CASE STUDY

AGENT-BASED MODELING (ABM)

NUTECH SOLUTIONS
science for business

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AGENT-BASED MODELING

COMPLEXITY SCIENCE OVERVIEW

Complexity is a relatively new interdisciplinary approach to studying the complex adaptive systems that make up much of the world, as we know it. Complex systems are composed of numerous, varied, simultaneously interacting parts, or agents – from molecules or bacteria in a biological process to individuals, machines, or businesses in an economic setting. Complexity science strives to uncover the underlying principles and emergent behavior of complex systems, elements that are often invisible to traditional approaches.

Complexity is a shift in the way scientists think, rather than a new field of science. Traditional science uses cause-and-effect reasoning: if you know all the factors that go into creating a situation, then you can predict what the outcome will be – or vice versa.

By contrast, in complex adaptive systems, patterns of behavior emerge that are often unpredictable and have unexpected outcomes that cannot be understood by an examination of the parts. Birds flock, yet flocking would not be predicted by looking at individual birds. Other examples of emergent behavior include how a system finds balance between order and disorder, and how agents, both individually and collectively, evolve new behaviors in response to change. Emergent behavior is exhibited by systems ranging from ecologies and immune systems to economies and organizations. The goal of complexity science is to understand these systems: what "rules" govern their behavior, how they adapt to change, learn efficiently, and optimize their own behavior. With this knowledge, a system's emergent behavior can often be altered advantageously.

Complexity science spans many disciplines, including physics, biology, and systems theory. The development of complexity science is not a single technological innovation, but a shift in scientific approach with the potential to profoundly affect business. Applying this approach to solve real-world business problems is the main pursuit of the NuTech Solutions.

AGENT-BASED MODELING

In agent-based modeling (ABM), real-world systems are modeled as collections of autonomous decision-making entities, called agents. Each agent individually assesses its situation and makes decisions based upon its own set of rules. Agents may execute various behaviors appropriate for the system they represent – for example, producing, consuming, or selling. Repetitive, competitive interactions between agents are a feature of agent-based modeling, which relies on the power of computers to explore dynamics out of the reach of pure mathematical methods.

Model simulations are run hundreds or thousands times to generate a distribution of behavior. Then that behavior is compared with historical data to ensure that the model is correctly calibrated.

ABM results in a realistic simulation of a system because it emulates the manner in which the world really operates. Even a simple model can exhibit complex behavior patterns and provide valuable information about the dynamics of the real world. Agents are capable of evolving, allowing unanticipated behaviors to emerge. ABM, as practiced by the NuTech Solutions, incorporates recent advances in neural networks and genetic algorithms to allow realistic learning and adaptation. Such models can be used in decision-making, as well as to develop flexible, adaptive strategies in dynamic business environments.

Agent-based simulation makes it easier to validate and calibrate the model through expert judgment because the agent-based description the model is using is often the most appropriate way of describing what is actually happening in the real world, and clients can easily “connect” to the model. In business, models have to be intuitive and easily understood by the practitioners, otherwise no one will use the model. By identifying the agents in a system and modeling their activities, the model can express very complicated dynamics in simple, easy-to-understand terms.

Agent-based models often are the only realistic method of capturing non-aggregate behavior. As an example, assume that a model contains a million agents representing customers. If the behavior of each of those customers is completely independent of the behavior of every other customer, then ABM will not provide any additional value. It is possible to examine historical data and fit curves, and use these curves to predict future behavior. In this case, any quantities calculated by these traditional techniques should turn out identically to those quantities calculated by ABM techniques. However, there is no real way of judging how accurate those curves will be as market conditions and social circumstances change.

In the real world, agents are generally not independent entities. They interact with each other via social networks; they interact with agents who may give all of their own clients the same kind of advice; they all read the same news sources, which will have articles on the economy, markets, retirement, etc. The most effective way to model such heterogeneous populations is via an ABM.

In summary, ABM is a more natural, understandable, convincing model than traditional actuarial techniques. And in unknown situations, for which there is no historical data, ABM clearly provides an immensely valuable improvement.