Editorial

Advancements in the Practical Applications of Agents, Multi-Agent Systems and Simulating Complex Systems

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Introduction

This Editorial summarizes the content of the Special Issue entitled *Advancements in The Practical Applications of Agents, Multi-Agent Systems and Simulating Complex Systems*, published in the “Complex Systems” section of *Systems* (ISSN 2079-8954).

Complex systems have played a fundamental role in the simulation, modeling, and analysis of information in dynamic environments and under unexpected constraints [1–3]. These agent-based systems have evolved significantly throughout history, providing increasingly sophisticated solutions to address the complex challenges encountered across multiple fields. The history of complex systems dates back to early research in systems theory and cybernetics in the 1940s [4]. These disciplines laid the foundation for understanding and addressing problems involving complex and emergent interactions between multiple components. As computer technology advanced, the first agent-based modeling and simulation approaches emerged, allowing complex systems to be represented through the interaction of multiple autonomous entities [5,6].

At the heart of complex systems are agents, which can be individuals, organizations, robots, or any entity with the ability to make decisions and respond to its environment. These agents interact with each other and with their environment, generating emergent patterns and collective behaviors that cannot be attributed solely to the individual characteristics of the agents. Agent-based systems technology has been advancing rapidly, enabling greater sophistication in the representation and simulation of complex systems [7]. The importance of complex systems lies in their ability to address real-world problems in a wide range of disciplines, including economics, biology, ecology, logistics, and supply chain management, among others. These systems can model and simulate complex phenomena such as crowd behavior, traffic flow, the spread of disease, climate change, and the evolution of ecosystems [8–10].

The simulation and modeling of complex systems offer several significant advantages. First, they enable the evaluation of different scenarios and strategies without incurring the costs and risks associated with real-world implementation. This is especially valuable when dealing with unpredictable or highly complex environments wherein it is difficult to obtain empirical data or conduct controlled experiments [11]. Complex systems provide a deeper understanding of the underlying mechanisms and interactions that shape the system being studied. This helps to identify emerging patterns, hotspots, and non-intuitive behaviors, which in turn can guide decision-making and strategic planning. By better understanding complex systems, it is possible to reduce the risks and costs associated with the design and development of real-world validation tests [12–14].
An Overview of Published Articles

This Special Issue consists of fifteen practical papers covering key topics in the field of multi-agent systems and complex systems. These articles, presented during the 20th International Conference on Practical Applications of Agents and Multi-Agent Systems (PAAMS’22) (https://www.paams.net, 6 September 2023), are noteworthy for their highly innovative results and trends [15]. The conference was held in L’Aquila, Italy, and it was organized by the University of L’Aquila (Italy), Umeå University (Sweden), the University of Lille (France), and the University of Salamanca (Spain).

The first three articles address the relevance of using multi-agent systems for the analysis of information. Such an analysis is carried out through the application of natural language processing techniques. These articles aimed to understand public opinion, detect false information, or identify accounts that provide misleading information. Guzmán Rincon et al. (Contribution 1) present a mathematical model to simulate scenarios of disinformation propagation in social networks caused by bots, trolls, and others. The authors carried out simulations related to the increase in the rate of the activation and deactivation of disinformation agents and the disinformation caused by this mechanism. Ye et al. (Contribution 2) explored the specific attributes of individuals and opinion network nodes by incorporating parameters such as individual conformity and the strength of individual online relationships for the purpose of identifying an online opinion polarization of a group. Through simulations, the authors found that individual conformity and the difference in environmental attitude greatly influence the trajectory of opinion polarization events. Similarly, the analysis of shared beliefs, opinions, and views in groups is a topic of great interest that has been debated in sociology, political science, communication, and organizational science. Koponen (Contribution 3) performed an analysis of consensus group formation through an agent-based model. Agents’ views were described as complex, and they have extensive structures, similar to semantic networks, i.e., belief networks. In the agent-based model presented by the author, the agents’ interactions and their participation in the sharing of their views depend on the similarity of the agents’ belief webs; the higher the similarity, the more likely the interaction and the sharing of webs of belief elements.

In the areas of economics, finance, and e-commerce, complex systems have also had a major impact. Zhao et al. (Contribution 4) present an agent-based model created using empirical data from a number of cities as sample data to simulate the evolutionary trajectory of eco-protection and high-quality development under different policy scenarios, such as green innovation, ecological constraints on the environment, ecological compensation, etc. The model shows how, depending on the existing development model, the economic development of cities will be subject to different degrees of ecological and resource constraints and that different policy scenarios significantly affect the evolutionary trends of economic development. Other authors, such as Bae et al. (Contribution 5), introduce a formalism or multi-resolution translational discrete event system specification (MRT-DEVS) intended to facilitate the implementation of simulations and reduce simulation execution costs. MRT-DEVS embeds state and event translation functions into the model’s specifications so that it enables multi-resolution modeling with less complex mechanisms in terms of operations. Wang et al. (Contribution 6) studied the product encroachment behavior of composite e-commerce platforms with double-differentiated multi-product competition and constructed a game model of product innovation by an independent seller and product encroachment by the platform owner. Using multi-agent simulation, the authors simulated the bounded rational decision-making and interaction process of multiple agents in multiple periods and analyzed the influence of the main parameters. Moreover, Castañón-Puga et al. (Contribution 7) illustrate how earned value management (EVM) is an efficient method for measuring a project’s performance by comparing actual progress against planned activities, thus facilitating the formulation of more accurate predicted estimations using an agent-based simulation model.

Researchers have also focused on applying complex system algorithms to facilitate problem solving in the field of transport. Karalakou et al. (Contribution 8) propose the
design of autonomous vehicles using deep reinforcement learning and the combination
between various reward components that are able to gradually learn effective policies
in environments with different levels of difficulty, especially when all the proposed re-
ward components are appropriately combined. Spanoudakis et al. (Contribution 9) have
designed an open system for the V2G/G2V power transfer problem domain using an
agent-based architecture involving flexible microservices that are interconnected via an
IoT platform. Gómez Vilchez et al. (Contribution 10) describe a simulation model that
facilitates the analysis of potential emission penalties in the broader context of the financial
position of original equipment manufacturers. Through their simulation, the authors aim
to understand the channels through which money flows (e.g., to promote R&D in cleaner
vehicles and to finance zero-emission powertrain sales) between market players.

On the other hand, agent systems have demonstrated successful performance in the
application of Cartesian genetic programming to solve a series of use cases, such as complete
enumeration in local agent decisions. In this context, Bremer et al. (Contribution 11)
present the adaptation of a distributed optimization heuristic protocol for Cartesian genetic
programming and an extension using CMA-ES (Covariant Matrix Adaption Evolution
Strategy) to improve local agent decisions. By decomposing the evolution on an algorithmic
level, it becomes possible to distribute the nodes and regard the evolution process as a
parallel, asynchronous execution of an individual coordinate’s descent.

Atrazhev et al. (Contribution 12) address the issue of choosing an appropriate reward
function in multi-agent reinforcement learning. Among the traditional approaches to
employing joint rewards for team performance, this one is questioned because of its lack of
theoretical support. Thus, the authors explore the impact of changing the reward function
from joint to individual on learning centralized–decentralized execution algorithms in a
level-based foraging environment. The results show that different algorithms are affected
differently, with value factorization and proximal policy optimization (PPO)-based methods
taking advantage of the increased variance to achieve better performance. This study sheds
light on the importance of considering the choice of a reward function and its impact on
multi-agent reinforcement learning systems.

Within the area of optimization, Pincheira et al. (Contribution 13) present a frame-
work for evaluating the infrastructure costs and benefits of blockchain applications. The
framework includes a taxonomy that classifies relevant transactions, a model to evaluate
the infrastructure costs and application benefits using public or private blockchains, and
guidance on how to use the model. Another research work focusing on optimization comes
in the form of the paper by Esmaeili et al. (Contribution 14). The authors of this paper
introduce an agent-based collaborative technique for finding near-optimal values for any
arbitrary set of hyperparameters (or decision variables) in a machine learning model (or
a blackbox function optimization problem). The developed method forms a hierarchical
agent-based architecture for the distribution of the searching operations at different dimen-
sions and employs a cooperative searching procedure based on an adaptive width-based
random sampling technique to locate the optima.

Finally, within this Special Issue, Roussel et al. (Contribution 15) address the issue
of conflicting bundle allocation and weighted directed acyclic graphs. The authors pro-
pose several models for novel resource allocation problems where agents express their
preferences over conflicting bundles of items as edge-weighted on a directed acyclic graph
(directed path allocation problem, or DPAP), particularizing conflicts on vertices (V-DPAP)
and conflicts on resources (R-DPAP). The multi-agent system proposed by the authors al-
 lows for the search of path allocation. Conflicting bundle allocation and weighted directed
acyclic graphs are also commonly simulated using complex systems.

Conclusions

This Special Issue showcases a variety of research papers on practical approaches to
the use of complex systems and complementary agent-based AI models, facilitating the
parallel use of data treatment and knowledge processing algorithms.
List of Contributions


Author Contributions: P.M., J.M.C., A.G.-B. and F.D.I.P. worked together throughout the entire editorial process of this Special Issue entitled “Advancements in The Practical Applications of Agents, Multi-Agent Systems and Simulating Complex Systems”, published by the *Systems* Journal. A.G.-B. and F.D.I.P. drafted this editorial summary. P.M., F.D.I.P. and J.M.C. reviewed, edited, and finalized the manuscript. All authors have read and agreed to the published version of the manuscript.

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**References**


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