Luis Antunes
Keiki Takadama (Eds.)

LNAI 4442

# Multi-Agent-Based Simulation VII

International Workshop, MABS 2006
Hakodate, Japan, May 2006
Revised and Invited Papers

Springer

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Springer

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# Preface

This volume groups together the papers accepted for the Seventh International Workshop on Multi-Agent-Based Simulation (MABS 2006), co-located with the Fifth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2006), which occurred in Hakodate, Japan on May 8, 2006.

MABS 2006 was the seventh workshop of a series that began at ICMAS 1998 (Paris, France), and continued successively with ICMAS 2000 (Boston, USA), AAMAS 2002 (Bologna, Italia), AAMAS 2003 (Melbourne, Australia), AAMAS 2004 (New York, USA) and AAMAS 2005 (Utrecht, The Netherlands). The revised version of the papers of these workshops appeared in Springer's *Lecture Notes in Artificial Intelligence*, in volumes 1534, 1979, 2581, 2927, 3415 and 3891. All information on the MABS Workshop Series can be found at `http://www.pcs.usp.br/~mabs`.

Multi-agent-based simulation is an inter-disciplinary area which brings together researchers active within the agent-based social simulation (ABSS) community and the multi-agent systems (MAS) community. The scientific focus of MABS lies in the confluence of the ABSS and MAS communities, with a strong empirical/applicational vein, and its emphasis is on (a) exploring agent-based simulation as a principled way of undertaking scientific research in the social sciences and (b) using social theories as an inspiration to new frameworks and developments in multi-agent systems.

To promote this cross-influence, MABS provides a forum for social scientists, agent researchers and developers, and simulation researchers to (a) assess the current state of the art in the modeling and simulation of ABSS and MAS; (b) identify where existing approaches can be successfully applied; (c) learn about new approaches; and (d) explore future research challenges.

MABS 2006 attracted a total of 25 submissions from 11 different countries (Brazil, France, Italy, Japan, Pakistan, Portugal, South Korea, Spain, Sweden, UK, USA). Every paper was reviewed by three anonymous referees, and in the end 12 papers were accepted for long presentation and 3 papers were accepted for short presentation. Every paper was later reviewed again by a Program Committee member for this volume.

We are very grateful to every author who submitted a paper, as well as to all the members of the Program Committee and the additional reviewers for their hard work. The high quality of the papers included in this volume would not be possible without their participation and diligence. We would also like to thank Takao Terano, who gave a very interesting invited talk.

Thanks are also due to Jiming Liu (AAMAS 2006 Workshop Chair), Hideyuki Nakashima and Michael Wellman (AAMAS 2006 General Chairs), and Ei-ichi Osawa (AAMAS 2006 Local Organization Chair). Finally, we would like to thank

Springer staff, especially Alfred Hofmann and Christine Günther for their support of MABS, and their help in the making of this book.

As the social simulation community grows and spreads its multi-disciplinary influence over several scientific areas, the related conferences also get more prominence, autonomy and importance. To illustrate this point, consider the new WCSS (First World Congress on Social Simulation), the recent ESSA (European Association on Social Simulation) conference series, the already established NAACSOS (North American Association for Computational Social and Organization Sciences) conference series, or the PAAA (Pacific Asian Association for Agent-Based Approach in Social Systems Sciences) workshop series. In this new context, we still find that MABS has a place and a relevant role to play, serving as an interface between the community of social simulation and that of computer science, especially multi-agent systems.

April 2007

Luis Antunes
Keiki Takadama

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# Exploring the Vast Parameter Space of Multi-Agent Based Simulation

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**Abstract.** This paper addresses the problem regarding the parameter exploration of Multi-Agent Based Simulation for social systems. We focus on the principles of *Inverse Simulation* and *Genetics-Based Validation.* In conventional artificial society models, the simulation is executed straightforwardly: Initially, many micro-level parameters and initial conditions are set, then, the simulation steps are executed, and finally the macro-level results are observed. Unlike this, *Inverse Simulation* executes these steps in the reverse order: set a macro-level objective function, evolve the worlds to fit to the objectives, then observe the micro-level agent characteristics. Another unique point of our approach is that, using Genetic Algorithms with the functionalities of multi-modal and multi-objective function optimization, we are able to validate the sensitivity of the solutions. This means that, from the same initial conditions and the same objective function, we can evolve different results, which we often observe in real world phenomena. This is the principle of *Genetics-Based Validation.*

**Keywords:** Multi-Agent Based Modeling, Social Systems, Verification and Validation, Parameter Exploration, Genetic Algorithms.

## 1 Introduction

As Alan Kay stated, *the best way to predict the future is to invent it.* When we use Multi-agent based simulation (MABS) for social systems, we always invent a new world, or a new bird-view-like point, because we are able to design the simulation world as we would like to. Therefore, when we use MABS, we are predicting some future. After several decades of the Allan Kay's statements, we have a new gear for predicting the future: MABS is a new modeling paradigm [1],[2].

MABS focuses from global phenomena to individuals in the model and tries to observe how individuals with individual characteristics or "agents" will behave as a group. The strength of MABS 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 MABS, behaviors and statuses of individual agents are coded into programs by researchers. They also implement information and analytical systems in the

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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 [13], [14]. Axelrod [1] has 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*, which stands for the army slogan *"keep it simple, stupid."*

Running an agent-based model is an easy task, however, the analysis is not [7]. Even for a simple simulator with the KISS principle, we must cope with vast parameter space of the model. This paper discusses the problem regarding the parameter exploration of Agent-Based Simulation for social systems.

## 2 Coping with the Huge Parameter Spaces

There are no Newton's Laws, or the first principles in social systems. This makes MABS approaches both easy and difficult. The easy face is that we are able to build models as we like, on the other hand, the difficult face is that the models are hardly grounded in any rigorous grounding theories. For example, the application of finance engineering is one of good candidates of MABS approaches. They seem to follow the first principles, however, it is not true. The assumptions of finance engineering often come from the principles of statistical physics, one of the first principles of physics. However, the real data and real phenomena sometimes break the assumptions. This means that the assumptions about social phenomena are not based on the first principles.

The real phenomena in our society and social systems are only collections of instances. Therefore, using social simulation techniques, we are able to generate so many instances of simulation results through MABS. This is the very merit of our MABS approach.

However, even simple models with ten step decisions with ten alternatives in every step have 10**10 parameter spaces. This means that it would take over 10,000 days to complete them, if we could search 10 spaces per second. We must compute so many cases. To overcome the problem, one solution of the issue is to follow the *KISS principle*. Simple convincing models are welcome. However, the simpler the model, more explanatory interpretation of the result has to be, in order to avoid easy explanation such as "We did it and we got it." Actually, several extreme explanations were given to the models discussed in Axelrod or Epstein. 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 against the KISS principle.

To convince the results of MABS, we are required (i) to rigorously validate the models and simulators, (ii) to examine background social and organizational system theories, and (iii) to overcome the vast of parameters of both agent behaviors and models. Also, (iv) we need multiple good results to design and analyze social complex task domains. Therefore, as another solution, we propose a new method, which employs *Generate and Test* techniques in the simulation process. This follows the principles of *Inverse Simulation* and *Genetics-Based Validation.*

## 3 Principles of Inverse Simulation

In conventional MABS models, the simulation processes are executed straightforwardly: Initially, many micro-level parameters and initial conditions are set, then, the simulation steps are executed, and finally the macro-level results are observed. Unlike in conventional simulation models, in the Inverse simulation, we execute these steps in the reverse order: set a macro-level objective function, evolve the worlds to fit to the objectives, then observe the micro-level agent characteristics. Thus, we solve very large inverse problems. The basic principles are shown in Figure 1. The essential point is that we force to get desired results specified by the macro-level objective functions, then analyze the micro-level structures of the results.

They have thought such brute force approach is infeasible, so far, however, using recent competing genetic algorithms (GAs) [4] has made it possible to get multiple solutions in reasonable times. In our simulators in the following sections, we have employed GAs with tabu-search techniques in Operations Research literatures[5],[6]. The method is able to optimize multi-modal functions [3]. This means that, from the same initial conditions and the same objective function, we can evolve different results, which we often observe in real world phenomena.

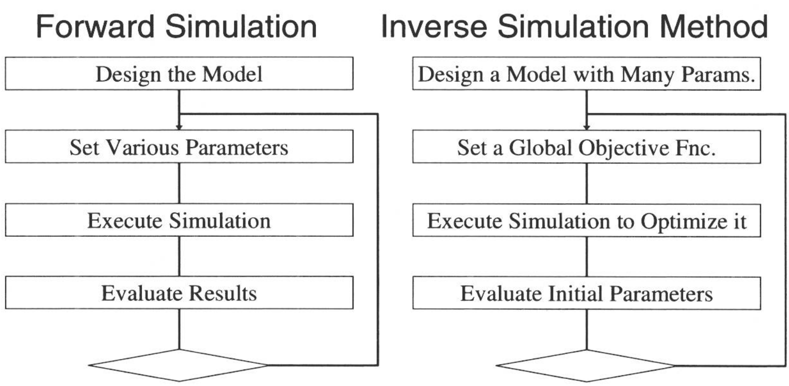


**Fig. 1.** Basic Cycles of Agent-Based Simulation

The agents, their behaviors, and the world are controlled by many parameters. In our settings, genotypes of GAs are corresponding to initial parameters of agents and the initial world we are considering. Phenotypes of GAs to be evaluated are simulation results, which can be measured macro-level evaluation functions. We will carry out so many simulation cycles to get the results. For example. To get one result, we might need several hundred simulation steps per simulation. To evaluate one generation, we might need several hundred populations in parallel, and to converge the macro-level objective functions, also we need several hundred GA generations. The outline is shown in Figure 2.

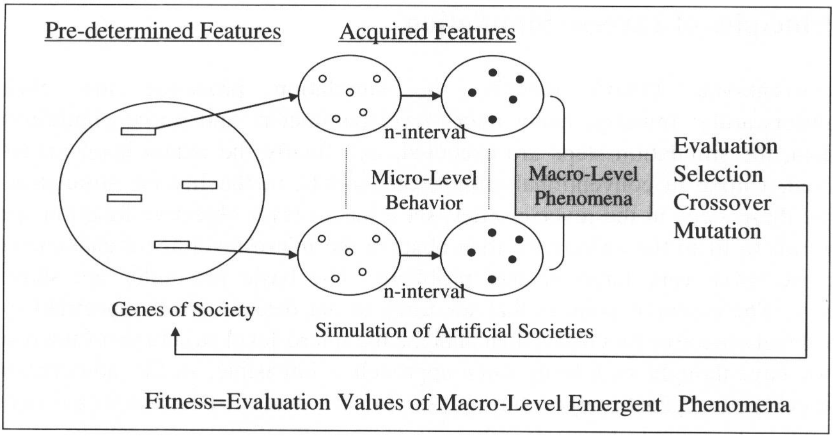


**Fig. 2.** Inverse Simulation

To apply *Inverse Simulation*, we assume that the MABS models have the following properties:

(i) micro-level rich functionalities of agent behaviors, interactions, and the world;
The requirement is important to leap simple models to be analyzed. If the model would be simple, the KISS principle would work better to convince the results.

(ii) macro-level clear evaluation measures to be optimized through the simulation processes;
The requirement is critical to quantitatively evaluate the simulation results. We usually use macro level measures of a social network, e.g., the centrality, agents' population distributions, or GINI index of some welfare of the worlds. The landscape of the objective functions might be very complex in the social phenomena, e.g., multiple peaks and multiple objectives. So, simple GAs are not adequate to get the results.

(iii) Fast execution of single simulation run.
The requirement is necessary to compute the simulation efficiently. Inverse Simulation is computationally high cost. Therefore, the faster the run, the better the results. We are planning to utilize Grid-based computer systems to apply the technique.

## 4 Principles of Genetics-Based Validation

Validation is one of the most critical tasks in MABS approach to convince the results. In this section, we address a new statistical validation method: *Genetics-Based Validation* for the solutions of simulation results. This is a kind of sensitivity analyses of parameters in the experimental system we target. The principle is summarized as follows. When *Inverse Simulation* terminates, using GAs for multiple solutions, if there were multiple solutions in the targeted MABS model, then every important parameter of the model would converge. This means that the objective functions have their peaks. However, non-essential parameters would have various distributed values. It is because the variations of non-essential parameters would not contribute to the values of objective functions. If we would have used conventional GAs, because of the effects of genetic drifts, the non-essential parameters would converge. This is a bad situation for our analysis. Competing GAs with the functionalities to cope with the multiple solutions, they keep diversity of the solutions. We are able to utilize the variance of the parameters to determine whether specified parameters are essential for the results of simulations or not.

In Figure 3, we illustrate the situations. we observe some distribution of simulation results. Initially, simulation results are several values in the sense of the objective functions values. In the final steps, the objective function values converge to the same level, however, the distributions of solutions are different according to the essential and/or non-essential dimensions of parameters. Therefore, applying statistical techniques, we are able to uncover the shape of the landscapes of the results measured by the specified objective functions. For example, to apply the principal component analysis technique, we are able to obtain the distributions of solution values, or simulation results, which will reveal both essential and non-essential dimensions of parameters.. We call the method *Genetics-Based Validation.*

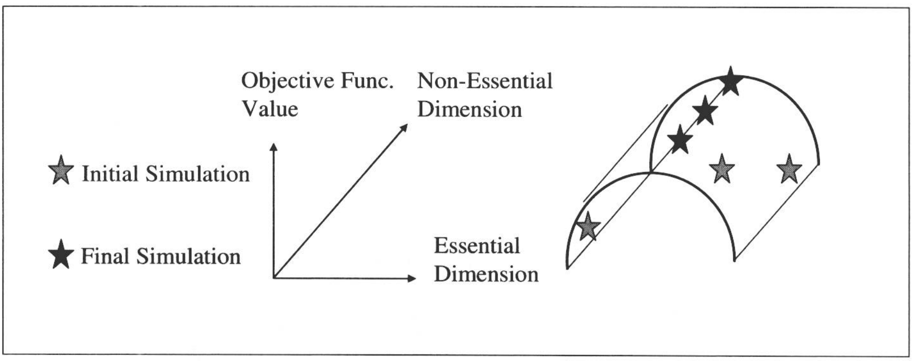


**Fig. 3.** Principles of Genetics-Based Validation

## 5 How Inverse Simulation and Genetics-Based Validation Work

We have applied the proposed techniques: *Inverse Simulation* and *Genetics-Based Validation* to various kinds of agent-based simulation models. In this section, we will briefly describe three of them. The first example is a MABS model for social interaction analysis. The second one is a marketing model of competing firms. The last one is concerned with a MABS model for financial decision making. The three models are too complex to understand from the KISS principle, however, we are able to uncover what have happened in the sense of parameter sensitivity analysis.