The social cognitive actor

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Summary

Multi-Agent Systems (MAS) is a field of research that is concerned with the design, analysis and implementation of computational decision and simulation systems—a collection of actors that work in conjunction with each other—to enhance one's understanding of how people cooperate and coordinate their actions to solve problems. Upon its foundation in the mid-nineties, MAS propagated in the fields of cognitive sciences and social sciences, and was adopted, more specifically, in cognitive modelling and modelling of multi-actor interaction such as in social simulation (Conte & Castelfranchi, 1995b; Troitzsch, 1997). However, there has not been enough interaction between these two fields, and tools that try to connect both fields have not been sufficiently developed (Sun, 2006b). In our research, we will address this problem and make an attempt to bring both fields closer together.

The aim of our research is to design and implement a cognitive actor-based computational social simulation model based on a selection of social and cognitive theories in an attempt to satisfy the need for a complex cognitive-social model. The motivation for our research is twofold: (1) to reveal the constituents of MAS and the social cognitive actor (cf. Conte & Castelfranchi, 1995b) based on theoretical considerations to (2) construct a simulation model that plausibly explains the interactive social behaviour of actors in a physical and socially situated environment (cf. Gilbert & Troitzsch, 1999). The aim is to relate the behaviour of individuals (micro level) that form a group or an organisation to the behaviour and performance of a group or organisation as a whole (macro level) (Alexander & Giesen, 1987; Van den Broek, 2001).

Social (and organisational) behaviour is an outcome of the interactions between individuals. These interactions can lead to (temporarily) stable patterns of (organisational) behaviour. An organisation can be seen as a group of people that has habits of action aimed at cooperation and coordination of work. An organisation is not a physical, tangible object like an apple or a computer keyboard. Its observation, demarcation and existence depend on the existence of human habits and human-produced signs, and is a product of interactive social behaviour (Helmhout et al., 2004). An organisation can be traced back to representations (in the mind of actors) that structure the interaction among people, thereby demarcating a group of people who are members of an organisation

(Van Heusden & Jorna, 2001).

The interaction and relationship between organisation, actors and the mental representation inside the actors is evident, and therefore, (controlled) organisation is not possible without coordination among actors and their representations. In our models, we use the concept of social constructs: social constructs can be seen as representations of cooperation and coordination, based on intertwined habits and mutual commitments that are often expressed in sign structures such as agreements, contracts, plans, etc. (Liu, 2000; Gazendam, 2003, p. 205).

In our research, a mixed-level analysis (Sun, 2006b) is performed, in which the following levels are discerned in descending order:

1. The *social level*, which involves negotiation, reaching agreements, social laws and overall behaviour influenced by individual behaviour of actors.
2. The *semiotic level*, which describes the use of language and signs in communication and interaction in order to reach an agreement on social constructs (e.g. common plans, or contracts) (Gazendam, 2004; Helmhout et al., 2004, 2005b).
3. The *intentional level*, which ascribes beliefs, desires and intentions to actors. Intentions of others, inferred from knowledge about others' beliefs and desires, enable the examination of others' actions (Dennett, 1987).
4. The *functional level* describes learning and cognitive mechanisms of the actor and is grounded in an empirically validated theory (cf. Anderson & Lebiere, 1998).
5. The *physical/physiological level* is a level described by appealing to physics, biology and chemistry. It predicts or explains behaviour in terms of physical laws or physiological properties (Dennett, 1987).

The social construct has different meanings and is present in all of these levels. First of all, a social construct is the result of interaction between actors. At the social level, actors habituate their action and thereby create a habitat of social constructs. Sign production delivers codes or signs (the semiotic level) to which actors assign (shared) meaning. This shared meaning or knowledge becomes normative at the moment it influences behaviour of the members in the community, e.g. norms that guide behaviour such as respect for older people. In order to change and understand meaning, actors require a signification system (Eco, 1976). Such a signification system needs to be grounded in the actor, which can be done with the help of a plausible cognitive architecture at the cognitive level (functional level), e.g. ACT-R (Anderson & Lebiere, 1998). It enables the actor to process and produce signs. The social construct or a derivative of the social construct (sign) needs to be present at the cognitive, social and semiotic level. In the community, the social construct is present as a sign(-structure). These signs or social constructs are exchanged by actors in the community via communication and rituals. The exchange is made possible by a medium that allows the transport of social constructs as messages, documents or events. Communication between actors and the reinforcement of social constructs (caused by the frequent

use of social constructs) will lead to stable habituated patterns of behaviour and shared normative knowledge. Furthermore, the individual actor needs a physical symbol system (Newell, 1980) that enables it to hold representations, process and produce signs/symbols/social constructs and exhibit intelligent action.

We are interested in the interaction between these levels. In our research, we aim not only to describe the interaction, but also to simulate these interactions with the help of a Multi-Agent System. The combination of theory and MAS has lead to the following research, implementation and experimental questions:

What are the aspects of actors that plausibly explain interactive (social) behaviour?

To answer this question, we need theories, models and requirements that address the individual as well as the interaction between individuals. The following three sub-questions will elaborate this:

What type of a model can explain interactive (social) behaviour?

Methodological individualism and social constructivism argue that social behaviour should be explained in terms of individuals, their properties and their interrelations in terms of these properties. Multi-Agent Systems as a model and methodology support this view and can serve to explain interactive social behaviour, because MAS is concerned with the study of behaviour, and the modelling of a collection of actors that interact with each other and their environment (Sycara, 1998).

What is required for an actor to exhibit (stable) social behaviour?

For an actor to exhibit social behaviour, it is necessary to create and transfer signs and meaning between actors. Although theories of MAS address coordination, cooperation and negotiation issues, they focus mainly on social structures and often overlook processes that describe how these structures emerge, stabilise and disappear.

Social constructivism and organisational semiotics consider that (stable) social behaviour requires (1) the creation of shared knowledge and the social construction of reality (cf. Berger & Luckmann, 1967), and (2) semiotic resources such as signs/symbols/social constructs that refer to social structures, institutions and habits of action.

What kind of an actor can plausibly handle signs, relations and social constructs?

An actor that handles signs, relations and social constructs needs to have a system that supports representations and mechanisms that manipulate these representations and exhibit intelligent action. A general intelligent actor (system), whatever additional structures and processes it may have, will contain a physical symbol system (Newell & Simon, 1976; Newell, 1980). Therefore, the actor should be equipped with a cognitive architecture. Such a cognitive plausible actor is able to generate and process symbols, create and 'understand' social constructs and build relations with other actors.

Whereas the theoretical research questions explain what theories are applicable to our research in order to implement a Multi-Agent System that is capable of simulating organisational behaviour, the implementation questions give guidance to the development of a software tool and what is necessary to implement such a tool.

How can (cognitive and social) plausible actors be implemented in a Multi-Agent System?

First, the cognitive actor, which is the main component of a MAS, is constructed. A production system is chosen from a selection of different approaches that are possible within AI (cf. Ferber, 1999, p. 125). It is the most elaborate choice that matches the necessary requirements for an actor to be a rational problem solver. A realistic computerised model of a cognitive plausible actor can be created with a cognitive architecture such as SOAR (Lehman et al., 2006; Newell, 1990) or ACT-R (Anderson & Lebiere, 1998). ACT-R was chosen here as the architecture to model the individual actor (see chapter 4 for a discussion). In its most recent release, ACT-R is an architecture of a single actor for which no multi-actor architecture version is yet available. Therefore, the ACT-R architecture is extended and transformed into a new architecture, RBot, that enables ACT-R to become a multi-actor system. Within the newly created MAS (Multi-RBot System or MRS), it is possible to incorporate multiple actors in a task environment.

With the help of this developed MAS, we try to answer the following experimental questions.

Is it possible that social constructs and organisational behaviour can emerge from social interaction?

Is a social construct a coordination mechanism that can influence the behaviour of interacting related actors towards a certain desired behaviour?

The objective of the implementation / experimental questions is to address the mechanisms inside the actor that process and produce social constructs, and are influenced by interactions with other actors. The underlying assumption is that the actor is socially connected to others on a continual basis. The second objective is that these questions are simultaneously design questions. First, the requirements are drawn up. Second, the design or model is constructed. This is followed by an implementation of the system, and fourth, demonstrative experiments show its working. The design questions guide the construction of a model that attempts to bridge the gap between cognitive and social sciences (cf. Sun, 2006a).

The research concludes that the implemented software, called RBot (cf. Roest, 2004), is able to analyse behaviour at different levels and that the software allows for studying the behaviour of actors at the group level (the habituation of behaviour) between individuals, of the individual itself (the rational level) and intra-individual (the functional level: symbolic and sub-symbolic level). Experiments or simulations are run to show that RBot can simulate behaviour

at all these levels. The first experiment is an internal validation showing that RBot is cognitive plausible by comparing its behaviour with that of ACT-R. Secondly, the emergence of social constructs is demonstrated in an experiment composed of a MAS environment whereby actors establish a (tacit) social construct by adapting towards each other's behaviour. The final experiment shows the implementation of an explicit social construct as a representation in the mind of the actor. The social construct is a condition-action pattern implemented at the normative level (meta-cognition) of the actor that influences the processing of productions at the lower level of the actor. In comparison to second experiment, the last experiment shows that a social construct enforces a faster stabilisation and a more predictable way of controlling the behaviour of the overall system (the group).

The conclusion is that this research contributes to a better understanding of how individual behaviour has impact on social behaviour and vice versa. The concept of social construct, because of its different meanings and presence at different levels, connects the social level with the individual level and therefore is a serious attempt to bridge the gap between the cognitive and social level (cf. Alexander & Giesen, 1987).

Finally, the work reported in this dissertation is encompasses both theoretical work and software development. The simulation experiments reported in the dissertation are mere demonstrations of the fact that the developed architecture works as intended; these experiments should not be considered as the core of the work done (as opposed to research consisting of experiments done with pre-existing software packages). The realised software architecture[†] is a tool that enables multi-actor simulations based on intelligent socially aware actors, and is thus a contribution to the community of people engaged in multi-actor simulations.

[†]http://sourceforge.net/projects/act-rbot