SOCIETY OF ACTUARIES Forecasting and Futurism Section

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Forecasting & Futurism

NEWSLETTER

Are Genetic Algorithms Even Applicable to Actuaries?

By Ben Wadsley

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NEWSLETTER

FROM THE EDITOR

Look! Up in the Sky! …
It's Super Actuary!

By Dave Snell

The television series "Numb3rs" was the most popular Friday evening show for its first four (of six) seasons. At first, the idea of a mathematician superhero crime fighter seemed a bit far-fetched. After all, the idea of using tools such as sabermetrics, predictive analytics, neural networks, Kohonen self-organizing maps, Riemann's hypothesis, and thought experiments such as the prisoner's dilemma in something as real-world as police work just was not the time-proven way to fight crime.

Then I read the book, *The Numbers Behind Numb3rs—Solving Crime with Mathematics,* by Keith Devlin and Gary Lorden. It turns out that the television series did inject a lot of drama to make the shows popular. However, they were careful to make sure the mathematics used was correct and that the applications were indeed possible. Some episodes were based on actual cases. At least one episode mentioned actuaries.

Surely, it was a stretch for traditional police departments to embrace these new techniques. They had a comfort level with their classical methods, which had been honed and vetted over many years. Why try new methods when the old ones still worked fine for many situations?

It is easy for us actuaries to realize that the initial resistance of law enforcement agencies to new scientific applications of mathematics was naive. We might attribute their reluctance to inertia, fear of the unknown, a less-mathematical orientation and a general resentment of the learning curves involved.

Yet, how many of us are feeling the same kinds of reluctance to try the new complexity science techniques to supplement our tool kit of classical actuarial methodologies?

In this issue, we have articles about some techniques you may consider too academic to be of use in your real-world pricing and valuation models. Yet the fact is that more and more other professions are making the effort to try them—and sometimes they are reaping high tangible rewards for their investment.

Our lead article is about genetic algorithms. In "Are Genetic Algorithms Even Applicable to Actuaries?" Ben Wadsley describes how he has been using them to reduce economic capital requirements. Ben's article was originally published in the February 2011 issue of the Investment Section newsletter, *Risks & Rewards,* and won the best article award for that issue. Many actuaries have watched us talk about

CONTINUED ON **PAGE 4**

Robby the Robot, and how a basic genetic algorithm works; and then they ask "yes, but do you have any actuarial applications?" Ben describes a genetic algorithm that did a better job of bond portfolio distribution for asset-liability management (ALM) than human actuaries did!

Another contribution is from Scott McInturff. He describes the value of collective intelligence in his engaging review of *The Perfect Swarm: The Science of Complexity in Everyday Life* by Len Fisher. Scott's review cites examples from bee colonies, to UPS drivers, to Wikipedia—a diverse spectrum of applicability for the phenomenon of "group dynamics and the power of a diverse group to apply individual intelligence to produce results superior to that of any individual in the group."

Min Deng, our co-coordinator of education, writes about the ways she is bringing complexity science into the actuarial curriculum at the university level ("Complexity Science Enters the Actuarial Classrooms"), to give her students a head start on techniques beyond the current actuarial study notes. Her program involves making use of local actuaries to introduce her students to ways they build upon the basics, and extend them for real business advantages.

Frank Grossman is a frequent contributor to the Management & Personal Development Section newsletter; but for us, he has written an engaging article questioning our continued complacency in assuming continual improvement in mortality. In "An Alternate View of Future Mortality," he provides insightful counterpoint to our customary extrapolation of past improvements. If you are a fan, as I am, of Michael Pollan's books (such as *The Botany of Desire*) that warn of the dangers of a monoculture food supply, you may find this especially thought-provoking.

In my article, "Complexity Science—Simplified," I have summarized one of our annual meeting sessions: "Complexity Science —What It Is and Why You Want to Know about It." This was a jointly sponsored session where we teamed up with the Actuary of the Future (AoF) Section and the Health Section; I wrote an earlier version for AoF's newsletter. The turnout at this session (over 200 attendees) and our follow-up session (with Ben Wadsley and Steve Conwill) drew many more actuaries than we expected—suggesting that a lot of you are at least curious, and perhaps willing to give these new techniques a try.

We are also including the winning article from our Forecasting & Futurism Contest. The goal was to write an article about judgmental forecasting, and Doug King is now the proud winner of an Apple iPad. Read his "Judgmental Forecasting in Determining Policyholder Behavior Assumptions" to see how he successfully incorporated the many judgmental techniques that Alan Mills described in our June 2010 issue.

Ben Wadsley's Chairperson's Corner column is upbeat and inspiring—and appropriately so! The section has blossomed over the past year. We are one of the few sections to be increasing in membership; and the increase was significant. Two years ago, we were in danger of dropping below the 500-member threshold to remain viable as a section. Now we are comfortably over 600 members, and still growing.

We are committed to breaking down silos between Society of Actuaries (SOA) sections; and the sharing of ideas and articles with other sections is one aspect of that initiative. Please give all of these articles a try. You may find that you get an idea about how to implement a new technique in a way never thought of before.

Perhaps the next television series can be about a superhero actuary! ▼

Dave Snell

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FROM THE CHAIRPERSON

Moving the Ball Forward

By Ben Wadsley

Forecasting and Futurism Section members,

2010 was a great year for our section. Through our newsletter, life & annuity symposium sessions, annual meeting sessions and forecasting competition, we have advanced the discussion of forecasting, futurism and most recently complexity science in the actuarial profession.

The credit for this success can only be given to the volunteers and Society of Actuaries (SOA) staff who have worked so hard to help move us toward our section's vision. Every contribution helps—all the way from being on the section council to commenting on an SOA meeting session.

As my time on the Forecasting and Futurism Section Council winds down this year, one thing I'd like to emphasize is that I've gotten much more from my volunteer experience than I've given. Three years ago I meekly entered the council elections encouraged by my mentor, Kevin Strobel. While I was initially looking for not much more than to get the "participation medal," I soon found myself involved in a few projects.

The amazing part happened when the projects turned from extra work into topics that I was truly passionate about. The genetic algorithm application that I was developing on the weekends quickly became a powerful tool that I (and hopefully many others) currently use on a regular basis. The complexity science discussions and research I've done with Dave Snell have changed the way I think about many real-world problems.

The main point behind my story is that for me the decision point of whether or not to be a mere participant in our section made a difference in my personal development as well as (hopefully) the profession. I hope that each of you considers the same call to volunteer and advance thought leadership. Especially with the emergence of complexity science and many other underutilized tools, there are plenty of spaces for new thought leaders.

Moving forward, our vision remains the same—to advance the profession and provide knowledge to our members. We hope you took advantage of the activities that we have offered in 2011 and that you are excited about the others planned to continue this mission.

1. Meeting sessions at three meetings, with topics spanning complexity science, behavioral economics and much more.
2. Forecasting competitions.
3. Exciting research.
4. Virtual sessions/online learning opportunities.
5. Much more!

If you'd like to learn more about any of our activities, visit our website at *www.soa.org/professional-interests/futurism/fut-detail.aspx*. Also, if you'd like to get involved in any of the above activities, please email me at *bwadsley@aegonusa.com.*

I'm looking forward to more great things from our section. Please consider joining the game instead of just watching it. Let's keep moving the ball forward! ▼

Ben Wadsley

Ben Wadsley

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Are Genetic Algorithms Even Applicable to Actuaries?

By Ben Wadsley

Editor's Note: *This article was first published in the February 2011 issue of* Risks & Rewards, *the Society of Actuaries' (SOA) Investment Section newsletter. Since publication in* Risk & Rewards, *some updates have been incorporated.*

Several professional fields are currently using genetic algorithms for different applications. Genetic algorithms are being used to plan airplane routes,[1] develop equity market bidding strategies,[2] point antennae on military vehicles,[3] optimize an iterative prisoner's dilemma strategy,[4] and even work toward developing artificial intelligence.[5] While these applications are very useful to other professions—and quite interesting to study—they don't seem to have anything to do with actuaries. As I was being introduced to the idea of genetic algorithms through the Forecasting and Futurism Section of the SOA, my main question was, "If these people are so successful in using genetic algorithms, why can't actuaries?"

This essay intends to answer the question: "Are genetic algorithms even applicable to actuaries?" by first walking through the example of "Robby the Robot" as derived from the example in Melanie Mitchell's *Complexity, A Guided Tour*.[6] Also, I will look at what characteristics of this application are useful and then apply those characteristics to an example based on my use of this technique to solve a life insurance asset and liability management (ALM) problem. The goal is not only to describe one use of genetic algorithms, but also to help the reader explore this thought experiment and discover how genetic algorithms can be expanded to solve many other actuarial problems.

AS I WAS BEING INTRODUCED TO THE IDEA OF GENETIC ALGORITHMS THROUGH THE FORECASTING AND FUTURISM SECTION OF THE SOA, MY MAIN QUESTION WAS, "IF THESE PEOPLE ARE SO SUCCESSFUL IN USING GENETIC ALGORITHMS, WHY CAN'T ACTUARIES?"

What is a Genetic Algorithm?

There are many different varieties of corn—some that are wind-resistant and some that produce many ears of corn. The objective of a seed corn company is to breed the two types of corn to hopefully develop a variety of corn that both produces a lot of corn and is wind-resistant. This is the exact idea that is being leveraged with the use of genetic algorithms—except instead of corn we are breeding computer programs and investment strategies.

"Robby the Robot"

Robby the Robot is a great example through which the steps of implementing a genetic algorithm can be learned. Robby lives in a two-dimensional 10x10 matrix that is littered with empty soda cans. In this twist on Mitchell's example, Robby's job is to pick up the soda cans from the grid with increasing efficiency, while being blind and having no initial intelligence. Below is the process used to train Robby's brain through genetic algorithms *(See illustration on page 7):*

1. Generate an initial population of solutions. This is done by creating random 'individuals' from the universe of possible solutions. An important step here is the definition of individuals; in this case they are defined as different sequences of actions Robby can take. They are defined by a string of numbers that represent several actions {12315…} where 1=bend over to pick up can, 2=move north, 3=move east, etc.

2. Calculate the 'fitness' of each individual in the current population. The fitness is defined by how well the solution performed, defined here by how efficient Robby's actions are. He receives +10 points for picking up a can, -1 point for bending over to pick up a can when there isn't a can there, and -5 points for running into a wall.

3. Select some number of individuals to become parents of the next generation. These parents are selected by using a 'fitness function' that gives the individual a higher probability of being selected if it has a higher fitness as calculated in step 2.

4. Pair up the selected parents through 'recombining' parts of the parents to make offspring. The offspring then mutate with a given probability. Recombining can be done in many ways, but is done here by taking a portion of the string from parent #1 and a portion from parent #2, creating offspring #1, and using the unused portion of the parent strings to form offspring #2. Mutation is done by randomly changing portions of the strings. Inspired by nature, mutation maintains diversity in the population and prevents the population from converging too quickly.

5. Repeat steps 2–4 for a specified number of generations, or until a sufficient fitness is achieved.

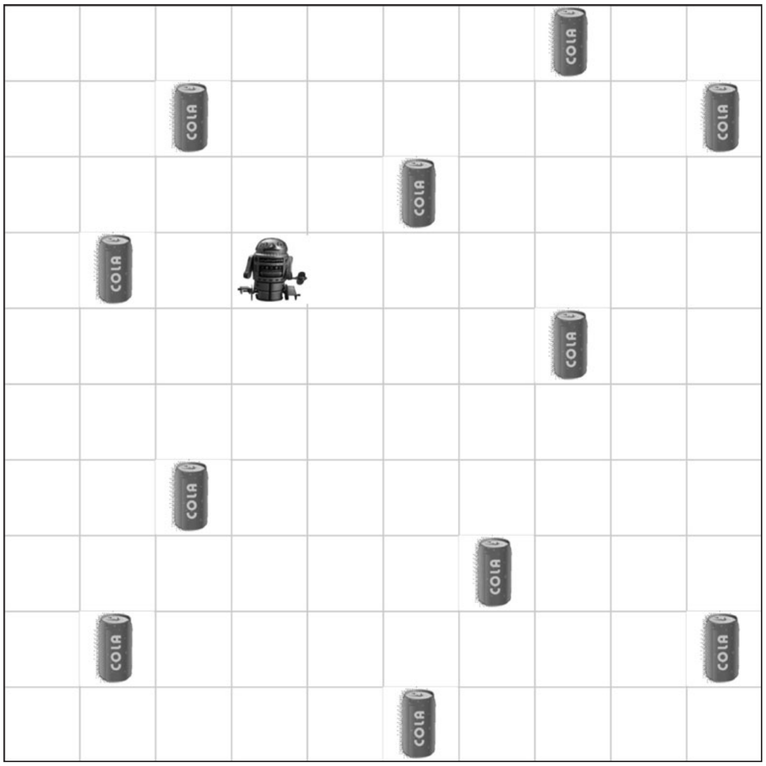
The result of this algorithm is a solution that, in Mitchell's example, outperformed several solutions that were derived by computer scientists.

Introduction to the Life Insurance ALM Problem

For our thought experiment, let's consider a life insurance company that measures its economic capital requirement for interest rate risk for an in-force block using the Principal Component Analysis (PCA) as described in *Options, Futures, and Other Derivatives*.[7] PCA is an approach to measuring risk from groups of highly correlated variables, such as yield curve movements, into principal components that attempt to explain historical movements. Due to the orthogonal nature of the principal components, the principal components are uncorrelated, thus allowing us to measure our exposure to interest rates as:

$$f(x) = \sqrt{\sum_{n=1}^{k} (\text{Surplus Reduction from PC Shock n})^2}$$

In short, the insurance company's goal is to reduce variability in surplus for given shocks to the interest rate curve.



Since this is an in-force block, the main tool that we have to minimize variability in surplus is our choice in asset allocation. Here lies the problem—we have thousands of assets to choose from to create our portfolio. Which ones and how much of each shall we choose? In practice, we would probably develop several portfolios and test them against the capital function and implement the best one. We may use other simple optimizers. The question we need to answer here is: can we do better?

Environments where Genetic Algorithms are Useful

There are several characteristics of problems for which genetic algorithms may be beneficial. Three of the

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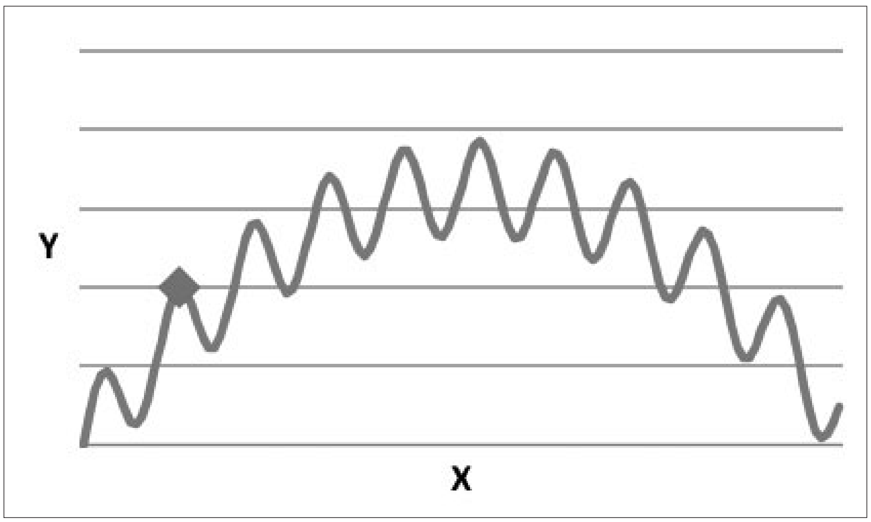

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characteristics and their applicability to our ALM problem are described below.

1. **The metric you are trying to optimize is not smooth or unimodal**. Many traditional search and optimization techniques will end up finding local minima. Consider the graph above:

   If we used an optimization technique such as hill-climbing while trying to optimize the function given in the graph above, we may incorrectly identify a point as a global maximum. The basic principal of any variation of a hill-climbing algorithm is to set an initial point, test the fitness to either side of the point, move to the point with the highest fitness, and repeat until fitness cannot be improved.

   In our ALM example, the fitness landscape is neither smooth nor well understood. A portion of this complexity comes from the way we measure fitness through the PCA approach and through the correlations of fixed income assets. If we were to compare two bonds with maturities one year apart, they would have similar market changes with a general move in rates, but a twist in the yield curve may cause them to act differently.

2. **The solution space is large.** If the number of solutions is finite and small, the best method is simply to try all of the options and choose the best one. Because we have thousands of assets to choose from and any dollar amount of each that can be purchased, there are infinite combinations of asset portfolios that we could try. The method that is often used is to narrow the universe of investable assets and limit the investment increments. However, there are still too many combinations to test, and if the universe is limited too far, we may have eliminated the best portfolio before beginning testing.

3. **It is a situation where good solutions tend to be made up of good building blocks.** If a portfolio of all short bonds does very well, the assumption is that short bonds are good building blocks of a great portfolio.

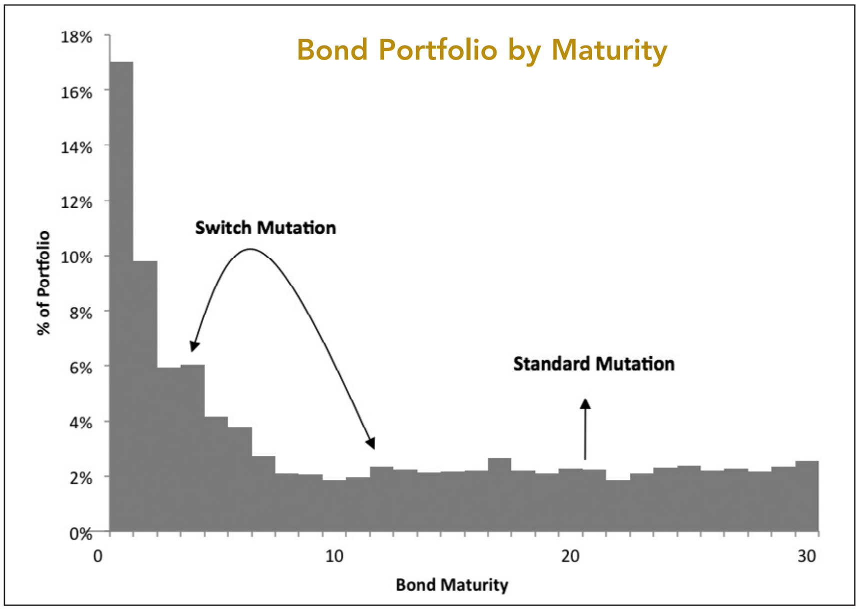
ONCE THE BASE CODE IS TOGETHER (WHICH IS ACTUALLY QUITE EASY), THIS IS A POWERFUL TOOL THAT SHOULD BE A PART OF EVERY ACTUARY'S TOOLBOX!

Life Insurance ALM Application

In applying the genetic algorithm technique to solve this life insurance ALM problem, I used a fair number of variations from the standard procedures found in texts. It is important to remember that genetic algorithms are a tool; they should be modified to fit your needs and to develop new uses. I used the basic steps of genetic algorithms as described above and modified them to fit with this example.

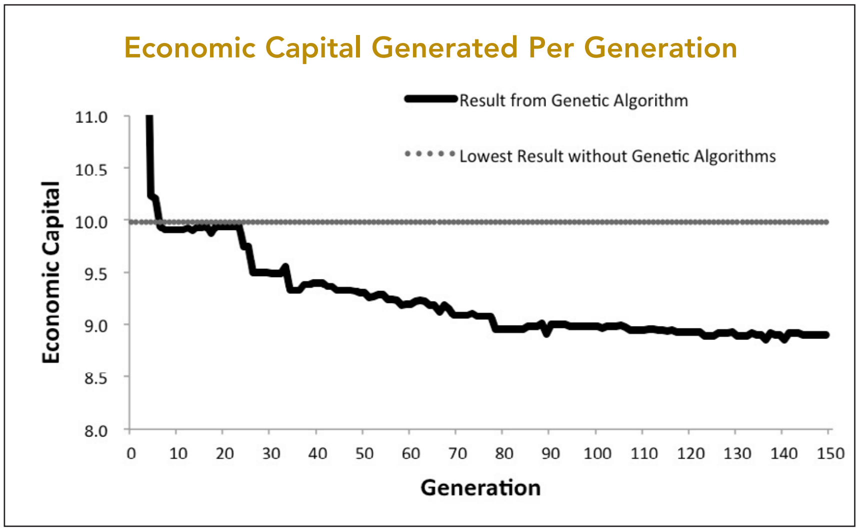
As noted above, the universe of assets is immense. I limited the scope of my model to concentrate on the optimum maturity profile to manage interest rate risk. The asset choices were limited to an investment grade corporate portfolio with 30 bonds—one for each maturity year up to 30 years. Instead of choosing a random initial generation, I used a population size of 600, with each initial individual being a portfolio with the entire portfolio invested in a single bond. Rather than defining the individuals as a string, I defined the individuals as a 30-element array, with each element being the dollar amount invested in each of the 30 bonds. The fitness in my example is easily defined by the capital function described above.

Once the parent individuals were chosen, I recombined the strategies by weighted multiples of the two parents' strategies chosen with random weights. The mutation was done in two ways: first, a random maturity bucket could be set to a random weight; and, second, two maturity buckets could swap weights. This maturity bucket swapping was a great way to eliminate early convergence on local minima. After 150 generations, a suitable result was obtained. *(See top graph to the right.)*



The genetic algorithm solved for an investment strategy that reduced the capital by about 10 percent further than the other two methods attempted—hill climbing and trying large numbers of reasonable portfolios. Even though hill climbing was more structured, it wasn't robust enough to capture the global minimum.

The graph *(bottom right)* of the best investment strategy from each of three generations of the model. The model tended to learn in bursts—the best strategy was similar from generation to generation for a few iterations, and then a new portfolio that had a much better fitness emerged. For example, from generation four to generation five, the model learned to get the asset duration correct. In later generations, the model learned that a barbelled strategy worked better than a more bulleted one.



As you can see from the graph of economic capital (where less required economic capital is better), around generation 5 the genetic algorithm does about as well as our other

CONTINUED ON **PAGE 10**

ARE GENETIC ALGORITHMS … | FROM PAGE 9

methods, and then around generation 25 and beyond the algorithm discovers much better matched portfolios!

Conclusion

Genetic algorithms have been used fruitfully in many other professions, and actuaries should be creative in finding ways to adapt this technique to make it a valuable tool for our profession. Not only did the genetic algorithm discover a better investment strategy, but it also gave me a structured way to solve for a result. We don't want to rely on luck to find a portfolio that does a good job of ALM matching. Many more uses for genetic algorithms are yet to be discovered. I recommend looking at examples in the resources listed in the endnotes and then programming some of the examples yourself. Once the base code is together (which is actually quite easy), this is a powerful tool that should be a part of every actuary's toolbox! ▼

Ben Wadsley

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Complexity Science Enters the Actuarial Classrooms

By Min Deng

Many of us remember the days of being a student—when the dorm rooms were a visual example of what we thought was chaos. Now, chaos has moved into the classrooms as well. Of course, this is a different type; and it is welcome. Recently, in my classes at Maryville University's actuarial science program, we have brought deterministic chaos into our curriculum. And if that does not seem revolutionary enough, it's being joined by behavioral economics, fractal geometry, experimental mathematics, predictive modeling, network theory, genetic algorithms and cellular automata.

What are all these strange-sounding new topics doing in an actuarial science program? They are helping us prepare for the sciences and techniques of the 21st century. Stephen Wolfram, a MacArthur Genius Award winner, and an eminent and highly respected physicist, has said, "I expect that the children of 50 years from now will learn cellular automata before they learn algebra."

Min Deng

Here, in the year 2011, we still expect our incoming actuarial science students to arrive with an excellent grasp of algebra and lots more of the traditional mathematics skills. They need those as background as we focus on the many actuarial subjects they will encounter in the Society of Actuaries' (SOA) exams. But in today's business environment, the actuarial subjects for the exams are, to borrow a phrase used often by mathematicians, "necessary; but not sufficient." Hence, we are supplementing them with complexity science techniques.

In both our undergraduate and our master's programs here at Maryville, we have brought in industry speakers who open our eyes to the world beyond deterministic equations, where the complex adaptive system we call humanity does not tend to meekly follow according to classical economic or actuarial theory. The primary focus, of course, for us still is making sure our SOA exam pass ratios remain very high, since those are a major advantage for our graduates in the tighter job market. But we also want our graduates to learn to keep an open mind to new tools and techniques that can benefit them and their employers in this dynamic marketplace.

We used to think chaos was something to avoid all the time. Now, we teach it! ▼

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Judgmental Forecasting in Determining Policyholder Behavior Assumptions

By Doug King

Introduction

The dynamic lapse assumption used for interest sensitive products can be very subjective yet have a significant impact on results. Whether it is economic capital (EC), European embedded value (EEV), International Financial Reporting Standards (IFRS), or some other project, the dynamic lapse assumption can be a crucial assumption for interest sensitive products. When running stochastic models that have extreme interest rate movements (and sometimes not so extreme), it can have an impact on your dynamic lapses and ultimately your results.

In discussions about the dynamic lapse assumption, people often ask me, "How do you know it is right?" or if I have experience studies to support it. My response is: when have we seen an example in the last 30 years since we have been selling universal life products, when interest rates have jumped up 300 to 500 basis points (bps) or more? I am confident in the assumption because of experience working with the assumption and in particular applying many of the judgmental forecasting methods outlined in the "Best Methods and Practices in Judgmental Forecasting" article by Alan Mills from the July 2010 *Forecasting & Futurism Newsletter*.

In this paper I explain how I used judgmental forecasting techniques to develop a dynamic lapse assumption. I define the techniques and explain how I combined these methods to develop a dynamic lapse assumption. I finish with the best practices used in adding controls and credibility to the assumption.

Methods and Implementation

We used the exponential formula as the base for the dynamic lapse formula, which takes into account the surrender charge. The other key factors are the competitor rate and the threshold (difference between the competitor rate and the credited rate) where the dynamic lapse is triggered. The competitor rate is determined from a weighted average formula of the treasury curve. It uses a moving average formula to try to capture competitors that credit

policyholders based on new money rates versus those that use portfolio rates.

The method I used to develop the dynamic lapse assumption has been an evolving process that incorporated several judgmental forecasting methods. I started with **expert opinion** to determine the assumptions to be used for each product line. *Expert opinion is where you ask the opinion of an expert. Although common, this method is perhaps the most error-prone.*[1]

I combined several sources of expert opinions to give me a starting point: Society of Actuaries (SOA) articles, industry recommendations from consultants and multiple actuaries within my company. The expert opinions helped me fit

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CONTINUED ON **PAGE 14**

reasonable assumptions to the various products along the spectrum of interest rate sensitivity.

Next I tested the assumptions under multiple scenarios. ***Scenario analysis*** *is a process of forecasting future events by framing alternative possible outcomes in terms of story-like narrative scripts that often include the impact of events such as new technology, population shifts or changing consumer preferences. The method usually includes development of a most likely scenario, along with at least one optimistic and one pessimistic scenario.*[2]

I looked at a deterministic scenario, several increasing and several decreasing scenarios to see if the lapse rates under each of those scenarios seemed reasonable. For each of the scenarios, I not only looked at the lapse rates but also looked at the credited rates relative to the competitor rate to make sure it all made sense. This analysis helped us put the assumption and results in perspective.

This work started about five years ago and was modified over the years based on results from different projects and sensitivity testing. After what seemed like a lot of tweaking over the years, and then becoming involved in the market-consistent world of EC, we found we needed to reevaluate the assumption.

We started with a **traditional meeting**. *A traditional meeting is the most common method to obtain a judgmental forecast from a group of people, with unstructured discussion around a table.*[3]

We brainstormed on what made the most sense for the products and markets we sell to. We grouped our product into categories where we believed the sensitivity to lapse varied. For each of these groups we determined the key characteristics of each group: what is the market, average age, average face amount, purpose of the product, wealth of policyholders and maturity of the block?

Grouping into these categories gave us a different answer than what we initially thought. This was not based on experience but was based on our "expert opinion."

Once we felt we had a reasonable assumption we performed scenario analysis again. With our focus on market-consistent work, we looked at more extreme scenarios. We learned a lot from this testing and made further tweaks to the competitor rate and the threshold. We found that the threshold and competitor rate were much bigger drivers than we initially thought.

Structured analogy is another judgmental forecasting method that we used. *It compares a recent series of events to a similar series that occurred in another context. Forecasted outcomes are then based on past actual outcomes in the other context.*[4]

We have had some experience in the past few years where we concluded we needed to further tweak the dynamic lapse assumption. There were situations in reality where the competitor rate was greater than credited rates beyond the formula thresholds. In almost all cases we did not see actual increased lapse rates from that time period; however our models indicated we would. With that experience we decided to increase the threshold for the low sensitivity groups. We did see some actual increased lapse rates in the high sensitivity group so we left that threshold the same.

Best Practices

In the Sarbanes-Oxley (SOX) world we now live in, it is important to implement controls and best practices around assumption setting. In keeping with the theme of judgmental forecasting, I hit on some of the best practices as defined in "Best Methods and Practices in Judgmental Forecasting" while developing the dynamic lapse assumption.

Several best practices employed were:

(1) Providing feedback. *One of the key findings of researchers is that records should be kept about judgmental forecasts, in order to provide the forecasters with feedback. Feedback is valuable because it enables the forecaster to learn*.[5]

(2) A forecast developed by a group, especially a **heterogeneous group,** *is generally more accurate than one by an individual, even if the individual is an expert*.[6]

(3) Providing checklists—*Give the forecaster a checklist of information categories relevant to the forecasting task. Checklists remind forecasters about factors relevant to their forecasts, and prevent them from being influenced by extraneous information*.[7]

(4) Requiring confidence intervals—*Require experts to use confidence intervals, rather than point predictions*.[8]

(5) Combine forecasts—*Researchers have found that combining judgmental forecasts with either statistical forecast or with other judgmental forecasts improves forecast accuracy*.[9]

No method stood out to me as being the single "best practice" but the combination of all five working together made for a better control framework and strengthened the credibility of the study.

Conclusion

The term judgmental forecasting was a new concept to me although I had been unknowingly using it for years. I found a lot of value in applying the methods and best practices to the dynamic lapse assumption. These methods helped me to put some rationale and structure around an assumption that is subjective and where there is a lack of experience to justify the assumption.

It is important to review the impact of the assumptions for all projects where the models are used. How does it impact your earnings on an EEV or IFRS basis? How does it impact your reserves on a statutory basis for cash flow testing or economic reserves for EC? How does it impact your value of new business or pricing internal rate of return (IRR)? It takes frequent monitoring of the results to make sure the assumption is behaving as you expect. Future assumptions are difficult to determine, especially in more extreme scenarios. The judgmental forecasting techniques have helped us to be as comfortable as we can be with the assumptions.

This was an assumption that evolved over time, applying at least four of the judgmental forecasting methods. Any of these methods alone was not as effective but using all four helped to develop a reasonable assumption. ▼

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An Alternate View of Future Mortality

By Frank Grossman

"Circumstantial evidence is a very tricky thing," answered Holmes thoughtfully. "It may seem to point very straight to one thing, but if you shift your own point of view a little, you may find it pointing in an equally uncompromising manner to something entirely different."

– The Boscombe Valley Mystery, *Sir Arthur Conan Doyle*

A seemingly inexorable trend of mortality improvement has emerged over the past century. Declining rates of population mortality in the developed Western world have been variously attributed to several causes, including: i) improved dietary standards; ii) better public health institutions and programs (e.g., immunization); and iii) better public infrastructure (e.g., emission controls and proper treatment of waste). Whether the beneficial influence of these diverse factors has substantively run its course, in terms of fostering additional mortality improvements in the future, remains an open question.

Frank Grossman

In principle, the many risks of out-of-sample extrapolation are widely acknowledged. Yet, how does this projection technique translate into contemporary actuarial practice? Trend extrapolation, long familiar to pricing actuaries, appears to have gained greater currency even among valuation actuaries of late. Is reflecting the anticipated effect of future mortality improvement as straightforward as mechanistically projecting decreases of 0.1 or 0.2 percent year after year? And could there be some risk in taking such an approach—without adequately considering the underlying drivers that may influence a change in life expectancy? One might hope for more from today's actuaries than rote application of a favorable projection scale to a given mortality table. Hence there is the need to consider whether the drivers of past mortality change are likely to be sustained into the future, and—critically—what new drivers may emerge in their stead.

The growth of "agribusiness" led to the advent of monoculture on an unprecedented scale in pursuit of the twin financial goals of greater yield and more profit. Many varieties of plants have been hybridized to grow more readily and withstand the vicissitudes of transshipment. Nowadays those living in northern climes can eschew winter root crops such as carrots and parsnips and opt for leaf lettuce all year; and tart currants and gooseberries have been virtually replaced by all-season celluloid strawberries from California. The obvious result has been ever more food at lower prices. A concomitant outcome, however, is that many people now

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consume a narrower range of foodstuffs, and a greater proportion of the population relies on a shrinking group of producers. The result has been less "diet diversity."

But what about the quality of mass-produced food? Store-bought broccoli assuredly has the form and color of the real thing, but does it convey the nutritional content that textbooks assert it does (e.g., one cup of broccoli has more vitamin C than an orange)? How much does it matter that food is improperly handled or stored—or flown halfway around the world—before being cooked and eaten? The extent to which the nutritive value of our foodstuffs is able to withstand the modern business of agriculture is a point worth considering.

Humans have consumed genetically modified (GM) foods, or livestock-fed GM-grain, for nearly a generation—it has been deemed to be safe. And maybe it is. However, students of history may recall that a factor supposedly contributing to the decline of Rome was the lead used in the construction of their aqueducts and cooking implements. The Romans literally poisoned themselves! Though marvelously accomplished in the fields of applied science and technology, it was Rome's basic ignorance of the long-term risk of contact with lead that posed a dire threat to their way of life.

Much has been written about the looming threat to the baby boomers' quality of life and mortality rates posed by Type 2 diabetes. Many factors contributing to the onset of this affliction are lifestyle-based and rooted in the pursuit of convenience: poor diet (reliance on over-processed food) and lack of physical activity. Type 2 diabetes is an example of a disease that may yet assume a different dynamic going forward than it has in the past, and consequently contribute to higher future mortality rates.

Change in habitat has led to the extinction of numerous species of flora and fauna. Is it possible that environmental degradation may translate into higher human mortality rates too? For example, climate change may enable pathogens normally killed by extended periods of frost to survive and get a second chance. And pernicious tropical diseases (e.g., malaria) may come to extend their reach into formerly temperate regions. Increased exposure to radiation (e.g., from the sun due to thinning of the ozone layer, or from man-made sources) also has the potential to cause more deaths. Can exceptionalism alone save humans from a fate heretofore reserved for other, lesser species?

CHANGE IN HABITAT HAS LED TO THE EXTINCTION OF NUMEROUS SPECIES OF FLORA AND FAUNA. IS IT POSSIBLE THAT ENVIRONMENTAL DEGRADATION MAY TRANSLATE INTO HIGHER HUMAN MORTALITY RATES TOO?

The perennial challenge when evaluating an alternate future state is to avoid Chicken Little alarmism, focusing instead on a "rich scenario" that links drivers in new ways to arrive at a coherent story line that can support the numerics. The so-called FADI Principle was the actuarial profession's mainstay for years. (Some may still recall, even at this late date, that "[t]he work of science is to substitute facts for appearances and demonstrations for impressions" abbreviated F-A-D-I.) And actuaries have traditionally challenged conventional wisdom. The key is to continue to do so by adopting rigorous methods both to analyze historical data and evaluate future prospects.

One thing to bear in mind is that one person's established fact may simply be another person's heuristic. A couple of paragraphs after the excerpt at the beginning of this article, Sherlock Holmes remarks, "There is nothing more deceptive than an obvious fact." Therein lies the wisdom of shifting one's vantage point to obtain an alternate view of future mortality—if only for a moment or two. ▼

BOOK REVIEW

The Perfect Swarm: *The Science of Complexity in Everyday Life* By Len Fisher

Reviewed by Scott McInturff

When I was a member of the Forecasting and Futurism Section Council (2008–2010), I became very attentive when other council members began to discuss complexity science. Though I had no clue as to exactly what complexity science entailed, I found the pairing of words intriguing as it seemed to imply that scientific methodologies could be applied to complexity to better understand and cope with it.

In spite of a diversity of opinion on many topics, most actuaries would agree that the world in which we operate is indeed complex. Many of us function within complex financial institutions that operate within complex financial systems. We apply our expertise within complex networks of social and political structures built upon the complex behavior of the individuals who require and benefit from our services. And we ourselves are complex beings. Better understanding the dynamics of complex systems through study using scientific methods can help actuaries function and thrive within these systems with superior tools and approaches. A science designed to probe complexity is an obviously important area of study for actuaries and other professionals.

The Perfect Swarm

As a current friend of the Forecasting and Futurism Section Council, when the opportunity arose to read and write a review of *The Perfect Swarm: The Science of Complexity in Everyday Life* by Len Fisher, I jumped at the chance. My goal was to establish a baseline of understanding as to what complexity science encompasses, hoping that I could expand my knowledge on a topic that could increase my effectiveness as an actuary. I was not disappointed by the level of information I received from reading this book; nor was I overwhelmed by the amount of information that was presented. *The Perfect Swarm* proved to be a straightforward and informative introduction to several aspects of complexity science.

Scott D McInturff

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Fisher leads us through complexity with an intentional and logical approach. He begins by exploring swarm intelligence in nature through studying the behaviors of locusts, ants and bees. Each of these insect groups uses swarm intelligence in a different way that provides insights into the complex systems that they operate within. The discussion extends into how individuals move through crowds of other humans, following essentially the same fundamental rules as insects. Leaving bugs behind, we explore human group dynamics and the power of a diverse group to apply individual intelligence to produce results superior to those of any individual in the group. The author next takes us to networks. Understanding their structure can lead to more effective communication strategies as well as better tools to prevent the spread of contagious diseases. Next Fisher discusses techniques that allow individuals to make decisions when encountering complex problems with limited information or knowledge as to the best option. The text ends by looking at complexity itself and techniques to discover patterns in complex systems that will lead us in the right direction.

There are numerous nuggets throughout the text that I will briefly describe in the following paragraphs.

The Best Route

A few bees with a clear direction can lead an entire swarm to a desired target without being clearly identified as the leaders and without even being at the front of the swarm. They simply move from the middle of the swarm in a straight line, at a pace slightly faster than other bees, to the target destination. With this approach the entire swarm ends up in the desired place, it appears, without clearly identified leaders. Social scientists have demonstrated that this same phenomenon can be observed in human experimental settings where select individuals can lead groups to certain destinations, using subtly different instructions than given the rest of the group, without even knowing that they themselves are leading. Within our companies we can use this approach to leadership by recruiting a few like-minded individuals who are willing to lead anonymously from within our organizations.

Through pheromones, which fade over time, ants use selective reinforcement to find the most efficient route to their food. Ants tend to follow trails with the most pheromones left by predecessors. As more and more ants identify the most efficient path to a source of food, more and more pheromones accumulate and more ants follow these paths. Paths that do not attract additional traffic gradually have their pheromone trail disappear. Through this positive feedback and reinforcement, the best paths are clearly marked by the heavy traffic that uses them.

UPS collected and studied data concerning the routes followed by their drivers. They realized that the preponderance of right-hand turns was not a random event. Rather this approach was an intentional strategy developed by their drivers to optimize their delivery routes, saving time and avoiding accidents. UPS began to incorporate these optimal path rules in routing their fleets, saving 3,000,000 gallons of gasoline in 2006 alone.

Upon reflection I can see that I have personally incorporated some of the same means of dealing with complex systems in my own life. I have always followed commuting routes that avoid traffic lights and, where there are traffic lights, I have followed the routes with the most opportunities for "right turn on red." In addition, like ants following a pheromone trail, I observe other drivers and make inquiries into the driving patterns of co-workers who have similar destinations to mine in hopes of finding even more efficient commuting routes. I am certain I am not the only driver who has developed a complex strategy for finding the most efficient route to and from work as evidenced by the small number of other cars that seem to be following the same shortcuts as the ones I have chosen. However, I think my activities are instinctual as well as logical. Perhaps in general actuaries have stronger connections to our primordial roots of solving complex problems. I certainly gain material pleasure in outmaneuvering my fellow drivers as I find the most efficient route home, while others seem oblivious to this driving competition.

Cognitive Diversity

When discussing the wisdom of crowds, a concept skillfully explained by James Surowiecki in *The Wisdom of Crowds* (reviewed in the July 2010 *Forecasting & Futurism Newsletter*), Fisher provides an excellent synopsis of the type of diversity that is essential to using groups to solve problems. Diversity must be of a specific type to lead to superior group results. The diversity that is required is cognitive diversity, which includes diversity of knowledge, perspectives, interpretations, approaches and models. Without cognitive diversity in combination with individual opinions developed and collected independently of others in the group, group decision making has all the flaws of individual decision making. Unless there is diversity and independence, group decision making is as likely to produce the wrong answer as it is likely to produce the right one. Thus, a non-diverse group without independent decision making would be best advised not to waste the time of the entire group to make a decision when a simple coin toss would have equal probability of choosing the best direction.

Swarm Intelligence

Swarm intelligence can be used as a foundation for a business that operates in a complex environment. The key to swarm intelligence is that each member of the group must participate in the group as a stakeholder rather than merely as a shareholder. Cooperatives are examples of the best applications of combining group intelligence and swarm intelligence. Swarm businesses gain their power by giving it away. These businesses share with and support the swarm by putting the welfare of members of the swarm ahead of an unyielding objective of making money.

CONTINUED ON **PAGE 20**

THE PERFECT SWARM … | FROM PAGE 19

As a nonprofit organization, Wikipedia demonstrates the power of allowing stakeholders open access to build a database of information to be used by others. By limiting editorial control and trusting the stakeholders to control the content, Wikipedia has grown to become one of the most widely used single sources of information in the world, though with an accuracy that is somewhat lower than that of carefully controlled and researched encyclopedias *[citation needed … as usual with Wikipedia]*.

Heuristics

One interesting and practical chapter is concerning decision rules called heuristics. We are often asked to make decisions based on little data. It turns out that sometimes having less information can lead to a better decision than having more information. The author lists five heuristics that he suggests are simple approaches to complex problems:

1. Recognition: When given two alternatives and only one is the right answer, choose the one that is most familiar.
2. Fluency: When asked to choose the correct answer given multiple alternatives and you recognize more than one, choose the one that is most recognizable.
3. Tallying: When given a choice between which of several options is correct, consider positive and negative cues that point to the veracity of each option and choose the one with a greater number of positives over negatives without weighting them.
4. Take-The-Best: When facing a choice between two options, order cues by ranking them based on your expectation of which cue has the highest utility. Choose the option based on the first cue that allows you to favor one choice over the other.
5. Satisficing: When given several alternatives, choose the first one that exceeds your aspiration level.

Fisher discusses each of these heuristic rules in some detail, and, using examples, he significantly increases the logic behind each rule beyond what can be surmised by a simple listing of each rule above.

Fisher continues in this chapter to discuss rules used by Internet companies such as eBay, Yahoo and Amazon and technology companies such as Dell, Cisco and Intel who are operating "on the edge of chaos" where there is short-term order with rapidly fluctuating patterns and unpredictable long-term trends. These companies rely on simple rules that allow them to respond rapidly and flexibly to emerging opportunities that may be short-lived. The operating rules must be clearly established in advance and address the following: 1. actions to take when a certain situation arises; 2. boundaries for the businesses in which to operate; 3. priorities for resources; 4. parameters for the timing of efforts; and 5. circumstances for exiting initiatives.

Begin at the End

In his introduction, the author comments that some readers of his prior works have started at the Notes section at the end of the book. The Notes section contains thoughts and references that the author excludes from the flow of the text. He includes these at the end for those seeking to go deeper into the topics he discusses in the main body of the text. While some might find this a reasonable starting point, I personally would have no inclination to start at this particular point. However, I would have found it useful to read the final chapter, Chapter 10, titled "Simple Rules for Complex Situations" before reading the preceding nine chapters. In his final chapter, which is only six pages long, Fisher lists 10 tips for dealing with complex situations and then summarizes multiple sets of rules regarding complexity that emerge from various disciplines and that were discussed in the preceding chapters. Now I am not suggesting that one should read only Chapter 10 and skip the rest of the text. Much would be lost in doing so as the author ably builds to the final chapter over the course of the book. My suggestion is simply that while it is an appropriate and natural approach to follow the careful path set out by the author starting at Chapter 1, one might find it useful to take a peek at the final chapter to see where the book is heading, just as many prefer to look at a map to get an overview of the route to the final destination before blindly following the twists and turns of a GPS system. By perusing Chapter 10 first, you'll have a better understanding while you travel as to how you will get to your final destination. Whatever your approach, be sure to enjoy the scenery along the way.

BY PERUSING CHAPTER 10 FIRST, YOU'LL HAVE A BETTER UNDERSTANDING WHILE YOU TRAVEL AS TO HOW YOU WILL GET TO YOUR FINAL DESTINATION. WHATEVER YOUR APPROACH, BE SURE TO ENJOY THE SCENERY ALONG THE WAY.

Conclusion

The Perfect Swarm is an easy read. The author has an understated sense of humor that shines through from time to time, making the reading enjoyable. The book scratches the surface of complexity science, leaving the reader hungry for more, the same way the perfect appetizer satisfies and still leaves one with plenty of room for the main course. Hopefully the hunger from reading this book will lead the reader to have increased involvement with the Forecasting and Futurism Section to explore complexity science further. ▼

Complexity Sciences—Simplified!

By Dave Snell

***Editor's Note:** An earlier version of this article appears in the May 2011 issue of the* Actuary of the Future *newsletter.*

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.

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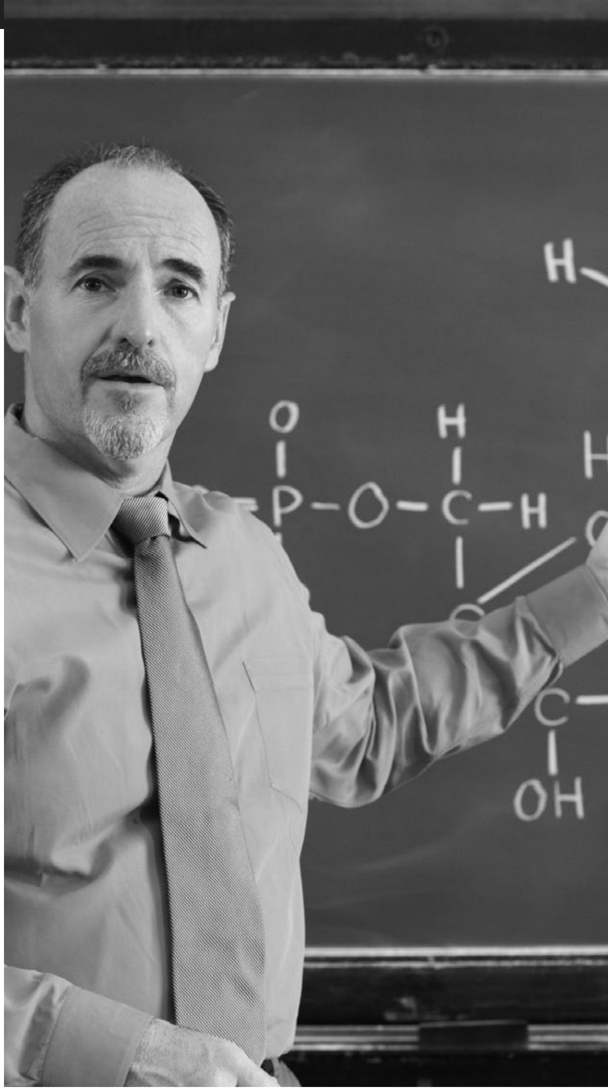
A gross oversimplification of the difference between these tools and our more familiar modeling tools would be that classical actuarial models employ deterministic methods, while complexity science tools seem to be more oriented toward inductive methods. For example, actuaries build sophisticated theoretical 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-



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

http://www.soa.org/library/newsletters/forecasting-futurism/2010/july/ffn-2010-iss2.pdf ▼

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