Modeling Building Information in a Parametric Environment

Kene Meniru

1Community College of Baltimore County (CCBC), illom.org.

The building design stage starts with an early effort by the architect to create a sketch which embodies the fundamental building knowledge that forms the basis for all later work. This knowledge is mostly lost in current building design practice procedures where the sketch is reduced to individual building components such as walls, floors, etc. By the time the building is constructed, new efforts have to be made to document information about the building necessary to control and maintain it during operation. This paper represents the next step to a Ph.D. study that describes the early building process and important features to support. It presents a sample design session from the study and based on observations from this session, it identifies and describes important digital objects that can be used to capture building knowledge in the sketch.

Introduction

Design begins at an early stage when the design problem is still unclear. Graphic symbols are used to both understand and investigate possible solutions and the symbols are often incomplete in both form and meaning. At the end of the early design stage the designer arrives at a configuration of building parts that functionally and...
aesthetically satisfies the requirements of the overall building problem which is typically called a sketch.

Much building knowledge is utilized to arrive at a sketch even though certain issues cannot be fully considered that involve dimensions and other specifics. These are largely resolved in later design in which scales and more standardized symbols are used to evolve the sketch into a proposal.

In a typical design process the transition from sketch to proposal involves some loss in knowledge. For example as spaces are turned into a collection of wall components there is little knowledge of the spatial relationships that were considered in creating the spaces. By the time the building is constructed a substantial amount of such building knowledge about the building cannot be retrieved.

Background

There are some solutions that capture building knowledge at the early design stage such as (Leclercq, 2001) however the issue of using this knowledge in work beyond the design phase is not addressed. This paper draws from a Ph.D. study (Meniru, 2005), (Meniru, 2010) which provides a clear description of the early building design process and lists features that are important to be supported in a digital tool (Meniru et al., 2003). Eight designers’ early design processes were studied using the method of protocol analysis.

This paper takes the next step in this Ph.D. work by identifying objects needed in a digital environment that will capture the building knowledge created in the early design process.

Method

To put the goal of this paper in context a presentation of an early design session from the Ph.D. study is provided from where observations are drawn concerning the actions of the designer.

Based on these observations, the rest of the paper identifies and describes digital objects and features/capabilities to capture the building knowledge embedded in the design session.

Our description of support for the design process addresses SPC B.6 i.e. understanding of the interdependency between various elements of a building assembly and SPC A.2 i.e. simplification of construction coordination and opening up “What if...” speculative exploration that allow for broader questioning of design intent and possibilities.

Early Design through Protocol Analysis

The following report contains some of the designer’s descriptions using the think-aloud method. The researcher is describing the actions with references to the images. Not all of the transcribed work is provided.

The designer reads the requirements carefully underlining parts of it. The designer traces the site and marks off the setbacks in Figure 1 at A. In addition, the north-direction was determined and illustrated clearly at B. “When you design the first stage of a project the scale is very important because you have no architectural party [team ?], so you must work at a very small scale. What is very important is to work at the same time in plan as well as in elevation and section, because you are missing opportunities”. Due to the site being narrow and the requirement for a two-car garage, the designer starts by establishing the dimensions for the garages as shown in Figure 2 then working with this diagram as a template established the main entrance to the right side of the site and with a few steps rising beside the garage to meet it.

This solution does not please the designer and a second option is begun (Figure 3) where alternate garage and entrance ideas are explored at F.

This time the steps are located in the middle of the garage shown in Figure 3 at A. Designer uses a center line at C to divide the design into two parts to enable the concept of a central staircase. Soon a problem is
encountered with circulation. The designer reverts to the original idea as shown in Figure 3 at G with the stair at H. Shrubs are drawn at I as a way to access the courtyard at the back of the house. The designer uses diagram at J to think about the height difference between the garage level and the entrance level.

**Figure 1. Sheet showing site and north-direction.**

Designer continues on a new sheet to resolve the upper level bedrooms when, discovering inadequate spacing, returns to the main level to adjust the area for the kitchen in Figure 3 at M.

**Figure 2. Establishing space for the garage.**

The circulation path is shaded at K. An approximate area for the dining space is shown with a bubble at L and space for the living room is created at N.

**Figure 3. Sheet showing configuration of spaces**

The wall is slanted at O to bring in more light into the kitchen area. Furniture is placed in Q which is used to establish some scale and to work out specifics in circulation. A terrace is also created at P which leads into the courtyard at the back of the house. The designer goes on to create some elevations that help to resolve the spaces in the upper level.

The designer finally retraces the spaces in all floors, combines the plans and elevations into a 3D sketch for presentation. During this procedure it is mentioned that a CAD system would preferably be used at this stage however no details will be provided more than what has already been done. Once the general idea of the sketch is accepted by the owner, the next step will include changes and more details of the building components.

**Observations from Design Session**

The building model is created using a hierarchy of containers. Only the most important information is presented or required when the container is created. For example the site is created with a North-direction and setbacks only. We present and describe this hierarchy as well as some of the type of knowledge that is captured. Embedded knowledge in the hierarchy is parametrically modeled to apply/represent building components. The
Modeling Building Information in a Parametric Environment

The following is a list of the rest of our observations.

1. The designer begins work by getting the important information about the site. This includes establishing the maximum available footprint for the proposed building using required setbacks for the design area. The North-direction is then established to designate the orientation on the site.

2. The designer is not interested in the detail of components at this early stage. Work begins using a metric scale of 1:100.

3. The designer needs to work using more than one type of view, e.g., plan and section.

4. The designer works with lines and shapes. Lines are used to show generic information such as axis, distance, emphasis, etc. Shapes are used to show building components such as spaces, stairs, walls, etc.

5. The designer “puts” necessary details in the design as opposed to drawing them such as doors, windows, furniture, etc. Only basic information is shown such as size or swing.

6. The designer cleans up the design by retracing shapes before presenting to the client (not shown). Most of the lines are left out of this final sheet except those that are part of the shape for example the direction of travel on the stairs.

7. The designer prefers to present the final sketch as a 3D model to the client because they read better than flat drawings.

The Building Model

The following sections describe the different containers required in a building model in sequence to their hierarchy level and based on the early design session presented.

1. The Building Site

At the top of the hierarchy is the site container (Figure 4). The top of which is invisible. It must contain an orientation object and setback containers. While the orientation can be shown anywhere on the site, the setbacks are confined to set distances from the sides of the site container. Parameters for both orientation and setbacks can be set by the system through the application of requirements provided at the beginning of the early design session or manually during the session.

![Figure 4. Site container showing setback containers.](image)

The Site container is automatically created once a building project is initiated with a minimum of 3 sides. The designer then moves these sides and/or adds additional sides as required.

2. The Building Level

At the second hierarchical level is the level container (Figure 5).

It allows the designer to bring together the different systems necessary to support the activities desired by the client. Examples of systems in a building are architectural, structural, mechanical, etc. Levels are typically created when needed by the designer and are stacked one on top of the other i.e. the base of a newly created Level container partially or completely rests on the top of a previously created one.

Levels maintain a connection with each other through this contact. Apart from the elevation of the base of the level container, its borders are not configured by the designer and so are invisible. Level containers assist the designer by coordinating information amongst each or all of the different systems such as in calculating total space used or structural load.
When the site container is created, a single level container is also created by default. The base of this first level container can modify the base of the site container. Likewise the top of the last level container, when created, can modify the top of the site container.

3. The Building Space

At the third hierarchical level is the space container (Figure 6). The Space container is the main part of the architectural system.

Much of the knowledge in the early building design stage is used to manipulate the space container. Building spaces are areas in a building that are designated or set apart for accommodating specific types of activities desired by the occupants. Most activities supported in a residential building can be accommodated using 4 types of spaces including sleeping, living, service and traffic. Additional specialization of these spaces must be provided for example a stairwell is a special type of traffic container. These different space containers have different parameters and considerations which assist the designer in the early building design process. For example the shared boundary between a sleeping space and a service space may be flagged by the system for special treatment to reduce possible noise transmission
that is fully described i.e. the space must be enclosed by a combination of solid and open sides. When two spaces share a boundary, a share-side is created automatically along the common area.

The share-side also makes it possible for the part of the side facing each space to be treated appropriately to seclude the activities as required.

Other parts of a space such as openings, windows, doors, furniture, etc. are called object containers. Each embodies specific knowledge applicable to it for example a window has a sill, a lintel and a hole.

4. The Building Form

The building form is the digital component for describing the physical shape or property of the building.

Forms are containers prefilled with specific building material properties which are then used in different sizes and combinations for prebuilt components or directly by the designer in the design process.

Several form containers can be combined for example to create the solid side of space containers as wall assemblies (Figure 8). Forms can also be used to describe holes for example in an object container like a window.

Using Digital Objects in a Design Session

This section describes the use of a building information modeling tool with the capabilities described in the preceding sections in an early design session. The sequence of this description will follow the observations listed.

Early Design:

1. When the system is started the site container is created by default. The designer provides the number, length and angle of the sides. Each side has a setback container attached by default. The designer enters the distance of each setback on the corresponding side of the site container. The site container also has an orientation object by default so the designer sets the degree for the north-direction. This establishes the available footprint and orientation for the proposed building.

2. The tool uses a 1:1 scale. The zoom factor can be used to reduce the size of the drawing area.

3. All spaces are volumes. Orthographic views are available so the designer can work as desired.

4. Lines are like strokes and do not represent building components. The distance and angle a stroke represents can be shown. Different stroke sizes are available for visual impressions such as emphasis. Spaces are initially created with single lines as borders. The designer is free to add
more sides with desired changes to angle of inclination as well as length.

5. Object containers can be placed in the desired locations of the space. All objects have defaults settings so distractions are kept at a minimum. For example when placed in a space, a window object attaches itself to the nearest location on a wall and only requires the designer to establish its length.

6. All lines (strokes) can be cleaned automatically from the design when the sketch is complete as they are not part of the building. At the end of the sketch, all boundaries for spaces automatically change to reflect a default width. Share-sides automatically adjust shared boundaries accordingly showing a single width for any two touching sides from different spaces. Very little additional work is required of the designer in this step.

7. All containers are already 3D building components so no additional work is required in this step. Analysis can be performed to ascertain that the spaces are appropriate. For example sun path studies can be performed as the space containers combine inherited North-direction (site container) and size of openings (object containers in their sides).

Detail Design:
Work required in this stage is mostly focused on adjusting parameters for containers and the addition and configuration of building forms for construction documentation. For example you may have a complex combination of finishes for the side of a space container. Building forms of the required finish material may be added and sized as desired to the sides.

Construction Documentation:
Section planes are established and construction documents extracted.

Facility Management:
All knowledge accumulated so far remains available for controlling and managing the building. Materials used in the construction are those specified in the building forms. Sizes for repairs as well as maintenance due dates can be queried.

Conclusion
As a next step to a Ph.D. research, we made some observations about a designer’s actions in a sample design session which show that designers create building parts that relate hierarchically. We then identified and described four digital objects with capabilities/features that can be used to capture building knowledge from the session. Finally, we described the use of the objects in the context of the design session to show how building information can be modeled in a computer environment with the knowledge from the early design stage accessible all through the phases of AEC/FM.

References

