Preface

MAIN IDEA OF THE BOOK

Computational Economics: The Old Style

The attempt to make economics computational is not new, given that economics is by nature both mathematical and quantitative. The use of computational models is so prevalent that one can hardly see the need to disentangle a field called *computational economics* from other branches of economics, let alone even bother to ask *what it is*. On their Web site, the Society of Computational Economics provides us with a simple description: "Computational economics explores the intersection of economics and computation." However, what is this intersection? Which parts do they intersect? Do they change over time, and what is the significance of these changes? These questions are not easy to answer without first making an effort to delineate what computational economics is. For most people most of the time, however, it is nothing more than using computing tools or algorithms to solve economic problems, when they become analytically intractable. This is what we may regard as old-style computational economics.

In old-style computational economics, computing resources, be they software or hardware, are basically viewed as ancillary to economic theory. They at best serve merely as a refinement to the already well-established theory, instead of being the core itself. A quick review of the past can help us recall what this old-style computational economics has been up to. In the 1970s, the development of *computational general equilibrium models* provided numerical algorithms to solve already well-formalized Walrasian general equilibrium structures, pioneered in the 1950s by two Nobel Laureates, namely Kenneth Arrow and Gerard Debreu. Computational economics at this stage sought to provide a numerical realization of Brouwer's or Kakutani's *fixed point theorem* to economic models.

In addition, in the 1970s, viewing the whole economy as following a law of motion and having its associated dynamics became somewhat standard in economic theory. With the advent of the *era of economic dynamics*, computational economics embarked upon new missions. First, it enhanced the application of optimal control theory to large Keynesian macroeconomic models. Led by a few economists, such as Robert Pindyck, David Kendrick, and Gregory Chow, computational economic models were further extended from conventional static temporal optimization to dynamical intertemporal optimization problems. Numerical algorithms involving computer simulation were used in solving these dynamic economic models to help in designing the optimal macroeconomic policy.

Second, in the late 1970s, the then dominant Keynesian view of the world was challenged by the *rational expectations revolution*. The former treats the economy more or less as a system of controllable objects constantly following a time-invariant rule (consumption functions, investment functions, ..., and so on.), whereas the latter attempts to acknowledge the ability of humans to change behavior when they expect economic policies to change. When the view of the world changes, the techniques for generating solutions also have to change accordingly. Therefore, in the 1980s and 1990s, one evidenced a great amount of effort being devoted to solving for linear or non-linear rational expectations equilibria, which, from a mathematical viewpoint, once again gave rise to a fixed point problem.

Coming as a result of the rational expectations revolution is a new interpretation of business cycles, known as *real-business cycle theory*, which was pioneered in the early 1980s by another two Nobel Laureates, Finn Kydland and Edward Prescott. The real-business cycle theory postulates that business cycles are created by *rational agents* responding *optimally* to *real shocks,* such as fluctuations in productivity growth, preferences, government purchases, and import prices. In a sense, the real-business cycle theory is under the joint influence of general equilibrium models and rational expectations; therefore, it is also commonly referred to as a *dynamic general equilibrium model* or a *stochastic dynamic general equilibrium model*.

The real-business cycle model per se is very computational. Real-business cycle theorists actually evaluate the model's suitability for describing reality by using a quantitative technique known as *calibration*. If the calibrated model can fit the real data well, then one should take its quantitative policy implications seriously. So, from the late 1980s until the present, working on the numerical aspect of the real-business cycle model has become another major activity of computational economics.

This review intends to be brief, and hence not exhaustive. However, the point here is to highlight the essential feature of the old-style computational economics or, at least, one aspect of computational economics, namely, using numerical methods to solve or optimize already established economic models, when the embedded theoretical environment is complicated by dynamics, nonlinearity and uncertainty. This volume, however, shares a different aspect of computational economics.

Computational Economics: Legacy of Herbert Simon

We do not treat computational economics as only a collection of numerical recipes. Instead, for us, computational economics comprises the economic models *built* and *solved* computationally. The role that computation plays is not just to solve or optimize something already established, but, what is more important, *to define and model what the problem itself is*. Therefore, it is not just ancillary to economic models, but can be the core itself. To distinguish our vision from the old style, we call this approach to computational economics *a perspective from computational intelligence*.

We shall elaborate on the reason why the term *computational intelligence* (CI) is preferred here (see also Chen, 2005).

The idea of looking at computational economics from the perspective of computational intelligence arises essentially from acknowledging the legacy of Herbert Simon to economics. Herbert Simon, the only person to win the Nobel Memorial Prize in Economics, the Turing Award of the ACM and the ORSA/TIMS von Neumann Prize, initiated the interdisciplinary research field and broke down the conventional distinctions among economics, computer science and cognitive psychology. The latter two played almost no role in the early days of Herbert Simon, but have now proved to be an indispensable part of computational economics, in particular, when *agent-based computational economics* emerges as an integration of the originally disparate research on experimental economics, behavioral finance and economics with heterogeneous interacting agents. The increasingly enlarged interdisciplinary framework really leads us to an even richer environment than in the days of Herbert Simon.

The idea behind computational intelligence is basically to model the intelligent behavior observed from linguistic behavior, biology, insects (swarm intelligence), neural sciences, and immune systems, just as it is said "natural does it all." This is different from the classical AI, which was mainly motivated by and built upon mathematical logic. It is also different from the conventional models of learning which are mainly based upon probability and statistics. However, modeling intelligence observed from natural behavior often leads us to computationally intensive models because the subjects that we are trying to model are by no means simple as in the classical dynamic systems. It is our anticipation that if we can model this observed behavior successfully, we can then have a better chance of understanding the operation of the economic system as a complex adaptive system, which is already a research target of many well-known research institutes.

With this anticipation in mind, we attempt in this volume to present chapters on novel economic and financial applications of computational intelligence. We began from those basic tools that every standard CI textbook should cover, namely, fuzzy logic, artificial neural networks, and evolutionary computation. Nevertheless, the ever-increasing interdisciplinary network makes us quickly realize that it would be meaningless to draw a clear line like this in such a complex, dynamically evolving scientific environment. Although intelligent behavior (and learning behavior as a part of it) is still one focus of this volume, we do not necessarily restrict this volume to computational intelligence only, be it narrowly defined or broadly defined. Chapters that introduce novel ideas motivated by computational theory, statistics, econometrics, physics, mathematics, and psychology are also included.

The second focus of this volume is on the application of CI to modeling the autonomous agents in agent-based computational models of economics and finance. Thus, agent-based computational economics and finance have become another broadly defined interest of this volume. Since agent-based modeling has now also become a very popular tool in the management sciences, we also prepare chapters on agent-based models of management in this volume. While CI is a key weapon for agent engineering, other approaches, such as the formal approach or the analytical approach to agent-based modeling, are also considered in this volume. In fact, the most striking example is the approach coming from *Econphysics*.

MAKING OF THE BOOK

The making of the book is based on the working guideline prepared by the IGI publisher. All papers are subjected to a peer-review process. We first send out call for papers to a selection of participants who presented their papers at the Third Workshop on Computational Intelligence in Economics and Finance (CIEF'2003), held at Cary, North Carolina, September 26-30, 2003. There were 72 papers out of 84 accepted by CIEF'2003, but only about 45 papers were in the invitation list. By the deadline, we had received 27 submissions. Each of these was sent to two to three referees, and the authors of each paper were asked to revise their drafts by taking the referees' comments into account. Authors who failed to do this or were unable to meet the deadline were eventually not accepted. In the end, we published a total of 15 chapters in this book.

CONTRIBUTORS TO THE BOOK

Before we go further into the main body of the book, a few things should also be said about the book's contributors. First, readers may find that there is a great variety in the authorss backgrounds. Table 1 enumerates all the associated academic departments or organizations that they belong to. The diversity in their background says something about the essential feature of computational methods in the social sciences—its diverse constituent techniques and wide applicability. A solid knowledge of both natural sciences and humanities is needed and fused in this research regime. Second, by probing deeper, it can be found that the authors of five co-authored chapters come from both the natural and social sciences, which is very typical, just as we should expect from a fast-growing interdisciplinary research community.

Third, in addition to the scientific background, Table 2 provides the authors' geographical background. While the sample is pretty small, it still reveals some stylized

Table 1. Authors' background

Division	Department/Classification	Author(s)
Academic Institution	Economics	7
	Finance	1
	Financial Economics	1
	Management	2
	Management Science and Engineering	1
	Information Sciences	1
	Information & Decision Sciences	2
	Computer Science	3
	Computer Software	1
	Computer Sciences & Engineering	1
	System Information Engineering	1
	Electrical Engineering	2
	Physics & Complex Systems	1
	Mathematics / Psychology	1
Company	Scientific Research & Application Company	3
Others	Research Institution	1
	US NASA	1

Table 2. Authors' geographical relationships

Continent	Geographical Region	Author(s)
Asia	Japan	5
	Taiwan	2
Europe	France	1
	United Kingdom	2
America	Argentina	2
	United States	17
Oceania	Australia	1

facts. The United States still plays the dominant role in research of this kind, and Japan has already taken the lead in Asia in this area for more than a decade.

CI TECHNIQUES

As the subtitle of this book suggests, the main methodology adopted in this book is computational intelligence. Table 3 reveals the specific CI techniques used by the authors. Among the many existing CI techniques, fuzzy logic, artificial neural networks, and evolutionary computation (specifically, genetic algorithms) are the three most popular ones. In addition to these three, other techniques used in this book are wavelets, Bayesian networks, and reinforcement learning. What is particularly striking here is that many authors use more than one CI technique, and make them work together as a hybrid system, which has been a research direction in CI for many years. Chapters I, II and IX are illustrations of why and how these CI techniques can be hybridized and used more efficiently.

A major methodologically distinguishing feature that readers may find interesting in this book is agent-based modeling. Agent-based modeling is a button-up method used to construct a system such as an organization, a market, or even an economy. In an agent-based model, economic individuals or members of organizations could be constructed heterogeneously by CI algorithms or by encoding with computer languages. The idea of modeling in this way follows people's knowledge of complex adaptive systems (CAS). In a complex adaptive system, individuals interact and form the macro results in a nonlinear way, and they also face an environment that is constantly changing and in which decision-making becomes a more sophisticated problem. The recogni-

Table 3. CI approaches adopted in this book

Chapter	CI techniques
I	Artificial Neural Networks + Genetic Algorithms
II	Wavelets + Artificial Neural Networks + Genetic Algorithms
III	Bayesian Networks
V	Genetic Algorithms
VII	Reinforcement Learning
VIII	Reinforcement Learning
IX	Artificial Neural Networks + Fuzzy Inference System
XI	Fuzzy Sets

tion of nonlinearity in complex adaptive systems, together with the aggregation problem in representative agent models, provides the basis for agent-based modeling. Chapters I, IV, V, VI, VIII, XII, XIV in this book employ agent-based models or similar settings.

Apart from computational intelligence, some chapters in this book also employ analytical methods borrowed from computer science or physics to facilitate their respective studies. Simulation plays an important role in such research due to the complexity of the specific problems looked into.

STRUCTURE AND CHAPTER HIGHLIGHTS

The formulation of a taxonomy of chapters in an edited volume like this one is not easy and definitely not unique. Depending on how this book is to be used, there are always different taxonomies. Nevertheless, only one can be considered here, and the criterion used here to divide these 15 chapters into sections discussing their major associated application domains. Based on this criterion, this book is composed of six sections, namely, financial modeling of investment and forecasting, market making and agent-based modeling of markets, game theory, cost estimation and decision-support systems, policy appraisal, and organizational theory and interorganizational alliances. We shall present a highlight of each chapter below.

Section I of this book, Financial Modeling of Investment and Forecasting, demonstrates some novel applications of CI techniques for tackling issues related to financial decisions, including financial pattern detection, financial time series forecasting, option pricing, portfolio selection, and so on. In Chapter I, Financial Modeling and Forecasting with Evolutionary Artificial Neural Network, Serge Hayward uses artificial neural networks to search for optimal relationships between the profitability of trading decisions and investors' attitudes towards risk, which serve as an appropriate loss function minimization in the learning process. A dual network structure is then designed accordingly, and genetic algorithms are employed to search for the best topology of the network.

In Chapter II, Pricing Basket Options with Optimum Wavelet Correlation Measures, Christopher Zapart, Satoshi Kishino, and Tsutomu Mishina introduce a new approach for dealing with correlations between financial time series. By transforming time series data into time-frequency domains via wavelets, and by using two versions of wavelet models (i.e., static and dynamic models), the authors overcome the limitations of existing methods and find that their outcomes are superior to those resulting from standard linear techniques in out-of-sample tests.

In Chapter III, Influence Diagram for Investment Portfolio Selection, Chiu-Che Tseng applies Bayesian networks to construct an influence diagram for investment portfolio selection by inheriting the concepts of Bayesian theory. The resultant influence diagram is able to provide decision recommendations under uncertainty. The author finds that the system outperforms the leading mutual fund by a significant margin for the years from 1998 to 2002.

Section II of this book, Market Making and Agent-Based Modeling of Markets, is concerned with the operation of the market mechanism and connects the observed aggregate phenomena to the interactions among agents at the micro level of the markets. In Chapter IV, Minimal Intelligence Agents in Double Auction Markets with Speculators, Senlin Wu and Siddhartha Bhattacharyya study the potential impact of the intelligence of individual market participants on the aggregate market efficiency in a double auction setting. They extend some early studies on this issue to an interesting case of asymmetric markets with speculators. They find that under various market conditions with speculators, ZI-C (zero-intelligence with constraints) traders, who shout prices uniformly but not beyond their own reservation prices, are incapable of making the market price converge to the equilibrium level. They also observe that, when there are not too many speculative activities in the market, ZIP (zero-intelligence plus) traders, who are able to learn by altering their profit margin, are sufficiently capable of driving market price to the equilibrium.

In Chapter V, Optimization of Individual and Regulatory Market Strategies with Genetic Algorithms, Lukas Pichl and Ayako Watanabe delineate the limitations of static portfolio optimization models, and propose agent-based modeling methodology as a promising alternative. They employ genetic algorithms as the agent engineering technique, and then build a model to demonstrate the distinguishing feature of complex adaptive systems, namely, co-evolutionary dynamics. In addition to the bottom-up behavioral modeling, they also consider a Kareken-Wallace setting to study the policy optimization problem for the social planner from a top-down perspective.

In Chapter VI, Fundamental Issues in Automated Market Making, Yuriy Nevmyvaka, Katia Sycara, and Duane J. Seppi provide a rich overview concerning fundamental issues of market making. This chapter provides an excellent tutorial for readers who want to have a quick grasp of this research area. They also set up an electronic environment that can merge real data with artificial data to run market experiments. The decision process of a dealer is formalized. Statistical techniques are used to discern possible structures of the data, and dealers' optimal responses are then discussed. Borrowing from their experience in robotics, they present an appropriate experimental environment and all the necessary tools for real implementations in the future.

Section III of this book, Games, addresses game-theoretic issues. Game theory in economics has a long and active history and has received very intensive treatment in terms of CI methodology. Chapter VII, Slow Learning in the Market for Lemons: A Note on Reinforcement Learning and the Winner's Circle, by Nick Feltovich, deals with the famous issue in auctions known as the *winner's curse*. Due to asymmetric information, a bidder may systematically bid more than the optimal amount, and this raise the question of why people make the same mistake in this area over and over again. The author of this chapter tries to propose a more persuasive reason for this phenomenon—that human-bounded rationality causes people to learn in a way that could be described as reinforcement learning. The author finds that results can conform qualitatively to the typical experimental results observed from laboratories with human participants.

Chapter VIII, Multi-Agent Evolutionary Game Dynamics and Reinforcement Learning Applied to Online Optimization for the Traffic Policy, by Yuya Sasaki, Nicholas S. Flann, and Paul W. Box, studies Nash equilibria and evolutionarily stable strategy profiles of traffic flow. The choice of routes to a destination becomes a typical game when the number of people on the road starts to have a negative effect on everyone's access to and the quality of the transportability. Instead of a standard static method, Sasaki et al. also adopt reinforcement learning to model their agents in the complex traffic network problem. They identify the equilibria of the game. They further validate their method using geographic information systems to a complex traffic network in the San Francisco Bay area.

Section IV of this book, Cost Estimation and Decision-Support Systems, should interest those readers who would like to see CI applied to operations research or engineering economics. Chapter IX, Fuzzy-Neural Cost Estimation for Engine Tests, by Edit J. Kaminsky, Holly Danker-McDermot, and Freddie Douglas, III, attempts to perform the tough task of cost estimation. Cost estimation is never easy since it is highly uncertain, especially in a huge project like the engine testing conducted by NASA. Besides relying upon past experiences, several software systems have been developed in the past to perform the cost estimation for NASA. Even so, they require either detailed data or data that are rarely available. Therefore, the authors propose a hybrid system that combines fuzzy logic and artificial neural networks in order to build an adaptive network-based fuzzy inference system. They show that the system can work even with a small set of data, and the accuracy of the predicted cost is enhanced as the complexity of the system increases.

In uncertain circumstances, the cost estimation and decision making of software development projects also pose difficult problems for small IT companies. The complexity in the interactions among project tasks, resources, and the people involved usually makes the estimate of the project factors very crude, which can lead to very harmful decisions. In Chapter X, Computer-Aided Management of Software Development in Small Companies, Lukas Pichl and Takuya Yamano tackle this issue by developing a customizable, object-oriented software project simulation environment that facilitates duration and cost estimates and supports decision making. They run simulations both to optimize the project structure and to determine the effects of stochastic variables in certain fixed structures. As a result, an online Java program is devised as a tool for software project management simulations.

In Chapter XI, Modern Organizations and Decision-Making Processes: A Heuristic Approach, Ana Marostica and Cesar Briano propose a hybrid decision support system that deals with several important topics in decision-making processes. The authors provide detailed definitions, principles, and classes for each element in a decision-support system: utility, subjective beliefs, rationality, and algorithms that can cope with ambiguity and vagueness. They also point out a hybrid decision-support system in which there is an embodiment relationship between the user and the computer program, and therefore make it applicable to multiagent systems.

Section V of this book, Policy Appraisal, includes chapters that contribute to the application of CI techniques to policy appraisal issues. Chapter XII, An Application of Multi-Agent Simulation to Policy Appraisal in the Criminal Justice System, by Seán Boyle, Stephen Guerin, and Daniel Kunkle, illustrates an interesting case of the criminal justice system in England. In an intricate system such as the CJS in England, three distinct departments are involved in these affairs. The diverse government bodies have reciprocal influences on each other and therefore any policy taken by one of them will have complex impacts on the system. Hence Boyle et al. have developed an agent-based program to simulate the whole system, and on assessment of the impact across the whole justice system of a variety of policies is thus possible.

Chapter XIII, Capital Controls and Firm's Dynamics, by Alexei G. Orlov, illustrates another hot topic in economic policy, namely, capital controls. The issue of capital controls in multinational enterprises is always debatable. Evaluating the effectiveness of capital restrictions is a daunting task, let alone political or other debates. Orlov overcomes the time-series difficulties of evaluating exchange controls by examining transitional dynamics in a model of a multinational enterprise. He constructs a model of a multinational enterprise to quantify the effects of various exchange control policies on the capital stocks, debt positions, innovations and outputs of the headquarters and its subsidiary. The simulation results show that lifting exchange controls produces an inflow of capital into the less developed countries, and not an outflow as the governments sometimes fear.

Section VI, Organizational Theory and Inter-Organizational Alliances, extends the applications of CI to organization theory and management sciences. Chapter XIV, A Physics of Organizational Uncertainty: Perturbations, Measurement, and Computational Agents, by William F. Lawless, Margo Bergman, and Nick Feltovich, is a theoretic work in which two contradictory approaches to organizations are discussed and compared. The authors then point out the dangers of a subjective approach to multiagent systems and provide a model with the mathematical physics of uncertainty borrowed from quantum theory. This chapter could be viewed as having a goal of revising the rational theory of multiagent systems.

Chapter XV, Reducing Agency Problem and Improving Organizational Value-Based Decision-Making Model of Inter-Organizational Strategic Alliance, by Tsai-Lung Liu and Chia-Chen Kuo, is also an attempt to refine past theories and to explore the impact of interorganizational strategic alliances on organizational value-based decision-making processes. The authors attempt to solve the agency problem due to asymmetric information, specifically, asymmetric uncertain information. The authors combine past theories and accordingly form propositions as well as a conceptual model.

REFERENCES

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