Beyond the KISS Principle for Agent-Based Social Simulation

Takao TERANO, Tokyo Institute of Technology

Abstract
The "Keep It Simple, Stupid" (KISS) principle stated by Robert Axelrod is a good guideline to model agent-based social simulation. However, to cope with real phenomena, we must go beyond the KISS principle. This paper re-examines the principle and discusses the underlining requirements for agent-based modeling using our recently developed agent-based models as examples.
1 Introduction

As Alan Kay stated, the best way to predict the future is to invent it. When we use agent-based models for social systems, we always invent a new world, or a new bird-view-like point of view, because we are able to design the simulation world as we would like to. Therefore, when we use agent-based models, we are predicting some future. After several decades of Allan Kay's statements, we have a new tool for predicting the future: Agent-Based Modeling (ABM) is a new modeling paradigm.

ABM shifts the focus from global phenomena to individuals in the model, and tries to observe how individuals, with their individual characteristics or "agents", will behave as a group. The strength of ABM is that it stands between the case studies and mathematical models. It enables us to validate social theories by executing programs, along with description of the subject and strict theoretical development.

In ABM, behaviors and statuses of individual agents are coded into programs by researchers. They also implement information and analytical systems in the environment, so the model itself may be very simple. Even when the number or variety of agents increases, the complexity of simulation descriptions itself will not increase very much. Robert Axelrod [1997a] emphasizes that the goal of agent-based modeling is to enrich our understanding of fundamental processes that may appear in a variety of applications. This requires adhering to the KISS principle.

KISS stands for "Keep It Simple, Stupid!" It is a maxim that means: the simpler, the better, and is similar in notion the Occam's razor. Axelrod, who is known for the Iterated Prisoner's Dilemma Game competition, argued as follows in his book [Axelrod 1997a]:

"The two-persons iterated Prisoner's Dilemma is the E. colo of the social sciences, allowing a very large variety of studies to be undertaken using a common framework. It has even become a standard paradigm for studying issues in fields as diverse as evolutionary biology and networked computer systems. Its very simplicity has allowed political scientists, economists, sociologists, philosophers, mathematicians, computer scientists, evolutionary biologists, and many others to talk to each other. Indeed, analytic and empirical findings about the Prisoner's Dilemma from one field have often led to insights in other fields."

In the book, he also considers the "Iterated Prisoner's Dilemma Game" as a good model to realize the KISS principle and states as follows:

"Although agent-based modeling employs simulation, it does not aim to provide an accurate representation of a particular empirical application. Instead, the goal of agent-based modeling is to enrich our understanding of fundamental processes that may appear in a variety of applications. This requires adhering to the KISS principle, which stands for the
army slogan ‘keep it simple, stupid.’"

This paper discusses the KISS principle assertion once again and presents a new vision on agent-based modeling methodology regarding complex adaptive systems and collective intelligence. This paper is structured as follows: The second section examines agent-based modeling and the KISS principle. The third section identifies requirements for simulation experiment to surpass the KISS principle. The forth section states how these requirements are reflected in the model, based on our study. The fifth section will give concluding remarks.

2 Agent-Based Modeling and the KISS Principle

Traditionally, study of society, economics and systems has approached the theory through cases, in which researchers examine well-structured documents with historical facts or approached mathematical and/or statistical models with some numerical data. For example, financial theorist and engineers utilize concepts of probability and statistics. They often use tools from statistical physics for financial problems. In financial engineering, accordingly, the market is assumed to satisfy certain given conditions like physical laws in the natural world. However such assumptions usually do not hold. That is because the market is affected by decisions and actions of individuals who compose the market, and the trading rules on the market, unlike natural phenomena, are designed based on the decisions of those contained in the market.

On the other hand, study of agent simulation, or more generally agent-based modeling, takes advantage of recent advances in computer's processing power, and shifts the focus from global phenomena to individuals in the model and tries to observes how individuals with their individual characteristics, or "agents" will behave as a group [Deguchi 2000], [Carley 1999], [Carley 2000]. Study on simulation methods in organizational systems has a long history. For example, the book written by Cyert and March [Cyert 1963] is a start point of organizational simulation. Among them, the garbage can model is well-known in organizational decision-making behavior [March 1972]. The strength of the agent simulation approach is that it stands between the case studies and mathematical models. It enables us to validate social theories by executing programs, along with description of the subject and strict theoretical development.

Axtell [Axtell 2000] suggested that agent simulation in social science could extend various aspects, which have been neglected in conventional theoretical studies.

"The simplest use is conceptually quite close to traditional simulation in operations research. This use arises when equations can be formulated that completely describe a social process, and these equations are explicitly soluble, either analytically or numerically. In the former case, the agent model is merely a tool for presenting results; while in the latter it is a novel kind of Monte Carlo analysis. A second, more commonplace
usage of computational agent models arises when mathematical models can be written down but not completely solved. In this case the agent-based model can shed significant light on the solution structure, illustrate dynamical properties of the model, serve to test the dependence of results on parameters and assumptions, and be a source if counterexamples. Finally, there are important classes of problems for which writing down equations is not a useful activity. In such circumstances, resort to agent-based computational models may be the only way available to explore such processes systematically, and constitutes a third distinct usage of such models.

In agent simulation, behaviors and statuses of individual agents are coded into programs by researchers. They also implement information and analytical systems in the environment, so the model itself may be very simple. Even when the number or variety of agents increases, the complexity of simulation descriptions itself will not increase very much. Though they cannot cope with computational complexity or combinatorial explosion in the simulation, agent base models are very effective to analyze complex social phenomena with simple description. We should switch our principles of conventional artificial intelligence approach [Russel1995], which tries to make agents smart, into ones to ravel "intelligence as a group" through agent-based modeling.

Under such agent-based modeling principles, results of scientific study will be communicated in a form comprehensible to other researchers, and when it involves experiments, the results will be reproducible. Emphasis on the KISS principle in agent simulation is to truthfully respond to these two requirements. Needless to say, agent simulation is merely "understanding" and "execution" of a certain aspect of a phenomenon, but it has the potential to greatly advance the frontier of existing studies when it is used as a supplement to the theory or when theory is used as a supplement to it.

On the other hand, the simpler the model, the more explanatory interpretation of the result is necessary, in order to avoid easy explanation such as "We did it and we got it," as Izumi mentioned. Actually, several extreme explanations were given to the models discussed in Axelrod [Axelrod 1997a] and Epstein [Epstein 1996]. When the model is simple, the result seems to be obvious, and the harder we try to understand phenomena, the more complex the model becomes, which goes against the KISS principle.

3 Requirements for Agent-Based Simulation Experiments

It is necessary to depart from the KISS principle to better understand social phenomena. However, it does not mean that we shall implement unnecessarily complex models to conform to the actual world. Below I summarized the requirements for simulation experiments, especially agent-based simulation of social phenomena.
1. It should produce results, which correspond with real world phenomena

Unlike natural phenomena, social phenomena are not reproducible. However, there are established theoretical systems to explain phenomena, such as financial engineering and economics. It is important that simulation provide results that agree with these theories and actual phenomena.

2. It should show phenomena difficult to explain by existing theories

It is also important that phenomena that are difficult to explain by existing theories but exist in reality will be reproduced in a limited manner. For example, the fat tail phenomenon, which is observed in stock price distribution, is difficult to explain by existing theories, but it can easily be reproduced in simulation, and an explanation is provided by economic physics.

3. It should generate satisfactory results

Simulation study of social phenomena requires numerous parameters. Therefore, we can produce desired results by parameter tuning. Results unsatisfactory to the researchers of model builders are meaningless. Researchers must at least be convincing in the literature regarding simulation results.

4. The results must be rigorously validated

When a simulation experiment is performed, it produces results. However, it is extremely difficult to demonstrate the validity of the results. The results will lack persuasion without a theory upon the simulation is based, a basis for the functions equipped to the agents, accuracy of the program, strict sensitivity analysis of the results, and so on.

5. It should approach the issues difficult to explain by existing theories

Existing theories are based on the assumption that there is some sort of rationality in the agent's behavior or decision making. In actual phenomena, however, this rationality assumption often does not hold. Simulation may provide a systematic explanation for, and reveal hidden conditions of such issues.

In the following chapter I will briefly present recent studies that shows how we have been working to fulfill these requirements. I will use [Takahashi 2002], [Takahashi 2003], and [Takahashi 2003] as examples for (1) and (2), [Kurahashi 1999], [Terano 2000], and [Kurahashi 2001] for (3) and (4), and [Sato 2000], [U-Mart 2003], and [Terano 2003b] for (5).

4 What We Find from Agent-Based Simulation

In the following sub-sections, I will describe several interesting results, which take place in social and economic systems, with focus on research results from ABM we have conducted. The following examples are obtained through systematic validations on simulation results. However, due to restriction of space, I do not detail simulation prerequisites, model architecture, or experiment methods. For details, please see the references.
4.1. Agent Simulation of Behavioral Finance

Understanding the mechanism of the financial market is important to analyze rapid development of e-commerce and the robustness of the economic system. So far, however, such analyses have mostly used macroscopic mathematical models. Conventional financial models are analytical and require 'rationality' in the market and individual behaviors. The assumptions of rationality of conventional theories are summarized as follows: (i) that the market is effective and the information will be known to agents immediately and completely, (ii) that agents are capable of decision-making that maximizes their utility functions, and (iii) that there is no limitation in the agent's financial resources, and transaction of any scale is possible. These assumptions are not met in reality, but they are inexplicitly assumed in designing, for example, financial products.

Based on the background, we have developed an agent-based simulation model to evaluate financial market behavior (Fig. 1). We paid attention to the gap between the GARCH (Generalized Autoregressive Conditional Hetero-scedasticity) model and prospect theory in social psychology, and have examined the influence of the agent's risk management methods on the financial market [Takahashi 2002], [Takahashi2003], [Takahashi 2003]. Here the GARCH model is a model to explain macro-level phenomena, which presumes the volatility (price dispersion) in financial engineering. On the other hand, the prospect theory is a micro-level model, which explains the nature of human decision making in cognitive psychology, which explains that the loss is estimated as larger than in actual fact. These theories are well-known in finance and cognitive psychology, respectively, and can be combined by the agent-based model to enable macro-level analysis based on micro-level behavior.

In our model we implemented a virtual market composed of four types of (rational and irrational) investors, which is also equipped with two types of risk management methods, VaR (Value at Risk) and portfolio insurance. The market we have developed consists of one thousand investors and allows them to trade two types of assets: a stock and

![Diagram](https://example.com/diagram.png)

**Figure 1. Agent model for the financial market**
a risk-free asset. In this market, multiple types of investors exist and conduct transactions based on the investment rules defined for each type. The market operations contain the following three steps: accrual of the corporate profit, formation of the investors' predictions, and determination of the traded price. In the following, we explain in detail, about the trading assets, decision rules of both active and passive investors, and decision procedures of market prices.

Findings from the experiment results are summarized in the following five points: (1) Even when there are a certain number of rational decision making agents in the model, the effective market assumption does not hold; (2) Even when there are rational decision making agents, irrational decision making agents will survive; (3) Behavior of agents with the mental model based on the prospect theory will determine volatility prospect based on the GARCH model. (4) Risk management methods in financial engineering are useful for individual agents. (5) However, in some cases, e.g. when excessive risk management is conducted or when there are investors who care about others, risk management may have a negative influence on the market. These results suggest that irrational investors incessantly have an impact on the price in the actual market as well, and further, indicate the effectiveness of applying agent simulation to the field of finance.

Our model is validated based on the following points: For requirement (1) a typical model in financial engineering and cognitive science is employed for an agent's micro-level decision making, and well-known results in the literature are employed for the market. Therefore, the results were conforming to existing theories within the range of 'rationality' on the macro-level. For requirement (2), relaxation of the 'rationality' assumption regarding agents, widens the gap between existing theories and at the same time gave no results conforming to actual data on the macro-level.

4.2. Agent Simulation of Social Interaction

We have been working on an artificial society simulator TRURL, which aims to explore social interaction problems observed in such real-world activities as e-mail-oriented organizations and electronic commerce markets. We used this simulator to (i) analyze the emergence of leadership and conforming behavior in the electronic community [Kurahashi 1999], as well as (ii) analyze the stabilization and breakdown of distribution rules of information resources, which is the foundation to maintain the community [Kurahashi 2001].

TRURL is an artificial society model composed of agents with decision making functions based on the multi-attribute attitude model. This society is characterized by physical distance between agents, confidence distance, and communication attitude, and has a parameter space of the 13th power of 10 to the 15th power of 10. The agent has event-action rules [Russel 1996] and acts consuming the parameter called "participation motivation" (equivalent to the amount of energy or metabolism) during simulation. Furthermore, exchange of "knowledge" changes the agent's decision making structure.
and motivation value.

Decisions of the agents are made based on each agent's knowledge, but independent of this, there is a message exchange process among agents. Each agent interacts with other agents at discrete time steps according to the restrictions set for each simulation model. The interaction is performed according to knowledge attribute. When an agent receives unknown knowledge, it will accept it as is. However, when known knowledge is received, the nature of knowledge will change based on the following attenuation behavior rules in accordance with its attribute.

With agent parameters set on the microlevel, the conditions of the society can be measured by macro-level information or social indices such as the speed of change in general social opinion, maldistribution of information goods measured by the Gini index, and the topological scale of the communication network.

In TRURL, the social index is optimized by Genetic Algorithms. That is, many parameters in the artificial society are adjusted by the evolutionary computation method. At this time, we will use the above social indices to evaluate the society as an objective function, and the resultant convergent society is analyzed from the characteristics of the agent group that composes the society. In the actual social system, these macro indices are measurable, but the system's individual agent characteristics cannot be obtained. On the other hand, in the artificial society, it is possible to create a society with the above-mentioned nature through "evolutionary computation" by using such macro-level measures as objective functions. Furthermore, we can obtain different knowledge by conducting simulation in the created society, and analyze the characteristics of the agents that compose the system based on parameter distribution information. The significance of simulation experiments of an artificial society lies in this point.

We call this method "inverse simulation," because it solves an inverse problem to

![Figure 2. Evolution of the artificial society through inverse simulation](image)
identify agent parameter, and also "genetics-based validation," because it analyzes agent parameters created by genetic algorithms.

Agent simulation models using the artificial society model TRURL are validated based on the following. For requirements mentioned in (3) in the previous chapter, by systemically exploring a sufficiently large parameter space, it achieved the optimum value expressed by the objective function; in other words, it eliminates arbitrariness in parameter-tuning in design and execution of simulation. To address requirement (4), we statistically analyze a lot of individual information; that is, many simulation results to systemically perform sensitivity analysis of the simulation results.

4.3. Participatory Simulation by Mixing Human and Machine Agents

U-Mart is a test bed aimed at examining various problems rooted in the complexity of the economic trading market. Issues at hand include (1) clarifying decision making issues, including human group's learning/emergence and interaction regarding behavior of trading stock and so on, as well as system design; (2) clarifying the relationship between speculative trading behavior and market instability such as violent price fluctuations in the market, and designing a system that can prevent it; (3) assuming an agent's behavior from market conditions, such as testing of use of insider information; and (4) experimenting with coevolution aspects of trading strategy in the market. All of these problems are difficult to discuss by conventional economic theories, and require the approach using agent simulation with some degree of complexity.

To develop the test bed, we set the following three requirements:

(1) association with the real world:
The U-Mart targets the actual stock price index and virtually creates the market that deals not in "spot" but in "futures," which does not exist in reality.

Figure 3. Configuration of the U-Mart system
(2) Openness with wide participatory opportunity:
To enable interdisciplinary research among various fields, including economics, financial engineering, and computer science, the system will be designed as an open system that allows participation of various bodies. In the study of artificial market, (limited) rationality and diversity of trading strategy are important. In U-Mart, we explore potentials of various strategies through software agent contest and gaming simulation by human players, and study price formation based on these results.

(3) Provision of the experiment environment for system analysis and design:
Virtual experiment of the market under various trading strategies enables anatomical analysis of experiment results. We also evaluate the influence of various systems of the market, such as pricing, settlement, and commission, and handle system design issues.

Fig. 3 shows the architecture of U-Mart system. As shown here, U-Mart is relatively simple as an experiment system. However, our various experiments over three years showed the following interesting phenomena.

(1) In the actual market, small fluctuations of trivial information often trigger violent fluctuations. Similar erratic fluctuations also take place in the U-Mart. Some triggers are incorrect data entry by humans participating in the U-Mart. Similar phenomena are also observed in the real world.

(2) An agent's performance cannot be determined by a limited number of experiments. Even agents designed to succeed in a transaction may greatly vary in performance, depending on information given or whether they are acting in combination with other agents. Accordingly, a diversified aspect is important for agent evaluation.

(3) Even small changes in trading rules of the market significantly affect agent's performance. Accordingly, designing a system for a robust market is extremely difficult.

Such knowledge could not be obtained without the simulation environment where software and humans exist at the same time, which corresponds to requirements (5) in the previous chapter.

5 Concluding Remarks

In this paper, I have discussed the principle of agent-based modeling and the necessity to go beyond the KISS principle, keeping in mind application to social/economic system study.

The agent simulation method is very powerful as it can produce results without unnatural assumptions, unlike conventional approaches. For this reason, it is also gradually attracting much attention in the field of social science, which has little connection with artificial intelligence study [Epstein 1996], [Deguchi 2000b], [Gilbert 1999]. Furthermore, many simulation tool kits have been released in recent years (e.g. [Ascape
2001], [Swarm 2001], and [MAS 2003]). On the other hand, there has been little persuasive discussion in the traditional social science field, due to beliefs such as that it ignores conventional research hypotheses, or that the basis of the model is too weak to overcome the discussions in the literature. However, agent-based modeling is a very effective approach when considered as the third study method that interpolates the case study approach and mathematical approach.

In recent years, many texts on agent-based modeling have been published in artificial intelligence-related fields as well [Izumi 2003], [Namatame 1998], [Nishida 2002], [Ouchi 2002], [Weiss 1999]. As I have mentioned in this paper, now is the time to call for a new methodology that goes beyond the KISS principle. More recent results and discussions through various lines of study are found in [Terano 2007a] and [Terano 2007b], in which I emphasize the methodology of ABM validations and the needs for continuous improvement on ABM research.

Notes
(1) Preliminary version of the paper was presented at the 21st-Century COE Program Creation of Agent-Based Social Systems Sciences, 2nd Symposium on July 12, 13, 2005 at Tokyo Institute of Technology, pp. 69-78 (2005). The symposium is conjunct with AESCS 2005.

References


Beyond the KISS Principle for Agent-Based Social Simulation


