WHY SOCIAL SCIENCES NEED NATURE-INSPIRED COMPUTING

For nearly four billions years, life has invaded Earth. Throughout eras geological upheavals have deeply transformed the environment. Here, deserts left place to a tropical environment; there ices were replaced by conifers forests .... Despite these transformations, life is so vigorous that one can find it on the top of the highest mountains, in the depths of oceans, as well as in clouds or deep underground.

Life has proved its capacity to cope with deep transformations—its ability to overcome mass extinctions and to rebirth after disasters. These adapting and surviving capabilities have inspired computer scientists who try to conceive algorithms imitating nature, hoping to confer in them some of the aptitudes of living beings.

Darwinian natural adaptation has been transferred into evolutionary algorithms; artificial neural networks are a metaphor of nervous systems; ants foraging behaviors gave rise to ant colony optimization; birds flocks or fish schools inspired particle swarm optimization; artificial immune systems mimic the biological ones; insect or animal autonomy and abilities inspired distributed artificial intelligence, multi-agent systems, and artificial societies.

In the fields of social sciences, economics, and management, two types of contributions must be emphasized:

• Social insects, buffalo herds, or human societies show that social life dominates the macrofauna. This fascinating characteristic of living systems, and more particularly the study of social insect behavior, inspired the rebirth of artificiality. Starting with artificial life and artificial intelligence, modern artificiality now reaches social sciences with the development of artificial societies which contributes to renewed approaches of social and economic phenomena.

• Living systems are supple and able to adapt to huge transformations in their environment. Transposition of these properties into algorithms provide with ground-breaking tools able to deal with complex problems.

After a six-chapter introduction to nature-inspired computing for modeling and optimization, the first volume of the handbook is oriented toward social sciences (sociology and economics) modeling and experiments; the second volume mainly handles modeling, exploration, and optimization for management.
The core hypothesis of artificial societies is that human societies are complex adaptive systems (CASs) whose properties emerge from non-linear interactions between their members. Since the famous Jurassic Park by Steven Spielberg, everyone has been aware of the existence of “chaos” and “complexity.” Despite the highly disputable treatment of chaos in that movie, it addressed a core problem of modern science that Nobel Prize recipient Illya Prigogine nicely termed “The End of Certainty” (Prigogine, 1997).

At least since the French philosopher René Descartes in the 17th century, science has mainly been based on analysis. Analysis tries to understand reality by breaking down observed phenomena, thanks to the fundamental hypothesis that a global process is the result of the mere (linear) aggregation of its components.

At the end of the 19th century, French mathematician Henri Poincaré proved that analysis is unable to describe most systems based on non-linear interactions. Those systems are now said to be more than the sum of their parts (Waldrop, 1992). The resulting complex dynamic is unpredictable. The only way to know their state at a given step is to compute each step. The usual analytical method is of little help; the necessary mathematics are still to be invented. Non-linearity thus challenges the traditional approach, which tries to understand a system by analyzing its components: “The key feature of non-linear systems is that their primary behaviors of interest are properties of the interactions between parts, rather than being properties of the parts themselves, and these interactions-based properties necessarily disappear when the parts are studied independently” (Langton, 1989, p. 41, original italics). How do we study processes that are “more than the sum of their parts?” How do we analyze properties that cannot be forecasted? The solution proposed by computer scientists is termed bottom-up modeling.

Since core properties disappear when the components are studied independently, bottom-up modeling is based on the gathering of interacting components. Such constructions and the study of the dynamic resulting from non-linear interactions of the simple components constitute the “bottom-up method.” Instead of modeling the global dynamic of the studied system (“top-down method” usually based on differential equations), one merely models the components to study the potentially emerging regularities.

Bottom-up modeling is based on multi-agent systems (MASs). Agents are a kind of “living organism,” whose behavior—which can be summarized as communicating—and acting are aimed at satisfying its needs and attaining its objectives (Ferber, 1999, p. 10). MASs are a gathering of interacting agents. In social sciences (mainly sociology and economics), they are the base of artificial societies.

Section II: Social Modeling includes seven chapters providing a global view of this research. Chapters by Robert Axelrod and Harko Verhagen demonstrate the huge potential contribution of artificial societies to social sciences. Corruption, trust, and academic science are then studied in the light of MASs, showing the cross-fertilization of social sciences and multi-agent systems.

Section III: Economics includes thirteen chapters providing global coverage of the use of nature-inspired computing for economics. After an introduction to agent-based computational economics (ACE), original research using multi-agent systems, evolutionary algorithms, or neural networks to deal with fundamental economic forces are presented. Clusters, innovation, and technol-
ogy are then particularly emphasized to enlighten the complex cross dynamics of space and technology.

VOLUME II

Management is confronted with challenges of growing difficulty:

- The complexity of the environment, the unprecedented speed of its evolution, and the unmanageable resulting mass of information require specific powerful tools.
- The never-ending search for productivity has made optimization a core concern for engineers. Quick process, low energy consumption, and short and economical supply chains are now key success factors.

The six-section, thirty-two-chapter second volume provides comprehensive coverage of the contributions of nature-inspired computing to management. It shows its ability to solve problems beyond the capabilities of more traditional methods.

Section IV: Design and Manufacturing presents pioneering research, particularly using evolutionary algorithms. Applied to design, project management, as well as to manufacturing, this research clearly demonstrates the capacity of nature-inspired algorithms to stimulate design creativity and to manage complex associated issues.

Section V: Operations and Supply Chain Management contains twelve chapters. After an introduction to evolutionary optimization and ant colony optimization for operations management, main nature-inspired tools are used to solve very diverse operations and supply chain management problems (scheduling, organization of production, distribution, etc.). The section includes the presentation of a powerful Java framework designed to use evolutionary computation to solve operations and supply chain problems.

Section VI: Information Systems presents the novel agent-oriented paradigm of information systems and provides innovative research, demonstrating the power and suppleness of nature-inspired computing when applied to information management, e-learning, and peer-to-peer systems.

Section VII: Commerce and Negotiation includes a synthesis of agents for multi-issue negotiation, and presents original research on automatic negotiations and auctions using agent-based modeling and evolutionary computation. This research outstandingly leads the way toward future virtual organizations.

Section VIII: Marketing uses evolutionary computation and agent-based modeling to analyze price wars and word-of-mouth, and to contribute to the understanding of complex socio-economic systems to provide a decision support tool for commercial organizations.

Section IX: Finance uses genetic programming, evolutionary computation, neural networks, and agent-based modeling to deal with complex financial problems. They are applied to housing prices, financial decision aid, insurance-linked derivatives, and stock-market simulations.
The fifty-eight chapters of this two-volume handbook provide a unique cross section of research using nature-inspired computing for economics and management. Social scientists, economists, and people dealing with management science will find both an introduction and a valuable presentation of state-of-the-art research in these fields, giving them a unique reference tool for their own research. Students in computer sciences, social sciences, and management will find all the necessary material to master the field and to help them in their training. Managers, engineers, and practitioners will find a great deal of efficient and powerful tools to help them solve difficult problems, and to anticipate the use of tools that will undoubtedly be part of tomorrow’s key success factors.

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REFERENCES