AWARENESS IN PROJECT INFORMATION SPACES FOR IMPROVED COMMUNICATION AND COLLABORATION

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Abstract: The paper argues that facilitating timely and contextually grounded communication could help improve both coordination and decision making / problem solving in the construction project process. The paper discusses the authors' previous work in construction IT, as well as related literature, and the findings that have led to the development of a framework for awareness of activity in project information spaces. A detailed description of the conceptual model and software architecture of the proposed resource awareness framework is given, followed by directions for future research.

1 INTRODUCTION

Lack of communication and coordination has often been cited as a cause of problems in the construction project process (Latham 1994, Egan 1998). Researchers have deployed information technology to ameliorate the detrimental effects resulting in a history of tools aimed at the management of project information. These tools have focussed on the versioning and consistency of information across projects and have culminated in the development of project extranets and building information modelling. Some initiatives have taken a knowledge oriented approach in an effort to improve the communication of information within projects, whilst others have looked into organisational issues in order to model the structures and processes typically involved in a construction project and how they may be supported with IT. The authors have undertaken research work in all of these fields and this paper reports on ongoing research extending this work into more pro-active support for interpersonal communication within construction projects. The aim of the research is to facilitate communication at opportune moments and assess whether or not such facilitation can further improve coordination and decision quality and creativity in the project process.

2 BACKGROUND

The authors have conducted research into the management of information and its alignment with the project process and on ways and means of using that information in a distributed or virtual team setting (Boddy et al., 2007). This work has spanned a number of funded projects beginning with the Commit project, which defined an information management model (The Commit Information Management Model or CIMM) for construction projects. The CIMM featured constructs for information versioning, ownership, rights management and decision tracking (Rezgui et al 1998).

Following on from Commit, the Advanced Decision Support (ADS) project extended the

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CIMM with elements for interoperation with common desktop applications via a plug-in adapter architecture. ADS placed particular emphasis on the information versioning and dependency tracking aspects of the CIMM culminating in software for the recording of versions and the rationale for the changes made in particular versions of information elements (Cooper et al 2005).

With the OSMOS project, information was viewed more as a collection of semantically linked resources and we also started the move to a service oriented platform for virtual team support. A model for instantiating and running a virtual team, The Generic VE Process Model (Rezgui, 2007a; Rezgui 2007b), was created as the conceptual framework around which the services were specified and implemented.

The e-Cognos project developed the semantic linkage elements further. Automated creation of links was integrated into the platform with the aim of mimicking some of the knowledge socialisation processes in groups. This yielded a system which implicitly identified and supported knowledge communities within the user population. The system also provided services for maintenance of information (versioning, change notification etc) and for push and pull of information around the system (subscribing to information, flagging to interested parties etc) (Wetherill et al 2002).

Each project created a software demonstrator, which was evaluated with its industrial collaborators. The evaluations yielded feedback with common themes around information maintenance in the guise of tracking and transparency of activity in the project process. For example, the e-Cognos evaluation revealed that this type of functionality, including real time information on current project activity, was rated as moderately to highly important (e-Cognos 2002), though the e-Cognos software only met such goals at a very basic level. The field trials for the ADS software validated the activity and decision rationale records kept as a valuable aspect of information management. Evaluators noted however that more could be done with the information captured. We concur and believe that by further exploiting the mechanisms by which the ADS software captures activity, we can improve the real-time information management capabilities of our research outputs. If we can leverage that information in rendering the ongoing state of project activity more transparent to those working within it, we believe we can facilitate interpersonal communications that take place at appropriate times and within the context of related aspects of the project work. Such timely and contextually grounded communication we believe may help to improve both coordination and decision making/problem solving in the project process.

3 THE SOCIAL DIMENSION OF COLLABORATION

In light of our aim to support timely and contextualised communication and collaboration, we started thinking about the social structures and processes involved. In the authors' experience, it is at the boundaries between disciplines within construction projects that the most crucial collaborations occur. These boundaries are typically also organisational and knowledge boundaries defining the physical and social groupings of individuals and resources within a project. Coordination in construction projects is a problem primarily of resolving differences at the social, organisational and physical system boundaries. The resolution and successful integration of physical system interface issues comes about as a result of collaboration at the discipline or social interfaces by explicating and transforming the knowledge in the discipline groups across the boundaries between them. The literature on collaboration, particularly collaborative design, has much to say about the boundaries between the various socio-technical groupings involved in the design process. Star (1989) introduced the concept of boundary objects, which are physical or conceptual artefacts existing at the boundaries between communities, but which span those boundaries to become the shared context through which the communities can collaborate. Studies conducted into the formulation, use and effects of boundary objects, a number of them taking the construction industry as their knowledge domain, have been conducted. Gal et al (2004) for example, in their research into the effects of boundary objects on the constitution and identity of social groups within processes identified CAD files, both 2D drawings and 3D models, as crucial boundary objects in a construction context.

Other research into collaborative design environments has highlighted the need for them to be open and transparent to enable a creative and productive discourse. The research into Communities of Practice (COP (Wenger 1998)) has illustrated the ways in which interactions within a community influence the generation and sharing of knowledge associated with the practice. Fischer et al (2005) cite the potential of Communities of Interest (COI) for increasing creativity in design problem solving. A COI shares some characteristics of COP, but is generally comprised of a broader spectrum of individuals from differing professional and social backgrounds. The common interest is the pursuit of a particular goal (such as a project) rather than the sharing and development of knowledge in a particular sphere of practice. Thus a COI, encompassing a broader spectrum of knowledge can stimulate different solutions to problems than would have been likely with individuals or single discipline groups. All of this has resonance for construction projects where to some extent decision making but particularly coordination, tend to be distributed activities that could benefit from timely communication between those involved.

4 COLLABORATION, AWARENESS AND WORKSPACES

In addition to boundary objects, our investigations into previous collaboration research from a social standpoint have emphasised the importance of openness and transparency in successful collaborations (Fischer et al 2005). Erickson and Kellog have written on what they term 'social translucence', and cite the essential characteristics of socially translucent systems as:

- Visibility – the visibility of socially significant information
- Awareness – of the presence and/or actions of others
- Accountability – for one's own actions in the context furnished by visibility and awareness

(Erickson & Kellogg 2000)

They argue that systems exhibiting these characteristics can help to replicate social cues we rely upon in interpersonal communication in a digital context. Visibility and awareness have been research themes in the field of computer supported cooperative work (CSCW) for some time and some of the early outputs employ mechanisms that Dourish & Bellotti (1992) refer to as Role Restrictive. Here a person's role within a system implies information about their likely activity within the system. Roles however are rejected as rather limited as an activity awareness mechanism as they only furnish information about the "*character* of the activity, not the *content*" (Dourish & Bellotti 1992). Another mechanism, the Informational mechanism, is identified wherein the users of a system are responsible for creating and distributing information for the consumption of other users. Again this is rejected as too burdensome on the users of the system. Because the content and delivery of awareness information is controlled by the producer using these mechanisms, what is received may be neither relevant nor timely in the context of the receiver. Dourish & Bellotti propose a mechanism they term Shared Feedback wherein the system itself monitors and redistributes information about the activities of users. The proposal allows users of the system to negotiate their activities as appropriate to the current context and objective such that a user may fulfil several different functions throughout the course of the collaboration.

Concurrent with Dourish and Bellotti's work, Benford and Falhen (1993) were researching the notion of awareness in virtual reality spaces. Their work resulted in the influential Spatial Model of Awareness used to establish the level of mutual awareness and potential for interaction between objects in a virtual space. The model employed several factors in its calculations:

- Space, Objects and Medium – Space is the entire volume of the virtual world. Objects are the artefacts populating that world. Medium refers to the interfaces through which interactions between objects in the space occur.
- Aura – Defined as the part of the space (sub-space) that bounds an object with respect to a particular medium and determines the extent of its presence within that medium. Two aura must collide for any interaction to be possible
- Focus, Nimbus and Awareness – Given a collision of auras, Focus and Nimbus determine the level of interaction in a given medium:
    - Focus is directed attention from an object A to an object B – "the more an object (B) is within your (A) focus, the more you are aware of it." (Benford et al 1994).
    - "Nimbus is a sub-space in which an object makes some aspect of itself available to others" – "The more an object is within your

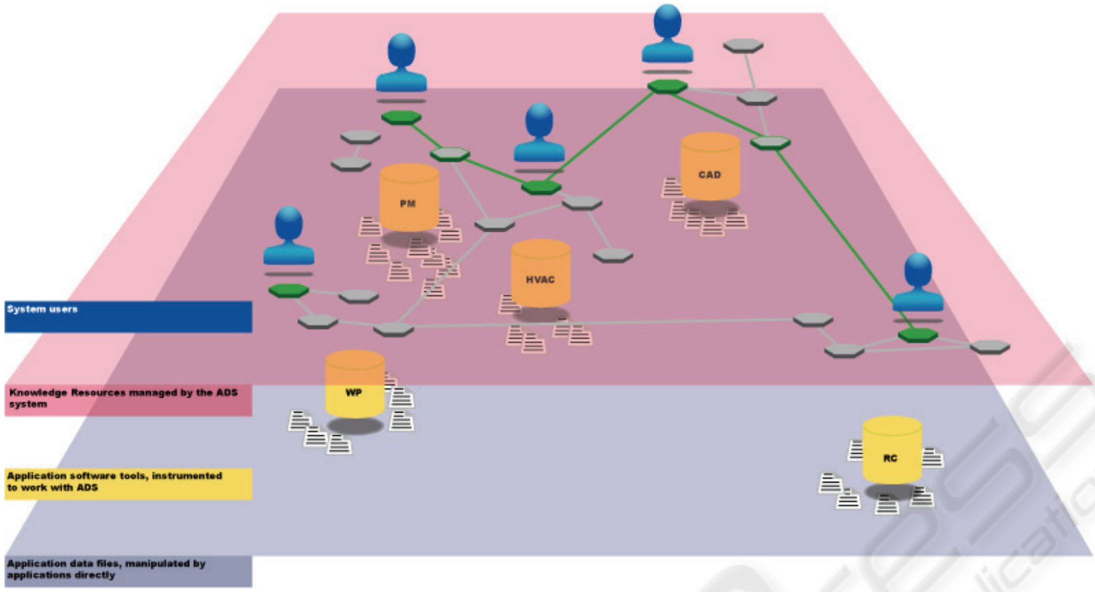

Figure 1: Framework Conceptual Model.

> nimbus, the more aware it is of you." (Benford et al 1994)

The spatial model has found application in a number of experimental VR environments over time.

Gutwin & Greenberg (2001) investigated groups collaborating through shared workspaces as part of groupware applications. They defined a general framework of issues to consider in the design of awareness systems. The framework identifies three broad areas of concern:

- The components of awareness – The essential information for awareness in a shared group workspace? Basically the *who, when, where and what* of the activity in the space.
- The maintenance of awareness – How to collect and present that information and keep it up to date.
- The use of awareness in collaboration – When and where to present that information, based on observation of where awareness information is normally used.

This research has value as a guide for thinking about the requirements of any system to provide awareness information, a guide which has informed our thought processes in formulating our proposals.

We believe that monitoring activity on informational resources that form potential boundary objects may help to identify opportune moments to facilitate communication. We can leverage derived relationships between objects to identify people who are working on related aspects of the project at the same time and thereby facilitate them in communicating and collaborating to achieve better coordination and decisions in their work.

5 PROPOSED FRAMEWORK

The conceptual framework for our system to leverage potential boundary objects in facilitating communication is described below. Figure 1 shows the general concept of our system, which is based on the resources involved in or created and manipulated in a construction project. These are the resources some of which would typically constitute the boundary objects for collaboration in the project in the traditional sense, certainly during the design stages. They are also the objects the production of which is directly related to the level of activity and progress apparent in the project process at any given time. Thus reporting on activity on these objects makes the process more transparent to those involved in it.

The diagram comprises four layers from the bottom as follows:

1. Application data layer – this layer represents the digital data of a project. Objects in this layer are those that are often cited as boundary objects in the literature.

2. Application software layer – this layer represents the actual tools used to create and manipulate the data at layer 1.
3. Resource abstraction layer – this layer represents a set of abstract representations of the data at layer 1. The lines between items in this layer represent relationships between them, which are automatically created by the system
4. User layer – this layer represents the system users.

As a user works with their applications the system tracks the interactions and records which resources are involved. This tracking is performed for all users of the system constantly, thus the system knows who is working with what at any given moment. If the system finds that two related resources are being manipulated by two different users concurrently, it will inform those users of each other's activity on the basis that a relation between resources may indicate a need to coordinate the work. The system thus provides a context within which the users can decide if they need or want to take action. Our framework then, employs a mechanism similar to Dourish and Bellotti's shared feedback (Dourish and Bellotti 1992), but subsequently applies a filter based on the relationships between resource abstractions. The abstractions themselves could be said to be candidate boundary objects for collaboration.

6 RESOURCE AWARENESS ENVIRONMENT

Our implementation of this proposal is partly based on previous research work carried out at the University of Salford (with partners) under the auspices of the ADS project. The ADS software architecture featured a core for the management of version information, augmented with plug-ins that allowed the core to interoperate with standard software applications. It is in the plug-ins that the level of granularity of information item to be handled is set. The level could be the entire data file handled by an underlying application, or it could be some object defined by the object model of the application, or any stage in-between. This allows for flexibility in implementing plug-ins for different applications and types of data/information. A plug-in is responsible for triggering notifications to the ADS core that a user is performing an action that changes information items in a way that we are interested in recording. It also sends metadata to the core about what changed, what information items were involved, who made the changes and when and allows the user to provide an explanation of the rationale for the change. Thus ADS already records for us most of the information that Gutwin and Greenberg defined as the 'components of awareness' (Gutwin & Greenberg 2001)

We have augmented the ADS software architecture with new modules dedicated to the creation of resource abstractions and links between those abstractions. Each of these modules also works on a plug-in system whereby it is possible to register plug-ins that 'understand' different types of resources, or different ways in which to create abstractions of a resource. For example, our initial implementation of an abstraction module is based on simple keyword extraction and indexing. Likewise, our first link creation module uses search techniques on the keyword index to create links between resource abstractions. We are aware that this is a very naïve implementation of our activity awareness concept as it may produce links between resources that have relatively little to do with each other in real terms. At this stage in the development however, we have been more concerned with developing the framework than the details of individual abstraction mechanisms. As the research is carried forward, more sophisticated abstraction and linking mechanisms will be developed, with those handling geometric data perhaps having the greatest promise for finding genuinely related parts of the construction project based on the evolving building model where one exists.

We have altered the software architecture of the original ADS system in other ways. Firstly, we have created a server-based core to the system, which communicates with an ADS client application on each user's local machine. It is this client application that handles interaction with user application plug-ins. We have chosen this route to take some of the processing load off of the server and also to reduce network traffic to some degree. As such the system now comprises of a core, a local client at each user's machine and a number of application plug-ins, also at each user's machine. Of course, in this enhanced version of the ADS software, application plug-ins take on a broader range of functions. In particular, a plug-in must now be designed to show activity notifications using UI elements judged to be most appropriate to the application being instrumented to work with ADS.

7 CONCLUSIONS

This paper has discussed the authors' previous work in construction IT and the findings that have led us to develop a framework for awareness of activity in project information spaces. We have reviewed a sample of the previous research work in the areas of collaboration and workspace awareness that has informed our thinking on the conceptual underpinnings of our framework, particularly issues related to boundary objects and how they may be leveraged to actively promote timely communication and collaboration, and then function in their normal role as the context for that communication and collaboration. We have gone on to describe the conceptual model and software architecture of our framework in more detail such that its operation can be understood.

As we have already alluded to, this is a report on ongoing research and as such we envisage future publications detailing the results of field trials amongst industrial collaborators. Further, we intend to research and develop more sophisticated methods and modules for resource abstraction and relation building, particularly modules dealing with spatial information of the type embedded in building models such that we can 'locate' people's current activity relative to the geometry of the evolving design.

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