A Planning Process Model for Computer Supported Cooperative Work in Building Construction

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1 Introduction

Common planning strategies in building construction are usually based on a sequential approach where individual project partners cooperate mainly to exchange results. The main purpose is not to jointly to develop project goals and objectives. For each individual project partner, this typically results in a very limited view on the overall project. Based on this fact, early design stages are usually the time where wrong decisions are made and not recognized. In later design stages those wrong decisions are almost impossible to correct.

Because of the continuously increasing complexity of today's buildings, a high level of integration in the planning process is needed. This means that each group or individual participating in the design process needs to cooperate effectively in a goal oriented manner. Only a goal oriented view, essentially holistic in nature, guarantees the successful completion of all tasks involved in a project. This becomes obvious if we look at the design process as an iterative process composed of the stages: analysis, synthesis, and evaluation [Schön 1983].

Since solving problems through the cooperative efforts of individuals within one group or several groups is fundamental to any planning endeavor, the planning process can also be seen as a social process [Fitzpatrick at al. 1994]. While working on a project, the degree of collaboration among team members varies widely. During activities which involve intensive information interchange and cooperation, it is important to recognizes the parallel, rather than sequential, nature of information flows. This approach raises concerns relating to the ability of a group of individuals to function as a coherent entity with collective intelligence, rather than a collection of independent individuals [Smith 1994]. Therefore, an important requirement for the achievement of a state of collective intelligence is a high rate of information transfer among individual team members. Also, the ability of individual team members to quickly adjust themselves to changing conditions is crucial in order to optimize time constraints, quality standards and cost.

The approach of solving problems through the cooperative efforts of individuals within one group or several groups has become fundamental to most planning, design, management, and other decision making endeavors. The design process can therefore also be seen at as a social process [Fitzpatrick et al. 1994] in which the degree of collaboration among team members varies widely from loose to close. It is important to recognizes the parallel, rather than sequential, nature of information flows and the advantages of decentralized problem solving activities. At the same time this approach raises concerns relating to the ability of a group of individuals to function as a coherent entity with collective intelligence, rather than a collection of independent individuals [Smith 1994]. An important requirement for the achievement of a state of collective intelligence is therefore a high rate of information transfer among individual team members. Also, the ability of individual team members to quickly adjust themselves to changing conditions is crucial in order to optimize time constraints, quality standards and cost.

The focus of this paper is the introduction of a planning process model, based on the principles of integrated planning. In the future, the process model is aimed to provide the background for the implementation of a computer supported cooperative work (CSCW) platform. The paper covers results of the research project INTESOL which is jointly undertaken by the Institut für Industrielle

Bauproduktion (ifib) at the University of Karlsruhe and other partners [http://ifib41.ifib.uni-karlsruhe.de/Intesol/index.html]. Only issues related to the planning process model will be discussed.

2 Background

According to Newell [1990] the communication band-width among human beings is insufficient for the members of a team to share the same knowledge. However, sharing the same knowledge is a perquisite condition for collective intelligence. On the other hand, Smith [1994] argues that individuals do not necessarily utilize all of the relevant knowledge that is available to them when making decisions. There does not appear to be an a priori reason why complete shared knowledge is required for a group to achieve collective intelligence. Furthermore if the principal objective is for the team to devise a solution to the problem, then the purpose of collective intelligence is to ensure the existence of an adequate level of coherence within the group. While Newell's premise cannot be disputed, from a practical point of view, one has to be more concerned with the degrees of collective intelligence. Accordingly, the information transfer rate in the planning process must be sufficiently rapid to ensure that differences in relevant knowledge remain relatively small.

The view of collective intelligence further supports the distinction that can be drawn between: information, coordination, cooperation and collaboration. Traditionally, the degree of communication among team members is dominated by sharing information and, to achieve the highest amount of coordination of shared activities. However, to reach a considerably high degree of collective intelligence the range in communication has to be extended to collaboration and cooperation [Borghoff et al. 1995]. Cooperation assumes a high level of coherence among individuals as the team pursues a common goal. Each individual member of the team has fuzzy knowledge regarding the global solution objectives, though being an expert in a particular domain. Collaboration on the other hand has less stringent requirements for intellectual coherence and shared knowledge. The individual members of a team cooperate by carrying out their individual tasks without necessarily having knowledge of all contributions to the project. In this sense, cooperation could be regarded as a more sophisticated form of collaboration and in fact, most groups tend to display behaviors that range between cooperation and collaboration.

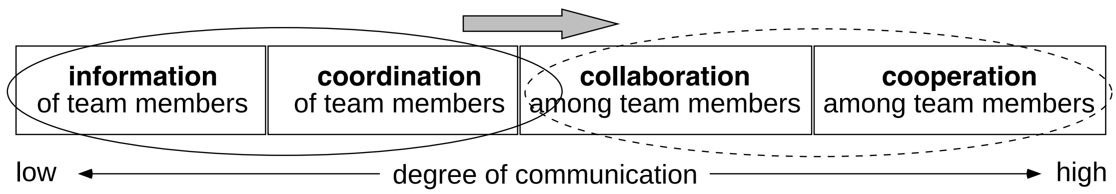

Figure 1: Different stages of communication among team members

Formal theories and protocols for the coordination of cooperations have been a subject of research for some time, with a significant increase in activities since the 1980s onward [Chaib-Draa et al. 1992]. The principal catalyst for this increased activity has been the introduction of networked computers in educational, commercial and legislative environments and the need and willingness of commercial and legislative organizations to address complex problem situations in the management planning and design spheres.

Currently, questions and problems regarding computer-based cooperation are addressed in the research area of CSCW. However, the methods and tools developed in this area are limited to the support of single tasks and therefore not suitable for an integrated planing process which has different requirements regarding organizational forms and process management.

A more advanced approach therefore concentrates on the integration of different categories of CSCW applications through the development of so called open CSCW platforms, allowing the implementation of multiple forms of cooperation in a specific domain. However, this requires a total understanding and the careful development of models through the cooperative planning process.

There have been several approaches to model design processes by formalizing logical and physical dependancies on the level of design objects and linking communication related aspects to them. This leads to very complex deterministic product models, which are hard-coded in solution strategies. They are only valid for projects with very specific and restricted requirements. Common product models can be used as database models for particular CAD tools however as mentioned at the beginning, this approach seems not to be suitable to support an integrated design process.

It can be expected that a continuous definition of goals, tasks, requirements, and resources etc. results in a successful integrated planning. This definition itself is a planning process to be explicitly considered in the model.

3 The Process Model

To clearly define the difference between deterministic and non-deterministic aspects in the design process, a two-leveled approach has to be introduced. It is the idea, unlike hard-coded product models, to describe and to model projects on the level of goals and resources needed to achieve them. This level is called: *level of project goals and ressources* and is different to the *level of design objects* with their physical and logical dependancies.

3.1 Level of project goals and resources

At the beginning of a project the model offers to structure it in any meaningful kind through providing planning scenarios. After that it transforms itself to a platform allowing for a continuous and dynamic structuring and organization of the cooperation process. This concerns e.g. the definition of goals, information infrastructure, tools, methods, roles, and the allocation of resources in every respect. In this model we consider explicitly aspects of concurrent engineering from the beginning.

This level offers every participant of the planning process the context for his individual contribution, and is therefore a system for the metaplanning („planning the planning"). This makes possible the integration of knowledge and experience over all stages and in all tasks of the project. Management of the planning process will be done through goal oriented cooperation of multiple teams instead of deterministic coordination.

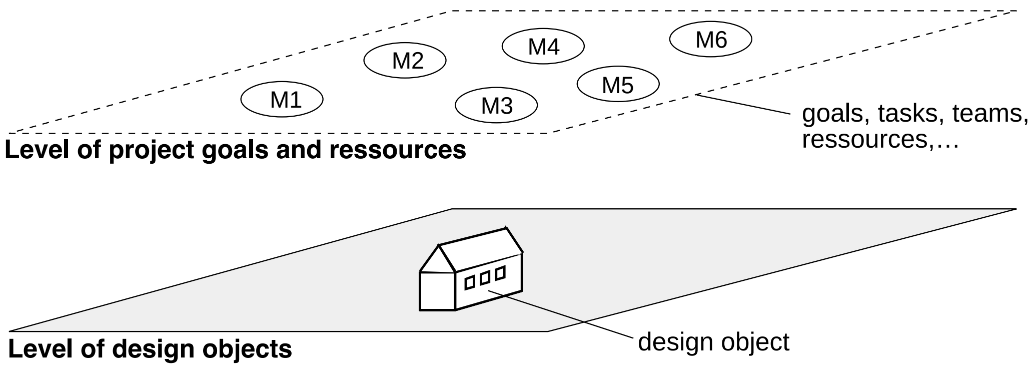

Figure 2: Two level view of a project

3.2 Level of design objects

Generic problem areas such as architectural design require a high degree of freedom of choice and the ability to compromise on certain subjects in collaboration with others. Because of this, the variety of solution strategies to implement design objects can not be predetermined and therefore is only limited by the ability of team members to innovate new solution strategies.

The transition between the two levels is continuos and different for the specific project tasks, because definitions and actions on the level of the design objects change aspects on the level of project goals and vice versa.

The planning process model is based on the idea, that the complete design task can be described as a net of interdependent task bundles. These task bundles will be dealed collectively in a team-oriented manner. The particular task bundles can have logical and informational dependencies on each other. This means that for an integrated dealing with each task bundle, information and resources from others are necessary. It is not necessary to define constraints of time because it can be seen as a resource or results implicitly from the logical and informational dependencies. The lack of these explicit constraints of time opens up a enormous potential in optimizing the planning process through concurrent implementation of single design processes. In the following, task bundles are indicated as nodes and the dependencies as edges.

Unlike the common way of structuring the design process, e.g. the German HOAI, project related phases are not taken into account for the concept of the planning process model. The structure of the planning process model is identical for all phases and sees the project as a system of nodes, which must be dynamically configured and worked out.

The model differentiates in two phases: the *Strategic Phase* and the *Design & Implementation Phase*.

The goal of the Strategic Phase is the realization of an idea, a wish or a necessity toward an aim-oriented solution concept. This means:

- Definition of guidelines and constraints for a project. As a rule this will be financial, chronological and aesthetic guidelines, but even more technological or political (solar architecture)
- Definition of an appropriate a priori structuring of the project
- Putting together the team members

The realization of the so-defined solution concept then takes place in the Design & Implementation Phase. Design and implementation will then not be handled differently, but as a real integrated process with complex dependencies.

Figure 3a shows a project being in the Strategic Phase. The different aspects for the Design & Implementation phase are not yet defined. After completion, the a priori structured project merges into the Design & Implementation phase (Figure 3b).

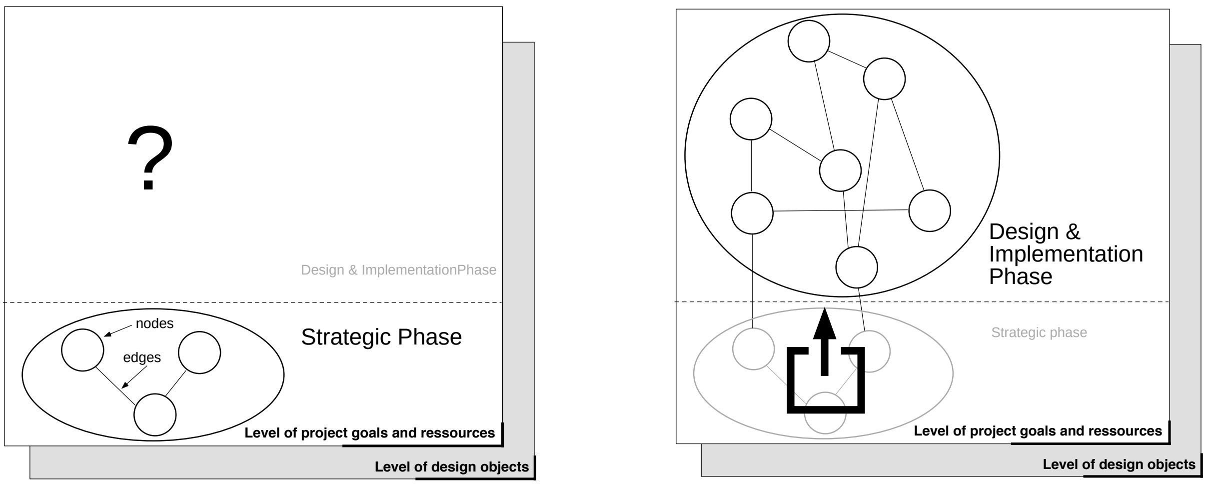

Figure 3a/b: Two phases of a project represented by a net of nodes

3.3 Nodes

Every node is identified by a task- and goal definition. Furthermore it presents a process, to collectively work out the task linked to it. It can be seen as a „team process“.

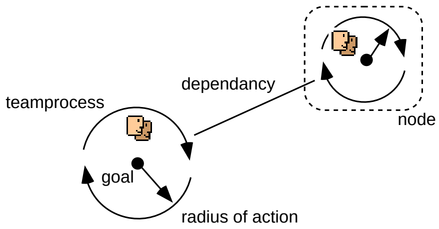

Figure 4: Interpretation of nodes as „centers“

Nodes can also be seen as some kind of „centers“ with a specific radius of action. In the center it is possible to find the task- and goal definition. The radius of action hereby represents the context for action of the team members. This interpretation is very important and useful for later computer support. [Fitzgerald et al. 1994]

Therefore a node does not represent a particular activity, but instead puts together team members, goal definitions, objects for example: documents, tools, links or even workflow definitions.

Behind every node the structuring element is the team process which is systematized focusing on the following aspects:

- Specifying the goal
- Need of knowledge, disciplines
- Organization of the team-process, tools, methods
- Information infrastructure, information logistics [Szyperski et al. 1993]
- Dependencies to other nodes

In our planning process model a node can contain as kind of a template a certain amount of generalized design knowledge of the aspects above.

Additionally, to the linked design-task every node has implicitly the task of organizing and coordinating itself on the level related to the projects goals and resources.

There are exclusively two logical node states, which are taken on by all nodes in this order at least one time:

State of personalization

The function of this node state is the planning of the design process with the goal to achieve as soon as possible the ability of work of this node. The ability of work of a node is defined as the complete definition („personalization“) of all aspects linked to the node for the specific planning task. These are:

- Definition of the goal
- Setting up the team: roles, competences
- Selection of the to be used tools and methods
- Setting up and configuring the information infrastructure
- Allocation of resources

This state is of great importance because an early and exact definition of the task, providing necessary information and acquisition of knowledge (e.g. via team members or tools), is elementary for a successful integrated design. After that state the node switches into its active state.

Active state

Based on the guidelines made in the state of personalization, now begins the task oriented cooperation with the goal of achieving the task linked to that node. This represents the change to the level of the design objects. Processes on that level can not be described by the planning model.

If there are some changes in aspects made during personalization, the node state falls back to the node state of personalization.

3.4 Edges

Dependencies between collective task bundles will be represented in the model as edges between nodes. In the interpretation of nodes as „centers“, as mentioned above, these edges can be seen as a form of overlapping contexts. In the model the edges represent purely informational dependencies.

At the beginning of a project, edges are qualitative descriptions at any level of detail of dependencies between collective tasks. Based on the so described dependencies, information flows are growing in different ways along these edges during the project.

Every edge has an administrator. He must be a node team member connected by the edges. He guaranties implicitly initialization, control, and coordination of information flows between nodes. This role must be filled permanently during the project. Administrators of all or only a specific number of edges can once again form a node with the task of coordinating the information flows. These nodes have edges to all participating nodes (see figure 5).

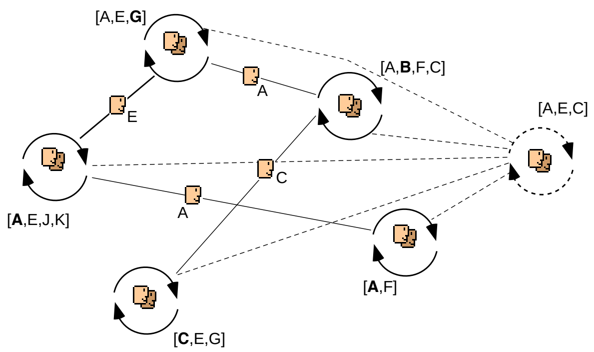

Figure 5: Node team members and administrators of edges

At the beginning of the phase of design and implementation, all nodes switch at the same time to the state of personalization and try to fulfill the tasks/goals linked to them. Whenever the requirements or the goal or task definition changes (e.g. more detailed definition required) and the node is in the active state it switches back to the state of personalization. Figure 6 shows a snapshot of a project in the design and implementation phase. The nodes in the strategic phase have already been terminated, while the others are either in state of personalization or in active state.

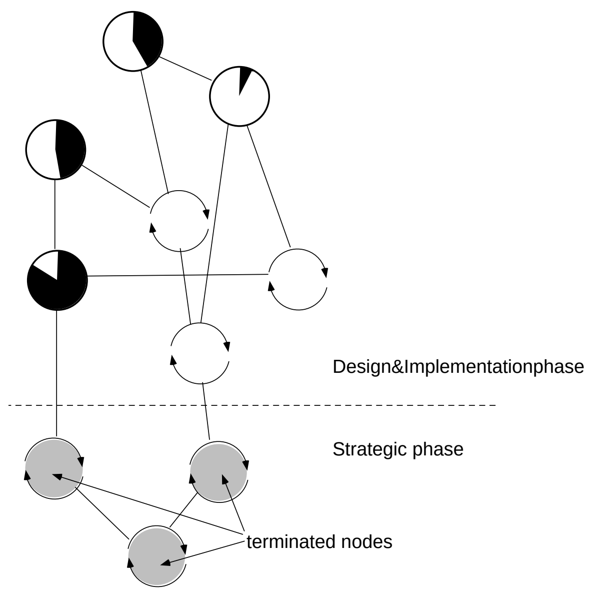

Figure 6: Snapshot of a project represented by a net of nodes

Project management can be achieved due to an allocation of resources and information. Therefore it is possible to once again classify the nodes due to different tasks and attributes e.g. a classification in core and support processes.

It is important to emphasize that restrictive management methods take only place on the level of the goals of the project, while team members have completely free hand on the level of implementation of the task. The members of the design process can keep their own working methods appropriate for their domain.

Due to the common starting point for all nodes and any state changes of the nodes we achieve a good concurrency at the cooperative implementation of the project. The Linkage of nodes with edges minimizes the danger of redundancies.

Assuming that the information flow along the edges as well as the node processes are not disturbed the presented planning model guaranties a good adaptation to the requirements and a very fast terminating of the project. At the same time the model is very immune to faults, because changes in goals and requirements have been considered in the concept of the planning model. A project is finished when the tasks of all nodes have been achieved.

4 Conclusion

In this paper, the current state in planning with special focus on problems among team members related to information, coordination, collaboration and cooperation has been discussed. The idea to extend today's perception of teamwork by a more holistic approach has been introduced. Several solution strategies presenting the current state of the art have been examined.

A two leveled planning process model for computer supported cooperative work in building construction has been introduced and discussed in detail. The paper presents the current state of the ongoing research project INTESOL.

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