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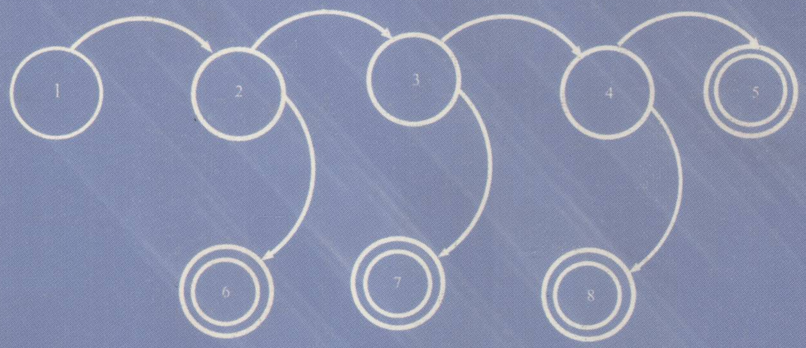
Andrea Omicini
Paolo Petta
Jeremy Pitt (Eds.)

Engineering Societies in the Agents World IV

4th International Workshop, ESAW 2003
London, UK, October 2003
Revised Selected and Invited Papers



Springer

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Engineering Societies in the Agents World IV

4th International Workshop, ESAW 2003
London, UK, October 29-31, 2003
Revised Selected and Invited Papers

Springer

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Jaime G. Carbonell, Carnegie Mellon University, Pittsburgh, PA, USA
Jörg Siekmann, University of Saarland, Saarbrücken, Germany

Volume Editors

Andrea Omicini
Università di Bologna a Cesena
Dipartimento di Elettronica Informatica e Sistemistica
Via Venezia 52, 47023 Cesena, Italy
E-mail: andrea.omicini@unibo.it

Paolo Petta
Austrian Research Institute for Artificial Intelligence
Freyung 6/2, 1010 Vienna, Austria
E-mail: paolo@oefai.at

Jeremy Pitt
Imperial College
Intelligent Systems and Networks Group
Electrical and Electronic Engineering Department
Exhibition Road, London, SW7 2BT, UK
E-mail: j.pitt@imperial.ac.uk

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Lecture Notes in Artificial Intelligence 3071

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Preface

The fourth international workshop, "Engineering Societies in the Agents World" (ESAW 2003) was a three-day event that took place at the end of October 2003. After previous events in Germany, the Czech Republic, and Spain, the workshop crossed the Channel, to be held at the premises of Imperial College, London.

The steady increase in the variety of backgrounds of contributing scientists, fascinating new perspectives on the topics, and number of participants, bespeaks the success of the ESAW workshop series. Its idea was born in 1999 among members of the working group on "Communication, Coordination, and Collaboration" of the first lease of life of the European Network of Excellence on Agent-Based Computing, AgentLink, out of a critical discussion about the general mindset of the agent community. At that time, we felt that proper considerations of systemic aspects of agent technology deployment, such as acknowledgement of the importance of the social and environmental perspectives, were sorely missing: a deficiency that we resolved should be addressed directly by a new forum.

A first focal point was the vision that to tackle the issues inherently connected to the emergent complexity of multi-agent systems (MAS) it would be inevitable to introduce the notion of a *society of agents* as a first-class entity in the modeling and engineering of MAS. In particular, paying attention to software infrastructure as a location to provide intelligence in MAS, and the notion of social intelligence drove the first ESAW workshop, co-located with ECAI 2000 in Berlin. ESAW 2001, held in Prague together with the by now renowned European Agent Systems Summer School (ACAI'01), reinforced the line of research relating to the design of agent society and underlined further the necessity for methodologies to properly guide the increasingly popular use of social and cognitive concepts in agent theories and technologies. The third workshop in Madrid took advantage of co-location with the workshop series on Cooperative Information Agents (CIA 2002) to set itself apart and gain further in identity by opening up to a yet a wider range of contributing technologies, while maintaining its central focus on theoretical and methodological aspects applied by this direction of research.

ESAW 2003 was the first workshop neither connected to nor co-located with any other scientific event. Even so, the stand-alone workshop proved the most vivid and rich one to date: this stands to testify, on the one hand, that the community aggregating around ESAW is by now sufficiently large and mature to sustain an autonomous scientific event, and, on the other hand, that the original intent to define and extend this community beyond the traditional (and already outdated) borders of computer engineering has definitely been met. Following the tradition of this workshop, the structure of the event developed around a few main themes constituting the pivotal elements of the sessions, as well as two invited talks that provided further topics of high relevance and prompted stimulating discussions.

In particular, the sessions addressed the following themes over the three days of the workshop:

- *Agent-Oriented Software Engineering and Formal Methods.* Two sessions covered methodological aspects of AOSE as well as formal methods in the analysis and planning of agent systems.
- *MAS Protocols and Interaction Management.* This session hosted presentations and discussions on communication and coordination between agents, focusing in particular on social aspects.
- *MAS Organization and Workflow.* Presentations in this session concentrated on organizational aspects, as well as related technologies and applications.
- *MAS Architectures, Cooperation and Teamwork.* In this session we discussed agent architectures, team and coalition formation, and economies of interaction in agent societies.
- *Artificial Intelligence Techniques in MAS.* This session covered more traditional (in a certain sense) topics in MAS research, such as planning and collective forms of intelligence.
- *Agent Society Dynamics and Engineering.* This session developed a series of notions from as heterogeneous backgrounds as sociology, political philosophy, and organizational theories, to serve as sources for foundational concepts for agent societies and their construction.
- *Agent Applications: Services, User Modeling, and E-Commerce.* In this session, different applications of agent technologies were presented, including user profiling, intelligent and dynamic service integration, and the realization of models of trust.

Two invited presentations rounded off the program in a most worthy manner. Dr. André P. Meyer, of the Command & Control and Simulation group of the Dutch TNO FEL, spoke about "Privacy-Aware Mobile Agents: Protecting Privacy by Modeling Social Behavior in Open Systems of Software Agents," examining the problem of privacy in open systems where a multitude of different MAS may interact. The presentation by Dr. Jean-Pierre Müller, now senior researcher at the French LIRMM, entitled "Emergence of Collective Behavior; Simulation and Social Engineering," examined the different notions of emergent behavior in complex systems and the correlation with concepts such as agent orientated and environment oriented programming. Techniques discussed in the analysis phase have been applied to resource management tasks – in particular, social engineering and ecological modeling.

It is useful to underline how the tradition of ESAW differs from other scientific workshops: here, the selection process includes the very meeting event, to which in particular the typical borderline paper submissions are also invited: The workshop allows the presenters to utilize the open atmosphere of discussion (promoted as much as possible by the organizers) to get their own innovative contributions into focus and make them stand out as deserved, whilst, at the same time, offering the organizers in their role as curators of the event the possibility to catalyze and encourage original approaches and judge individual efforts in a more comprehensive way. The constructive quality of the workshop – in particular, of this most recent event – thus contrasts decidedly with the dry and meticulous climate that all too often characterises analogous events, and it thereby promotes a typically broader and more collaborative scientific development of presented work.

The complete range of contributions that were collected in the working notes of the event are available online – along with the presentation slides – at the ESAW 2003 workshop site. The present post-proceedings continue the series published with Springer-Verlag (ESAW 2000: LNAI 1972, ESAW 2001: LNAI 2203, and ESAW 2002: LNAI 2577). This volume contains reworked and extended versions of selected papers and also includes contributions by the two invited speakers.

The organizers gratefully acknowledge financial support granted by the following institutions:

– Polo Scientifico-Didattico di Cesena, Università degli Studi di Bologna
– Imperial College London
– the Austrian Society for Artificial Intelligence (ÖGAI)
– Whitestein Technologies

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The next ESAW workshop is scheduled to be hosted in France by the University of Toulouse in October 2004, with Marie-Pierre Gleizes, Andrea Omicini, and Franco Zambonelli as organizers. We look forward to an ever broader and larger attendance, an even more lively interaction, and a still higher level of originality and innovation.

April 2004

Andrea Omicini
Paolo Petta
Jeremy Pitt

Organization

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Paolo Petta	Austrian Research Institute for Artificial Intelligence, Vienna (Austria)
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Emergence of Collective Behaviour and Problem Solving

Jean-Pierre Müller*

CIRAD-TERA-REV-GREEN**
73, av. Jean-François Breton
34398 Montpellier cedex 5 - France
jean-pierre.muller@cirad.fr

Abstract. The goal of this paper is to explore the notion of complex system and, in particular the emergence phenomenon, in order to see which lessons could be learned for both understanding and designing complex software systems. Complex systems are described as sets of non-linearly interacting components making multi-agent systems particularly suitable for modelling and designing such systems. The notion of emergence is explicited and used to derive ways of understanding and designing such complex systems. We conclude by discussing the pros and cons of the emergentist approaches and the research perspectives.

1 Introduction

As explicited in the aims and scope of the "Engineering Societies in the Agents World" workshop, software systems are undergoing drastic changes in scale and complexity, making them more resemble natural systems and societies than mechanical systems and traditional software architectures. The goal of this paper is to explore the notion of complex system and, in particular the emergence phenomenon, in order to to see which lessons could be learned for both understanding and designing such software systems.

A traditional approach in computer science is to decompose the system in manageable components (functions, objects or coarser grain components) with clear interfaces, i.e. manageable way of handling the interactions, most often carried out by a middleware (as discussed in [1]). Artificial Intelligence and Multi-Agent Systems are proposing problem solving methods inspired by the strategies developed by the natural systems (from ant colonies to human beings conceived as thinkers). Nevertheless these methods mostly rely on an *a priori* formalisation of the problem domain. In dynamic and uncertain domains, this *a priori* formalisation becomes difficult and requires an increased adaptive capability. Nature seems to have solved this problem by emergence of collective

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** Also associate researcher to LIRMM, 161, rue Ada, 34392 Montpellier cedex 5 - France.

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behaviours self-organising from the dynamics of entities in interaction between themselves and with an environment. Unfortunately, the notion of emergence itself is problematic for the modeller as well as for the designer, being most often defined by an absence of "something" as composability, predictability, and so on when the notion itself is not criticised.

The notion of emergence is usually associated with a misunderstanding or with an intuition facing some phenomena observed in nature; it is therefore rejected for a reductionist interpretation. For example, Daniel Memmi [2] limits emergence to a problem of description or explanation and assumes that emergent phenomena are examples among others of the variety of scientific explanations. In this sense, emergence is not in nature but in the change of observation focus on the phenomena. However, even if emergence can be characterised epistemologically, these phenomena have to pre-exist to our observation. In other terms, the emergence of an entity, a structure, a function or a process is in the system independently of our observation even if it is a change of the point of view of the observer, which reveals the emergence.

To better understand and exploit these emergent phenomena, one should provide an alternative approach not only to computer modelling, but also to problem solving. This approach principle is to build a society of agents, immersed in an environment, which by their interactions will evolve towards a stable state representing a solution. This approach, initiated by R.Brooks in robotics [3], is opposed to the classical problem solving approach where the global resolution task is decomposed into subtasks. The program then codes the resolution steps; while executing, the process follows the predefined path until the solution is reached. In the "emergentist" approach, the program codes the agents, the environment and the interactions; while executing, the process self-organises and builds a solution.

Another characteristic of the emergentist approach is the adaptative capability of emergent phenomena or structures to the changes of the environment. These phenomena are in dynamic interaction with the environment, but are not totally dependent on it. Generic regularities and properties are abstracted away through self-organisation and are applicable in other environments. In reality, the environment instantiates behavioural and structural rules, raising the emergence of a global phenomena. For example, a bacteria following a sugar gradient can go towards a sugar source or follow such a source without modifying the "program" controlling the behaviour of the bacteria. This adaptability to external changes is immediate because it does not rely on internal representations nor internalisation of paths. Therefore it does not necessitate updating or modification of the representation.

In the french multi-agent community, the concept of emergence for problem-solving has gained considerable interest. We can cite the teams at LIRMM [4, 5], LIP6 [6], LEIBNIZ [7, 8], CASCAD [9] or IRIT [10]. It is less used in the anglo-saxon community with the important exception of the work by Van Parunak around industrial applications [11]. The notion of emergence is better explored in the artificial life domain where we can cite the work of Deneubourg [12],

E. Bonabeau [13], J.L. Dessalles, L. Steels [14]. The two papers of [13] : "Characterizing emergent phenomena", give a number of examples of phenomena considered as emergent and propose a frame of study for a better understanding of these phenomena. Finally, we have to make reference to the seminal work of S. Forrest [15, 16] in the domain of emergent computation, we shall come to later on.

In the following, we will first introduce the notion of complex system, pointing out the importance of emergence in this definition. Several approaches to cope with complex systems shall be reviewed and illustrated. We shall conclude that multi-agent systems are good candidates for modelling and designing complex systems. The next section will introduce the notion of emergence, which is of outmost importance to understand complex systems. We shall propose a definition, which can be operational for understanding and for designing multi-agent systems. In section 4, we will discuss how we can use this definition to derive a methodology for designing emergentist multi-agent systems. Section 5 will conclude on the interest of the advantages and limits of using an emergentist approach to multi-agent systems and open research perspectives.

2 Complex Systems

It is hard to find a definition of what a complex system is but a mere list of properties (as is the case for intelligence, life, etc.). We can cite the exception of the definition of complex adaptive systems in [17] with a bias towards darwinian adaptiveness. Roughly speaking (and almost tautologically), a complex system is:

A System: a set of interacting components composing a whole (which whole to consider is dependent on the observer, hence on the question being asked) creating, *de facto*, a distinction between the system to be considered and the rest (the environment or outside);

Which is Complex: the interactions among the components are non-linear, such that the global behaviour of the system cannot be compositionaly deduced from the components' behaviours.

The second property makes the distinction between a complex system and a mere complicated system, which may have up to a huge number of components and still be compositionaly understood (like the digital electronic circuits, for example).

This definition exhibits most of the properties generally ascribed from complex systems [18], i.e.:

- the need of multi-scale descriptions, because it minimaly implies the articulation of the level of the components, the level of the whole and the level of the underlying environment;
- the multiplicity of view points because the wholes to consider are intrinsically related to the question being asked and therefore give rise to interacting view points (in addition to interacting components!);