T. Terano • H. Kita • S. Takahashi • H. Deguchi (Eds.)

Agent-Based Approaches in Economic and Social Complex Systems V

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The AESCS International Workshop 2007

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Agent-Based Social Systems

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Volume 6

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ABSS—Agent-Based Social Systems

This series is intended to further the creation of the science of agent-based social systems, a field that is establishing itself as a transdisciplinary and cross-cultural science. The series will cover a broad spectrum of sciences, such as social systems theory, sociology, business administration, management information science, organization science, computational mathematical organization theory, economics, evolutionary economics, international political science, jurisprudence, policy science, socioinformation studies, cognitive science, artificial intelligence, complex adaptive systems theory, philosophy of science, and other related disciplines.

The series will provide a systematic study of the various new cross-cultural arenas of the human sciences. Such an approach has been successfully tried several times in the history of the modern science of humanities and systems and has helped to create such important conceptual frameworks and theories as cybernetics, synergetics, general systems theory, cognitive science, and complex adaptive systems.

We want to create a conceptual framework and design theory for socioeconomic systems of the twenty-first century in a cross-cultural and transdisciplinary context. For this purpose we plan to take an agent-based approach. Developed over the last decade, agent-based modeling is a new trend within the social sciences and is a child of the modern sciences of humanities and systems. In this series the term "agent-based" is used across a broad spectrum that includes not only the classical usage of the normative and rational agent but also an interpretive and subjective agent. We seek the antinomy of the macro and micro, subjective and rational, functional and structural, bottom-up and top-down, global and local, and structure and agency within the social sciences. Agent-based modeling includes both sides of these opposites. "Agent" is our grounding for modeling; simulation, theory, and real-world grounding are also required.

As an approach, agent-based simulation is an important tool for the new experimental fields of the social sciences; it can be used to provide explanations and decision support for real-world problems, and its theories include both conceptual and mathematical ones. A conceptual approach is vital for creating new frameworks of the worldview, and the mathematical approach is essential to clarify the logical structure of any new framework or model. Exploration of several different ways of real-world grounding is required for this approach. Other issues to be considered in the series include the systems design of this century's global and local socioeconomic systems.

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With 123 Figures

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Preface

This volume contains papers selected from presentations at the AESCS'07, which was held at Waseda University, Tokyo, Japan, August 29–30, 2007. The workshop was the fifth in a series of Pacific Rim activities in emerging interdisciplinary areas of social and computational sciences. Since the fourth AESCS, in 2004, the workshop has been held as a regular meeting of the Pacific Asian Association for Agent-Based Social Sciences (PAAA). In 2006, it was extended as the First World Congress of Social Simulation (WCSS06) in collaboration with PAAA, NAACSOS, and ESSA, the three regional societies in the field in the Asia-Pacific, North American, and European areas, respectively. Following the success of AESCS'05 and WCSS06, AESCS'07 received 29 submissions of original papers. Each paper was reviewed by at least two program committee members of AESCS'07, and in the workshop we had 25 presentations. At AESCS'07, we also had one plenary talk by Prof. Shu-Heng Chen, National Chengchi University, Taiwan, and two invited talks, by Dr. Gaku Yamamoto of IBM Research and by Dr. Richard Warren, Air Force Research Laboratory, USA.

For this volume, we selected 21 papers from among those presented in the workshop, along with two invited papers by Prof. Shu-Heng Chen and Dr. Richard Warren.

Contributions cover various areas of the social sciences such as the market, finance, and other topics in economics, organization and management, marketing, and sociology. Contributions also deal with subjects more closely related to engineering, such as production and traffic. The progress of study in this field shows that researchers have started to construct more complex and realistic models with implications for policy making and engineering design, as well as simplified models to elucidate principles of social systems. This trend shows the growing importance of the field both in the social sciences and in engineering. Further contributions from social sciences and computer science through interdisciplinary study are anticipated in such a promising field.

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Plenary Talk

Genetic Programming and Agent-Based Computational Economics: From Autonomous Agents to Product Innovation

Shu-Heng Chen

Abstract Despite their great development over the last decade, most ACE (agent-based computational economics) models have been generally weak in demonstrating discovery or novelty-generation processes. In this sense, they are not very distinct from their counterparts in neo-classical economics. One way to make progress is to enable autonomous agents to discover the modular structure of their surroundings, and hence they can adapt by using modules. This is almost equivalent to causing their "brain" or "mind" to be designed in a modular way. By this standard, simple genetic programming is not an adequate design for autonomous agents; however, augmenting it with automatic defined terminals (ADTs) may do the job. This paper provides initial research with evidence showing the results of using ADTs to design autonomous agents.

1 Introduction

GP maintains a unique position when compared with other computational intelligence tools in modeling autonomous agents. Basically, there are two distinguishing features of using GP in modeling autonomous agents. First, in a sense, GP provides agents with a larger degree of autonomy. Second, it provides us with a concrete picture to visualize the learning process or the discovery process as a growing process, i.e., that of growing the evolving hierarchies of building blocks (subroutines) from an immense space of subroutines.

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1.1 Autonomy

The first feature, a larger degree of autonomy, has two implications. First, it lessens the burden of model-builders in their intervention or supervisory efforts over these agents. Second, it implies a larger degree of freedom left for agents to explore the environment around them, and a better chance for us to watch how they adapt and what they learn.

The first implication is important when model-builders themselves know very little about the structure of the environment in which their agents are placed, and hence they do not even know how to supervise these agents in a well-defined manner; in particular, they do not want to misinform these agents with biased information. The second implication is even more important because what they learn or discover may be non-trivial for us. In this case, we are taking lessons from them. Alternatively, it makes us able to have the novelties- or surprises-generating processes, an essential element of any complex adaptive system. By observing and making sense of what agents learned, we as outsiders are also able to learn.

1.2 Learning

The second feature is also appealing because it enables us to give an alternative interpretation of what we mean by *learning*. Learning is a highly interdisciplinary concept, which concerns many disciplines, ranging from psychology, education, neural sciences, cognitive sciences, mathematics and statistics, to information sciences.

Its meaning in economics also varies. In some situations, it is very trivial and means nothing more than *making a choice* repeatedly under the same or a very similar environment with the same options. There are a number of learning algorithms corresponding to this simple case. The most famous one is *reinforcement learning*, and the other equally familiar and related one is the *discrete choice model* associated with the Boltzmann-Gibbs distribution. These learning algorithms only involve a very simple stimulus-reaction mechanism, and the development of sophisticated reasoning is not required, at least, not explicitly.

In some other situations, learning means the attempt to find out the law between the causes and the effects, the mapping between the inputs and outputs, and the underlying mechanism by which observations are generated. It is more like a scientific learning. The feedforward neural networks (FNNs) represent such a kind of learning. Numerous mathematical analyses of neural networks show that FNNs are universal function approximators, even though to build such an approximation process is another issue.

However, these two kinds of learning, the stimulus-reaction learning and the scientific learning, may cover only a very limited part of what we generally experience about learning. What has been missing is the idea of the *building block*, which connects what we have learned before to what we are learning now or what we will learn in the near future. In considering the learning of mathematics as an example, we cannot study differential equations without having calculus as the prerequisite. If we perceive learning as a walk along a *ladder* which makes us move higher and become more experienced at each step, then the kind of learning which we are interested in is developmental learning, and genetic programming is one of the learning algorithms which are able to demonstrate this feature.

2 Genetic Programming and Economics

Genetic programming is a methodological innovation in economic. It is so because it captures three essential elements in the making of economics. The three elements are *constant changes* from inner nature to outer forms, *evolving populations* of decision rules, and *modularity*. These three elements have been initiated by three prominent economists at different times. Two of them, Herbert Simon and Robert Lucas, are Nobel Laureates, and the one, who is not, died in 1924 when the Nobel Prize had not yet existed, but who is generally regarded as the father of the neo-classical economics. In what follows, we shall go through them in chronological order.

2.1 Alfred Marshall

The first connection between GP and economics is the idea of *constant change*. Its origin can be traced back to the late 19th century. Alfred Marshall [20] wrote:

> Economics, like biology, deals with a matter, of which the inner nature and constitution, as well as outer form, are constantly changing. (Ibid, p. 772)

He also wrote

> The Mecca of the economists lies in economic biology rather than in economic dynamics. (Ibid, p. xiv)

Alfred Marshall is regarded as a pioneer in starting the dialogue between economics and biology, whose legacy has been further pursued in a branch of economics, referred to as *Evolutionary Economics*. To have an idea of the *constant change* of the inner nature, the constitution, and the outer form of a matter, one can think of the evolution of technology, from its primitive form to its state of the art.[1] Nevertheless, this picture of constant change has not been demonstrated in any model known to economists before the advent of GP. Even the leading economists in Evolutionary Economics did not provide us with a tool to simulate this developmental-biology-like process.

[1] For example, see [3], in particular, Figures 1.3 and 1.4.