Institutional Social Networks for Ambient Intelligence

Guido Boella[1] and **Leendert van der Torre**[2] and **Serena Villata**[3]

Abstract. Ambient Intelligence creates scenarios in which the reality is modified by devices that augment the possibilities of social interaction. In this paper we propose an approach based on institutions to model the virtual reality created by an application of Ambient Intelligence. Starting with our previous results that give a model of institution in terms of the relations of power and dependence, defined by means of a description of goals and skills of a single agent, our aim is to show with this framework, thanks to the help of an example, how to model the social structures developed in a system of Ambient Intelligence thanks to the notion of institution.

1 INTRODUCTION

The social network theory is emerged as a key issue in modern sociology, communication and information science. This theory has been used to connote complex sets of relationships between members of social systems, from an interpersonal point of view to an international one.

Ambient Intelligence [14] is a vision that enables intelligent environments by means of pervasive technology. This vision puts human users at the center of the discussion, but technological devices and humans are seen as equal inside the environment, collaborating, to improve both human being and machine performance. Ambient Intelligence offers many benefits. For example, by instrumenting public and private spaces to understand their users activities and requirements, embedded intelligent systems can react by guiding an elderly person, helping students to improve their learning and others relevant contributions. Artificial intelligence is the key technology for enabling and catalyzing this vision. In particular, AI theories, like the Multiagent one [17], will make it possible to model complex realities that represent new levels of interaction among groups of humans that are created by the use of technological devices.

A social network is a social structure composed by nodes and arcs where nodes usually represent individuals or organizations while arcs represent dependencies among nodes. Arcs can represent various types of dependencies like financial exchange, conflict, trust or friendship. Our framework, using the methodology of dependence networks, presents a kind of social networks called institutional social networks with the aim to describe an environment of Ambient Intelligence and its inner features with the application of the concept of institution. An institutional social network is a social network that represents set of individuals regulated by norms and in which it is present the application of social roles to each individual involved. We model Ambient Intelligence applications as institutional social networks using the multiagent model, because it seems to be a descriptive framework able to represent all facets that are present in an environment of Ambient Intelligence. We use our previous results of [7] as framework and we apply it to an environment of Ambient Intelligence with the aim to give a compact and understandable model. This breaks down in the following questions:

- How to define an approach based on the multiagent model and using social networks to describe an environment of Ambient Intelligence?
- How and why to model the use of a technological device in Ambient Intelligence as a new level of reality?

A Multiagent system can be viewed as an environment populated by agents. These agents interact with each others creating a complex net of dynamics inside the system. The study of these dynamics and, as a consequence, of the social structures [2] (such as groups and collectives) is an important aim in the field of Multiagent Systems. In a single agent framework, to achieve a given goal an agent has to be able to do it. On the contrary in Multiagent frameworks, especially those in which agents are heterogeneous and have different abilities, it is possible that, when an agent is not self-sufficient with respect to some goal, he can resort to some other agent, given that the latter cannot be self-sufficient itself in every respect. Hence, agents benefit from the interaction with the other agents and cooperate with them to achieve the goals of the other agents of the system. This makes clear the existence of relations as power and dependence that are the base of the social and organizational structure of a system.

In a scenario of Ambient Intelligence, we can see humans as the agents of a Multiagent system or associated with agents assisting them that have to interact with each other. The reality that describes the internal state of the agent, in terms of its goals and beliefs can be defined the private realty of the agent. This kind of reality can be viewed not only as private beliefs and goals of the agent but, from a multiagent point of view, also as the relationships among agents of the system that describe the power to achieve goals and can be visualized thanks to dependence networks. The use of a technological device, such as a pocket pc, establishes a new level of reality in the relationships between involved people. This reality is created thanks to only the use of the technological device and can be defined as the public or institutional reality. This new kind of reality can be considered as the public version of the private one because it contains public beliefs and goals of the agent. Moreover, the relationships among agents change thanks to the addition of the institutional reality and institutional social networks have to represent also the institutional powers to achieve goals.

For example, if students use a pocket pc during a lesson at the same time the teacher can limit the number of messages that they can send to their school friends not nearby. In this case, we have on one hand the private reality of the relationships among people (a student can

[1] Department of Computer Science, University of Turin, Italy, email: guido@di.unito.it
[2] Computer Science and Communications, University of Luxemburg, Luxemburg, email: leon.vandertorre@uni.lu
[3] Department of Computer Science, University of Turin, Italy, email: villata@di.unito.it

speak with his school friends, also if the teacher won't) and, on the other hand, the institutional reality of the relationships developed thanks to the device that improves a new type of communication (the teacher can block the possibility to send messages among students). The example shows the two types of reality that have been created by the use of the technological device. It is important to note that also the roles of the people involved in the system are relevant to establish the relation among people in both realities. From a methodological point of view, inspired by Sichman and Conte [15], we use the notion of agent dependence to create dependence graphs extended in [3], in order to highlight the topology and the symmetries of dependencies. Giving the agents the ability to reason about their social relations it enables us to model the institutional reality, moreover it makes it possible to proceed from a hierarchical view of institutional design to a more dynamic approach, where the agents are able to define their own powers, obligations and permissions on the actions performed by the other agents. We use a scenario for Ambient Intelligence to illustrate the different facets and cases in which the two levels of reality are more evident.

In this paper we don't treat the management of the system of pocket pc from a point of view of the implementation of software agents and of the architecture of the system [12] and the development of systems to support human organizations [10].

The layout of this paper is as follows. In Section 2 we introduce our running example of Ambient Intelligence for teaching a lesson with the supply of pocket pc for the students and the teacher. In Section 3 we formalize the concepts of power and social dependence networks. In Section 4 we apply the dependence framework to role-based institutions to model the scenario for Ambient Intelligence. Related work and conclusions end the paper.

2 THE ENHANCED CLASSROOM SCENARIO

The scenario we will describe is based on the use of technological devices during a lesson in a classroom. Our aim is to create a situation in which the participants (in this case, students) augments their possibilities of interaction thanks to the presence of the technological interface. Each student and the teacher have been provided with a pocket pc that augment the possibilities of communication among the students and also between the students and the teacher. We will follow the development of a lesson to underline the discordance from a common lesson. First, the teacher arrives in the classroom. At this point it is important to note that the privileges associated to the two types of pocket pc are different. In fact, the pocket pc of the teacher is provided by a software that lets him to see the flow of messages that the students send to each other (also with a graphic visualization) and he has also the possibility to stop selectively this type of messages if the students don't pay attention to the lesson. The reasons of this attention to the messages lies in the great importance that the possibility to communicate has for new generations. This is a fundamental component of their lives and the technological devices add new possibilities. In that way, the teacher can detect groups that take a form inside the class. From the point of view of emotional intelligence this is a relevant information. The number of groups can be changeable compared with the total number of students of a class. Moreover, these groups have not to be disjoint each other and some students can belong to more than one group. From the point of view of the social relationships, these groups represent ("happy islands" where these relationships are very intense because the members are strictly related to each others (thing that is documented by the flow of messages) by connections that can represent requests, acceptance of favors and meetings. In this context, we can also put in evidence the negative connotation of groups because they seem to be also close entities where it is difficult to enter for, for example, a new student arrived from another school. In this way the teacher can remedy if he notes that someone remains secluded from the other students trying more to involve him in the activity of the class.

Another point of view that has to be considered is the one of the presence of groups created virtually by the teacher with the aim to put together students with the same level of preparation in the subject without moving physically. First, this subdivision has not to be seen as a sort of discrimination because the reasons underlying a worse performance can be multifaceted, like the origin from another school, a different mother language and many others. The subdivision has the aim to help the teacher to do in parallel different kinds of lesson. For example, if the teacher is explaining a new topic, like the post-impressionist movement, he can send a preliminary material on the artists of this movement like Gauguin and Seurat, to the students that are on a base level and another material, consisting in quotations from the critic Rewald about this movement, to the students of high level. In this way, explaining the same topic, the teacher has given to the different students the kind of material more appropriate to them, allowing so a better preparation to all. The same point of view can be applied to the questions that the teacher poses to the students; as a matter of fact, he can pose questions with different level to the different groups to help the learning of everyone. The teacher can also individuate a representative for each group and he can send the material and the questions only to him. The representative is the only member of the group that has to send the answer of the group to the teacher and eventually the questions of the group to the teacher on the lesson. The students with a low level in the subject feel themselves in an ambient that, staring from their level, encourage themselves to do better, without the bad situation in which they don't understand anything because the lesson is too hard and advanced for them. The students of high level have so the possibility to increase their knowledge without hearing a lesson of a lower level that becomes boring. The analysis of the flow of messages is possible evidently only with the adoption of these devices and in a common lesson it is not possible to do that. Moreover, the subdivision of the material or, in particular, of the questions is more difficult, in particular the point of the questions. Another thing that has to be considered is that the teacher doesn't make public the groups that are created, so the students cannot be mocked by the others if they are in the group of lowest level. In a common lesson it is not possible or, better, do this distinction, taking care also of these problems is very difficult. For example, The messages can underlines two spontaneous groups of students. The first one composed by students S4, S5, S7 and S10 and the second one is composed by students S1, S2, S3, S4, S6, S8, S9. As can be seen, student S4 can belong to both the groups and so the groups are overlapping. Moreover, there can be other two different groups that represent two groups created by the teacher to divide the students of different level of preparation on the matter. The low level group is composed by students S2, S6, S7, S10 while the high level group is composed by students S1, S3, S4, S5, S8, S9. The teacher so poses two different questions to the two groups. An advantage of this type of learning is the possibility, connecting the pocket pc, to take part to the lesson as well if the student is ill or not in the classroom. This can help those students that have to stay at home (or also at the hospital) for long periods, but maintaining the physical possibility to follow a lesson. In this way, the student doesn't feel himself out of the class and gets behind also respect with the program of the subjects. This type of integration increases the sensation to be in

a ambient that helps them moreover all these things are not possible without the technological devices. Going on with the lesson, the teacher can start a new topic. The previous topic was the impressionist movement. Before starting with the new matter, the teacher would like to understand if the previous one is clear so he puts some questions to the students. The questions are posed using the pocket pc and they appear on all the pocket pc of the students. For example, the teacher can ask "What is the painting that represents the beginning of the impressionist movement?". The students who knows (or thinks to know) the answer can write it and than send it to the teacher (the answers can be send also to the class). The teacher reads the answers that appear on his monitor and then he can give the correct answer to the whole class, underlining or not the students that have supplied it. If we think to the same situations but without the use of any type of device, the students who want to answer the question have to do it in front of the whole class, risking to be mocked if it is wrong and to give a bad impression to the teacher. Because of one of these two reasons, a student can choose not to do answer to the question. These motivations can be solved also using anonymity in the messages. In practice, it is possible to use of pocket pc with a software that associates an alias or avatar to every student like "Student 1", "Student 2", ..., etc. In this perspective, another interesting reason to use the anonymity is the problem of prejudices of the teacher. If a student is considered to not have a gift for a particular subject, for example art, it is possible that the teacher has a different behavior with him during the lessons and during the answering of the questions. If the answering is done with the anonymity such behaviors disappeared automatically.

Another point can be that the teacher can choose every week a different student to substitute him during the lesson to answer to the questions of the other students. During the week all the questions done to the teacher are re-addressed to the pocket pc of the chosen student, that has to answer to them. This can be seen as a sort of training for the student or it can be used as method to do the exam of the matter. As said, the students can send messages to each other, apart from the possibility to send messages to the teacher. Such type of messages can contain different kinds of communications, from communications inherent to the lesson to communications inherent to a date for the next afternoon. First, it seems necessary that the teacher has the possibility to stop messages among the students if these are the reasons for a loss or a decrease of the attention of the class. The teacher is provided with a software that allows him to see the number of messages that the students send each other in real time. So, if this number overcomes a given threshold he can decide to stop the messages.

During the explanation of a new topic the teacher would like to know if the matter and the method used to treat it are considered interesting by the class. This is an important type of feedback that allows the teacher to know the degree of interest of the students and eventually to do some changes to make the lesson more interesting. In fact, the students can have a previous knowledge of a particular aspect of the topic, for example because they have treat it during another lesson of another subject. This type of feedback can be considered more realistic thanks to the presence of the anonymity that helps the students to be sincere. From the point of view of the students, this feedback return them a sensation of interest for their thoughts. A problem that can come out is that to the teacher can arrive too many questions at the same time and he is not able to answer. Moreover, the risk is that the teacher answers always to the questions of the same students and never or very rarely to the ones of the others (there is always anonymity). To manage this problem it is necessary to set a protocol that allows to every student to communicate to the teacher. This type of protocol can be used also to manage the answers that arrive from the students or from the representatives, if present. So it is possible to establish a protocol like the Delphi method that is used in the field of business to obtain answers to a problem from a panel of independent experts through a number of rounds. Since the physical space helps social interaction, the lesson has to be supported by a virtual ambient into the pocket pc with the features of visibility, awareness and accountability (a so called translucent system) as seen in Erickson [11]. The above scenario underlines the big difference that the use of the pocket pc brings to a traditional situation as a lesson. The institution adds new powers that are not possible in a situation without technological devices such as the possibility to communicate not only with the student seats nearby but also with the students on the other side of the classroom, the possibility to communicate with the class when we are ill at home or the possibility to stop the flow of messages among students or the creation of virtual groups inside the class. There is also the possibility to change the dependencies among agents, so if the teacher selects a student to answer to the questions send by the other students instead of the teacher, these students depend now from the selected student to obtain answers. We can argue that the net of dependencies among the participants of the lesson can be represented as an institutional social network where nodes represent people and arcs the dependencies created by the powers to achieve one own goals.

3 POWER AND SOCIAL DEPENDENCE NETWORKS

A simple representation of an agent is characterized by a set of features like the set of goals that he wants reach, the set of his beliefs and the set of skills that represent his capabilities. When an agent is put in a system that involves also other agents, he can be supported by the others to achieve his goals if he is not able to do them alone, thanks to the concept of power. In a Multiagent system, the concept of power, taken from the basic notions of Castelfranchi's social model [9], represents the capability of a group of agents (possibly composed only by one agent) to achieve some goals (theirs or of other agents) performing some actions without the possibility to be obstructed. The power of a group of agents can by defined as follows:

Definition 1 (Agents' power) $\langle A, G, pow : 2^A \rightarrow 2^{2^G} \rangle$ *where* A *is a set of agents,* G *is a set of goals. The function* pow *relates with each set* $S \subseteq A$ *of agents the sets of goals* $G_S^1, \ldots, G_S^m$ *they can achieve.*

Example 1 shows a set of agents and a set of goals taken from the scenario and what are the goals that each agent can achieve even if these aren't their own goals.

Example 1

- *Agents* $A = \{E, S, M, P, K\}$ *where agent P represents the teacher and the other agents represent the students. The teacher has created two groups for the base level of preparation on the subject Art and the high one. The two groups are* $\{S, M\}$ *and* $\{E, K\}$ *where the chosen representatives are agents E and S.*
- *Goals* $G = \{g_1, g_2, g_3, g_4\}$ *where* g_1*: to obtain the material sent by the teacher for its group from his pocket pc,* g_2*: to communicate with other students using the pocket pc,* g_3*: to obtain some feedbacks via pocket pc on the topic of Post-impressionism and* g_4*: to obtain an answer to the question "Why artists as Van Gogh or Gauguin are often considered as impressionists?".*

- $pow((S,E),(g_1))$,$pow((K,S,M,E),(g_3))$,$pow((P),(g_2,g_4))$

3.1 Social dependence networks

In order to define the relations that exist between the agents of the system in terms of goals and powers to achieve these goals, we adopt the methodology of social dependence networks as developed by Conte and Sichman [15]. In these models, an agent is described by a set of prioritized goals, and there is a global dependence relation that explicates how an agent depends on other agents for fulfilling its goals. For example, *dep*$(\{a,b\},\{c,d\}) = \{\{g_1,g_2\},\{g_3\}\}$ expresses that the set of agents $\{a,b\}$ depends on the set of agents $\{c,d\}$ to see to their goals $\{g_1,g_2\}$ or $\{g_3\}$. A social dependence network can be defined as follows:

Definition 2 (Social dependence networks) *A social dependence network is a tuple* $\langle A, G, dep, \geq\rangle$ *where:*

- A *is a set of agents and* G *is a set of goals.*
- *dep* $: 2^A \times 2^A \rightarrow 2^{2^G}$ *is a function that relates with each pair of sets of agents all the sets of goals on which the first depends on the second.*
- $\geq$: $A \rightarrow 2^G \times 2^G$ *is for each agent a total pre-order on goals which occur in his dependencies:* $G_1 \geq (a)\ G_2$ *implies that* $\exists B, C \subseteq A$ *such that* $a \in B$ *and* $G_1, G_2 \in depend(B,C)$.

We show how to model example 1 as a social dependence network where agents are related with each others by a set of dependencies created by power to achieve goals.

Example 2 *Consider the following social dependence network* $DP = \langle A, G, dep, \geq\rangle$*:*

1. *Agents* $A = \{E,S,M,P,K\}$ *and Goals* $G = \{g_1,g_2,g_3,g_4\}$
2. *dep*$(\{M\},\{S\}) = \{\{g_1\}\}$*: agent* M *depends on agent* S *to achieve the goal* g_1.
   dep$(\{K\},\{E\}) = \{\{g_1\}\}$*: agent* K *depends on agent* E *to achieve the goal* g_1.
   dep$(\{K,S,M,E\},\{P\}) = \{\{g_2\}\}$*: agents* $\{K,S,M,E\}$ *depend on agent* P *to achieve the goal* g_2.
   dep$(\{K,S\},\{P\}) = \{\{g_4\}\}$*: agents* $\{K,S\}$ *depend on agent* P *to achieve the goal* g_4.
   dep$(\{P\},\{M,K,S,E\}) = \{\{g_3\}\}$*: agent* P *depends on agents* $\{M,K,S,E\}$ *to achieve the goal* g_3.
3. *Agents K, M and S have the following pre-order on goals:* $\{g_1\} > (E)\ \{g_2\} \succ (P)\ \{g_4\}$ *and* $\{g_1\} \succ (S)\ \{g_2\}$ *and* $\{g_1\} \succ (P)\ \{g_4\}$.

3.2 Agent view

The passage from the concept of power to the social dependence networks can be explained using the concept of α-ability, as said by [3]. In fact, the definition of a social dependence network based on the abilities of agents and goals can be done using the notion of power as the so called α-ability, that is the capability of a group of agents to assure a state of affairs, independently from what the other agents do. This concept, coming from the classical game theory [13], does not consider the presence of useless agents in the system, so it is necessary to require that all the agents of the system play a profitable role in the achievement of the set of goals. In general, a dependence concerns the possibility of a group of agents to satisfy goals of agents, with the condition that in the group all members should be useful

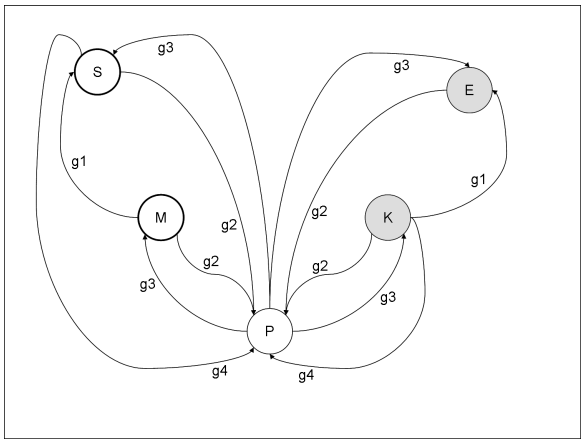

Figure 1. Social Dependence Network of Example 2

to the fulfillment of goals. After the definition of the relationships among the agents of the Multiagent system, the next step to perform is the modeling of the two levels of reality that emerge in a system of Ambient Intelligence such as by our scenario.
The first level of reality is the one that describes beliefs, goals and skills of the agent, the real ones. Skills or abilities of a group of agents (or of a single agent) play a relevant role as regards the power to achieve goals but power does not consist only of the group's abilities to achieve affects. There should also be at least one agent that desires those effects. In our model, skills can be represented as beliefs common to every agent, about the environment. Another component that has to be mentioned are the rules, also called effect rules in [3]. The environment of a multiagent system can be described by a pair of states, the initial one and the next one. A rule is conditional both on the initial state and on the actions performed by the agents. The link between rules and power is given by the concept of goal that contains rules and is contained in the definition of power. For example, in our scenario student S1 can have the goal to communicate with student S3 and student S6 can have the belief that the questions done by the other students to the teacher are useless. This level of reality can be called Agent view and can be defined as follows:

Definition 3 (Agent view) $\langle A, F, B, G, X,$ *beliefs*$: A \rightarrow 2^B$ *goals*$: A \rightarrow 2^G$, *skills*$: A \rightarrow 2^X, R : 2^X \rightarrow 2^G\rangle$ *consists of a set of agents* A*, a set of facts* F*, a set of beliefs* $B \subset F$*, a set of goals* $G \subset F$*, a set of actions* X*, a function beliefs that relates with each agent the set of its beliefs, a function goals that relates with each agent the set of goals it is interested in, a function skills that describes the actions each agent can perform, and a set of rules* R *that relate sets of actions with the sets of goals they see to.*

Example 3 shows, continuing by previous examples, how is constituted the agent view both from the point of view of sets and from the point of view of functions.

Example 3

- *Agents* $A = \{E,S,M,P,K\}$ *and Goals* $G = \{g_1,g_2,g_3,g_4\}$.
- $B = \{b_1,b_2,b_3\}$ *where* b_1*: answer the questions is useless,* b_2*: feedback is useful,* b_3*: communicate with schoolfriend is funny.*
- $X = \{x_1,x_2,x_3\}$ *where* x_1*: communicate with school friends,* x_2*: answer to the questions,* x_3*: require feedback and* x_4*: distribute material*

- $goals(M) = \{g_1, g_2\}$, $goals(K) = \{g_1, g_2, g_4\}$, $goals(P) = \{g_3\}$, $goals(S) = \{g_1, g_2, g_4\}$, $goals(E) = \{g_1, g_2\}$
- $beliefs(M) = \{b_3\}$, $beliefs(K) = \{b_3\}$, $beliefs(P) = \{b_2\}$, $beliefs(S) = \{b_1, b_3\}$, $beliefs(E) = \{b_1, b_3\}$
- $skills(M) = \{x_1, x_3\}$, $skills(K) = \{x_1, x_2\}$, $skills(P) = \{x_2, x_3, x_4\}$, $skills(S) = \{x_1, x_2, x_4\}$, $skills(E) = \{x_1, x_2, x_4\}$
- $rules(\{x_1\}) = \{g_2\}$, $rules(\{x_2\}) = \{g_4\}$, $rules(\{x_3\}) = \{g_3\}$, $rules(\{x_4\}) = \{g_1\}$

4 INSTITUTIONAL MECHANISM

The addition of a technological device changes in a relevant way the relationships among agents, giving a different aspect also to different roles composing an institution. For example, in our scenario we can recognize three different roles: the role of the teacher that has more power as regards the other roles, the one of the representative of a group that is not a common student because he has the power to communicate to the teacher and, finally, the role of the common student. In a multiagent perspective, roles are instances to be adjoined to the agents which play the role and they can be called also social roles. Obligations and permissions are a fundamental feature of normative positions of roles but, in general, we need also powers to specify normative or institutional positions. For more details, see [4].

The second level of reality is the one that describes public beliefs and goals of the role played by an agent and represents the institutional level. For example, taking again our scenario, student S3 can have the public goal to answer to the questions of the students instead of the teacher, so in spite of his private beliefs, he has in his public ones the utility of the answering to these questions. All the other students expect that Student S3 will conform to his role otherwise he will be sanctioned or even enforced. At this level becomes important, as previously said, the role of the agents because to some roles are associated more powers than to other ones. The role of the teacher, for example, has the power to change beliefs and goals of other roles, changing the institutional reality. Social institutions are entities which exist thanks to the collective acceptance of the public believes and goals and the rules regulating them. A role can not do any institutional action without the consent of the social entity (the system in which agents are). The reason is that social entities are not material ones and depend just on the collective acceptance. This level, called Institutional view, can be defined as follows:

Definition 4 (Institutional view)
$IV = \langle RL, IF, RB, RG, IX, beliefs: RL \rightarrow 2^{RB}, goals: RL \rightarrow 2^{RG}, skills: RL \rightarrow 2^{X \cup IX}, IR : 2^{X \cup IX} \times 2^{RB} \rightarrow 2^{IF}, roles: RL \rightarrow A\rangle$ *consists of a set of role instances RL, a set of institutional facts IF, a set of public beliefs attributed to roles $RB \subset F \cup IF$, a set of public goals attributed to roles $RG \subset F \cup IF$, a set of institutional actions IX, a function $ibeliefs$ that relates with each role the set of its public beliefs, a function $igoals$ that relates with each role to the set of public goals it is committed to, a function $iskills$ that describes the institutional actions each role can perform, and a set of institutional rules IR that relates sets of institutional actions, sets of facts and institutional facts with the sets of institutional facts they see to. A function $roles$ assigns a role to its player in A.*

Example 4

- *Agents* $A = \{E, S, M, P, K\}$
- $RL = \{Te, Re, St\}$ *where role Te is the role associated to the teacher, the role Re is the one associated to the representative of a group of students and the role St is the one associated to a common student.*
- $RB = \{rb_1, rb_2\}$ *where rb_1: possibility to send messages to the other school friends, rb_2: answering to the questions put to the teacher is useful.*
- $RG = \{rg_1, rg_2, rg_3, rg_4, rg_5, rg_6\}$ *where rg_1: answer to the questions sent to the teacher, rg_2: give next turn for asking a question, rg_3: sent the questions to the representative, rg_4: give feedbacks to the teacher, rg_5: give authorizations to download the material sent by the teacher, rg_6: send messages to other school friends.*
- $IX = \{ix_a, ix_b, ix_c, ix_d, ix_e, ix_f, ix_g\}$ *where ix_a: authorize to download the material, ix_b: stop the flow of messages among students, ix_c: put tasks in public goals and common points in public beliefs of every student, ix_d: give a absence note to the teacher, ix_e: give the turn to the next group asking questions according to the order of reservations, ix_f: delete public beliefs incompatible with public goals, ix_g: set the substitute of the teacher.*
- $IF = \{if_a, if_b, if_c, if_d\}$ *where if_a: turn as substitute of the teacher agent E, if_b: permission to download the material, if_c: possibility exchange messages with shoolfriends, if_d: turn of group with as representative agent S.*
- IR: *irules* $(\{ix_a\}) = \{if_b\}$, *irules* $(\{ix_b\}) = not\{if_c\}$, *irules* $(\{ix_g\}) = \{if_a\}$, *irules* $(\{ix_e\}) = \{if_d\}$.
- *IV:*
  - $igoals(Te) = \{rg_2\}$, $igoals(Re) = \{rg1, rg_4, rg_5, rg_6\}$, $igoals(St) = \{rg_3, rg_4, rg_6\}$.
  - $ibeliefs(Te) = \{rb_2\}$, $ibeliefs(Re) = \{rb_1, rb_2\}$, $ibeliefs(St) = \{rb_1\}$.
  - $iskills(Te) = \{ix_b, ix_c, ix_e, ix_f, ix_g\}$, $iskills(Re) = \{ix_a\}$, $iskills(St) = \{ix_d\}$.
  - $roles(Te) = \{P\}$, $roles(Re) = \{S, E\}$, $roles(St) = \{K, M\}$.

Example 4 shows the institutional view applied to the scenario. In this framework each participant is assigned with a set of public beliefs and goals, describing what he can do (e.g., authorize to download material) and should do (e.g., give feedback to the teacher). The agent that represents the teacher has the function of facilitator and so he has the aim to give the turn to the next student that desires to put a question and eventually to give the task to answer to these questions to a student. Agents with the role of representative can have the institutional goal to manage the questions that the members of its group want to send to the teacher while agents with the role of common students can perform the institutional action that send a message to a school friend on the other side of the classroom. The two levels, the public level and the private one have to be related together. To pass from the Agent view to the Institutional one we need a function that takes the private beliefs and goals of the agent and returns the public ones. The difference between the two sets of beliefs is not trivial, because there can be beliefs that remain from the passage from the private set to the public one, beliefs that disappear from the private set to the public one and, finally, beliefs that are present only in the public set and not in the private one. The same considerations can be done for goals. The difference between the private level and the public one is the existence of power. An agent can have the power to delete or add new goals and beliefs in the public sets of another agent such as the case in which the teacher stops the flow of messages and this action in our model is represented by a deletion of goals (the goal to send a message to other students) from the public set of goals

of students. The separation of the sets of public goals and beliefs has the aim to avoid contradictions between what the agent believes and what it has to perform (its goals) [1]. Our scenario allows to enforce the behavior of the agents in the institution, for example, by blocking them from making statements which contradict common beliefs, or by performing (virtual) actions which are not allowed (e.g., taking a turn in the wrong situation). We have to argue that these examples illustrate that our two level model is compact and understandable and succeeds in modeling all the facets that rise from an environment of Ambient Intelligence.

5 RELATED WORK

The formal model can be extended with the obligations, as done by Boella and van der Torre [5]. In this work, to model obligations they introduce a set of norms, associated with each norm the set of agents that has to fulfill it and what happens when it is not fulfilled. In particular, they relate norms to goals in the following two ways. First, each norm is associated to a set of goals. Achieving these normative goals means that the norm has been fulfilled; not achieving these goals means that the norm is violated. They assume that every normative goal can be achieved by the group, that means that the group has the power to achieve it. The second point is that each norm is associated to another set of goals which will not be achieved if the norm is violated, this is the sanction associated to the norm. We assume that the group of agents does not have the power to achieve these goals, otherwise they would avoid the sanction. An interesting approach to the application of the notion of institution to multiagent systems is defined in [16]. Electronic Institutions (EIs) provide the virtual analogue of human organizations in which agents, playing different organizational roles, interact to accomplish individual and organizational goals. As in human societies, it seems necessary the need of regulatory structures establishing what agents are permitted and forbidden to do. EIs introduce sets of artificial constraints that articulate and coordinate interactions among agents. In this approach, roles are defined as patterns of behavior and are divided into institutional roles (those enacted to achieve and guarantee institutional rules) and non-institutional roles (those requested to conform to institutional rules). Another approach to EIs is given by [6]. In this approach they propose the use of 3D Virtual Worlds to include humans into software systems with a normative regulation of interactions. Their methodology has two independent phases: the specification of the institutional rules and the design of the 3D Interaction environment. The normative part can be seen as defining which actions require an institutional verification assuming that any other action is allowed. Inside the 3D Interaction Space, an institution is represented as a building where the participants are represented as avatars. Norms determine the consequences of user actions that are modeled as commitments and these commitments may restrict future activities of the users. In the last two works, unlike us, the methodology is applied to an practical approach without a formal definition of the concept of institution and a description of its dynamics while they are similar to our one in the establishment of a different level of reality related to the institution.

6 CONCLUSIONS AND FUTURE WORK

We have observed as the possibility of interaction increases in a scenario of Ambient Intelligence thanks to the technological devices. We have presented the problem using as basis an example of scenario from Ambient Intelligence that describes a lesson done with the help of the device of a pocket pc.

We have defined an approach based on the Multiagent model, using social dependence networks, with the aim to describe the reality of an environment of Ambient Intelligence. The concept of power is used to model the reality of our scenario and the dependencies that the power sets in the system are represented as social networks, using the methodology of dependence networks.

To model the use of a technological device in Ambient Intelligence as a new level of reality, we have based our framework on the concept of institution with the aim to give a compact and realistic model of the reality. We have formalized the concept of institution, relating it with the one of power and we have applied this result to social dependence networks, obtaining institutional social networks.

Presently we are working on the definition of a dynamic model of the institutional view to represent the changes in the dependencies with the application of institutional actions. A first step in this direction seems to be in the dynamic social networks [8] that aim to bring together traditional social network theory and multiagent systems and contain multiple types of nodes and multiple types of connections among them with the feature to be larger dynamic. We are also defining measures on social dependence networks and their variations with the previously cited dynamics.

REFERENCES

[1] G. Boella, R. Damiano, J. Hulstijn, and L. van der Torre, 'A common ontology of agent communication languages', *Applied Ontology*, **2**, (2007).

[2] G. Boella, L. Sauro, and L. van der Torre, 'Social viewpoints on multiagent systems', *Proceedings of AAMAS'04*, (2004).

[3] G. Boella, L. Sauro, and L. van der Torre, 'From social power to social importance', *Web Intelligence and Agent Systems*, (2007).

[4] G. Boella and L. van der Torre, 'The ontological properties of social roles in multi-agent systems: Definitional dependence, powers and roles playing roles', *Artificial Intelligence and Law Journal*, (2007).

[5] G. Boella and L. van der Torre, 'Power in norm negotiation', *Proceedings of KES-AMSTA'07*, (2007).

[6] A. Bogdanovych, M. Esteva, S. Simoff, C. Sierra, and H. Berger, 'A methodology for developing multiagent systems as 3d electronic institutions', *Proceedings of AOSE@AAMAS'07*, (2007).

[7] P. Caire, S. Villata, L. van der Torre, and G. Boella, 'Conviviality masks in role-based institutions multi-agent teleconferencing in virtual worlds', *Proceedings of AAMAS'08*, (2008).

[8] K. M. Carley, 'Dynamic network analysis', *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*, 133–145, (2003).

[9] C. Castelfranchi, 'The micro-macro constitution of power', *Protosociology*, **18**, 208–269, (2003).

[10] H. Chalupsky, Y. Gil, C. K. Knoblock, K. Lerman, D. Oh, D. V. Pynadth, T. A. Russ, and M. Tambe, 'Electric elves: Applying agent technology to support human organizations', *Proceedigs of AAAI*, (2001).

[11] T. Erickson and W. A. Kellogg, 'Social translucence: an approach to designing systems that support social processes.', *ACM Trans. Comput.-Hum. Interact.*, **7**(1), 59–83, (2000).

[12] J. Masthoff, W. W. Vasconcelos, C. Aitken, and F. S. Correa da Silva, 'Agent-based group modelling for ambient intelligence', *Proceedings of AISB'07*, (2007).

[13] B. Peleg, 'Effectivity functions, game forms, games, and rights', *Social choice theory*, **15**, 67–80, (1998).

[14] P. Remagnino and G. L. Foresti, 'Ambient intelligence: A new multidisciplinary paradigm', *Systems, Man and Cybernetics*, **35**, 1–6, (2005).

[15] J. S. Sichman and R. Conte, 'Multi-agent dependence by dependence graphs', in *AAMAS'02*, pp. 483–490, (2002).

[16] C. Sierra, J. A. Rodriguez-Aguilar, P. Noriega, J. L. Arcos, and M. Esteva, 'Engineering multi-agent systems as electronic institutions', *European Journal for the Informatics Professional*, (2004).

[17] M. Wooldridge, 'An introduction to multi-agent systems', *The journal of policy, regulation and strategy for telecommunications*, **7**, 33–51, (2005).