# AN INNOVATIVE USER INTERFACE FOR
# MICROCOMPUTER-BASED COMPUTER-AIDED DESIGN

Larry Lichten
Ronald Eaton

Manufacturing Engineering Program
University of California, Los Angeles, California 90024

## ABSTRACT

This paper describes an innovative user interface for a general purpose computer-aided design system. It is being developed as part of an investigation into distributed processing in manufacturing environments. The system supports three-dimensional design capabilities for execution locally and incorporates model compatibility for communication with mainframe CAD systems.

KEYWORDS: boundary representation, computer-aided design, distributed computing system, microcomputer-based workstation, solid modeling, user interface, wireframing

## INTRODUCTION

A general purpose computer-aided design system is being developed as part of an investigation into distribution of function between microcomputer-based workstations and mainframes in manufacturing environments. Visually-oriented user interaction, good resolution display graphics, powerful interactive three-dimensional manipulations, and model compatibility with mainframe CAD systems are major objectives. The system, herein called MicroDesign, is intended to run on inexpensive hardware; it incorporates new approaches to interfacing with designers and to creating and displaying models. The MicroDesign system models objects in a hierarchical boundary representation while providing a "natural" user interface with standard wireframe operations. Volumes are defined by hierarchical groupings of bounded surfaces or by sweeping planar faces linearly or rotationally.

## HARDWARE AND SOFTWARE ENVIRONMENT

MicroDesign is intended for a stand-alone or networked engineering workstation in an integrated manufacturing environment in which both training and production design occur. In evaluating potential engineering workstations, our criteria included:

-sufficient power for numerical computation and medium resolution color graphics,
-rich software development and support environments,
-likely upward compatibility to avoid obsolescence, and
-cost.

Furthermore, we evaluated graphics hardware with respect to their networking potential in a distributed computing system. We concluded that the IBM PC/ES series of personal computers with fixed disk and IBM medium resolution graphics best met our requirements. Microcomputers of comparable or greater cost-performance were considered; however, non-obsolescence, quality technical support, and compatibility with the large installed base of IBM mainframes in manufacturing environments were overriding.

The PC AT (or AT/370 if graphics interfaces become available), in particular, with either IBM Enhanced or Professional Graphics provides strong local functionality and networking facilities. Of other IBM PC models available, we considered the 3270 PC and XT/370--the 3270 PC for its multiprocessing windows and multiple host sessions and the XT/370 for its ability to execute mainframe software directly and to network with a remote host. We believe that as applications software and "hardened" PCs for manufacturing environments become available, these systems will predominate as "standard" engineering workstations in factories.

Although MicroDesign software is intended to be usable stand-alone, we feel that workstation-based systems can be significantly enhanced by the addition of networking facilities. In particular, we are addressing some of the problems of communication between existing mainframe packages through host communication, terminal emulation, and the ability to copy information between windows. A critical consideration in such a distributed system is the trade-off between local power and bandwidth; insufficient bandwidth limits the level of interactivity for some applications that necessitate transferring models to a host. From

our initial experiences, we anticipate minimal need for remote mainframe execution; for example, only analysis, realistic display, and file and plot serving may be relegated to a host.

Software requirements included:
- high level language programming except where assembler language could exploit special hardware characteristics,
- support for windows,
- device independence only within the limits of our initial hardware configurations, and
- ability to exchange information with existing mainframe CAD systems.

## CURRENT DEVELOPMENT STATUS

When we began work on microcomputer-based CAD more than two-and-a-half years ago, we surveyed available hardware and software as well as turn-key systems. At that time, microcomputer CAD was in its infancy; recently, however, several vendors have begun to offer functionally-rich systems. UCLA's Manufacturing Engineering Program has also designed and implemented a special purpose microcomputer-based CAD system, which is described in [8]. Menus, prompts, color queues, and other graphical techniques were investigated during the course of our work. Initial implementation of MicroDesign began more than a year-and-a-half ago; since that time, our target hardware and some significant parts of the software have changed greatly. For example, third-party graphics enhancements to the IBM PC were originally necessary to provide the required resolution and color.

Development is currently under way using both PC-DOS and VM/PC. We feel that the lack of multi-processing support in these operating systems may present serious limitations, and implementation in a Unix[TM] environment is being considered. In order to best utilize our existing equipment and to provide an efficient development environment, we are also implementing low level graphics support for other IBM workstations such as the 5080.

## SYSTEM OVERVIEW

Although much current Computer Science research focuses on human-computer interfaces, there seems to be insufficient understanding of engineering design processes and human interaction with computer-aided design and drawing systems. We feel that "user friendliness" is exemplified by some microcomputer software, particularly for the Apple MacIntosh (which, in turn, borrows from Xerox Star office automation technology) and for many computer video games. Mainframe CAD systems' interfaces (notably those with tablet-menu-oriented or keyboard entry)

unfortunately approach "user hostility". Our approach to user interface design is supported by several studies of man-machine interaction [1,4,6,7,10,11], while choices of modeling and display functions were based primarily on our experience with mainframe CAD systems.

In MicroDesign, users display models in stackable dynamic windows during design sessions; interaction with system functions is through "pop-up" and "pull-down" menus that temporarily overlay model display. Windows may be added, deleted, or changed in size at any time. Windows, as generalizations of engineering drawings, can contain arbitrarily-oriented views of a single model or of separate models. Separate models also may be "assembled" in a window. Geometric operations in a particular window affect model display in all windows containing that model.

Geometric entities are "drafted" in working planes and grouped or "swept" into three-dimensional models. This type of wireframe interaction is supported by geometric definition and manipulation functions and by inclusion of pre-defined volumes that can be scaled and placed within a model. Standard tools used in design and conventional drafting such as temporary grids, construction lines and planes, and dimensional information are supported. For example, a construction grid can overlay a plane without modifying the model being created.

Primary user interaction can be entirely with a mouse or other pointing device. Some of the reasons we believe this to be advantageous are
- It leaves one of the user's hands free to browse drawings, documents, or other materials.
- It frees desk space.
- We believe new users are intimidated by a number of input devices. A mouse is convenient since one just points and "clicks".
- Fewer hand movements and keystrokes are required so experienced users should be able to work faster.

Function keys and keyboard entries are also supported. Some functions can be invoked immediately at any time during a design session; they include obtaining "help" information, and display pan, zoom, and rotate.

Most functions define or operate on geometry in a construction plane, and two-dimensional operations default to this plane. Any visible planar entity can define a new construction plane, which is then displayed normal to a user's line of sight. Closed profiles may be translationally or rotationally swept; alternatively, topologically adjacent "trimmed" surfaces may be grouped into volumetric models.

Hierarchical groupings of such bounded surfaces are all user-directed as in Dassault's CATIA[R] system [2]; no algorithmic support of Constructive Solid Geometry (CSG) Boolean operations is anticipated or, we believe, desirable since

-CSG implementation requires considerable computing power,
-set union and intersection have no counterparts in piecepart manufacturing (other than assembly),
-CSG operations may be less "natural" than wireframe "drafting" for many classes of objects, and
-objects' bounding surfaces provide useful information for most manufacturing operations (especially NC cutter paths), and CSG systems often contain no surface information explicitly.

INTERNAL DATA STRUCTURING

For mathematical tractability and host solid modeling compatibility, volumes are modeled as approximating polyhedra. Curves are linearly approximated and surfaces are faceted; techniques used are described in [9]. The underlying polyhedral structure is that of GDP, an experimental solid modeling system [3], which uses a boundary representation containing faces, loops, edges, and vertices. It is similar to the proposed topology of the IGES Experimental Solids Proposal [5].

DISPLAY FORMAT

Three classes of entities can be displayed:
(1) geometry and annotation of models,
(2) windows, and
(3) command "icons" containing menu items and prompts.

Specific functions supported are listed in a subsequent section of this paper. Only two command icons--HELP and EXIT--are always selectable and immediately executable. In order to provide consistency, the command language structure is, in a sense, recursive; major functions may be used as sub-functions of other major functions. For example, definition of a horizontal line requires a point through which the line will pass. Within major function LINE, sub-function HORIZONTAL, all options of major function POINT are available with identical icons and actions.

The window is "active" for resizing or re-orienting view of a model. It is possible to copy entities from one window to another or from one place to another within a window. Selecting VIEW provides capabilities to zoom, pan, or change orientation without leaving the current function. An L/R icon allows panning a window left or right by using the left or right mouse button. The UP/DOWN icon provides up and down pan.

When a user presses one of the mouse buttons while the cursor is over an icon and holds it for about a second, a menu will be displayed (or "pulled-down") only as long as the button is depressed. A user may then move the cursor under his next choice in the menu and select with a single key stroke. Icons may react differently depending upon whether the left or right button is pressed. A short information message may also appear as a prompt.

An icon displayed in the upper left corner of the screen represents the current primary function, as shown in figures on the following pages. Selecting this icon "pops-up" a list of primary functions. When one of these is selected from the icons, the chosen primary command appears in the upper left corner. If the function has secondary functions, those appear to the right of the primary function name also as icons. Selecting a secondary or tertiary function icon also "pops-up" a multiple choice menu listing options from which to choose and appropriate prompts.

FEATURES SUPPORTED

In our experiences with mainframe CAD systems, designers generally use only a small subset of a system's functions, which is often based on their initial training with the system. We therefore chose to support a minimum set of geometric, display, and system management functions. The table below lists functions to be supported for local execution:

Geometry Creation
    Points
    Lines
        construction and model lines
        segment and unlimited lengths
    Curves
        circle
        interpolating piecewise cubic spline
        rational B-spline
    Surfaces
        construction and model planes
        tabulated cylinder
        singly-ruled
        bicubic network
        rational B-spline
    Volumes
        enclosed by bounded surfaces
        from basic elements library
        planar entity swept linearly or
            rotationally

Geometric Manipulation
    Intersection and tangency
    Bounding
      line and curve segmenting
      line and curve extrapolating
      cornering
      trimming surfaces
      circular-section filleting
    Projection
      entities onto planar entity
      offset entities
    Assembling (multiple layers)
    Editing
      rescaling
      translation
      rotation
      delete geometric entity

Viewing
    Zoom, pan, rotate object in active window
    Create, delete, resize window
    Display viewing parameters

System Management
    Models
      get, save, merge, delete model
      list models
      basic elements library
    Plot
      model
      print text from associated file
      screen dump
    Miscellaneous
      dimensioning and annotation
      physical properties calculation
      on-line documentation and tutorial
      "undo"

In addition to saving models on mainframe peripheral storage and communication with other manufacturing functions, host invocation seems desirable for
    -realistic display of complex models
    -CSG operations
    -IGES pre- and post-processing
    -NC code generation
    -interfaces to engineering analysis systems

SAMPLE SESSION

Figures one through five provide an example of MicroDesign's user interface. Figure one displays three models, in which the "top" model is an assembly of the models "below". Major function icons are "popped up", and SURFACE has been selected. Immediate function icons HELP and EXIT are displayed in the upper right corner. Within SURFACE, secondary function CONSTRUCTION PLANE has been selected in Figure two. Figure three displays several views of the model, including the newly-created construction plane in a background window. Other windows were created

by VIEW. Figures four and five show definition of concentric circles within the construction plane.
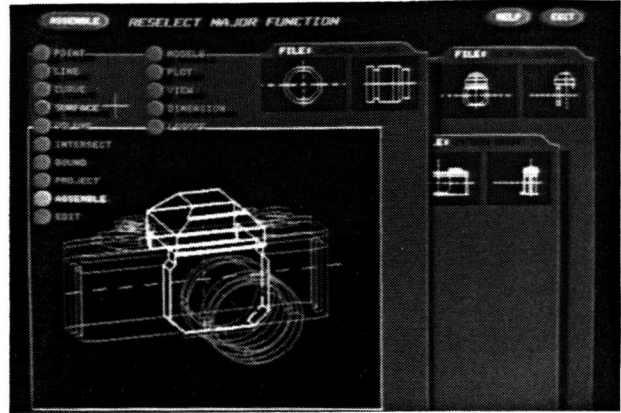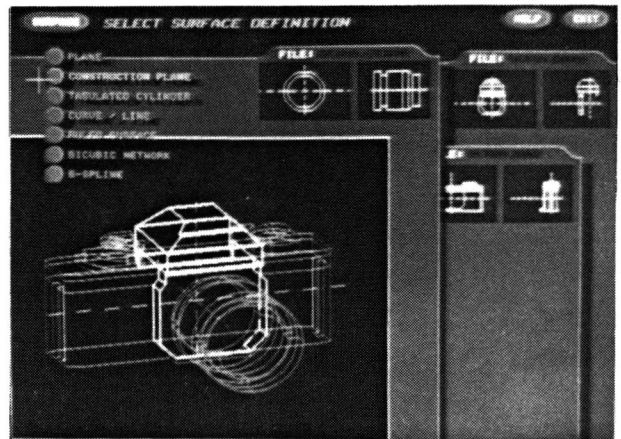

Figure 1. Stacked windows and pop-up menus
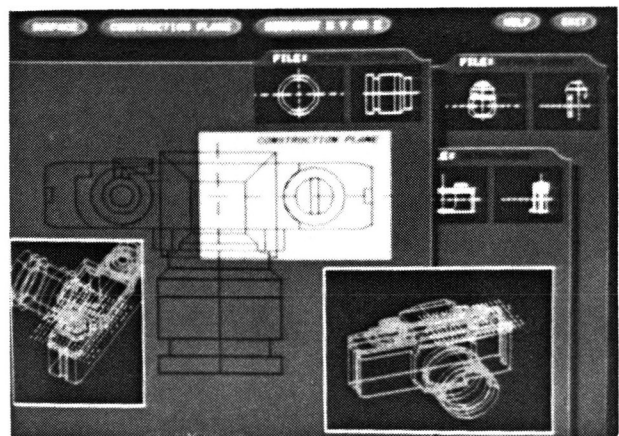

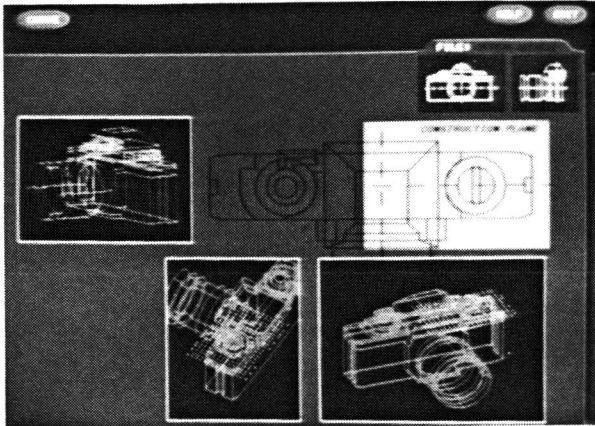Figure 2. Surface definition


Figure 3. A construction plane

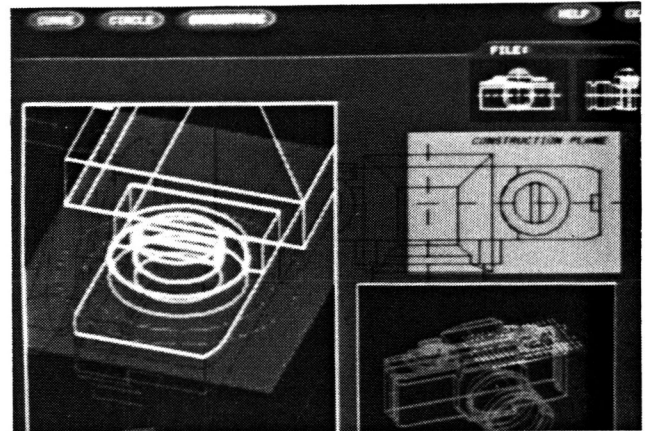Figure 4. Curve definition in a plane



Figure 5. Zooming in a window

CONCLUSIONS

This paper summarizes the progress of our investigations into distributed computer-aided design and techniques for interaction. We have thus far concluded

- Both standalone and distributed CAD are significant components of integrated CAD/CAM.
- Wireframing with additional surface and grouping information provides an appropriate geometric model for microcomputer-based systems.
- The PC AT with graphics enhancement provides the best workstation based on cost/performance and upward compatibility.
- User interaction through dynamic windows and menus provides flexibility and ease-of-use generally not found in current systems.

System functions have been specified and partitioned into local and remote based on their anticipated computing requirements and the communication speeds in a distributed system. We are currently proceeding with prototype implementation; we feel that MicroDesign's functions and operations provide

- a natural interface to three-dimensional modeling,
- a generalization of multiple-view engineering drawings,
- capabilities for retaining volumetric infor- in the system's data structures, and
- potential compatibility with mainframe solid modeling systems.

As implementation progresses, we will be testing the system by using it in teaching CAD and in developing a prototype distributed manufacturing system. We will then be able to better evaluate both the system's interface and its functionality in its intended environment.

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