Multi-agent systems (MAS) provide powerful modelling concepts for representing real-world applications with an appropriate degree of complexity and dynamics [1]. Several academic and industrial experiences have already shown that the use of MAS offers advantages in many different areas such as manufacturing processes, e-Commerce, and network management. Since MAS in such contexts need to be tested before their deployment and execution in real operating environment, methodologies that support system validation through simulation (e.g. discrete-event simulation, agent-based simulation, etc.) are highly required. In fact, simulation of MAS cannot only demonstrate that MAS correctly behaves according to its specifications but can also support the analysis of emergent properties of the MAS under-test [2,3].

In the last few years there has been an increasing number of initiatives to develop agent-based methodologies for the development of software agent-based systems (e.g. GAIA, Tropos, Prometheus, INGENIAS, PASSI, ADELFE, PASSIM) and simulation tools for the analysis of complex systems modelled as multi-agent systems (Repast, Repast Simphony, Swarm, Netlogo, Mason). As “Agent-oriented Software Engineering” (AOSE) [4] and “Agent-based Modelling and Simulation” (ABMS) [5] are recognized as very interesting emerging paradigms that will have a major impact on the quality of science and society over the next years, their knowledge will help position the researchers and practitioners at the forefront of the field. Therefore, we believe that the methodological and technological trends in the convergence and integration of these areas need to be widely explored to provide an exclusive research roadmap to both ABMS and AOSE communities.

The aim of this special issue is to provide a comprehensive guide on new ideas and results in the integration of Simulation of Multi-Agent Systems and Agent-oriented Software Engineering domains. It captures the state-of-the-art in such domains in terms of techniques and methodologies for agent-based modelling and simulation, simulation-driven development processes for multi-agent systems, and simulation-oriented analysis of emergent agent behaviours in complex multi-agent systems. It also identifies potential research directions and technologies that will drive innovations within this domain. We expect the papers of this special issue to serve as a valuable reference for larger audience such as software architects, practitioners, developers, researchers, and students.

The nine papers of this special issue successfully capture the state of the art in the integrated AOSE and ABMS domains, and offer very interesting perspectives both on current trends and on the innovation forces that will drive research and development efforts in the coming years. In particular, significant key issues are tackled in the papers, among which: model driven development (MDD) based methodologies for agent-based simulation, modelling collaborative agent behaviours in multi-agent systems, agent-based techniques to solve real-time scheduling problems in complex systems, self-organization as key element to drive adaptive system behaviour, analysis of interaction in reputation and trading systems, etc.

The paper by José Alberto Araúzo, Javier Pajares, Adolfo Lopez-Paredes, “Simulating the dynamic scheduling of project portfolios”, shows how agent-based modelling can help to solve the problem of dynamic scheduling of resources for multiple concurrent projects in real time. Mathematical approaches, like integer programming or network based techniques, cannot describe the complexity of multiple projects environments, which have many interrelated elements, and specially to adapt the analysis to dynamic changes. MAS allow capturing real complexity, and managing the dynamical issues of the environment. In this case, projects compete for resources, whose price evolves in real time depending on current demand. As a result of the negotiation among project manager agents and resource manager agents, the prices of resources are established dynamically, changing in time according to actual demand, and the cost of a project is also calculated dynamically, taking into account the others and resources availability and cost. This ability to adapt to a changing environment, and the way prices emerge from interaction among projects and resources, are illustrative of the potential of agent-based simulation for the analysis of complex systems.

The use of agent-based simulation for open markets analysis is also illustrated by the work of Paulo Trigo, Paulo Marques, Helder Coelho, “Virtual Agents for Running Electricity Markets”. Here, the focus is on deregulated energy markets, where competition should be achieved in a fair and transparent way. The implementation of an artificial market allows exploring whether the application of market rules drive to a coherent market behaviour, which emerges from the overall simulated environment. This can be validated in different conditions, where there are companies of different sizes and market share,
and which can change their trading strategies along time. Furthermore, this work shows how to integrate the environmental physical market properties with decision-making (deliberative) and reactive agents. This is done systemically by applying an agent-oriented methodology, in concrete, INGENIAS, which facilitates a comprehensive formulation of the MAS and tools to drive the development process.

This interest for the application of agent-oriented methodologies in agent-based modeling and simulation is more clearly discussed in the paper by Alfredo Garro and Wilma Russo entitled “easyABMS: a domain-expert oriented methodology for Agent Based Modeling and Simulation”, where they present easyABMS, a methodological approach that is not MAS generic, as in the previous case with INGENIAS, but focused to agent-based modeling and simulation. The motivation for such approach comes from the fact that existing agent-based simulation tools provide support mainly at programming level, but not too much for conception and analysis of agent-based models. Given the degree of maturity that the discipline is achieving, it is reasonable to look for guidelines and methods that could facilitate the implementation of agent-based models. The proposed approach tries to leverage the effort required with existing agent-oriented modeling languages and the constructs of existing agent-based simulation toolkits.

The paper by Jorge J. Gomez-Sanz, Carlos R. Fernandez and Javier Arroyo, “Model Driven Development and Simulations with the INGENIAS”, shows how an agent-oriented development process can be applied for agent-based simulation. This work is realized with the INGENIAS methodology, and requires some additions on the original agent-oriented modeling language and new code generation modules. The modeling language has been extended with concepts such as: Simulation-Event, SimulationPackage and SimExtractedInformation. And a new code generation module has been added to INGENIAS to take into account discrete-time simulation. The process of simulation creation consists of the following steps: creation of a SimulationPackage instance, definition of the simulation goal, identification of the simulation inputs, identification of the simulation outputs, identification and application of abstractions which define an agent type. This process is evaluated on a case study of a technological watch system that concerns the automatic gathering of scientific and technological information from the inside and outside of the organisation.

The article entitled “Self-Organization Models for Adaptive Environments: Envisioning and Evaluation of Alternative”, written by Stefania Bandini, Andrea Bonomi, Giuseppe Vizzari and Vito Acconci, proposes an application of self-organizing MAS for illuminating a tunnel in an adaptive way. The idea is to agentify lights with actuator, sensor and behaviour. The multi-agent system adapts the ambient illumination to the human’s presence and trajectory. The authors propose two approaches to realize self-organisation. In the first one, the agent behaviour is based on cellular automata and the defined architecture is the Dissipative Multilayered Automata Network. In this architecture, the cells (agents) update asynchronously their state and are open to influences from the environment. In the second approach, the agents have the behaviour of “fire-flies” insects forming a swarm. The behaviour is composed of three simple steering behaviours: cohesion, separation and alignment behaviours. The Acconci Studion in Indianapolis tested the two models.

The paper by Marco Remondino and Guido Boella, “How Users’ Participation Affects Reputation Management Systems: the Case of P2P Networks”, explores the human factor and social participation in a reputation management system (RMS). The paper studies a peer-to-peer network by means of an agent-based simulation where reputation deals with the evaluation of agent’s actions and the opinions other agents have about those actions. These elements are then reported as a feedback in a loop influencing the social environment. In such a loop, the system effectively relies on feedbacks provided by members, it tunes its behaviour according to them, and in this way, it optimizes its performance. This case study shows that the adoption of such a reputation mechanism allows a great reduction of inauthentic files circulating on the network.

The paper by Noélie Bonjean, Carole Bernon and Pierre Glize, “Towards a Guide for Engineering the Collective Behaviour of a MAS”, proposes an agent-oriented methodology with a semi-automatic tool for helping designers to define the agents composing an adaptive multi-agent system (AMAS). This is a kind of tool guiding designers to affect the emergent global behaviour of an AMAS by acting on the local behaviour of its constituting cooperative agents. The approach proposed in this paper can be seen as a feasibility study aiming at developing a textual guide by considering the principles of the AMAS theory. An interesting case study is used to exemplify the methodology concerning simulation of the behaviour of healthy and cancerous cells.

The paper by Leszek Kotulski and Adam Sędziwy, “GRADIS - the multiagent environment supported by graph transformations”, introduces a platform for the specification and simulation of complex multi-agent systems labelled GRADIS. This platform provides a framework for distributed/parallel graph transformations. The authors propose an approach for automatically transforming a set of complementary graphs in one centralized graph. This approach may be used for obtaining the specification of the entire multi-agent system from the specification of single agents. The work also proposes a strategy for designing agents’ decisions by specifying a set of local criteria affecting the way agents achieve their goals.

The paper by Virginia Dignum, John Tranier and Frank Dignum, “Simulation of Intermediation using Rich Cognitive Agents”, studies the importance of interactions in trading networks. The work considers the importance of different (economic, social, environmental) parameters in the mediation of business processes. The assumption behind the paper is that the usefulness of a mediator is justified not only by the services it offers but also by factors like the social structure existing between suppliers and customers, the communication infrastructure and so on. The paper also presents a case study based on the simulation of the house market by means of an agent-based system.
This special issue is the outcome of a collaborative work. We would like to thank the editor in chief of SIMPAT, Helen Karatza, for her precious and continuous support during the review and publication process. The special issue selected nine high-quality papers among 27 initially submitted. The reviewing process was supported by renowned researchers in the agent-computing research field that provided their anonymous reviews.

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