Towards Social Dynamic Dependence Networks for Institutions

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Abstract. Social networks are structures that aim to represent the relationships among the actors of a society. In the multiagent model, these networks depict the dependencies among the agents. The dependencies reflect the relation between the goals of the agents and the agents who have the power to achieve them. Like any social structure, also a multiagent system can be regulated by a set of norms and institutional powers that form an institution. Differently than informal social networks, the institutional social structure has an inherent dynamic character which cannot be captured by the current dependence networks. The networks have to reflect the changes of dependencies among agents created by the exercise of institutional powers. The aim of this paper is to define more dynamic social networks. From a description of an agent system it is possible to build a static dependence network. In the same way we describe how to pass from an abstract representation of what is an institution with its institutional powers to a dynamic social dependence network.

Keywords. Social dependence networks, multiagent systems, institutions, norms

Introduction

The study of social relationships among actors, whether human beings, groups or organizations, agents, is a fundamental issue in social sciences. Social networks analysis has emerged as key technique in sociology, organizational studies and economics. The main use of this kind of analysis is the connotation of complex sets of relationships among the members of social systems. A social network is a social structure composed by nodes (that represents individuals or organizations) and edges (that represent various types of relationships among individuals) that form a complex structure. Any kind of society, as also a multiagent system, is continually in a state of change and this change takes the form of modifications of the underlying social network. The behavior of a social structure results not only from the union of the behavior of each single entity (humans, agents, groups and so on) but it emerges from the dynamics by which these entities interact with each other. As in any social structure, the presence of different types of entities with different capabilities inside the social network underlines the necessity of introducing institutions and social regulations that emerge as actors interact.

Normative multiagent systems are an example of the use of sociological theories in multiagent systems, and more generally of the relation between agent theory and social sciences such as sociology, philosophy, economics, and legal science. Social concepts

like norms are important for multiagent systems, because multiagent system research and sociology share the interest in the relation between micro-level agent behaviour and macro-level system effects (the relation between individual agent behaviour and characteristics at the level of the social system). A multiagent system is an environment populated by agents that interact with each other creating a complex net of dynamics inside the system. The study of these dynamics and, as a consequence, of the various forms of social aggregation [6] is an important aim in the field of multiagent Systems.

Whereas in a single agent framework to achieve a given goal an agent has to be able to do it, 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 structure of a system. These relations can be captured, as said, thanks to social networks using to model them the formal dependence network model of [1]. The aim of a normative multiagent system is regulating the behaviour of its agents thanks to norms and the institutional power that allows the introduction of new dependencies. This power is associated only to roles and gives them the possibility to change the dependencies inside the social network modifying institutional goals, skills and rules.

On one hand, social networks theory can be applied to study the relationships among the agents composing a multiagent system and the dynamics that arise from the interaction of these agents, modeling all by means of institutions. On the other hand, multiagent systems gives to social network theory new conceptual instruments as dependence networks, here used as the methodology to define social networks (so called social dependence networks) and their dynamic version. The research questions of this paper are: How to extend dependence networks to build social dependence networks which are able to model the dynamics of an institution? *and* How to map the Institutional view of a multiagent system into the dynamic social network representation of it?.

We answer to our research questions giving an abstract representation of institution and a formal definition of a dynamic social network, with the help of an example representing a government of a hypothetical state. The example illustrates on one hand the material relationships and structure of the system based on the agents composing it (we call it the Agent view of the system) and how it is possible to pass to a dependence network representation and, on the other hand, it presents the institutional relationships among agents and the normative structure of the system (we call it the Institutional view of the system).

Dependencies due to norms like obligations and permissions can be modeled by means of social dependence networks, as proposed in [12], however, institutional powers cannot be captured by the existing dependence networks formalism, since they introduce a dynamic element. Institutional powers can change the norms and permissions of agents playing roles, and, thus, by exercising a power an agent transforms a social dependence structure into a new one by adding or removing dependencies at the institutional level of the social structure. Thus, power is seen as the base of the change that is applied to the network describing a social structure, differently from what expresses by Jones and Sergot [14] and Grossi [17].

This paper is organized as follows. Section 1 describes the Government scenario used to explain the further social structures and formalizations. In Section 2 we provide the definitions of the agent view and of the institutional view and we formalize the notion of social network. In Section 3 we show how to pass from the institutional view to the dynamic social networks. Related work and conclusions end the paper.

1. The Government Scenario

The social structure we aim to represent as a social network has to be composed by a number of actors that play different roles and have a set of capabilities and goals inside the system. The scenario we will present is an imaginary Government environment with its ministers, similar in structure to the Italian one. Our aim is to present the actors involved in the scenario with their associated roles, the social network that can be derived from the set of dependencies among actors based on power to achieve goals of the agents, the institution that regulates the system and, finally, the dynamic social network. The roles that appear are the role of the Prime Minister and the roles associated to the other ministers. The role of the Prime Minister is the one provided with the greater number of powers while the other ministers have different powers as regards the area of action.

Starting with the description of the physical level (leaving for a moment the institutional one), a minister can need some material services to work. For example, if he has to travel in town, he needs a ministerial car for the travel. Another example can be the necessity of a service of translation available only in a particularly ministerial office. In that case, the minister has to ask to the suitable office to use the translation service. The same thing happens when the minister needs to do, for example, a press statement. Here, he has to ask to the office of public relations to set a press conference and he has to give a number of possible dates, according to his appointments. In the same way, the minister can need the publication on the web site of a particular Office of a relevant new information and so he has to contact the office with the job to update such web site asking it to do the changes. Each point presents a goal of the agent with the role of a particular minister and the dependence that the minister has as regards, for example, the office of public relations to achieve the goal to program a press conference. These kinds of dependencies are material ones and allow to built a social network describing them. But, as previously noted, a social structure is always settled by norms and social regulations that arise from the social acceptance of the community. For this reason, the scenario cannot be considered complete till it does not include also the institutional level of reality that regulates the system.

From an institutional point of view, the Prime Minister can assign to another minister, for example to the foreign secretary, a delegation to treat some diplomatic matter instead of him. From this moment, all the other ministers and the secretaries have to refer to the foreign secretary when they need something inherent to the above matter. On the other hand, the Prime Minister can also remove some delegation if there is a case of uncorrect behavior of a particular minister and he can take his delegations ad interim. From this moment, it will be the Prime Minister the minister to which the other ministers have to refer as regards the matter inherent to the removed delegation. The role of the Prime Minister is, as said, the one with the greater number of powers so he can also give a permission to the other ministers to do something, for example the permission to be absent

to a council of ministers for serious reasons. He can also create obligations to other ministers, for example, the Prime Minister can oblige the minister of transports to present a document within a precise date. This government structure is clearly hierarchical, thus as the Prime Minister has more powers that all the other ministers, at the same time the other ministers have more powers of deputy-ministers. These institutional powers create new dependencies among ministers and these dependencies have the feature to be dynamic. For example, when minister M1 depends on minister M2 to achieve a particular goal there is a dependence from M1 to M2 but if the Prime Minister removes the power of M2 to achieve a goal and takes it ad interim, then, from now on, M1 will depend on the Prime Minister.

The institutional dependencies are not only distributed in a vertical way in the hierarchical structure of our scenario but also in a horizontal way thus a minister can depend not only from the Prime Minister but also from other ministers. Such type of dependence is given, for example, by certain kinds of authorizations. In fact, the minister of transport can necessitate an authorization from the minister of infrastructures to bridge a river. Another example is when the minister of public works needs fundings from the minister of finance to call for tenders for building the bridge. These examples show how a minister M1 having a goal G1 depends on minister M2 to achieve it to have the authorization.

This scenario shows the possible dependencies that can be created in a Government, both from the material point of view and for the institutional one. Moreover, these dependencies are also dynamic and can change as regards the changes in the institutional powers associated to the ministers. In the following sections, we present the formalization of the material reality and the consequent definition of social networks depicting the dependencies among the actors of the scenario. Moreover, we will formalize the notion of institution basing our further examples on this scenario and, finally, defining the concept of dynamic social network, we will apply to these networks the institutional view.

2. Social Dependence Networks

An agent can be defined as an entity characterized by a number of features as his capabilities (here called skills), his world description and his goals (the tasks that he want to achieve). The representation of the system from a material point of view (called Agent view), so without taking into account the institutional view of it yet, can be imagined as composed by a set of agents, each of them with its associated sets of skills and goals and a set of actions, a set of facts describing the world and a set of rules that allow the application of an action by an agent that can perform it and the consequences of the action on the system. The formal definition of the agent view is defined as follows:

Definition 1 (Agent view) $\langle A, F, G, X, goals : A \rightarrow 2^G, skills : A \rightarrow 2^X, rules : 2^X \rightarrow 2^G \rangle$ *consists of a set of agents A, a set of facts F, a set of goals $G \subset F$, a set of actions X, 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 $rules$ that relate sets of actions with the sets of goals they see to.*

In a multiagent system, since an agent is put into a system that involves also other agents, he can be supported by the others to achieve his own goals if he is not able to do them alone, this leads to the concept of power. The power, taken from the basic

notions of Castelfranchi's social model [3], 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 is defined as follows:

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

It is not necessarily that an agent has the power to achieve all his goals. If the agent can't achieve a goal without the intervention of other agents that have the power to achieve it, this agent depends on these agents to achieve its goals. The relation between the Agent view and the power is as follows:

Definition 3 $\langle A, G, power : 2^A \rightarrow 2^{2^G} \rangle$ *is an abstraction from* $\langle A, F, G, X,$ *goals* $: A \rightarrow 2^G,$ *skills*$: A \rightarrow 2^X, rules : 2^X \rightarrow 2^G \rangle$ *if and only if: $g \in power(Q)$ if and only if $\exists Y \subseteq skills(Q)$ such that $rules(Y, \{g\})$.*

Example 1 shows an example of Agent view and what are the goals that each agent can achieve even if these are not their own goals.

Example 1

- *Agents* $A = \{T, I, F, L, P, K, J\}$ *and Goals* $G = \{g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_8\}$.
- $goals(P) = \{g_1\}$, $goals(L) = \{g_6, g_7, g_8\}$, $goals(T) = \{g_2, g_4\}$, $goals(I) = \{g_3\}$, $goals(F) = \{g_1\}$, $goals(K) = \{g_5\}$, $goals(J) = \{g_5\}$;
- $power((K), (g_1, g_2))$,$power((J), (g_3))$, $power((P, T, I, F, L), (g_5))$, $power((F), (g_6, g_7))$, $power((I), (g_4))$, $power((P), (g_8))$;

The dependence of an agent from other agents is defined in terms of power as follows:

Definition 4 (Agent dependence) *A group of agents $S \subset A$ depends on the group of agents $Q \subset A$ for the set of goals $K \subset G$, $dep(S, Q, \{K\})$, if and only if $power(Q, K)$ and $\neg power(S, K)$.*

This consideration brings to the definition of a structure with the aim to show the dependencies among agents. This structure is represented by a social network defined using the methodology of dependence networks, as introduced in our previous work [2]. In order to define the relations that exist among the agents of the system in terms of goals and powers to achieve these goals, we adopt the methodology of dependence networks as developed by Conte and Sichman [1]. In this model, 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 $\{g_3\}$. For each agent we add a priority order on its goals, and we say that agent a gives higher priority to goal g_1 than to goal g_2, written as $\{g_1\} >(a) \{g_2\}$, if the agent tries to achieve goal g_1 before it tries to achieve g_2. In other words, it gives more attention to g_1 than to g_2. A social dependence network can be defined as follows:

Definition 5 (Social Dependence Networks (DN)) *A dependence network is a tuple* $\langle A, G, dep, \geq \rangle$ *where:*

- A *is a set of agents.*
- 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 model Example 1 as a social dependence network in order to explain how can be depicted the dependencies that hold into the agent view of the system, before involving the institutional level of representation of the system.

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

1. *Agents* $A = \{T, I, F, L, P, K, J\}$ *and Goals* $G = \{g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_8\}$*;*
2. *dep*$(\{I\}, \{J\}) = \{\{g_3\}\}$*: agent* I *depends on agent* J *to achieve goal* $\{g_3\}$*;*
   dep$(\{T\}, \{I\}) = \{\{g_4\}\}$*: agent* T *depends on agent* I *to achieve goal* $\{g_4\}$*;*
   dep$(\{T\}, \{K\}) = \{\{g_2\}\}$*: agent* T *depends on agent* K *to achieve goal* $\{g_2\}$*;*
   dep$(\{L\}, \{P\}) = \{\{g_8\}\}$*: agent* L *depends on agent* P *to achieve goal* $\{g_8\}$*;*
   dep$(\{P, F\}, \{K\}) = \{\{g_1\}\}$*: agents* $\{P, F\}$ *depend on agent* K *to achieve goal* $\{g_1\}$*;*
   dep$(\{L\}, \{F\}) = \{\{g_6, g_7\}\}$*: agent* L *depends on agent* F *to achieve goals* $\{g_6, g_7\}$*;*
   dep$(\{K, J\}, \{T, I, F, P, L\}) = \{\{g_5\}\}$*: agents* $\{K, J\}$ *depend on agents* $\{T, I, F, P, L\}$ *to achieve goal* $\{g_5\}$*;*
3. *Agents T and L have the following pre-order on goals:* $\{g_4\} >(K) \{g_2\}$ *and* $\{g_8\} \succ(P) \{g_7\} \succ(F) \{g_6\}$.

Using dependence networks as methodology to model our social networks advantage us from different points of view. First, they are abstract, so they can be used, for example, for conceptual modeling, simulation or formal analysis. Second, they capture the essential features of social structures, because such structures reflect social relations, and thus social dependencies between agents. Moreover, they are used in high level requirement languages, like TROPOS [8], so they can be used also in software development.

However, as originally defined, dependence networks lack two ingredients: a normative structure and a dynamic representation of networks of social structures.

As said in [5], normative multiagent systems provide agents with abilities to automatically devise societies coordinating their behavior via obligations, norms and social laws.

2.1. The institutional view

Social dependence networks can be used to represent the dependencies among the individuals that are involved into a social structure. In this section we detail our definition of Institutional view, in such a way that the notion of social dependence network can be directly applied to it.

As mentioned, in any social structure both composed by humans and composed by agents, the importance of roles is considerable particularly for the definition of the set of powers associated to each agent. The notion of role is notable in many fields of Artificial Intelligence and, particularly, in multiagent systems where the role is viewed as an instance to be adjoined to the entities which play the role. In multiagent systems, roles have been introduced to constrain the autonomy of agents and to control their emergent behavior in the system by means of the notion of social structure. According to Ferber [13], "A role describes the constraints (obligations, requirements, skills) that an agent will have to satisfy a role, the benefits (abilities, authorizations, profits) that an agent will receive in playing that role, and the responsibilities associated to that role". So, a social structure is modeled as a collection of agents, playing roles regulated by norms where "interactions are clearly identified and localized in the definition of the role itself" [7].

The social reality is provided with two distinct views, the material one, previously called the Agent view and the Institutional one that aims to regulate the behaviour of the agents. As said, in a multiagent system each agent has a set of facts and goals that the other agents cannot change since agents are autonomous, formally presented in the Agent view. Thanks to its existence inside a social structure, to each agent is added also new sets of facts and goals called the institutional ones and that can be viewed and also modified by the other agents as regards their institutional role. Thus, the two levels are composed by the same sets of elements in such a way that as the social dependence networks formalism can be applied to the Agent view, it can be applied as well to the Institutional one.

The definition of power of Boella [4] can be directly applied to the description of the Institutional view. Also the ability to achieve goals can be directly defined in terms of facts, skills and goals attributed to roles following the definition given in [4]. The description of the Institutional view passes through two phases. The first one consists in the attribution of the sets of facts, goals, skills and rules with a public (or institutional) connotation to an agent. These sets can coincide or not with the same sets with the private connotation (the sets involved in the Agent view). This first phase can be characterized by possible conflicts between the sets of institutional features and the private ones. For example, an agent A can have as public goals $\{g_1, g_2, g_3\}$ but as private ones $\{g_1, g_4\}$. So, the public set can share elements with the private one (as for goal $\{g_1\}$) but can have other goals, based on social regulations and some elements are present only inside the private sets. The second phase consists, instead, in a new description of the social reality thanks to the institutional facts that represent the description of the world from the institutional point of view. Institutional facts are present as consequents of the institutional rules. These two phases describe the application of the concepts of social regulation and norms to the structure of a social dependence network that can represent them into a single structure. The Institutional view is defined as follows:

Definition 6 (Institutional view (IV)) $IV = \langle RL, IF, RG, X, igoals\colon RL \rightarrow 2^{RG}, iskills : RL \rightarrow 2^X, irules : 2^X \rightarrow 2^{IF}, roles : RL \rightarrow A\rangle$ *consists of a set of role instances* RL*, a set of institutional facts* IF*, a set of public goals attributed to roles* $RG \subset IF$*, a set of actions* X*, a function* $igoals$ *that relates with each role the set of public goals it is committed to, a function* $iskills$ *that describes the actions each role can perform, and a set of institutional rules* $irules$ *that relates a set of actions with the set of institutional facts they see to. A function* $roles$ *assigning a role to its player in* A*.*

Example 3

- *Agents* $A = \{T, I, F, L, P\}$*;*
- *Roles* $RL = \{Fm, Pm, Tm, Wm, Im\}$ *where role Fm is the one of the Minister of Finance, role Pm is the one of the Prime Minister, role Tm is the role of minister of Transport, role Wm is the role of minister of Public Works and role Im is the role of minister of Infrastructures;*
- $RG = \{pg_1, pg_2, pg_3, pg_4, pg_5, pg_6, pg_N\}$ *where* pg_1*: to obtain the authorization to built the bridge of Messina,* pg_2*: to obtain fundings to start a new series of public works in the major cities of Italy,* pg_3*: to not be present to a council of ministers because of family problems,* pg_4*: to obtain fundings to call for tenders to built the Messina's bridge,* pg_5*: to give authorizations,* pg_6*: to give authorization for fundings,* pg_N*: to obtain fundings.*
- $X = \{ix_a, ix_b, ix_c, ix_d, ix_e, ix_f, ix_g, ix_N\}$ *where* ix_a*: authorize to built the bridge of Messina,* ix_b*: authorize fundings to start a new series of public works in the major cities of Italy,* ix_c*: put or delete tasks in public goals of every agent,* ix_d*: put common points in public facts of every agent,* ix_e*: authorize fundings to start a call for tenders for the bridge of Messina,* ix_f*: delete legislative powers if the minister has a bad behavior,* ix_g*: give a delegation to minister F to give justifications of absence,* ix_N*: authorize fundings.*
- $IF = \{if_a, if_b, if_c, if_d, if_e, if_f, if_N\}$ *where* if_a*: public finance is not in a good situation,* if_b*: authorization to built the bridge of Messina,* if_c*: fundings to start a new series of public works in the major cities of Italy,* if_d*: fundings to call for tenders for building the bridge of Messina,* if_e*: legislative powers to P ad interim,* if_f*: approved absence of L,* if_N*: fundings.*
- *Function irules: irules* $(\{ix_a\}) = \{if_b\}$*, irules* $(\{ix_b\}) = \{if_c\}$*, irules* $(\{ix_c\}) = \{if_e\}$*, irules* $(\{ix_d\}) = \{if_a\}$*, irules* $(\{ix_e\}) = \{if_d\}$*, irules* $(\{ix_f\}) = \{if_e\}$*, irules*$(\{ix_g\}) = \{if_f\}$*, irules*$(\{ix_N\}) = \{if_N\}$*;*
- *Function igoals: igoals* $(Fm) = \{pg_6\}$*, igoals* $(Pm) = \{pg_5\}$*, igoals* $(Tm) = \{pg_1\}$*, igoals* $(Wm) = \{pg_2, pg_3, pg_4\}$*, igoals* $(Im) = \{pg_5\}$*;*
- *Function iskills: iskills* $(Fm) = \{ix_b, ix_d, ix_e, ix_g, ix_N\}$*, iskills* $(Pm) = \{ix_c, ix_d, ix_f\}$*, iskills* $(Tm) = \{ix_g\}$*, iskills* $(Wm) = \{ix_g\}$*, iskills* $(Im) = \{ix_a, ix_g\}$
- *Function roles: roles* $(Fm) = \{F\}$*, roles* $(Pm) = \{P\}$*, roles* $(Tm) = \{T\}$*, roles* $(Wm) = \{L\}$*, roles*$(Im) = \{I\}$*;*

This scenario describes a mechanism in which to each participant is assigned a set of public goals, describing what he can do (e.g. authorize to built a bridge) and should do (e.g. be present to a council of ministers). Our scenario allows to enforce the behavior of the agents in the institution, for example, by blocking them from making statements which contradict facts, or by performing (virtual) actions which are not allowed (e.g. embezzle public money).

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.

3. Dynamics of Institutional Social Networks

In the material world, no elements can be added dynamically to the agents' facts, skills and goals, since agents are autonomous by definition. Thus, this level can be adequately described by social dependence networks as defined in Section 2. In contrast, the institutional level can be changed in all its aspects. The reason is that the Institutional view is publicly attributed to agents by collective acceptance according to the constitutive rules of the institution [11]. Institutional powers allow to change the structure of the Institutional view, and thus, changing the powers of roles agents play, it consequently changes the structure of the social dependence network.

The dynamics of the institutional view can be defined as follows, by means of a function which allows to pass from an Institutional view to another one:

Definition 7 (Dynamics of institutional view) *The dynamics of the Institutional view is modeled via a function DR which, given a set of institutional facts, transforms an institutional view IV into another one:*
$DR\colon IV \times 2^{IF} \rightarrow IV$

The gap between the abstract social dependence network and the detailed institutional model is represented by the absence in the social dependence networks of the possibility for some roles to add new dependencies to other agents. We therefore propose an extension of the dependence networks called dynamic social dependence networks, which cover the most essential property needed for the institution: the possibility to change the institution according to the constitutive rules it specifies by itself.

Definition 8 (Dynamic Social Dependence Networks (DDN)) *A dynamic social dependence network is a tuple $\langle A, G, ddep, \geq \rangle$ where:*

- *A is a set of agents.*
- *G is a set of goals.*
- *$ddep : 2^A \times 2^A \times 2^A \rightarrow 2^{2^G}$ is a function that relates with each triple of sets of agents all the sets of goals on which the first depends on the second, if the third creates the dependency (this can also be viewed in the form $ddep : 2^A \rightarrow dep$).*
- *$\geq\colon A \rightarrow 2^G \times 2^G$ 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 $G_1, G_2 \in depend(B, C)$.*

Example 4 illustrates that a dynamic social dependence network can represent various static social networks, by depicting two networks into a single dynamic social dependence network.

Example 4 *Consider the following dynamic dependence network $DDP = \langle A, G, ddep, \geq \rangle$:*

1. *Agents $A = \{T, I, F, L, P, K, J\}$ and Goals $G = \{g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_8\}$;*
2. *$ddep(\{I\}, \{J\}, \emptyset) = \{\{g_3\}\}$: agent I depends on agent J to achieve goal $\{g_3\}$;*
   $ddep(\{T\}, \{P\}, \{P\}) = \{\{g_4\}\}$: agent T depends on agent P to achieve goal $\{g_4\}$ if it is created by agent P;
   $ddep(\{T\}, \{K\}, \emptyset) = \{\{g_2\}\}$: agent T depends on agent K to achieve goal $\{g_2\}$;

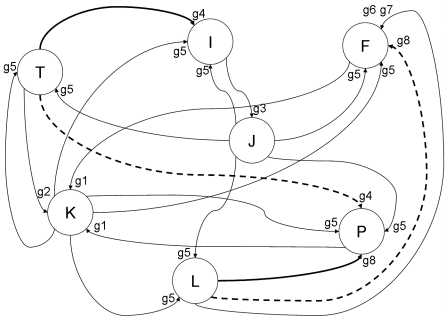

Figure 1. Social Dependence Networks of Example 4 where bold arcs represent old dependencies and dotted arcs represent new dependencies.

ddep$(\{L\},\{F\},\{P\}) = \{\{g_8\}\}$*: agent* L *depends on agent* F *to achieve goal* $\{g_8\}$ *if it is created by agent* P*;*
ddep$(\{P,F\},\{K\},\emptyset) = \{\{g_1\}\}$*: agents* $\{P,F\}$ *depend on agent* K *to achieve goal* $\{g_1\}$*;*
ddep$(\{L\},\{F\},\emptyset) = \{\{g_6,g_7\}\}$*: agent* L *depends on agent* F *to achieve goals* $\{g_6,g_7\}$*;*
ddep$(\{K,J\},\{T,I,F,P,L\},\emptyset) = \{\{g_5\}\}$*: agents* $\{K,J\}$ *depend on agents* $\{T,I,F,P,L\}$ *to achieve goal* $\{g_5\}$*;*

3. *Agents T and L have the following pre-order on goals:* $\{g_4\} \succ(K) \{g_2\}$ *and* $\{g_8\} \succ(F) \{g_7\} \succ(F) \{g_6\}$.

Figure 1 represents the dynamic social dependence networks of Example 4 if there is the execution of the institutional actions ix_f as regards agent I and ix_g.

We can see each IV as a state of the multiagent system with an associated *dep*. The passage from an Institutional view to another one can be viewed as a dynamic dependence social network composed by all the social dependence networks coupled with the different Institutional views. The main changes, that can occur to the Institutional view to make it dynamic and pass from an Institutional view to another one, are the addition or deletion of an $igoal$, of an $iskill$ and of an $irule$. These additions and deletions change the number of dependencies and what agents are involved in them, passing from a social dependence network to another one. This change can be represented by means of dynamic social dependence networks.

Example 5 *This example shows the case of the addition of an institutional goal. If* $IV \rightarrow IV'\{igoals + (Tm,\{pg_N\})\}$ *where* $T \in roles(Tm)$, $pg_N \in igoals(Tm)$ *then:*

- *if* $\exists Y$ *such that* $\{pg_N\} = power(Y)$ *(so, for example* $\{pg_N\} \in power(\{F\})$*) then* $dep_2 = dep + (\{T\},\{F\},\{pg_N\})$*. The number of dependencies present in the DDN changes and increases of one.*
- *if* $\neg\exists Y$ *such that* $\{pg_N\} = power(Y)$ *then* $dep_2 = dep$*.*
- *if* pg_N *already belonged to the set of goals of agent with role* Tm *then the addiction has no consequences.*

4. 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, associating to each norm the set of agents that has to fulfill it and what happens when it is not fulfilled. Each norm is associated to a set of goals and 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. They 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 [9]. Electronic Institutions (EIs) provide the virtual analogue of human organizations in which agents, playing different organizational roles, interact to accomplish individual and organizational goals. 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). The purpose of their normative rules is to affect the behavior of agents by imposing obligations or prohibitions. Another approach to EIs is given by [10]. 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. Once they enter the building their actions are validated against the specified institutional rules. The problem of dynamic institutions is treated in [15] as an extension to EIs definition with the capability to decide in an autonomous way how to answer dynamically to changing circumstances through norm adaptation and changes in institutional agents. The paper presents particularly the normative transition function that maps a set of norms into another one. As our approach, agents participating in the system have social interactions mediated by the institution and the consequences of these interactions are a change in the institutional state of an agent. A similar approach is also presented in [16] in which the authors apply the notion of dynamic EIs to the evolutionary self-organizing system of Digital Business Ecosystem.

5. Conclusions

Social structures, as multiagent systems, are composed by a number of actors that interact with each other creating complex relationships. These relationships have to be regulated by norms and this is possible using an institution with the aim to set the necessary social regulations. A social structure can be represented with all its relationships by means of social networks, here formalized using the methodology of dependence networks. One of the main difficulty to represent realistically a social structure consists in

the representation of the dynamics introduced by the institution. In this paper we have presented a formal definition of a multiagent system regulated by an institution, providing the definitions of Agent view and Institutional view. We have formalized the notion of social dependence networks to depict the multiagent system. Then, we have formalized the dynamics of the institution into the notion of dynamic social networks to describe the mechanism by which social networks change. Presently, we are working on the application of the notion of α-ability to social networks to better represent the possibility to dynamically add new dependencies and to delete them. Moreover, we are working on the addition of two new measures to social networks to compute a value associated to goals that are satisfied in the network and a value associated to dependencies present in the network. Always in this direction, we are working on the development of new measures related to the social importance of the agents involved in the social networks. The analysis of the variation of these measures as regards the changes in the dynamic social networks is our further interest. Finally, we are working on the application of the notion of coalition to social networks.

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