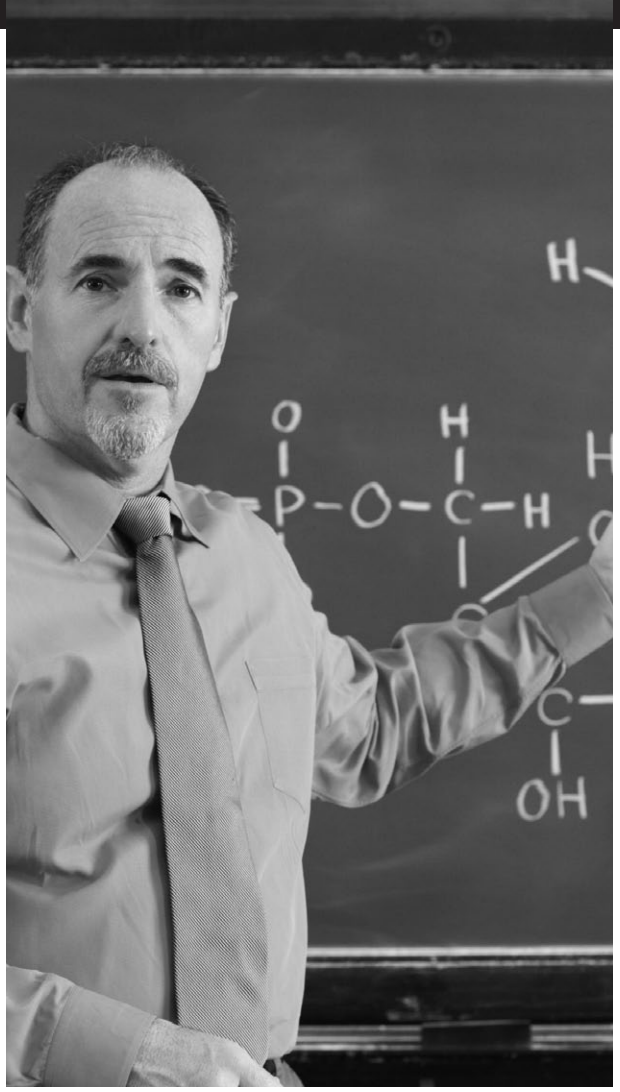

tions and precision. Even though it has no teeth as we know them, a butterfly effect can bite you. Our session examples included a simple equation of population growth that defies intuition; and a one-notch rating change that sent a 30-billion-dollar insurance company into receivership.

Behavioral Economics—Human beings are irrational—sometimes predictably so (see Dan Ariely's *Predictably Irrational*), and they do not always base their financial decisions on logic or self-interest. We showed some examples you can use in your product pricing, in your policy applications and in your dating strategies.

Fractal Geometry—We look back at the Pythagoreans and wonder how they could deny the existence of irrational numbers, or Descartes' later aversion to imaginary numbers; yet we steadfastly cling to Euclid's 2,000-year-old notion that dimensions ought to remain integers. We showed how pervasive the fractional dimensions are, and offered some applications to stock market analysis and to life itself!

Genetic Algorithms—Some actuarial problems have no clear deterministic solution, and an exhaustive search is beyond computational capabilities; yet we showed how a very simple set of rules and a technique mimicking evolutionary survival of the fittest can arrive at very practical solutions in real time. The sessions also introduced a sample workbook for attendees to use for learning genetic algorithm programming, and a practical hedging example by Ben Wadsley that his company uses to reduce economic capital requirements.

Predictive Modeling—Property and casualty companies have been employing inferential techniques where they learn from the data and win more good cases and more importantly lose more bad cases. We showed one company's phenomenal success with automobile insurance and also how Australian police used this technique to catch a serial killer.

Network Theory—We traced some effective tools used to spread a major religion, and showed the strength and the vulnerabilities of the North American power grid, our global airline routes and the Internet.

Cellular Automata—A nonconventional graphic artist used simple rules and the interactions of 'boids' to simulate bird flocking even though the physics behind the actions were far too complicated to compute. Current applications include major health company cost measures and a trading model that brought significant advantages to a global bank.

Again, the major point of the sessions is not to make you an expert in any of these new techniques, but to take away some of the hype both for and against their use in actuarial settings and to help you become better informed and excited about new tools and techniques that other scientific disciplines are embracing and using to great advantage. I think the years 2010 and 2011 will be viewed as the tipping point (Malcolm Gladwell, *The Tipping Point*) for actuaries to add these very powerful tools to our tool set. Don't be left behind!

Please check out the following for further introductory readings about complexity science.

CONTINUED ON **PAGE 24**

COMPLEXITY SCIENCES … | FROM PAGE 23

Recommended Book List to Get Started with Complexity Sciences

Summary of some recent complexity science sources I recommend:

- ***Complexity Science—An Introduction (and Invitation) for Actuaries***, by Alan Mills, commissioned by the Health Section *http://www.soa.org/research/research-projects/health/research-complexity-science.aspx*—an excellent way to get started.
- ***Complexity: A Guided Tour***, by Melanie Mitchell, is an excellent overview; and also describes the original Robby experiment. I wrote a review of it on *Amazon.com.*
- At the easy end of the spectrum, ***Complexity The Emerging Science at the Edge of Order and Chaos*** by M. Mitchell Waldrop, gives a nice history of the Santa Fe Institute (SFI). It is less technical than Melanie Mitchell's book, but still a good read.
- ***The Perfect Swarm: The Science of Complexity in Everyday Life***, by Len Fisher, is another easy read and it gives a good picture of the value of networks, and also some behavioral economics.
- ***The Smart Swarm: How Understanding Flocks, Schools, and Colonies Can Make Us Better at Communicating, Decision Making, and Getting Things Done***, by Peter Miller, describes a highly readable set of examples of ant colony optimization techniques and other ways we can learn so much from ants, bees, termites, birds and locusts.
- Also on behavioral economics is ***Predictably Irrational: The Hidden Forces that Shape our Decisions***, by Dan Ariely. The MIT test experiment was from Ariely's book.
- ***Simply Complexity: A Clear Guide to Complexity Theory***, by Neil Johnson, gives an excellent example of deterministic chaos, and it refutes some commonly held but incorrect views about complexity science.
- ***Complex Adaptive Systems: An Introduction to Computational Models of Social Life***, by John Miller and Scott Page, gets into more of the details of complex systems. I just purchased it so I can't comment on actual value yet; but scanning through it, it seems good.
- Another interesting book on behavioral science is ***Priceless***, by William Poundstone. He is also the author of ***Fortune's Formula***, another favorite of mine.
- ***Linked: The New Science of Networks***, by Albert-Laszlo Barabasi, gives lots of examples (like the spread of Christianity example) of networks and network theory along with the history of the major developments in it.
- ***Kludge: The Haphazard Construction of the Human Mind***, by Gary Marcus, makes a great case for evolution and how the human mind, like the body, is still quite imperfect and in a state of development for the higher intelligence functions like language and art.
- ***The Origin of Wealth***, by Eric Beinhocker, is an excellent intellectual history of economics and of the new science of complexity economics. The title is unfortunate. I would have called it "The Foundations of Classical Economics—and Why They Were Wrong." The anchoring example is from here.
- ***Agent-Based Models,*** by Nigel Gilbert, is concise but meaty. I think it is a good read after an overview book such as Melanie Mitchell's ***Complexity: A Guided Tour***.
- ***A New Kind of Science***, by Stephen Wolfram, is 1,200 pages on cellular automata (CA) and probably the seminal work reference for CA studies; but it is a tough read and he is overflowing with hubris so at times he seems a bit over the top. I had to think about it a lot before starting to appreciate it.
- ***Complexity and Chaos***, by Roger White, is an audio book (*www.audible.com*) with a good overview and some passages actually spoken by the scientists who made the discoveries (the accents are sometimes hard to follow; but then again, those are the ones that are read by the real scientists).
- Another interesting audio book recently was ***The Nature of Technology***, by Brian Arthur (mostly history of Santa Fe Institute); and still another is ***The***

Numerati, by Stephen Baker (Big Brother is here, and watching us all).

- An old favorite that predates the term complexity science, but helped bring it about, was ***Gödel, Escher, Bach: An Eternal Golden Braid***, by Douglas Hofstadter. This was the inspiration for Melanie Mitchell to study under Hofstadter and John Holland, a founder of complex adaptive systems.

Free Software

XAOS: *http://fractalfoundation.org/resources/fractal-software/* Great introduction to fractals.

NetLogo: *http://ccl.northwestern.edu/netlogo* Simple modeling language.

StarLogo: *http://education.mit.edu/starlogo/*

Repast Simphony: *http://repast.sourceforge.net/*

Robby—an Excel 2007 workbook to demonstrate genetic algorithms, from dave@actuariesandtechnology.com.

Newsletter articles from the Forecasting and Futurism Section:
http://www.soa.org/library/newsletters/forecasting-futurism/september/ffn-2009-iss1.pdf

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