Participatory Architectural Modeling: Common Images and Distributed Design Developments

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Abstract

Drawing on cases of teamwork in architectural modeling, this paper reports a study in rich and informative approaches to participatory design. Two features of participation and coordination among designers are observed: (1) for technical necessities, members of a design team work in individual design worlds calling upon heterogeneous conceptual structures and instruments; and (2) for critical judgements, the emergence of final unity in design products as a whole is of common concern shared by all participants, which is dynamically related to the developments of design solutions in individual domains. By abstracting generic patterns of cooperative modeling from the cases discussed, several concepts of communication in participatory design are explored. It is found that a view of situating modeling acts in coupled modeling spaces can lead to a useful exposition of participatory design in terms of the interrelations between *common images* and *distributed design developments*. As guiding pointers to further research, the current study identifies two distinct generic patterns of communication in participatory design.

Keywords

architectural modeling, teamwork, modeling acts, modeling spaces, common images, heterogeneity, distributed design developments.

1 Introduction

In the field of design study, there are two ways of seeing participatory architectural design. One sees the participation among prospective users, professional designers, and clients etc, taking part in the planning, design, or even construction processes (see [Ers80, AHMC85, Kro88], among many other world-wide examples). The second focuses on participation by professional designers, for which various interpretative frameworks of how designers work with one another have been proposed. In this paper, I attempt to define participatory design from an architectural modeling perspective with the participation in the second sense mentioned.

In *PDC'92: Proceedings of the Participatory Design Conference*. M.J. Muller, S. Kuhn, and J.A. Meskill (Eds.). Cambridge MA US, 6-7 November 1992. Computer Professionals for Social Responsibility, P.O. Box 717, Palo Alto CA 94302-0717 US, cpsr@csli.stanford.edu.

However, in the absence of "user participation", the usefulness of this study remains justifiable by two points: (1) it demonstrates non-trivial examples of design perspective and undertakings of highly heterogeneous natures that often participate in the practice, and (2) it asks for an exposition of the relationships between the emergence of design products as a whole and the integration of partial solutions developed in distributed individual object worlds.[1] It can be argued that the issues of the nature confronted here may occur in most occasions of participatory design involving users; and it can be even more relevant if the design and use of computing tools is considered, as contemplated in [Gru91].

On interpreting participatory design of a narrower scope, one of the well-known metaphors is design as *game*. Lawson has reviewed several design games that were specially devised to model group dynamics in architectural and urban design [Law80]. Following the game paradigm, Habraken and Gross invented a computer program called *Concept design game* which can record players' interactive moves during sessions of control distribution and territorial organization [HG88]. Schon proposed a theory of *reflection-in-action*, drawing on one of his protocol analyses of a design dialogue between an architecture student and a studio master [Sch85. A similar studio-based study of participatory architectural design on a larger scale was carried out by Ward, in which seven subjects went through group processes and developed *archetypes* for a commercial complex project by gathering individually made cardboard models [War87].

Assuming that professional designers participating in a project are capable of communicating and acquiring user requirements, this paper adopts a somewhat different measurement toward an analysis of the communicative aspects of participatory design. Basically, it is considered that an adequate understanding of participatory design can be gained by studying, not simulated nor controlled but naturally developed, design expressions drawn from real cases of group practice. In particular, the largely graphical expressions are examined from a *modeling* point of view.

[1] The term and concept of "individual object worlds" is borrowed from Bucciarelli's recent ethnographic study of engineering design. For a more detailed description, see [Buc88].

That is, design is mainly taken as an activity of modeling complex objects. The drawings, diagrams or 3-dimensional models are the artifacts that designers produce to convey and coordinate individual design intentions and judgements.

As a general finding from analysing the artifacts, a long and heterogeneous participatory design process is said to involve two things: one is the emergence of *common images* that is shared among participants; the other is the developments of *domain design specifications* that are distributed over participants' individual modeling spaces. Having introduced common images first does not mean that what is common has to be developed in the first place; as shown in this study, it can be the other way around. By further inquiring into the interrelations between the modeling of the common and of the distributed, a general setting of participatory modeling is concluded. When situated in this generic setting, a number of modeling acts performed by participants are observed to demonstrate certain communicative properties.

The remainder of the paper is arranged as follows. In Section 2, a study of three examples of participatory architectural modeling, taken from real cases of group practice in design, is presented. Based on the case discussions, Section 3 gives an exposition of how common images are formed in relation to distributed developments of domain design specifications. The implications of two abstract patterns of communication identified in this paper for further research into computer-supported cooperative design is discussed in Section 4.

2 Examples of Participatory Architectural Modeling

Architectural modeling can take place in various dimensions, allowing for a variety of approaches to participation. What follows in this section is an introduction to this variety through three case studies of participatory architectural modeling. The first shows an example of one dimensional convergence of two conceptual design worlds participated in a fountain design project. The second shows an approach of overlaying two-dimensional diagrams constructed by at least three different design disciplines for re-engineering a large industrial building. The third case gives an exceptional illustration of a three-dimensional funicular model that was commonly constructed but used differently by a number of designers for a church design.

2.1 (Case 1) Between score and diagram

Design project: Seattle Center Fountain, Seattle, USA, 1962-1964.

Aspects & participants: waterscape design by two landscape architects (Lawrence Halprin, Curtis Schreier); and fountain engineering by a mechanical engineer (Daniel Yanow) [Hal69].

The scoring and diagraming spaces

- The Landscape Architects (LA) used a particular representation scheme called "score" for modeling fountain patterns and actions in a temporal frame (Fig. 1). A score has two dimensions: one for regulating multiple temporal sequences, represented in certain lengths of bars; the other for configuring spatial structures of different fountain stages (platforms), represented as point, square cross, rectangle etc. By manipulating the bars, a score reveals different compositions of active fountain stages against the inactive ones over a period of time.

- The Mechanical Engineer (ME) used "diagrams" to model mechanical components for piping, jetting, sprinkling design (Fig. 2). A pool piping grid was composed in a system of graphical symbols, corresponding to a set of design objects whose attributes were specified in words and numerals. In relation to the piping grid, a mechanical section was constructed to convey sectional information. Due to the correspondence set up between the mechanical components and the graphical symbols, the ME could virtually change the attributes and relations of particular design objects by manipulating parts of the diagrams.

A common space for projecting water effects

The graphical expressions in Fig. 3 shows a series of *squiggles* spreading over a formal *grid*. This evidence implies that a common modeling space shared by LA and ME was formed on the basis of combining the designs in the score and in the diagram, in which a sequence of water effects can be *projected*. Here we see an example of a set of *common images generated*, allowing for *interpretations* of the design consequences from various viewpoints. It is clear that the images of water effects can be interpreted both in LA's view -- the actions of fountain stages as scored over a time span, and in ME's view -- the fountain kinematics concerning the motions of pipes, jet heads, sprinklers as configured in the piping grid and mechanical section.

Interrelations between modeling spaces

Given the above evidence, two interrelations between scoring, diagraming, and projecting spaces are worth noting, which yields further accounts of what constitutes participation in developing the fountain design:

- Sequences of water effects at particular moments cannot be projected solely in LA's scoring space nor in ME's diagraming space; the possibility of projecting is conditioned by knowing what fountain stages are active at those moments and what mechanical devices are operative on those active stages plus how they shall behave -- a convergence between two individual modeling spaces whenever a projection is undertaken.

- Modeling actions taken in individual spaces change not only the state of the score or the diagram but also the state of the common image when projected; ME may take further actions upon his interpretation of the changing water effects propagated from LA's actions of changing score, and vice versa -- communication and coordination are called for to resolve disagreements or conflicts thus arising.

2.2 (Case 2) Participation through overlay diagraming

Design project: Cummins Research and Engineering Center, Indiana, USA, 1964-1968.

Aspects & participants: Structural Engineering (SE) (The Engineers Collaborative; Lighting Engineering (LE)

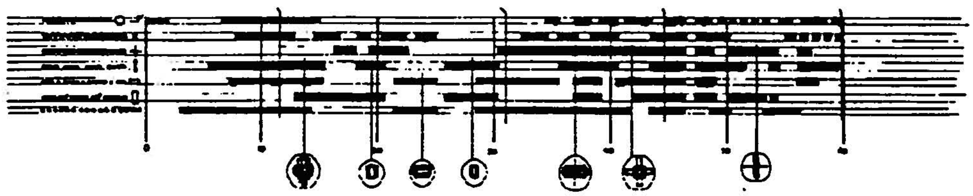

Fig. 1 The landscape designers' introducing and operating with *Score* in modeling fountain patterns and actions over a period of time. (Drawing taken from [Hal69], page 56)

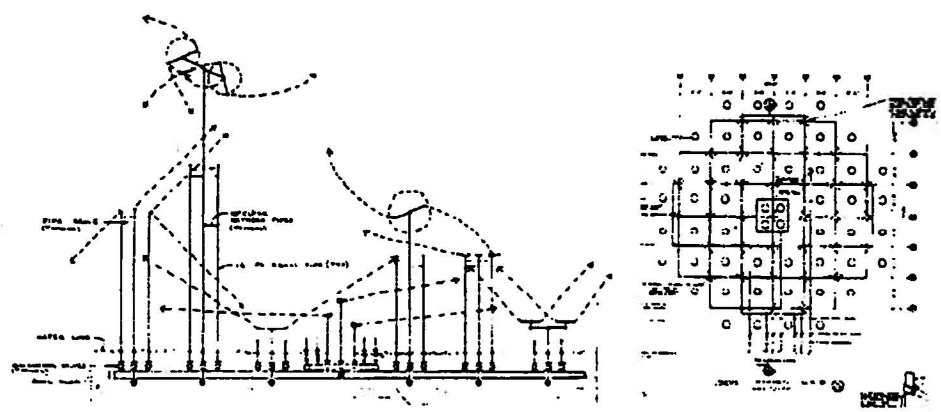

Fig. 2 The mechanical engineer's introducing and operating with *piping diagrams* in modeling the behaviors of the mechanical components. (Drawing taken from [Hal69], page 56)

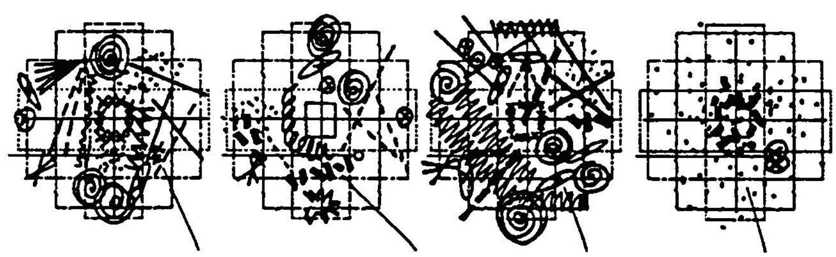

Fig. 3 The graphical indications of a shared fountain modeling formed by a combination of LA's scoring and ME's diagraming, which can project water effects, allowing for different interpretations. (Drawing taken from [Hal69], page 56)

(William Lam Associates); Mechanical Engineering (ME) (Cosentini Associates).

The main design issue is centered on how to "rearrange ductwork to the structure and to baffle the indirect light sources" [Lam77].

Distributed diagraming spaces
Each engineering discipline had its own object-based diagraming space.There were at least three domain-oriented diagraming spaces participating in the project: SE, ME, and LE (Fig. 4). Each diagraming space employed a special coding system to represent the modeled building components.

Evolving the environmental design through overlaying
According to Lam, the group processes evolved a "fishbone layout" which proved to be economical and satisfactory to all participants [Lam77] (see Fig. 5). Clearly, the emerging of the fishbone image is conditioned by the participants' continuously *overlaying* their individual diagrams.

Articulation of common images
Apart from the interrelations noted in Case 1, the current case shows that participants can further articulate a common image into various parts that play different roles or functions (the spinal cord or ribs of a fishbone, for example); differentiated portions of a common image are then distributed to serve individuals' developing domain solutions. Participation in design is therefore maintained by a *to and from* relation between the individual and the common which is in turn built up by the following processes:

- *overlay diagram construction:* A participant can construct diagrams on top of extracted common images

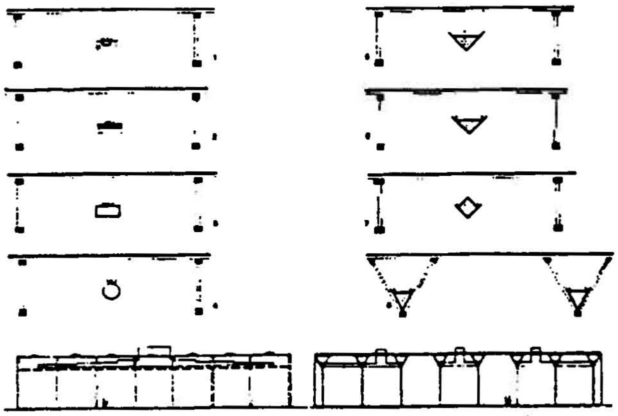

Fig. 4 Multiple diagraming spaces in different layers showing the participants' heterogeneous coding systems for modeling the aspects of the building design. (Drawings taken form [Lam77], p. 126)

which may contain parts of diagrams drawn by other designers working on different aspects.

- *overlay design checking:* Participatory design can be evaluated by checking overlaid consequences according to certain criteria such as detection of spatial clashes.
- *overlay design amendment:* A participant can modify parts of diagrams by referring to the diagrams underlaid in various ways (e.g. geometrically, economically, or aesthetically etc.); and one designer's amendments may cause related changes to be made by others.

2.3 (Case 3) Funicular modeling revisited

Design project: The Colonia Guell Church, Barcelona, Spain, 1889-1914.

Aspects and the participants: site planning and structural form by architects (Antonio Gaudi, Jose Canaleta); structural engineering by a civil engineer (Eduardo Goetz); ornamentation by a sculptor (Juan Bertran)

The funicular modeling space

An upside-down funicular model was constructed by the design participants at the inception of the project. According to Collins and Nonell [CN83], this large 3-dimensional model, which was shared and manipulated by all participants for different design tasks, had the following distinctive types of model components (see Fig. 6):

- *cords* hung in loops corresponding upside down to the placement and shapes of the piers and arches of the building's vault;
- several pieces of irregularly shaped (wooden) *boards* fixed onto the structure of the workshop, representing contour lines of the building site;
- *weights* made of pellets contained in small sacks (measured in the scale of 1/10,000), when attached to the hung cords, distorting the cords' catenary curves into funicular polygons;

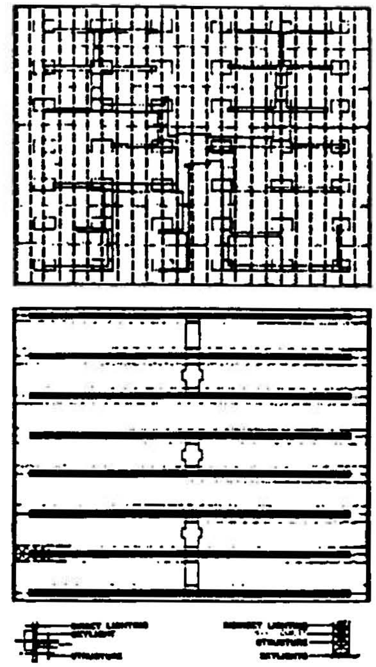

Fig. 5 The combined images of structural, mechanical, lighting design solutions get evolved through the participants' overlaying individual developments. (Drawing taken from [Lam77], p. 126)

- *fabric* draped onto the web of funicular polygons, representing the volumetric effects of the building exterior;
- a set of domain-neutral objects made of *jointers*, *hooks*, and *clippers*, which do not represent any particular components of the building design but function importantly in connecting the model objects and in manipulating parts of the funicular model.[2]

Funicular modeling and distributed drawing spaces

- The civil engineer's structural calculations: the distribution of loads in space and the thrusts of force lines were calculated by the engineer in a 2D vector space; to him, the funicular model was a 3D illustration of his 2D graphic static modeling.
- The architects' sketching out the exterior and interior spaces: photographs of the exterior and interior of the funicular model were taken and turned right-side up by the architects as the underlay information for modeling the locations, proportions, and shapes of openings (the fenestration of the building).
- The sculptor's sketching out the ornamentations: the sculptor was concerned with the design of sculptural objects such as the ornaments for the building's exterior and interior; like the architects, he took photographs of the funicular models for his own design interests and tried out design solutions by overlay sketching (Fig. 7).

[2] Jointers were used for attaching weights to cords; hooks for connecting the ends of cords to particular locations on the boards; clippers for clipping cords together at various heights (bifurcation).

Fig.6 The funicular model constructed for the Coionia Guell church project as it hung in the workshed. (Picture taken from [CN83], Fig. 39)

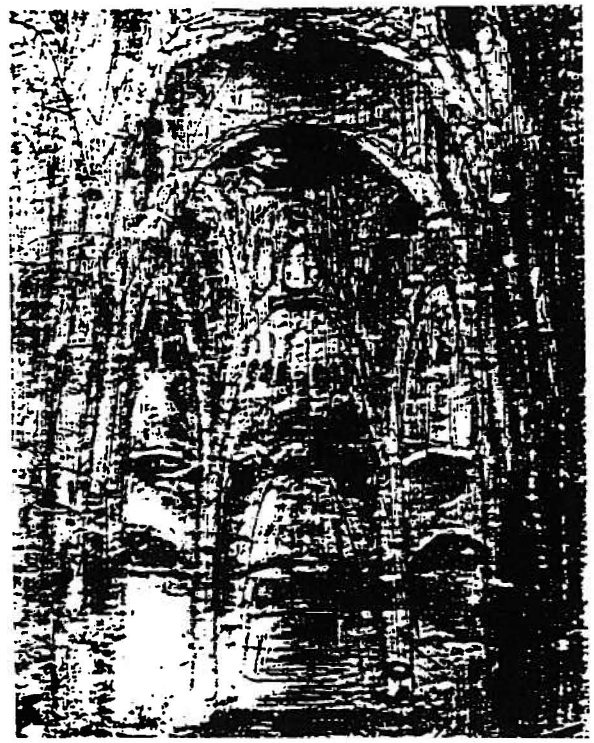

Fig. 7 A freehand sketch of the church interior design, tried out on top of a photograph of the funicular model inverted. (Drawing taken from [CN83], Pl. 57)

Group interaction in the funicular modeling space

Given the above observations, several accounts can be made for what makes the funicular modeling space a shared workspace for the design team, and how the shared model served as an evidence of interaction between the participants:

- First of all, the funicular modeling space was continuously developed and used by the design team for supporting long term participation; the participants collaborated on the modeling in delicate exploratory work lasting over 10 years [Mar79].
- The model served as a common image of a structural form shared by the participants, since the modeling space allowed them to manipulate the funicular model for reasons other than the strictly structural.[3]
- For any state of the model, the participants could have individual interpretations and derive design information from, perhaps, different measurements; and the information derived further served as the basis for the individuals to elaborate individual design models distributed over several work settings.
- The factor that the earth's gravity was one of the (direct) forces in shaping the model can explain how the group interaction could be coordinated by the shared modeling space. Through the action of G-force, the model constructed and manipulated always conforms to the physical law of *funicular structure* [Sch80]. Therefore, a modeling action taken by an individual, for whatever reason, can motivate or activate other team members' interpretations and actions in response to the changing state of the funicular model.

3 Modeling Complex Objects by Participation: An Exposition

Alternative conceptual frameworks for describing the communicative aspects of group working have been proposed by researchers working in Computer-Supported Cooperative Work (see e.g. [TL88,Kuu91,SB91] among many others). The proposed frameworks are useful in two respects: first, they serve to describe, in more precise terms, the complex human phenomena, processes, or activities observed in practice, and produce coherent overviews; second, they indicate a range of requirements for guiding the developments of prototype computing or communication tools. In this section, by abstracting the previous case observations, a conceptual framework of modeling design objects by participation is proposed. Starting with the basic notions of modeling acts and modeling spaces, three communicative aspects of participatory design are explored. As a result of the exposition, two generic patterns of participation are found, which indicate several issues for further investigation.

Given the observations in the preceding section, design in general may be better characterized as an open-ended *modeling* process consisting of the following basic ele-

[3] For instance, for the purpose of site planning, cords can be shifted to different hooks or by moving the hooks around the board; for modifying fenestration design, cords can be bifurcated at various heights via sliding the clippers along the force lines; for changing structural form, loads can be redistributed in space by controlling the number of pellets in sacks or by displacing the sacks' jointers to different positions on cords.

ments: (a) design constructs or concepts are (continuously) introduced and (re)structured, i.e. the forming of a design modeling space; and (b) shapes or forms of design artifacts are attributed, manipulated, and evaluated iteratively, i.e. the performing of modeling acts. Therefore, design as an activity can be conceptualized as the performing of modeling acts in a modeling space. In a long participatory process involving heterogeneous sources of design knowledge and actions, another distinction can be made among the modeling spaces that are formed/used by individuals and those by all participants: (c) multiple Individual Modeling Spaces (IMSs) are separated but logically and/or functionally connected with a Group Modeling Space (GMS).

By combining the above setting with the different types of artifacts identified, a space-action framework for characterizing participatory modeling can be set forth. The framework is constructed in three parts, presented in the following subsections.

3.1 Common images in a GMS

The fact that participants speak heterogeneous design languages does not prevent them from achieving design images that are commonly shared among them. Taking in various forms, common images can serve either as conceptual structures or as specific instances which allow for individual interpretations from different viewpoints. As observed, in modeling common images, expressions can be constructed in a group modeling space by the following approaches:

- A common image is constructed jointly by all participants, employing a shared construction method or system; serving as a shared conceptual structure, a common image allows for each participant's deriving and distributing its parts over individual modeling spaces.
- Common images are formed by participants' combining and integrating domain-specific design expressions with perhaps heterogeneous underlying structures; serving as the outcomes of participation and collaboration, common images are inspected and interpreted by the individuals for reflecting on design consequences from various viewpoints.

The state of a common image is subject to continuous changes that may well motivate intensive group communication in respect of how the image may be formed:

- Changes can be made directly in parts of a common image by any participant, if its existence originates from a group modeling space; and changes made by one individual in parts of a common image may have consequences somehow meaningful to other individuals' modeling spaces.
- Changes can be effected indirectly in parts of a common image, if it is formed on the basis of combined and integrated domain structures. The state of a common image gets updated by way of one or more participants' manipulating parts of domain expressions; a changing common image caused by one individual in an individual modeling space may thus motivate other participants' further actions in respect of the changing states of domain expressions.

3.2 Distributed design developments in IMSs

Design calls for participation mainly because its development requires a combination of design judgements and technical specializations that in reality one individual can hardly have. In parallel to the forming and evolving common images, aspects of a design project are often developed by designers trained with different design disciplines in a logically and/or geographically distributed manner. From a local perspective, design developments can be distributed according to two approaches:

- Participants employ individual working methods or object worlds in their own modeling spaces which are not necessarily known to each other; design expressions specific to certain modeling aspects are thus produced by perhaps markedly different individuals which then serve as the basis of joint construction of common images.
- Participants interpret the states of common images from different viewpoints; the structural images thus derived provide the basis for further domain-oriented design elaborations using modeling methods appropriate to the tasks.

Design changes targeted at local design developments can take varied accesses regarding how they may be developed, and the actions of making changes need to be interactive since they all have something to do with common images in group modeling spaces:

- Changing parts of domain design expressions constructed on top of derivative structures needs to be based on participants' manipulating corresponding parts of common images which may consequently change parts of underlying structures distributed in other design domains.
- Changes in local developments can be made directly in individual modeling spaces which may lead to changes in a common image that, in turn, motivate participants' taking modeling actions in related domains.

3.3 Interrelations between the common and the distributed

In the above, the artifactual aspects of participatory design including those of Common Images (*CI*) in a Group Modeling Space (GMS) and of Domain Design Expressions (*DDEs*) in multiple Individual Modeling Spaces (IMSs), are described in conceptual terms. Given these concepts, a natural question to ask is how these aspects are interrelated with each other. To draw the interrelations, two further concepts need to be introduced explicitly: the participants' performing a range of *modeling acts*, and the coupling of modeling spaces.

Performing modeling acts

A number of distinct actions involved in design modeling can be drawn from the case studies, for example:

- *Representing* -- involving, first, listing a collection of basic objects (constructs) which represents analogically or symbolically the corresponding elements of a design artifact; secondly, specifying how instances of the primitives are related in terms of what *operations* are applicable to the constructs.The act of representing leads to a *conceptual structure* of a modeling space.

Spaces Couping / Modeling Acts	*CI* / GMS → *DDEs* / IMSs	*DDEs* / IMSs → *CI* / GMS
Representing	- (L:) a shared conceptual structure made of group objects and operations - (R:) distributed derivatives of common images imported as underlying conceptual structures for domain uses	- (L:) individual conceptual structure made of heterogeneous sets of objects and operations - (R:) integrating individual conceptual structures into common sets of objects and operations
Mapping	- applying deductive, projective means on states of common images and acquiring derived structures for individual purposes	- translating parts of individual conceptual structures in one design domain into another for interpersonal/group purposes
Constructing	- (L:) changing states of common images yieled from applying group opertaions onto group objects - (R:) changing states of domain expressions yielded by applying some coding devices onto distributed derivative structures	- (L:) changing states of domain design expressions yielded in individual object worlds - (R:) changing states of common images yielded from combining/integrating domain design expressions
Querying	- retrieving and juding states of common images regarding design developments manifested in domain design expressions	- reflecting on domain design developments in respect of what emerges as states of common images

Fig. 8 When situated in the settings of coupled group/individual modeling spaces, modeling acts become communicative acts that require participation and coordination among designers working in different modeling domains.

- *Mapping* -- the act of translation and integration of (parts) of an existing conceptual structure to (parts) of another conceptual structure.
- *Constructing* -- (given a conceptual structure) the act of applying operations onto selected primitives for creation/modification of *CI* or *DDEs*.
- *Querying* -- (given a conceptual structure) the act of applying operations onto parts of *DDEs* or *CI* for evaluations of design instances.

The Coupling of modeling spaces
Based on the previous observations of how common images and domain design expressions are formed and changed, it can be inferred that there are two distinctive ways of interconnecting a group modeling space with multiple individual ones.

- {(*CI* /GMS) → (*DDEs*/IMSs)}
  Creating, storing, and updating common images in a group modeling space leads to the creating, storing, and updating of domain design expressions in distributed individual modeling spaces. This coupling of group-individual spaces enables modeling acts to be performed directly on common images modeled in a group space which can consequently affect the states of local design expressions. The funicular modeling is an example of such an interconnection between group and individual modeling spaces.
- {(*DDEs*/IMSs) → (*CI* /GMS)}
  Creating, storing, and updating local design expressions in any individual modeling space leads to the creating, storing, and updating of the state of a common image. This coupling facilitates direct modeling acts performed in individual spaces which, consequently, can trigger the projection of changed common images.in a group space. The coupling of the spaces for scoring, diagraming, and projecting in the fountain design is an example.

To conclude the current exposition of participatory design, the performing of modeling acts and the coupling of modeling spaces are put together into a matrix [Fig. 8]. The example modeling acts are said to be situated in two types of participatory setting for modeling design objects, and modeling acts become *communicative acts* that require, or lead to, communication among designers working in different domains of modeling.

3.4 Related work

The problem of what and how to develop communication or computer systems that can be supportive for people involved in collaborative design has become an active research area within the field of Computer-Supported Cooperative Work (CSCW). In a recent CSCW bibliographical survey, Greenberg [Gre91] suggested the keyword "shared workspaces" to cover an emerging research area. In this subarea of CSCW research, the understanding of "collaborative design" is one of the focus objects of observational studies, and some research prototypes of "shared drawing spaces" have been developed to support, mainly, group drawing activities.[4] In contrast, this paper proposes a view of design as modeling activities, by which more attention is drawn to the issues of participants with heterogeneous backgrounds and the interrelations between modeling by sharing and by

[4] For a survey of CSCW-oriented designs in shared drawing space with a particular interest in reviewing how the issues of supporting collaborative design work have been addressed by the research prototypes, see [Pen92a].

differentiating. Clearly, to support participative modeling activities sufficiently shared workspaces are expected to be designed with more dynamic features.

Research in Distributed Artificial Intelligence (DAI) has been concerned with the design and implementation of computational frameworks for cooperative distributed problem solving. In particular, the aspect of group modeling of common images discussed here bears some relation to two researchers' work on the representation and use of organizational knowledge for communication. Among these, Leigh Star [Sta89] reported a study of four types of "boundary objects" that function in organizational problem solving observed in scientific communities. Boundary objects were then considered as appropriate candidates of data structure for DAI systems. In examining the cooperation of specialists with distributed knowledge for carrying out large engineering design tasks, Bond [Bon89] explored the use of predicate logic in describing the collaboration of agents with disparate knowledge. Bond's paper came up with a simple model of collaborative design, consisting of a separate "private language" for each agent and a shared "argument language" that can work with rules and strategies of collaboration specified in the model. Apparently, a conceivable elaboration of my current work is more related to the formalisms that have been experimented in DAI not particular computational models of collaboration.

4 Conclusions and Further Work

In this paper, a problematic situation of participatory design is considered. As a precondition, in undertaking design tasks, participants need to work with design worlds that are dedicated to particular domains of design concerns. As a meta-goal, designers work to develop shared common goals in parallel to individual ones such that general design unity and technologically sound domain specifications can be achieved. An interesting issue to explore is how we may account for the communicative approaches involved in the participatory situation. For this, an exposition of group communication in the realm of group practice in architectural modeling is presented.

By abstracting observations of three examples of participatory architectural modeling, it seems that we may better capture the generic elements and patterns of communicative activities by formulating the connections between [(common images)/(group modeling space)] and [(distributed design developments/(individual modeling spaces)] that are clearly present in all the case studies. Within this conceptual setting, it is easier, and, hopefully, clearer, to point out certain communicative properties of the actions performed by individuals in modeling complex design objects.

To take some stock of the concepts explored in the paper, two distinct patterns of participatory design, as seen from the perspective of architectural modeling, can be put forward. The intention is that the current exposition actually indicates a spectrum of possible functionalities of an enabling environment. The two alternate patterns of participatory design are tentatively defined as: *structuralist* vs. *metaphorist* (Fig. 9).

Seen from the *structuralist* standpoint, common images, manifested as shared generic structures and built upon group primitives and operations, play a significant role in coordinating participants' modeling activities. Group modeling space in this pattern is basically a shared construction system that may usually make use of some sort or sorts of structuring mechanisms. The funicular modeling space may be exceptional on its own. However, in serving a similar role, there can be other form-finding systems introducing innovative physical or formal laws that members of a design team would like to experiment with. In mapping parts of common images by perhaps different means, participating designers can derive spatial/functional structures of interest, on top of which domain design solutions can be developed and elaborated in individual ways. The sharing of common images enables participants to know the consequences of making changes in the derivative images, which is bound to occur in the course of developing domain solutions.

On the other hand, seen from the *metaphorist* standpoint, participatory design is approached by participants' introducing individual primitives and operations that may not be know to each other at the outset. With these initial settings, domain design expressions can be modeled in individual spaces. By presenting domain proposals in a public forum, participation in combining and integrating original conceptual structures or schemata is initiated and leads to the sharing of group constructs and generative functions. In this pattern, common images need to be constructed or assembled on the basis of domain proposals modeled by each party, using the shared constructs and operations. As shown in the fountain and the engineering research centre projects, the common images, evolved as shared design metaphors (i.e. the images of squiggles and fishbone), enable participants to know the consequences of making intended changes in domain expressions.

As follow-up studies of the above characterizations, two further investigations are now in progress. By emulating the metaphorist pattern just described, a simplified example of participatory modeling of building envelope design was planned and put into an algebraic setting for a formal analysis. Some initial results of a computational representation of integrating different spatial schemata by participation are reported in [Pen92b]. Another exercise, much inspired by the structuralist approach, is now under development, concerning how communication can be represented and maintained between the evolution of common images and those of domain expressions modeled in participating object worlds.

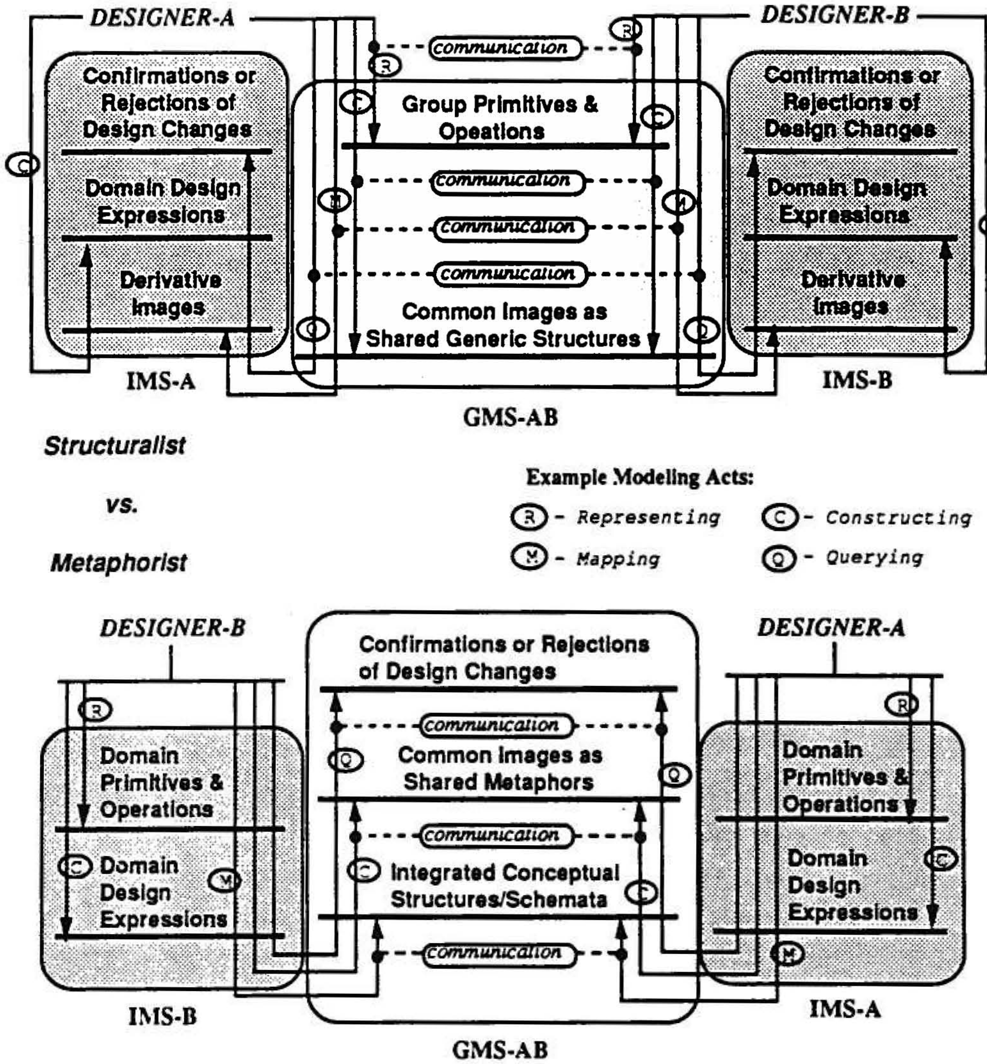

Fig. 9 Two abstract communication patterns found in the present study of participatory architectural modeling are characterized as *Structuralist* vs. *Metaphorist*. The number of designers indicated is arbitrary. The scaling of 2 to *n* designers can be envisaged by viewing this diagram as "a section of a cylindrical structure." Seen from this picture, in coordinating modeling activities with other members of a design team, an individual's workspace is a combination of his or her own IMS with a GMS.

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