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COM-GEOM INTERACTIVE DISPLAY DEBUGGER (CIDD)

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To speed the process of debugging Combinatorial Geometry (COM-GEOM) target description data used in the Geometric Information For Targets (GIFT) computer code, a program was written to interactively display the geometric figures called solids and their combinations called regions on a desk top graphics terminal.

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I. INTRODUCTION

The Com-geom Interactive Display Debugger (CIDD) program was written to speed up the process of formulating the Com-Geom data used by the Geometric Information for Targets (GIFT)[1,2] computer code. The purpose of CIDD is to allow the Com-Geomer to quickly view parts of his target description from any direction on an inexpensive desk top graphics terminal after it has been described and to make minor changes to it. Currently there exist two versions of CIDD: CYBER-NOS and VAX-UNIX.

1.1. The Com-Geom Method

Com-Geom is a method for synthesizing a three-dimensional representation of an object for a computerized analysis. The Com-Geom data requires three tables to describe an object: Solid, Region and Region Identification. The Solid Table contains the basic building block shapes and is formed by selecting from a set of elementary three dimensional geometric figures (solids) that are described mathematically in a right handed Cartesian coordinate system. Solid types that may be used along with their respective code designations are listed in Table 1. A more detailed description of allowed Com-Geom solid types may be found in reference 1.

Table 1. Com-Geom Solid Types

CODE	SYMBOL	SOLID
1	RPP	Rectangular Parallelepiped
2	BOX	Box
3	SPH	Sphere
4	RCC	Right Circular Cylinder
5	REC	Right Elliptical Cylinder
6	TRC	Truncated Right Angled Cone
7	ELL	Ellipsoid
8	RAW	Right Angle Wedge
9	ARB	Arbitrary Convex Polyhedron
10	TEC	Truncated Elliptical Cone
11	TGC	Truncated General Cone
12	HAF	Half Space
13	TOR	Torus
14	ARS	Triangular Surfaced Polyhedron

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[1] Lawrence W. Bain, Mathew J. Reisinger, "The GIFT Code User Manual; Volume I, Introduction and Input Requirements (u)," BRL Report No. 1802, July 1975. (AD# B0060371)

[2] Gary G. Kuehl, Lawrence W. Bain, Jr., Mathew J. Reisinger, "The GIFT Code User Manual; Volume II, The Output Options (u)," USA ARRADCOM ARBRL-TR-02189, September 1979. (AD# A078364)

One or more solids or regions may be combined in the Region Table using the boolean operations of union (sum), intersection and negation to approximate the basic shape of an object. A descriptor is a solid or region number plus an operation to be performed using that solid or region to form the region. The operations used to combine solids or regions are illustrated in Figure 1. Table 2 contains a list of region operators and the code numbers.

Table 2. Region Operations

Code	Operator	Boolean Operation	Operand
1	OR	union	+Solid number
2	OR	union + negation	-Solid number
3	RG	intersection	+Region number
4	RG	negation	-Region number
5	blank	intersection	+Solid number
6	blank	negation	-Solid number

Each region is assigned an item code number and verbally described in the Region Identification Table. The item code number is used to specify and to differentiate the role each region plays in the target.

1.2. What CIDD Does

CIDD plots the solids and regions of the Com-Geom description from any specified view. Marking and locating points on the plot can be performed, and zooming is also performed.

CIDD plots all solids available in GIFT with the hidden lines for each of them removed. Figure 2 depicts the solids plotted by CIDD. CIDD plots regions with the hidden lines of the positive solids removed. The negative solids do not have any hidden lines removed. If a descriptor for a region contains the "RG" operator, that descriptor is ignored. Figure 3 depicts a region plotted by CIDD. CIDD labels each plot with the azimuth and elevation angles and the scale.

CIDD also performs editing. Solids and regions can be changed. Solids and regions can be added to the Com-Geom description. Solids can be moved.

II. USING CIDD

CIDD uses a random access binary file as the storage medium for the Com-Geom description. If this binary file does not exist, CIDD will create it from a file containing Com-Geom data. The binary random access file created by CIDD will have a ".cd" (on VAX-UNIX) or "CD" (on CYBER) appended to its name.

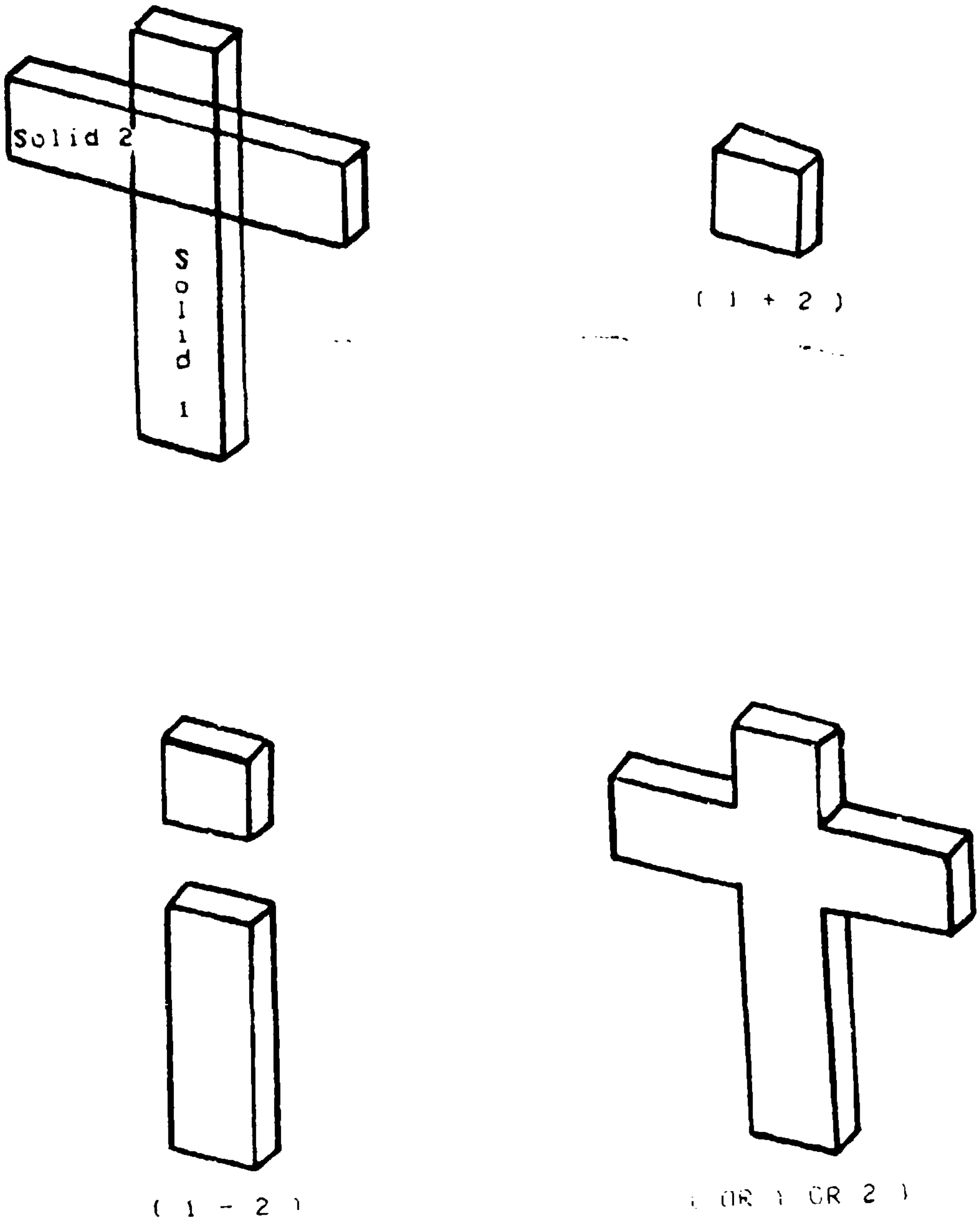

Figure 1. Region Boolean Operations

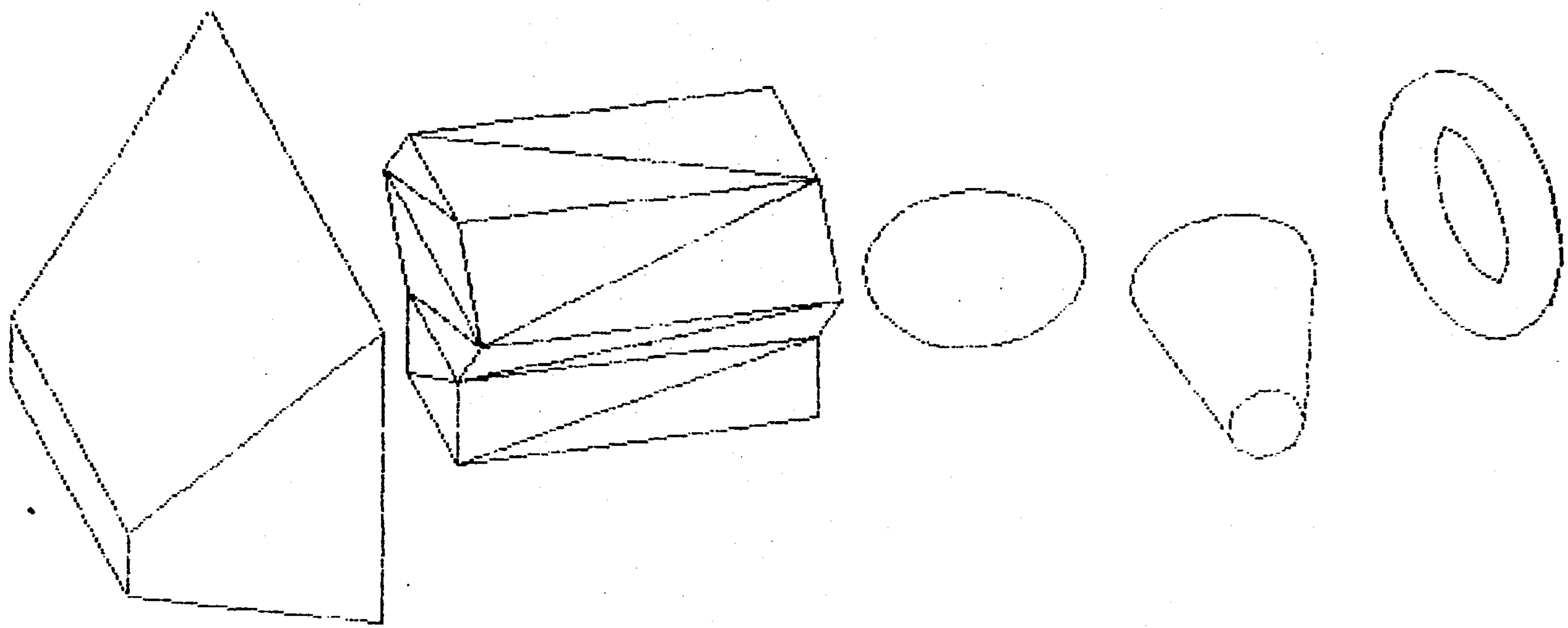

Figure 2. Solids Plotted by CIDD

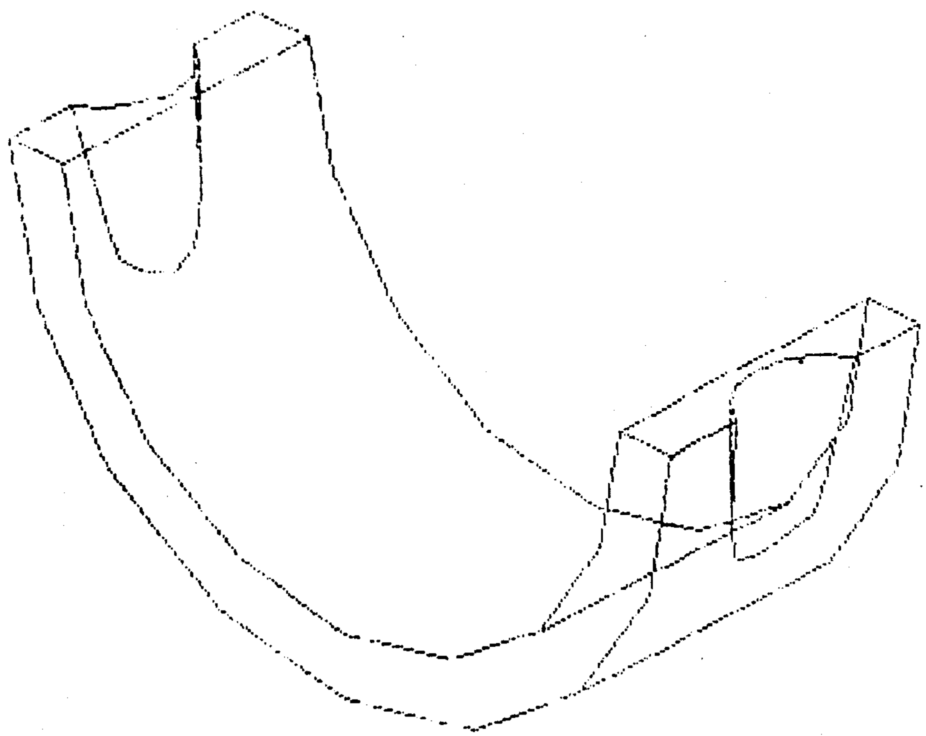

Figure 3. An Example of a Region Plotted by CIDD

As CIDD is creating the binary file, the following will be printed:

```
CIDD - TARGET INPUT SECTION
Title - title of the target
Number of solids    28
Number of regions   28
Binary file "filename" created (replaced on CYBER)
```

To plot a specified solid or region, CIDD randomly retrieves the data required from the binary file, processes and stores it in an array called AQ/MQ. As CIDD is plotting, it retrieves this processed data from the AQ/MQ array and computes the line segments to be plotted. The solids and regions located in the AQ/MQ array are called the display list. CIDD prints the horizontal and vertical range of the solids and regions in the display list to indicate the location and size of the plot to be done.

The following is an example of the three lines that will be printed if a binary file exists:

```
CIDD   - Plot Section
Title  - in   sample input for gift
Solids -   28  Regions-   28
```

CIDD's first prompt is "Term Type (1-HP2623,2-HP2648,3-HP9845,4-TEK4010+, 5-TEK4025,6-VT100)?". Enter the code number for the terminal type being used. For example, if your terminal emulates a VT100, enter a "6". The VAX-UNIX version of CIDD will not prompt for terminal type, if it can be obtained from the system and is known by CIDD.
The following menu will be printed next:

Options

C - Clear list	D - Delete from list	S - Solids
R - Regions	E - Edit target data	A - Area toggle
I - Input printed	T - Type display	O - Old data list
F - Find & print	L - Label toggle	? - Menu print
M - Mark plot	W - Where is pt?	Z - Zoom
V - View	P - Plot it!	Q - Quit!

2.1. CIDD Options

2.1.1. A - Area Toggle

This option turns on or off computation of presented areas of the plot located on the screen. If the area option is turned on, a second plot indicating how well the area was computed will appear.

2.1.2. C - Clear List

This option clears the display list by setting the end pointer of the display list to one. It does not affect the Com-Geom data located on the binary file.

2.1.3. D - Delete from List

This option deletes solids or regions from the display list. Whether it is a solid or a region (s or r) must be specified before entering a list of solids or regions. For example, to delete solids 10,13 and 20 through 34 from the display list, enter "ds10,13,20-34".

2.1.4. E - Edit Target Data

This option edits the data in the binary file. Because of the volume of sub-options, this topic is discussed further under a separate heading (Section 2.4).

2.1.5. F - Find & Print

This option prints data from the binary file without adding it to the display list. There are five options to find and print. It will print solid (s) data, region (r) data, item (i) data (item codes specified), air (a) data (air codes specified) or string (/) data. For string data, it will match the entered string with the alphanumeric data in the region identification table. For example, to find all "armor" components, a "f/armor" would be entered.

2.1.6. I - Input Printed

This option turns on or off the printing of solid and region data as they enter the display list.

2.1.7. L - Label toggle

This option turns on or off the labeling of solids and regions plotted on the screen. The labels will be located at the extreme left edge of the screen. The number of labels is limited to those that will fit on the screen for the terminal being used. If the zoom option is on, labels which point to areas outside the rectangle are ignored. Solids are labeled with positive numbers and regions are labeled with negative numbers.
Figure 4 depicts a plot with the solids and regions labeled.

2.1.8. M - Mark Plot

This option plots a cross on the screen for an entered point. If no plot is on the screen, CIDD will plot the solids and regions in the display list before plotting the point.

2.1.9. O - Old Data List

This option lists the solid and region data replaced by editing.

2.1.10. P - Plot it!

This option plots the solids and regions in the display list. If there is nothing in the display list to be plotted, CIDD will either print another prompt or "Window has no area". When the plot is finished, a bell will sound.

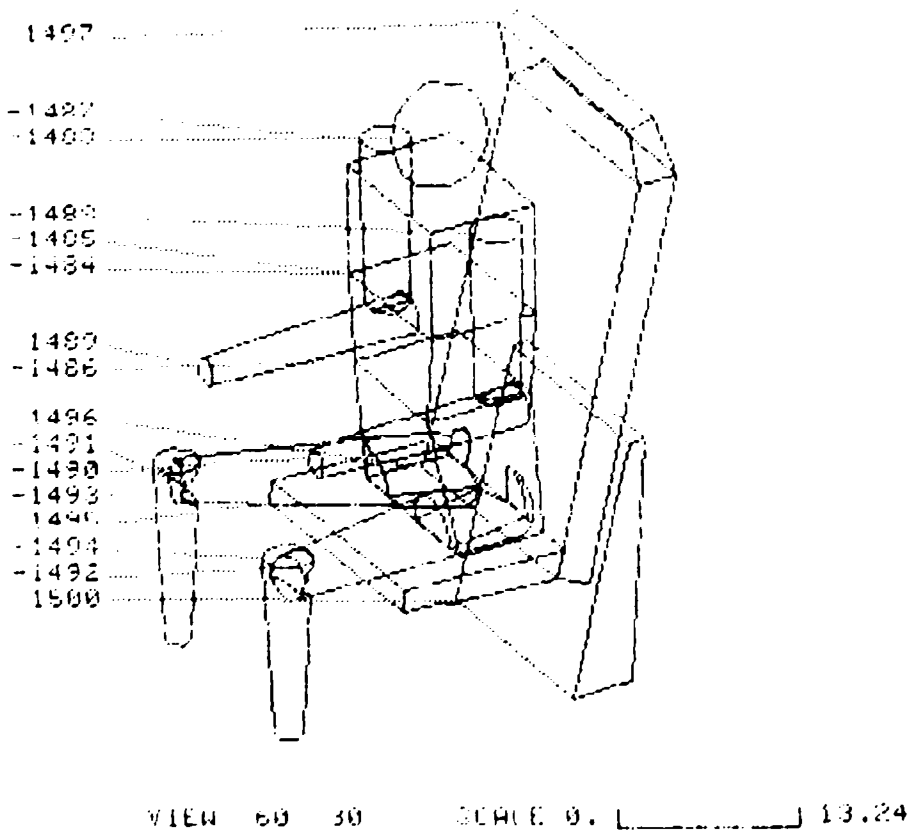

Figure 4. An Example of a Labeled Plot

2.1.11. Q - Quit!

This option is used to exit CIDD. If editing changes had been made, CIDD will ask if the generation of a Com-Geom description is desired. CIDD will also pack a binary file containing deleted solids or regions and renumber the kept solids and regions at this time.

2.1.12. R - Regions

This option is for adding a list of regions to the display list. For example, to add regions 5 through 7 and 10 to the display list, enter "r5-7,10".

2.1.13. S - Solids

This option is for adding a list of solids to the display list. For example, to add solids 10 and 15 through 20 to the display list, enter "s10,15-20".

2.1.14. T - Type Display

This option prints the data retrieved from the binary file to compute solid and region data in the display list.

2.1.15. V - View

This option is for specifying the aspect from which the plotted solids and regions are to be viewed. The view is initially set for azimuth 0, elevation 0 (front view). The view does not change unless it is respecified.

2.1.16. W - Where is pt?

This option prints the horizontal and vertical location of a point on the plot. If the last option specified is not the plot (p) option, CIDD will plot the solids and regions in the display list first. A cursor will appear on the screen. Move the cursor to the desired location on the plot and press any letter other than a carriage return. Only press the carriage return after entering the letter if there is no further response from CIDD. Most terminals will automatically send a carriage return after a key is pressed. Entering the letter "p" is preferred because CIDD will use the letter pressed as the last option specified. Therefore, if the location of another point on the same plot is desired and a "p" was pressed, CIDD will not replot the solids and regions in the display list again before the cursor reappears.

2.1.17. Z - Zoom

This is an option to zoom into a portion of the plot on the screen. If the last option specified is not a plot (p) option, CIDD will plot the solids and regions in the display list first. A cursor will appear on the screen. Move the cursor to one of two diagonal points on the rectangle which defines limits of the area to be zoomed and press any letter other than a carriage return. Only press a carriage return after entering the letter if there is no further response from CIDD. Most terminals will automatically send a carriage return after a key is pressed. Entering the letter "p" is preferred because

CIDD will use the letter pressed as the last option specified. Therefore, if the letter "p" was pressed, zooming may be repeated without replotting the solids and regions in the display list at the original scale. The cursor will appear for a second time for the opposite corner of the rectangle.

2.1.18. ? - Menu print

This option prints the menu printed when CIDD was first entered.

2.2. Lists

Separate numbers in a list by a space, a comma, or a minus. If a minus is used, it denotes a "through". The number before the minus is the lower end of the range of numbers, the number following the minus is the upper end. A zero or a carriage return will end the list. See sections 2.1.3, 2.1.12, 2.1.13, and 2.3 for examples of lists.

2.3. Prompting

CIDD is written for the inexperienced user as well as the experienced user. Data can be entered one at a time or as many as desired that will fit in 80 columns. If an entry does not satisfy an option, CIDD will prompt for more data.
The following is an example of two ways a sequence of commands for deleting solid 23 from the display list and adding regions 1 through 5 and 8 and then plotting at azimuth 30, elevation 45 can be input:

```
ds23,0 r1-5,8,0 v30,45 p
```

or:

```
ds23
r1-5,8
v30,45
p
```

If CIDD detects an error in the data entered from the keyboard, it will print out "Input bad, Try again" and prompt for the data again. CIDD will always end a prompt for data with "? ".

2.4. Editing

Editing of the Com-Geom data can be accomplished by entering an "e" (See section 2.1.4). Any change to a solid or region via editing will be reflect d in the display list as well as on the binary file. Any solid or region not previously in the display list will be added to it. Regions in the 'ispl-, list which contain edited solids will also be changed.

2.4.1. ? - Menu

This option prints the following edit menu:

```
Edit options
S - Solid edit    R - Region edit       C - Change s/r
A - Add to s/r    D - Delete from s/r   M - Move solids
T - Trans/rot     W - Write file        Z - Zap changes
```

2.4.2. A - Add to S/R

This option is for adding a solid or region to its respective table. All the data required to satisfy the description of a solid or region is required. CIDD will prompt for all the necessary data, if data are entered one at a time. Some expedient ways of entering data can be used.
For example, the following data could be entered to satisfy the input requirement for an ARB8:

```
arb8 10.7,15.8,-91 x1,y1,67 -13.4,y1,z2 -15.6,y1,z1 x1,-15.8,z1
x2,y5,z2 x3,y5,z3 x4,y5,z4
```

The entered data "x1" will be equal to 10.7, "y1" will be equal to 15.8, "z2" will be equal to 67, etc.

2.4.3. C - Change S/R

This option is for replacing an existing solid or region with a new one. Prompts for changed solids or regions are handled in the same way as ones which are added.

2.4.4. D - Delete from S/R

This option deletes solids or regions from the binary file. If a deleted solid or region is referenced after it has been deleted, CIDD will print a message to that effect. As CIDD is exited, a new binary file will be written with the solids and regions renumbered.

2.4.5. M - Move Solids

This option is for moving solids. If translational and rotational vectors have not been previously entered, CIDD will prompt for them before prompting for a list of solids to be moved.

2.4.6. R - Region Edit

This option is for making minor changes to a region.
The following is an example of region data printed for editing:

```
Region    13  man-torso              rec
(  1:      13)(  2:      -15)(  3:      -16)(  4:      -17)
Code (end=0, insert=i, next=n)?
```

The data for the region specified will be printed with an integer code before each descriptor. A descriptor may or may not include an "or" or a "rg" plus a solid or region number. To change a given descriptor of a region, enter the integer code in front of that descriptor and then its new value. To delete a descriptor, enter the integer code for the descriptor and then a zero. To insert a descriptor before another use "i". For example, to insert "or 14" before descriptor 3, do an "i3,or 14".
If an "n" is entered, CIDD will prompt for region identification table changes as exampled below:

```
(1:   31)(2:  0)(3:  0)(4:   0)(5:man-torso          rec  )
Code (end=0)?
```

To end changes to a region, enter a zero for the integer code.

2.4.7. S - Solid Edit

This option is for making minor changes to a solid. The solid type can not be changed by this option.
The following is an example of solid data (except for the ARB and the ARS) printed for editing:

```
 11 sph
 11   21.5000  2     .0000  3   37.0000  4    5.0000
Code (end=0)?
```

Each of the data values for the solid is preceded by a code number. To change the data value, first enter the code number and then its new value. For example, to change the data value above from 37.0000 to 43.0, enter "3,43".

For the ARB and ARS, the following type of print is given:

```
Set.     3arb  Num of pts   5
  1. (  1:   75.0000)(  2:  -36.0000)(  3:   12.0000)
  2. (  4:   75.0000)(  5:   36.0000)(  6:   12.0000)
  3. (  7:   75.0000)(  8:   36.0000)(  9:   48.0000)
  4. ( 10:   75.0000)( 11:  -36.0000)( 12:   48.0000)
  5. ( 13:  100.0000)( 14:     .0000)( 15:   12.0000)
Code (end=0,n=next,[del=d,ins=i,move=m] set)?
```

There are more choices for editing an ARB or an ARS. One data value at a time may be changed as explained above for editing a solid. The code number to use for changing one number at a time is the one with a colon following it. A set of numbers may be deleted, inserted or moved. In above case the set includes the x,y and z components of a point. The set (point) number is followed by a period. For example to move point 5 before point 3, enter "m5,3".

To end changes to the solid, enter a zero for the integer code.

2.4.8. T - Trans/Rot

This option is for entering new translational and rotational vectors which will later be used to move solids.

2.4.9. W - Write File

This option applies only to the CYBER version of CIDD. It allows for the periodic replacing of the cataloged binary file with the edited binary file.

2.4.10. Z - Zap Changes

This option is for recovering data which existed before it was edited. Recovery of data from a previous CIDD run is not possible if CIDD was exited normally.

III. PROCEDURE

CIDD is written in standard FORTRAN 77. However, it does contain a few calls specific to CYBER-NOS or VAX-UNIX. The plotting subroutines were written from scratch.

3.1. Display List Data

The AQ/MQ array contains the data needed to plot solids and regions in the display list. The size of the AQ/MQ array is currently set at 10,000 words. Solid and region data are read from the binary file, processed and an enclosing rectangular parallelepiped is computed (RPP). This processed data and RPP are then stored in the AQ/MQ array. If there is not enough room in the AQ/MQ array for this processed data and RPP, CIDD will print a message and will ignore that solid or region.

3.1.1. Storing a Solid

There are only five solid types actually stored and plotted by CIDD: ARB, ARS, ELL,TGC, and TOR. The BOX, HAF, RAW, and RPP solid types are converted to an ARB type solid and then stored. The RCC, REC, TEC and TRC are converted to the TGC solid type and then stored. The SPH is converted to the ELL solid and then stored.

The first word stored in the AQ/MQ array for a solid is the solid number. The second is the solid type which is the code number listed in Table 1. This code number is not changed when a solid is converted from one type to another. For example, an REC would still be five after it has been converted to a TGC (11). The third word stored for a solid is the amount of storage required to store the solid minus nine (six for the enclosing RPP and first three words). The fourth through the ninth words contains the enclosing RPP for the solid. The rest of the storage is for the converted solid data. Table 3 summarizes the stored solid data.

3.1.1.1. Storing an ARB

The ARB solid consists of a convex set of planes. The planes are

Table 3. Solid Data in AQ/MQ Array

Location	Description
1	Solid number
2	Solid type code number
3	Amount of storage for solid
4	Minimum x value
5	Minimum y value
6	Minimum z value
7	Maximum x value
8	Maximum y value
9	Maximum z value
10	Solid Data
	ARB - (A(i)x+B(i)y+C(i)z=D(i), i=1,number of faces)
	ARS - Nc, Nppc, Nprd, (PT(i),i=1,number of points)
	BOX - Converted to ARB
	ELL - Vertex, A vector, B vector, C vector
	HAF - Converted to ARB
	RAW - Converted to ARB
	RCC - Converted to TGC
	REC - Converted to TGC
	RPP - Converted to ARB
	SPH - Converted to ELL
	TGC - Vertex, A base, B base, A top, B base
	TEC - Converted to TGC
	TOR - Vertex, Normal vector, Radius 1, Radius 2
	TRC - Converted to TGC

described by the equation Ax+By+Cz=D. The equation is normalized ($A^2+B^2+C^2=1$) and the normal vector thus described is directed so that it points toward the interior of the ARB. Four words of data are stored in the AQ/MQ array for each plane.

3.1.1.2. Storing an ARS

The ARS solid consists of an arbitrary set of triangular faces. The ARS solid is stored in the fashion it is read. The first word of the solid data contains the number of curves. The second word contains the number of points per curve. The third word contains the number of points read directly. The rest of the ARS solid storage contains the points read.

3.1.1.3. Storing an ELL

The ELL solid is a general ellipsoid. Any cut orthogonal to the major or minor axis produces an ellipse. The general ellipsoid is defined by a vertex and three orthogonal vectors describing the three semi-major/minor axes. CIDD stores in the AQ/MQ array the vertex and the three vectors.

3.1.1.4. Storing a TGC

The TGC solid contains an elliptical base and top separated by a height vector. The planes defining the base and top must be parallel. The two vectors describing the top ellipse must point in the same directions as the two vectors describing the bottom ellipse. CIDD stores in the AQ/MQ array the vertex of the base, the height vector, the two vectors describing the bottom ellipse and the two vectors describing the top ellipse.

3.1.1.5. Storing a TOR

The TOR solid is a torus. The TOR solid is defined by a vertex, a vector normal to the center plane whose intersection with the solid would contain two concentric circles, the outer radius which is the distance from the center of the torus to center of the tube and the radius of the cross section. CIDD stores in the AQ/MQ array the vertex, the normal vector and the two radii.

3.1.2. Storing a Region

Each region containing the "or" operator is divided into sections. Each section is delineated by the "or" operator and is treated as a separate region. A region with no "or" operator has only one section. Regions ("rg" operator) referenced by regions are ignored. Each solid used to form a region has an enclosing rectangular parallelepiped (RPP) computed for it. The region's RPP is computed from the solid RPPs. If the solid is negative and its RPP does not intersect the region's RPP, it is ignored and a message is printed expressing that it is not needed to describe the region.

CIDD converts all the solids (except ARS and TOR) referenced by a region into an ARB-like solid. Before the solids describing a region are converted to ARB-like solids, they are converted to solid types as though they were going to be plotted as solids. For example, the TRC would be converted to a TGC and then to an ARB-like solid. This ARB-like solid differs from the ARB in that it may not be completely closed. However, the closed portion will be convex. The ARS and TOR solids are converted to a number of ARB-like solids. The converted TGC solid has one plane for the base, one for the top, and sixteen for the curved side for a total of eighteen. The ELL solid is defined by a set of seventy-two planes. The TOR solid is defined by a set of ninety-six planes. If the TOR solid is positive, it is converted to four outer cones with four interior cones subtracted from the four outer cones. Each cone has twelve planes defining it. If the TOR solid is negative, it is converted to twelve cylinders arranged in a circle. Each cylinder has a bottom and top plane and eight planes defining its sides. If the ARS solid is positive, it is divided into a convex portion with sets of concave planes subtracted from it. If the ARS solid is negative, it is divided into ARB-like sections.

The description of a section of a region then ends up being a set of ARB-like solids, combined by positive (intersection) and negative boolean operations. The location of each plane computed to describe an ARB-like solid is tested. If the plane is located outside of the region RPP, it is ignored. If the plane existed before in the region and the boolean operation is positive, it is ignored. Each plane has five words used to describe it. The first four words contain the coefficients of the equation Ax+By+Cz=D. The fifth word is a bit map of the location of the plane in the region RPP. When the FORTRAN 77

AND() function is used on the fifth word of two candidate intersecting planes, it is quickly determined whether they intersect or not.

Each section of the regions (separated by the "or" operator) has a separate set of storage data. Each set of storage data begins with a negative region number. The second word is the number of descriptors for this section of the region. The third word is the amount of storage minus nine (six for the enclosing RPP and the first three control words). The fourth through the ninth is the enclosing RPP for this section of the region.

The tenth word through nine times the number of descriptors plus nine words are information concerning the solids used to describe the region. The first word of this group is the solid number. The solid number is negative if it was subtracted from the region. The code number (see Table 1) for the solid type is the second word of this group. The third word is the amount of storage required for the planes describing this solid. The fourth through ninth words are the enclosing RPP for this solid. These nine words are repeated for each descriptor in this section of the region. The remainder of the data for this section of the region contains the five words for each plane used to formulate this region section. Table 4 displays the storage for each section of a region.

Table 4. Storage in AQ/MQ Region

Location	Description
1	Region number (negative)
2	Number of descriptors (ND)
3	Amount of storage for region
4	Minimum x value of region
5	Minimum y value of region
6	Minimum z value of region
7	Maximum x value of region
8	Maximum y value of region
9	Maximum z value of region
10	Descriptor 1 - Solid number (+ or -)
11	- Solid type
12	- Amount of storage for Descriptor
13	- Minimum x value of solid
14	- Minimum y value of solid
15	- Minimum z value of solid
16	- Maximum x value of solid
17	- Maximum y value of solid
18	- Maximum z value of solid
.	
.	
.	
9*ND+10	(A(i)x+B(i)y+C(i)z=D(i), Location mask(i) i=1,number of planes)

3.2. Plot Package

The plot package was written to conserve space and to provide an efficient means of interactively plotting lines and symbols. The plotting package contains an inner core which drives a TEKTRONIX terminal. Special character sequences are used to set up the non-TEKTRONIX terminals to act as a TEKTRONIX type terminal. The page size is also set up to reflect the terminal used. There is an algorithm for clipping the view when the zooming option is used. There is also a subroutine for plotting symbols.

3.3. Plotting Solids

3.3.1. Plotting an ARB

CIDD performs a rotational transformation on all the planes used to describe the ARB for the view selected. CIDD then takes two of the planes (at least one of the planes is visible) and computes the line segment formed by the intersection of these two planes which exist on the exterior surface of the ARB. If the label option is on, the label will point to the vertex of the ARB closest to the left edge of the screen. Figure 5 is an example of an ARB solid plotted by CIDD.

3.3.2. Plotting an ARS

First, CIDD performs rotational transformation on all of the points used to describe the ARS for the view specified. Then CIDD computes the equation of the plane described by three adjacent points and determines if the computed plane is visible. If the plane is visible, the triangle described by the three points is plotted. If the label option is specified, the label will point to the first point of the triangle that is closest to the left edge of the screen. Figure 6 is an example of an ARS solid plotted by CIDD.

3.3.3. Plotting an ELL

First, CIDD performs a rotational transformation on the vertex and the three vectors used to describe the ELL for the specified view. Then, CIDD computes the ellipse defining the perimeter of the ellipsoid. The solution for the perimeter ellipse was derived from the ELL subroutine of the GIFT code by solving the case where a ray (defined by a starting point and direction cosines) for a particular view is tangent to the surface of the general ellipsoid. Thirty-two line segments depicting the perimeter of the ellipsoid is computed and plotted. If the label option is specified, the label points to the center of the ellipsoid. Figure 7 is an example of an ELL plotted by CIDD.

3.3.4. Plotting a TGC

First, CIDD performs a rotational transformation on the vertex, the height vector, the vector describing the semi-major axis of base, the vector describing the semi-minor axes of base, the vector describing the semi-major axis of top ,and the vector describing the semi-minor axes of top for the specified view. Thirty-two points on each of the ellipses (the base and the top) are computed. The top or base is determined to be visible by the direction of the height vector. The ellipse of the visible end is then

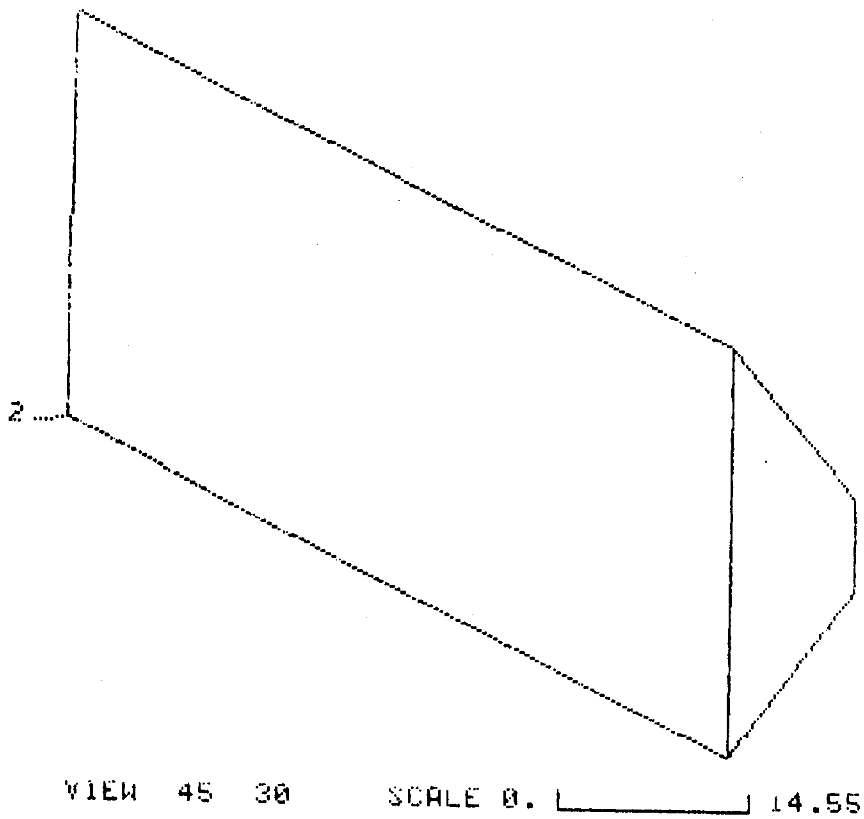

Figure 5. An Example of an ARB Solid Plotted by CIDD

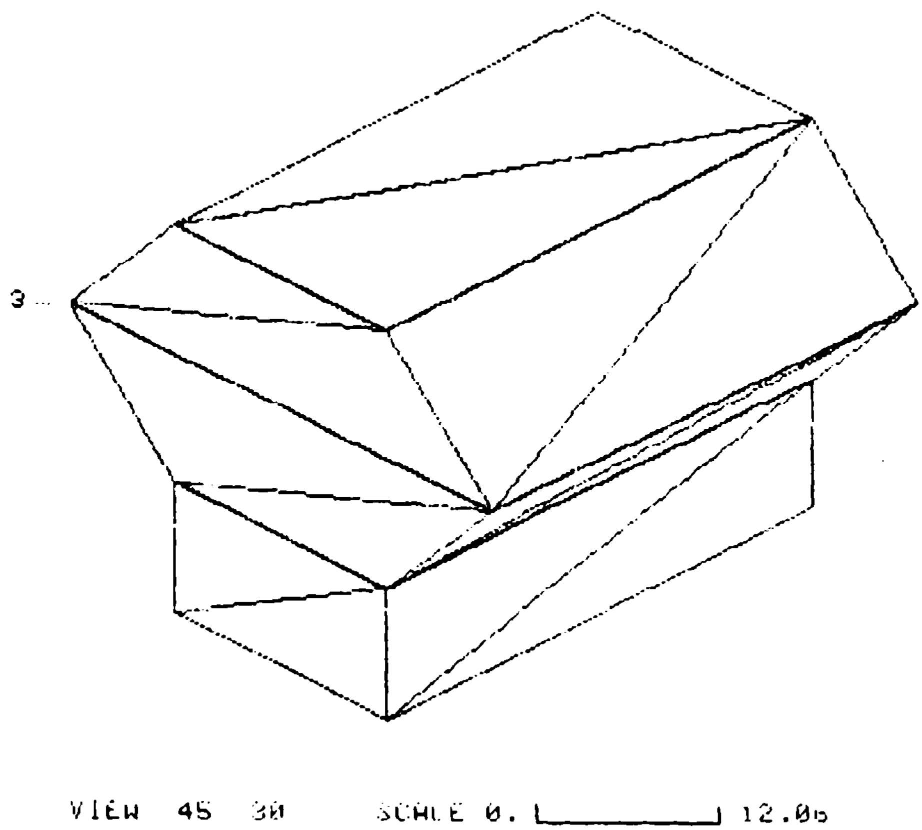

Figure 6. An Example of an ARS Solid Plotted by CIDD

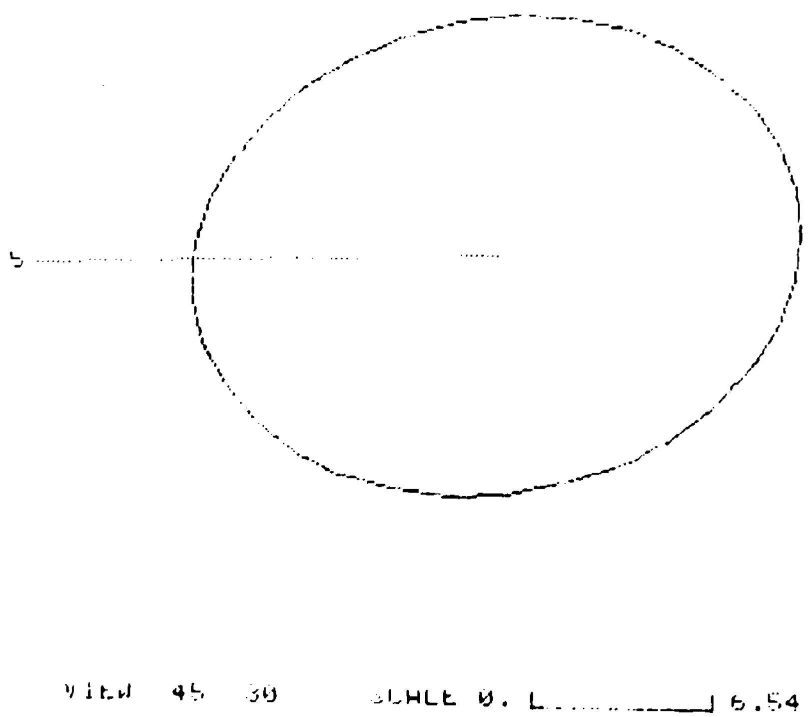

Figure 7. An Example of an ELL Solid Plotted by CIDD

plotted. For the end of the TGC which is partially visible, two of the adjacent points on the base plus one on the top are used to compute a plane. If the plane is visible, a line between two points (line segment) on the partially visible end is plotted. When adjacent line segments describing the partially visible end of the TGC goes from visible to invisible or from invisible to visible, a line from the base to the top or top to the base is plotted. If the label option is specified, the label points to the vertex of the base. Figure 8 is an example of a TGC solid plotted by CIDD.

3.3.5. Plotting a TOR

First, CIDD performs a rotational transformation on the vertex and normal vector used to describe the TOR for the specified view. Circles whose vertices are located at the center of the tube are computed for thirty-two points around the torus. Lines are drawn between the tangents of adjacent circles on the inside (if a hole exists) and outside facing arcs. If the label option is specified, the label points to a center point of the tube. Figure 9 depicts an example of a TOR plotted by CIDD.

3.4. Plotting a Region

To plot a region, CIDD first selects two planes at a time and determines whether the RPPs of the solids in which they are contained overlap (if the RPPs don't overlap, CIDD will skip all the planes used to describe the second solid in combination with the first plane), whether they are located in the same area of the region (using the fifth word describing the plane) and whether they are non-parallel. If the two planes pass all three of these tests, CIDD computes the direction cosines of a ray formed by their intersection. The starting point of the ray is computed from the intersection of the line with the plane describing the minimum of the region RPP whose normal is closest to the direction cosines of the ray. The intersections of the ray with the region are then computed to obtain any gaps in the line describing the edge formed. If either of the two planes belong to a negative solid, then that negative solid is temporarily made positive so that the ray is limited to that section of the region formed by that negative solid. The end points of the line are rotated for the view specified and are then plotted. If the label option is specified, the label will point to the closest point to the left edge of the screen. Figure 10 depicts the solids and their operations. Figure 11 depicts the resultant region plotted by the combination of the solids in figure 10.

3.5. Computing Areas

When the area option is specified, CIDD will store in the MQ/AQ array all the line segments describing as a minimum the perimeter of a region or a solid. Some extra line segments are stored to delineate holes. Along with the line segments a number used to differentiate surfaces will be stored. The line segments are ordered from left to right across the screen. The end points of the line segments and points of intersection of line segments are used to locate horizontal coordinates where the base or top of a trapezoid is computed. Each trapezoid determines the area increment for that section of the plot. To determine the length of the base or top of the trapezoid at a particular horizontal coordinate, a line is traced vertically and lengths of the segments of the line which lie on the surface of an object on the screen are

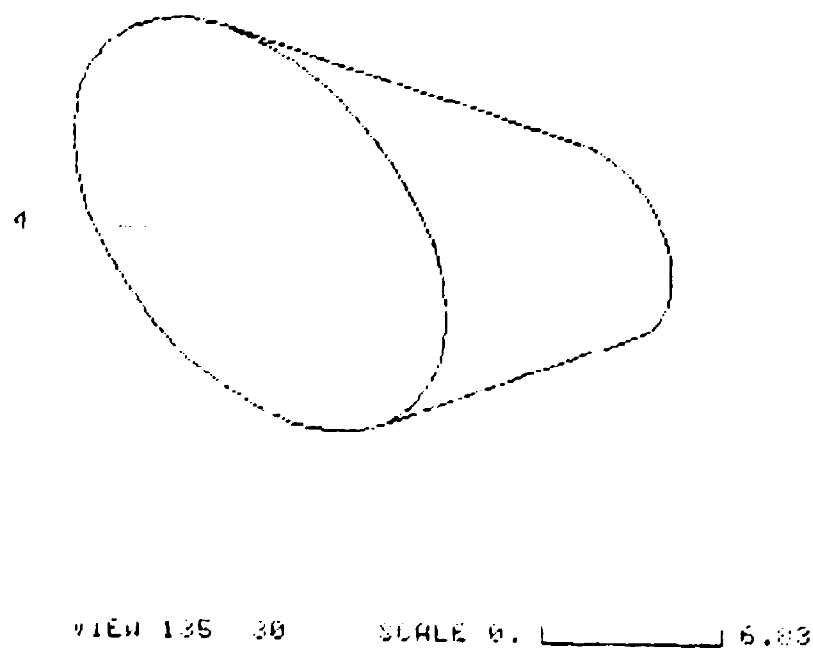

Figure 8. An Example of a TGC Solid Plotted by CIDD

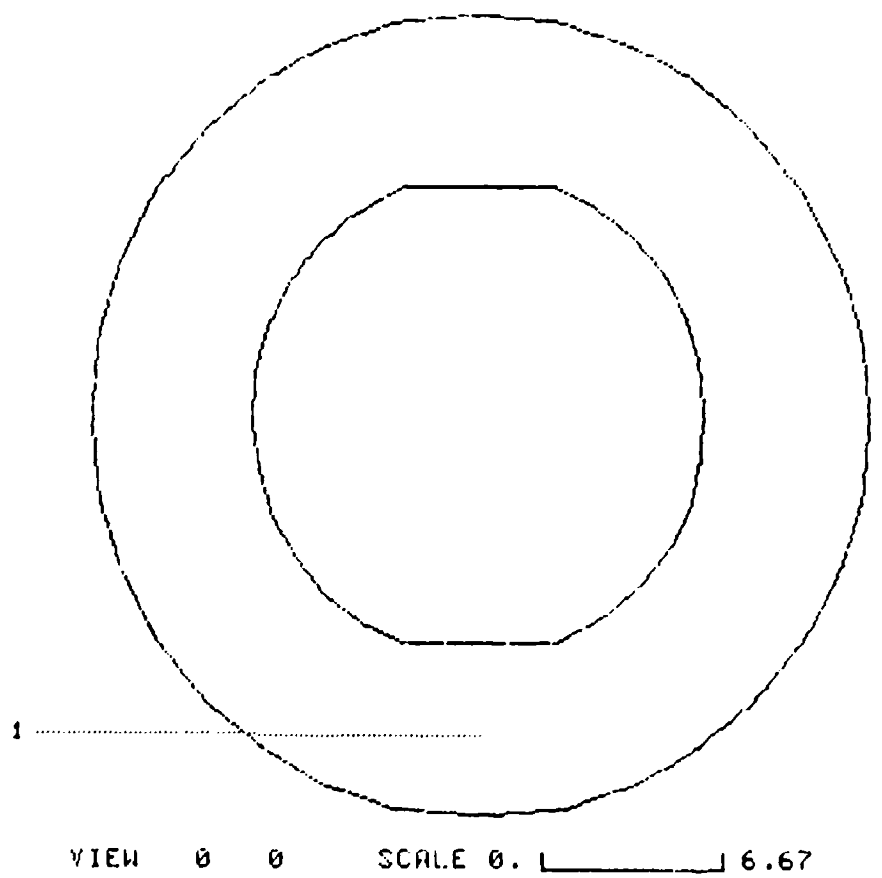

Figure 9. An Example of a TOR Solid Plotted by CIDD

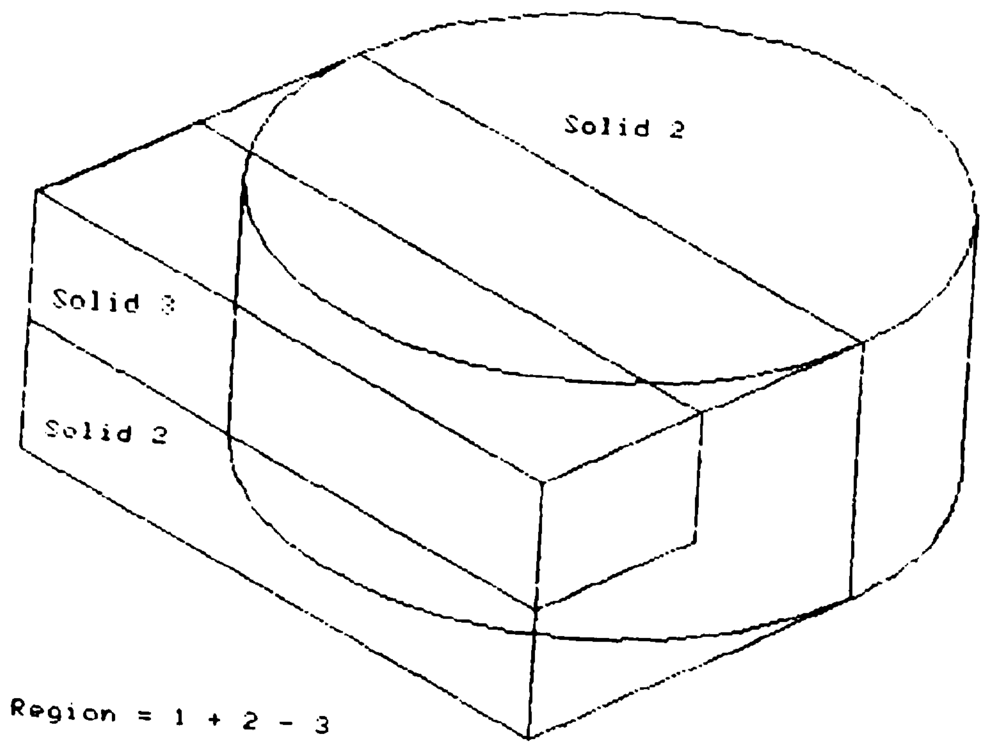

Figure 10. A Combination of Solids Used to Describe a Region

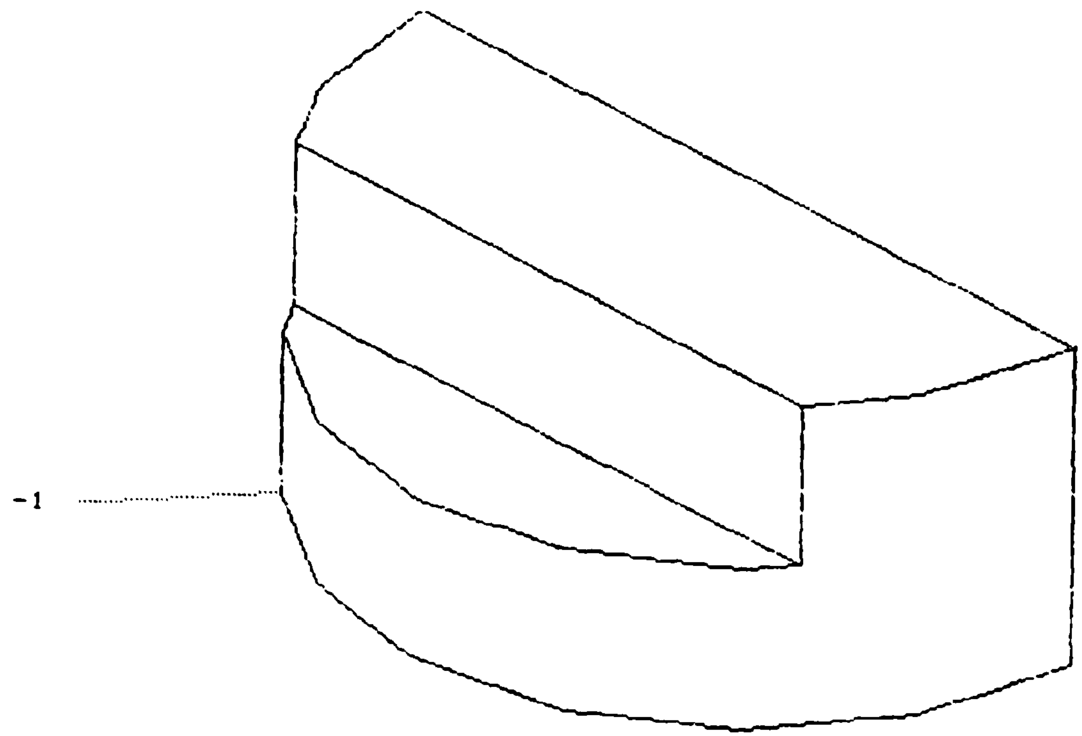

Figure 11. Region Plotted by CIDD from the Combination of Solid Depicted in Figure 10.

summed. Therefore, the base may have gaps in it where no surface is depicted on the screen. CIDD plots these vertical line segments to present an indication of how well the area was computed. Each area increment is summed to compute the presented area of the object on the screen. Figure 12 depicts an example of the CIDD plot with the area option turned on.

IV. CIDD BINARY FILE FORMAT

Solid and region data are retrieved from the binary file in a random fashion. The binary file has fixed length sixteen word records. The first record of the binary file contains the title of the Com-Geom description. The second record of the binary file contains the the maximum number of solids and regions, the location of the next free record for solids and for regions, the number of solids and regions deleted and the number of solids and/or regions on the old data file (data which existed that were changed by editing).

Each odd numbered record from the third record through a record whose number equals two times the number of solids plus one contains initial data for each solid. For example, the initial data for solid ten would be on record twenty-one (2*solid number+1). Additional data required to store solids will be located in odd numbered records following the initial data records. The first word of a solid's initial data record is a packed word containing the first record number of the additional solid data plus the amount of storage for the solid. The second word of a solid's initial data record is solid type code. The third through the sixteenth word of a solid's initial data record is solid data. Data for a solid that requires more than fourteen words is stored on the first odd record number available and is written on as many odd numbered records as are required to store the solid. Each additional data record contains one word for the solid number plus fifteen words of solid data.

Each even numbered record from the fourth record through a record whose number equals two times the number of regions plus two records contains the initial data for each region. For example, the initial data for region six would be on record fourteen (2*region number+2). Additional data required to store regions will be located on even numbered records following the initial data records. The first word of a region's initial data record is a packed word containing the first record number of the additional data plus the number of region descriptors. The second word of a region's initial data record is a packed word containing the item code plus space code. The third word of a region's initial data record is a packed word containing the material code plus the volumetric percentage factor. The fourth word through seventh (on CYBER-NOS, thirteenth on VAX-UNIX) word of the region's initial data record is the alphanumeric description of the region. The eighth (on CYBER-NOS, fourteenth on VAX-UNIX) through sixteenth word of the region's initial data record contain descriptors of the region. If there exist more descriptors for the region than can be stored in the initial data record, the first even record available will contain them. Each record of the additional data contains a word for the region number plus fifteen words for descriptors. The descriptors are packed numbers containing the operation code number (see Table 2) plus the solid or region number. Table 5 indicates the method used to store Com-Geom data on the binary file.

When a solid or region is deleted, the first word of all the records used

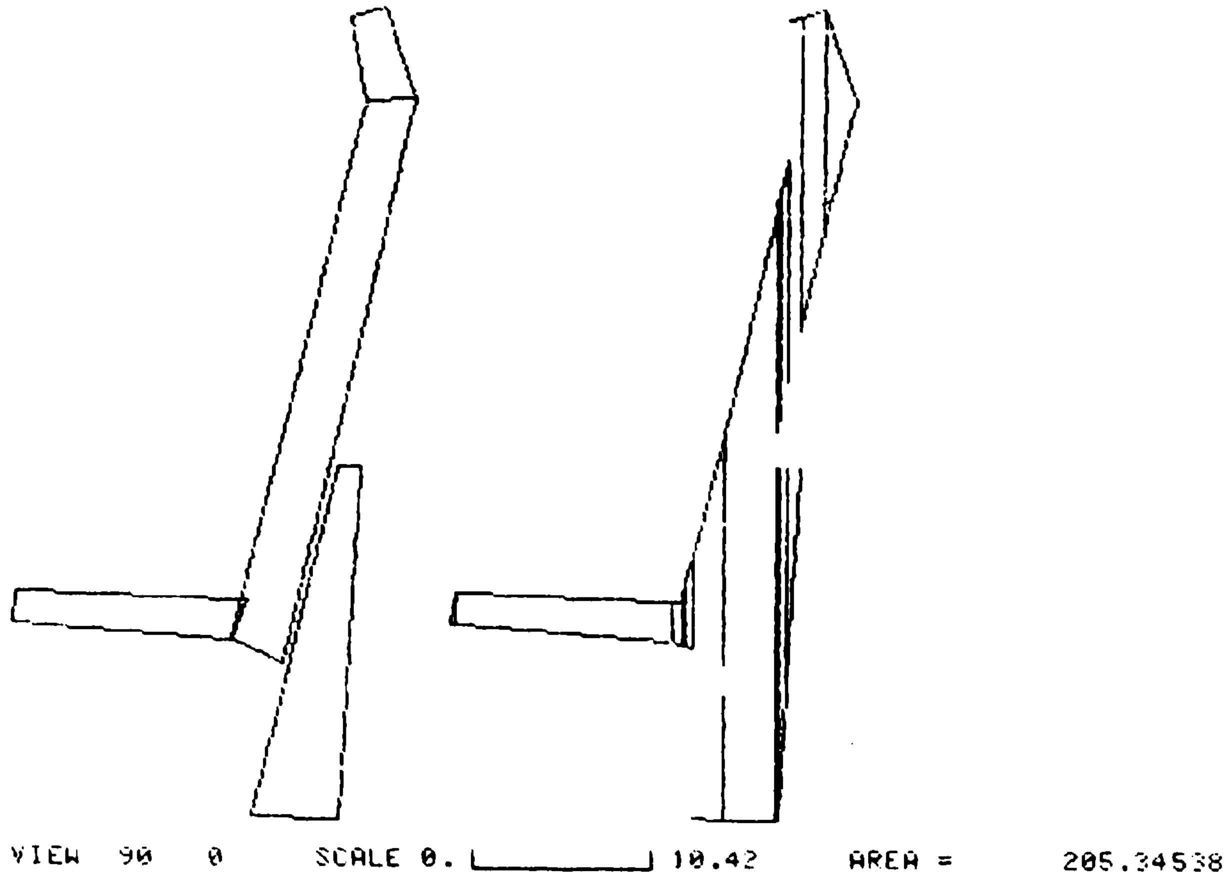

Figure 12. An Example of a CIDD Plot with the Area Option Specified

Table 5. Form of Storage on Binary File

Record	Description
1	Title of target
2	NSOL - Number of solids
	NREG - Number of regions
	LNS - Location of next available solid record
	LNR - Location of next available region record
	NDS - Number of deleted solids
	NDR - Number of deleted regions
	LD - Number of solids plus regions edited
3	Overflow record * 32768 + amount of storage
	Solid type code number
	Solid data (14 words)
4	Overflow record * 32768 + number of descriptors
	Item code * 32768 + air code
	Material code * 32768 + volumetric percentage
	Alphanumeric data (40 characters)
	Region data - Op code * 32768 + solid/region
.	
.	
.	
NSOL*2+1	Solid number
	Solid data (15 words)
.	
.	
.	
NREG*2+2	Region number
	Region data (15 words)

for that solid or region is set to zero. When a solid is added to the data, the number of solids is first increased by one. Then the first word of the record whose number equals two times the number of solids plus one is tested. If the first word is not zero, the data contained there and any additional records that contain data for that solid are moved to the end of the solid data. Then the first record of the added solid data is placed at the first record moved. The first word of any additional records from which the data was moved is set to zero. Any additional data for the added solid are written at the end of the solid data. If an edited solid needs more records than it had before it was changed and there are not sufficient zeroed records following the old additional data, the new additional data are moved to the end of the solid data and the first word of records containing the old overflow data are set to zero. The same method for added, deleted, and changed regions is used as for solids.

V. CONCLUSIONS

CIDD provides an invaluable tool for interrogating Com-Geom data. CIDD has proven to run efficiently and to be readily accessible to the user. CIDD will expand as the need arises for new options.

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