UNDERSTANDING COLLECTIVE INTELLIGENCE OF CONSTRUCTION PROJECT ACTORS WITHIN A SOCIAL NETWORK TECHNOLOGY

Ivan Mutis, PhD / Associate Research Scientist, imutis@ufl.edu
Centre of Advanced Information Modeling, University of Florida, Gainesville, Florida, USA

ABSTRACT

The disjointed group of actors who team up to work on a project constitutes a collective entity that is represented by social networks. The advancement of social network technologies enhances the researcher's ability to understand individual and collective actions in order to effectively solve problems, make decisions, enrich knowledge, and reach consensus. These technologies enable the interfacing of actors who belong to the project network in order to facilitate the execution of project activities in collaboration. Since the aggregation of either individual or collective actors' actions constitutes project activities, this research investigates the nature of these actions within a project organization, defined as a social structure that is represented as a project network through a web-enabled social network system. The actions form and reveal patterns that are scrutinized as routines within the project organizations. Of particular interest to this research are the potential gains in the efficiency, profits, and effectiveness of satisfactorily executed routines as an aggregation of actions.
Moreover, this new kind of collective intelligence allows for the exploration of how actions performed through a web-enabled social network system may collectively act more intelligently than they have done before. It is critical, therefore, to scientifically explore actions within web-enabled social network environments through the study of routines executed by (1) single actors and (2) the aggregate of single individual actors. For this purpose, we developed theoretical constructs as framework for collective intelligence. Articulated by human-centered actions, four main constructs are involved in the framework: (1) social actors and communities of practice, (2) social structures, or organizations, (3) social objects as forms of representation of information, and (4) web-enabled social network technology. Examples of expected benefits are the facilitation of group strategies to reach decisions and control of group performance.

Keywords: Collective-intelligence, social networks, routines, social actors, communities of practice.

1 INTRODUCTION

To realize the full scientific potential of web-enabled social network environments in the construction domain is essential the assessment of the performance of construction activities. This exploration should include the technology utility and evolutions. New knowledge on collaboration requires the users' understanding of the resources, technology layers, and collaboration tools. Wikipedia, for example, consisting of thousands of contributors' collective work on layer is designed to expand concepts with minimum consensus. This research focuses on understanding the underlying components in a web-enabled social network environment for collaboration in construction projects so that actors can collectively act more intelligently than they have done before, a question that is addressed by a new kind of collective intelligence (Malone, 2010). *Actors* are human agents who have the capacity to reflect on their actions and their identities and to act according to their intentions, in this case personnel from a project organization.

It is critical, therefore, to identify project activities executed in the social network by (1) single actors and (2) by the *aggregate* of single individual actors. For this purpose, we developed theoretical constructs to serve as frameworks for collective intelligence. For the research analysis, four main constructs are involved in the framework: (1) social actors and communities, (2) social structures, or organizations, (3) social objects and forms of representation of information, and (4) web-enabled

social network technology. The routine is the basic unit of analysis that articulates the fundamental components of individual or aggregated actions. As shown and represented by the circles in Figure 1, one or more actors are associated through a social structure. They individually or collectively make decisions and subsequently perform actions that correspond to particular organization activities. The members of the organization repeatedly perform these actions that produce an effect, which in turn reveals a pattern or routine. In conceiving the recurring action patterns or routines as the central concept, there are significant implications to advance the understanding of collective intelligence. Sections 2 and 4 focus on the theoretical implications of relating social structures and routines as research constructs within the framework of collective intelligence. The emphasis is on researching social structures for the civil and construction domain, primarily construction project organizations, interfaced through web-enabled social network technology.

1.1 Main assumptions and research expectations

The assumptions in this study are that (1) the actors are rationally bounded (Simon 1996), (2) the social network technology shapes the interaction with other actors in the network, and (3) the technology changes the social practices as adopted (Oliworksi 1992). In building and associating this framework to the construction project, there are significant challenges related to the quality of the actors' participation within an activity due to the nature of the projects: (a) *the composition of the social network is heterogeneous*. Construction actors have different educational backgrounds, from architecture to engineering to vocational or technical training, as well as a variety of cultural backgrounds with diverse sets of values, individual goals, attitudes, and experiences. (b) *The actors' participation in a project is temporal but the bonds to the network are not.* Most construction project teams exist only for the duration of a single project. The specialized actors join and leave the team and project, as their knowledge, skills, and input are required.

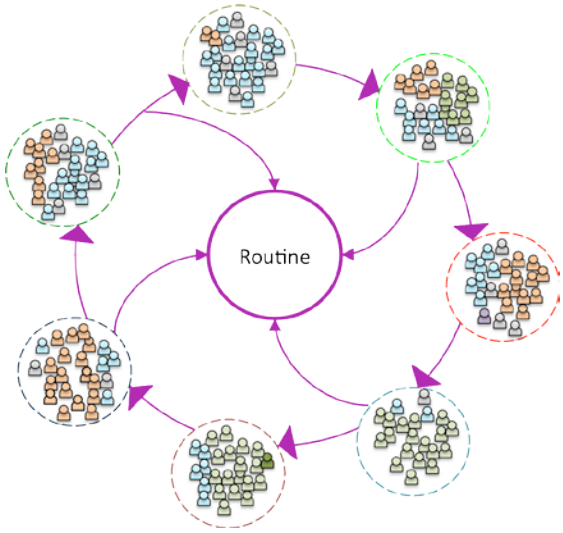


Figure 1: Individual and group actions

Based on the above tenets and challenges, this investigation will search for evidence of collective intelligence. In particular, collective actions will be explored by focusing on practices, which are engaged by humans, who are interdependent, sensitive to other social agents (Barnes 2001) and to institutional contexts. The main expectations of this research are the following:

- The identification of innovative methods of communication, new patterns to connect social actors, new social practices, new strategies, and new knowledge that arises about how a group works, to collectively reach more intelligent decisions.
- The advancement of scholarly research on collective intelligence in the civil and construction engineering domains that focus on inquiries that replace traditional methods of connecting social actors for executing business processes.
- New ways of performing project activities and business processes collectively; namely the aggregation of single actions leading to gains in efficiency, profits, effectiveness, and value generation in projects.
- Awareness of social network relationships to leverage actors' abilities to identify roles, obligations, information delivery requirement, and actors' responsibilities.

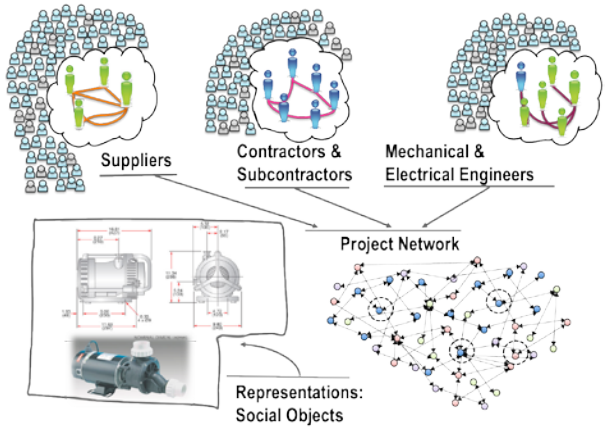
2 SOCIAL NETWORK AS A SOCIAL STRUCTURE AND TECHNOLOGY

In lieu of face-to-face meetings for construction team actors, a web-enabled mediating technology functions as an interface system that makes possible the actors' virtual meeting. This technology eliminates geographical barriers by connecting actors across a project. The mediating technology is a

social network. It is a resource to investigate the interaction of the construction workforce and technology from (1) social, (2) organizational, and (3) technological viewpoints. It enables, for example, real time data collection and knowledge discovery by capturing new contexts, variables, and units of analysis, as new social media systems provide a platform for information sharing, interoperability, and collaboration with new contexts that controlled experiments cannot adequately capture (Shneiderman 2008; Suchman 2007).

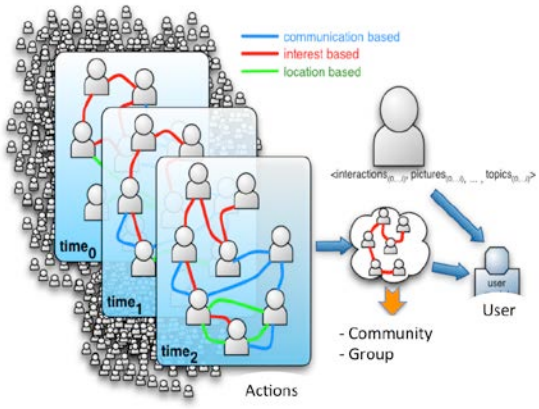
The creation, contribution, and distribution of information content, its personalization and semantic analysis, and the collaborative evaluation in a social network technology, collectively are new ways of interacting with information, called the 'social information processing' paradigm (Lerman 2008). The underlying groups of actors that form the social network are the ones that have ties around interests and expertise. In defining a social network, this investigation takes into account the social dimension of the network. This research includes this dimension in studying actors as entities of a network structure, or individual interconnected entities, or individual nodes from the network. Actors are members of one or more communities, perform individual or collective actions at different instances in teams (see Figure 2(b)), and have a role with a social dimension. For a further conceptualization, actors, teams, communities, and social objects are defined as follows:

- **Actors.** Actors are legitimized entities of knowledge, and their identity is constructed as they begin to be engaged with acts within an organization (Chia 2000). Organizations are systems of social individuals that create a social structure, while actors are social entities and can be defined as discrete individuals, units of organizations, or collective social units (Wasserman et al. 1994). Actors are linked to one another in a project through a network and organizational sets of relationships defined by common, specific project objectives. This research defines the connected actors as a *project network*. Actors will define their relationships to one another in a rich set of ties to the social network (Kadushin 2004). For example, to define the relationships within the project network, ties connect individuals and a set of individuals that structure teams in the project network (Foley et al. 2005).
- **Teams.** Construction project teams have a mixture of actors from different disciplines and communities. They have different views of seeing problems, subjects of discussion, and motivations. A widely accepted definition of team is a collection of individuals "who are interdependent in their tasks, share responsibility for outcomes…[and] who manage their relationship across organizational boundaries" (Cohen et al. 1997, p. 241). Project teams are formed as the project progresses, and get together through face-to-face settings through mediating technologies to discuss on technical issues, cost reviews, and problem-solving matters, among other motivations. They are also actively engaged in discussing the business processes of the project. The creation of project teams constitutes a surge of ties between actors, and these ties are the connections that form the social network. Actors are responsible for making decisions, and their actions within teams are alternatively executed at distributed geographical locations. Project teams' features resemble those of global virtual teams (Jarvenpaa et al. 1999; Maznevski et al. 2000; Powell et al. 2004; Shachaf 2008) and they operate as culturally diverse and geographically dispersed virtual organizations (DeSanctis et al. 1999).



(a)

Sharing *social objects* among connected communities of practice in a project network



(b)

Aggregating actions within groups and communities

Figure 2

- **Communities.** To contribute to a construction project activity, actors share their expertise within the communities with which they are associated. Communities are centers where actors engage with specific interests, constituting communities of practice (Wenger 1998; Wenger 2010). Our research considers actors as social entities, that can be defined as discrete individuals, agents of organizations (Chia 2000), or collective social units (Wasserman et al. 1994). This research views the underlying groups of actors that form the network as the ones that have ties around interests and expertise. These actors, therefore, constitute distinct communities of practice in the network. They constitute a dynamic social network, a structure composed of actors who may be human or organizations (Kadushin 2004) that have one or multiple relationships among them, as shown in the Figure 2(b).
- **Social Objects.** We understand social objects as representations that have different meanings in different social worlds, but whose representation structure (primary quality) is common in the social worlds when these objects are shared across the communities. The social objects, as shown in Figure 2 (a), are representations typically employed in construction projects, such as drawings, specifications, and project manuals.

2.1 Social Network Technology

The proposed research involves the extension of the in-house social network prototype, Floorbook, which is a web-based social networking platform that implements many of the standard features associated with modern social networking sites, as shown in Figure 3 (e.g., user login, personal profile management, friend lists, etc.), and as such is intentionally designed to be familiar to potential users.

Figure 3: Actions of the social network system

As explained in Mutis' semiotic framework (2008), there is a social dimension associated with the social objects. The in-house social network system exchanges and shares social objects that are instances of construction project documents. The assumption is that the aggregation of individual actors' interactions within a network would lead to an effect of semantic discovery of collective actions. For example, Floorbook system's purpose is to have the ability to extract semantics of the representations and of the annotations to suggest information for particular users.

Figure 3 shows two screenshots of the Floorbook network system prototype. It displays components of the system that are designed to enable collaborative processes. These components serve to coordinate and support actors' collaborations. The system has service components, which are functional for simulating the virtual project sessions.

3 COLLECTIVE INTELLIGENCE FRAMEWORK WITHIN CIVIL AND CONSTRUCTION PROJECTS

Motivated by the web-enabled cyber-infrastructure, the power to make organizations and firms execute collaborative activities through this technology is yet to be discovered. To realize the potential of the system, it is necessary to have a good understanding of how the building blocks that underlie collective activities work to make organization practices efficient and effective. Although there are multiple successful examples of collective intelligence through on the web (e.g. Wikipedia), the potential of collective actions has not yet been explored and the fundamental dimensions have not been laid out for civil and construction organizations. The challenge, therefore, is to design a framework that underlies the collective actions of the members of the community to gain efficiency and effectiveness when these members participate in civil and construction projects.

The term 'collective' as used in 'collective intelligence' refers to the condition in which anyone from a member of one or more communities can perform an action or an activity. This study focuses on communities that participate within project networks as was explained in section 2, and whose

actions are executed through the web-based network. The actors perform an action provided one of two conditions is met: (1) the voluntary or (2) the authoritative condition. A voluntary condition is one in which any member of the community decides to participate in an action at any time without been assigned such action by any other member with a position of authority mandating the execution of the action. An authoritative condition is one in which members of the community act according to their obligations and to their role within the community, obeying a well-defined social structure. Firm organizations and project organizations are examples of social structures; for simplicity we treat them as organizations in this study. The actor's participation within the organization through activities or actions is defined within hierarchical social structures. The social structure defines actors' roles and functions under hierarchical configuration, which implies authoritative distinctions. The actor's position and role, therefore, are explicitly defined within a social structure through organization norms. In the case of Floorbook, members of the community voluntarily subscribe to the social network as members, but their participation within a project has strictly defined roles. Their position in a particular task is defined by a role with the project's organization by another actor with a position of authority.

'Intelligence' is a complex concept to define since it is framed within different disciplines that include, for example, psychology, cognitive science, biology, and computer science. To give ground to this concept, this investigation associates the term 'intelligence' with the single, two-word concept of 'collective intelligence'. We generalize collective intelligence as the group performance of organization members that act collectively to execute particular actions through a mediating technology. Though the use of information technology, people and computers can be connected so that any individual or group can act more intelligently than any individual or group has ever done before (Malone 2010).

Web-enabled mediating technologies are platforms that define new identities, virtual team rules, and degrees of commitment and bonds to the team project and to the organization. These new features significantly increase the complexity to define a frame of reference in order to analyze the gains of performance with collective action. For example, consider the complexity of relative success or failure involved in satisfactorily completing a collective of actions (Hackman 2004), and the complexity of measuring the quality and quantity of these actions. Conversely, the new features originated by the web-enabled mediating technologies, which enables new value-added services, make it possible to seamlessly register the actions and self-learning from the history of user actions in order to enable new value-added services. It is anticipated that these new features will generate the potential for a new research paradigm on intelligently communicating, interfacing, and connecting actors, beyond the understanding of the performance of collective actions.

3.1 Framework Constructs and Assumptions

The ability to increase the performance of the organization through the use of web-enabled technology is what is used by this research to measure collective intelligence. Benchmarks as sources of reference are useful features to analyze the performance of the individual or group of members who participate in collective actions. Collective and individual actions are characterized by patterns within a routine, as explained in section 4.

This research takes an approach that defines a routine based on the performance of individual and group actions that exhibit patterns. The actors' performance is observed by focusing on their interaction with the environment through the mediating technology. The performance is modeled on the actor's routine, which is the minimum unit of analysis. The definition and implication of this assumption are further explained in section 4. As shown in Figure 4, there are three main constructs of this framework: (1) actor(s), (2) social structures, and (3) technology and information.

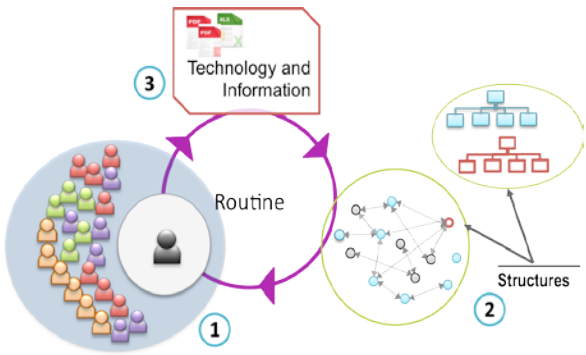


Figure 4: Components of the research framework

3.1.1 Actors

Individual actors and groups of actors are those who have been assigned the responsibilities to execute an action within a project. These actions are the result of a deliberated cognitive task that involves a decision making process. Actors are rational bounded (Simon 1991). They might fail to respond to the demands, goals, and efficiencies, among other referents, which stems from erroneous decisions. These internal conditions are cognitive and they reflect the actors' abilities, skills, motivations, and emotions to perform actions. Actors can rely solely on following procedural instructions or on obeying the learned processes to perform actions, which rationally limits their decision-making abilities (Autor et al. 2003).

The actor's ability to choose and decide is bounded to his or her environment. There are two environments where the decision arises (Simon 1996), internal and external. The external is the environment in which actors respond and recognize while making a decision. The internal environment refers to the internal conditions that make an actor deviate from the goals and demands of the task.

Central to understanding collective actions, since individual decisions directly influence group behavior, is to recognize that individual actors are rational bounded. For example, an actor or a group of actors are forced to rely upon other groups of actors. Therefore, they act under the situations and beliefs of others. Actors find consensus and coordinate the course of an action based upon the beliefs, assumptions, and work of others. In contrast, deductive reasoning derived by perfect logical process (perfect rationality) form well-defined assumptions from to other actors cannot apply (Autor et al. 2003). For example, a Project Manager (PM) is assigned to review a design that the subcontractors have previously requested. The PM builds the schemata that contain a collection of hypotheses to decide if further clarification is required. The PM relates the schemata to the opinion and assumptions of other engineers in the field. The schemata of hypotheses, for instance, are that the subcontractors' paper-based representations are not up-to-date, and that these documents do not have all the information delivered by the design-engineering firm. Deciding upon searching for additional information to clarify the versions of the document with the subcontractors or performing a request for the engineers depends on the PM's beliefs and subjective assumptions. The weight of the value of other actors' input is an example of the belief that the actors' rationality dictates. For instance, the PMs probably rely on the hypotheses built on plausible experiences, rather than considering only the associated costs of performing this particular action, such as getting the approvals to create an electronic requirement within the workflow system.

From the above explanation, we can observe that actors who participate in the actions do not act on economic rationality (e.g., inquiring which one of the solutions have the least cost), but actors look for the most plausible, credible, and profitable hypothesis. This assumption is central since the decision maker and performer will build on future decisions and actions from other members of the virtual team and project participants. The web-enabled mediating technology that connects these actors should have the ability to record poor and good performances of the resulting actions and the schemata of hypotheses. Actors will build on previous experiences even though the hypotheses taken were not the correct ones. One of the characteristics of the web-enabled mediating technology, therefore, is that a set of hypothesis and the actions taken evolve to a new state where other members of the community act upon those decisions. For example, Wikipedia users who collaborate within a community build their editions on previously written editions from which other members have given their input about a particular concept or topic.

3.1.2 Social Structures

The social structure construct refers to the relationships of group of actors or individual actors that define to some extent the actions among them, and in this particular framework, through the information technology (see the second construct in Figure 2). Construction firm organizations, project organizations, and social networks are examples of these structures. Within the structures, actors have expectations for each other's roles and actions (López et al. 2000), and a basic understanding of the interconnection and position they have. Conversely, there are also multiple instances when the structures are not defined explicitly. In this case, the actors' actions with the technology are required to

uncover or to evolve the implicit structures into new dimensions, from a non-explicit social structure to an explicit structure.

Social networks have a flexible structure in their composition (unintended and intended interconnections, and interdependencies) and present an array of social structure patterns. The social network ties can be defined dynamically according to environmental contexts and other actor properties (e.g., the attributes and expressions of identity to which members identify themselves to a community of practice). The environmental context, for example, is defined by the status of an actor within the organization, which generally is expressed by the organizations normative. This construct is based on the Adaptive Structuration Theory (AST) (DeSanctis et al. 1994; Giddens 1984; Orlikowski 2000); this template is employed to understand: (1) the social structures that emerge from actors' actions with the use of technology, (2) the organizational changes as technology is used, and (3) the changes in the work practices.

3.1.3 Technology and information

The third construct represents the actors' medium for decision-making through technology and information. This medium is used to further perform actions, including governing within the social structure and manipulating information. The technology and its resources are brought into action along with the users' social structures. These actions are the actors' responses toward the technology, and they reflect the reactions to the technology rules and constraints (DeSanctis et al. 1994). Typical uses of technology are integration, sharing, and exchanging information. These actions, therefore, reflect either the good or poor understanding of the reasons and purposes of both the technology and the information. The understating reveals the control and meaning actors have of their external environment.

The information as a component of the framework is defined by properties of form, procedure, and structure. For example: a database is defined by its constraints, a workflow is defined by it procedures, and drawings and visualizations are images and symbols of form. The representations of information are social objects, as was stated in section 2.1. The properties that define the technology construct are associated with the (a) capabilities and (b) resources. For example, capabilities and resources of the social network technology involve the ability to search and connect project actors and other social network members, to annotate, to organize meetings, and to retrieve, index, and store documents. The resources are semantic annotations and synchronous and asynchronous dialogs.

This third construct embraces the description of a mediation process between the technology and the actors. For instance, there is a mediation activity on processing, computing, and facilitating the accessing, retrieving, and searching of information. Other mediation activities also connect users, which is the case of the web-enabled social networking system.

4 ROUTINES

Conceived as an analytical concept that defines patterns of actions performed by individuals or groups of actors within organizations, this research uses routines to explore a new understanding of collective intelligence for construction projects through the use of web-enabled mediating technologies. Routines are collective in nature since they take place within social organizations that define the actors' collective objectives. Routines are aggregates of low-level actors' decisions that are instantiated through actions within the social organization. We recognize that in the creation of these *aggregates* of decisions, each individual actor contributing to the aggregate is aware of the existence of alternative decisions in addition to his or her own. The existence the actors' condition of independency (e.g. actors independently decide) is prerequisite to the *aggregate*. The condition of independency remains even when the actors have to be bound by a group decision, including the actor decision(s) that are in disagreement with one of the group. This research discounts the practicality of the analysis when individual, independent actor's decisions are not aggregated but are *independently* collected in construction project organizations.

Routines can be identified by abstract patterns and actors' actions that typically involve information processing activities. Routines are traditionally defined in two separate distinctions. The first define routine as recurring analytic patterns of complex automatic behavior performed by

individuals in organizations (Cohen 2006; Winter 2006). The second defines routine as understanding of decision rules, analogue as procedural rules in artificial intelligence. Organization actors refer to these rules as a guide to perform and shape the organizational behavior.

This research takes a complementary approach by recognizing abstract patterns in a dimension of performance, according to the aforementioned conditions. In this research and in sharing the multilevel perspective of routines of Salvato and Rerup (2010), routines take place within two basic levels: (1) low level, at the individual level, and (2) higher abstract level, at the organization level, as illustrated in Figure 5.

At the individual level, routines are strongly influenced by the actors' habits and skills. Individuals or groups of individuals have associated competencies that determine how the project activities objectives will be achieved. At this level, actors rely on habits and skills to execute actions and to make decisions. These individuals choose the scheme they need to follow. In deciding the course of action, they capitalize on taking prior choices and deliberately recognize rules and protocols defined by the normative structure of the organization. Therefore, their performance at an individual level or group level is influenced by the external environment, (e.g., normative context and historically recorded information), and the internal environment (e.g., beliefs, motivations), since actors are rational bounded. The patterns of actions in the virtual team within a project are examples of low-level routines within the organization of the project. At the organizational level, these patterns of actions are analyzed according to the organization's rules, procedures, and objectives, among other patterns of relations in a given structure or organization.

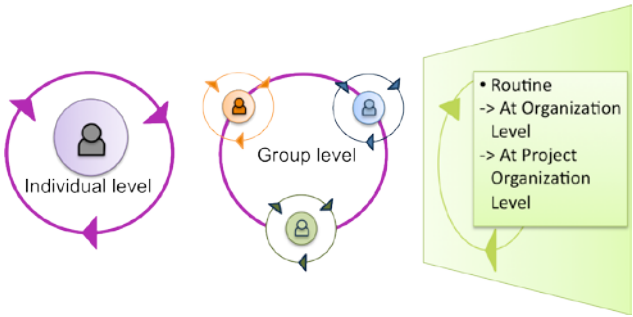


Figure 5: Patterns of actions

4.1 Routines and Construction Business Processes

Although the actors repeatedly want to be rational and they take precautionary actions as a form of limiting the damage that they do, deciding to perform an action is deference to rationality in deliberated decision-making (Elster 2007). There are frequent and inevitable lapses due to the actors' propensity to make mistakes. As was also explained in section 3, actors are rational bounded and their ability to choose and decide is limited to their environment. The challenge therefore is to contest actions in a way that satisfies the goals of the project's organization. One approach is to strongly follow a normative appeal through well-established *business processes* within the organization, which is the traditional method. Alternatively, to respond to the challenge described above, *business processes* are leveraged with gains in efficiency, profit, effectiveness, and value generation, by taking advantage of a web-enabled technology and the supported services and resources. This approach consists of but is not limited to:

(1) Searching for skilled and motivated personnel from the communities of practice. Web-enabled technologies connect members of the communities of practice and allow the rapid and effortless search of the members of their communities according to specific properties, including their level of expertise, geographical locations, and historical record of performance. The technology enables the anticipation of the actors' required resources and skills.

(2) Prompt access of records of previous decisions at the organization, project, and team levels. The availability of this information increases the actors' awareness and learning. To exemplify this particular strategy, this research's proposed social network prototype has the ability to record previous decisions from virtual meetings. This information is organized in a database to allow actors to query historical decisions by subjects.

(3) Engaging other motivations to collaborate within the business processes rather than contractual obligations. For example, members of a community can be invited to collaborate in virtual meetings to provide their input and expertise regarding a pending decision or a problem. The community member's motivation might be, for instance, the promotion of the organizational

services. Technology provides a new medium to faster pursue specific goals and directions of the organizations that belong to the communities of practice.

(4) Facilitating group work strategies to reach decisions, including group decisions such as voting, consensus, and predictions. The technology enables virtual teams to use these strategies to effortlessly arrive at group decisions, especially in heterogeneous populations of actors with markedly different viewpoints and backgrounds.

(5) Leveraging the ability of actors to search for and retrieve information. Additional information leads the actors toward better-informed decisions.

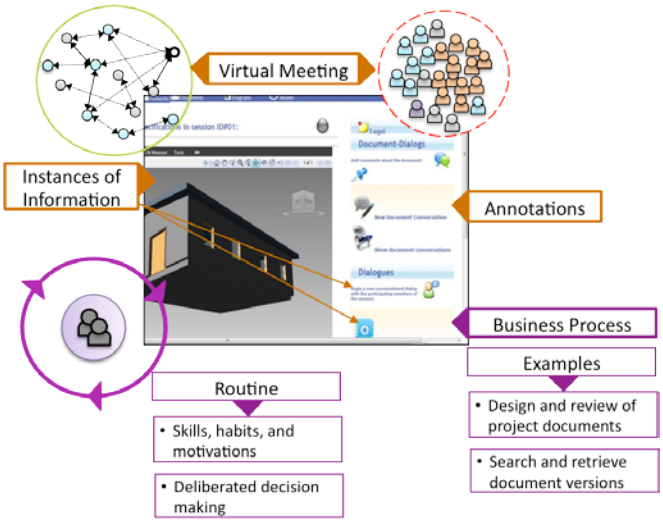


Figure 6: Business process

To illustrate the approach and to have a better understanding of collective intelligence in construction project organizations, consider a design and review of project documentation, as illustrated in Figure 6. This example goes beyond the analysis of a business process and scientifically approaches collective intelligence through the study of routines within an enabled web social network environment. Figure 6 shows a screenshot of this research social network prototype of a virtual meeting where construction project actors from the project network are invited to participate. The shown instances are the annotations of a 3D representation of a design. This representation is a section of the project documentation and is a social object of the network. The sets of scripts are asynchronous dialogs of the virtual session. Instances of the set of scripts of the participants' comments in the virtual session are also shown. In contrast to the traditional design and review documentation business process, virtual team participants are able to make better informed decisions, and with the input and support of a wide range of motivated experts. For instance, actors deliberately recognize additional implications that involve a design change which have to be recorded to originate a Request for Information (RFI). It is expected therefore, at an individual level or a group level in the virtual team, to have better performance in executing actions, since internal and external environments positively influence actors. In researching collective behavior performance, it is central to study the influence of these contextual factors. Through a mediating technology, such as the web-enabled social network, actors experience context and they have the ability to interface with each one of the contextual factor in new way of accessing information and connecting with members of the network, to deliberate and make their choices. The affinity for other individuals in their relationships, and the weight of their input and motivations are examples of the conditions and features that the social network technology supports (Malone et al. 2010).

The benefits of this approach can also be identified at the project organizational level. For example, the aggregate of individual actions generates a pattern of a routine in a project organization whose resulting performance is poor or deficient according to the project organizational objectives. The identification of this performance raises questions for project management since actions to control errors or reduce the negative feedback at the project level might be urgently required.

5 CONCLUSIONS

In sum, the members of the organization repeatedly perform actions that produce an effect that reveals a pattern or routine. In conceiving the recurring action patterns or routines as the central concept, there are significant implications to advance the understanding of collective intelligence. The resulting patterns of the aggregate within organizational entities suggest a new way of understanding the dynamics of low and high levels of entities within construction organization. The use of a social

network technology builds a collective intelligence research environment to understand individual and collective actions in order to effectively solve problems, make decisions, enhance knowledge, and reach consensus.

REFERENCES

Autor, D., Levy, F., and Murnane, R. J. (2003). "The skill content of recent technological change: an empirical exploration." *The Quarterly Journal of Economics*, 118(4), 54.

Barnes, B. (2001). "Practice as collective action", (1) in *The practice turn in contemporary theory*, Ch. 1, T. R. Schatzki, K. Knorr-Cetina, and E. v. Savigny, eds., Routledge, London ; New York, ix, 239 p.

Chia, R. (2000). "Discourse Analysis Organizational Analysis." *Organization*, 7(3), 513-518.

Cohen, M. D. (2006). "What's different is routine." *Industrial and Corporate Change*, 15(2), 387-390.

Cohen, S. G., and Bailey, D. E. (1997). "What Makes Teams Work: Group Effectiveness Research from the Shop Floor to the Executive Suite." *Journal of Management*, 23(3), 239-290.

DeSanctis, G., and Monge, P. (1999). "Introduction to the Special Issue: Communication Processes for Virtual Organizations." *Organization Science*, 10(6), 693-703.

DeSanctis, G., and Poole, M. S. (1994). "Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory." *Organization Science*, 5(2), 121-147.

Elster, J. (2007). *Explaining social behavior : more nuts and bolts for the social sciences*, Cambridge University Press, Cambridge ; New York.

Foley, J., and Macmillan, S. (2005). "Patterns of interaction in construction team meetings." *CoDesign: International Journal of CoCreation in Design and the Arts*, 1(1), 19 - 37.

Giddens, A. (1984). *The constitution of society : outline of the theory of structuration*, University of California Press, Berkeley.

Hackman, R. J. (2004). What Makes for a Great Team?, American Psychological Association, Washington, D.C., Accessed, January, 2011

Jarvenpaa, S. L., and Leidner, D. E. (1999). "Communication and Trust in Global Virtual Teams." *Organization Science*, 10(6), 791-815.

Kadushin, C. (2004). Introduction to social network theory, Accessed, December

Lerman, K. (2008). "Social Information Processing in News Aggregation." *IEEE Internet Computing*, 11(6), 16-28.

López, J., and Scott, J. (2000). *Social structure*, Open University Press, Buckingham England ; Philadelphia.

Malone, T. (2010). MIT Center for Collective Intelligence, Cambridge, MA, Accessed, January, 2011

Malone, T., Robert, L., and Chrysanthos, D. (2010). "The collective intelligence genome." MIT Sloan Management Review, MIT, Cambridge, MA, 10.

Maznevski, M. L., and Chudoba, K. M. (2000). "Bridging Space Over Time: Global Virtual Team Dynamics and Effectiveness." *Organization Science*, 11(5), 473 - 492.

Orlikowski, W. J. (2000). "Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organizations." *Organization Science*, 11(4), 24.

Powell, A., Piccoli, G., and Ives, B. (2004). "Virtual teams: a review of current literature and directions for future research." *SIGMIS Database*, 35(1), 6-36.

Salvato, C., and Rerup, C. (2010). "Beyond Collective Entities: Multilevel Research on Organizational Routines and Capabilities." *Journal of Management*, 37(2), 468-490.

Shachaf, P. (2008). "Cultural diversity and information and communication technology impacts on global virtual teams: An exploratory study." *Information & Management*, 45(2), 131-142.

Shneiderman, B. (2008). "Computer Sciecne: Science 2.0." *Science*, 319(5), 1349-1350

Simon, H. A. (1991). "Bounded Rationality and Organizational Learning." *Organization Science*, 2(1), 125-134.

Simon, H. A. (1996). *The sciences of the artificial*, MIT Press, Cambridge, Mass.

Suchman, L. A. (2007). *Human-machine reconfigurations : plans and situated actions*, Cambridge University Press, Cambridge ; New York.

Wasserman, S., and Faust, K. (1994). *Social network analysis : methods and applications*, Cambridge University Press, Cambridge ; New York.

Wenger, E. (1998). *Communities of practice : learning, meaning, and identity*, Cambridge University Press, Cambridge, U.K. ; New York, N.Y.

Wenger, E. (2010). "Communities of practice and social learning systems: the career of a concept", (Chapter 11) in *Social learning systems and communities of practice*, Ch. C. Blackmore, ed., Springer, London, xv, 225 p.

Winter, S. G. (2006). "Toward a neo-Schumpeterian theory of the firm." *Ind Corp Change*, 15(1), 125-141.