GENERATION OF GEOMETRIC MODELS BY LINE SKETCHES

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ABSTRACT

This paper introduces a user-friendly man-machine interface to create geometric models by inputting sketches on the screen. The screen provides coordinate axes of a 3D space drawn perspectively with vanishing points which are familiar to most designers as sketch aids. The system, Sketch interpreter, is constructed in terms of three characteristic operations on a workstation with a pointing device: (1) To recognize handwritten sketches on the screen: freehand lines are drawn by pen operations from which a computer can construct a geometric model. This first operation computes mathematical parameters for the projective transformation. (2) To construct additional geometric models by inputting more sketches drawn perspectively. (3) To redraw modified geometric models replacing the sketched lines. The interactive methods are suited to realistically constructing any geometric shape that a designer imagines.

Keywords: Sketch interpreter, Geometric model, Parrallelepiped

INTRODUCTION

In engineering design, training is required for a designer to imagine a 3D object that does not exist yet, and to transform it into a 2D sketch before making engineering drawings. The aim of this research is to help the designers to create strictly geometric models from their ideas formed in rough sketches. Sketch interpreter is an interactive system to support a designer at his workstation with graphic input and output devices. Engineering design is generally composed of six stages of procedures, as shown in Figure 1. At every stage, the shape of a target object is inspected from various aspects such as artistic design, functional requirements, ... etc. When not satisfied, a modified shape is tried from the preceding steps. Trial and error procedures usually take time, so that it is desirable to shorten the repeated steps. At the stage of imaging a shape, a designer makes individually drawn sketches. However, some advanced 3D-CAD systems demand only correct digital data, and will not accept such fuzzy information [1,2].

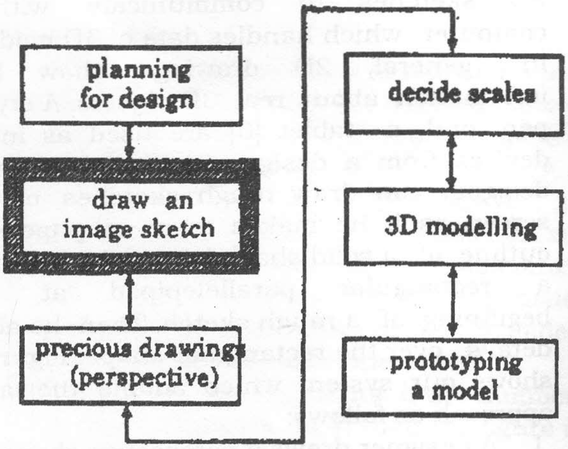

Figure 1 Design stages of procedures

Until 1996, typical techniques for recognizing a sketch drawing of a 3D object have used the perspective theory [3,4], and the orthographic view theory for engineering drawing [5]. These theories only suit special drawings which are inconvenient for designers. Our system is unique, since a

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sketch drawn on the screen is directly recognized by a computer as a 3D object. The system records the history of the designer's operations from the first step of pixel drawing to the last step for detailed drawings, as shown in Figure 2. The designer can play back any preceding steps to repeat the process, so that he can remind himself where the shape is to be modified. This uniqueness has two characteristics. One is to recognize free lines, and other is to support reasonable interaction.

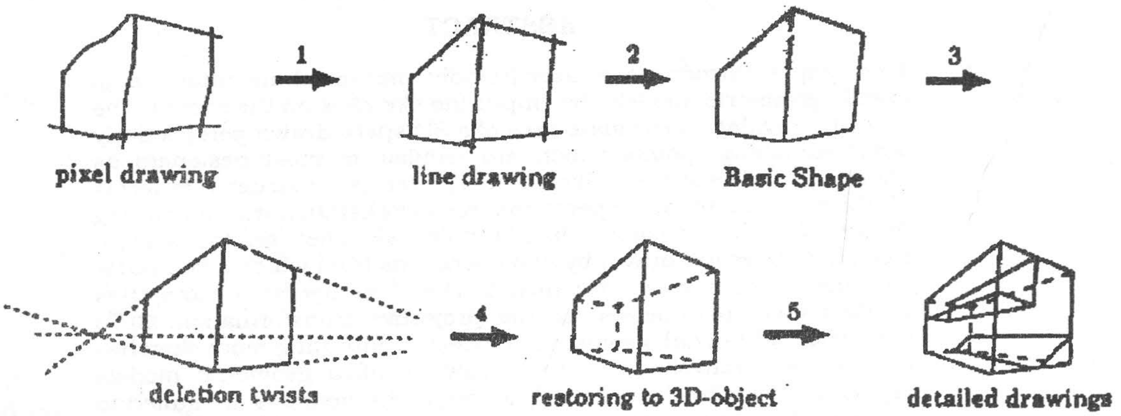


Figure 2 Steps of drawing stage in Sketch interppreter

SYSTEM CONSTITUTION

Sketch interpreter is an interactive system which allows a designer who draws 3D sketches to communicate with a computer which handles data of 3D models. In general, 2D drawings show less information about real 3D objects. A stylus pen and a tablet [6] are used as input devices from a designer to a computer. A designer can draw rough sketches on the screen as if he makes them on paper. An outline of a solid shape is usually drawn as a rectangular parallelepiped at the beginning of a rough sketch. Then, he adds details over the rectangular shape. Figure 3 shows our system which adopts the same approach as follows:

1. A designer draws a perspective shape of some possible rectangular parallelepiped on the screen with freehand lines. He has to remember that the parallelepiped on the screen is a working model which is 300mm in height. If another size is needed, he can change the default size on the menu; otherwise, the model is reduced or magnified into a strict geometric model after all the details are completed. A computer adjusts the freehand lines into straight edges. Vertices are decided as starting positions of relevant edges. Two or three reasonable vanishing points, using perspective theory, are proposed by the computer, and a geometrically correct perspective view is redrawn on the screen. At this moment, a view position is decided, representing the eye of the designer. We call this perspective shape the 'basic shape', which plays an important role in our system.
2. A designer then draws additional freehand lines over the basic shape to create lines indicate cutting lines to the model and the cutting operation is carried out by pointing at the part to be eliminated.
3. In order to join several parts to the basic shape, additional parallelepipeds should be composed. Edges of additional models are created to be parallel to those of the original parallelepiped.

4. Models on the screen can be inspected perspectively by changing view positions. After the model is satisfactorily completed, geometric data of the model are transferred to other advanced procedures such as coloring, rendering, and so on.

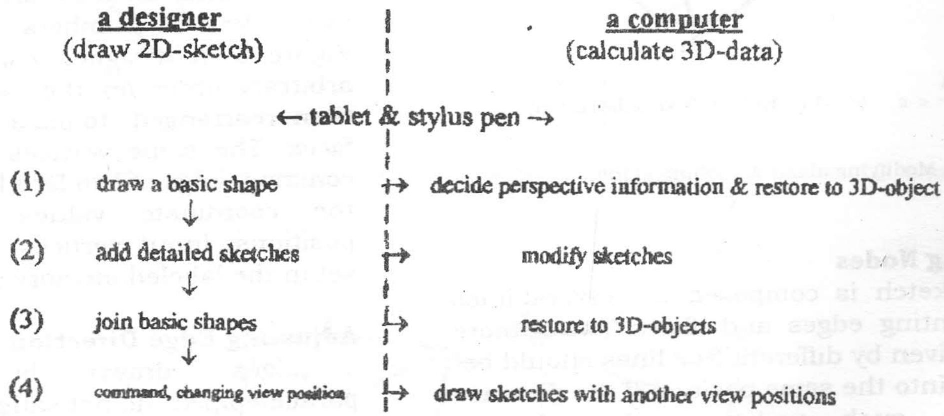


Figure 3 System constitution

FUNCTIONS OF SKETCH INTERPRETER

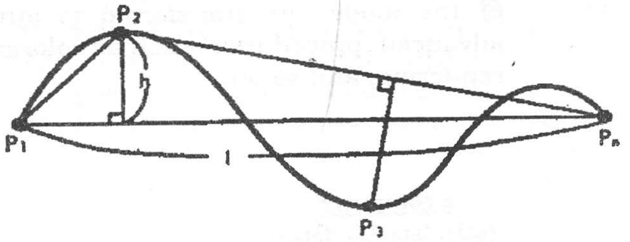
Line Recognition

A stylus pen on a tablet serves as a digitizer for the input data of a freehand line. The data are a series of positions which become a chain of pixels on the screen. As the starting position P_1 and the end position P_n are absolutely given, a straight line connecting P_1 and P_n can be theoretically decided. Among the series of positions, let us find a position P_2 whose distance h becomes maximum from the straight line, (see Figure 4). The distance h is compared with the length l of the line. If the ratio h/l is less than a threshold ε, then the given chain of positions is assumed to be a straight line. Otherwise, the freehand line is divided at the node P_2 into two segments, P_1 to P_2 and P_2 to P_n. Each segment is tested in the same way in order to find another node that may divide more segments. Finally, the original freehand line is recognized as a folded line. The data of freehand line are reduced to a finite number of nodes. When the freehand line forms a loop, the starting position becomes the same as or very close to the end position. The length l is compared with a minimum length Δl, which can be modified by a designer on the menu. Position P_2 is similarly decided as the farthest position from the starting position.

Identification

After the freehand line is reduced into a folded line with n nodes, the freehand line is identified as one of, or a part of the specific figures, such as a polygonal line, a square, a rectangle, a circle, an ellipse, an arc, or some curved line. Rules for identification are composed by the following four parameters:

1. The length between the starting node and the end node: this checks the folded line as being closed or open.
2. Number of line segments: if the number of line segments is 4, then the figure is possibly a square or a rectangle.
3. Angles between adjacent line segments: when the angle at a node ranges about 150° or more, two adjacent segments are possibly part of a curved line.
4. The aspect ratio of width and height of an imaginary rectangle containing the given freehand line: the ratio becomes nearly .



$\frac{h}{l} < \varepsilon$ (ε : threshold of Nodes detection)

Figure 4 Modifying about vanishing point

Unifying Nodes

A sketch is composed by several lines representing edges and faces. Two or more nodes given by different free lines should be unified into the same position if the distance between such nodes is less than a predefined threshold.

Perspective Mode

There are three ways of perspective projection depending on the position of the eye against a parallelepiped, that is, one-point, two point, and three-point perspective projections. In our Sketch interpreter, we do not deal with the one-point perspective projection with six vertices, the projection mode is either two-point or three-point perspective mode. If the third vanishing point is calculated farther above or below the screen, the two-point method is adopted on the screen, and all the vertical edges are set parallel.

Numbering on Nodes and Faces

In order to store parallelepiped data, we have a fixed memory area for vertices and faces. Vertex numbers are as shown in Figure 5. A designer can draw edges in an arbitrary order on the screen. Vertices are then rearranged to make a loop around the faces. The same vertices appear along the common edge of two face loops. Considering the coordinate values of their relative positions, input vertices can be reasonably set in the labeled memory area.

Adjusting Edge Direction

Edges drawn by the original parallelepiped do not satisfy the perspective theory. This means that three or more edge lines never meet at a fixed vanishing point. A designer at first decides the principal edges along each of which a vanishing point will be found. According to the direction of other edges, the most probable point is decided as the vanishing point. The other edges are then rotated at their middle point in order to fit the new direction aiming at the vanishing point. When two vanishing points exist on the horizon at different heights, they are adjusted to lie on the mean height. Edges are rotated by the same method, as sen in Figures 6 and 7.

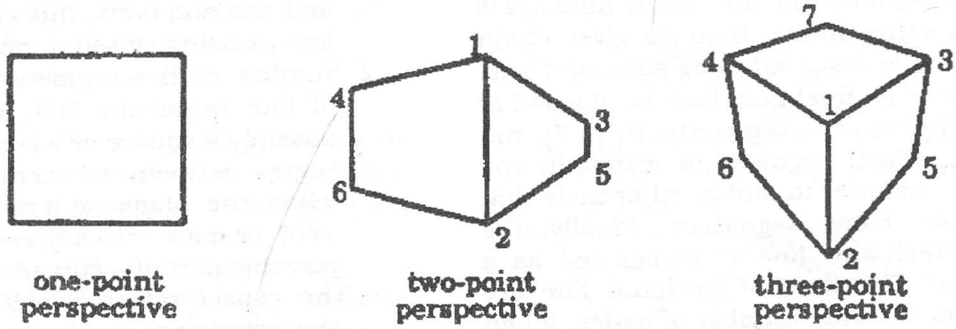


Figure 5 The types of a prespective rectangular parallelepiped drawing

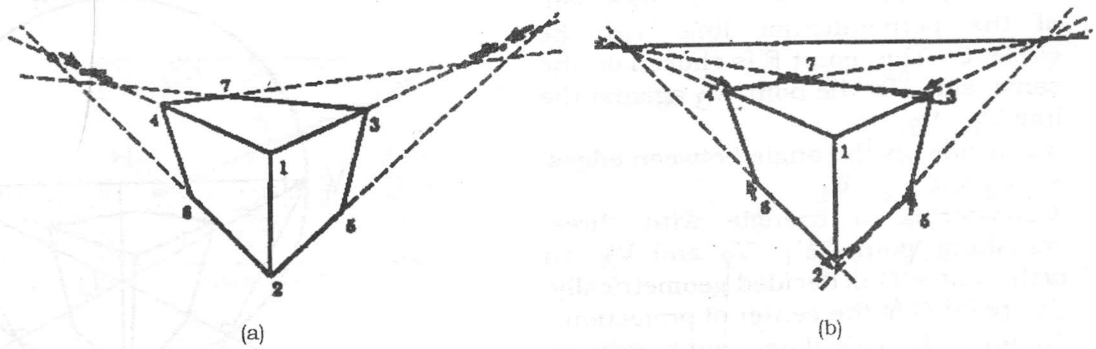


Figure 6 Modifying about right and left vanishing points (a) decision of right and left vanishing points; (b) modifying vertices

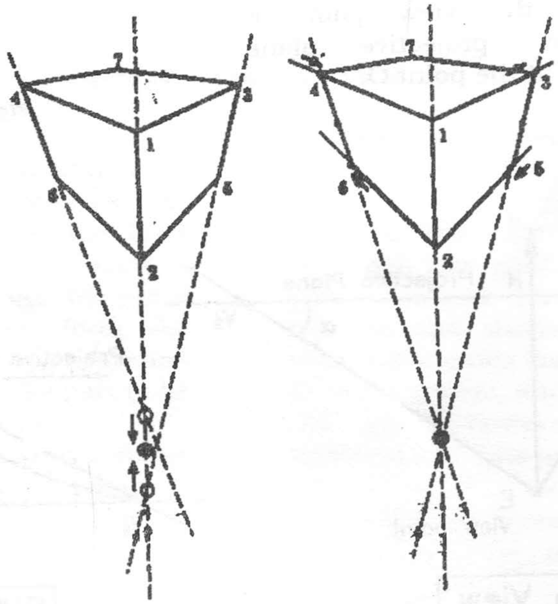


Figure 7 Modifying about vertical vanishing point

Decision of a View Point

Let us introduce a method to decide a view point, from the vanishing points, on the projective plane which stands in space. Practically, our viewpoint on the screen shows a part of the theoretical projective plane which is similar to the scope of a camera. The projective plane is decided by three parameters, that is, angles of pan and swing σ and β, and a view distance f. In addition, position O is required as the center of projection, that is, as the origin of the projective coordinate system. The position O will not be located at the center of the viewpoint on the screen. Therefore we have to decide the coordinates of position O on the graphics screen. Parameters are calculated by the following procedures, with the help of Figures 8 and 9.

1. To draw a circle C whose diameter is a line $V_1 - V_2$, where V_1 and V_2 are the left and right vanishing points on the horizon.
2. To draw a perpendicular line from V_3 toward the line $V_1 - V_2$, where V_3 is the third vanishing point. In the case of two-point perspective mode, the perpendicular line passes through the center of the circle C.

3. To decide a point E at the intersection of the perpendicular line with the circle C. The point E is chosen on the same side as the point V_3 against the line V_1 - V_2.
4. To decide as the angle between edges E - V_2 and V_2 - V_1.
5. Considering a triangle with three vanishing points V_1, V_2 and V_3, an orthocentre O is decided geometrically. The point O is the center of projection.
6. In order to calculate f and β, refer to Figures 8 and 9. The point E represents the view point in perspective space. A half line u beginning at the view point E intersects the projective plane perpendicularly at the point O.

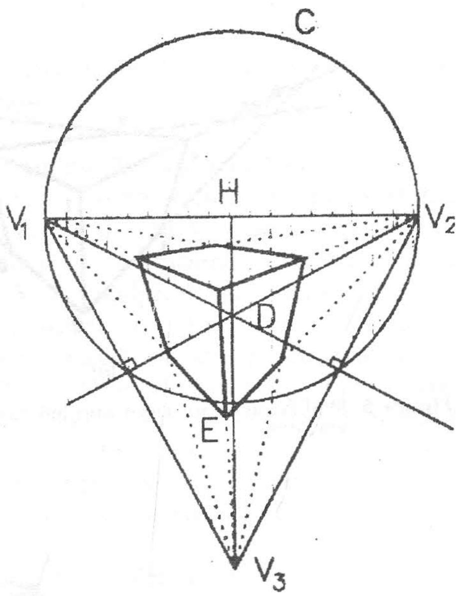


Figure 8 Decision of a view point

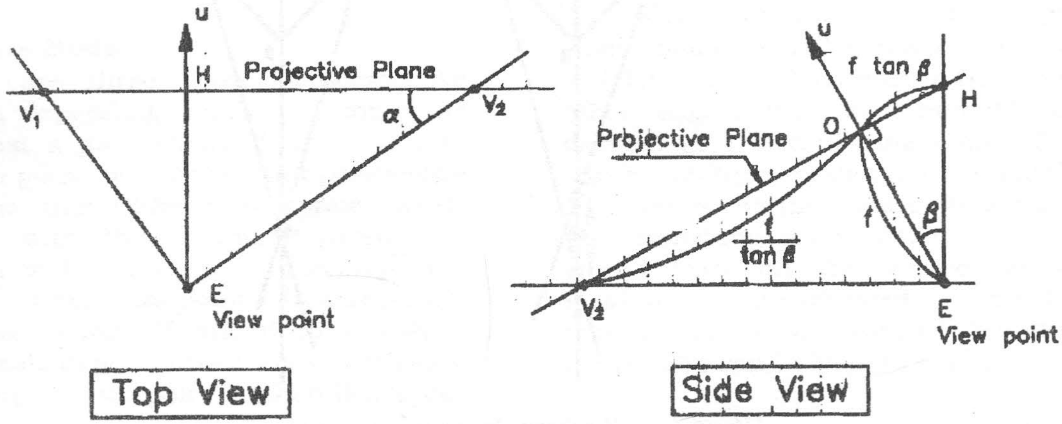


Figure 9 The relation of a view point and a view plane

Restoring the 3D Coordinate System

A camera coordinate system (u, v, w) is assumed in the world coordinate system (x, y, z). The position of the camera, i.e. the view point, is the point E and the projective plane is in front of the lens at a distance f. The origin of the camera is located at (f, 0, 0). Angles σ and β are those of rotation between coordinate system is at point O.

In order to decide the coordinates (u, v, w) of the vertices in the camera coordinate system, four reference points on the screen are chosen. These are vertices P_1 and P_2 which form a vertical edge with length 300mm, (see Figure 4), the origin O of the camera coordinate system, and the third vanishing point V_3, as shown in Figure 10. In the 3D space, the edge P_1 - P_2 is parallel to one of the axes of the world coordinate system. Let us consider the position in space of the view point E and the vanishing point V_3 on the projective plane. The line E - V_3 is also parallel to the coordinate axis of the world coordinate system, (see Figure 10), so that a transformation matrix is deduced from the data of the graphic image.

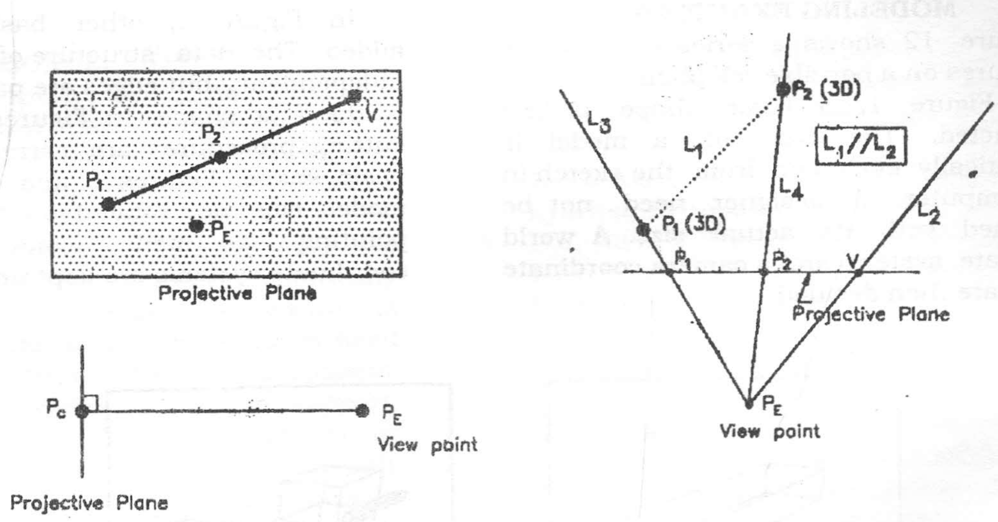


Figure 10 Restoring 2D to 3D

Modifying a Model

We now mention modification of a model which has been drawn by a designer. The designer draws additional freehand lines over the model to provide more details. A cutting plane is calculated from the world coordinates of vertices which form the additional lines. Then, the cutting operation is carried out by pointing at the part to be eliminated, as shown in Figure 11.

The ACAD system is somewhat suitable for processing these functions, however it needs digital input data. In the early stage HG program was used to implement sketch interpreter but has little environment t identify projective plane, viewpoint ar coordinates. Software like "Mechanic Designer" (the advanced engineering versio of ACAD) has good and suitable menu wit proper toolbox for fuzzy input, rotatir function and shaded property. While in ar and easier cases Paint program can be use for our system, and to observe 3D from 2I The graph, however can be reloaded, fc modification, into another program, such a ABC, VISUM, ... etc. Most of which indicat the useful facilities for our system, withou considering the complicated process c ACAD system.

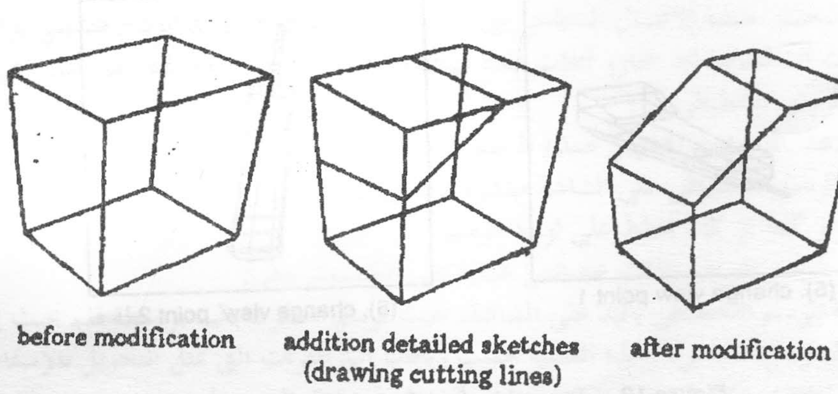


Figure 11 Procedures of drawing more details

MODELING EXAMPLES

Figure 12 shows a series of modeling procedures on a portable telephone:

In Figure 1, a basic shape is first constructed. The size of a model is automatically evaluated from the sketch in the computer. A designer need not be concerned with its actual size. A world coordinate system and a camera coordinate system are then decided.

In Figure 2, other basic shapes are added. The data structure of each shape is independent, but edges are parallel to those of the first shape. In Figures 3 and 4 the cutting procedures are carried out on each basic shape. Figures 5 and 6 show that a model can be rotated on the screen by pointing at menu icons. The space coordinate systems are kept unchanged.

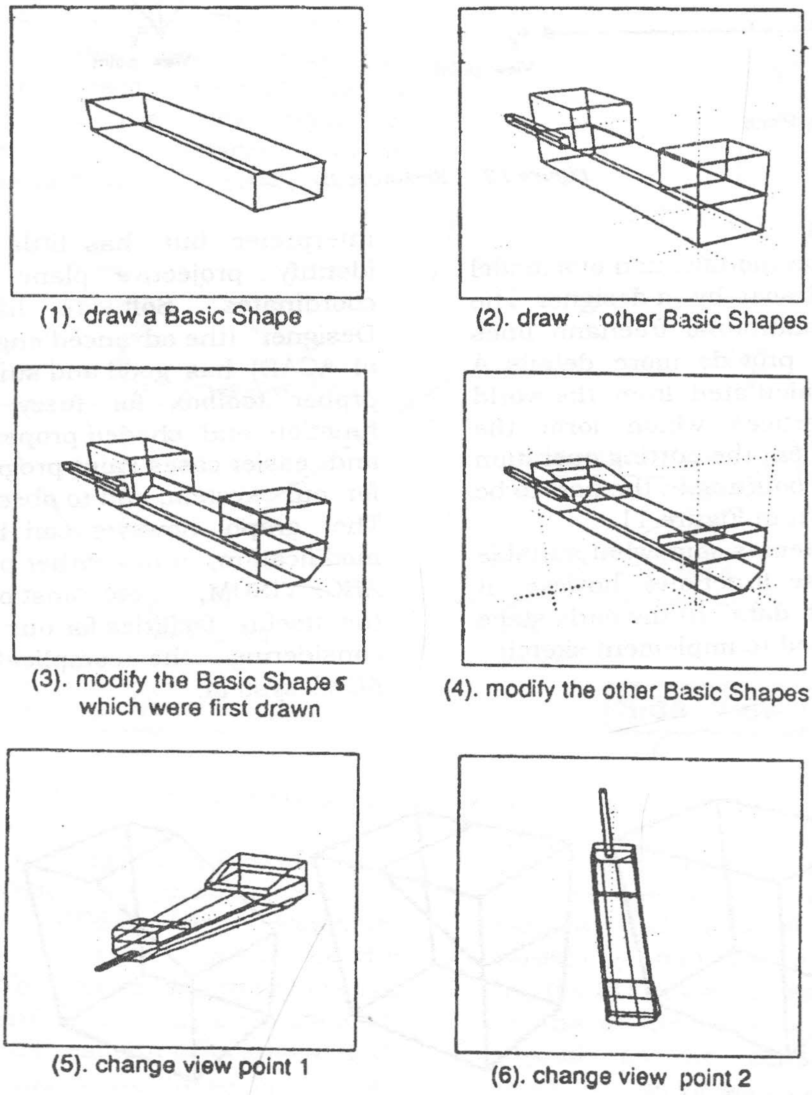


Figure 12 Examples of a telephone sketch

CONCLUSION

Sketch interpreter helps the designer to design industrial parts whose shape is basically that of a parallelepiped. A designer can work at a workstation in the same manner as drawing sketches on paper. Freehand lines are input to a computer and instantly redrawn to provide geometrically correct sketches. This procedure is intelligent enough so that the designer need not worry about space dimensions. Interactive procedures do not yet support, however, the creation of cylindrical or curved faces. The graphics display only allows wire frame drawings. This may cause some confusion when hidden lines are not eliminated. For such advanced procedures, we recommend our other modeling programs using the data transferred from the Sketch interpreter.

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توليد نموذج هندسى بواسطة رسم تخطيطى على الكمبيوتر

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ملخص البحث

يمهد هذا البحث عملية الاتصال السطحى بين الانسان والكمبيوتر فى توليد نموذج هندسى بواسطة رسم تخطيطى على الشاشة. حيث أن الشاشة تمد المحاور لثلاث أبعاد فى فضاء الرسم المنظورى مع نقط الهروب. وهى التى تكون مألوفة لمعظم المصممين بالرسم التخطيطى.

ويهدف هذا البحث إلى تسهيل عملية الرسم الهندسى للمصممين بواسطة الرسم المترجم من خيال المصمم فى فضاء الثلاث أبعاد الى الرسم التخطيطى على الشاشة مباشرة ممثلا فى مجموعة من الرسومات فى فضاء البعدين. كما يجعل المصمم يعمل على الكمبيوتر كما لو كان يخطط على لوحة الرسم.

وقد عبر الرسم المترجم بثلاث خصائص عملية على الكمبيوتر وهى:

١. ملاحظة الرسم التخطيطى باليد على الشاشة، حيث ترسم الخطوط باليد بواسطة قلم بحيث يمكن للكمبيوتر أن ينشئ النموذج الهندسى، وهذه العملية تحسب رياضيا البارامترات التى تمثل التحويل بالإسقاط.

٢. اضافة زيادات على النموذج الهندسى بواسطة خطوط زيادة بالرسم المترجم.

٣. إعادة رسم النموذج مع تعديلة ليأخذ مكان الرسم التخطيطى.

وتتلاءم الطرق المتبادلة فى الانشاء الواقعى