A New Approach to Defining 3D Models with 2D Sketches

SUMMARY
The goal of this project is to develop an alternative technique for designing new buildings using sketches and photographs. Rather than a “top-down” approach defining large masses in 3D and refining and decorating these masses, designs will be developed from sketches and photographs of varying levels of detail arranged by the user in a 3D environment. The system will allow the user to tour the 2D sketches and photographs in a manner that lets the model emerge by the fusion of images by the user’s own visual system. After the design is detailed by sketches, computer vision techniques could be used to extract a three-dimensional model from the user’s input. The advantage of the proposed approach is that the user works in a familiar 2D mode for defining details, without the limitations and time delays of a full 3D model being defined at each step in the process.

For this project, I plan to combine my interests in computer science generally, computer graphics and vision more specifically, and additionally in cognitive science, visual art, and architecture. I hope to motivate my design decisions from the perspective of the psychology of human perception, and from some understanding of tools that would be useful to artists and architects.

This project is the continuation of a project already well underway, and I also plan on continuing this project next semester. As such, I only plan to complete certain parts of the project this semester.

DETAILS
3D computer modeling systems have become very successful in design, and especially in architecture. In particular, CAD (computer-aided design) systems have become essential for the development of complete documentation of structures to be built. CAD models are developed late in the design process as a tool for documentation and communication. CAD models enable the precise specification of materials and their configuration, and can be used to perform both visual and structural simulations.

Recently there has been great interest in 3D modeling systems for earlier phases in the design of structures. Sketching programs that allow users to quickly define rough 3D definitions using specified gestures and commands have been developed. Many of these programs follow a simplified form of the procedure for defining a structure in a more sophisticated CAD program. Larger masses are defined by extruding building footprints. Detail is subsequently added by defining small geometric structures on these masses, or by attaching texture maps to faces of the building models. At each point in the process, the user has a well-defined 3D shape to work with, that can be viewed from arbitrary points. This approach allows a user to experiment with shape, but facilitates just one of many ways a user may want to develop a design.
A classic example of a design that would not naturally be roughed out in a CAD-like system, and an inspiration for this project, is the Ingalls Rink. An early sketch of the arena by architect Eero Saarinen and the building today are shown in Figure 1. While a sketching system can’t give a user an architect’s talent and skill, the goal of this system is to at least provide the freedom to experiment with similar non-traditional and complex forms. This requires a different approach focusing on how a user can organize ideas in 3D, rather than on many current efforts in sketching research that attempt to interpret simple sketches as 3D shape. Earlier work that we draw on for this approach includes Tolba et al. 1999 and Cohen et al. 2000.

I propose a system that allows a user to collect and arrange 2D sketches and photographs as an initial “sketch” of a 3D model. A mock-up of such a system is shown in Figure 2. Images, sketches and combinations of the two are positioned to appear correct for the view the user originally had in mind when the 2D image or drawing was produced.

As an intermediary to creating full 3D shapes, the sketches and drawings would be converted to view-dependent “billboards” that allow the user to inspect views composed of multiple sketches and photographs.
This project will have four major phases:

**Phase 1:** Sketch and photo arrangement. Many existing modeling systems allow users to place texture mapped planes. The standard methods for this type of placement, however, are too laborious for the design process envisioned in this project. I have begun creating a system for conveniently defining and placing planes for user sketches and photos with the specific goal of defining and viewing emerging form. The major challenge is a simple user interface for specifying the size, location and orientation of the planes, and for ensuring that multiple views can be easily made to line up. To facilitate this process, I have so far implemented a tools that allows the user to sketch from any particular view and subsequently ‘push’ the sketched lines onto any slice of that view’s view frustum. This allows the user to immediately begin sketching new lines in 2D without first worrying about lining everything up in the 3D environment.

I have also attempted to simplify the user interface by emphasizing context based tools and feedback, and I plan to continue streamlining the user interface by creating parallel control structure between the various tools and workspaces.

**Phase 2:** View-dependent billboards. I will create a system that will selectively show the planes depending on the current view point, and user selections, such as whether interiors, or only some region of 3D space should be considered. When viewing images that are taken as an object movie in QuickTimeVR, we mentally fuse them and have the illusion of interacting with a 3D object. The goal in Phase 2 is to determine the density and opacity of views needed to gain this illusion.

**Phase 3:** Sketch navigation system. I will create a 2D workspace that complements the 3D world and allows the user to organize and quickly search through all the 2D content they have made. Users will be able to scan external sketches and photographs into this workspace and automated tools will help arrange these prior to insertion into the 3D world. Organizational schemes may include sketch tagging, hierarchical semantic graphs, and ‘unfolding’ of sketches based on their positions in the 3D world.

**Phase 4:** Visual sketch abstraction system. This system would use computer vision techniques to extract the salient features of a sketch and retain these as the sketch is scaled. The main point of this would be to create easily identifiable thumbnails and summaries of sketches for integration into the sketch navigation system. Techniques might include automatic combination of multiple sketches into a single ‘averaged’ sketch, and automatic grouping of sketches based on matching elements in one sketch to those in similar sketches (perhaps sketches of the same object, just from different angles).

**Phase 5:** Development of full 3D. In the last step, full 3D models will be approximated from collections of 2D sketches positioned in the 3D environment. Once a user is able to gain the illusion of 3D form, we can have some confidence that the sketches, images and views the user has defined correspond to an approximation of images that would be captured by a camera of the form the user is designing. With such a consistent set of images and view points we can apply a variety of computer vision based methods to
reconstruct the 3D structure. A variety of techniques including “shape from silhouettes” and “shape from stereo” will be used. Methods would be tested to start off the reconstruction process including having the user click corresponding points on different views of the same structure, and painting 3D depth on different views. For basic techniques for estimating or imposing 3D information on images that would subsequently be merged we would begin with methods outlined in Oh et al. 2001.

The output of the project will be a method of creating new detailed objects without the restrictions of working with pre-defined primitive objects and without the computational delays of the system updating a full 3D model as the user enters each stroke.

**DELIBERABLES**

1) Complete a basic usable application for the creation of a descriptive 3D model (phases 1 and 2). This application will feature a streamlined user interface that allows for simple sketch organization in a 2D graphical user interface, basic file operations (loading textures, saving environments, etc), essential 3D environment navigation and manipulation, and the core tools for 2D sketching.

2) The design for and an implementation of a more complex sketch organization and navigation system (phase 2). I plan to research current ideas on how to organize and search image archives, and I hope to apply human perception research to this task as well.

3) The design for and a beginning implementation of a visual sketch abstraction system to be incorporated into the navigation system (beginning of phase 3).

Many possibilities remain for continued work next semester. Specifically I plan to focus on automatic extraction of 3D models and other algorithmic aids to the design process.