Article from:

Actuary of the Future

May 2012 – Issue 32

New Tools and Techniques for Actuaries Living in a Complex World

by Dave Snell

Actuaries are very good at building mathematical models to simulate the financial impact of real world risks. It is important to remember though, that a model is not reality. If it were, it would no longer be just a model.

When we build our models, we have to make simplifying assumptions. We assume a set of variables to represent the real world situation. Then we assume the values of these key variables and the relationships between them. Over the years, our actuarial models have served us well. Sometimes, however, we discover that the world does not conform to them as well as we had hoped and expected.

Complexity sciences provide complementary ways to test, or extend our models to address situations where classical deterministic mathematical techniques sometimes do not adequately anticipate unusual situations. Nassim Taleb, in his popular book, The Black Swan, contends that financial models are defective in that they seem to be unable to predict the occurrence of highly improbable but very significant events. We believe that actuarial models are useful and necessary, but perhaps not sufficient to cover these outlier events that can have a great impact on results, yet occur under unusual circumstances. It is not likely that we will ever be able to accurately model the world well enough to predict all the outlier events. A goal of complexity tools is to help us anticipate them a bit sooner than usual – perhaps soon enough to develop mitigation strategies so that their impact is not as severe.

Examples abound: Many lives could have been saved if the Katrina hurricane disaster could have been anticipated a few weeks sooner. The economic crisis of 2008 could have been lessened if the collapse of interrelated securities markets could have been more widely noticed sooner.

Over the past 25 years, several other fields of study have been embracing inductive techniques that seem to take a bottom-up rather than top-down look at the complex relationships of our increasingly complex world. Some have categorized them under the general heading of complexity science (or even complexity sciences) since they attempt to recognize some aspects of the complex nature of interrelationships. Below I describe a small group of terms that have gained favor in sociology, physics, engineering, anthropology and several other fields of study. We feel that they should also be of interest to actuaries. The important point is not whether they fit a strict definition of complexity science (which is still under debate), but whether they may be of use to you as a complement to your classical deterministic actuarial techniques:

Deterministic Chaos – One of the early population growth equations, the logistics map, was published in 1838. It is a very simple equation: $x(t+1)=R*x(t)[1-x(t)]$, where R is a constant, and x(t). When R is small, say R=2, it does not matter what starting value you choose

Dave Snell, ASA, MAAA, is technology evangelist with RGA Reinsurance Company in Chesterfield, Mo. He can be reached at dsnell@rgare.com.

CONTINUED ON **PAGE 20**

for x(0). The resulting iterations will always converge to a single attractor of 0.5. As R increases every so often, according to Feigenbaum's constant (4.6692016) the number of attractors doubles and the later iterations oscillate between them. Once R reaches 4, the later durations become hypersensitive to the starting value. A starting value difference of 0.0000000001 will have very noticeable impact on the later duration values. The implication for actuarial models, which may be far more complicated than the logistic equation, is that very small variations in starting values may have huge unforeseen consequences. Read more about the science of *Chaos Theory in Chaos: Making a New Science,* by James Gleick.

IN THE LIFE ACTUARIAL ENVIRONMENT, PREDICTIVE MODELING IS A POTENTIALLY USEFUL TOOL, BUT MANY PEOPLE HAVE RAISED CONCERNS ABOUT ITS APPROPRIATENESS FROM A LEGAL AND ETHICAL CONCERN.

Predictive Modeling – In many actuarial models, we look at data and 'fit' this data into a mathematical model that presumes a deterministic causal relationship. Y is some function of X. The relationship is then used to predict a future outcome. In predictive modeling, the underlying data may or may not have some discernible causal relationship, but the outcome can be inferred from the clustering of the data itself. In essence, the data becomes the model. Auto insurance companies have embraced this technique and use it extensively. In the life actuarial environment, predictive modeling is a potentially useful tool, but many people have raised concerns about its appropriateness from a legal and ethical concern. Predictive modeling texts abound and are often found under searches for detection theory, data mining, and customer relationship management.

Network Theory – Networks cross many science boundaries and the key elements go by many names: vertex and edge (geometry); site and bond (physics); website and hyperlink (); neuron and synapse (anatomy); actor and tie (sociology) etc. but the basic idea is that a network has locations and it has connections between those locations. The strength of a network is its usual fault tolerance. Random hits may take out as many as 80 percent of the locations and the network will still have functionality. The weakness of a network is its vulnerability to targeted hits. Some locations have far more connections than others and targeted hits may take out just one, or a few of them and cause chaos. Network theory applies way beyond computer networks – to power grids, supply chains, air traffic and organizational dynamics. A good start on network theory can be found in *Linked: The New Science of Networks,* by Albert-Laszlo Barabasi.

Fractals – Fractals have emerged as a lot more than pretty pictures. In recent years we have learned that many aspects of life, such as trees, our lungs, and life itself – our DNA strands, all follow a fractal pattern. Furthermore, many mathematicians make the argument that stock prices and financial instruments exhibit fractal tendencies. Fractals involve what are called fractional dimensions, which are a disturbing deviation from the Euclidian geometry we learned in grade school. Yet in many mathematical circles, the Hausdorff-Besicovitch dimension has gained favor over the former ideas of dimensionality. Actuaries may find readings such as *The Misbehavior of Markets: A Fractal View of Financial Turbulence,* by Benoit Mandelbrot, an interesting read.

Behavioral Economics – A long-standing assumption in economic and actuarial models has been that people always act in their own self-interest. Yet recent researchers have shown that to be a false assumption. Humans tend to be conditional cooperators, who will go out their way to help someone they believe has their best interest at heart, and altruistic punishers, who will strike back at those perceived to behave unfairly – even at the expense of their own immediate interests. Behavioral science addresses the many ways that we are manipulated to do things contrary to our assumptions of rationality. *Predictably Irrational, the Hidden Forces that Shape our*

Decisions, by Dan Ariely gives an excellent introduction to this important science that can help actuaries get more honest information from insurance applicants and make better modeling assumptions.

Genetic Algorithms – Some problems have a relatively small number of variables and a solution can be derived theoretically. Others may have a limited number of solutions and all of them can be tested to see which one is optimal. However, if the potential interrelationships between variables are too complex for a direct theoretical approach and the number of possible solutions is too large for an exhaustive search in real time, then the problem may be a good candidate for a genetic algorithm solution. In this approach, you can define your restrictions (such as boundary conditions) and then randomly assign a case table of actions for various conditions. Run several hypothetical robots through the trials, grade the results, and let the winners survive to another generation and even propagate offspring via gene splitting. In a sense this is mimicking our genetic evolution for a very small universe that we define. Over the course of hundreds or thousands of generations, the robots develop solutions that are often far superior to those that we would derive from our theory. *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.*

Cellular Automata – The most famous book on cellular automata is *A New Kind of Science,* by Stephen Wolfram. In one sense, cellular automata are very simple applications of very simple rules. Yet in another, they can be thought of as a dimensional extension of genetic algorithms. Instead of a generation of robots each acting on their own, in a cellular automata simulation all of the generation interacts with one another. They cooperate, they compete for scarce resources and they form alliances. Wolfram is convinced that this is the most important science of all and that all others can be derived from it. He predicts that the children of 2056 will learn cellular automata before they learn algebra.

This is, by no means, an exhaustive list of newer techniques for actuaries. Our complex society has spawned several nontraditional tools such as Serious Games, Delphi Studies and a host of other innovative ways of approaching the current and anticipated problems of risk management. The important thing to remember is to keep an open mind to new developments in fields outside of the mainstream actuarial literature. It's an exciting. Enjoy it! Continue your education beyond study notes. ☆