Agreement Technologies and Multi-agent Environments*

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Abstract. Agreements as crucial social concepts are present in all human interactions and without them there is no cooperation in social systems. As a consequence of rapid development of different disciplines, agreement and processes for reaching agreements between different kinds of agents, getting a subject of perspective research activities. Agreement Technologies refer as well to computer systems in which autonomous software agents negotiate with one another, in order to come to mutually acceptable agreements.

The goals of this paper are to present the essential issues in Agreement Technologies and highlight its influence on multi-agent environments.

1 Introduction

One of the most important social skills human beings possess is perhaps their ability to explicitly *reach agreements* with each other. A world without agreement would be incredible. Human social skills represent an intriguing challenge for researchers in artificial intelligence: can they build *computers* that are capable of exhibiting these skills? Can they develop software systems that can *reach agreements* with each other on behalf humans? These questions present deep research challenges and has led to the emergence of a new research field, *Agreement Technologies* [27]. Agreement Technologies (AT) refer to computer systems in which autonomous software agents negotiate with one another, typically on behalf of humans, in order to come to mutually acceptable agreements.

In meanwhile a lot of high-quality research activities and initiatives emerged and significant scientific results are achieved in this area. One among most important initiatives in the area of Agreement Technologies is surely realization of big COST Action IC0801 on Agreement Technologies [20].

The rest of the paper is organized as follows. In Section 2, basic concepts of Agreement Technologies are briefly presented. Section 3 brings wider view on these concepts and their role in multi-agent environments. Last section concludes the paper.

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2 Agreement Technologies

Nowadays in different working environments people are supported by specific software components - *agents* to stress their capability of representing human interests. Such systems are built, enacted, and managed away from rigid and centralized client-server architectures, towards more flexible and decentralized means of interaction. In next-generation open distributed systems interactions between *computational agents* are based on the concept of *agreement* where two key elements are needed: a normative context that defines rules; an interaction mechanism by means of which agreements are first established, and then enacted [21]. AT paradigm is characterized by: autonomy, interaction, mobility and openness, and supported by technologies: semantic alignment, negotiation, argumentation, virtual organizations, and learning.

2.1 A Computing Perspective of Agreement Technologies

Nowadays, agreement and all the processes and mechanisms involved in reaching agreements between different kinds of agents, are also a subject of intensive research.

Software agents as specific software components are able to solve complex tasks, interact in sophisticated ways, and posses higher levels of intelligence. Services, agents, peers, or nodes in distributed software systems usually imply different degrees of openness and autonomy. Interactions between them can be abstracted to the establishment of *agreements for execution*, and *execution of agreements*.

Traditional software components remain *unchanged* at execution-time. But when software systems become open, adaptive and autonomic software components need to interact with others and adjust to changes that appear in the environment. Accordingly agreements have to be changed *dynamically* at run-time. In a long term interoperation agreements can evolve by further interaction between the computational entities. So agreements could be seen as basic run-time structures that determine if a certain interaction is correct [21]. It introduces new term “interaction-awareness” where software components explicitly represent and reason about agreements and their associated processes. There are several key dimensions where new solutions for the establishment of agreements need to be developed [2]: *Semantic Technologies*, *Norms*, *Organizations*, *Argumentation* and *Negotiation*, and *Trust*.

2.2 Agreements between Software Agents

Crucial elements of open distributed systems are *software agents* characterized by: **autonomy**, **social ability**, **reactivity**, **proactiveness**. Interactions between a software agent and with its environment must be supported by a quite complex program which includes sophisticated activities: reasoning, learning, or planning. So software agents in next-generation open distributed systems must be inevitably based on agreements including a normative model and an interaction model [21].

Agreement Technologies are getting unavoidable in contemporary systems and characteristic areas of applications are *E-Commerce*, *Transportation Management* and *E-Governance*. Researchers in the area forecast that AT will play essential role in future *smart energy grids* [23].

3 Key Dimensions of Agreement Technologies

There are several key dimensions that characterize AT: Semantic Technologies, Norms, Organizations and Institutions, Argumentation and Negotiation, and Trust.

3.1 Semantics in Agreement Technologies

Over the last several years Web has got rather matured and consists of several standards endorsed by the World Wide Web consortium: XML, RDF, Ontologies and OWL, RIF, XQuery, SPARQL. In AT these standards include new elements:

1. *Policies, Norms and the Semantic Web "Trust Layer"* - Rules and constraints that model intended behaviors represent in fact policies. Necessary standards are protocols to exchange policies and also rules languages that support describing and exchanging policies (as RIF - Rule Interchange Format and XACML - eXtensible Access Control Markup Language).

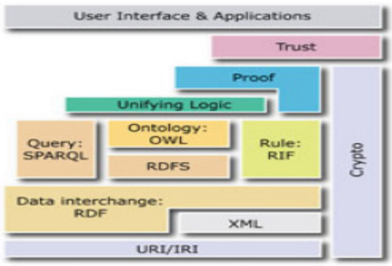

Fig. 1. Semantic web layers (2009)

Agreed policies in a community represent norms but they also can be something individual (as mail filtering policies). Formalization of (private and organizational) policies and (community) norms is important for different applications.

2. *Evolution of Norms and Organizational Changes* – Usually the evolution of norms and policies and organizational change are connected to merging and aligning existing policies and norms. Description Logics based ontology languages are not sufficient to express semantic models and policies and it is necessary to use other formalisms.

3. *Semantic Web Languages versus Norm-Based or Organization-Based Programming Languages* – "trust layer" of the Semantic Web is still in immature stage. Different protocols and languages (as P3P, XACML) are developing and it is necessary to resolve how to embed rule based and formal descriptions of and norms.

4. *Implicit Versus Explicit Norms on the Semantic Web* - Best practices and norms on the Web are not (yet) made explicit.

Logical formalisms for AT - Semantic Web standards serve for representing the knowledge of local agents, in order to achieve a goal in agreement with other agents. In distributed, open and heterogeneous systems that use AT, formalisms of Semantic Web safer of limitations. Autonomous agents define their knowledge according to their own beliefs. Semantic Web standards do not provide the means to compartment knowledge from distinct sources, so conclusions reached when using the global knowledge of disagreeing agents could be inconsistent.

Recently a number of logical formalisms in order to handle the situations appeared. They usually extend classical or Semantic Web logics [30] and the common name for them is *contextual logics* or *distributed logics* or *modular ontology languages* [13].

3.2 Norms in Agreement Technologies

Norms recently have been an issue of growing interest in agent environments and systems. They started to be important mechanisms to regulate electronic institutions and electronic commerce and also to deal with coordination and security. Study of norms, as interdisciplinary approach, includes different views and caused an innovative understanding of norms and their dynamics. Deontic logic is highly connected to norms. It is the field of logic that is concerned with obligation, permission, and related concepts. On the other hand, it is a formal system that attempts to capture the essential logical features of these concepts. Several key research questions and dilemmas connected to deontic logic are: Norm Without Truth, Reasoning About Norm Violation, Normative Conflicts, Revision of a Set of Norms, Time and Action Issues, Norm Emergence and Games, Permissive, Knowledge and Intentions.

In [5] authors proposed 'BOID' architecture that incorporates interaction between beliefs, obligations, intentions and desires in the formation of agent goals. Essential issues discussed here is that the interaction between 'internal' and 'external' motivations (deriving from norms of the agent's social context) points out several types of agents (benevolent and egocentric agent).

Constitutive Norms - In legal and social theory there are different types of norms: regulative norms describing obligations, prohibitions and permissions; constitutive norms that support 'institutional' actions - making of contracts, the issuing of fines. Constitutive norms are extremely important mechanism [4] to normative reasoning in dynamic and uncertain environments. Characteristic example is realization of agent communication in electronic contracting.

Early works of application of norms and cooperation in software systems were concentrated on simulation [3]. In meanwhile study of social phenomena had become prominent and interconnection between the social sciences and artificial intelligence born new discipline devoted to multi-agent systems. Also research in normative multi-agent systems is boosting and there is main assumption that norms are specified by the institution and all the agents in the society know about these norms ahead of time [1]. Alternatively, researchers interested in the emergence of norms do not assume that agents know the norms in advance.

Recent works on model agents interactions based on cooperation or coordination [26] studying how norms emerge. Agents are supposed to perform few actions (e.g. cooperate and defect) and research is concentrated on studying mechanisms that facilitate small number of actions that an agent is capable of performing. An interesting approach is presented in [25] where authors propose a data-mining for the identification of norms. Quantity of domain knowledge and prior knowledge about norms an agent possesses may play significant role in norm identification.

Another limitation of current simulation-based works on norms is the lack of consideration of all three aspects of active learning on the part of an agent: learning based on doing, observing and communicating. Most studies that investigate norm emergence using simulations employing simple games have only used learning based on doing. But it is expectable that in future research authors will integrate these three types of learning in different applicable domains. Also an interesting approach recently appeared in multi-agent systems is to provide agents with the ability to identify the presence of norms through sanctions and rewards. A promising research area for the study of norms could be inclusion of humans so in different simulations agents can learn from human agents and software agents can recommend norms to humans.

3.3 Organizations and Institutions in Agreement Technologies

Open multi-agent systems and Agreement Technologies are promising technologies for organizations and institutions. Complex task or problem in organizations can be solved by appropriate declarative specifications to a number of agents, agents can work together as teams in order to solve delegated task in reaching the goals of the organization. Besides, the notion of institution has been used within the agent community to model and implement a variety of socio-technical systems. During the interaction among autonomous agents norm compliance could be ensured. Organizational perspective proposes that the joint activity inside Multi-Agent Systems regulated by a consistent body of formally specified norms, plans, mechanisms and/or structures will achieve appropriate tasks. An organizational model consists of a conceptual framework (Organization Modeling Language) in which organizational specification can be enacted on a traditional multi-agent platform or by using some organization management infrastructure (OMI) [10], [16].

Agents have to know how to access the services of the infrastructure and to make requests according to the available organizational specification. Such agents possesses

Organization Awareness skills making them able to contemplate the organization and decide whether or not to enter such a structure, to change it by setting in place a reorganization process and whether or not to comply with the different rights and duties promoted by the organization. Multi-Agent organizations exhibit basic traits that may be part of the organizational models: system structure i.e. elements that form the system and the relationships interconnecting these elements; static/kinetic perspectives: time independent/dependent description of the system.

In modern complex sociotechnical systems it is not possible to possess and keep updated all the information about the environment. Agent-oriented modeling [28] presents a holistic approach for analyzing and designing organizations consisting of humans and technical components (agents). They are active entities that can act in the environment, perceive events, and reason [28] in *sociotechnical organizations* consisting of human and software agents.

Recently several different organizational models have been developed. A lot of interesting examples of organizational model appear recently: Moise (Model of Organization for multI-agent SystEms) [15], AGR [11], TAEMS [19], ISLANDER [10], OperA [8], AGRE [11], MOISEInst [12], ODML [14], TEAM [29], AUML [22], MAS-ML [7]. For these models different modeling dimensions are presented in Table 1.

Table 1. Organization modeling dimension in some organizational models

Model	Structure	Interaction	Function	Norms	Environment	Evolution	Evaluation	Ontology
AGR	+	+	−	−	−	−	−	−
TAEMS	−	−	+	−	+	−	+	−
ISLANDER	+	+	−	+	−	−	−	+
OperA	+	+	+	+	−	−	−	+
AGRE	+	+	−	−	+	−	−	−
MOISEInst	+	−	+	+	−	+	−	−
ODML	+	−	−	−	−	−	+	−
STEAM	+	−	+	−	−	−	−	−
AUML	+	+	+	−	+	−	−	−
MAS-ML	+	+	+	+	+	−	−	−
Moise	+	−	+	+	−	+	−	−
VOM	+	+	+	+	+	−	−	+
Agent-oriented	+	+	+	+−	+	−	−	−
AAOL	+	+−	+−	+	+	+	+−	−

These and some additional dimensions (Organizational Environment, Organizational Evolution, Organizational Evaluation, and Organizational Ontologies) are widely present in existing organizational models.

3.4 Augmentation and Negotiation in Agreement Technologies

As other AT concepts, argumentation is also initially studied in philosophy and law. The theory of argumentation is interdisciplinary research area (include philosophy, communication studies, linguistics, psychology and artificial intelligence). In last decade argumentation has been researched extensively in computing especially for inference, decision making and decision support, dialogue, and negotiation. Generally speaking argumentation focuses on interactions where different parties plead for and against some conclusion. They are unavoidable in situations when incomplete, possibly inconsistent information exists and for the resolution of conflicts and differences of opinion amongst different parties. Agreement also benefits from negotiation, especially when autonomous agents have conflicting interests/desires.

The nature of argumentation is predominantly modular and most formal theories of argumentation adopt that: (1) arguments are constructed in some underlying logic; (2) interactions between arguments are defined; (3) given the network of interacting arguments, the winning arguments are evaluated.

Recent work in computer science community has illustrated the potential for implementations of logical models of argumentation, and the wide range of their application in different software systems.

Furthermore any non-trivial process resulting in an agreement presupposes some kind of conflict and the need to resolve the conflict. Such conflicts may arise between different parties/agents involved in wide range of negotiating situations. In these dialogues, the reasons or arguments for offers, stated beliefs, or proposed actions can be usefully used to further the goal of the dialogue. Nowadays the key area of research is online negotiations involving automated software agents. In e-commerce systems in a handshaking protocol, a seller would simply successively make offers and have these either rejected or accepted. The exchange of arguments provides for agreements that would not be reached in simple handshaking protocols. Having it facts in mind it is clear that argumentation may be of significant value in AT.

Interesting is concept of Argument Web. The plethora of argument visualization and mapping tools [18] testifies to the enabling function of argumentation-based models for human clarification and understanding, and for promoting rational reasoning and debate. The development of such tools is a consequence of existence of pile of discussion forums on the web, and the lack of support for checking the relevance and rationality of online discussion and debate. Such tools offer possibility of reuse of *readymade* arguments authored online.

3.5 Trust and Reputation in Agreement Technologies

Computational trust and reputation mechanisms at the moment have reached certain level of maturity. Appearance of the multi-agent systems paradigm initiated an evolution in the kind of topics explored by researchers in this area. Trust and reputation models can not be treated as black boxes isolated from any other process performed by the agent. Computational trust and reputation have to be considered together with the other elements of the agents' environments.

Trust is a social construct present in everyday life. Always a person needs to interact with another person or group a certain kind of decision about trust has to be made.

As trust has vital role in society, it is interesting research areas that include apart from sociology, philosophy, economics, management, and political science also computer science community, particularly researchers from multi-agent systems [20]. Equipping intelligent agents with ability to estimate the trustworthiness of interacting partners is crucial in improving their social interactions [24]. This means that agents use *computational trust models* to assist their trust-based decisions. Trust theory offers a diversity of notions and concepts that reveals a “degree of confusion and ambiguity that plagues current definitions of trust” [6]. This makes easier a job of computer scientists when they attempt to formalize models of computational trust in decision making processes of artificial entities. Trust could be considered twofold, first as a decision and not an act, and second as a multi-layer concept that includes disposition and decision [6]. Also it is not necessarily mutual or reciprocal. [9] introduces *situational trust* by defining trust as a measurable belief that the truster has on the competence of the trustee in behaving in a dependably way, in a given period of time, within a given context and relative to a specific task.

So to construct robust computational trust models, it is necessary to understand how trust forms and evolves. This will allow intelligent agents to promote their own trust-worthiness, and to allow them to correctly predict others’ trustworthiness even in case of new partnerships.

Reputation is again a social concept as complex as trust. Interrelation between trust and reputation is rather ambiguous: reputation is an antecedent of trust, and it may or may not influence the trust; the process of reputation building is subject to specific social influences.

So it is possible to see trust and reputation as isolated constructs therefore reputation does not influence trust.

Recently in the distributed artificial intelligence several computational trust models have been proposed with intention to allow intelligent agents to make trust-based decisions. Most of them have focused on the aggregation of past evidence about the agent under evaluation in order to estimate its trustworthiness.

Although *computational reputation* is a field that has its own set of research questions different researchers have proposed models of computational trust and reputation that integrate both social concepts, assuming the perspective of reputation as an antecedent of trust [17], [24].

4 Conclusions

The paper brings some key concepts, dilemmas and aspects of usage of Agreement Technologies in open distributed environments predominantly based on multi-agent systems. These define environments that are based on norms, argumentations and trust within which agents interact. Agreement Technologies are obviously contemporary, interesting and promising research area. Its multidisciplinary and interdisciplinary character offer great future possibilities for applications in more intelligent and sophisticated artificial societies.

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