TOWARDS CALLIGRAPHIC INTERFACES: SKETCHING 3D SCENES WITH GESTURES AND CONTEXT ICONS

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ABSTRACT

GIDeS (Gesture-based Intuitive Design System) is a gesture-based modeling system that addresses the known ergonomic shortcomings of present-day CAD systems for conceptual shape design. GIDeS uses a tablet and stylus combination to combine the intuitive appeal of gesture-based interfaces with context-based icons. GIDeS draws on previous modeling work, using contextual information and feedback to free users from remembering detailed modeling gestures, allowing them to concentrate on drawing, towards our end goal of bridging the chasm between paper and pencil and CAD interfaces in the early design stage.

Keywords: Interaction Techniques, 3D Modeling, Gesture Interfaces, Sketching, Calligraphic Interfaces.

1. INTRODUCTION

Although CAD systems have evolved markedly over the past 30 years, they are still a long ways from replacing pencil and paper in the desks of most designers and creators when it comes to rapidly capturing shape and model ideas. This is mostly because even the most “user-friendly” computer-based systems tend to impose rigid and very structured dialogues on users, challenging the creative flow of ideas. Designers prefer pencil-and-paper to the computer as the medium of choice for conceptual shape design. However, if computers could be made usable for the early stages of model design, the advantages could be enormous, given the impact of early product changes in the later stages of development.

Moreover, if an image is worth a thousand words, physical models are worth an unlimited number of images to convey conceptual design and shape information [Potte94]. Currently, only a few design ideas become physical models due to the comparative difficulty of creating them versus the combination of imagination and sketches that most designers favor. This could significantly change if it were easier to produce CAD and physical models from sketches.

In 1994 we have presented IDeS [Branc94a], a menu-oriented vector system that tried to explore creating approximate polyhedral models by a combination of direct drawing and constructive operations. GIDeS is a step towards a new generation of user interfaces that will help rather than hinder users in the task of making models from sketches. We call these interfaces, organized around sketching, drawing and pen input, calligraphic interfaces [Jorge94], because they explicitly address the ambiguity and imprecision natural to human-generated sketches, using these as strengths to bring computers closer to the pencil-and-paper feel. It is our contention that many calligraphic techniques may also be very useful in later stages of product design, bearing the promise of making CAD systems more usable in the product life-cycle.

GIDeS is meant to work with a tablet and stylus to make the interface behave closer to designer's expectations. We have replaced the menu-oriented interaction style by a gestural one, in order to improve system usability. To minimize cognitive load on the user and to deal with ambiguities, we have included a context-based icon mechanism.

The designer can draw without worrying about memorizing modeling gestures, because whenever his or her gestures are recognized, the application displays an icon (or a set of icons) related to the drawing context, in an attempt to anticipate whatever the user has in mind. She/he may either accept the suggestion or proceed with the drawing.

In this way context-based icons provide an intuitive way to accelerate the design process without encumbering the user's drawing freedom. They also provide an ergonomic and technically interesting way of addressing eventual recognition ambiguities.

The remainder of this paper describes GIDeS, comparing it to other work and presenting our approach to naturally handle ambiguous interactions. We show how the system works with examples and provide an early experimental evaluation. Finally we describe ongoing research directions and future work.

2. RELATED WORK

In spite much work in the design methodologies [Jones92], drawing continues to be the main method for 3D shape ideation. So, the main paradigm in interface design for a 3D modeling tool should rely on sketching/drawing.

Designers' mental model of a conception tool seems to depend on their ability to draw. Therefore we maintain our approach based on 2D interaction devices, although 3D input devices may be more suitable for later stages in the design process [Galye91] [Sachs91].

Three-dimensional model input based on drawing interpretation of scanned sketches/drawings [Wang93] is an important technique but is not enough for modeling purposes, as it does not include 3D model editing neither offers the designer the possibility of using the computer from the very beginning, as a tool capable of assisting in the drawing task itself.

The interpretation of drawings and sketches must be complemented by conventional modeling techniques (primitive instantiations, CSG, transformations), while providing an interaction style based on drawing.

Zeleznik's et. al. [Zelez96] [Forsb97] approach with the SKETCH/JOT system brought gesture recognition to the field of 3D modeling. In this system, “gestures that instantiate primitives provide enough information to select which primitive to create, determine its dimensions, and place it in 3D”.

All interaction with SKETCH [Zelez96] relies on a three-button mouse, occasionally combined with a modifier key on the keyboard. There are two types of gestural elements - five classes of strokes (made with the first mouse button) and two classes of interactors (made with the second mouse button). Camera manipulation is made with the third mouse button.

Another aspect of the SKETCH system is the use of direction dependent gesture strokes to infer CSG operations.

In GIDeS, we use a different approach. Since the pen has no buttons, commands and primitives must be inferred only from the available (drawn) information. Also, all gestures are direction independent. This has the advantage of not disturbing the designer's normal thinking and drawing processes and the potential to provide more “natural” dialogues. When drawing, designers' freedom must be respected, allowing them to concentrate their attention to developing their ideas, not to remembering details of computer's modeling-specific tasks.

This implies that, for instance, the recognition of a gesture doesn't lead directly to a 3D primitive action, but instead to a suggestion of its use. Also, since each designer has a unique drawing style, it should be possible to train the gesture recognizer, thus allowing gestures to be customized [Rubin91]. Those are the reasons why we decided to implement context-based icons.

Encarnação et. al. [Encar99] developed a system that combines traditional desktop metaphors with a virtual reality interface. This allows the user to directly create simple objects in true 3D, through the use of iconic gestures that resemble the contours of the top-down projection of object geometry. The system relies on very sophisticated equipment such as transparent pen and pad, shutter glasses, magnetic trackers and a virtual table display device.

In GIDeS, we use a different, minimalist approach. Object creation is done in a “natural” constructive way, by drawing 2D sketches of object geometry. Also the paper-and-pencil metaphor avoids the need of sophisticated and expensive hardware. Further, we support extrusion and constructive geometry operations which are not addressed in their work.

3. GIDES: CURRENT WORK

GIDeS is based on the IDeS system [Branc94a], which included interaction techniques that enabled the user to create 3D sketched models, either from a draft, by combining drawing and conventional modeling tools, or by semantic transformations.

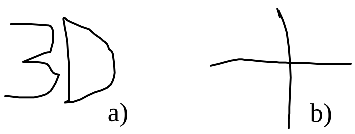
Basic functions such as drawing operations (line, polyline, rectangle, ellipse), modeling functions (primitives, CSG operators, geometric transformations) and scene visualization functions were accessed through a menu-based interface.

The ability to draw contours and geometry directly on 3D model and scene representations, generating geometric information, an operation known as "gluing" [Branc94b], allowed us to create drawing-driven versions of CSG operators thus extending Lamb and Bandopadhay's [Lamb90] perceptual approach. This supports the interpretation of drawings not only in isolation, but also in the context of scenes with existing models.

In addition to the gestural interface, GIDeS offers the possibility of interacting with a presentation with four views (top, front, side and axonometric) or, alternatively, a presentation with only one view, similarly to what is available in IDeS.

3D Model Construction

In GIDeS the interaction relies mainly on freehand drawing, which is made via a button-less 2D input device (stylus). When sketching, it is possible for the user to enter any of two modes using the gestures shown in Fig. 1. In either case the system tries to perform a 3D reconstruction for each component input by the user.



Mode Gestures
Figure 1

The 3D gesture (Fig. 1a) tells the system that the user is about to sketch a 3D model/scene using only one view; the system proceeds interpreting her/his following gestures as 3D modeling gestures.

There is the possibility of applying the reconstruction process only to one drawing component. For this to happen, the desired component must be selected with a lasso gesture before issuing the 3D command (Fig. 2).

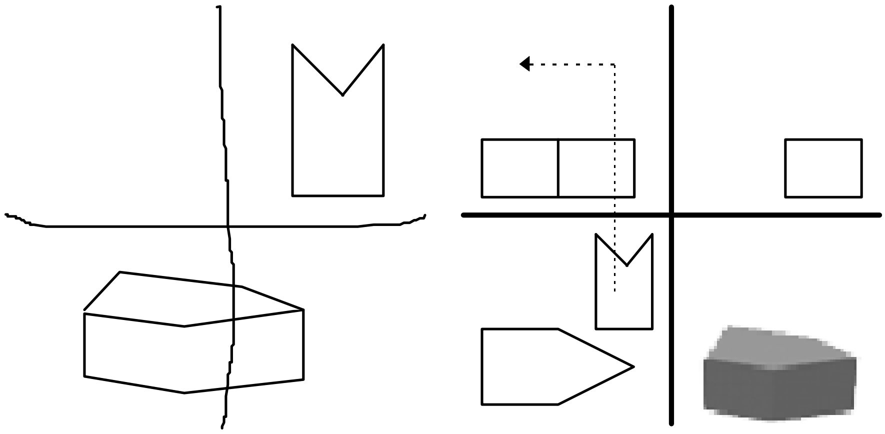
3D Reconstruction of drawing component
Figure 2

The cross gesture (Fig. 1b and Fig. 3a) tells the system to begin modeling using a four-view presentation. To accomplish this, the user draws a big vertical line followed by a horizontal one, dividing the sheet in four views.

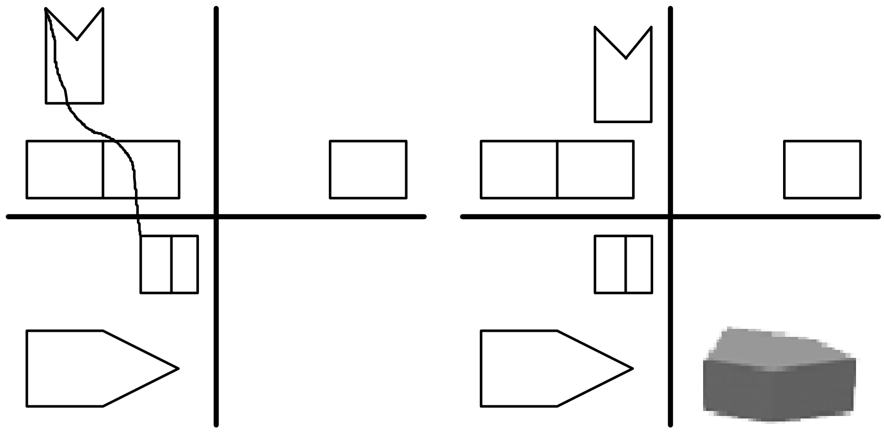
We adapted the 3D reconstruction algorithm from IDeS [Branc94a] taking as input the drawing graph generated by the gesture recognizer. Successfully 3D reconstructed components are then shaded to provide feedback. In the case of four views, components for which the system was not able to generate a 3D model appear only in the top view (Fig. 3b).

When working with four views, it is possible to move a non-reconstructed sketch from one view to another (Fig. 3b-c). In addition, a line drawn between two points belonging to different views means that they are the same point in 3D (Fig. 3c and 3e), eventually causing an automatic displacement (Fig. 3d and 3f) of the sketch pointed by the end of the gesture and, if necessary, its contraction or expansion.

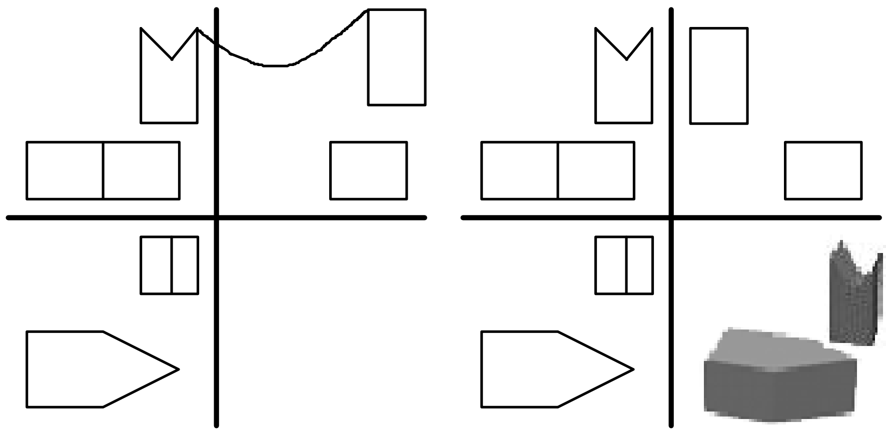
Another way of constructing 3D models consists in recognizing sketches associated with 3D primitives. Those sketches (Fig. 4) may be drawn either in one-view mode or in the axonometric view of the four-view presentation. Both the direction and sequence of strokes are irrelevant. For instance, the extrusion gesture creates a 3D model based only on the recognition of a closed polyline together with a trivalent junction in any of its vertices.



a) sketching followed by a cross gesture   b) non-reconstructed sketch moving to the front view

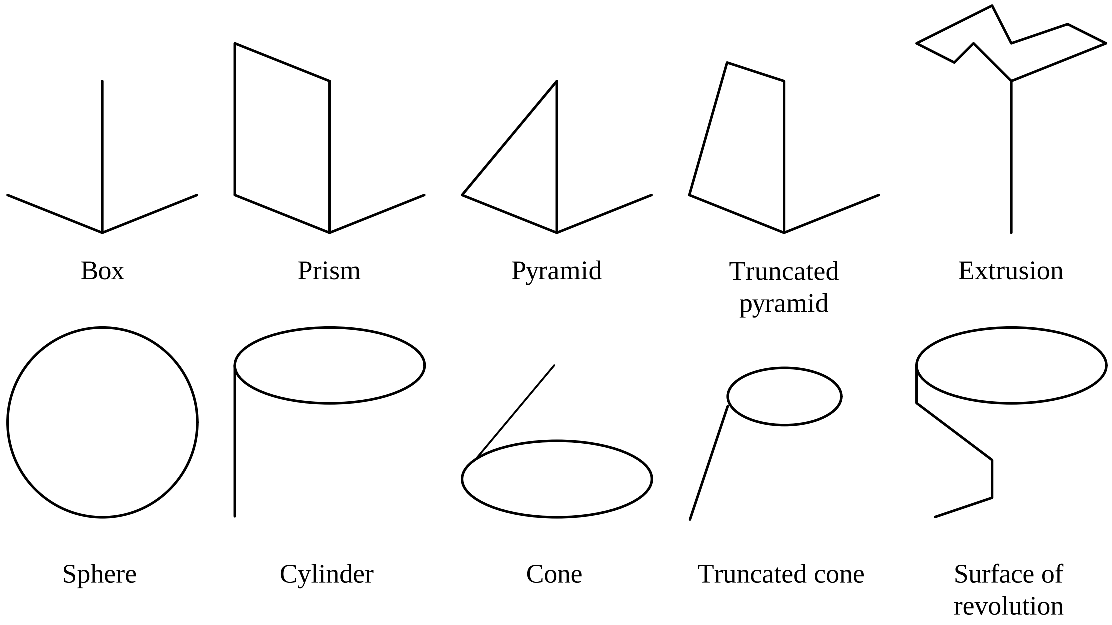


c) top view sketched and linked with corresponding front view   d) front view sketch alignment with corresponding top view



e) left view sketched and linked with corresponding front view   f) left view sketch alignment and 3D reconstruction

3D model construction in four views mode
Figure 3



3D Primitives
Figure 4

It would be detracting from our objectives to force the designer to remember many different gestures associated with primitives. Therefore, context-based icons appear every time a primitive instantiating gesture is recognized, i. e., an icon representing that primitive appears next to the cursor. If the user clicks that icon, its associated primitive is automatically constructed, extracting parameters from gesture characteristics as needed. Otherwise the user may elect to ignore the suggestion, proceeding with drawing to create a different, possibly more complex, object.

In the same spirit, whenever there is an ambiguity in the recognition process, an expectation list is created. By expectation list we mean that whenever the recognizer hesitates between two or more primitives, a set of icons representing those primitives appears next to the cursor. The user may either accept one of those choices or proceed with the drawing.

There is the possibility of sketching models over the image of other existing 3D models, allowing the construction of more complex scenes. In this case, the placement rules suggested by Zeleznik [Zelez96] are valid, but we also took advantage of our "gluing" algorithm [Branc94b] which enables the construction of polymeshes based on sketches of flat figures made on the surface of existing models.

Editing models

Model editing can be carried out in whatever presentation the user is working on.

If a 3D primitive is recognized from a gesture drawn over an existing 3D model, a context-based expectation list appears next to the cursor, with icons representing the union and difference operators along with the icon corresponding to that primitive.

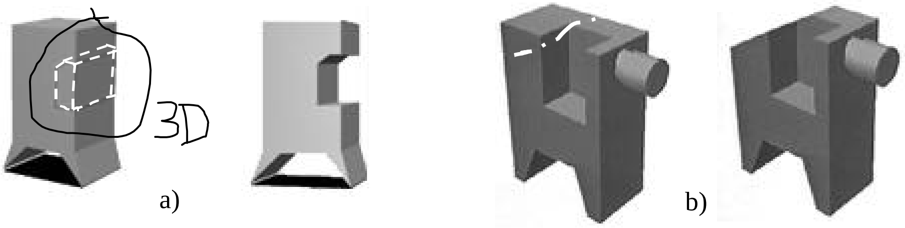
Alternatively, difference operations are inferred whenever a 3D reconstruction process is requested for a component drawn with dashed lines (Fig. 5a). Also, dash-dotted lines drawn in any of the views enable the user to perform cuts by planes (Fig. 5b).

4. IMPLEMENTATION

The GIDeS system shares with its ancestor IDeS the same base modeling architecture, 3D reconstruction algorithm, graph construction and drawing engine.

The changes to the system's architecture (Fig. 6) consist of the inclusion of a gesture-recognition module and a presentation manager.

The system's state manager ensures the logic of the gesture-recognition process with its main function



3D model editing with CSG operators
Figure 5

modes: sketch, one view, four views, transformations and visualization.

The event flow manager receives events resulting from:

- the user's action;
- the gesture recognition process;
- the execution of behaviors.

The interaction manager, uses system state and events generated by the recognizer to choose the right behavior, directing the flow of events and information to that behavior.

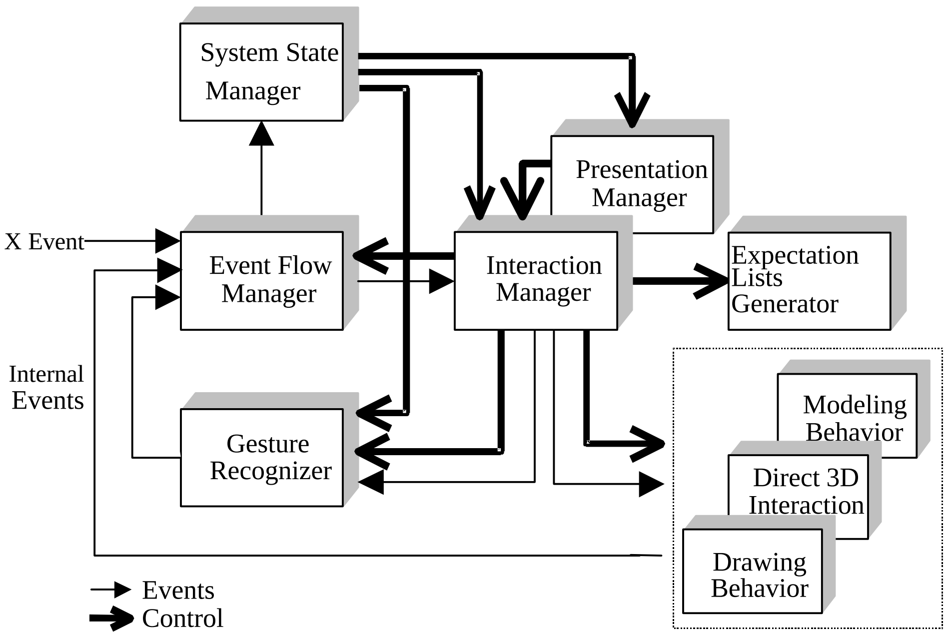
The gesture recognition module comprises four essential components (Fig. 7):

A linetype recognizer differentiates between solid lines, dashed lines (used to make holes and cavities) and dash-dotted lines (used to perform cuts by planes).

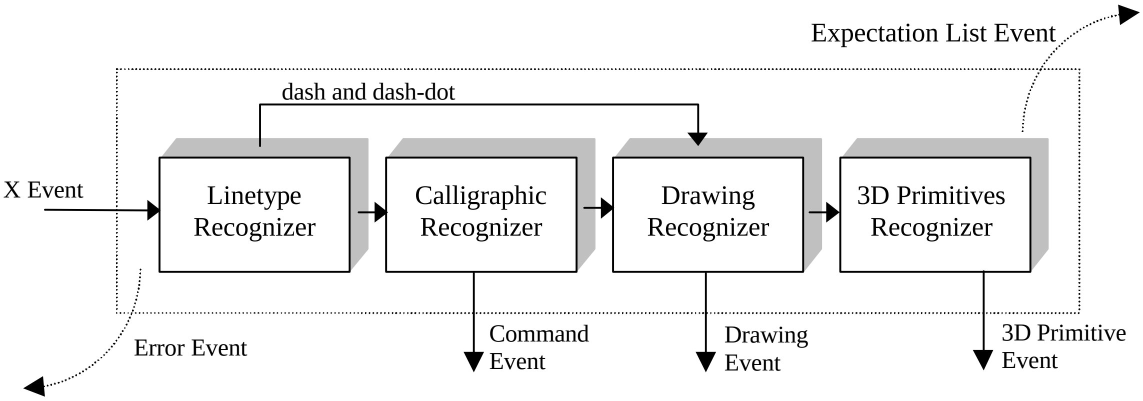
The calligraphic recognizer is responsible for identifying all command gestures.

The drawing recognizer identifies drawing elements such as line segments, circles, ellipses and polylines used to construct the system's drawing graph.

Finally, the 3D primitive recognizer is responsible for the identification of the gestures presented in Fig. 4. It performs both a topological and a perceptual analysis of the drawing [Branc94a] to yield the most likely primitive(s).



GIDeS basic architecture
Figure 6



Gesture recognizer module
Figure 7

5. USABILITY EVALUATION

The evaluation of GIDeS usability has been centered on two attributes: first impression and initial performance. These attributes seemed to be the most adequate to provide clues in order to improve our system.

The evaluation group consisted of six architects and designers that normally use 3D CAD systems for their work.

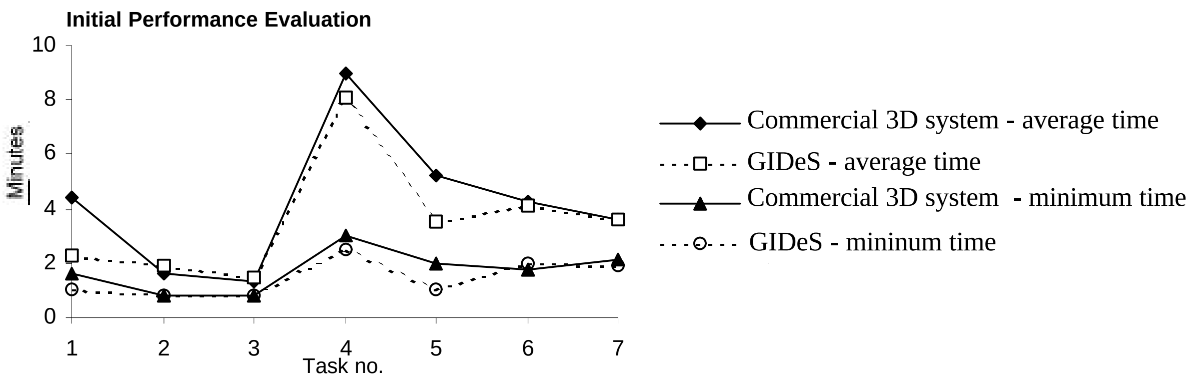
The measuring instrument for first impression evaluation consisted of a questionnaire which has been presented twice to the users: the first time after a demonstration of the system and the second time after the first contact with the system. Answers could range from -3 (worst case) to +3 (best case).

The data collected from this evaluation inquiries (mean values: +1 and +2) showed that the participants opinion of the system became more and more positive as their knowledge and experience with the system increased.

Initial performance has been evaluated measuring the time it took different subjects to complete seven modeling tasks, using both a commercial 3D system and our system (Fig. 8).

The first three tasks consisted mostly of modeling simple objects. To perform task 1, each participant was asked to reproduce a specified view of a 3D model and to invoke the reconstruction gesture. Extrusions and revolutions were evaluated in tasks 2 and 3.

3D primitives together with Boolean operations (union and difference) were created by the participants in tasks 4 to 6. Task 7 was reserved for geometric transformations.



Results of initial performance evaluation benchmarks
Figure 8

6. CONCLUSIONS AND FUTURE WORK

Many of the ideas presented in this paper came out of conversations with designers and architects, who unanimously emphasized the necessity of being able to draw with the maximum possible freedom.

Contrarily to what we initially thought, the presentation with four views is easy to use by creative people, provided they can draw/edit models in any view.

The usability evaluation of GIDeS shows that it is possible to improve the effectiveness of 3D systems for conceptual object design and to establish a better relationship between creative people and computational tools.

We are working mainly on the exploration of new interaction techniques of construction/editing of 3D scenes. We hope that new developments will arise not only in the area of drawing interpretation based on one or more views, but also in other areas that are related with our research.

We are currently improving the prototype and assessing its usability. We are assessing some ideas that will ease moving from a sketched model to a finished product using gestures for specifying constraints (for instance, parallelism) and associating measure information to orthogonal views of a model.

In 1990, Jim Blinn wrote [Blinn90]: "There is a tool that works perfectly fine for the ideation phase of creation. I know it might be heretical to say this, but the ultimate creative design tool is: Paper and Pencil". After describing paper/pencil advantages (cheap, quiet, portable, lightweight, no power requirements, good resolution), Blinn concludes: "The combination of paper and pencil works ... and I don't see computer graphics replacing it. AND THAT'S OK. I'm not being funny here".

We should take these wise words both as a challenge and a beacon. In the ideation phase of creation the combination of paper and pencil works... perhaps one day computers will become an adequate tool for this task.

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