COLLABORATIVE CAD MODELLING IN MULTIDISCIPLINARY DESIGN DOMAINS

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Abstract. In a multidisciplinary design environment, such as the AEC domain, the various designers will have their own concepts and representations of the design object making communication in such an environment a complex task. This paper argues for a multiple view approach based upon an assumption that different concepts of an object are based on different functional contexts. Thus an understanding of concepts such as function, purpose and intent is critical since the representation of the functional properties of design objects is the underlying basis for the formation of different concepts and coordination of these concepts. The paper points to the modelling of multidisciplinary design teams as cooperative intelligent agents in a distributed decision-making system where the explicit representation of function and purpose are essential, in a CAD environment, for the necessary communication of intent and effects.

1. Introduction

Large scale design projects involve many different disciplines each with their own area of concern and expertise. At various stages of the design designers from different disciplines will represent an abstraction (a model) of the current design according to their views. These different models will initially be incomplete and inconsistent but through collaboration they will undergo changes as inconsistencies are removed and details are added and eventually a consistent representation emerges which allows for the realization of the design object under consideration.

While currently paper-based representations are the conventional method used for representation, it is being realised that the complexity of large-scale design projects can only be adequately handled by a systems integration and automation approach and that computer-aided design (CAD) is the vehicle for providing this integrated information processing (Madison, 1991). However, the use of CAD systems for representing design objects brings into focus the aspects of explicit/implicit representations and especially the requirement of different views and representations of the same design object by different design disciplines.

In order to make CAD modelling useful to designers in a collaborative environment, such as the Architecture-Engineering-Construction (AEC) domain, each designer's view and representation must be accommodated and integrated within a comprehensive representation of the design under concern. This paper argues that a multiple view approach is essential for any meaningful representation in a multidisciplinary environment. Since views and representations depend upon a functional context, i.e. a particular set of functional concerns, the representation and application of functional properties is an essential aspect of any successful collaborative CAD modelling.

2. Multidisciplinary Design Domains

2.1 CONCERNS AND CONCEPTS

The AEC domain typifies a multidisciplinary design domain. In the AEC design environment many disciplines are involved, each dealing with a specialized aspect of the building design and each with its own concepts and interpretations of the object (the building). The fragmentation of the design and construction disciplines in the AEC domain is due to the specialization of each discipline according to functional concerns.

Architects are mainly concerned with providing sufficient, efficient and aesthetic spatial environments for a given set of activities. They are thus concerned with the form and organization of spaces and those elements relevant to those purposes and with concepts such as spatial sufficiency, spatial organization, comfort, aesthetics, weatherproofness, rooms, storeys, facades, floors, walls, etc. Structural engineers, on the other hand, are concerned with providing stability by resisting or transmitting forces and moments. They are concerned with concepts such as gravity/lateral loads, support, bending, shear, deformations, beams, columns, shear walls, etc. Mechanical engineers are concerned with providing functions such as transportation and climate control through the provision of mechanical facilities, such as transportation systems and mechanical HVAC systems. They are concerned with concepts such as flow, capacity, time, energy and power, elevators, escalators, motors, coolers, heaters, piping, etc. Contractors, on the other hand, are concerned with the constructability of a design and hence with the relationships between the physical elements and the operations and sequence of operations required to construct the building. That is, they are concerned with concepts such as availability, composability, time and place, stability, walls, windows, beams, pipes, etc. Some aspects are the concern of more than one discipline, e.g. environmental aspects are the concern of both the architect and the HVAC engineer.

2.2 COLLABORATION BETWEEN THE DISCIPLINES

At different stages of the design process different kinds of information are communicated. At the preliminary or conceptual stage of the design process, the main aim is to communicate concepts and intentions to enable the selection of systems and elements. At the detailed design stage, the main aim is to set consistent values for the structure attributes of the elements.

Paper-based representations have been the conventional method used for representation. These drawings, actually contain only unstructured graphic entities such as lines, text and symbols. Through agreed conventions, structure and meaning is added by humans and these graphic entities are interpreted as a coherent structure of some design object. However, since the graphic entities are essentially unstructured and different kinds of agreements (knowledge) exist, these drawings may be interpreted in many ways. This is both a weakness (ambiguity) and a strength (flexibility). Using traditional methods of communications, each discipline represents its model in its own set of drawings (blueprints). Each such set of drawings represents that discipline’s model of the building using that discipline’s set of representation conventions. Any inconsistencies between the various models have to be discovered and corrected. This is done, traditionally, by marking the appropriate drawings and sending them back to the appropriate discipline. This process usually goes through several iterations. The result is a number of sets of drawings, one per discipline, where, although each set represents the building using a different model, the comprehensive representation is consistent. There is no attempt to integrate the various sets of drawings into one drawing.

The use of CAD in design documentation and modelling is becoming ubiquitous. The use of electronic media allows communication between distributed team members, of the same and different design disciplines, and over larger distances. While it is possible to use CAD as merely a drawing tool and convey the same information that a paper drawing would, i.e. line drawings and annotations, the advantages of using CAD as a modelling tool for systems automation and integration have been extensively presented (Madison, 1991). The method which has generally been accepted, as the means of enforcing consistent representation and interpretation is the construction of a single unified model of the design object under consideration (Bjork, 1987,1989; Gielingh, 1989; Myers et al., 1993; Nederveen et al, 1991). The argument put forward in this paper is that this single model is incapable of representing the different views and models of the different disciplines and that the traditional paper approach, actually represents a necessary approach which has to be dealt with in any electronic communication medium such as CAD.

3. Multiple Views and Models

3.1 MULTIPLE VIEWS

We are concerned with the perception, conception and representation of design objects. Our view of an object depends on our collective experiences and concerns. We build a conceptual model of an object based on that view, i.e. a representation, and manipulate that representation when we communicate. Within certain common groupings, such as design disciplines, there are, generally, common views and common understandings and agreements regarding the interpretation and description of objects thus leading to common representations. In a design context, the view that a person takes depends on the functional concerns of that person, where functional concerns include, in addition to technical functions, non-technical functions such as aesthetics, symbolism, psychological effects, etc. Given a design object, such as a building, there are many views that we may take, leading to different conceptual interpretations. For example, a building may be viewed as a set of activities that take place in it; as a set of spaces; as sculptural form; as an environment modifier or shelter provider; as a set of force resisting elements; as a configuration of physical elements; etc. In fact, a building is all of these, and more.

3.2 MULTIPLE MODELS

A model or abstraction of an object is a representation of that object resulting from a particular view taken. Since there are many different views of a building there will be many corresponding models, Figure 1.

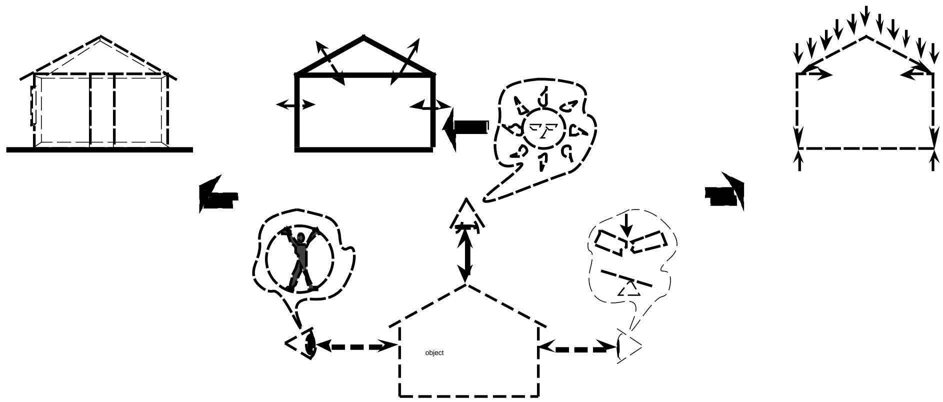

Figure 1. Multiple Views and Models

Depending on the view taken, certain properties and descriptions of the object become relevant. The sound insulating properties of a wall are not relevant to a structural engineer's description of that wall. In fact, many walls may not be relevant at all to a structural engineer. The architects will model certain elements such as floors, walls, doors and windows. For the architects, these elements are associated with the spatial and environmental qualities with which architects are concerned. Structural engineers, however, see the walls and floors as structural elements capable of bearing loads and resisting forces and moments. Both models must coexist since the structural engineers will need to carry out calculations based on their model while the architects may need to ascribe different properties to their separate wall elements, e.g. different finishes. The engineers may modify some of the properties assigned to these element by the architect and may add some new elements, such as beams and columns. The addition of such new elements may affect the architect's model (and vice versa). Any such decisions taken by the engineer must be conveyed to the architect by making changes in the architect's model as appropriate. It will be shown that such changes in another discipline's model can be done when the change affects a function which is the concern of that discipline.

3.3 REPRESENTING MULTIPLE MODELS

There exists considerable work using a single model approach based on the construction of a model from 'primitive' elements from which multiple interpretations are derived (Howard et al., 1992; Amor and Hosking, 1993; Clayton et al., 1994; MacKellar and Peckham, 1994). However, this approach is insufficient since the 'primitive' elements themselves are subject to the views taken by the different viewers and that different primitive models are constructed by each such viewer (Rosenman et al., 1993; Rosenman and Gero, 1996). Moreover, it is never stated who builds the model. Since the basic description of an object differs from viewer to viewer, each viewer may represent an object with different elements and different composition hierarchies. So that not only is the interpretation of the meaning of a design object different from one viewer to another but also the description of the structure of the object differs. No one model contains a comprehensive description of the object but each model must be consistent vis-a-vis the object being described. This approach is similar to that taken by Nederveen and Tolman (1992) and Nederveen (1993). Thus, there exists no single unified model nor even a single set of unique elements but rather different descriptions of the same elements and different subsets of these descriptions in different models.

Since the various models constructed by the various disciplines are representations of elemental models as seen through views based on functional contexts the representation of functional properties of design objects is the underlying basis for the formation of different concepts.

4. Purpose, Function, Behaviour and Structure

The essential factor in a description of any design object allowing for the formation of multiple interpretations is a description of its functional properties in addition to its structural properties. This is because the functional properties associated with a design object reflect the concerns of the various designers and their intent. There have been various attempts at defining the concepts of purpose, function, behaviour and structure (Bobrow, 1984; DeKleer and Brown, 1984; Rodenacker, 1984; Umeda et al., 1990; Hundal, 1991; Gero et al., 1992; Rosenman and Gero, 1994). The approach taken here follows the following definitions:

purpose: is the reason why an artefact exists or why it is what it is;
function: is what is performed by an artefact;
behaviour: is the manner in which an artefact acts under specified conditions;
structure: is what constitutes an artefact (or defines the constitution).

So that *structure* is what an artefact is, *behaviour* is exhibited as a result of a certain structure under given conditions and results in certain *functions* being performed. Thus function is *what* an artefact *does* and behaviour *how* it *does* what it does. Since an artefact may carry out many functions some of which are unintended, *purpose* defines those functions which are intentional and defines *why* an artefact *is* and does what it does (or alternatively *what* it is *for*). In that sense purpose is synonymous with intent.

The acceptance that the function of an artefact is what it does results in the recognition that artefacts perform many functions, only some of which were intended. Motor cars belch out exhaust fumes, they clog up streets, they make noise. None of these functions were intended but occur. In some cases unintended functions can be recognized as being useful and new purposes assigned and hence new uses found for objects. The recognition of the function of a cup that it holds a fairly constant amount of substance leads to assigning a purpose of measuring quantities and to its use as measuring device.

In a multidisciplinary domain, different disciplines will assign different purposes to the same artefact or element arising from their different functional concerns or views. Different functions, and hence behaviours and structure descriptions will be of concern to the different disciplines. Since, intentions or purpose are interpreted as intended functions, the representation of functional properties and functional concerns become the essential factors in a representation schema for modelling in a multidisciplinary collaborative environment. The current practice in CAD systems is to represent merely the structure properties of an object, usually only the graphical representation. It is not always possible to infer functional information from a structural description. For example, one cannot determine that a wall is loadbearing from topological relations alone. Experience in acquiring information from drawings in a case-based reasoning project at the Key Centre of Design Computing has shown that it is not possible to determine information such as whether a beam is part of the lateral force-resisting system, from the structural engineer's drawings, without recourse to the designers (Balachandran et al., 1992). The recognition that graphical properties, while important, are not the only properties that need be described in an object’s representation forms the underlying basis of the STEP effort for electronic data exchange of product information (Spiby, 1991; STEP, 1991).

5. Concepts and Descriptions

Design prototypes describe classes of design elements (Gero, 1990; Gero and Rosenman, 1990). They are object-centred schema specifically dealing with design objects through their categorization of function, behaviour and structure properties. In a fragmented environment, such as AEC, each discipline has its own set of design prototypes with its own concepts, terminology and visual representations which are not necessarily shared between the disciplines. Specific examples of design prototypes, i.e. instances, are described using the design prototype schema and by instantiating all relevant properties to specific values and form that discipline's model.

However, to provide integration between the concepts of the different disciplines, abstract or core concepts are necessary (Nederveen and Tolman, 1992; Nederveen, 1993). These core concepts describe properties which are common to the disciplines. Any element of any discipline's model will inherit these properties and thus be subject to being part of other disciplines' models. Figure 2 shows an example of a core concept for a wall and the architect's and structural engineer's (SE) concepts.

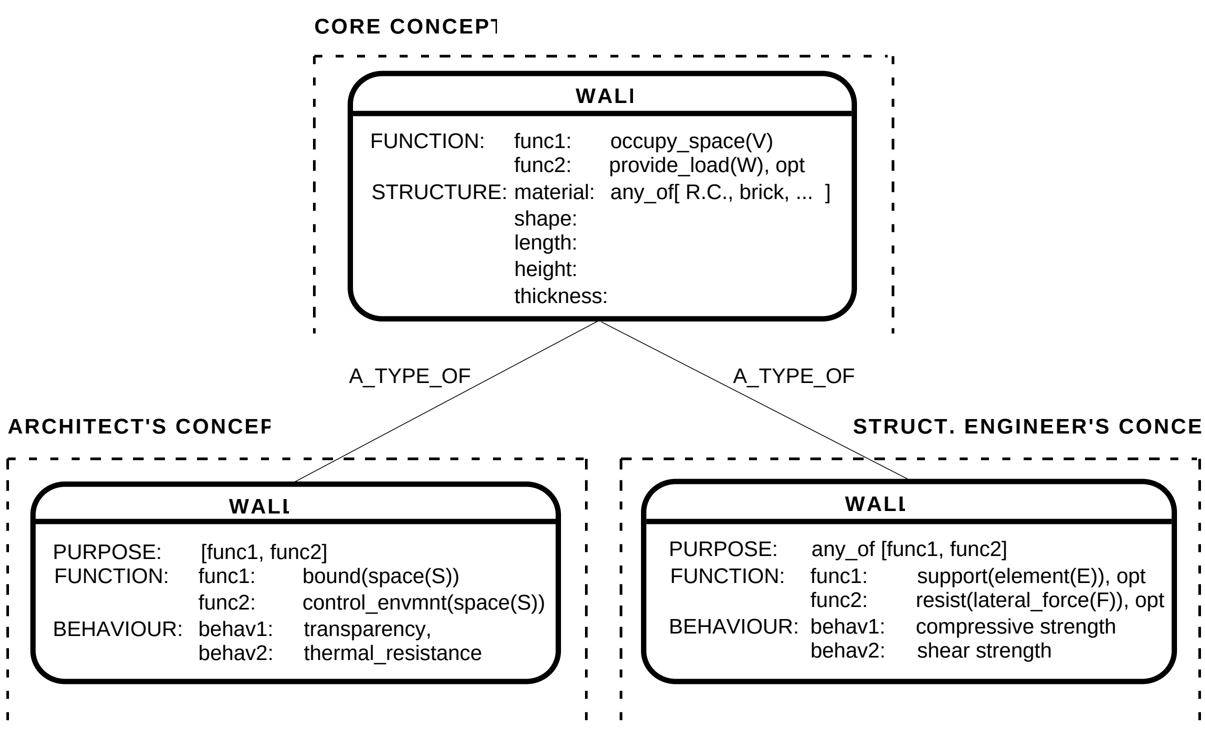

Figure 2. Core and Discipline Concepts

The core concept does not include any purpose, since purpose is strictly a view-based concept but includes two functions which occur whenever a wall occurs. These are side-products to the existence of a wall. The provide_load function is marked as optional since it depends on the actual composition of the wall and the SE's decision. For example, a timber construction would not necessarily cause a provide_load function to be inherited. However, any wall element created by the architect for space bounding and environment controlling purpose which inherits a possible provide_load function from the core concept produces a corresponding element in the SE's model. The SE may then assign any of the two optional functions and purpose to this element. Conversely, any wall element created by the SE for a functional purpose will inherit the occupy_space function from the core model and hence produce a corresponding element in the architect's model.

While design prototypes describe a class of design objects, a design object can also be regarded as a functional system (FS) composed of various functional subsystems, each of which carries out or contributes to the intended functions of the whole (Rosenman et al., 1993; Rosenman and Gero, 1996; Rosenman, 1993a). Unlike a design prototype, a functional subsystem, e.g. the climate control FS, is a purely functional concept without embodiment. It is represented by the functions it carries out and the behaviours required for those functions. Eventually, however, it will be embodied by a set of design elements, in a model, whose functions contribute to the functions of the FS.

Functional subsystems allow designers to express their functional concerns, i.e. views. Once a designer's view has been expressed as a set of FSs, all elements, whose functions contribute to the functions of the FSs defined for that view will become part of that designer's model even if created by another designer. This will be so even if the functions were not intended by that other designer. This was exemplified in the explanations above. Finding the relationships between contributing functions is not a simple text match but may have to be carried out through various levels of abstraction (Hwang, 1994).

6. Functional Modelling in Collaborative CAD Modelling

There are two main ways in which functional modelling, that is the modelling of functional properties, can help in communication between the different disciplines as they collaborate to achieve the intentions of each designer as well as consistency in the description of the artefact under consideration.

1. assigning purpose to define intentions, i.e. intended functions;
2. assigning functions to elements and relating those functions to the concerns of the various designers.

In the first case, an intended function, a purpose, assigned to an element by a designer will result in an indication that the existence of that element is contingent on that purpose. Thus, the element cannot be modified in a way that will impair the intended function. Obviously this includes the removal of that element unless something is done to replace the intended function. For example, the assignment of a stabilizing function to a wall by a structural engineer should now prevent the architect from removing that wall unless the function of that wall is replaced by, for example, a beam.

In the second case, elements will, by their existence, carry out certain functions which will be associated with their conceptual description, e.g. in a design prototype. So that even if a designer does not assign a particular intended function to an element, this function will still be assigned to the element by default. This function may not be of concern to that particular designer but may be of concern to other designers. For example, the structural engineer may add a column in a space to carry out some intended support function. However, one of the unintended yet existing functions of columns is that they occupy space. Note that this is a description of what a column does not what it is thought it should do. This function of space occupation is of concern to the architect and as a result, that description of the column which relates to the space occupation function will now form part of the architect's model. That is, the column will appear in the architect's model.

Since it was stated that each discipline has separate concepts and therefore builds different models of the elements under consideration, elements in the different models which are related must be related explicitly through explicit relationships. For example a floor element in the architect's model and a slab element in the structural engineer's model, which refer to essentially the same physical element, must be related by a relationship such as a *same_as* relationship. This same_as relationship specifies that the structural properties of the 'two' elements are the same. The same_as relationship may be made between two elements or between specific properties of the elements. For example, the shape of one element may be stated to be the same_as the shape of another element. Other constraining relationships need also be stated, as for example, that the height of a wall element in the architect's model is related to the depth of a beam element in the structural engineer's model.

7. Multi-Agent Cooperative Decision-Making Systems

The various disciplines collaborating in a design project can be viewed as a set of intelligent multi-agents cooperating in a distributed decision-making system (Bond 1989; Avouris and Gasser, 1991). While each such agent has its own agenda, information representation and decision-making processes nevertheless each agent cooperates with the others to attain some overall goals. An agent may be an individual or a team of individuals. The agents are intelligent agents, in that they are not completely autonomous but take into consideration the intent of the other agents. In addition, the effects caused by the actions of the other agents must be conveyed to those agents concerned.

As described previously, the conveying of intent is carried out by the assignment of purpose to design objects and the effects of decisions carried out by one agent (discipline) is transmitted through the assignment of functions which occur as a result of such decisions. Agents which are concerned with such functions are notified of their occurrence. Thus it is through the concepts of function and purpose, assigned to design objects, that information is transmitted, allowing for the coordination of the overall decision-making effort.

8. Graphic And Non-Graphic Representations

The models represented by the various disciplines include both graphic and non-graphic properties and are represented graphically and non-graphically, usually in separate databases. However, these representations are just different aspects of the same model and must be linked through appropriate links between the graphic database descriptions and the non-graphic database descriptions. When a model is manipulated, corresponding effects may have to be made in another model. When, for example the structural engineer selects a shear wall for discussion, the corresponding walls in the architect’s model should be highlighted. The SME and VisionManager systems implement this through the concept of shared graphic objects (Clayton et al., 1994; Fruchter et al., 1996). However, this is not by itself sufficient as more than the graphics may be shared and moreover, even within one discipline's view, several graphic representations of a design object may be required for different aspects of the design process. However, representation is not a topic of this paper.

9. A Building Example

Below is set out a simplified example of a collaborative CAD session between different disciplines. Firstly, the architects model some concept for part of a horizontal slab-type office building. The wall, floor and roof are represented as lines since their material and thickness are as yet undecided. Some of the dimensions also are not fixed. the architect also desires walls WL7 and WL8 to be moveable so that the room arrangements can be flexible. Figure 3 shows the architects' first conceptual graphical representation.

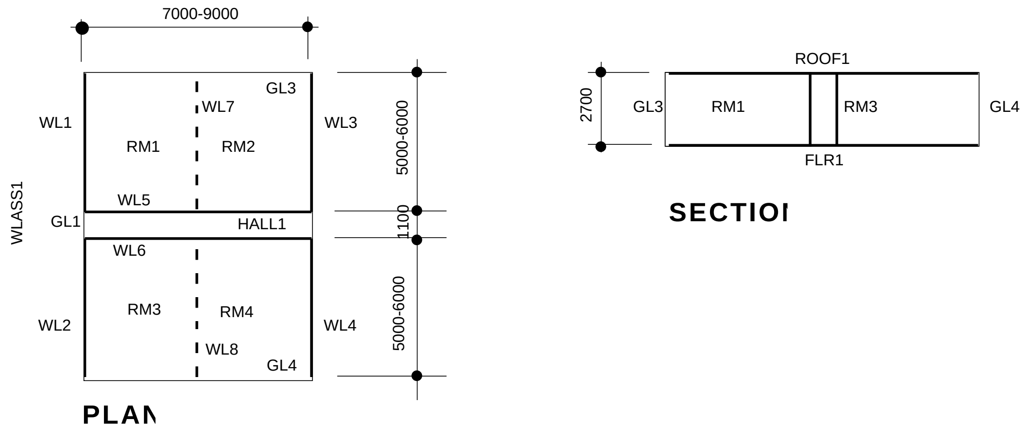

Figure 3. Graphical Representation of Architects' First Concept.

Figure 4 shows a simplified description of some of the architects' first model. Only those elements and attributes which serve to demonstrate the collaboration process are shown. Behaviour attributes are not shown.

<u>WLASS1</u>

AN_INSTANCE_OF:
    WALL_ASSEMBLY
PURPOSE:
    [func1, func2]
FUNCTION:
    func1: bound(STOR1)
    func2: control_envment(STOR1)
STRUCTURE:
    components: [WL1, GL1, WL2]
    length: 11100-13100
    height: 2700
    thickness:
    component_of: [STOR1]

<u>WL1</u>

AN_INSTANCE_OF:
    WALL
PURPOSE:
    [func1, func2]
FUNCTION:
    func1: bound(RM1)
    func2: control_envment(RM1)
STRUCTURE:
    component_of: [WLASS1, RM1]
    material:
    shape: rectangular_prism
    length: 5000-6000
    height: 2700
    thickness:

<u>GL1</u> <u>WL7</u>

AN_INSTANCE_OF:
  GLAZED_ELEMENT
PURPOSE:
  [func1, func2]
FUNCTION:
  func1: allow_light(HALL1)
  func2: control_envment(HALL1)

STRUCTURE:
  component_of: [WLASS1]
  material: GLASS
  shape: rectangular_prism
  length: 11100-13100
  height: 2700
  thickness:

AN_INSTANCE_OF:
  WALL
PURPOSE:
  [func1, func2, func3]
FUNCTION:
  func1: bound([RM1, RM2])
  func2: control_envnmnt([RM1, RM2])
  func3:provide_flexibility([RM1, RM2])
STRUCTURE:
  component_of: [STOR1]
  material:
  shape: rectangular_prism
  length: 5000-6000
  height: 2700
  thickness:

Figure 4. Architect's First Model

The structural engineers (SEs) examine the architect's first model and note that walls WL7 and WL8 have intended functions of providing flexibility to the room spaces. As such the SEs propose the following scheme, Figures 5 and 6.

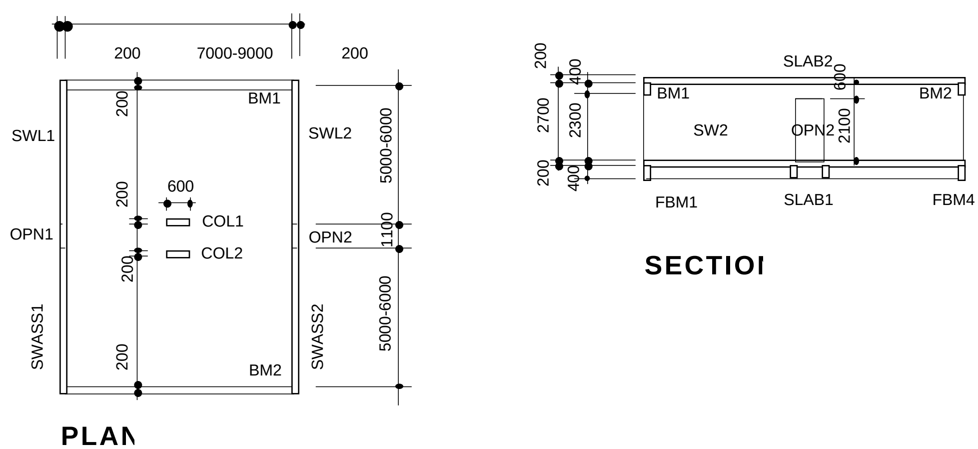

Figure 5. Structural Engineers' Graphical Representation

SWASS1

AN_INSTANCE_OF:
  SHEAR_WALL_ASSEMBLY
PURPOSE:
  [func1, func2]

FUNCTION:
  func1: support(SLAB2)
  func2: resist(lateral_force(F))

SWL1

AN_INSTANCE_OF:
  SHEAR_WALL
PURPOSE:
  [func1, func2]

FUNCTION:
  func1: support(SLAB2)
  func2: resist(lateral_force(F))

STRUCTURE:
  components: [SWL1, OPN1]
  component_of: [BLDG1]
  length: 11500-13500
  height: 2700
  thickness: 200

STRUCTURE:
  component_of: [SWASS1]
  parts: [WL1, WL2]
  material: R.C.
  shape: rectangular_prism
  length: 11500-13500
  height: 2700
  thickness: 200

<u>OPN1</u>

AN_INSTANCE_OF:
  WALL_OPENING
PURPOSE:
  [func1, func2]
FUNCTION:
  func1: create_hole(SW1)
  func2: provide_spaceGL1)
  func3: reduce_strength(SW1)
STRUCTURE:
  component_of: [SWASS1]
  width: 1100
  height: 2100
  thickness: same_as(SW1)

<u>BM1</u>

AN_INSTANCE_OF:
  BEAM
PURPOSE:
[func1, func2]
FUNCTION:
  func1: support(SLAB2)
  func2: transfer_force(F,SWL1,SWL2)
  func3: interferes(GL3)
STRUCTURE:
  component_of: [BLDG1]
  material: R.C.
  shape: rectangular_prism
  length: 8000-9000
  depth: 400
  thickness: 200

<u>COL1</u>

AN_INSTANCE_OF:
  COLUMN
PURPOSE:
  [func1]
FUNCTION:
  func1: support(SLAB2)
  func2: interferes([WL5,WL7,RM1,RM2])

STRUCTURE:
  component_of: [BLDG1]
  material: R.C.
  shape: rectangular_prism
  length: 600
  height: 2700
  width: 200

Figure 6. Structural Engineer's First Model

The SEs decide that the transverse walls should act as shear walls. However to do this the two walls, WL1 and WL2 of the architects, must be joined into one wall. This is done by reducing the height of the opening for GL1 from full storey height to 2100 mm, thus creating one wall assembly element. The wall opening has no constructive structural purpose (actually it has a degrading effect on the function of the shear wall assembly), but is to provide space for

GL1, an architectural purpose, assumed by the SEs. This will ensure that the element OPN1 will form part of the architects' model. Further, the relation that the shear wall SW1 has parts WL1 and WL2 will cause those elements to inherit the material and thickness properties of SW1. Beams BM1 and BM2 are added and one of their functions is that they interfere with the glazed elements GL3 and GL4 respectively. Again this will ensure that they appear in the architects' model and will require changes in the height of the glazed elements. The SEs have taken into account the architects' intention of a flexible location for walls WL7 and WL8 by orienting the columns with their long dimensions along the hall walls. This provides a constrained flexibility for the location of walls WL7 and WL8. Again the function that the columns interfere with the walls and room elements will cause them to be part of the architect's model.

Although the above example has included material and thickness properties for the shear walls and dimensions for the beams and columns, a preliminary stage could have left these undecided so that decisions could first be made only regarding the structural system proposed. The architects could have accepted the proposal but placed constraints on certain dimensions, such as on the depth of the beams, BM1 and BM2.

On inspecting their model and the SEs model, the architects discover that new elements and inconsistencies exist. They accept the need for the shear walls and beams and the reduction of the height of GL1, GL2, GL3 and GL4, and modify their model accordingly, but may not accept the columns since these interfere with the rooms. However, the architects cannot remove the columns since their purpose is structural. They must send a note to the SEs that this solution is unacceptable. Such a method of annotation is provided for in the VisionManager system (Fruchter et al, 1996). The SEs may either decide on a new system, such as providing for beams above walls WL5 and WL7 or may argue that the columns are necessary. If the beam solution is chosen, the HVAC engineers may subsequently notify the architects that they need penetration for their ducts. The negotiations continue through several stages of development and modelling until all participants are satisfied and consistency is reached.

It can be seen in the above simplified example how each discipline views the design object under concern in a way as to satisfy its own goals set by its functional concerns. A completely distributed model of the actions of each discipline would not have each discipline take into consideration the intent of other disciplines. However, in a cooperative collaborative environment where the agents are deemed to be intelligent, each such agent must take the intent of the other agents into consideration for the efficient achievement of the overall goals of the design process. Where CAD is used as the modelling and communicating medium, the assignment of purpose and functional effects must be made explicit.

10. Summary

This paper has shown that current single fixed representations are inadequate to model the various concepts that necessarily exist in multidisciplinary design situations. It has put forward the need for multiple views and models of a design object based on functional contexts and has shown how these can be used to provide the necessary modelling capabilities for a collaborative CAD environment. The essential factors are the representation of functional properties of design objects and the definition of functional subsystems allowing different interpretations of design objects to be constructed through the definition of views as functional contexts. An important factor is the definitions accorded to the terms purpose, function, behaviour and structure, especially that of function as any effect which results from the behaviour of a design object, whether intended or not. The paper has shown how the concepts of function and purpose are essential in collaborative CAD modelling between different disciplines to allow the representation of the different viewpoints and yet to provide coordination and consistency.

Work to date has already demonstrated the potential for CAD systems to allow the modelling of different views through the linking of graphic and non-graphic databases using a graphic database a relational database and an interface command language (Hwang, 1994; Rosenman, 1993b). Future work will focus on the modelling of multidisciplinary design teams as cooperative intelligent agents in a distributed decision-making system where the communication of purpose and function are the essential ingredients for achieving the goals of the project.

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