Social constructs and boundedly rational actors: A simulation framework

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Abstract

In this paper we sketch a framework for multi-actor simulation of an organization. In contrast to many approaches to multi-actor simulation, we design the actors as cognitively plausible actors. The interaction and cooperation of the actors is based on social constructs. In elaborating a cognitive perspective on actors, we use the cognitive architecture ACT-R for modelling the individual actors. This cognitive architecture implements a part of Simon's bounded rationality. In the recent discussion about bounded rationality, fast and frugal heuristics play an important role. Some of these heuristics will be included in the simulation model as a compensation mechanism for the limits to rationality. Individual actors and organizations always function within an environment that is structured in terms of space, time, objects, resources, other actors and signs. Because of the demands of the task environment, in which things often cannot be done alone, actors have to cooperate. Cooperation is only possible based on intertwined habits and mutual commitments that are expressed in sign structures, such as agreements, contracts and plans. At a semiotical level of description, these sign structures are seen as social affordances or social constructs. Social constructs guide the formation and reinforcement of habits of individual actors that are aimed at cooperation, coordination and socially accepted behaviour. At an organizational level of description, organizational configurations can be identified. These organizational configurations can be seen as networks of social constructs.

1. Introduction

Due to improvements in computer power and software languages, multi-actor simulations nowadays are more applied in research than ever before. This increased power of simulation models makes it possible to investigate armchair thoughts about organizations and the cooperation of (human) actors. Simulation models enable experiments that cannot be done in real life for several reasons, such as the undesirability of interfering with people's ordinary behaviour, the complexity of situations, all kinds of measuring inadequacies and, especially in case of organizations, the long time horizon.

The goal of this paper is to give a framework for multi-actor simulation of an organization that uses simulated boundedly rational actors (Simon, 1945/1976, p. 80) and social constructs (Liu, 2000, p. 64; Gazendam, 2003, p.205) as the main building blocks. A simulation model based on this framework can be used for investigating the effect of social constructs on the behaviour of actors and organizations. The resulting knowledge could be used for the development of new forms of coordination in organizations, for designing information systems, and for understanding the development of virtual organizations. This paper uses the following theoretical perspectives in the design of a multi-actor simulation framework: cognitive science, organizational semiotics, organization theory, and multi-agent simulation. It is limited to the design of a simulation framework, and nor the technical design of simulation models, nor the results of simulation experiments will be reported.

Multi-actor simulation is based on the idea that a system that shows complex behaviour has to generate this behaviour by performing computations. We see the behaviour of such a system, for instance an organization or society, as complex because that behaviour can not be described by traditional mathematical tools, for instance, mathematical equations (Wolfram, 2002, p. 3). The shortcut taken by traditional mathematics does only work when the behaviour of the system is simple. In the case of complex behaviour, this behaviour can more often than not be simulated by computations that use the interaction of computer agents following simple rules (Holland, 1995, 1998; Wolfram, 2002). The complex behaviour at the system level of description can be seen as *emergent* relative to the simple rules represented at the agent level of description (Holland, 1995, 1998). This discovery has led to a new form of theory development based on the principle of computational equivalence. *Computational equivalence* means "that whenever one sees behaviour that is not obviously simple . . . it can be thought of as corresponding to a computation of equivalent sophistication" (Wolfram, 2002, p.5). Because of the idea of computational equivalence, we can study human organizations based on simulation models consisting of computer agents.

In contrast to many approaches to multi-actor simulation, we model actors as boundedly rational actors based on cognitive architectures known from cognitive science. This emphasis on cognitive actors contrasts with the standard empty actor modelling in economy and organization studies. In order to survive, an actor has to participate in an (social) environment, which provides the actor with enough opportunities for acting, individually as well as collectively. However, a "real life" actor has various constraints that can be formulated in terms of bounded rationality, e.g., an actor is ontologically not able to take all information of the complex world into account. And even if he can, he is cognitively unable to process all this information. Because of this, actors have to cooperate with other actors in many situations.

Another difference with respect to other simulation research is that we see cooperation and coordination as resulting from the use of social constructs, which allows a semiotic orientation. This is in contrast with the common non-social perspective in cognitive science. Cooperation is only possible based on intertwined habits and mutual commitments that are often expressed in sign structures such as agreements contracts, and plans. At the level of description that organizational semiotics uses, these sign structures are seen as social affordances (Liu, 2000, p. 64) or social constructs (Gazendam, 2003, p.205). Social constructs guide the formation and reinforcement of habits of individual actors that are aimed at cooperation, coordination, and socially accepted behaviour. Social constructs can be modelled based on concepts and methods used in organizational semiotics.

The aim of doing simulation experiments based on our multi-actor simulation framework is to gain a deeper insight into what effects the use of fast and frugal heuristics —necessary because of bounded rationality— and social constructs have in terms of the efficiency of individual and collective task fulfilment. Important themes to investigate are (i) how, actors learn, select and use social constructs given a certain cognitive architecture and the knowledge of certain heuristics, (ii) which configurations of social constructs emerge in a certain environment, and (iii) how these configurations correspond to known organizational configurations.

The structure of this article is as follows. In section 2, we investigate the systems and levels of description that we have to use in our simulation framework. In this investigation, we use several theoretical perspectives: cognitive science, organizational semiotics, organization theory, and multi/agent simulation.

In section 3, we start with a discussion of the environment in which actors work together. This environment can be seen as a system maintaining physical laws, a task environment, and a semiotic Umwelt.

The modelling of the individual actor based on a cognitive architecture and on bounded rationality is explained in section 4. Psychologically plausible cognitive architectures give simulated actors the ability to interact with the environment in a way that is "somewhat" comparable to real human behaviour. We are talking about humans as information processing systems that interpret, hesitate, think, reason and use their memory. The cognitive processes are based upon mental representations the actors have, construct and use. Bounded rationality means that there are limits to the capabilities of the cognitive system. As a result of cognitive limitations, people use compensation mechanisms, for instance, fast and frugal heuristics. The simulation has to incorporate some of these mechanisms.

In section 5, the modelling of social constructs is described. Social constructs are units of shared knowledge of a normative character. They are the glue that holds organizations together. Instead of using rather complex social constructs that would give the simulation a large amount of complexity, which makes it more difficult to implement and analyse the outcomes of these social constructs, a selection of rather simple social constructs is discussed. One of the ideas behind the simulation design is that organizations can be seen as glued together by configurations of many small and simple social constructs. Social constructs are the building blocks for organizational configurations that will be formed. Negotiations about which social construct should be applied will finally form a relationship or organization. The organizational configurations as formulated by Mintzberg (1979) are explained as a starting point for the investigation of the relationship of these organizational configurations with types of social constructs.

Finally, we discuss in section 6 the design of the simulation model.

2. Systems and levels of description

2.1. Theoretical perspectives for distinguishing systems and levels of description

In the definition of our simulation framework, it is important to distinguish the proper systems and levels of description. *Systems* are distinguished based on their coherence and their functioning as a whole. Systems often have clear boundaries. *Levels of description* are defined based on the perspective taken when describing one and the same phenomenon (Newell, 1990, p. 46, p.118). The perspective taken describes a certain system level at which components can be discerned that interact, thus producing behaviour at that system level. According to Simon (1996, p. 183), a stable system generally will consist of a hierarchy of system levels to which levels of description correspond.

For distinguishing the systems and levels of description that are relevant for our simulation framework, we use four perspectives: cognitive science, organizational semiotics, organization theory, and multi-agent simulation.

Cognitive science distinguishes the human actor system and the task environment system. Human beings, animals, robots, and computer agents are functionally equivalent according to Newell and Simon's (1972; Newell, 1990) physical symbol system hypothesis.

In setting out a research agenda for cognitive science in the early seventies, Dennett (1978, 1991, p. 76) introduced the distinction in various levels of description. He discerned a physical, a functional and an intentional level of description (or stances, as Dennett called them). Other authors (Newell, 1982, 1990; Pylyshyn, 1984) have given similar accounts in which, however, the number of levels varies. The physical stance describes behaviour in terms of physical properties of the states and the behaviour of the (individual actor) system. For its proper functioning the human organism requires a complex interaction of its parts with the external world. The central nervous system and the endocrine system transmit information that reveal the state of one part of the system to other parts. We can also mention the transmission of currents in the synaptive system of neurons. Within cognitive science, the physical level is the endpoint of successful ontological reduction.

The second level of description takes the point of view of the functional design of a system. The behaviour of a system is conceived of as the result of the interaction of a number of functional components or processes. In a functional description, it is important to know what the components of the system are, how they are defined and how the components and, possibly the sub-components, of a system are connected with each other. In other words, if the input and output of every component is known, it is possible, given a certain input at the beginning of the system, to predict the resulting behaviour on the basis of the properties of the states. The physical structure (architecture) of the system is not explicitly taken into account, although it may impose constraints on the behaviour of the system. The capacity limitations of human memory will, for instance, impose constraints on solving very complex problems.

The third level that Dennett distinguishes is the intentional level. Complex behaviour that is adapted to prevailing circumstances, according to some criterion of optimality, is said to be rational or intelligent. A behaving system to which we can successfully attribute rationality or intelligence qualifies as an intentional system. It is not necessary for a behaving system to 'really' possess rationality or intelligence, as long as the assumption allows us to correctly predict the behaviour of the system on the basis of our knowledge of the circumstances in which the system is operating.

The main message Dennett wanted to express with his distinctions in levels is firstly that the functional level is an adequate level of description for cognitive science to study all kind of cognitive phenomena and secondly that the intentional level, although the common level of description within social (and organizational contexts), can, or better, should be reduced to the functional level.

Mental representations are said to consist of symbol structures that can be processed within the cognitive architecture (Newell & Simon, 1972). Although rarely formulated explicitly, the (mental) symbol structures in most representational theories of mind are semiotic by nature (Jorna, 1990).

Newell (1990, p.122) distinguishes system levels based on their time scale and space scale. Adjacent levels are grouped into bands[1]. In this way, the biological band, the cognitive band, the rational band and the social band are distinguished. The physical level of description can be situated at the higher part of the biological band, the functional level resides at the cognitive band, and the intentional level corresponds to the rational band.

Newell requires from each system level that it has a relatively stable structure, based on the organization of elements that are based on lower system levels (Newell,

[1] Newell's definition is slightly different: a system consists of bands, which consists of (system) levels; this should not be confused with figure 1.

1990, p. 117). System levels with a strong organization are called strong system levels. Newell sees all system levels above the rational band as relatively weak.

Organizational semiotics (Stamper, 1973, 2001; Liu, 2000; Gazendam, Jorna & Cijsouw, 2003, pp. 1-12) distinguishes six levels of description in the form of a semiotic framework or semiotic ladder: the physical world, empirics, syntactics, semantics, pragmatics, and the social world. Within the social world, social constructs in the form of social affordances (Liu, 200, p. 64) play an important role. Furthermore, there is the language action perspective within organizational semiotics that distinguishes speech-act based scenarios for establishing social constructs, like the DEMO scenario (Dietz, 1995, 1998). The systems that organizational semiotics distinguishes are agents in the form of the human actor and composite agents in the form of communicating human actors (Liu, 2000, p. 64). Furthermore, an environment can be distinguished in the form of a semiotic Umwelt (Von Uexküll & Kriszat, 1936/ 1970). This is an environment around a human being or animal based on the signs and symbols that it creates and perceives. The types of signs and symbols that can be created and perceived depend on the biological species.

In *organization theory*, there are three system types that are distinguished: the organization, the individual actor, and the organization network. In our simulation framework, we will not use the organization network. The individual actor generally is a human individual, but can also be for instance a computer agent. Organizations can be described at the level of the organization as a whole, at the level of the individual actor, or at the intermediate level, for instance based on the (inter) actions of actors, the sign structures they use, or as graphs depicting communication and control lines between actors and subsystems (Gazendam, 1993, p. 102).

Multi-agent simulation (Carley & Gasser, 2001; Wooldridge, 2002) distinguishes the agent system, the task environment system, and the organization as system. There are two levels of description: the agent level and the level of patterns at the organization level, a level that we would call the intermediate level in organization theory (see Table 1).

	cognitive science	organizational semiotics	organization theory	multi-agent simulation
organizational level	1)		●	
semiotical level	1)	●	●	●
intentional level	●	●	●	
functional level	●	●		●
physical level	●	●		

Table 1. Theoretical perspectives and levels of description
(1: not distinguished except as Newell's social band)

2.2. The theoretical perspectives combined

Combining the perspectives of cognitive science, organizational semiotics, organization theory, and multi-agent simulation, we can distinguish three systems and five levels of description that are interesting for the development of our multi-actor simulation model.

The three *systems* are: the individual actor system, the organization system, and the environment system. A common problem within cognitive science is the neglect of the social environment of the human information processing system (the individual actor). To put it in terms of our simulation, the focus is only on the individual actor system. However, individuals always live in groups, families, firms or societies. We can state this more generally in saying that individual actors live in organizations.

This means that besides the individual actor system we also have the more aggregate organization system. An *organization* is a collection of individual actors, together with the work processes, the sign structures, and the objects they see as belonging to the organization. The individual actor and the organization live in the environment system. This defines especially time and space, and the physical laws actors and objects must comply to.

The five *levels of description* are: the physical level, the functional (or cognitive) level, the intentional (or rational) level, the semiotical (or social construct) level, and the organizational level. The *physical* level includes Stamper's physical world and empirical levels of description. The *functional* level includes Stamper's level of syntactics and the agent level in multi-agent simulation. The *intentional* level includes Stamper's levels of semantics and pragmatics, and the human actor level in organization theory.

The *semiotical*[2] (or social construct) level of description can be seen as a relatively strong system level based on the stability of communication patterns, languages, and social constructs. Communication patterns, languages, and social constructs persist through decennia, and even centuries (take, for instance, the social construct of property/ ownership). They have a key position in communication, learning, and developing social behaviour by human beings. They can be seen as knowledge units that are shared in groups or even social systems, reinforcing themselves by communication and their daily use. These shared knowledge units can influence individual behaviour by forming habits, thus creating a cycle of selection and reinforcement, where some knowledge units are reinforced and others disappear. The semiotical level of description focuses on sign structures, and processes of sign production and sign use as relatively stable, independent phenomena. In this way, one can focus on communication patterns, texts, knowledge units, knowledge types, habits of action, and social constructs as meaningful kernel concepts. One abstracts from the problem of processing the corresponding sign structures by the human cognitive system and the representation of these sign structures in the human mind. The semiotical level includes the description in organizational semiotics of the use of social constructs and language action scenarios, and the intermediate level of description in organization theory and multi-agent systems. Organizational coordination mechanisms can be analysed as being based on social constructs as building blocks. In this way, organizations can be explained as systems of coordinated behaviour of individual human actors, with complex semiotic processes in a key role. The semiotic band corresponds to the lower part of Newell's social band.

The *organizational* level of description abstracts from questions around the emergence and persistence of communication patterns, knowledge units, social constructs, and so on, and focuses on a description of organizations in terms of variables and configurations of these variables. The organizational level corresponds to the higher level of Newell's social band. The organizational level of description includes the description of the characteristics of the organization as a whole in

[2] Organizational semiotics distinguishes four of the levels of descriptions that we use. In cognitive science, the symbol system hypothesis is used for descriptions at the functional level. Therefore, it may seem somewhat strange that we use the name 'semiotical level' for a level of description. The problem is that a long name like 'social construct level' may be confusing as well, because not only social constructs play a role at this level, but also speech acts, interaction scenarios, shared knowledge units, and so on. Because organizational semiotics focuses especially on this level of description, 'semiotical' seemed the best choice for a name, giving (organizational) semiotics a place as a discipline that can form a bridge between cognitive science and organization theory.

organization theory, like for instance Mintzberg's (1979) description in terms of design parameters, intermediary variables, contingency variables, and structural configurations.

The actor system can be described using the physical, functional, and intentional levels. The organization system can be described using the physical, semiotical, and organizational levels. The environment system can be described using the physical level (see Table 2).

	actor system	organization system	environment system
organizational level		●	
semiotical level		●	
intentional level	●		
functional level	●		
physical level	●	●	●

Table 2. Systems and levels of description

Sign structures play a role in all three systems. Sign structures play an important role at the functional level of description of an individual actor. Sign structures reside as physical inscriptions in the semiotic Umwelt, that is, the environment. Shared sign structures play a role as social constructs that are part of an organization.

In figure 1, we show the connection between the systems and the levels of description used in our simulation framework. At the left side are the levels of description ranging from the physical, the functional, the intentional, the semiotical, and the organizational level. At the right side we show the three systems: the environment, the individual actor and the organization. Shared signs in the form of social constructs have to be represented (as 'cognitive' signs) in the minds of individual actors (at the functional level), and are used to define an organization at the organizational level.

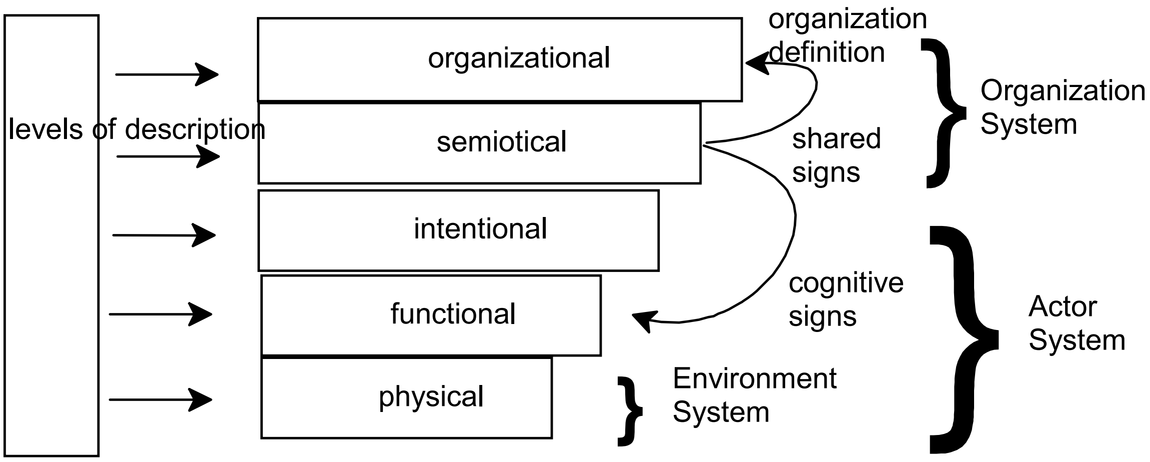

Figure 1. Systems and levels of description

3. The environment system

The environment system can be seen from the perspective of multi-agent simulation as a system maintaining physical laws, from the perspective of cognitive science as a task environment, and from the perspective of semiotics as a semiotic Umwelt.

In most multi-agent simulations (Wooldridge, 2002, p. 16), it is assumed that the environment in which agents operate is non-deterministic and dynamic. *Non-determinism* means that agents only have partial control of their environment. They have a limited sphere of influence and a perception horizon. In a non-deterministic environment, the action of an agent when performed twice may have different results. The action may also fail. However, the reaction of the environment on the agent's actions is not totally random. In most simulations it is assumed that the environment has to maintain physical laws.

The environment is also *dynamic*, which means that it changes independently of the agent's actions. This means that the agent has to gather information to determine the state of the environment before deciding about what to do. Furthermore, other processes (like the actions of other agents) may interfere with the actions of an agent. The agents therefore have to worry about coordinating and synchronizing their actions, something that is not necessary in static environments.

The environment may also be *discrete or continuous*. In a computer simulation, the environment is per definition discrete. Continuous environments, however, can be simulated to any desired degree of accuracy. An example is the determination of time intervals in discrete event simulation.

If we want to compare the performance of human actors with computer agents, the simulation environment has also to work in *real time*, adapted to the interaction with the human users.

Newell and Simon (1972) used the term *task environment* to indicate that a problem space representation does not come out of the blue. Setting goals and determining constraints are necessary for any search activity. The structure of the task environment provides part of the information that is needed to account for intelligent behaviour (Simon, 1969). The cognitive system represents and interacts with the task environment in performing tasks.

A task is defined as a sequence of actions in order to reach (various) goals, taking into account (various) constraints (Waern, 1989). Examples of tasks are giving mortgage advice, diagnosing illnesses, scheduling staff shifts, storing goods in a warehouse and trading. A task always requires an explicit or implicit task model. A task is not a natural entity. From the perspective of organizational semiotics, it is a social construct. This means that task analysis may result in several sub-tasks, sub-sub-tasks, etc. Arbitrary end points may result from this situation. Various dimensions to divide tasks can be discerned. In terms of the dimension of time, keystrokes are at the lowest level (less than one second) and loaning a book from the library is at a realistic level (about 10 to 20 minutes), and writing this article (more than one week) is at the highest level.

Characteristics of tasks refer to task domain, task context, task organization, task division, task dependencies, and task content. The task domain concerns the determination of the "what" of the task. The task context refers to the organizational environment where the task takes place. The task division refers to the "who" does "what" without taking into account the order. Task dependency concerns whether the second actor has to wait until the first actor is ready or whether they work in a parallel way. The task content concerns the knowledge actors have about aspects related to the task domain.

The *semiotic Umwelt* is an environment around a human being or animal based on the signs and symbols that it creates and perceives. The types of signs and symbols that can be created and perceived depend on the biological species. The basic structure of the semiotic Umwelt, its space and time, depends on the sign processing capabilities of the living being. Time is dependent on its biological rhythms. Space is structured in a way that the signs an organism can perceive are localized in a meaningful way.

> "Während wir bisher sagten, ohne Zeit kann es kein lebendes Subjekt geben, werden wir jetzt sagen müssen, ohne lebendes Subjekt kann es keine Zeit geben. . . . das gleiche gilt für den Raum. . . . Ohne ein lebendes Subjekt kann es weder Raum noch Zeit geben." (Von Uexküll and Kriszat, 1936/ 1970: 14; Von Uexküll, 1998: 2189).

The semiotic Umwelt supports the survival of human and animal actors, and affords certain species-specific behavioural patterns (Gibson, 1969; Von Uexküll, 1998). Based on the development of these species-specific behavioural patterns, an actor has access to a task environment that is structured in terms of space, time, objects, resources, other actors, and signs.

4. The individual actor system

4.1. Modeling boundedly rational actors

In many economic and organizational studies, organizations, and the human actors within, are considered as behaving in a fully rational manner, searching for optimal solutions. Opposed to that, we describe actors as boundedly rational. Bounded rationality is the concept that Simon (1945/1976, p. 80) coined to conceptualize the limitations of "perfect" representations of the environment by the human actor and also of the mental processing capacity of the actor. They are boundedly rational, because they do not have a complete representation of the world around them (the ontological argument) and even if they have, they are not able to process all the information and opportunities they encounter (the cognitive argument). The ontological argument says that you cannot predict, for example, the weather situation in Reading at September 23, 2009. The system is too complex. The same holds for the behaviour of all humans at September 23, 2003. That is also too complex. The cognitive argument says that even if you could, your mental system is not fit in terms of representations and architecture to accomplish these predictions.

If we go back to how Simon over the years elaborated his "satisficing" organism (including the human information processing system), he never changed the fundamental characteristics. They include the following:

- Limitation of the organism's ability to plan long-term behavioral sequences; a limitation imposed by the bounded cognitive ability of the organism as well as the complexity of the environment in which it operates.
- The tendency to set aspiration levels for each of the multiple goals that the organism faces.
- The tendency to sequentially operate on goals rather than simultaneously, because of the "bottleneck of short-term memory".
- "Satisficing" rather than optimizing search behavior.

However, to model boundedly rational actors for our simulation, we have to give them one or more of the following specific properties:

- Bounded knowledge or information about the environment. Normally, the actor absorbs only a small amount of knowledge or information about the environment by interacting with this dynamic environment.

- Decrease in activation of information and rules, which will further restrict use or application. In this way, bounded rationality will never become fully rational.
- An incomplete and imperfect model or representation of the surrounding environment. The representation of the environment of the human actor in consciousness, presupposing the cognitive architecture, is principally not in accordance with reality.
- Restricted processor capacity. The actors are not capable of computing all the symbolic calculations on the knowledge they possess. When, for example, an actor uses heuristics a boundedly rational actor has a preference for a simple heuristic instead of a difficult one.
- Other resources, such as memory, are restricted, which makes it impossible for an actor to remember everything.

To implement these properties, the actors have to be equipped with a cognitive architecture, which enable them to interact with the environment, to create representations (semiosis), to set goals and to learn. This architecture is ACT-R.

4.2. The actor architecture: ACT-R

A cognitive architecture is an implementation of bounded rationality. Many architectures of cognition have been developed (Posner, 1989). In order to implement the properties mentioned in the previous section, we choose the ACT-R architecture (Anderson & Lebiere, 1998; see figure 2) for this simulation. ACT-R tries to incorporate the functional as well as the physiological level of cognition and it also has a more elaborated account of learning as compared to the cognitive architecture that is described in SOAR (Laird, Newell, & Rosenbloom, 1987).

The architecture consists of three main parts: procedural memory, declarative memory and the goal stack. Procedural memory mostly consists of if-then rules. This makes it possible for the actor to reason. Procedural memory is also responsible for actions of the actor towards the outside world. Declarative memory is more like a database consisting out of facts, which are most of the time perceived by the actor by interacting with the outside world. Every part, called a chunk of knowledge, has a parameter, which indicates the importance of that knowledge. The base activation level of a chunk depends on the frequency with which it has been used and on the duration since the last time it has been used. Selection of chunks is based on these activation levels. The goal stack makes it possible to divide goals into less complicated sub-goals, which, after solving the sub-goals, makes it possible for the actor to solve the main goal.

The cognitive architecture can also deal with the selection of procedural rules, like having a preference for simple, instead of for complex rules. An assumption is that different decision strategies need different amounts of processor capacity (Simon, 1955). Another feature is that it is possible to limit the amount of elements (chunks, etc.) of procedural and declarative memory.

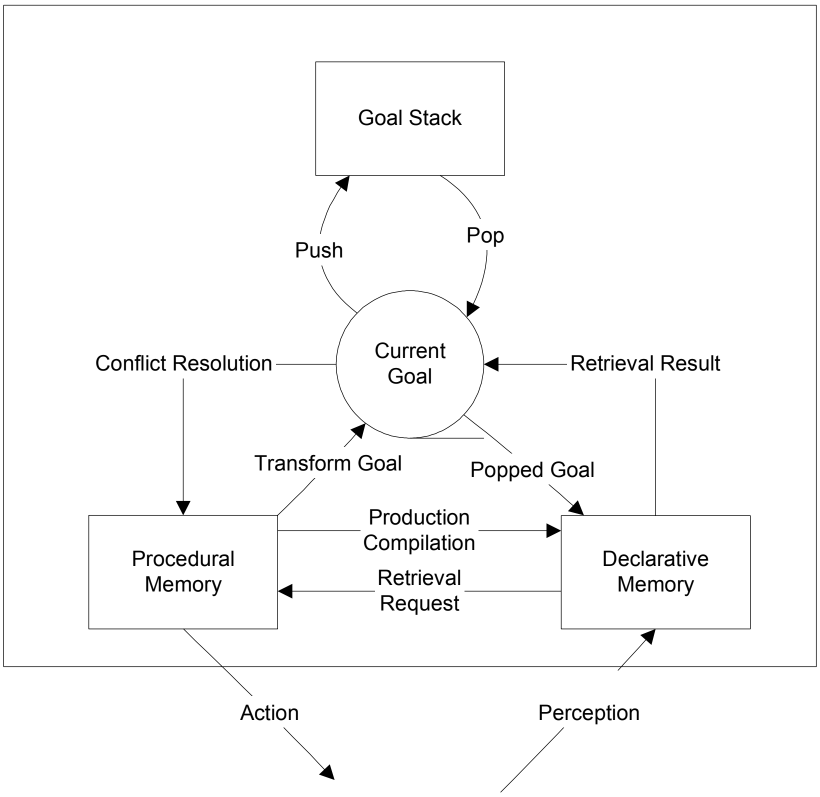

Figure 2: Information flow within ACT-R: a cognitive architecture

The basic assumption within ACT-R (and SOAR and other cognitive architectures) is that at the functional level this architecture mimics the mental processes of humans. This is what Newell and Simon (1972) called the symbol systems hypothesis. Symbols, architectural components and processing are comparable to the knowledge (representations) we have, to the restrictions that are part of our mental make-up and to the way we think. Architectures of cognition are models of humans, who are conceived to be boundedly rational.

This individual cognitive part is implemented in the actors as basic elements in our simulation. The social part comes in when we look at how we try to overcome our inherent limitations. We argue that bounded rationality, that is to say, the restrictions, humans and organizations experience, is (partly) compensated for by the use of other mechanisms, such as trust, loyalty and reputation between actors and the social environment on the one hand and by coordination mechanisms and governance structures at the organizational level on the other hand.

4.3. Mechanisms to compensate: Trust, loyalty and reputation

In order to compensate for the boundedness of cognitive capabilities, humans have developed fast and frugal heuristics through evolutionary time (Gigerenzer & Selten, 2001). Examples of these fast and frugal heuristics are the imitation of behaviour of successful others, the use of culturally transferred models or stereotypes and the use of emotions (Bouissac, 2003). The use of trust and of norms is also considered as such a heuristic.

Trust is the subjective probability that another party has no intentions to behave opportunistically (Deutsch, 1973; Gambetta, 1988; Numan, 1998). It is possible to distinguish two types of trust: trust in intention and trust in competence. Trust in intention is trust in someone's intention to perform at the desired aspiration level.

Trust in competence is trust in someone's capability to perform at the desired aspiration level.

A mechanism to express trust, for example, is "goodwill", accounting for all actors whom an actor had contact with. "Goodwill" will help an actor to establish a representation of the intentions and competences of other actors. Trust in itself is not an independent characteristic, because it is dependent on behaviour of other actors and on the 'hostility' of the environment. For example Gulati (1995) states that trust increases with time, when the partner does not show opportunistic behaviour, such as breaking the relationship or not complying with the acquired competence. Trust is subjected to changes and can be very unstable in a rapidly changing environment. Loyalty on the other hand is more dependent on the properties and behaviour of the actor itself. Loyalty forms the behaviour of the actor itself and can determine the trustworthiness for this specific actor. For example, when an actor behaves stable in a relationship and is not defecting, even if there is a better opportunity, this actor can be defined as a loyal actor. But what are the benefits of loyalty versus opportunism?

Probably, there is a clear connection between loyalty and reputation, because when an actor wants to keep a good reputation for not defecting a relationship, it will behave more loyal towards other actors to preserve this good reputation. Reputation can be seen as a partly shared representation of what all actors think about an actor.
To acquire this reputation, an actor has to behave properly; the actor has to have knowledge about how to behave in certain circumstances. McAdams (1997), for instance, argues that every actor has (social) norms, to which it has to obey. They are perceived from the environment, from other actors (inheriting of parents) or created/changed by the actor itself. Norms are a result of shared characteristics of proper behaviour and the willingness of individuals to reward correct behaviour and to punish incorrect behaviour. If, for example, you are invited to a dinner that you thought of would be an informal dinner and you are wearing jeans, but everybody else wears formal clothing, you interfere with a social norm and as a result you feel embarrassed. In procedural memory, this norm could look like: if <<personal norm> rebellious == false> and if <formal dinner == true> → then <clothing == formal >. This is just a small example. In reality decisions about what to wear are obviously more complicated. Besides this, norms provide also solutions for coordination problems regarding behaviour, which makes it easier to adjust to one another and causes less time and money expenditure.

Adjusting to one another means that the actor has to have capabilities or social aids to interact with other actors or its environment and to interpret signs of other actors and its environment to coordinate actions and cooperate successful.

Next to the capability of the actor to use and interpret signs, sign-structures like social constructs will enable actors to interact more efficiently and create more 'stable' interaction patterns.

5. The organization system

5.1. Cooperation and organization

Very often the environment poses such demands on the individual actor that *cooperation* with other actors becomes necessary. Situations in which this can occur are, according to Schmidt (1991) and Gazendam & Homburg (1996) that a single actor has insufficient work capacity, insufficient specialized knowledge, one-sided interests and views, and insufficient power to handle conflicts. *Augmentative* cooperation is based on the fact that single actors are limited by mechanical, physiological and cognitive capacity. Therefore, cooperation is necessary to overcome these limitations. *Integrative* cooperation brings in the specialized knowledge of the participants necessary for performing a common task. *Debative* cooperation brings in a variety of values and interests and aims at acceptable conclusions. Knowledge-based work processes are fragile and contestable. The function of debative cooperation is to alleviate this deficiency. Debative cooperation can be found in scientific communities and, for example, in the organization of governments in clearly independent executive, legislative and judiciary bodies. Actors can also cooperate in order to handle conflicts efficiently and non-destructively by using authority, negotiation, and regulated competition and dialogue between discussants.

An *organization* can be seen as group of people that have habits of action aimed at cooperation and coordination of work. An organization is not a physical, tangible object like an apple or a computer keyboard. Its observation, its demarcation, and its existence are dependent on the existence of human habits and human-produced signs[3]. This point of view is a kind of methodological individualism (Franssen, 1997; Van den Broek, 2001, p. 25). Basically, an organization can be traced back to representations that structure the interaction among people, thereby demarcating the group of people that are members of the organization (van Heusden & Jorna, 2001). Especially the participants in the organization recognize its existence by their behaviour and their knowledge. According to Simon (1945/1976, p. 16), not only the owners (entrepreneurs) and employees of an organization - groups that are normally seen as its members - belong to its participants, but also its customers, its suppliers, and possibly other stakeholders in the organization.

5.2. Social constructs

A *social construct* (Liu, 2000, p.64; Gazendam, 2003, p. 205) is a relatively persistent socially shared unit of knowledge, reinforced in its existence by its daily use. The semiotical level of description can be seen as a relatively strong system level based on the relative stability of social constructs. Compared to compensation mechanisms, social constructs are not only characteristics of individual actors, but are characteristics of relations between actors or groups of actors. Social constructs are relatively persistent units of knowledge that are shared in groups or social systems and are reinforced in their existence by their daily use. When social constructs are known by a group of actors, the habits that are formed based on this knowledge, help to regulate their behaviour aimed at cooperation and coordination of actions. Cooperation also encompasses nonverbal interaction patterns. They can be studied using the observation of recurrent paths in time and space (Giddens, 1984), or as nonverbal work practices (Clarke, 2001).

In organizations, social constructs take the form of, for instance, shared stories, shared institutions (behaviour rule systems), shared designs, shared plans, and shared artefacts. These social constructs support habits of action aimed at cooperation and coordinated behaviour. Each habit of action consists of a commitment to act in a certain way, and a more or less flexible action program that governs the actual acting. If we look at people in organizations, they do not necessarily require similar representations of the organization they are participating in. However, people participating in organizations need a certain minimum of shared social constructs, and

[3] And, possibly, to a smaller extent, based on the representations embedded in information systems, and signs produced by information systems.

perhaps other shared knowledge, in order to be able to cooperate and coordinate their actions.

At the semiotical level, social constructs emerge based on individual behaviour and mechanisms of reinforcement and selection. At the organizational level, organizational structures can be analysed as being based on social constructs as building blocks. In this way, organizations can be explained as systems of coordinated behaviour of individual human actors, with complex semiotic processes in a key role.

Commitments to act in a certain way and norms can be seen as being attached to social constructs. For instance, there are norms attached to the general social construct of "property" that are inherited by the specific instance of that social construct in the form of the social construct "ownership of my bicycle". An example of these norms is the rule that no one can use my bicycle without first asking my permission to do so.

We have to explain what we mean when we say that a social construct is a unit of socially shared knowledge. Not all knowledge and all norms, attached to a social construct, will be shared by all the people that see themselves as committed to that social construct. What is shared is the knowledge of, and commitment to, the social construct as a "root concept"' with some norms or default behaviour patterns connected. For instance, if I fill out my income tax form, I feel committed to the social construct of paying taxes, I recognize the social construct of authority of the tax service, and I have a very limited knowledge of all laws and regulations concerning taxes. What I need to know about filling out certain fields in my tax form, I can look up in a tax compendium, which is only a short abstract of all tax laws and regulations.

More or less following Dignum's (1996) stratification of social norms, we distinguish three kinds of social constructs. Firstly, we have plans and models as social constructs to the implementation of which individuals or groups can be committed. These social constructs help to determine the actions to be taken. Secondly, there are social constructs that form a relation between two actors, for instance contracts. The actors create obligations and a certain dependency between them. Thirdly, we distinguish behaviour rule systems or institutions that are shared in an organization, community, or social system. An important part of these rule systems is the description of punishments and rewards in case of (in)correct behaviour. In these behaviour rule systems, also responsibility, authority and power relations between actors can be described. Sometimes these behaviour rule systems are established and modified by authoritative rituals, or take an authoritative form as formal laws or regulations.

If we try to see an organization, or a coordination mechanism such as a market, as a network of many small social constructs that people use to regulate their social behaviour, we have to look for some simple, basic social construct types as building blocks for our simulation. For inspiration we have looked at, for instance, Weber's theory of authority (Weber, 1925/1968) and simple forms of cooperation agreements found in the medieval times and the early renaissance (Origo, 1957). Based on these sources, we distinguish five types of social constructs to use in our simulation:

- Principal-agent contract/labour contract (high inequality): Actor A (principal) *offers* a certain amount of hours of work and a certain amount of money, and *gets* profit or loss of the enterprise. Actor B (agent) *offers* a fixed amount of hours of work and *gets* a fixed amount of money.
- Company (Italian com pagno, eat bread together) (low inequality): Actor A *offers* a certain amount of hours of work and a certain amount of money, and *gets* a percentage of the profit or loss of the company. Actor B *offers* a certain amount of hours of work and a certain amount of money, and *gets* a percentage of the profit

or loss of the company (sometimes there is a principal/agent or father/son relationship here with respect to who can decide about what).

- Trade transaction (no inequality): Actor A *offers* goods, or services (e.g., specified hours of work of a certain type), or money, or a mixture of these, and *gets* what B offers. Actor B *offers* goods, or services (e.g., specified hours of work of a certain type), or money, or a mixture of these, and *gets* what A offers (1, 2 and 3 are possible special cases of a more general type of transaction).
- Action plan (no inequality): Actor A and actor B agree to do certain actions at certain points of time.
- Authority (high inequality): Actor A and actor B agree that A has the right to decide about certain subjects that are in their common interest. This is mostly based on rational authority, instead of traditional or charismatic authority (Weber, 1968). Traditional authority means no agreement and charismatic means an agreement, which is more or less tacit. (Possible a part of the social constructs 1, 2, and 4 mentioned above, and perhaps a (recursive) part of an agreement of type 5 itself)

According to the Stamper school of organizational semiotics (Stamper, 2001; Liu, 2000), authority is necessary to start or finish a social construct. So, once authority has been established, it can be used for the specific social construct. The establishment of new authority as part of the establishment of social constructs 1, 2, 4, and 5 has to be distinguished from the existing authority under which the construct is established. Because most social constructs are built up on authority, authority can be used as the main social construct on which norms are attached to regulate authority. However, authority is in the eye of the authoritarian actor as well as in the eye of the perceiving actor. Here the cognitive/actor system comes in. Both have representations and authority only works if both actors share larger parts of the representations.

We already discussed the cognitive architecture of actors, but an architecture of social constructs can also be formulated. According to the Stamper school of organizational semiotics there are main social constructs called social affordances, to which norms are attached. Norms can be specified by if-then rules (Liu, 2000). Furthermore, each social construct starts and finishes with an actor having an adequate authority to do this. Each social construct may presuppose other social constructs, for instance to establish a marriage a law or regulation saying how to establish this and what behaviour rules are attached to marriage has to be present. According to the language action school, there is a more or less standardized process (scenario) for establishing a social construct between two actors. So we arrive at the following architecture of social constructs:

- Main social construct ("social affordance") consisting of:
    - Attached norms;
    - Authority under which it starts;
    - Time of start;
    - Authority under which it finishes;
    - Time of finishing;
    - Prerequisite of other social constructs (from which norms can be inherited, and which defines who has the authority to start and finish);
    - Scenario for establishing the social construct;
    - Authority that is created and allocated as part of the social construct;

5.3. The organizational configuration

Social constructs are necessary for actors to cooperate. At an organizational level of description, we can interpret this as the use of coordination mechanisms and the formation of organizations. After forming a small organization, the organization can grow, and organizational division of work can become more complicated over time. This implies, according to Mintzberg (1979), that the favoured means of coordination are shifting, as shown in figure 4, from a) mutual adjustment to b) direct supervision to c) standardization of c1) work processes, c2) outputs, or c3) skills, and finally reverting back to a) mutual adjustment. These coordination mechanisms are partly based on social constructs. With changes of coordination mechanisms, social constructs also change.

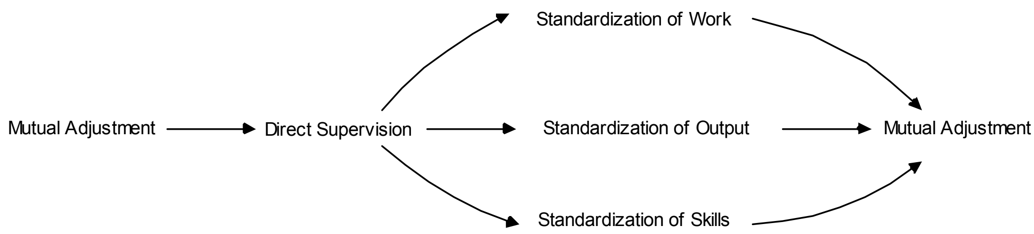

Figure 3: The coordinating mechanisms: A rough continuum of complexity

We can now describe which kinds of social constructs play an important role in types of coordination mechanisms. According to Mintzberg there are 5 coordination mechanisms (see Figure 3):

– *Direct supervision*: Coordination by having one individual take responsibility for the work of others. Direct supervision can be seen as a combination of the social constructs: principal/agent and allocation of authority
– *Standardization of work processes*: The tasks of an actor are highly specified and coordination is carried out by standardization. The social construct applied here is the company and allocation of authority.
– *Standardization of skills*: Standardization of skills indirectly controls and coordinates the work by training the actors. Communication between actors is hardly necessary, because specialists know exactly what to do. The social construct here applied is the action plan. Actor A and B agree to do some action at a certain time. Allocation of authority is possible only if an actor has the final responsibility of the task to be performed.
– *Standardization of outputs*: In this case coordination is specified towards the output of the work, meaning that the actor has a lot of freedom in deciding how to reach the desired output. The social construct of a trade transaction can be applied, combined with allocation of authority.
– *Mutual adjustment*: A simple process of informal communication achieves the coordination of work. Social constructs like action plan and company can be applied with some allocation of authority.

When the social constructs are determined it is possible to figure out the coordination mechanisms and with the coordination mechanisms it is possible to figure out which type of organizational configuration the actors are involved in. With the help of this information and looking back at the conditions of the actors, we can try to explain why certain structures emerge and others not.

6. The design of the simulation model

To study multi-actor systems, two approaches can be taken: a) empirical research in real world situations or b) creating and using a (simulation) model that attempts to reflect the reality of organizations. We choose the second approach, because it gives us opportunities to easily change environments, variables and other characteristics of actors without losing time and energy in investigating real world organizations. However, even the best model has to be based on empirical findings, meaning that simulation research can never replace empirical research. It can be complementary to it and, to formulate it stronger, it can be conducted at its own right. Empirical research has to help in (dis)confirming simulation results. Because of this, we haven chosen a layered simulation environment that enables human actors to play roles in the simulated world, much like playing a computer game. This enables the comparison of human behaviour with simulated actor behaviour.

As we already indicated, in this paper we sketch the constituting conceptual elements of the simulation. Parts of the simulation have already been tried out. Klos (2000) built a first simulation (in Simula) in which he studied the effects of trust, loyalty and profit on the overall performance of two groups of equal buyers and suppliers. In this simulation the organizational level was studied without taking into account cognitively plausible actors. The theoretical background was inspired by the shortcomings of Transaction Cost Economics (TCE). The task environment consisted of a simple trading game. Suppliers produce goods and can sell this to buyers or they can produce goods for themselves. In a number of time steps relations between buyers and suppliers start, continue or break up. In a parallel line Van den Broek (2001) developed a simulation of the cooperation of two actors using a SOAR-architecture. A very important result of his simulation was that actors need representations of others actors in order to co-operate. Helmhout (2001) elaborated upon the simulation of Klos by varying the buyers and suppliers in terms of power and by reprogramming the simulation in Java. Within the simulation environment of Klos and Helmhout, Kraaykamp (2003) started the implementation of cognitive actors by using the ACT-R cognitive architecture as a psychologically plausible implementation of buyers and sellers. He used Smalltalk as programming language. Because we want to be able to systematically vary cognitive variables such as amount of memory chunks and learning speed at the individual system and governance variables such as kinds of social constructs and coordination mechanisms at the organizational system, we had to describe extensively the conceptual parts behind the simulation. We did this in the foregoing sections.

We end this paper by giving a sketch of the simulation environment and its elements. As a task environment we will continue with the trading game. In section 1, we have described the core of the simulation model as a combination of three systems (I) the environment system, (II) the individual actor system, and (III) the organization system. This leads to the following approach in the construction of a multi-actor simulation model of organizations. First, we distinguish an environmental system structured by time, space, objects and resources (System I). Second, we group the physical, functional, and intentional (rational) levels of description of human behaviour to an actor system (System II; in figure 4: ○). Third, we distinguish an organizational system corresponding to the semiotical and organizational levels of description (System III). Sign structures (in figure 4: □) have their place as representations within the mind of individual actors (system II), as signs in the semiotic Umwelt (system I), and as social constructs that are part of an organization (system III). The organizational level of description is seen, for the purposes of the simulation, as dependent upon the semiotical level of description. In figure 4, elements taken from these systems are shown. Space, time, objects, and resources belong to the environmental system. The actors are instances of the actor system. The squares (□) denote social constructs residing as representations within actors, or represented in documents or in communication in s the semiotic Umwelt of the actors. These constructs and the arrows communication between actors belong to the semiotical level of description.

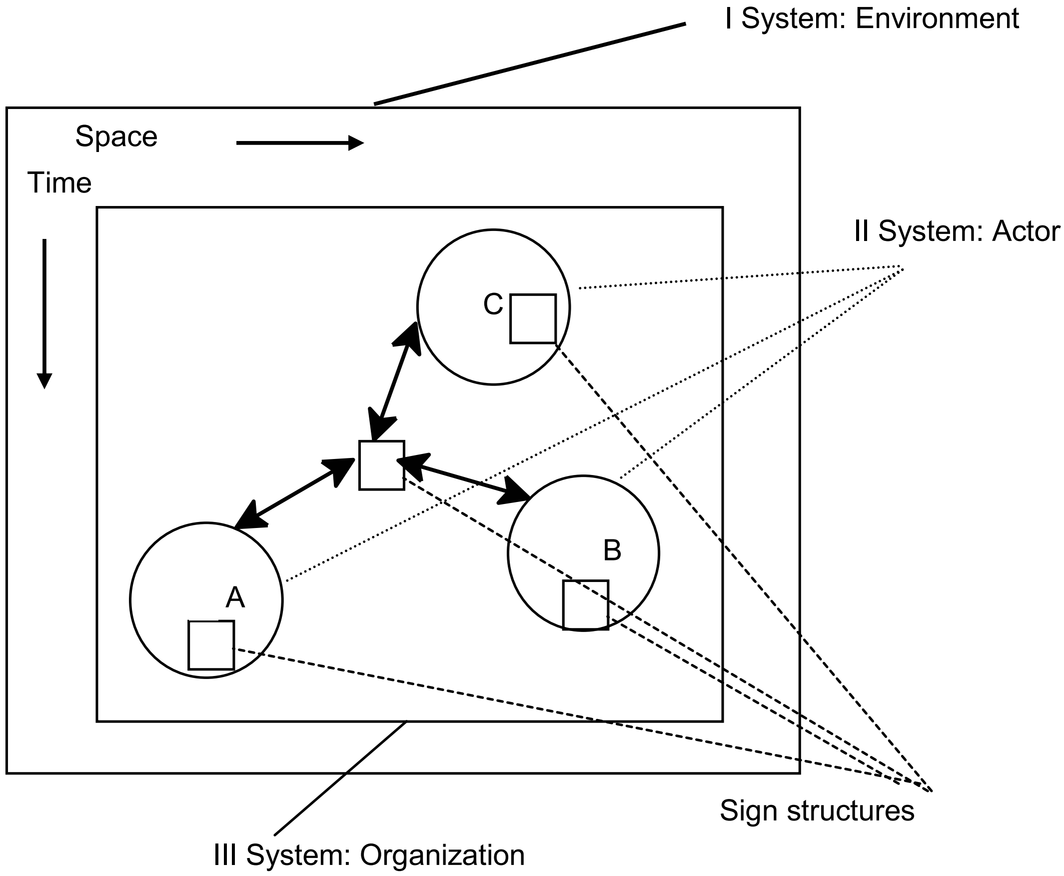

Figure 4. Organizational. Semiotic Environment
(○: actors; □: sign structures;←→: interaction)

System I of the simulation concerns the environment. In order to represent an environment in a computer-based simulation, we have to make simplifications, compatible with cognitive, semiotic and organizational theories. A first step in designing a simulated environment is distinguishing space, and time as dimensions. Objects like resources and signs can be placed in this environment. Actors explore and use their task environment in terms of space, time and signs. Space is bound to the perception of surfaces and objects. Time is bound to the perception of recurrent phenomena. Signs can be perceived based on architectural mechanisms and social conventions. A second step in the design of a simulated task environment is to see affordances as units in which the environment is organized from the point of view of the actor living within the task environment. Behavioural patterns can be based on these affordances, but are not identical to these affordances. Spatial surfaces and objects afford behaviour and count as physical affordances. Events, especially recurrent events, mark the passage of time and afford the formation of time-based concepts and habits. Signs contain knowledge that is shared within a social system, afford behavioural patterns tuned to that social system, and count as social affordances or social constructs. Phenomena that cannot be perceived or interpreted by the actor do not count as affordances or social constructs. A third step in designing a simulated environment is to provide for the possibility that actors discover new elements of space, objects, resources, recurrent events and signs. Resources are objects or substances that are consumed by the actor, but may renew themselves in a limited way. Knowledge can be part of the signs to be discovered, or can be learned from recurrent events that are supported by the environment. Parts of the environment can also be created or changed by the actors (artefact objects, signs, events and consumption of resources). The environment has to maintain the consistency of physical laws.

System II of the simulation concerns the actors. They can be described as based on the cognitive architecture of ACT-R, on an implementation of bounded rationality, and on some fast and frugal heuristics, necessary because of the boundedness of rationality. The ACT-R architecture enables the actor to reason on the basis of goals, procedures and declarations. Because of this cognitive architecture, the actor is able to have norms, which can be applied to form relationships and social constructs with other actors. During the simulation, the actor takes actions based on decisions in procedural memory and by means of perception receives new input in declarative memory. Every rule or chunk is based on activation levels based on experiences in the past. In this way, the actor perceives a problem by creating a new goal and depending on the complexity creates subgoals. The (sub)goal is compared with past experiences and if past experiences delivered success of solving the particular goal, the actor applies the connecting procedures to take action towards its environment. Learning of past experiences and creating new procedures and chunks make it possible for the actor to adjust its behaviour towards other actors and also with respect to the environment. This is accounted for by activation levels of chunks and rules; chunks used more often and more successfully, have a higher activation level than chunks that caused loss or less successful solutions.

Resources, objects and other actors together create a complex environment, which makes it impossible for an actor to process all information in one time-step. An actor interacts with this environment, but due to the complexity, it is difficult to estimate what the preferences of the actor are and how they will develop.

If we assume that the actor itself has social constructs with attached norms, then the actor also undergoes normative behaviour and applies those social constructs in relationships of which it has experience and knowledge. Normative behaviour can be learned from other actors, due to interaction or is implemented in the beginning of the simulation, at the initiation or "birth" of the actor. These norms are, according to Liu (2001), simple if-then "rules" which can easily be stored in procedural memory. Normative behaviour in social groups, for example in clans, is often copied to remain part of the group.

System III of the simulation concerns the organization. In our simulation set-up, we see organizational configurations (at the organizational level of description) as derived from the social constructs level (at the semiotical level of description). Actors use social constructs to from relationships and cooperations. When actor A interacts with actor B to complete a certain task, both actors have to come to a certain agreement under which conditions a relation starts, under which conditions a relation ends and under whose authority this is taking place. Agreements are often reached by conflicts and compromises. For example the employer-employee relationship; the employer wants wages to be as low as possible, while an employee wants the opposite. If both actors come to an agreement, the relation starts. The agreement is a social construct and is often documented in standard labour contracts. However, both the employer and the employee have their own social construct in memory, which can be copies from former experiences with labour contracts. In the simulation we will give the actors the possibility to choose between different kinds of social constructs that can be learned or discovered in the environment. The simulation probably results in emergent behaviour in terms of knowledge build-up by the actors, the heuristics used most frequently, and the configurations of social constructs learned and used. These patterns of emergent behaviour, especially the social construct configurations, can be interpreted at the organizational level of description as coordination mechanisms and organization structures that emerge.

The simulation experiments will use cognitive characteristics, compensation mechanisms (fast and frugal heuristics), available types of social constructs, and types of environmental constraints as independent variables. Dependent variables are the configurations of social constructs formed, their interpretation in terms of coordination mechanisms, and the efficiency of task fulfilment at the individual and group/organization system. Some of the questions the simulation experiments will have to answer are:

I. *How, given a certain cognitive architecture, do actors learn, select and use social constructs in order to cooperate effectively?*
II. *Which configurations of social constructs emerge in a certain environment?*
III. *Do the emergent configurations of social constructs correspond to known organizational configurations?*

Discussion

This article contains a conceptual framework for multi-actor simulation. The idea of building simulation models consisting of actors with a cognitive architecture that cooperate and interact with the help of social constructs is a challenging one. However, the question to what extent the implementation and outcomes of the simulation model are consistent with empirical data still remains open. Empirical evidence, for instance based on the recording of the behaviour of humans participating as an actor in the simulation, can support, or give counterarguments against, the theory implemented in the simulation model. Another point to look at is the complexity of the simulation model. A model with three systems and several levels of description has a lot of parameters that must be tuned. Where possible these tuning factors will be taken from empirical research findings.

Future work focuses on the relationship between the semiotical level of description and the organizational level of description, and will possibly use game theory and sociological network analysis. However, for the shorter and more realistic term, the implementation of, and experimentation with, the model have our attention. The simulation software is now being programmed, and the first experiments will be run in the next year.

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