Cognitive Social Knowledge Grid Infrastructure for Collaborative Environments

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Abstract: Collaborative environments are virtual workplaces where agents can communicate, interact and collaborate. We introduce a model to compare different social structures and make a comparison between famous network structure and our goal infrastructure. Based on the differences, the main reasons to present our proposed model are described. Therefore we introduce an infrastructure to support optimized interoperability and propose a novel architecture, called Cognitive Social Knowledge Grid architecture, as a solution to perform information and knowledge operations through interaction and collaboration of humans and machines. CSKG services and mechanisms have been described and relationship models of CSKG components and services have been presented using UML. Utilizing capabilities of social network services, user profiles information, social culture and operational environment, CSKG collaboration management services form a community to perform an activity. Ultimately, CSKG performance and execution capabilities in large-scale collaboration networks have been evaluated. Furthermore, community formation based on user profiles similarities and social culture like trust and commitment is argued using weighted cosine similarity function.

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1. Introduction

Increasing development of distributed data, information and knowledge resources in geographical spaces lead the need of implementing distributed and decentralized systems. In decentralized environments, design and implementation of such programs needs several mechanisms and services to perform different operations on information and computing resources. Organizations have been come out of traditional forms and converted to open enterprises systems. In addition to services interactions, interactions between human and machines also play an effective role in such systems.

We introduce an infrastructure to implement an environment to perform optimized interaction and collaboration. We discuss about the environment that this infrastructure is defined for. Social structures and the main factors of social and network structures are introduced and some existing network structures that are relevant to our structure are compared with each other. In fact, it is the main reason that why we propose our infrastructure. Therefore, we propose a model and a novel architecture, called Cognitive Social Knowledge Grid Architecture (CSKGA) to execute in the proposed infrastructure. It is introduced as a solution to perform information and knowledge operations, and collaboration of agents. CSKG utilizes capabilities of social network and semantic overlay network (SON) approaches 1, and service-oriented architecture. It has to be noticed that in this research, using word of Grid does not necessarily mean using grid infrastructure but it means a management and communication network among nodes operating in the environment. This architecture includes three groups of social network services, application services, and management services. Social network services supply a communication environment for users; application services present single and distributed services; and management services are used for total system management, security, discovery, monitoring and service improvement, and collaboration management. We describe CSKG services and mechanisms and model the relationships among its services and components using UML.

In this research, we have focused on social and semantic aspects of collaboration in an environment. Therefore, to utilize social preferences, social network has been proposed in order to come over limitations caused by information flows in collaborative environments. Using capabilities of social network services, agents' information, and cognitive and social characteristics (like trust and commitment), CSKG collaboration management services form a community to perform an activity.

Eventually, CSKG performance and execution capabilities in large-scale collaborative environments have been evaluated. Then community formation based on user profiles similarities, and cognitive and social parameters like trust and commitment will be argued. We use weighted cosine similarity function to find one or more right partner, collaboration, and operation common performance.

The remainder of this paper is organized as follows. Section 2 deals with related works. In section 3 we outline social structures and its important factors. Section 4 describes definition and characteristics of CSKG. We present the Cognitive Social Knowledge Grid architecture, its services, and relationships among services in Section 5. We discuss collaboration and simulation of community formation in collaborative environments in Section 6. Finally section 7 concludes the paper.

2. Related Works

The concept of virtual communities is increasingly used to enable the collaboration between geographically distributed members belonging to various organizational units. Studies on distributed teams focus on human performance and interactions 5. Service-oriented architectures (SOA) have emerged as the defacto standard to design and implement open enterprise systems. Web service technology 6 enables cross-organizational interactions in collaborative networks 23. The grid is a set of computer resources spread all over the world, belonging to any organization (private or public) that are shared by a user community under specific constraints 7. Grid computing involves an evolving set of open standards for Web services and interfaces that make services, or computing resources, available over the Internet 8. Cloud computing is the next stage in evolution of the Internet. The cloud in cloud computing provides the means through which everything - from computing power to computing infrastructure, applications, business processes to personal collaboration - can be delivered to you as a service wherever and whenever you need 910.

In addition, Social networks have received tremendous attention recently from both research and academia. It becomes essential to adapt and influence the information exchange in an automated manner 11. Social networks become more and more interlinked with enterprises and collaborative platforms 5. Collaboration networks are among the most extensive databases of SNs considered to date. In particular, Newman 12 has shown that scientific collaboration networks have all the general ingredients of small-world and scale-free networks, while Barabasi et al. 4 have followed a complementary approach more focused on the dynamical processes determining the network evolution.

F. Berman proposed the concept of knowledge grid in 2001 which supports the synthesis of knowledge from data 13. Cannataro and Talia designed a reference software architecture, which they called the knowledge grid (KG), for implementation of parallel and distributed knowledge discovery systems on top of grid toolkits such as Globus 14,15. We developed an extended architecture for the KG 16 using Social Network and Semantic Overlay Network approaches 1. 17 introduced an Intelligent Service-Oriented Architecture for Distributed Data and Knowledge Management which utilizes some features of data, semantic, and knowledge grid architectures to provide more advantages. Zhuge proposed the principles and methodology of establishing knowledge grid as a human-machine interconnection environment 18,19.

A virtual organization is a temporary connection between organizations to share their skills, capabilities, and resources to respond better to business opportunities. Collaboration in such organizations supports by computer networks 20. Nowadays, SOA concepts, like WSDL, support virtual organizations. Human can participate in such networks and provide services in a uniform way using Human-Provided Services framework 21, 22. Social trust in service-oriented systems has become a very important research area. Depending on the environment, trust may rely on the outcome of previous interactions 23,24 and skills and interests similarity 25. Application of trust relations in virtual organizations and team formation have been investigated in 26,24. In our approach, metrics like trust and commitment express social behavior influenced by the context in which collaborations take place. Commitment 27 is a concept describing contracts, tasks, and promises that are aligned between couple of agents.

3. Social Structures

A social structure is a structure which has several independent agents to decide and act.

3.1. A Global Model for a Social Structure

From a systematic view, components of a social structure can model up to six key components, shown in figure 1. In this model, Meaning is the most important functional component. It is also considered as the goal that social structure is made to fulfil. *Meaning* can be realized in two ways. *Shared awareness* is perception of each society members about current situation of their social structure. Agents of a society interact together based on *communication* component. *Organizational Culture* is the component defining nature of existing concepts in the network. Next parameter mentioned as a result of organizational culture is the *roles* that determine which *resources* have to be in the organization and which do not. In this paper, Meaning is considered to define different evolution levels of an organization and Resources are noticed as the main modelling component in adaptation level. Organization is also a learning level while defining its executing procedures based on roles. Finally an organization is considered as an evolution level when modelling is to be based on culture.

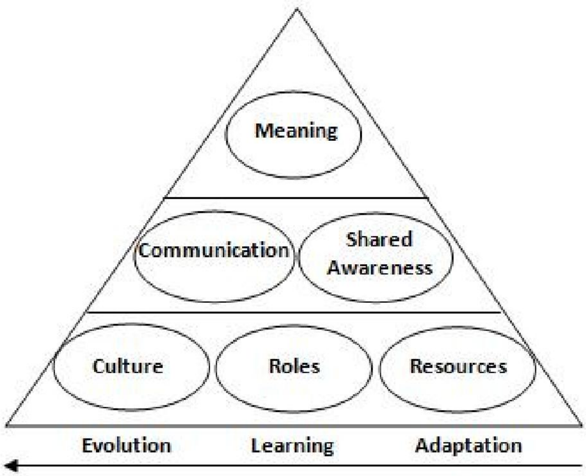

Figure 1. Key components model of social structures 28

3.2. Important Factors in Network Structures

Here some important parameters in a collaborative network are going to be studied. A network structure is a set of information and processing resources which communicate together as a common structure in order to fulfil different system requirements. These parameters are:

Network structure: The structure corresponding to the topology which network members are connected together by means of that. It also can be *open* or *close*. Open structure is the one allowed to change according to necessities during runtime, while no change can be observed in close structure or they are so rare.

Commitment rate: Agents in a processing network might have different levels of commitment to collaborate in a network process. The presence of agents can be voluntary or mandatory. If mandatory in a common situation, agents have to share their resources in a network if needed so that they can utilize interaction advantages instead. Otherwise, they may share their resources and services in the network voluntary.

Interaction Content: Depending on the environment, content interacting in the network might be data, information, or knowledge.

Meaning of relationship: In a social network, Relationships have two important specifications: content and meaning. According to what two sides of a relationship need, different meanings are going to be applied to that. Consequently, the communication network becomes a special semantic network.

Network management: There are four resource management categories in network structures. The first one is *centralized* in which a central manager accesses to all resources and manages them based on the network demands. The second category is *distributed*, which has a distributed management structure that accesses to different resources and manages them. In the third one, *semantic* management, there is not any central or distributed management, but a global meaning and logic, manages resources based on users' demands. In the last category, there is no resource management in the network at all.

These parameters can develop based on future needs. To a better understanding of differences between the CSKG and other network structures, the CSKG is compared with some other network structures relevant to the meaning of that. This comparison has been illustrated in table 1 so that the border between the CSKG and other similar systems can be illuminated.

4. Cognitive Social Knowledge Grid (CSKG)

4.1. Definition of CSKG

Table 1. Description of network structure using the mentioned parameters

Network Structure	Network Structure	Commitment Rate	Interaction Content	Interaction meaning	Network Management
Grid Computing	open	mandatory	data	no	centralized
Cluster Computing	close	mandatory	data	no	centralized
Web	open	voluntary	data	no	no
Semantic Web	open	voluntary	information	no	distributed
Knowledge Grid	open	voluntary	knowledge	no	distributed
Cloud Computing	open	voluntary	data	no	distributed
Social Networks	open	voluntary	data	has (trust)	no
CSKG	open	voluntary	knowledge	has (trust)	semantic

The CSKG is a social network composed of data, information and knowledge producers and consumers. Since all facilities are provided in form of services, users can present their facilities in form of services to the others too. Therefore, the CSKG supports interactions among different services. Besides, Users in the CSKG can be human agents or computer programs. As a consequent, the CSKG can be considered as the facilitator of information and knowledge services, while in several cases it may be actor and provide the required services. The CSKG is a proper infrastructure for interaction and also collaboration of processing components. So that, it has three main tasks: 1) data, information and knowledge storage and processing tasks; 2) interoperability tasks; 3) collaboration tasks. The CSKG is an infrastructure used by an organization just for its data and information middleware facilities, or for its social grid too.

CSKG has been analyzed due to two approaches in this paper. First, we consider it as a multiagent environment in which each user is a member of agents' network collaborating to reach a special purpose. This approach is used to answer how CSKG works, how the processing algorithms are, and also how it is guaranteed that CSKG realizes its defined meaning. Second approach shows that CSKG can be considered as a distributed system in which different system complexities are to be analyzed. This approach addresses in which infrastructure CSKG uses, what its existing technologies are, and how these technologies provide services to the first approach's algorithms. The main reasons of this classification are two main problems in CSKG. First one is self-management problem that can be solved using MAS approach. The second is that CSKG is an environment which human and machines interact in. Therefore, we use intelligent environments advances in addition to MAS approach.

4.2. CSKG Model

CSKG can be considered from three different views. In the first one, we model CSKG as a multiagent system in which CSKG users are autonomous agents. CSKG services are to be in these agents' service to realize a special purpose. This purpose is equivalent to the meaning of social structure realizing defined culture. In another view, which is perpendicular to the first one, we consider CSKG as an IT system. CSKG software components are introduced in this view corresponding to the second layer of the social structure model (figure 1), communication and shared awareness. In another word, social structure members communicate to reach shared awareness using communication structure, processing tools, and information and knowledge storage. Finally, the third view is a physical view in which three components of the last layer in the social structure model (i.e. organizational culture, roles, and resources) can be observed. This view shows how the components communicate. Relation between these three views has been shown in figure 2.

4.3. CSKG as a MultiAgent System

Through this approach, CSKG components are autonomous software agents which provide some services. We use this approach to solve self-management problem. Since CSKG has a distributed management, there is no central manager in it.

We coordinate and manage CSKG by developing a social network through social culture development approach. It means social components are put together by social culture. Basis of defining relations are not individual experiences, but different agents have a scale to show their commitment rate to social culture. Besides, social culture helps agents to trust new ones without necessity of experiences. Therefore, it allows forming larger societies. In fact, individual elements of a society would find the importance of trust, reputation, and commitment as time passes. Set of these cognitive parameters forms the social culture. Through this approach, social network get its social infrastructure from past experiences.

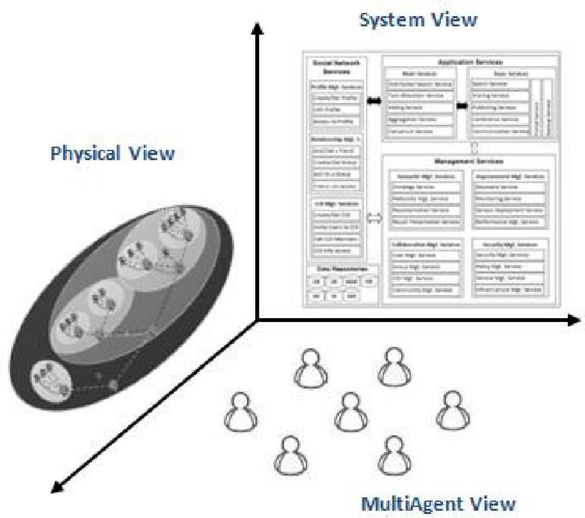

Figure 2. CSKG from different views

4.4. Requirements of CSKG

The environment, that the CSKG is used in, has some characteristics that have a direct effect on CSKG architecture. These characteristics include answering time, scalability, accuracy and quality, and reconstruction ability.

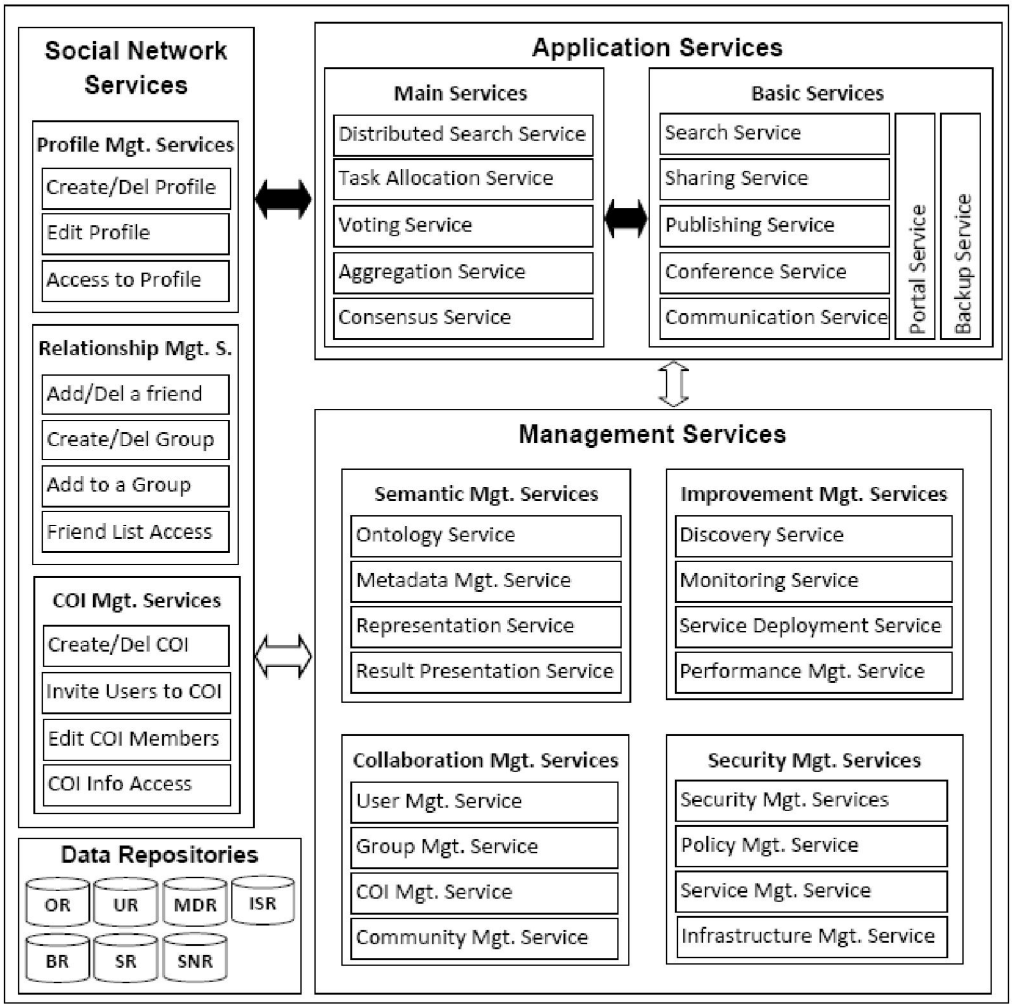

Figure 3. CSKG Architecture

5. CSKG Proposed Architecture

CSKG is a system which helps users to interact in various collaborative environments and to collaborate with each other in order to reach their goal. CSKG architecture has been illustrated in figure 3. All interactions in CSKG happen in a service-oriented context. CSKG services are divided into three groups which can be invoked directly through API or GUI and respond the requests. These three services are: Social Network Services, Application Services, and Management Services. In figure 3, there are two types of arrows. The filled arrows show orthogonal relations between services and blank arrows point to normal relations between them. The latter part means that it is just possible for some services of that group to interact with services of another one and use them.

5.1. Social Network Services

We use the concept of social networks for collaboration infrastructure and communication between users to perform various operations in decentralized environments. This mechanism provides the possibility of information and knowledge flow between users and forming communities in order to execute the requested operations in dynamic networks. Social network services respond to social network requests submitted by other services or agents which are arranged in a social network to interact. Connections in social network are established using system primary ontology.

All relevant information about social network members, profiles, friend lists, groups, COIs and defined accesses in social network level are stored in a data repository called social network repository (SNR). As illustrated in figure 3 social network services are divided into three main groups: Profile Management Services, to create, delete, edit and access to a user profile; Relationship Management Services, to manage users' connections and groups, friendship relations between users; Community of Interest (COI) Management Services, to manage COIs, which classify people with common characteristics.

5.2. Application Services

Application services are the most important services in CSKG to be. These are set of services which perform various operations to reach information and knowledge and also individual or community goals. This should be considered that these services are semantic application services.

Main Application Services: These are the most important CSKG services, which are presented in distributed environment with the various agents' collaboration. Main application services include Distributed Search Service, Task Allocation Service, Voting Service, Aggregation Service, and Consensus Service. The main application services are not limited to the mentioned services and developers can develop and add new ones if necessary.

Basic Application Services: Main application services, end user, and application programs use these services. The basic application services contain Search Service, Sharing Service, Publishing Service, Conference Service, Portal Service, Backup Service, and Communication Service.

5.3. Management Services

These services supply the possibility to control other services. Application services and social network services are under control of these ones. User, group and COI management, security, semantic, and infrastructure management services, creating new services and applying changes in services, are all to be done by management services. In addition, these services can make CSKG policies and security considerations change. Besides, they consider and monitor tasks and services and propose suggestions to improve other services quality.

Collaboration management services: These services manage users, groups, and communities of interest. Moreover, collaboration management services are used for cooperation management, and make communities of users to perform different activities. Differences between group, COI and communities are one of the key points of CSKG. Users in groups may know each other through a special place, like university or work place, or be in a family relationship, while COI users just are interested or expert in a determined issue, and may not meet o know each other before. A community is defined based on a special mission and performing a special activity. In communities, each agent chooses one or a number of tasks and performs it to reach the determined goal. To perform, main application services use community management service.

Security management services: These services manage security of users and services. They manage other services and control security in every components of system. Policy management service manages public and privacy policies which should be applied on CSKG. All services should follow policies applied by system manager. Also this service helps CSKG managers to control security and management policies. Besides, security services like authentication, authorization, access control, and encryption are provided.

Semantic management services: These are services which apply semantic to the system entities. Creating and editing ontology, their storage and management, and the possibility of definition, storage and management of metadata in CSKG, are all to be done by these services. Ontology management service makes creation and editing ontology possible. Also this service can receive a defined ontology by managers, store, maintain and manage it. Indeed, storing all system metadata is to be done by metadata management service. Any kind of data which is used in any service should register its metadata in this service.

Improvement management services: These services improve system's quality and efficiency, supervise the other services and monitor them. They propose new suggestions to the other services through performing data mining and reasoning and make services' development possible. Data and information determined by development standards (i.e. usage data) have to be sent to monitoring service by CSKG services. It sends registered data to discovery service, which is used by system developers, not normal users, to improve services. Data discovery services receive registered data from monitoring services and system policy from policy management service. Discovery services extract useful data and send it to monitoring service. Moreover, discovery services send some suggestions to the other services including management and application services to improve their functionality.

5.4. Architecture Services Relationship

Relationships between four groups of CSKG management services, social services and application services, and also system users have been shown in figure 4. Avoiding figure's complexity, details of services and relationships have not been demonstrated. Security management services are in a Request/Response relationship with all users and other services in order to provide security for them, inform other services about system policies, manage other services, and interact with system managers to manage the system. Improvement management services monitor other services performance. They

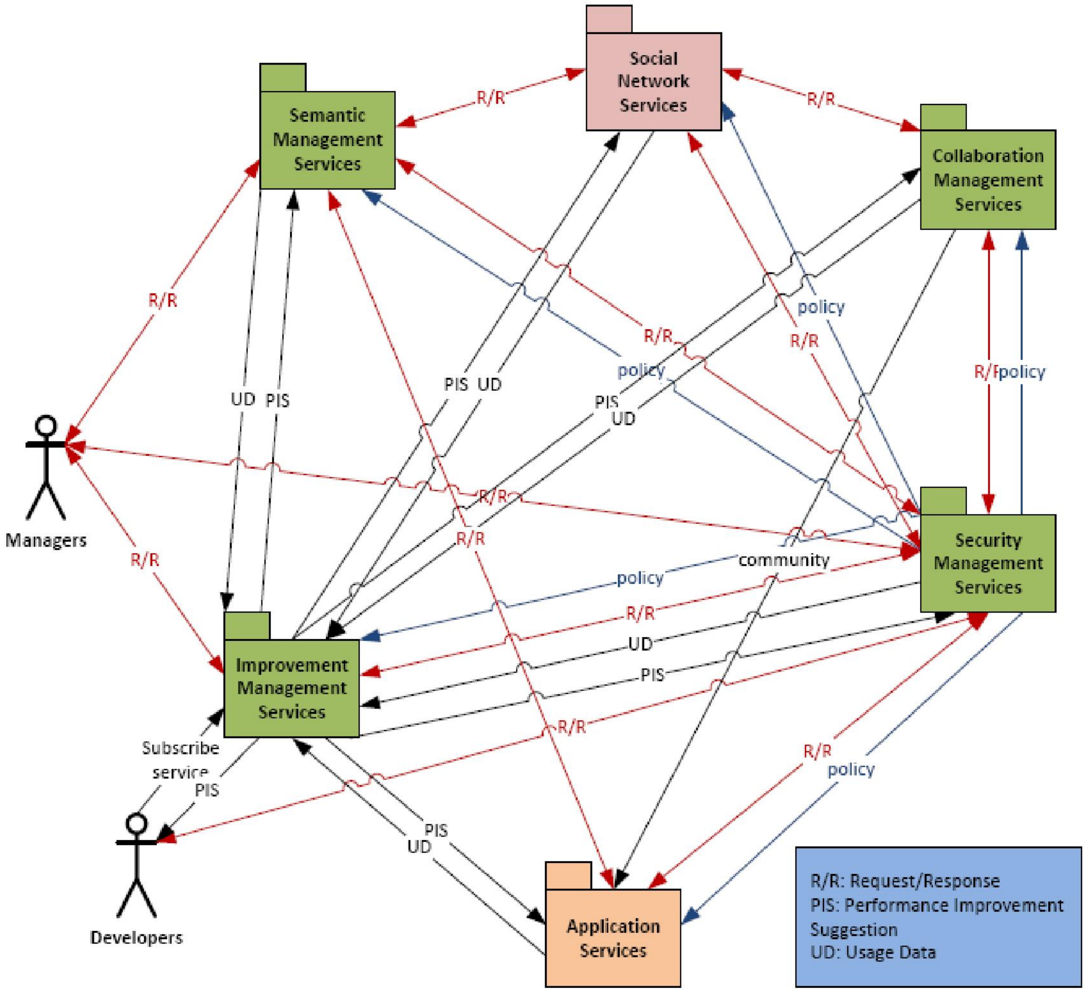

Figure 4. ER diagram of CSKG management services with other services

send some suggestions to management and application services in order to improve functionality of services (i.e. performance improvement suggestion, PIS). Service deployment service is in communication with system developers and adds and deploys new services to application and semantic services if needed. Semantic management services perform creation, editing, receiving, storage, and management for system ontology and metadata and it provides ontology and metadata for other services. Collaboration management services manage users, groups, and COIs. Social network services are in interaction with application services to receive services from them. Basic application services are invoked by main application services and other services.

6. Collaboration in CSKG

The idea to design CSKG is to decrease manager role and seek self-management in collaborative scenarios. We ask agents to work autonomously in environment. While agents are interacting and collaborating with each other, global awareness and eventually their awareness grow during time. Therefore, they can innately work in the system and know to whom collaborate. Considering semantic and social characteristics of agents and environment, like trust, commitment, reputation and etc, help them to increase their awareness and collaborate accurately and consciously.

Helped by social network services and other parameters like user profile information, social characteristics, and performance environment, CSKG collaboration management services create a community to perform an application service or a submitted activity by a user or an application program. In such community, not only people attend and supply some services, but also autonomous software agents and semantic services, which are able to do complex reasoning, play role.

Considering trust in relationships to choose people, services, and needed resources results in more efficient collaboration and combination of software and human services. We do not look at trust from security aspects, but focus on it with a social approach. The other parameter considered to form a community is commitment. Commitment is a concept extracting meaning of a couple of agents (neighbour agents) in their relationships. This concept has been set up to express promises, contracts, and tasks between two agents. We consider the concepts of trust and commitment for agents in order to have successful collaborations in a community. Agents have been described by their profiles. Each agent is in a friendship relation with one or more other agents. Groups and COIs have been composed of agents and also are able to have common members which means that each agent can be member of more than one group or COI. Different agents perform submitted activities by means of collaboration. Each agent plays a special role in this performance. To perform an activity, agents form a community based on their characteristics, relationship properties, activity's characteristics and parameters determined weight in that activity.

In addition to characteristics like age, sex, place, skills and education, each agent utilizes individual characteristics like motivation and self-accuracy, and social characteristics like trust and commitment. This should be mentioned that the two first groups of characteristics are totally individual while social characteristics are signified in agent relationships with its neighbour agent.

Profile vector Pu_i of agent u_i in Eq.1 shows the characteristics values of agent u_i which have been considered above. The att_k is the k^{th} agent characteristic and m shows number of agents characteristic.

$$Pu_i = \{Patt_{i,k} \mid k=1..m\} \qquad (1)$$

Social network of agents has been shown by an undirected graph in which every agent is connected to a number of agents through an edge as a relation. Connection between two agents of u_i and u_j has been illustrated by edges e_{ji} or e_{ij}. Characteristics like trust and commitment can be defined on a directed graph mapped to the main graph. We use a matrix of n*n to show trust, and one for commitment, to provide measure of trust and commitment between two related agents in network. Parameter n is considered as number of agents. Besides, activity A_i has an activity vector AV_i, which determines its characteristics. The activity vector characteristics are corresponding to characteristics of agent profile vector, but with different values. Moreover activity A_i has a weight vector WAV_i, which shows importance of any characteristic in the corresponding activity. These vectors have been illustrated in Eq.2 and Eq.3:

$$AV_i = \{Aatt_{i,k} \mid k=1..m\} \qquad (2)$$

$$WAV_i = \{w_{i,k} \mid k=1..m\} \qquad (3)$$

When an activity is submitted to CSKG, the similarity between Pu of initiator agent's neighbors with AV is calculated by means of weighting cosine similarity (WCS) function (Eq.4) and regarding to WAV. Then if the calculated amount exceeds a determined threshold, considered agent will be chosen for collaboration, and similarity function for that agent's neighbors will be calculated too. This process will be continued to a determined number of hops, and collaboration agents will be selected to perform that activity.

To measure collaboration among agents, using Eq.5, the average similarity of final agents chosen for the formed community with submitted activity has been calculated. In fact, this amount shows the level of agents' collaboration performing an activity. Also in this formula, *na* represents the number of agents participate to perform the activity.

$$WCS_m\,(Pu_i\,,AV_j) = \qquad (4)$$

$$\frac{\sum_{m}^{k=1} WAV[k]*AV[k]*Pu[k]}{\sqrt{\sum_{m}^{k=1} WAV[k]*AV[k]^2}*\sqrt{\sum_{m}^{k=1} WAV[k]}}$$

$$Co = \frac{\sum_{i=1}^{n} WCS_m\,(Pu_i\,, AV_j)}{na} \qquad (5)$$

To simulate agent-based complex systems, each agent has been defined by a set of important and effective parameters. Simulation softwares for multi-agent system emphasize on agent aspects and forming social patterns. We use Netlogo to simulate our collaborative environment. Netlogo 2 is a programmable modeling environment to simulate social and natural phenomenon and also social behavior analysis. This tool is appropriate for modeling complex systems variable during time. Besides, an instruction can be defined for many agents working independently. Agents, their characteristics, relationships, and community formation to perform different activities have been simulated in this environment.

In this simulation, first a social network gets form of agents. Each agent enjoys characteristics which their values are determined in time of their creation. After forming network and determining value for agents characteristics, groups and COIs are created. Agents become members in groups like family, colleague, and coworker groups. In addition, agents can become member of COIs according to their interests. Each agent can be member in a number of groups and COIs, which means that groups and COIs may have common members. We evaluate collaboration accuracy and quality, answering time, and number of collaborative agents. Besides, effect of using social and cognitive measures like trust and commitment to perform activities have been evaluated. The results of agents' collaboration showed that trust and commitment cause the more qualified cooperation to execute activities. The similarity of agents who participate in the formed communities, help to find more similar agents who understand each other much better. This eases the process of executing an activity like making a decision through consensus service. Therefore we provide an architecture which agents can interact and collaborate in a qualified, fast, and accurate manner to execute activities.

7. Conclusion

This paper has presented an infrastructure for agents' collaboration and interaction in social and collaborative environment. A model for comparison of different social and network structures has been presented and different network structures have been compared based on. Besides, we present a novel architecture for collaborative environments which agents, services and applications can interact through a standard GUI or API. We utilize SOA technologies for interaction of services, and use social network approach to communicate and collaborate human agents. SON has been used to semantically enrich CSKG architecture and update it. CSKG architecture consists of three types of services. Social network services to provide human interactions and collaborations; application services to perform the activities; and management services to manage and monitor the services, perform security and policy services, and deploy and improve services.

We investigated CSKG performance in collaborative environments. The community formation based on user profiles similarities and social parameters like trust and commitment will be argued. We proposed a method to find partner for agents. We assumed a vector for any agent, consists of its personal, cognitive and social characteristics. Besides, we introduced an activity vector and a weight vector for any activity. Then the weighted cosine similarity function has been used to compare agent vectors and activity vectors to find the right partners for any submitted activity. We simulated our approach for collaboration and showed that using social preferences like trust and commitment enhance the community formation in collaborative environments. The similarity of these agents helped to find more similar agents who understand each other much better. This eased the process of executing an activity like a consensus decision-making. Hence, we provided an architecture which agents can interact and collaborate in a qualified, fast, and accurate manner to execute activities.

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