Grouping Techniques for 3D Conceptual Design

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ABSTRACT
Conceptual session is an early stage of the design process, where a designer explores possible solutions from a design specification. In this session, the designer produces many drawings to evaluate them against the design problem. Computer Aided Design (CAD) systems are not generally used because creating a model with them is laborious, and also they distract users into editing details. As drastic changes to a design solution are very common in this session, we consider structural modification to be an important feature. Here, we present two new techniques for efficient group manipulation, which help users easily build a structurally complex scene.

Categories and Subject Descriptors: H.5.2 [**User Interfaces**]: Interaction styles, Prototyping

Additional Keywords and Phrases: Computer Aided Design, Conceptual session, Grouping, 3D object manipulation

INTRODUCTION

Design is an activity to create a description of a form from a design specification. To do this, a designer iteratively goes through several distinctive stages of a design process. They are: analysis of problem, conceptual design, embodiment of schemes, and detailing [3]. The goal of the conceptual design stage is to produce an optimum solution that satisfies a set of design constraints. In this session, the designer generates and evaluates a broad range of solutions. For the best solution, the designer may have to incorporate knowledge from other disciplines, such as engineering science, production methods, and commercial aspects.

In general, sketching is the primary method to develop ideas. In sketching, the designer can quickly create a draft, expressing his/her concept even though they are not finalized. Research [7, 8] into the process of sketching emphasizes that the ability of reinterpretation of a drawing is the most important factor in developing design solutions. This argument is supported by the fact that the drawings in the earliest stages are rather more vague and conceptual than those of later stages. After the reinterpretation, alteration on the drawing usually follows. Since editing sketches is not an easy task, the designer usually creates a new drawing out of the reinterpretation.

UIST '04, October 24–27, 2004, Santa Fe, New Mexico, USA
ACM 1-58113-962-4/04/0010

As opposed to sketching, Computer Aided Design (CAD) systems are only used for a later detailing session, when drastic changes to a model are no longer required. The reasons are: 1) CAD systems enforce certain types of behavior in designers, which would not be natural for someone who sketches most of the time. 2) They often require the input of precise parameters, which are not always available at this stage or are prone to future change. 3) The types of modifications are incremental. They drive designers to place an emphasis on editing details rather than exploring other alternatives. 4) The cognitive effort while using CAD systems is generally higher than that of conventional tools (*e.g.* see [1]). Instead solve the actual design problems they have to focus substantially on using the tools.

It is generally known that 3D computer models make it easier to illustrate the solution to others, and they also may be useful for further evaluation through computer simulation. Therefore, the designer sometimes has to create a 3D model using a CAD system for such purposes. With an easy-to-use CAD, the designer can build and modify a model quickly. Also, the system will facilitate a discussion in a design project team, since the group of involved people will be able to collaboratively change a design and interactively test it. Note that the interactive modification and testing would be something very difficult with a pen and paper. Therefore, many researchers attempt to bring CAD systems into the earlier phases of the design process. Major focus is on incorporating sketching capabilities into the computer system [1, 5, 10].

Different tools influence people to perform in different ways. With a pen and paper, people generally tend to create a new drawing rather than to modify an existing one, because creation is very efficient and editing is almost impossible. Alternatively, when the users are placed in front of the computer, they tend to perform more modification than creation. In typical CAD programs, creation itself is so difficult that the users would rather modify the existing ones. However, most of the modifications happen to be on small details such as moving vertices, adjusting lines or surfaces, etc. Consequently, the users are distracted from the overall design process, and focus on small details.

We argue that a computer system should be efficient in creating anything from scratch, should prevent users from modifying the details of the solution at an early stage, and should allow easy modification of the overall structure of a model. Many prototype systems recognize the easy creation as an important criterion, but fail to provide efficient structural alteration. Therefore, the types of scenes that can be easily created are either a single object or a simple composition.

The importance of the structural modification during the conceptual session is supported by the research into creative problem solving processes (*e.g.* [4, 11]). The researchers argue that the most of cognitive activity to create a form is in combination and restructuring. In [11], in addition, authors state that CAD systems must support these operations very easily for a design process to be effective.

The main theme of the thesis is to support easy structural modification through efficient group manipulation. This paper presents two new grouping schemes and their implementations in our proto-type applications.

RELATED WORK

Group selection is fairly easy in 2D drawing applications and is usually implemented by a rectangle selection process or via shift-click selection. However, in 3D, these solutions are not applicable due to perspective distortions as well as due to occlusions by other objects. A few systems [2, 1] support hierarchical grouping or lassoing. A hierarchical relationship is usually established when one object is placed on another, e.g. a cup placed on a tabletop. Lassoing allows for more flexibility and for selection of groups of arbitrary objects, but the accuracy of a lassoing gesture, a quick circling motion, is usually very limited. Furthermore, the problem of perspective and occlusion still exists.

Another approach for grouping can be found in DDDoolz [12], an architectural conceptual design tool. In this system, a user fills space with blocks, and these blocks are grouped together by assigning them the same color. The authors motivate their choice with the fact that different colors are used to visualize different architectural elements. However, in other application domains this may not be appropriate and seems to be unnecessarily restrictive.

MIVE [9] investigates the use of a set of constraints to rearrange predefined objects efficiently. This system supports a form of bi-directional grouping, named dual constraints, to align objects of the same kind (e.g. cabinets on a wall, or chairs in a classroom). Objects satisfying dual constraint snap together, and can be manipulated as a group. However, dual constraints must be pre-defined for each object and the grouping process still supports only 2D relationships.

CONCEPT OF GROUPING TECHNIQUES

We present two grouping techniques, called *directional dragging* and *grouping with anchoring*. Both techniques allow users to select a subset of connected components. The first motivation for these schemes is that people generally recognize an object from connected elements; e.g. a table is composed of four legs and a tabletop. Secondly, there are many situations that show an alignment of repeated components, for example rows of chairs, windows of a building, or houses along a street. Even in a scene where each component is not exactly the same, people tend to simplify components in an effort to identify a structure of a group from objects in proximity. In the same way, repeated alignment of similar objects is largely used in design, especially architecture.

In *directional dragging*, a user drags an object as if he/she is tearing one part from the other. If the object is on the side of the dragging direction, then it gets selected. Figure 1 demonstrates a 2D example of the scheme. For example, in Figure 1e, dragging rightwards selects all blocks on the right side, not only the dragged object itself. We assume that objects are “sticky” in that if an object is in contact with currently selected object and is not in the direction explicitly opposite of the dragging direction, then that object also becomes selected. This way, larger cluster of objects are grouped together.

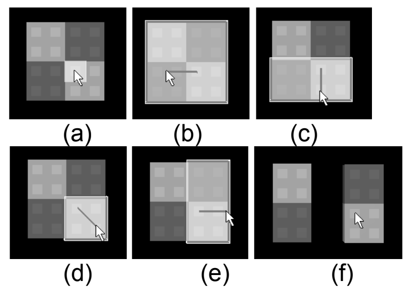


Figure 1: Intelligent separation technique. (a) Start of separation by clicking on a block, (b)-(e) different drag directions form different groups, (f) dragging further separates a group of blocks.

Grouping with anchoring (Figure 2) is a variant of directional dragging. In directional dragging, we observed that users sometimes inadvertently broke the existing compositions. Grouping with anchoring technique takes two explicit steps to choose a group: *anchoring* and *dragging*. First, the user will place an anchor onto an object that should *not* be in a group, and then he/she will drag the other object to select a group. The positional relationship between the anchored object and the dragged object is considered to be a dragging direction, which is used to choose a group of objects, just like in the directional dragging scheme. If the user does not choose an anchor, all connected objects are selected as a group. With this grouping method, the user will be less likely to break the composition by mistake.

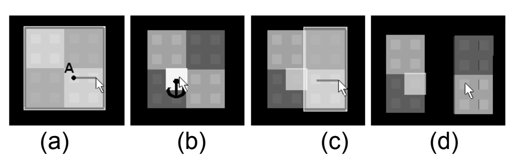


Figure 2: Grouping with anchoring. (a) Dragging into any direction without placing an anchor selects the whole (connected) object. (b) The user places an anchor visualized by the white rectangle, (c) clicks and drags rightwards, and (d) once a certain threshold is reached the group is separated.

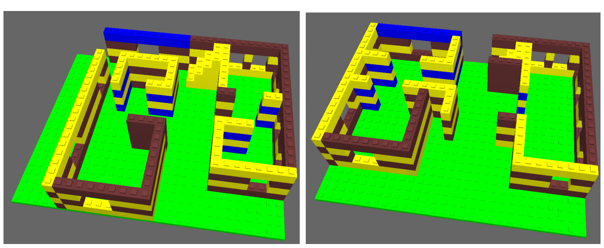
These techniques, presented above, provide a natural way of selecting "an object" perceived by a user, since people generally recognize a connected group of elements as an object. For example, we know that "table" is composed of four legs and a tabletop. By dragging an element of the table in a direction, the user will be able to select the whole table by a dragging gesture rather than by repetitive selection steps, such as five shift-clicks. Note that the system does not have to know the semantic meaning of the geometric shapes, but the user can still naturally select a meaningful group of objects.

IMPLEMENTATION OF GROUPING

We first tested our interaction techniques in a simplified block world, Virtual Lego system [5], and then we extended it into a more conventional system, SESAME (Sketch, Extrude, Sculpt, and Manipulate Easily). In the latter system, we incorporated simple sketching gestures to create various shapes, while the other system is constrained to use only predetermined elements.

Virtual Lego

In the Virtual Lego system, a scene is composed of blocks of similar sizes, suggesting objects relationship is fully bidirectional. The grouping techniques are implemented as described in the previous section without any modification. We compared the two proposed algorithms against one another. The experimental task was to change a layout of a floor plan (Figure 3) using both techniques. All participants, who were all first time users, were able to complete the task. The results also showed that grouping with anchoring was more robust. The detailed experiment results are published in [5].



(a) Initial 3D floor plan, and (b) Target 3D floor plan.
Figure 3: Rearrangement of 3D floor plan

SESAME

In SESAME, a user can create various shapes by sketching a closed contour on a planar surface and then extruding it by a simple dragging gesture. After that, the user can sculpt the extruded shape by drawing on the shape and caving into the shape.

As objects can be of different sizes and shapes, the perception of object relationship may change. Consequently, the implementation of grouping should be modified to take it into account. For a composition like an object resting on top of the other object, people perceive that the object on top should *belong* to the other due to gravity. This means that hierarchical concept should be incorporated into the current grouping scheme as well. As shown in Figure 4b and c, if a desk is selected, all the objects on top of the desk are also selected. On the other hand, if any object on top of the desk is selected, only the object is selected. However, note that bidirectional relationships and the techniques associated with them are still applicable for objects placed side by side.

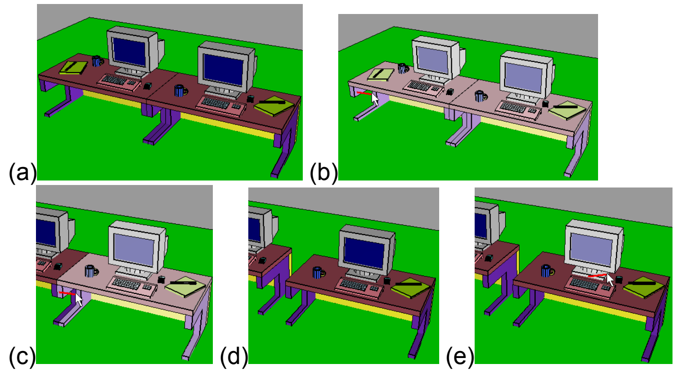


Figure 4: Grouping desks and computers. (a) Initial scene (b) Dragging from the left-end to the right side selects desks side by side. (c) Dragging on the right side selects only the right side of the desk. (e) To select a monitor, the user drags the base of it.

Hierarchical relationship is also taken into account in grouping with anchoring. Therefore, if an object is selected without anchoring, then all of the connected objects *and* ones that are resting on the selected one are grouped together. For example, in Figure 5a, all of the desks with their contents are selected. If an object is selected after anchoring, then the dragging direction is taken from the contact normal between the anchored object and dragged object. After that, we use the dragging direction to select a group as in the directional dragging.

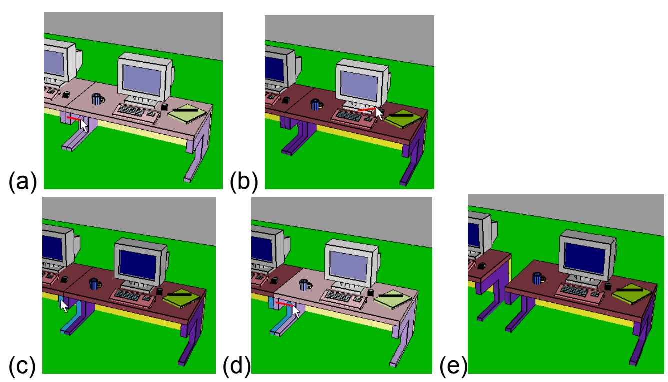


Figure 5: Dragging without anchoring group objects in a same hierarchy and its children objects. (a) Dragging on the leg of the desk selects whole connected objects, and (b) dragging on the base of the monitor selects the monitor. (c) The user is placing an anchor onto the leg of the desk. (d) Then dragging beside it selects the desk. (e) The selected desk is separated from the other one.

GROUP MOVEMENT

In addition to group selection, it is important to provide a way to intuitively manipulate groups. We provide a natural object motion using 2D mouse without using axis handles or widgets typically provided in conventional CAD systems.

Our initial approach was to move objects on top of the surface that is currently under the mouse cursor. However, an informal evaluation showed that this approach is not intuitive to most users. We noticed that users consider the entire area of the visual overlap of a foreground object and a complex background. The users seem to expect that the object moves on the foremost (hidden) surface behind the moving object. Consequently, we select the movement plane according to the object surface that is closest to the viewpoint in the region that is occluded by the moving object. Figure 6 demonstrates the concept. When the mouse cursor is in position (1), surface A is the surface closest to the viewer among all hidden surfaces. Therefore, the object slides on surface A. When moving to position (2), the closest surface is B and consequently, the object slides on top of the block. For efficiency, we perform the computation of the foremost occluded surface with the aid of the graphics hardware.

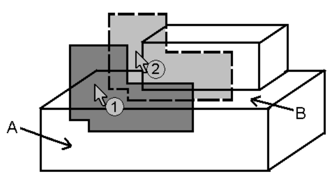


Figure 6: Objects slide on the surface that is both closest to the viewer and occluded by the object.

This scheme works for general types of shapes. For the curved surfaces, the graphics library approximates the surface into small planar faces. Therefore, the technique is applicable for curved surfaces. This same algorithm is implemented in the Virtual Lego and SESAME.

USER EXPERIENCE

The authors and several graduate students created number of scenes with the system (Figure 7). Users generally get quite engaged in drawing the scene, actively editing and suggesting changes as modification and rearrangement is intuitive in the system. Cloning and repositioning was frequently used to create the scenes in Figure 7. The grouping feature was especially useful on building Figure 7b, c.

More formal user evaluation will be performed. We plan to compare SESAME with conventional sketching and another easy-to-use CAD system. We want to see if our system improves the creativity of a resulting design, and ability to communicate between a client and a designer.

CONCLUSION

Two grouping techniques, directional dragging and grouping with anchoring, are presented. The goal of the techniques is to help users easily modify complex designs. Eventually, this will allow effective computer support of the conceptual stage of a design process.

(a)

(b)

(c)

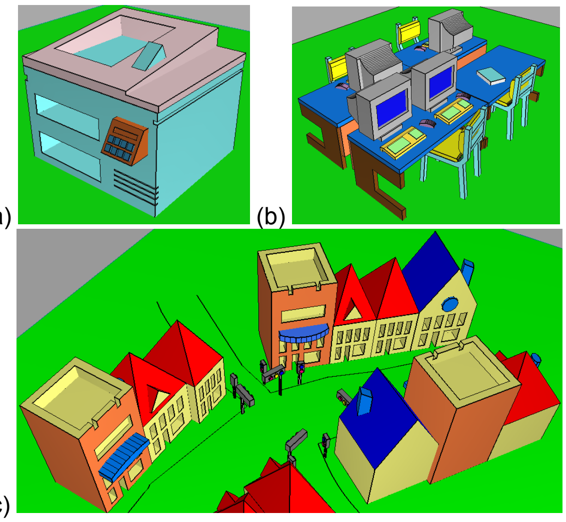


Figure 7: Example scenes constructed with SESAME, (a) Printer (b) Computer lab (c) A town.

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