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Simulation Technology for Managing Risk

by Lilli Segre-Tossani

Editor's Note: This is the second of three articles exploring the new technology offered by Santa Fe, New Mexico-based Assuratech, Inc.(www.assuratech.com) that promises to revolutionize the way insurance companies model and manage risk. In our last edition, we introduced the potential of the emerging technology of simulation in the context of the insurance industry. This time, we describe the development of the applied complex adaptive systems technology behind Assuratech's highly sophisticated program that uses simulation and data mining techniques for accurate, reliable versatile risk modeling.

Reality does not conform to the ideal, but confirms it.

Gustave Flaubert

Simulating Reality

To Plato, the ontos, the ultimate, permanent, eternal, spiritual ideal was the only reality. Earthly phenomena, ideals manifested in matter and time and space, were merely illusions destined to decay and die. For many centuries, however, modern western science has held fast to the concept of a singular reality of matter, time and space. Statistical and mathematical descriptions of phenomena were held to be the key to describing, understanding and, eventually, controlling reality.

In recent decades, scientists have come to believe that, in some instances, there are more accurate and useful ways to talk about reality than linear mathematics. In fact, non-linear, complex systems—things like atoms, molecules and economies—are far better studied through the technology of simulation. Simulation technology has been used in scientific laboratories for several decades.

Practical applications of simulation technology have been proven in the physical and life sciences, in transportation-systems modeling and in the financial services markets, to name just a few. These tools were used at Citibank to uncover over $200 million of previously unidentified exposure for delinquent credit card payments, and the Internal Revenue Service improved their fraud detection capability by 8000% using this technology.

In the insurance industry, the use of simulation as a decision-making tool is just beginning to emerge, primarily as a result of the work of Assuratech, Inc. Assuratech is an emerging technology company that designs and builds business risk-management tools for the insurance and financial services industry using adaptive agent-based simulation technology. The technology is derived from decades of work done at supercomputing facilities at the Los Alamos National Laboratory (LANL) in New Mexico.

The Technology of Simulation

The word simulation comes from the Latin word *simulare*, which means to make like or to put on an appearance of. To the Romans, simulacra were shams (Cicero), reflections (Lucretius) or ghosts (Vergil) of what was real—that is, existent in the world. A simulation is commonly thought of as a representation of the operation or features of one process or system through the use of another.[1] In business or science, simulation is understood as a model of a problem or course of events.[2] Simulation is used to examine a problem because the problem is not subject to direct experimentation.[3]

Analysts are hampered in their ability to study complex systems like a national economy using traditional experimental methods because it is simply impractical, too expensive or too dangerous to tinker with the system as a whole. But with simulation technology, they can build complete silicon surrogates of these systems inside a computer, and use these "would-be worlds" as laboratories within which to look at the workings and behaviors of the complex systems of everyday life. Simulations can be of the internal processes of an organization and/or all of the external forces that impact it, such as economic, competitive, regulatory, consumer, supplier, natural events and capital market effects. The simulation is validated by comparing known information about common outcomes with the data generated by the simulator about these same outcomes, producing a benchmark by which to determine accuracy. In this way, to paraphrase Gustave Flaubert, reality confirms the simulation.

Simulations are used by decision makers to understand the causal links among the various aspects of internal processes and/or external forces, to identify weaknesses in those links and to understand the optimal tactics or strategies for operating organizations of all kinds. They are not predictive tools or forecasters. They are designed to uncover the often-surprising

1) The American Heritage® Dictionary of the English Language

2) The Cambridge International Dictionary of English

3) Merriam-Webster's Collegiate® Dictionary

emergent behavior that occurs in complex systems and to inform managers of the risks they are taking and the potential consequences of those risks. Simulations provide managers with an environment to test strategies *in silico*, which is much cheaper and faster than testing them *in vivo*.

At one time, the huge amounts of data required to build a useful simulation could only be processed on large supercomputing platforms. Today, the processing power to create a realistic simulation of a restricted environment can be packaged in a personal computer ,or even a laptop. In December 2002, for example, the National Oceanic and Atmospheric Administration (NOAA) launched its Science On a Sphere™[4] exhibit. This exhibit uses four personal computers to synchronize and blend the animated images from global environmental data sets and four projectors to display the blended images on a 68-inch suspended fiberglass sphere. Images include the Earth's topography, bathymetry, weather events, weather prediction models and past and future climate change.

Adaptive Agent-Based Simulation Technology

Assuratech's adaptive agent-based modeling uses self-learning, non-linear technology to simulate the complex system of the insurance industry itself. It allows managers in the industry to narrow their decision-making parameters by rapidly testing the effects of different scenarios on their market position and financial integrity. As is true of many technologies in the United States, defense-funded and defense-oriented research drove the development of simulation technology at the beginning and continues to drive its refinement. One of the "hottest" centers for theoretical and applied research in intelligent systems, distributed systems and advanced computer simulation LANL.

Mathematical Origins

The mathematical foundations of adaptive agent-based simulation technology can easily be traced back to work of John Louis von Neumann and Stanislaw Ulam in the 1940s and 1950s. Von Neumann was a brilliant mathematician who, among other things, worked with scientists at LANL to develop computational solutions to nuclear problems related to the hydrogen bomb using the advanced computing capabilities then available. Ulam is known as the mathematician who solved the problem of how to initiate fusion in the hydrogen bomb. He also devised the "Monte-Carlo method" widely used in solving mathematical problems using statistical sampling.

Their theoretical work was picked up by others and spawned a broad spectrum of new analytical technology, including simulation technology. Chris Barrett, center leader of the National Infrastructure Simulation and Analysis Center (NISAC) Research and Development at LANL, summarizes it this way: "They were all working on what it means to compute, basically simulate, different kinds of really complicated systems from the bottom up. They looked at discrete methods, self-organization, decision-making and so many other technologies. Even game theory can be traced back to these origins, although John von Neumann was not at the lab when he and Oskar Morgenstern wrote *Theory of Games and Economic Behavior*."

The Developmental Application

In about 1992, Barrett was on a LANL team working on using supercomputers to develop decision support systems with embedded simulations for a national security application. The team was looking for a place to test their theoretical work by applying it to a real-world situation—a way to motivate the purely abstract mathematical and computer science work. The search led them to a project initiated by the Department of Transportation that eventually became known as TRANSIMS.

The TRansportation ANalysis SIMulation System[5] (TRANSIMS) was developed to help communities meet the Clean Air Act, the Intermodal Surface Transportation Efficiency Act, Transportation Equity Act for the 21st Century and other regulations that impact transportation systems and planning. It is a set of mutually supporting simulations, models and databases that use advanced computational and analytical techniques for transportation and air quality analysis and forecasting. TRANSIMS is used to create an integrated regional transportation system analysis environment that simulates the dynamic details that contribute to the complexity inherent in transportation issues.

In developing TRANSIMS, the first study Barrett's team undertook examined the impact of implementing a commuter public transit solution for Albuquerque, NM. As they developed it, they found that, because transport systems are characterized by complex interdependencies, the results of different scenarios were often counter-intuitive. This led directly to the development of agency-oriented simulation.

"Who is driving is a very complicated issue of relationship in households among individuals, whether they are family or non-family households, the demographics, availability of access to the transport infrastructure," explains Barrett. "Evaluating all of

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4) *A full description can be found at http://www.fsl.noaa.gov/sos/*

5) *http://transims.tsasa.lanl.gov/*

these interactions that wind up putting people on roads, basically devolved into understanding that transit technology is end-to-end simulation of the activities of people, not traffic. Traffic is a by-product."

The Agent

Thus, for TRANSIMS, Barrett's team built households of individuals synthesized from census and marketing data and placed them in households based on demographic data and land use information. The relationships between the people were evaluated from very small sample activity surveys. At the conclusion of this stage, the team had virtual individuals, who, if sampled, returned the same census and the same marketing survey data and were associated into households through relationships to one another that were all consistent with the original data.

What they had accomplished was to transform the demographic information into a form that enabled it to interact with a planned roadway, a change in policy, a change in land use or any other change scenario. Agents pursue activities that are consistent with their constraints, their demographic structure and their relationships to each other. "All along the way," says Barrett, "we were inventing new technologies: disaggregation, data fusion systems, information integration, data mining where the engine is actually a simulator pulling together information that was never intended to be pulled together and mapping it onto agents." Now, these technologies are being used in other commercial and non-commercial applications throughout the world.

Next, the team had to route the agents through the system so they could pursue their activities. Again, new technology was created to develop a highly complex router—formal language constraint path-finding, based on graph grammars. Like many other pieces of the total TRANSIMS, the router developed in the context of transportation turned out to have myriad applications in widely divergent fields. It's been used to design VLSI wire routing on integrated circuits and to look for pathways through chemical reactions.

In routing the agents through the router, they found that some of the non-unique solutions produced "crazy" plans, so they had to develop feedback mechanisms to test the plans to validate that the interaction of the agent program and the router program yields feasible results. Again, Barrett says, "So when we simulate these cities, we have millions of people [agents]. And the first time you try to run a micro simulation of traffic using a plan set that matches the activity patterns, that matches the demographics, that maps into the land use and the network of the city, the traffic won't go! Because it's a computer and the computer is stupid. And so we iterate between driving and planning, planning and activities, activities and the demographics to find solutions that are consistent with the input data that's being fused, but also that actually produces traffic of the kind that you actually see when you do measure traffic."

Other new technologies related to testing were developed out of this iterative process. The large parameter spaces and non-linear interactions that characterize complex simulations make understanding such models using traditional testing techniques extremely difficult. To test these extremely complex systems, Barrett and his team built a theoretical program that drew, again, on the foundations of the fathers of modern computing science. In the tradition of the analysis of computational complexity and algorithmic complexity described by Hartmanis and Stearns, they developed a method to use algorithmic semantics to examine the validity of the computations.

From Transportation to Insurance

TRANSIMS is now in the process of being commercialized and will shortly be put into use in its first practical application, where scenarios will be run not by supercomputing experts or mathematicians, but by urban transport planners. The collaborative work of scientists, mathematicians and theoreticians from LANL and the Santa Fe Institute,[6] a private, non-profit, multidisciplinary research and education center, has also led to the evolution of other commercial applications of this research, including *Insurance-World*™ from Assuratech.

In fact, Barrett was one of the original collaborators in the development of *InsuranceWorld*™. Some of the things scientists learned from TRANSIMS were different ways of understanding the agency. They also learned how activities can be characterized and taken from aggregate statistical models to understandable agency-oriented simulations. As these notions began to be discussed in the scientific and mathematical community, one of the people Barrett conversed with about these ideas was John Casti.

Casti is a globally recognized science writer, mathematician and complexity science expert and one of the scientists who serves on Assuratech's board of directors. In 1995, Casti was a speaker at a meeting that had been put together with the aim of providing a forum for some research-oriented people in the catastrophe reinsurance industry to explore with a number of scientists what science might have to offer the reinsurance

6) *http://www.santafe.edu*

world. The Center for Oceanic Research in Bermuda was a principal participant. "Folk wisdom at the time was that the most important thing that science could tell the reinsurance industry was where and when hurricanes were going to occur," says Casti. "I didn't believe that this was the most important problem that reinsurance would be facing or that science could shed some light on. Rather, I felt that a much more interesting and important question was: 'How do you understand your place as a firm within the overall industry?'"

Casti envisioned a tool that would represent the entire catastrophe insurance system—the consumers of the product, the suppliers of the product, the primary insurers, the reinsurers and so on—all gathered together into one integrated system on an insurance executive's computer. Decision-makers in the industry could then ask such a system various kinds of questions, ranging from the effect on the financial standing of insurance companies in the market of a force five hurricane hitting Miami to the effect on the market position of one company of a 10 percent improvement in the accuracy of its performance predictions.

Intrigued by the potential of such a tool, Casti proposed a consortium of reinsurance companies, insurance companies and research institutions and companies to fund research aimed at developing a simulator that would represent the catastrophe insurance world. In 1997, the Insurance World consortium came together and the project began.

The Enterprise as Agent

Barrett and Casti had already been exploring how the TRANSIMS work on agency-oriented simulations would naturally lead to concepts like symbolic representation of an enterprise and the activities of that enterprise and its interactions. They now had the opportunity to build such a simulation for the insurance industry. It could display capital stratification by the net result of agency interactions and activities, whether the agencies are competing or cooperating enterprises in a market, or collections of people within a business that are contributing to the enterprise by performing the functions they perform, and whether or not the scenario is impacted by a natural event.

To round out the scientific team, Barrett and Casti approached Roger Jones, now chairman of the board and chief scientific officer of Assuratech and one of the company's co-founders. Well-known in the advanced computing academic and scientific communities, Jones had been at LANL since 1979. During his tenure at LANL, he founded the Nonlinear Adaptive Computation effort, which focused on developing software data mining and control systems that had the capacity to learn from data as they interacted with it. Jones led the successful development of solutions for global financial corporations that suffered from the effects of the Latin American debt crisis, and, at the time the idea for the Insurance World consortium was forming, was founding the Center for Adaptive Systems Applications (CASA), which focused on assisting clients in the financial sector manage and protect against risk.

Insurance World 1

While simulation technology existed and had been proven on a supercomputing platform, the Insurance World consortium had the ambitious goal of recreating it on a platform that would be accessible in any decision-maker's office. The team chose Microsoft Excel, a choice that, while very convenient from a user's point of view, was very inconvenient from a programming point of view. Nonetheless, Casti says, "The major technical hurdle, I think, was not a hardware or even a software issue, it was an intellectual issue—how to get all the various relationships that link the actions of all these various decision-makers in the system to make the simulation reasonably realistic, to bear some resemblance to what enterprises actually do."

As with the first TRANSIMS scenarios, initial versions of the Insurance World simulator produced "silly" results. This was the purpose of the consortium, whose members had committed not only to fund the research, but also to participate in a series of five meetings, two months apart. During these meetings, representatives of Ernst & Young Actuarial Division, Swiss Re, Zurich/Centre Re, ACE Limited, CAT Limited, Wintherthur and others critiqued the program and squeezed out, one after the other, the logical gaps in the code. When they were done, the Insurance World simulator produced results that not only made sense to everyone sitting around the table, but also to people in the insurance industry.

The first Insurance World simulator was essentially a "toy model" of the real world of catastrophe insurance, incorporating only two types of catastrophes —hurricanes and earthquakes—occurring in three geographic regions: Japan, California and the Gulf Coast. There were five primary insurance firms and five reinsurers. The simulation extended over a 10-year period, in steps of one quarter each.

The program allowed a user to set parameters for the external economic climate, estimates of the physical climate and earthquake conditions and the various

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factors distinguishing one firm from another. The simulation then traced out the implications of the decisions each firm made in regard to developing market share, repayment of loans, attitudes toward risk, amount of risk assigned to reinsurers, etc. Users could try various management strategies in response to different scenarios, and, through the familiar representation of a financial report, see if decisions they made led to success, survival or extinction.

Insurance World 2

The Insurance World simulator was successful, but it was a very limited representation of reality. It had served the research purpose—to demonstrate that the technology could successfully be applied to the insurance industry. Now what was required was to develop a simulator that could represent a comprehensive picture of the entire risk environment within the industry.

In every endeavor, whether we are speaking of the defense of the country or the management of a business, senior executives manage enterprise-wide operations from a conceptual or a macro perspective. The search for management tools for accurately assessing strategies and initiatives at the macro level—decision-support systems—drove the development of the technology at LANL. The same objective drove the formation of the Insurance World 2 consortium in 2000.

The new iteration of the simulator was to focus on issues associated with managing the total risk within an enterprise. This would include not only insurable risks (including those associated with large losses and catastrophes), but also financial and investment risks. The Insurance World 2 simulator, which eventually reached the commercial market, considerably enhanced, as Assuratech's *InsuranceWorld™*, was designed to provide answers to these questions:

- How do the frequency, magnitude and geographical distribution of natural catastrophes affect the balance sheet of a (re)insurance company?
- How is business/exposure spread among companies?
- What is the effect of different pricing strategies on the industry as a whole and on individual companies?
- How does the consumer affect the business of companies?
- What effect does the availability of capital have on the strategy of a company?
- What is the effect of marketing strategies?
- What is the effect of the desired retention under the given (re)insurance structure?

The Insurance World Agent

In the Insurance World simulator, the agents are not individuals, but individual enterprises. Each agent has four goals:

1. To achieve its desired net combined ratio—the ratio of expected annual retained losses R plus costs C to retained premium π
2. To achieve its desired premiums to total assets
3. To achieve its desired efficiency of capital use—the ratio of subscribed capital to total assets
4. To achieve its desired market share

The goals are defined mathematically as:

1. $CR = (R + C) / \pi$
2. $\gamma = \pi / TA = (R + C) / (TA * CR)$
3. $\eta = SC / TA$
4. $F = f(CR; \gamma; \eta; dMS)$

The Insurance World Interactions

Each agent (company) achieves its best performance in the simulation through a mechanism of interaction that works on three different key levels:

- Simulation of natural catastrophes and their impact on the considered insurance and reinsurance markets in terms of amount
- Simulation of the technical components of developing company growth and their vulnerability to natural catastrophes
- The impact of the natural catastrophes on the (re)insurance companies' balance sheets, following the strategy of each company (market, investment, etc.)

The mechanism of interaction was based on three principal factors—price, desired supply of capital and desired risk retention. The simulation incorporates a wide variety of external parameters such as regulatory requirements, fixed and variable costs, inflation, outstanding losses, premium reserve, etc.

Insurance World Simulation

The output of the simulation is a complete set of company balance sheets and earnings statements at quarterly intervals over a 10-year period. In detailed format, the decision-maker can see the effect of the company's investments strategy in terms of fixed/current assets and derived interest, losses and premiums according to each single market, etc.

InsuranceWorld™

The commercial product, *InsuranceWorld*™, provides industry decision makers a means to model their total enterprise risk. The simulation can be populated by five or more primary insurers and five or more reinsurers and operates in 10 user-defined regional catastrophe markets. It incorporates all of the complex economic models identified by the Insurance World 2 consortium (fixed and variable costs, inflation and recession, outstanding losses, company solvency requirements, antitrust legislation, etc.) as well as a wide choice of capital markets (bonds, stocks, real estate, catastrophe bonds).

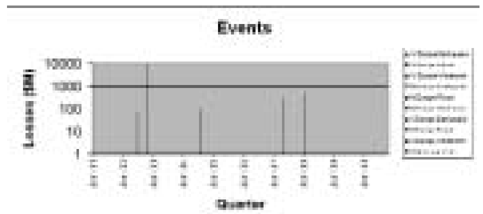
The software runs on a laptop computer and requires no technical expertise to operate. It is expertly packaged so that a non-technical user can begin to develop scenarios immediately, and the simulations run in a matter of seconds.

The user begins a simulation by defining a scenario —either a default scenario, or a new one created on the spot. Each scenario may represent an existing or potential corporate strategy. The scenario defines the space (the geographical location and type of hazard), the interacting agents or objects, the rules (represented by individual company operating, market, investment, pricing and debt strategies), the random events, and the time frame to be modeled.

InsuranceWorld™ Screen: Building a Custom Scenario

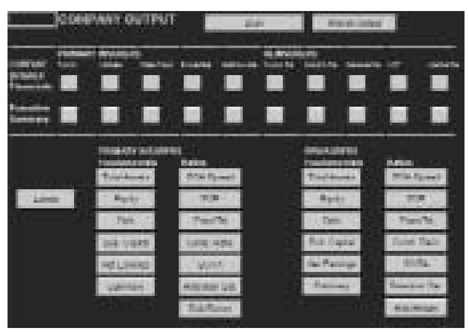
Events may be created by a random seed process, or set manually.

InsuranceWorld™ Screen: Event Timeline



As catastrophes occur, the simulator calculates resulting financial and market share effects on each of the primary and reinsurance companies being modeled. The simulator output is in the form of detailed balance sheets, earnings statements, financial ratios and solvency data, quarter by quarter over the period being modeled. The user can stop the simulation and insert new strategies as it moves along the time line. In addition to calculating the financial effects of strategies, it also models their effects on market share and it calculates reinsurance contracts.

InsuranceWorld™ Screen: Accessing Results



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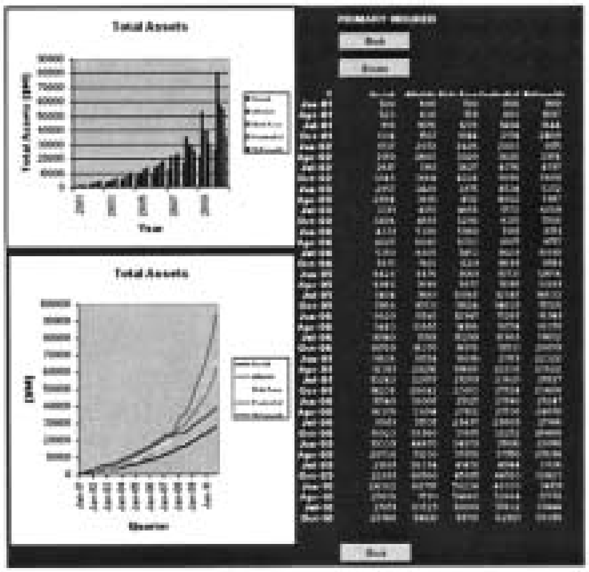
InsuranceWorld™ Screen: Presentation of Total Assets After Simulation



InsuranceWorld™ thus provides management with a bird's-eye view of their entire environment and the ability to understand outcomes over time. As mentioned above, this technology is about narrowing decision-making parameters. It is not a predictive tool, but a complete decision-support system. A company's already developed micro analytics and other sophisticated systems including DFA and ERM applications can be integrated into the *InsuranceWorld*™ environment to provide increased resolution and fidelity.

The insurance industry has huge stores of data that can be mined for patterns. The data-mining techniques that we have described reveal patterns overlooked by traditional analyses. The data need not be integrated—the data fusion technology mines all the data sources and extracts patterns from the entire flow, without regard for the source. Using the patterns, the system forecasts a data output stream that can be compared to the actual output data stream. If the two do not match, the system adjusts the parameters until they do—it "learns" from the comparison.

Using the described patterns, *InsuranceWorld*™ then builds the simulation and populates it with agents who behave independently according to the predefined patterns and those identified by the mining techniques. The agents begin to behave according to the identified patterns, including reacting to the behavior of their neighboring agents—interactions or correlative behavioral patterns.

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The interactions among the agents in the simulation cause them to react together, learn and adapt their behavior, duplicating real world interactions. This constantly adapting, collective behavior is the force that drives bottom-line business profitability and may pose danger to capital. Companies using adaptive agent-based simulation are able to see emerging capital exposures as well as profitable opportunities that would otherwise not be revealed to them.

Real World Uses

InsuranceWorld™ can be used to test diversification scenarios and hedging strategies, identify previously unrecognized risks, understand growing debt at a customer and portfolio level, run budget simulations to track the affects on company capital up to 10 years in the future and model the effect of extreme events such as catastrophes and terrorism on the capital base of a company or its competition.

The technology supplements actuarial models based on linear, statistical analyses and provides realistic, independent scenarios to evaluate management initiatives. It is fully customizable, allowing companies to analyze and project outcomes of scenarios related to specific risk environments. Because adaptive agent-based simulation technology builds a modeling system that permits the modeler to keep track of and modify the behavior of each individual in a synthetic population, the simulations can easily be adjusted in response to changing environments, be they altered by inside or outside influences.

Terrorist behavior, for example, is non-linear and these technologies are being used today to enhance the national security by modeling terrorist behavior and potential reactions to it. Terrorist events can be inserted into an *InsuranceWorld*™ environment just as natural catastrophes are. Analytically, Casti and Jones agree, a terrorist event is analogous to a natural catastrophe. With federal terrorism insurance legislation in the formative stages, organizations will need flexible tools like *InsuranceWorld*™ to rapidly assess and model terrorism risk within a changing regulatory landscape.

In our next article, we will explore applications of the adaptive agent-based simulation technology in the financial and insurance markets, including new modules to address the risks of terrorism.