Coordinative Virtual Space for Architectural Design

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The paper explores group coordination in the design process through communicative innovations brought *by computers. It is divided into three main sections. The first is the analysis of the design group coordination and communication. The second introduces the concept of Coordinative Virtual Space: this is a common multi-dimensional space where the group members share design information. The third presents the implementation: each member can connect to the shared space through the computer network and display several projections of the design information space.*

Keywords: collaborative design, virtual workspace, shared workspace, groupware, design paradigm

1 Introduction

The design process takes much of its character from the way in which individuals interact. In Florence, during the Renaissance, there were many formal and informal opportunities for architects to compare and discuss their work. There were frequent meetings among the members of the same guild, i.e. among specialists in a particular domain, and with members from other guilds. In addition, it was in the studios themselves that the various levels of competence, from the masters to the assistants, down to the hired help, were coordinated in pursuit of a common objective. Then there were the well-known public and private discussions: the famous dinners shared by Donatello, Brunelleschi, Toscanelli etc. [1], where serious topics were discussed, such as the foundations of the perspective method; but there were also instances of cruel derision.

Today the computer is the most powerful communication tool ever invented. Whatever task the computer carries out can be understood as setting in motion and enriching communicative processes, while computer networks have expanded the range of communication, at first locally and now worldwide.

But the communicative innovation is only secondarily a question of technology; it is rather a matter of how individuals interact. Though computers are extensively used in design studios and in design companies, and are beginning to be connected in networks, they tend to be used more in support of individual work than in group work. The transition from the individual to the group, from the single task to the overall design process, is directly relevant to the organizational structure, whether in a small studio or in a large company.

1 Group paradigmatic framework

1.1 Group coordination

The design process may be studied at the level of procedures (visible behavior and relationships), structures (behavior patterns observed) and paradigms (the models towards which the activity tends, or to which it conforms).The coordination paradigm sets out the reference criteria to which the organization of a group may tend in the course of the design process. Although paradigm is an overused and often misused term, here it is employed in its strictest sense to mean a model that embodies a set of underlying and generally implicit assumptions through which the world is interpreted. An organizational paradigm is, thus, both a standard or model for an organization and a world view, a way to make sense of organizational reality' [2].In order to clarify the meaning of the communication paradigm, and its function in describing the mechanisms with which individuals interact, we shall take the example of an architectural contest involving a small group of architects.

First case: the group works according to a hierarchical order. One member of the group, a recognized expert or a strong personality, establishes the outlines of the design, evaluates members' suggestions as they arise and attributes the various tasks.

Second case: the group puts its faith in individual initiative. Each designer expresses his/her own creative freedom and acts independently. The individual lines of the design are developed independently according to individual inclinations and talents.

Third case: the group seeks participation. Through discussion and negotiation, the members tend towards a working consensus. The group converges on a design solution and seeks consensus through comparison of various hypotheses.

Fourth case: the group tends towards collaboration. After comparison or, in any case, consensus on the lines along which the design is developed, the group goes more deeply into the agreed design solution.

Every group has its own specific physiognomy and if someone does not fit a specific paradigm, this is because it is rare for a group to tend to conform to a single paradigm; members are more likely to act according to different paradigms according to the main objective at a given moment. Experimental studies [3] [4] of the activity in an architectural office confirm that a single group may tend to different organizational paradigms at different moments, according to different objectives and functions. Each paradigm is the reference for different objectives of the design process (Figure 1). Thus, for the attribution of tasks the group may tend towards a hierarchical organization, whereas in choosing a design outline the chosen method may be participation.

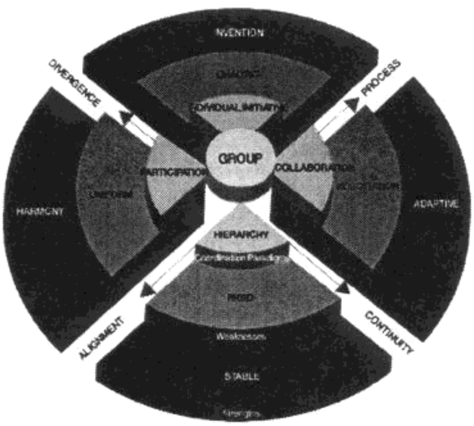

Figure 1

It seems that there is no paradigm known to guarantee better results than the others, but studies in the sphere of organization [5] recognize that certain paradigms are more appropriate to specific objectives. Hierarchy has the advantage of guaranteeing greater stability and continuity in decisions, though it may penalize creativity an innovation. Individualism offers members the chance to express greater creativity, but at the cost of coordination and perhaps of efficiency. Participation and Collaboration have positive and negative aspects. First, we must distinguish real participation, through discussion and comparison of various solutions and hypotheses, from pseudoparticipation, found for example in agreement with the proposal put forward by a particularly authoritative member of the group, or when a compromise solution is reached, with features of various proposals but without truly representing any (mean solution). Real participation and collaboration should attempt to involve, and count on, all participants contributions, even at the cost of a greater investment of time and resources.

1.2 Group communication

Group activity is achieved through communication among the actors, where 'actor means a person, a group or an institution which carries out a procedure relevant to the process. Communications are information acts set up by the actors who may be within or outside the group: within the group if they are communications between members of the group, outside it if they are directed to clients, public administration, businesses etc.

A communication system can be represented in terms of interaction structures and processes. The coordination paradigms are the organizational reference for the structures, while some authors [6] [7] recognize and analyse certain factors which are of particular importance for the processes.

1.2.1 Communication structure and process

Communication structure describes the recurrent patterns of communication among the actors of the design. The concept of structure refers to cycles of acts, formalized in terms of the organization of the group. Each coordination paradigm may be referred to a structure and can be visualized in graph form (Figure 2).The process is, rather, the succession of communicative acts in the temporal dimension. The definition of process concerns the "traditional" media, established in practice (drawings, written reports, sketches), as much as newer technological media (video, telephone, fax, computer and network).

1.2.2 Communication factors

Among the many factors which influence the communication process in a group, there are four which are considered particularly important: the size of the group, the relationships of the actors in space and time (Figure 3). Size: a group may have a variable number of members: an architect and his collaborators who share a common space, the studio, or several architects, each with his/her own studio, or a company with many designers and collaborators, who carry out all tasks within the company, or may make use of outside consultants. Each of these groups presupposes various structures, with different communication processes. Time: a distinction is made between communications which require the simultaneous presence of the interlocutors (synchronous), such as meetings, telephone calls and video conferences, and those which do not require this simultaneous presence (asynchronous), such as mail, fax and bbs. Another important distinction regards the synchronization of the communicative acts, which may be sequential or concurrent. Space: a distinction is made between communications which require co-presence in a single place, such as a meeting, and those where interlocutors are in different places, such as the telephone. Neither space nor time is an absolute factor, as classical physics hypothesizes; they are rather to be understood in relative terms, as places and manners of group interaction. They are the social aspects found in the organization of the group. Proximity in a small studio tends to encourage interrelations between members, whereas in a large company relations are less direct, more dependent on intermediaries. It is therefore arbitrary to quantify the size of the group in absolute terms on the basis of the number of members; it is more correct to define it in relative terms: relatively small or relatively large, according to the specific coordinative paradigm.

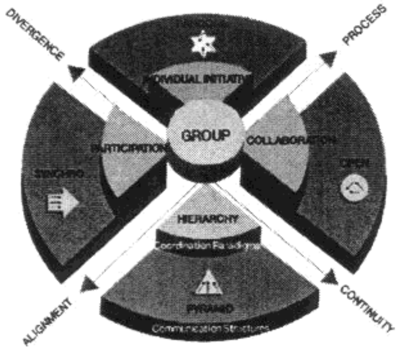

Figure 2

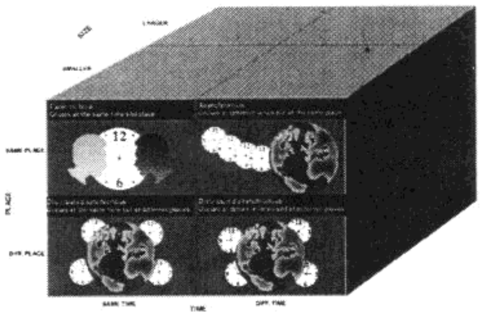

Figure 3

2 Coordinative virtual space

For the architect the drawing is a tool to understand and define spatial and building relationships within the material. Plans, elevations, cross-sections and the other projections defined by descriptive geometry work together to give a complete description of the design. The drawing is directed to the representation of the object: the building. Coordinative Virtual Space (CVS) is directed not so much to the support of the object as of the process, in other words the communication and coordination of the actors who collaborate to carry out the design. CVS offers an environment to support synchronous and asynchronous communications among group members. This environment is defined virtual because communication is chiefly mediated by computers through the networks. The coordinative function of the groups activity is intrinsic to the projections of CVS. The projections are the graphic tools to understand and define organizational and communicative relationships within the design process. Coordination of the design process is a multi-dimensional problem, because it is influenced by many factors: as representation of three-dimensional objects is based on several projections, many representations are necessary to understand the nature and complexity of the CVS (Figure 4). It has been experimentally demonstrated [8] that representation through many projections significantly aids comprehension of the structure of the group and coordination among the actors. The current implementation of CVS uses three simultaneous projections: Decomposition of problems, Decomposition of communicative activities, Semantic classification. These projections are also defined as 'orthogonal' -analogously with descriptive geometry- in that coordination and communication are complementary aspects in the organization.

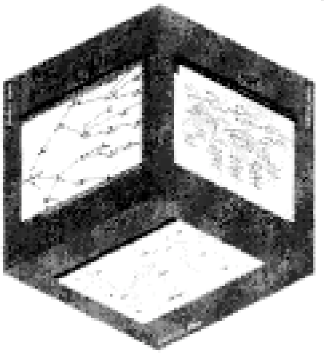

Figure 4

2.1 CVS communication

CVS aims to integrate the synchronous and asynchronous communications among group members in a single environment. Synchronous communication includes videoconference and shared-board, while asynchronous communication includes file transfer, e-mail, WWW and groupware applications which integrate various communicative. functions [9]. Today, a significant number of communicative acts in the design process s carried out through the 'conventional" media: telephone, fax, letters and above all interpersonal communication, even in the form of simple sketches. The rapid spread of C.A.D. programs is stimulating the transition from analogic to digital. Ease of access and use, and the greater capacities of network communications are gradually leading to a preference for forms of digital over analogic communication: file transfer rather than fax, e-mail rather than s-mail.

2.2 CVS projections

2.2.1 Decomposition of problems

The decomposition of problems projection is formed of:

(1) a projection plan representing the space of the design problem;

(2) the problem nodes which form the suggestions, topics, ideas and positions of the members of the group;

(3) reciprocal relationships among the nodes, definite links, which make clear the rhetorical mechanisms accepted and shared by the group and indicate the connections between the individual positions maintained by the actors.

Sharing a rhetorical method can aid the collaborative activity of the group [9] [10]. A rhetorical method is a methodology for the structuring of communicative activities, which aids the generation of argumentations and their connection and relationship. The definition of a rhetorical method is, of course, of great importance, since it is from this that the coordinative ability of the group arises. Research is still going on and various methods have been suggested, among them the Issue Based Information System (IBIS) [11], which offers a powerfully argumentative structure, directed to the motivation and explanation of the decision processes among the actors. The IBIS method, applied to the decomposition of problems projection, mainly consists in classifying the nodes according to their argumentative purpose. This classification is divided into Issues, Positions and Arguments. Issues formalize the problem in the design problem space. Positions are the decisive suggestion put forward by the individual actors. Arguments are the pros and cons.

IBIS contributes to the definition of a general rhetorical framework in which, starting for instance from an Issue node, we can derive a Position node through the rhetorical relationship indicated by the Respond-to link, with the intention of suggesting a solution to the Issue. An Argument node is connected to a Position node by the rhetorical Support and Object-to links in order to argue for or against a Position node (Figure 5).The problems decomposition projection aims to show the collaborative process in the group's choices. The graph offers a visual synthesis of the design process in terms of the relationships between the nodes and of development in time. It is a dynamic representation which is carried out in the time dimension of the design, signifying connections and causality between the positions of the actors in relation to the group's decisions. The evolution of the graph follows a recognizable temporal progress: starting from some initial nodes, it develops through the addition of new nodes connected by links to the initial ones. Problems decomposition in a graph aims not so much to record the stages of the design process as such, but to record the critical and suggestional relationships among the actors which influence the decisions taken in the course of the design process. The extension of the graph in space, the convergence or divergence of the nodes, represents the emergence and distinction of different design lines. The distribution of the Position and Argument nodes around the Issue nodes shows the degree of synthesis reached, or, in other words, the convergence of various actors towards one or more suggestions. The graph acts as the shared memory of the group: by observing the graph it is possible to infer the single phases of the design, the structure of the conversation, and the context in which contributions are inserted. The memory function allows the group to reconstruct the design phases, bringing out the themes and issues put forward and dealt with earlier by the actors. It is from this shared memory of the process that an important incentive to group work may arise [12].

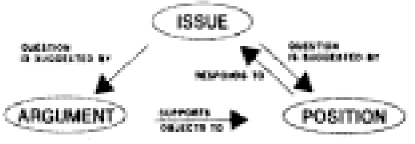

Figure 5

2.2.2 Decomposition of communicative activities

The decomposition of communicative activities projection can be formalized in:

(1) a projection plan representing the space of the communicative actions of the group;

(2) the nodes representing the single communicative acts among the actors;

(3) the links which describe the states of the communicative process.

The communicative activities decomposition graph is based on the language/action theory of Winograd & Flores [13]. This theory considers language as an operative tool (of action) between individuals. By means of the use of language, especially its pragmatic use [14], individuals activate reciprocal relationships which aim to fulfill an objective. This interaction through language is defined as "conversation for action". The term "conversation" has a general meaning and indicates "a coordinated sequence of acts which may be interpreted as having linguistic meaning" [14]. According to this definition, non-linguistic actions too may participate in a conversation: sketching, widely used during the design process, perfectly fulfills this definition. To carry the idea to its absurd extreme, a whole "conversation" may take place without the use of words. The formalization of communicative acts does not regard the content of the communication, which may be infinite, since it depends on the specific nature of the message, but rather the rhetorical functions, as a collection of acquired, codified forms, which are finite in number for a state of the conversation.

The graphic representation of communicative acts aims to bring out the communicative states and actions (e.g. questions, answers, expectations etc.) which the group members set up in terms of the specific design action (Figure 6).The representation of communicative processes has an important operative purpose: Flores [15] states that effective coordination of the actions of a group is equivalent to effective coordination of the communicative acts within the group. The organization of the group, or rather the coordination paradigm, to which it tends at a particular moment, is directly related to the communicative acts set up among the group members. The actors are often unconscious of the states of communication, but they know the causality between a new communicative act and the actions and activities which follow it. The representation of communicative acts is the operative tool which produces greater awareness of individual roles and responsibilities and makes possible the revision or restructuring of group practice.

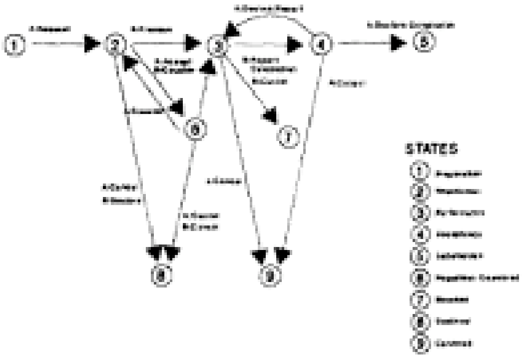

Figure 6

2.2.3 Semantic classification

The semantic classification projection is formalized in:

(1) a projection plan which represents the space of the communicative actions in the design;

(2) the nodes which represent each communicative act between the actors;

(3) the position of the single nodes on the projection plan which indicates the frequency of the semantic units of each communicative act.

The semantic classification orders the communicative acts on the basis of semantic content, the definition of which is related to the communication medium. In the case of texts, the semantic units are words and the frequency of each term is calculated for each document and for all documents. In the case of drafts, the semantic units are the minimal significant units' of the draft calculated as differences of length, frequency, direction and thickness, for each and every draft [16]. For other media, research is still continuing: in the case of film narrative (e.g. video, teleconference) the first step is to define a procedure for the recognition of semantic units. The map is subdivided into conceptual areas and the positioning of a node in a specific area or in the neighborhood of various areas is related to the semantic content of the node, while the size of the areas is determined by the frequency of the semantic units. Semantic representation is particularly useful in order to avoid the problem of information overload, which occurs with the use of CVS: group collaboration through computer network can generate thousands of nodes in a short time. The semantic map makes it easier to coordinate the work of the group because it shows the group's overall vision of the problem and the clustering of communicative acts in categories. Semantic classification does not take the place of database retrieval, i.e. exact research methods with keywords, but rather supports a graphic representation of the concept organization of communicative acts.

3 CVS implementation

CVS implementation is the result of integration between various programs from the commercial and the public domain. Each program fulfills certain functions in the specific context of the communicative and coordinative aims of CVS. This type of implementation offers a high upgradable system: the insertion of a new module makes it possible to add new communicative functions or projections to the CVS. Furthermore, the overall functionality of the system is in proportion to the degree of integration of the various programs.

Interaction with the user and the transfer of data among the various applications are crucial factors of the integration. The overall environment for the execution of the programs is given by operative system with graphic window interface (e.g. X-windows, Apple System, Microsoft Windows). The programs have a similar 'look and feel", though they do not reach the same level of uniformity in graphics, interface and functionalities compared with systems for which the developer has total access to the whole source code. Despite the programs' having the same system interface, users must become familiar with the single applications and know how to "move" among them in order to activate the various functionalities of the CVS. Various strategies have been adopted in order to achieve a high degree of transferability of data among the programs: dynamic links are faced by using object oriented techniques (e.g. dynamic data exchange, object linking and embedding [17]), while the exchange of data is achieved by using widespread formats (e.g. GIF, DWG, RTF, Quicktime), or standards (ASCII, IGES, JPEG, MPEG).

3.1 CVS communication

The current implementation of CVS is based on Microsoft Windows for Workgroups. Communications are carried out in Internet by means of the TCP/IP protocol and the communication programs currently integrated in the CVS are: e-mail, ftp, sharedboard and video conference. The communication model adopted by these programs is direct: actors create a flow (text, draft, image, video) towards other actors in the group. The existence of direct communications conflicts with the requirement, typical of the NS, to maintain a shared representation at the group level. The shared representation has to be updated, i.e. must include the most recent communicative acts, and consistent, i.e. simultaneous accesses must not compromise its congruence. The implementation of the shared representation is based on the Client-Server communication system: shared representation is maintained in the shared file system on the Server, while the Client is resident on the cup members' PCs and supervises communications between the application process and the Server. Application processes are the programs which export communicative acts from the PCs to the Server and visualize the CVS projections. The Server supervises the communications and applications designed first to recognize the individual Clients and hence to allow them access to the shared file system.

The Client can access the overall shared file system for reading only: modification of the files is not permitted, they can only be read or new nodes can be added. Each communicative act occurring within the group is not automatically memorized, but the actors decide to share, or not to share, a node. The addition of a new node means that the file is exported from the local computer to the Server. The ways in which files can be exported are controlled by the various programs which manage and update the single CVS projections. In the current implementation, three different programs supervise the CVS projections. Each program manages its own file system with its own access and update modes: exporting a new node towards the Server requires handling two distinct programs with their own procedures. The need to repeat the process may cause inconsistencies among the various projections. Implementation developments in the near future look forward to a closer integration among the programs, especially a unified procedure for the exportation of data from the Clients to the Server, which will also simplify interaction with the CVS to a significant degree.

3.2 CVS projections

3.2.1 Problem decomposition

The projection nodes and links are memorized in the file system on the Server accessible to the computers linked in the network. In order to visualize the overall graph of the nodes and their relationships (Figure 4, vertical plane), the program resident on the user's PC reads the file system. If the overall dimensions of the graph are greater than those of the screen, the user can pan across the map to look at the non-visible areas.

In order to export a new node on the Server, the user is asked to define the rhetorical role among those formalized by the IBIS method, the position in the overall graph and the links with another node/other nodes. Each Client linked to the Server inquires the file system with a polling mechanism, periodically and before exporting a new node, in order to avoid inconsistencies.

3.2.2 Activity decomposition

At the 1994 Groupware Conference [18], more than 130 commercial programs were presented with functionalities for the visualization of a communicative activity decomposition. These programs are usually articulated in two modules: for the modeling of the flows and the execution of the model. Only the first subsystem was used for the purposes of the CVS: the flow analysis subsystem. The flow analysis module is a graphic editor which integrates the methodologies and the tools in order to visualize in graph form the processes, rules, communicative acts (Figure 4, lateral plane).

3.2.3 Semantic classification

The implementation of Semantic classification is based on the 'self-organizing map" algorithm defined by Kohonen [19]; specifically, it makes use of the packages [20] for the development and simulation of artificial neural networks.

The self-organizing map shows the frequency and distribution of the information in the two file systems (Figure 4, horizontal plane) and at the same time checks their congruence. The program resides on the Server and is activated by the insertion of a new node in the shared file system. The program calculates the position of the new node in the map in such a way that the mutual positions of the nodes represents the occurrences of information in each node. Each Client carries out periodic polling in order to obtain an updated projection. However, the simulation of neural networks is computationally expensive, and hence the projection cannot include the most recent projections towards the Server, especially during phases of intensive CVS use.

4 Conclusions

The CVS prototype is first and foremost a knowledge tool for investigating the nature and complexity of design processes. CVS aims to deepen knowledge of the paradigms, structures and design processes, even before offering tools for the realization of what we have called "transition from the individual to the group, from the individual task to the overall design process". As a design paradigm, CVS is open to other forms of communication and to more important types of representation-projection, which a deeper knowledge of the relationships between the actors might permit us to formalize. The open nature of CVS is fulfilled in the implementation which aims at the integration of various programs with different functions and origins: the possibility of adding or replacing new programs to those already existing is an important aspect of the experimental and knowledge-directed aims of the research.

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