A Liberal Approach to Openness in Societies of Agents

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Abstract We outline a model for a society of agents based upon one of the classical theories of sociology: The Weber's model. We first investigate its links to agent technology through its relationship with the modeling of micro economy and the concept of expected utility. Then, some of the features of an agent society are enhanced by imposing security and validation requirements. We show that a societal concept from Sociology can be implemented through methods of Computer Science and thus is made feasible.

Key-words: Society of agents, sociology, security, knowledge society, legal validation.

1 Introduction

It is well known that agents interact with their environment. This interaction ranges from a simple link to a more involved reactive process. This implies that the concept of a society of agents is already valid for a system with a few agents. Indeed, formally speaking this interaction defines a concept of society. A possible organization of agents is thus achieved through the concept of a society of agents. This is well-recognized and different models have been proposed along the years ([15]). For instance, social dependence networks were introduced quite early to formalize an environment for agents (see [27]). Social network analysis, established in social science, is the mapping and measuring of relationships and flows between people, groups, organizations, computers or any processing entity. The nodes are the people and groups while the links show relationships or flows between the nodes. The analysis is both a visual and a mathematical analysis of human relationships.

This is however fully different from the classical concepts upon which sociology is based. It is better defined as social awareness. In general, social concepts in agent methodologies are seldom set in the framework of sociology. An example is [22] where social communication is seen as commitments set by agents. We set

* Work partially supported by the Calculemus Research Training Network, HPRN-CT-2000-00102

social communication in the context of sociology. We propose an approach that relies on the very basic ideas of sociology. Our society of agents is governed by rules similar to those enabling to govern a human society. We will quickly see that this implies to view a society of agents as a decision making system, again a well accepted idea. We adopt Weber's approach to sociology ([28] and [29]). This leads to a formulation that has many similarities with the rules and concepts that facilitate the design of mathematical models for the economy ([13]). We ascertain, that the resulting actions of the agents, viewed as a society, are the result of individual actions and not imposed by the society to the individual agents.

What does it mean for a society of agents to be open? A possible answer is to be neutral with respect to the architecture of the system ([1]). Another one is that from the prospect of agent technology, we may have agents without an assigned goal and the goals assigned to agents are, in general, loose. This society is open to new agents either with no definite goal or with goals not exceedingly relevant to the society, which is fully compatible with the sociological decision we made. This openness signifies that the architecture of the system is not driven by goals imposed to the collective of agents, but that general goals arise from the collective actions of agents. Also, the adjunction of new agents must be as easy as required. In other words, the architecture of the society can exhibit some dynamical features rather than being solely static or bounded.

At this stage we may already state that such a society can be said to be liberal. We do not provide a formal definition for the term liberal, we only say that it refers to a society which offers some specific features such as Openness, Security, Usability and Feasibility.

To design a usable, secure and feasible society we may set some basic conditions on top of the sociological requirements.

(i) To identify and eliminate intruders that would, purposely or not, destroy the society without altering the efficiency of action.
(ii) To let the agents achieve their goals and purposes. This is a function based on the number of intruders detected and on counting the number of goals reached.
(iii) Let the agents speak a common language. This must be interpreted as sharing a common semantics, not necessarily a same language. If the society is open, it is probably heterogeneous and shares all available different paradigms for knowledge.
(iv) Conflicts ought to be solved. This is a mostly technical requirement that must follow from the previous point when the architecture of the society is cleverly designed. In the language of agents, this means that the agents are intelligent.
(v) The society is a knowledge society. Translated into more technical terms, this implies, besides the previous two points, that a context for any action is available. When a semantic is not directly available, one may, for instance, rely on ontologies. We can also state that the society has features similar to those a semantic web would possess.

(vi) Let the actions of the agents be legally validated. Any society is governed by laws or at least their individuals must obey the laws. They can be real laws, whether national or international ones or internal laws set by the designer. In both cases, they amount to a cluster of legal ontologies. They must be validated as some form of legal syntax. This means, that besides a semantic meaning and validation, we introduce a legal validation. Examples of such clusters could be given for privacy, property rights, ciphering, authentication or authorization, just to quote a few.

The paper is structured as follows: We first present the sociological theory on which the organization and management of the type of society we propose is based. In the same section we outline how we can formally model such a society. The next sections address issues of security of agent systems, knowledge requirements and legal validation respectively.

2 Sociology and Societies of Agents

2.1 A Societal Organization of Agents

It is well-known that agents interact with their environment. When the number of agents in a system becomes very large, it makes sense to speak of a society of agents. The different relationships that do exist among individuals in a human society can simulate those existing in an agent society. This is probably why a literature search tends to demonstrate that research in this area is centered more on social simulation than on sociology itself ([30], [31], [12], [16] or [10]). We adopt the point of view that we can organize a society of agents as the main sociological entity: the Society. A question then immediately arises: what are the basic theories or models in sociology that can serve as a model to organize a society of agent.

In Sociology, two of the main ideas were set at the beginning of the previous century. There are two main entities in human science, the individuals and the society. Two primary approaches are possible. According to the first one, the society imposes or influences the actions of agents. The main reference for this line of thoughts is the book of Emile Durkheim ([11]) called "Suicide". It shows that even a very personal decision, such as deciding to commit suicide, has in fact its root in the society and not in the individual. The opposite approach of Max Weber ([28] and [29] that is a late translation of the German edition published posthumously in the early 1920s) states, that the behavior of the society is the result of the individual actions of the agents. The first cited reference is usually considered to be the founding stone of this theory. It is probably not necessary to remind that Durkheim is at the origin of collectivism (from socialism to communism) and Weber of what is called today liberalism.

From these early ages and until 1996 new theories have been mainly centered on social awareness. The link to computer science is illustrated by works such as [24]. A possible breakthrough occurs when Manuel Castells published his three books ([7],[8],[9]). Castells' goal is to make sense of the global social dynamics of the transformations at the end of the century. It seems that it is still a topic of discussion among sociologists to decide whether this is the third founding piece of work after Durkheim and Weber ones or a modern adaptation to the information society of classical social awareness approaches.

To base a sociological organization of a society of agents on Castells' model is probably worthwhile but in our approach we adopt Weber's theory. This explains partly the word "liberal" in the title. The approaches of Durkheim and Weber have influenced the social, administrative and political organizations of societies during the last century and still do. We simply forget this facet of the problem and notice two facts. First, the goals of a multiagent system are the results of specific goals of the constituting agents which is closely tied to the design decision adopted when defining the architecture of the system. This seems pretty obvious when the number of agents is limited: they are designed with local goals that ought to ensure that the global goals are reached. When increasing the number of agents we extrapolate this concept. We have thus a conceptual continuity between a system of agents and a society of agents. The second fact is that the approach of Weber is at the basis of the mathematical modeling of economy [13]. We can learn from it to design some decision making mechanisms in agent systems.

2.2 A brief history of mathematical modeling in Economy

We take the brief introduction here-under mostly from [13]. More precisely, this approach is at the heart of micro economy where individual agents take decisions that shape up the macro economy. This leads, by the way, to very challenging, still unsolved mathematical problems [20]. As a first approximation, this implies that we consider a society of agents to be a decision making system. This may look contradictory, but both are facets of the same thing. The actions done by the agents in the society are leading inevitably to discussions and we should be ready to accept such a constraint, as the price to pay to consider agents without a proper goal. At least collectively they will contribute to the community's actions and goals.

To proceed we must investigate whether we have a feasible model of the behavior of the agents. We aim at introducing the model of expected utility. It is widely accepted and used in economy. It was first proposed independently by the two famous economists Walras (founder of a school that is often opposed to Keyne's school of thoughts) and Pareto and finalized mathematically by von Neumann and Morgenstern [25]. It can be sketched as follows. Each agent is described through the following parameters or functions:

- a set of possible actions: $a \in \mathcal{A}$,

- a probabilistic measure on future events, $(x \in X)$, depending on the pending action, $a \in \mathcal{A} :\ d_{\mu_a}(x)$,

- a utility function $U(x) \in \mathbb{R}$,

- this utility function leads to the expected utility $E_a[U]$ defined through the integral

$$E_a[U] = \int U(x) d_{\mu_a}(x)$$

A decision making system then simply amounts to the following optimization problem:

$$\underset{a \in \mathcal{A}}{\text{Maximize}}\, E_a[U]$$

2.3 Utility function in agent systems

A preliminary remark is that the idea of defining a concept of utility for agent systems is not new, it is for instance, mentioned in the book of Wooldridge ([31]), but never as a von Neumann-Morgenstern axiomatization of expected utility. Let us try to specialize the above model to multiagent societies. First, what is the meaning of this expected utility model of von Neumann and Morgenstern? The key idea is that when probabilities are associated to some lotteries, then in this theory, preferences over lotteries logically precede preferences over outcome. In an agent society, this means that the choice of the "next" agent to fulfill a task logically precedes the choice of the possible decision. The simplest model is when there is no uncertainty regarding the future (assignment of a task to an agent for instance). The problem is then simply to select some available decisions

$$x = (x^1, \ldots, x^K) \in \mathbb{R}^K,$$

where x^K is the number of possible actions. The utility function will be $U(x)$ and is associated to the cost (for us the complexity)

$$px = \sum_{k=1}^{K} p_k x^k,$$

where the coefficients p_k are not set by the agent but by the environment (individual complexities). Complexities could be space or time complexities. Assuming that we set w as upper limit of the total complexity, we get in first approximation the decision problem

$$\underset{\substack{x \\ px \leq w \\ \forall k:\ x^k \geq 0}}{\text{Maximize}}\, U(x)$$

At this stage we must raise the question of the correctness of the model and of the existence of utility functions. Economists and mathematicians have investigate thoroughly these questions that have no easy solution. The reason is that this framework is set in function theory. Some references can be found in [20].

In the context of agent societies, we may investigate some other ways of identifying other types of functions. A first approach is fuzzy logic. Decision making systems based upon fuzzy logic have been designed in economy ([21])

or for environmental applications ([26]) and can most probably be investigated in our domain also. Another approach amounts to use social network analysis ([27]). Functions ought to be the outcome of such networks description.

However, there is a more straightforward approach for computer scientists. Instead of formulating the expected utility in terms of functions we can rely on a logic formulation of the actions performed by agents. We get a set of clauses that we resolve through resolution algorithms. This is fully suitable with the tools (see the section on KOMET) we have already designed and is under investigation.

A general comment regarding decision making implied by our approach is as follows. As pointed out by Wooldridge decision making processes can be affected by different properties of the environment around the agent thus leading to different architectures. We assume that decision making processes arise from the actions performed by agents. This is both a simpler and a more generic requirement.

3 Security in an open society

There are two very general and complementary approaches to the problem of security of multiagent systems or societies. First, we may assess that we have a software system as any other and can rely on tools from cryptography or system security. For instance, we can work under the protection of a firewall. This is well acknowledged and the FIPA standardization effort suggests to have such a security level in the architecture of agent systems. References can be found, among many other relevant for multi-agent systems, in the Road map published by the AgentLink network of excellence ([12]). For a very recent survey of provable security we refer to the work of Stern ([23]) that is based on cryptography. We assume that this aspect is covered by experts and that available software products provide satisfactory solutions.

The second approach deals with mobile agents and is required in case of open agent societies. Prototypical computations with systems encompassing a huge number of agents are to collect, filter and process large amounts of information either when available bandwidths or computing resources are limited or when a more suitable technology such as the GRID can be implemented. The broad range of such applications includes for instance mobile computing, information retrieval in large repositories and e-commerce applications. In such applications security means to identify and eliminate intruders and to secure the agents' functionality. Although there are some links to security issues arising in virus protection, the scope of this problem is different. To identify viruses is mainly seen as an overall protection of the system and essentially belongs to the first approach.

Until recently there was no satisfactory solution to the security problems in open multiagent systems without relying on a known trusted party (which means either regular communication with the agent's originator or a trusted third party). Indeed, for stand-alone agents it seems to be hard to provide any security guarantee without controlling them from time to time. This includes protection of data and execution integrity as well as prevention from malicious routing, deletion etc. More promising is the use of agent groups like those presented by Endsuleit and Mie in [14] where a new methodology is investigated that does not requires a trusted party:

By using a group of n collaborating agents which we call an Alliance, it is possible to guarantee the reliability of the community's functionality as long as no more than $t < \frac{n}{3}$ agents have been corrupted at any time. This property is achieved by using Canetti's mathematical model for secure multi-party computation (see [6]). This model has been selected because it is tailored to represent communication networks like the Internet. The main idea is to distribute the computational state and all data redundantly over all Alliance members. All computations are performed jointly on data shares and bear up to t dishonest inputs (this includes missing as well as wrong ones). They follow a suitable protocol ([14] uses the one of Ben-Or, Goldwasser and Wigderson ([2]), but [17] is more efficient with a linear communication complexity in each node) which maintains the $t < \frac{n}{3}$ requirement. Thus, we do not have to demand all hosting servers to be trustworthy. This is another reason to label our approach "liberal".

For the technical description of the approach see [14]. Recently, an analysis about possible attacks on violating the $t < \frac{n}{3}$ requirement has been done in the framework of [14] and showed that this is only possible by Denial-of-Service attacks (DoS). The model is a first step in the direction of achieving security for mobile multiagent systems. In its present state of development, this approach is fully suitable for societies of agents. It ought to be clear that it takes care of the requirements listed under the points i and ii in the introduction.

4 Knowledge requirements

We set our definition of a society of agents in the context of knowledge societies. Indeed, every piece of information is a piece of knowledge. A trivial consequence is that we deal with heterogeneous knowledge which can be structured, semi-structured, unstructured, complete or incomplete. Our answer to this challenge is the KOMET (Karlsruhe Open Mediator Technology) system that we developed for several years ([4]).

The goal is to incorporate multiple knowledge sources into one system, regardless of where the information is located and how the information is stored. Such a system needs to be intelligent in the sense, that it is able to choose and access appropriate knowledge sources for answering an agent's request. It is supposed to completely hide the process of query processing, network access, data conversion and data processing which might be necessary to answer a user's question.

Sources can not only be traditional databases with different data models, but any information source such as web pages, software systems or spreadsheet calculators – using a common data model. Even humans can be considered as information source in the mediator context. A mediator *contains integration knowledge*

(i) to compile new information which can only be obtained by combining information from different sources (horizontal value-addition)
(ii) to solve conflicts and contradictions between the sources using domain-dependent rules (vertical value-addition)

In the context of societies of agents we assume that we must deal with any available kind of knowledge society. In the context of agent technology information retrieval and processing, mediator systems are nowadays labeled intelligent agents. KOMET looks suitable to process knowledge engineering in a wide variety of forms. This is due to its main design ideas that, without going into technical details (see [4] for a general description, [19] for an in-depth presentation or [18] for some recent theoretical issues) are as follows.

(i) The KOMET language is a declarative language which implements a many-sorted annotated logic with a high degree of flexibility. This is known as the generalized annotated programming (GAP). It provides a set of basic data types and truth value sets which can be extended. The KOMET language extends GAP and defines the common data model.
(ii) The heart of the system is an efficient engine for annotated logic programs using SLG-resolution for evaluating the well-founded semantic, enhanced with constraints for integrating external knowledge sources. Therefore a KOMET mediator can be used like a deductive database.

In order to give uniform, integrated access to heterogeneous information sources, schema integration and conflict resolution needs to be done. Those conflicts, that can be solved, are the classical ones found in database or knowledge technology. Specifically KOMET allows to solve Knowledge Inconsistencies, Semantic Similarities, Domain Incompatibilities, Data Representation Conflicts, Default Value Conflicts, Schema Conflicts or Missing Data Item Conflicts among other problems.

Here once again the handling of heterogeneous knowledge sources is a prerequisite when defining a liberal and open society of agents. Although GAP enables efficient programming, it is true that the methodology is not always the most efficient for some applications. This is always possible when implementing resolution algorithms. However, the main results concerns the feasibility of the method and the solution of conflicts.

Another benefit of KOMET is to address the problem of the validation of queries/actions. In [5] we show how we can design and implement the syntactical validation of queries in a mediator system. We do not rely on a protocol of communication as it is often the case in multiagent systems. Instead, we plan to extend the syntactic validation to include a semantic validation to ensure consistency among the agents. This is more challenging since when dealing with heterogeneous knowledge bases a common semantic is only possible after the wrappers have transformed the source schema into the mediator one. In KOMET the latter one is soundly defined but there is no method to check that the source is semantically sound. A method under investigation is to define a context for such an external source when ontologies are available. The structure that must be part of any ontology leads indeed to a notion of context. Then, from the context, one may define some sort of semantic.

5 Legal validation of societies of agents

One of the basic features of any society is the existence of laws governing its behavior at the individual as well as at the societal level. In addition to laws there are a number of rules that set a code of conduct for any agent belonging to the society. In a first approximation we may say, that a society must be law obedient when it is open. The extent of such a statement can be discussed but it must exist. This applies also to societies of agents.

Such a society ought to be labeled a knowledge society since each agent is going to represent or simulate some sort of knowledge. We are very familiar in artificial intelligence with such concepts. A knowledge society relies on representing knowledge through several paradigms. This knowledge can be validated somewhat easily through the syntax of the representations. It is already much more difficult to validate it through the semantics. This is for instance the case of most of the projects that are labeled "semantic web". We claim that legal knowledge is a new sort of knowledge paradigm and thus must be investigated. There are at least two levels at which to assess laws. The first level is the usual one; we are governed by national and international laws that can be similar or different. Any software system must face such laws. Problems to be addressed are for instance those dealing with privacy, property rights or patents. For instance, protocols for a multiagent system in mobile communication are patterned but if we wish to enforce some sort of privacy or install silencing devices, we must modify the communication protocols and check the implications arising from property rights. If we send ciphered messages through the Internet, we must investigate whether this is legally allowed and/or authorized throughout the network or in restricted sections only.

The second level is internal. It deals with the internal rules set by the system designer. They can be explicit or implicit but always do exist. This is in fact the level with which we are familiar and we refer to when speaking of system security. This level may simply reflect the technology in use at a given time. It is well known that, besides semantic webs, our knowledge society will rely on the GRID technology to process large amount of data circulating at high speed. Such a technology is producing its own standards that amounts to laws to obey. For instance, we are all too familiar with standards in mobile communication when they are regulated through patents. We claim that besides the usual validation techniques that we master when designing software systems, we must introduce a new level of validation: the legal validation of societies of agents. At present, lawyers do use computer science technology to design tools aiming at making their trade easier. Conversely computer science uses, often reluctantly, law as a tool to provide a legal security net to many of its activities. None of these approaches look able to perform a continuous legal validation of a knowledge society. This is a pioneering domain at present although many projects are investigating related topics such as property rights or privacy to quote only two of them. A collaborative effort to investigate the main research directions in this new field is under construction.

6 Conclusion

We have presented a schema to define what a liberal, open society of agents could be. The model we propose is the result of works either performed or on-going. Their collection into a global framework delivers a concept for a society of agents. It is only a model among very many possible ones and is a challenge that will be met in future research. For now, we only claim that we can offer some kind of consistency in establishing this model. More precisely, KOMET enables to tackle a large scope of knowledge problems and is under development for several years. Innovative results on the security of mobile agents have already been obtained and this topic is still under investigation. They fit well with the societal approach we propose. If the main and only credits must be given to Weber and von Neumann-Morgenstern respectively, to use such methods in the framework of agent systems looks to be new. The relevant section concludes by giving some directions for research that are in fact well advanced. The first one relies on the classical approach within function theory. In [3] relevant functions are distance functions coming from basic principles. The second approach is basically a usual resolution problem as learned by any CS student. It looks like that once again a problem expressed through logics has a much simpler complexity than when expressed through functions.

It is amusing to remark that the model of Weber is nowadays present in what can be called common sense reasoning. Some authors (see for instance [13]) have noticed indeed, that this way of thinking about the organization of societies has been adopted, without even noticing that anything must be proven "by politicians introducing their agenda or religious leaders preaching for their faith". It is also questionable to know whether these persons were at all aware of the common origin of their agendas.

A concluding remark is that we start from a model for a societal organization. But, we may also think of starting from architectures for societies of agents to validate models in Sociology. It looks like there is no such example in the literature.

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