



SOCIETY OF ACTUARIES

**ERM Symposium
April 2010**

**1F: Agent-Based Models: ERM-Related
Applications**

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Agent-Based Models: ERM-Related Applications

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ERM Symposium
Chicago, IL
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“Who am I? Why am I here?”

– Admiral Stockdale, 1992

- Currently
 - Director, Actuarial Science Program
 - State Farm Companies Foundation Scholar in Actuarial Science
 - University of Illinois at Urbana-Champaign
 - Various actuarial / DFA / ERM publications
 - Mentor and direct undergraduate research
- Prior
 - Corporate and consulting actuary
 - Senior Vice President and director of internal audit & risk management

U/G Research Associate Projects

- Neuroeconomics / cognitive biases
- Power laws
- Predator-prey models
- Fuzzy modeling of risk
- Housing wealth: reverse mortgages and equity releases
- Public pensions: securitizing pension claims
- Agent-based models

Agent-Based Models: ERM-Related Applications

Agenda

- Framework: complexity and complex systems
 - Description
 - Validity?
- Cellular automata
- Agent-based modeling
 - Principles and characteristics
 - Examples
- Potential ERM-related applications

Complexity and Complex Systems

- A commonly heard definition: “the edge of chaos”
 - Between order and randomness
- Simple rules can lead to complex systems
- Self-organization
- Emergent phenomena
- Interrelationships

Complex Adaptive System (CAS)

- Interacting components / agents
- Emergent behavior / properties
 - Self-organization (and reorganization)
 - Macro (complex) properties are different from micro (simple) properties
 - Nonlinearity → can't simply project from micro to macro
 - Bottom-up rather than top-down
- Adaptive / evolving capability of agents
 - Learning
 - Feedback
 - Often, move toward goal or objective

Examples of CASs

- Economy
- Financial markets / stock market
- Ecologies / ecosystem
- Brain / consciousness
- Social systems
- Organizations

Historical Recognition

“He intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention.”

- An Inquiry into the Nature and Causes of the Wealth of Nations, Adam Smith, 1776

Complex Social Systems

“One must study the laws of human action and social cooperation as the physicist studies the laws of nature.”

- *Human Action*, Ludwig von Mises, 1949

Even in Classic Fiction...

War and Peace, by Leo Tolstoy

Book Eleven, Chapter 1

“Only by taking infinitesimally small units for observation (the differential of history, that is, the individual tendencies of men) and attaining to the art of integrating them (that is, finding the sum of these infinitesimals) can we hope to arrive at the laws of history.”

Tolstoy continued...

***War and Peace*, by Leo Tolstoy**

Second Epilogue, Chapter 9

“All cases without exception in which our conception of freedom and necessity is increased and diminished depend on three considerations:

- (1) The relation to the external world of the man who commits the deeds.
- (2) His relation to time.
- (3) His relation to the causes leading to the action.”

Tolstoy continued...

***War and Peace*, by Leo Tolstoy**

Second Epilogue, Chapter 11

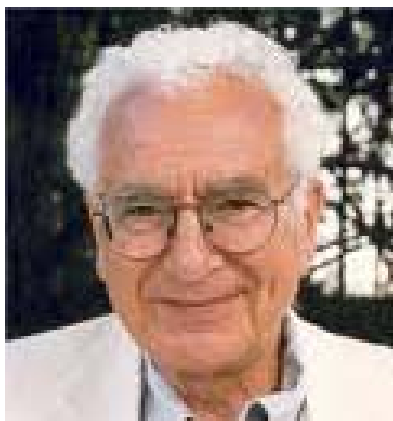
“And if history has for its object the study of the movement of the nations and of humanity and not the narration of episodes in the lives of individuals, it too, ..., should seek the laws common to all the inseparably interconnected infinitesimal elements of free will.”

Is “Complexity Science of Any Use?

- “Why and how did this vague notion become such a central motif in modern science? Is it only a fashion, a kind of sociological phenomenon, or is it a sign of a changing paradigm of our perception of the laws of nature and of the approaches required to understand them?”

- Vicsek, “The bigger picture,” *Nature*, July 11, 2002, p. 131

Murray Gell-Mann



Sante Fe Institute

- Founded in 1984
- Private, non-profit
- Multidisciplinary research and education
- Primarily a “visiting” institution
- Current research focus areas
 - Cognitive neuroscience
 - Computation in physical and biological systems
 - Economic and social interactions
 - Evolutionary dynamics
 - Network dynamics
 - Robustness

The ERM Perspective

- Concerned with a ***broad financial and operating perspective***
- ***Recognizes interdependencies*** among corporate, financial, and environmental factors
- Strives to determine and implement an optimal ***strategy*** to achieve the primary objective: ***maximize the value*** of the firm
- Recognizes that ***little things*** can have ***big consequences***
 - Trying to avoid a ***“failure of imagination”***

Issues in Advancing ERM

We can move ERM forward by better understanding and appreciating

- Complex adaptive systems
- Evolutionary processes
- Behavioral issues

Evolutionary Process

- There are several important parallels between economic systems and biological evolutionary theory
 - Complex systems
 - Self-organized agents / individuals
 - Adaptation / natural selection
 - Emergence of “order”
 - Understanding the historical process helps to explain behavior

Biology and Economics

“The precise mathematical relationship which describes the link between the frequency and size of the extinction of companies, for example, is virtually identical to that which describes the extinction of biological species in the fossil record. Only the timescales differ.”

- *Why Most Things Fail: Evolution, Extinction & Economics*, Paul Ormerod, 2005

Behavioral Concerns

- Various well-documented “fallacies” can cause inaccurate or biased estimates of values, probabilities, etc. E.g.,
 - *Anchoring fallacy*: bias toward an initial value
 - *Inattentional blindness*: concentrating in one area can induce blindness to other events
 - *Availability fallacy*: immediately-available examples have a perhaps undue influence on our estimates

Cellular Automata

- Matrix of cells
- Each cell
 - Follows a simple set of rules
 - Interacts with one another
- Result: potentially unpredictable, complex behavior

Game of Life

- Example of cellular automata
- Created by Mathematician John Conway (cited in 1970 in *Scientific American*)
- Rules of behavior:
 - Each cell either is or is not populated (i.e., living or dead)
 - Each cell with either 2 or 3 living neighbors survives (into the next time-step)
 - Each cell with 0 or 1 neighbors dies (loneliness)
 - Each cell with 4+ neighbors dies (overpopulation)

Steps in the Risk Management Process

- Determine the corporation's *objectives*
- *Identify* the risk exposures
- *Quantify* the exposures
- Assess the *impact*
- Examine alternative risk management *tools*
- *Select* appropriate risk management approach
- *Implement* and *monitor* program

Agent-Based Modeling (ABM)

- Simulation
- Discrete events and incremental time periods
- Object-oriented programming
- Agents which (potentially) interact with each other
- Bottom-up programming
- Detailed behavior → system (macro) behavior
- Insights into evolution of system

Agents

- Decision-makers
- Autonomous bundles of attributes and processes
 - State of nature, which can change over time
 - Rules of behavior and interactions
- Potentially heterogeneous
- Collective, rather than individual, control of overall system
- Emergent behavior
- Adaptability – learn, modify behavior

Some Past Applications of ABMs

- Flocks of birds
- Traffic jams
- Financial contagion
- Movements of ancient societies
- Housing segregation and other urban issues
- Disease propagation

ABM Software

- Lots of available software – e.g.,
 - NetLogo (<http://ccl.northwestern.edu/netlogo/>)
 - Prior incarnation was StarLogo
 - Swarm (<http://www.swarm.org>)
 - Repast (<http://repast.sourceforge.net/>)
 - Ascape (<http://ascape.sourceforge.net/>)
- We'll use NetLogo in this presentation

Examples of ABMs

- Schelling – housing segregation
 - Agent stays put if percentage of neighbors of same “color” is at least as great as its preference
 - Agent moves if percentage of neighbors of same “color” is less than its preference
 - Moves to nearest space where preference is satisfied

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<http://ccl.northwestern.edu/netlogo/models/Segregation> for terms of use.

Examples of ABMs (cont.)

- Virus propagation – factors:
 - Population density
 - Infectiousness
 - Duration of infectiousness
 - Recovery potential and immunity

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Examples of ABMs (cont.)

- Marketing behavior and the Competitive Insurance Market
- Factors:
 - Initial market shares of firms
 - Potential influence of other consumers in personal “network”
 - Marketing plans and capabilities

Potential Value of CAS and ABM for ERM

- Detailed, rather than aggregate-level, modeling
 - E.g., “it’s never happened before, so it can’t, or won’t, in the future” fallacy
- Specific applications
 - Finance and financial risk
 - Strategy and strategic risk
 - E.g., modeling competitive markets
 - Operational risk
 - E.g., organizational processes, cascading effects of errors / fraud

ABM and Risk Analysis

“... sometimes risk is a property of a system as a whole, an ‘emergent’ property. Then a comprehensive, system-wide assessment of the causal factors that lead to risk throughout the system needs to be addressed. In this case, agent-based modeling is a natural approach to representing the diverse characteristics and decision-making behaviors of companies or individuals that comprise the system or industry.”

- *Managing Business Complexity*, North and Macal,
Oxford University Press, 2007

Conclusion

“The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk”

- Peter Bernstein, *Against the Gods*



Merci

**THANK
YOU**

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