COORDINATIVE MODEL OF DESIGN AND BUILDING PROCESS

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Abstract

The paper presents a coordinative model of the design and building process. It is divided into three main sections. The first presents a brief formalization of the model and of its representations, respectively the argumentative, rhetorical and semantic graphs. The second introduces the framework adopted for the development of the model, and describes the two main sub- systems: communicative and coordinative. The third presents the computer implementation, based on the Client/Client model for the communicative system and on the Client/Server for the coordinative system.

Introduction

We can describe the design and the realization of a work of architecture on the basis of two different models: a descriptive model and a coordinative model.
Descriptive geometry establishes the method for realizing the descriptive model. For architects the drawing is a tool to understand and define spatial and building relationships within the material. The drawing is directed to the representation of the object: the building. Various C.A.D. programs help create the descriptive model by means of different two-dimensional projections, or a unitary three-dimensional model.
Coordinative model is defined as the formalization of the relations among the individual people, organizations, corporations etc., which work together in defining and realizing the process. The model takes into account the work and the interaction between individuals in so far as they are made evident as communicative phenomena.
"Communicative phenomenon" is understood in the broadest sense in that it can include the drawing. In fact the descriptive and coordinative models are complementar: the descriptive model defines the whole and the details of the object, while the coordinative model defines the relationships, the communicative activities of the process.

The coordinative model

The definition of the coordinative model is based on the concept of space *S* of the communicative relationships relevant to the description and realization of the design. The communicative relationships are defined acts *C(S)*, because in the design communication is considered, for pragmatic purposes, as an instrument of action. The people who produce actions are actors; by actor is understood an individual, group, public administration, clients, corporations, contractors etc., who performs an action in the space *S*. In *S* are performed both internal actions, among team members, or external actions directed towards

clients, public administration, contractors etc.
If n is the number of actors, the n th dimension includes the communicative acts of the actor $C(An)$, where $C(An)=(c_1, c_2, ..., c_m)$. The space S is a multi-dimensional space of n dimensions. In a real situation the actors in the process may be very numerous and consequently the space S may possess an equal number of dimensions. The method adopted to represent space S is to create as many two-dimensional projections as the number of coordinative relationships of which one wants to make a model.
Let a projection of space S be defined by:

- a projection plan P, which is the plan of the modelized coordinative relationships in S;
- a graph G, which consists of a finite non-empty set $V(G)$ of vertices, the communicative acts $C(S)$ in P, together with a set $E(G)$ of unordered pairs of distinct vertices, called edges, the modelized coordinative relationships P.

The graph G is defined by $V(G)=(v_1, v_2, ..., v_i)$ where $V(G)=C(A)$, i.e. it sets up a correspondence between the communicative acts in space S and the edges of the graph G. Graph G modelizes a sub-set of the whole communicative relationships $A(S)$, the edges $E(G) =(e_1, e_2, ..., ej)$.
The present coordinative model represents three aspects of the relationships in the communicative space S. Each aspect is represented by means of a specific graph, that is respectively the graphs of the argumentative, rhetorical and semantic relationships.
Each graph is a projection of space S. On analogy with descriptive geometry, these projections are defined "orthogonal" (figure 1), in that it is possible and desiderable to treat the descriptive model as orthogonal to the coordination model for purposes of the design and building process.

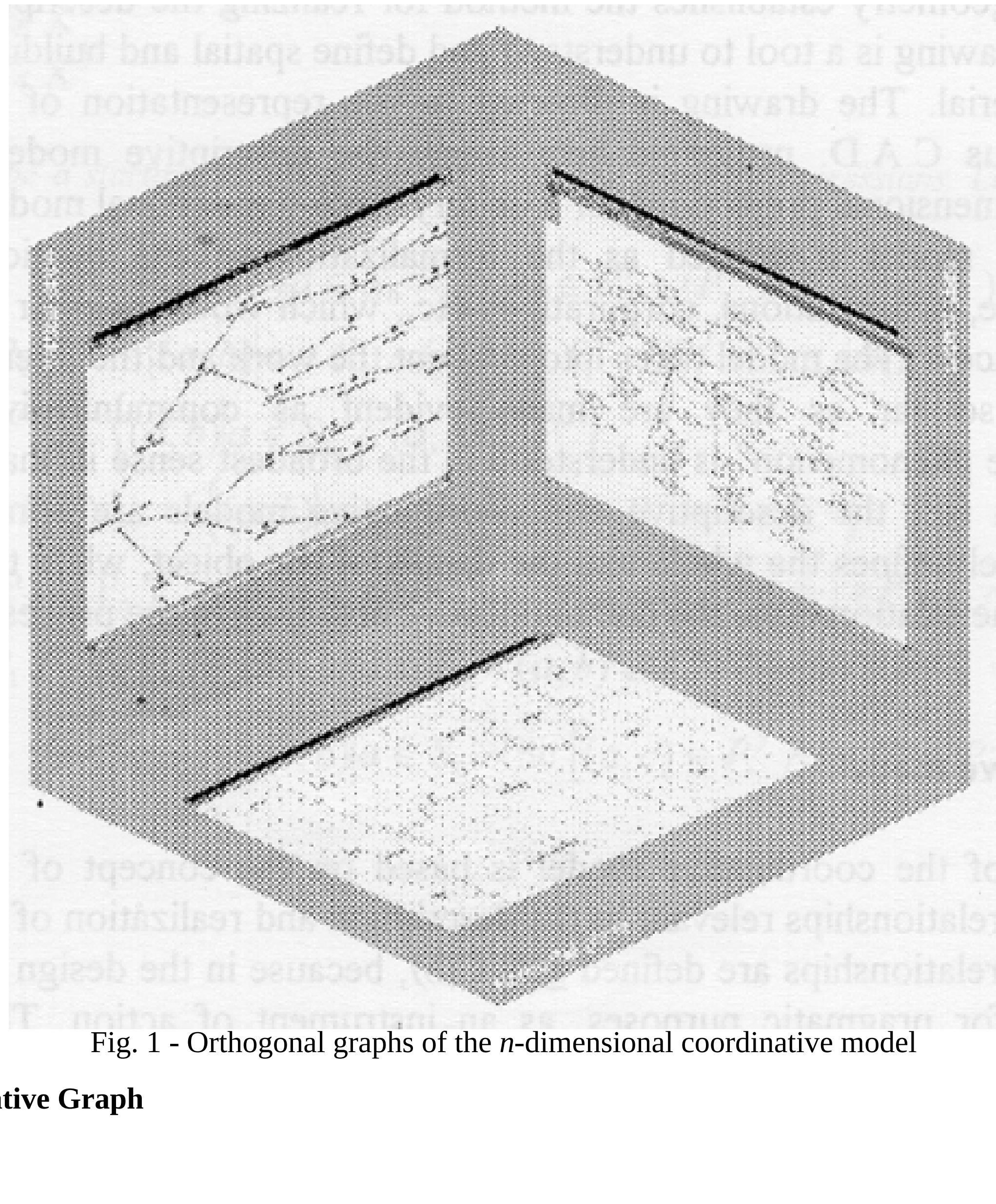

Fig. 1 - Orthogonal graphs of the n-dimensional coordinative model

Argumentative Graph

The graph G_{arg} of the argumentative relationships among the actors is defined by:

- the vertices *V(*G_{arg}*)*, which are the communicative acts *C(A)*, labeled according to their communicative function;
- the edges *E(*G_{arg}*)*, which are the argumentative relationships between the communicative acts *C(A)*, and modelize the rhetorical mechanisms accepted and shared and indicate the connections between the individual positions maintained by the actors.

The graph G_{arg} modelizes the argumentative relationships between the communicative acts *C.* These relationships are a part of the more general semiotics of conversational interaction, which pertain to the rhetoric (Perelman et al. 1958).
Sharing a rhetorical method can aid the actors' interaction (Zenie et al. 1993) (Caneparo 1994). A rhetorical method is a methodology for the structuring of communicative activities, which aids the generation of arguments 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 actors arises. Research is still going on and various methods have been suggested, among them the Issue Based Information System (IBIS) (Kunz et al. 1970), 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 graph G_{arg} , mainly consists in labeling the vertices according to their argumentative purpose. The defined argumentative purposes are: *Issue*, *Position* and *Argument. Issues* formalize the problems in space *S. Positions* are the decisive suggestions 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* vertex, we can derive a *Position* vertex through the rhetorical relationship indicated by the *Respond-to* edge, with the intention of suggesting a solution to the *Issue.* An *Argument* vertex is connected to a *Position* vertex by the rhetorical *Support* and *Object-to* edges in order to argue for or against a *Position* vertex (figure 2).

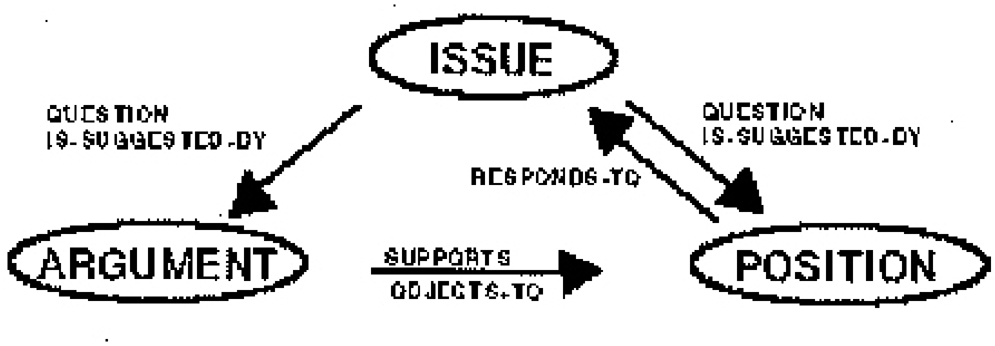

Fig. 2 - Vertices and edges in IBIS graph

The graph offers a visual synthesis of the design process in terms of the relationships among the vertices (figure 1, vertical plane). It is a dynamic representation, evolving in the time dimension of the design, signifying connections and causality between the communicative acts, pragmatically related to the decisions. The evolution of the graph follows a recognizable temporal progress: starting from some initial vertices, it develops through the addition of new vertices (communicative acts) connected by edges (argumentative relationships) to the initial ones.
The graph aims not so much to record the stages of the design process as such, but to record the critical and propositional relationships among the actors which influence the decisions taken in the course of the design process. The extension of the graph in space, vertices strongly connected with numerous argumentative edges, or instead local structures with reduced interconnections, represents the emergence and distinction of different design lines. The distribution of the *Position* and *Argument* vertices around the *Issue* vertices 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: by observing the graph it is possible to infer the single phases of the

process, the structure of the conversation, and the context in which contributions are inserted. The memory function allows the team 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 coordination may arise (Doyle et al. 1976).

Rhetorical Graph

The graph G_{ret} of the rhetorical relationships among the actors is defined by:

- the vertices $V(G_{ret})$ which are the acts $C(A)$ labeled according the status of the communicative process;
- the edges $E(G_{ret})$ which describe the rhetorical relationships between the actors $A(S)$.

The graph G_{ret} is based on the language/action theory of Winograd and Flores (1986). This theory considers language as an operative tool -of action- between individuals. By means of the use of language, especially its pragmatic use (Winograd 1988), 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" (Winograd 1988). 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 graph G_{ret} modelize the states and relationships which the actors set up. The vertices $V(G_{ret})$ are the acts $C(A)$ labeled according to the status of the communication: acceptance, canceled, declined, negotiation, performance, preparation, revoked, satisfaction etc. The edges $E(G_{ret})$ represent the rhetorical relationships between the actors $A(S)$. Rhetorical relationships do not regard the content of the communication (Eco 1975), which may be infinite, since it depends on the specific nature of the message. The edges represent the rhetorical functions, which as a collection of acquired, codified forms, are finite in number for a state of the conversation (e.g. accept, cancel, counter, declare, decline, promise, request).

For example, the client formulates a *request* to the designer in which he specifies what he requires. The designer may accept by means of *promise,* or decline by means of a *cancellation.* Through a succession of communicative states, the vertices of the graph, and of rhetorical relationships, the edges, the *request* of the client proceeds to a conclusion.

The graphic representation of communicative acts aims to bring out the communicative functions and states which the actors set up in terms of the specific design action (figure 3). The representation of the states and functions of communicative processes (figure 1, lateral plane) has an important operative purpose: Flores (1992) states that effective coordination of the actions is equivalent to effective coordination of the communicative acts. The organization of the design and building process, or rather the coordination model, is directly related to the communicative acts set up among the actors. 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 the process.

Semantic Graph

The graph G_{sem} of the semantic content of communicative acts is defined by:

- the vertices $V(G_{sem})$, with $V(G_{sem})=C(A);$
- the edges $E(G_{sem})$, which define the occurrence frequencies in $V(G_{sem});$ each edge has associated an integer number, which is the occurrence frequency.

In the graph G_{sem} (V,E) the communicative acts $C(A)$ are ordered on the basis of semantic content. The definition of semantic content 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 (Maggiora et al. 1995). 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.

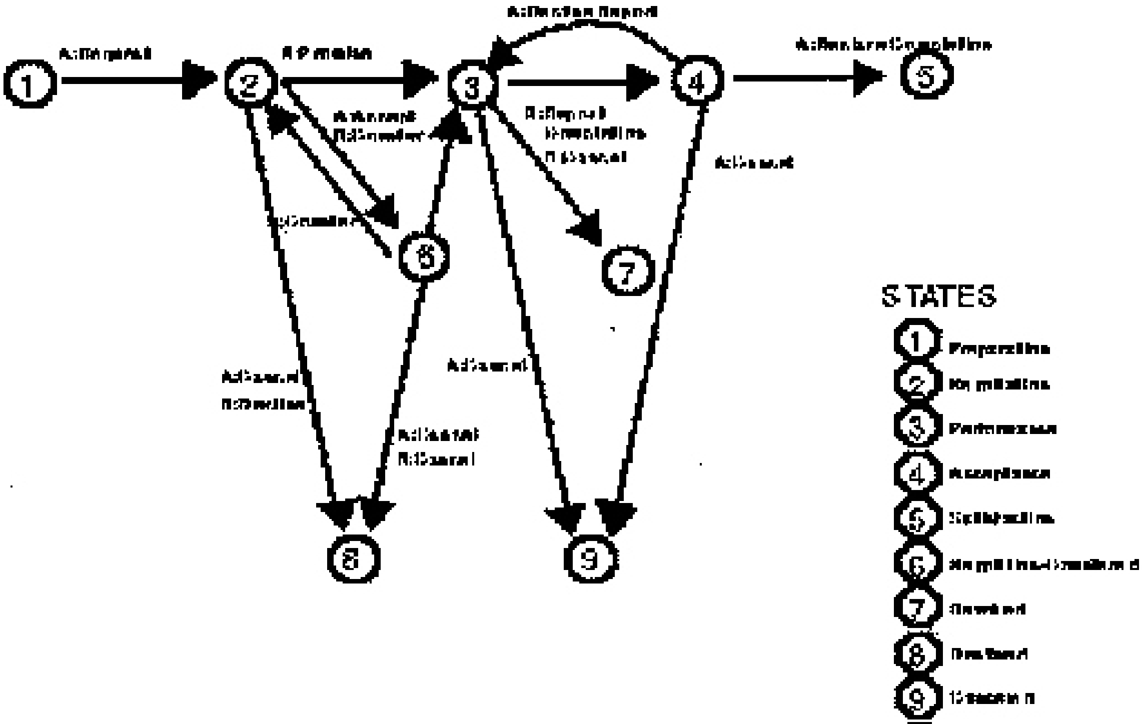

Fig. 3 - Functions and states in a conversation for action

The map is subdivided into conceptual areas and the position of a vertex in a specific area or in the neighborhood of various areas is related to the semantic content of the vertex, while the size of the areas is determined by the frequency of the semantic units (figure 1, horizontal plane). The edges are not represented not to overlap the boundaries of the areas.
Semantic representation is particularly useful in order to avoid the problem of information overload: collaboration of actors through a computer network can generate thousands of vertices in a short time. The semantic map makes it easier to coordinate the work of the team because it shows the actors' 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.

Communication system

The existence of space *S* of the communicative relationships presupposes an underling system of communication. The communicative system among the actors is based on synchronous and asynchronous programs: synchronous programs include video- conference and shared-board, while asynchronous include file transfer, e-mail, WWW. Substantially, these programs set up actor-oriented communications: an actor creates a communicative flow (text, draw, image, video) towards an another actor/other actors.

Coordination system

A communication system actor-oriented conflicts with the requirement, typical of the coordinative model, of the space *S* of communicative acts shared among all the actors. The coordinative system requires a shared network of the communicative acts. The system reflects a centralized philosophy in which a shared representation is accessed by the actors through an open set of applications using network transparent protocols. The applications are the programs to create, update and visualize each graph.
There are three dimensions of the coordination system that can potentially be optimized: integration among the different programs, upgradability of the shared representation, accuracy among the different graphs. The system aims to optimize all the dimensions, because in each instance of the design and building process there are tradeoffs among these dimensions, and it is difficult to assign priority to any

one dimension.

System Implementation

The implementation is the result of integration between various commercial and public domain programs. Each program fulfills certain functions in the specific context of the communicative and coordinative systems. This type of implementation offers a highly upgradable system: the insertion of a new module makes it possible to add new communicative or coordinative functions. 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 operating system with graphic window interface (e.g. X-windows, Apple System, Microsoft Windows).

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 (Microsoft 1991)), while the exchange of data is achieved by using widespread formats (e.g. GIF, DWG, RTF, Quicktime), or standards (ASCII, IGES, Jpeg, Mpeg).

Communication Implementation

The current implementation of the communicative system is based on Microsoft Windows for Workgroups. Communications are carried out in Internet by means of the TCP/IP protocol according the communication model defined Client/Client. The Clients are resident on the actors' PCs and supervise communications between the applications process without predefined hierarchical relations. The application currently integrated are: e-mail, ftp, shared-board and video conference.

Coordination Implementation

The implementation of the space *S* of the shared communicative relationships is based on the Client-Server communication model: shared representation is maintained in the shared file system on the Server, while the Client is resident on the actors' 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 single graphs.

Each communicative act of the space *S* is not automatically memorized, but the actors decide to share, or not to share, an information: the addition of a new vertex 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 graphs. In the current implementation, three different programs supervise each single representation of the coordinative model. Each program manages its own file system with its own access and update modes: exporting a new vertex towards the Server requires handling two distinct procedures. The need to repeat the procedures may cause inconsistencies among the various graphs. 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 system.

Argumentative Graph

In order to export a new vertex on the Server, the user is asked to: assign a rhetorical role among those formalized by the IBIS method, specify the position in the graph, define the edges with another vertex/other vertices.

In order to visualize the overall graph each Client connected to the Server inquires the file system with a polling mechanism, periodically and before exporting a new vertex, to avoid inconsistencies of the representation. If the overall dimensions of the graph are greater than those of the screen (figure 4), the user can pan across the hidden parts of the graph.

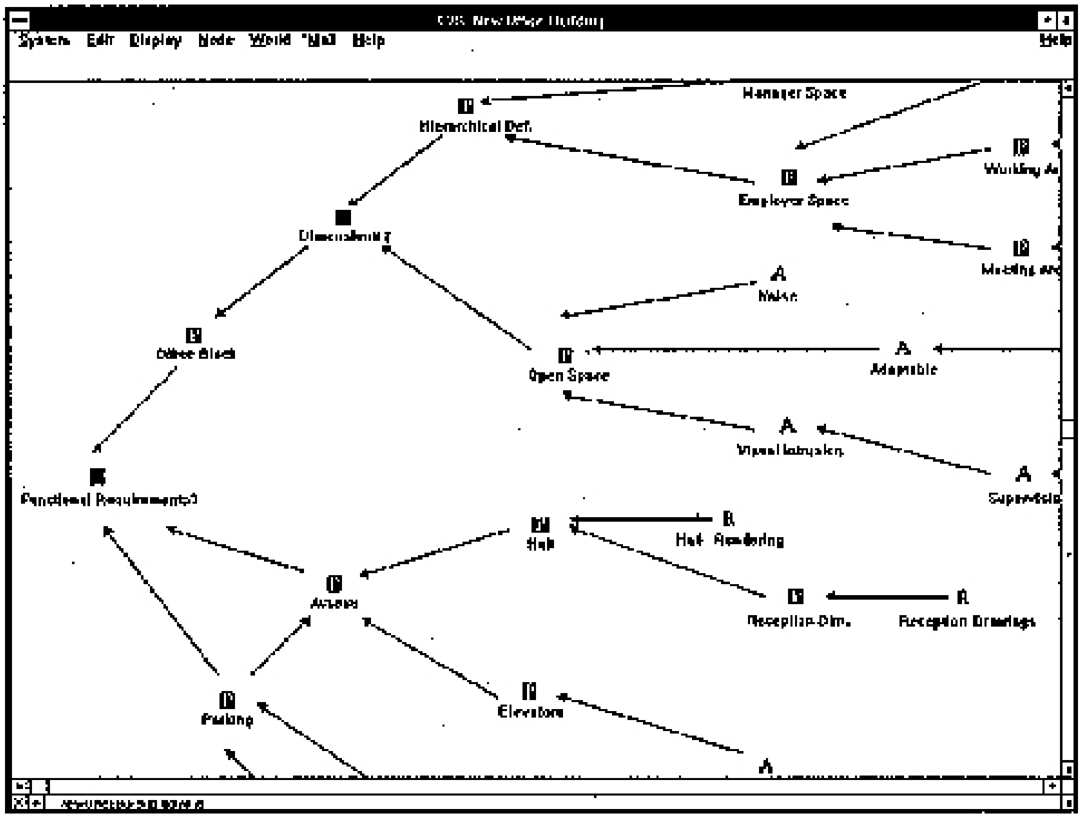

Fig. 4 - System implementation of the argumentative graph

Rhetorical Graph

In order to export a new vertex on the Server, a graph editor is used, which integrates the methodologies and the tools to represent the rhetorical states and relationships (figure 5). In order to visualize the graph, the various Clients can access the overall shared file system for reading only, while only one Client at a time can have writing access.

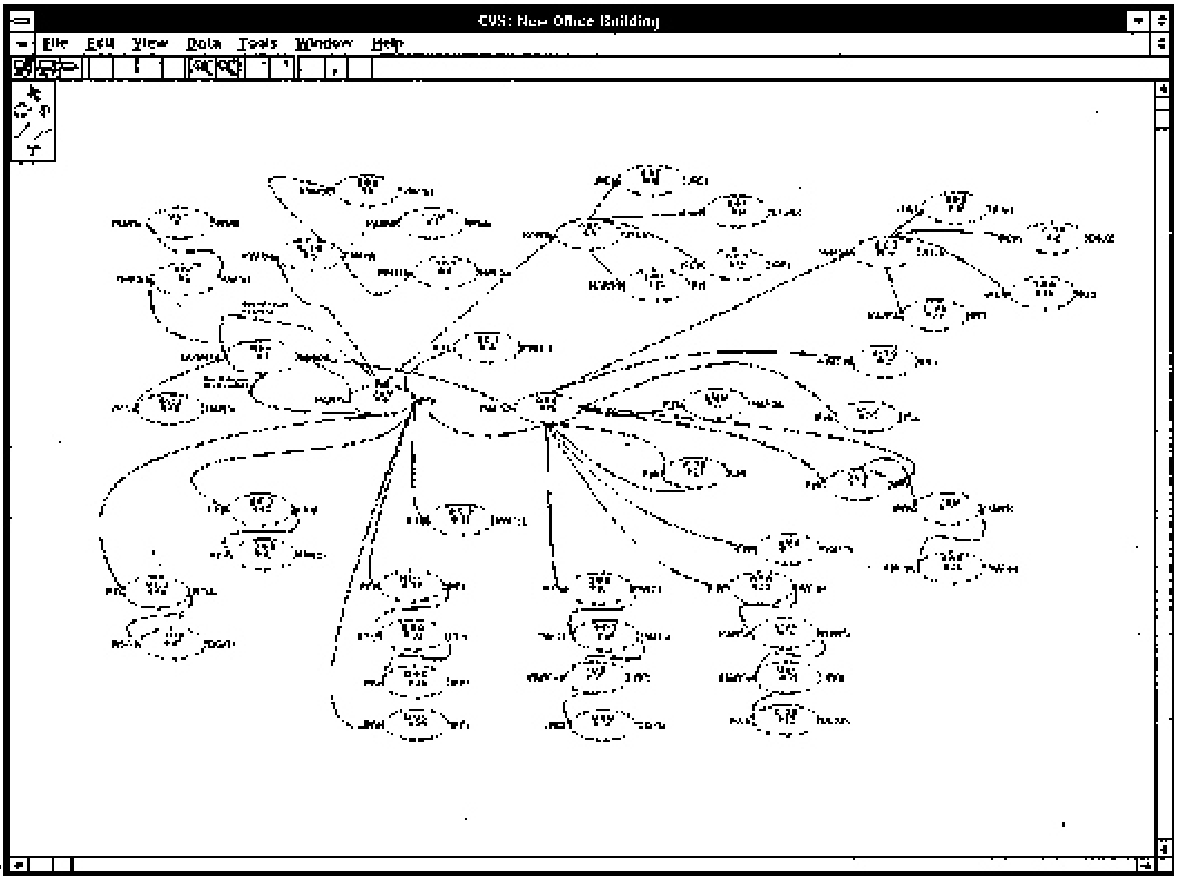

Fig. 5 - System implementation of the rhetorical graph

Semantic Graph

The program does not require its own file system, because it makes use of the file systems of the argumentative and rhetorical graphs. This program resides on the Server and is activated by the insertion of a new vertex in the shared file system.
The implementation is based on the "self-organizing map" algorithm defined by Kohonen (Ritter et al. 1989); specifically, it makes use of the packages (Wilke 1995) for the simulation of artificial neural networks. The self-organizing map shows the frequency and distribution of the semantic units in the two file systems (figure 6) and at the same time checks their congruence. The program calculates the position of the new vertex in the map in such a way that the mutual positions of the vertices represents the occurrences of information in each vertex.
In order to visualize the graph, 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 upgrades of the file system, especially during phases of intensive system use.

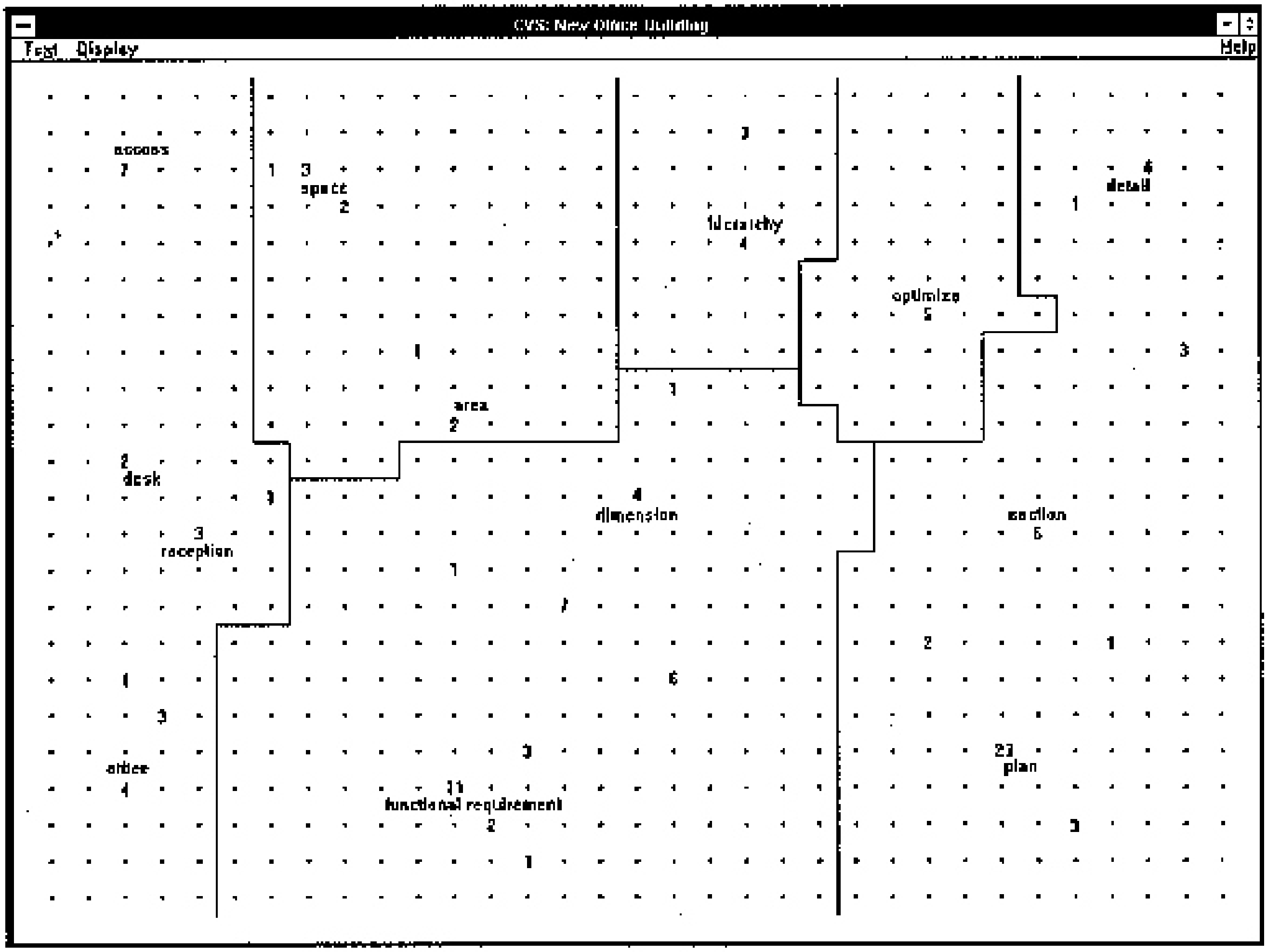

Fig. 6 - System implementation of the semantic graph

Conclusions

What are the implications of the coordinative model for the design and building process?
The coordinative model is first and foremost a knowledge tool for investigating the nature and complexity of the process. The model aims to deepen knowledge and its implementation in a system suggests further research issues. It is possible to study the process dynamically: how the actors interact, what information is communicated, what the actors' demands and expectations are and what the requirements and specifications of the communicative and coordinative systems are. The model proposed is potentially applicable to a wide range of design and building process, but further research might be done to refine and elaborate the characteristics of the coordinative model applied to different design and building issues and problems.
The implementation of the coordinative model might help actors to perform their jobs better. Since the design process takes many of its characteristics from the way in which actors interact, it is clear that incorporating coordinative technology in the design and building process might facilitate the dif5cult work of cooperation among the actors.

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