The CEDRA Corporation's

COMMAND OF THE MONTH

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Application Description

There are a myriad of applications that require the digital depiction of a surface. Many surfaces may be defined in terms of simple mathematical equations (the surface of a basketball for example), or of more complex equations, such as a Bezier which can be used to define the surface of a new sports car, or even the shape of a plastic container, which holds that new and improved soap detergent for the common household dishwasher.

However, for the purpose of this bulletin, let us come down to earth. Whether one is to design a highway or a subdivision for new homes, to explore for oil reserves, define the location of under and above ground pipelines, assess environmental impacts, or do anything that alters the surface or impacts the mother earth, one needs to be able to describe the earth's surface in a digital format.

Since no genius mind has to-date been able to derive an equation to describe any portion of the earth's terrain, we must rely on the old faithful, the methodology of contouring. For many years now, surveyors would locate key points on the earth (points where a change in the terrain would be visible) and obtain their elevation. This information would then go to the office where an expert would: (a) plot the points given their north (y) and east (x) coordinates, (b) annotate next to each point its elevation (z) coordinate, (c) connect the various points to create a multitude of triangles, (d) interpolate elevations along each triangle side to locate points of a whole

measure at a desired interval, (e) connect points of equal elevation (contours), and then (f) smooth or cusp the contours to make them look nice.

What made a person an expert in creating contours was the ability to create the appropriate triangles that correctly described the subject terrain. Many believed that the person to create the contours was the surveyor that was in the field and did the actual point pickup.

Over the years, and especially since the advent of the computer age, the means of collecting the field information has changed, but the concept of the methodology has not. We still collect points in terms of x, y and z coordinates (we

> ### Command Of The Month bulletin
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> *This month's issue discusses the methodology of developing a triangular irregular network (TIN) from a set of x, y and z surface points, and then using the TIN to create surface contours.*

now use a GPS gizmo rather than transit and stadia rods), we let the computer create triangles (only we now call them TINs, an acronym for triangular irregular network) and draw the contours (which we still call contours).

The objective of this month's issue of Command of the Month is to describe the methodology of creating contours for a set of random points no matter how they were picked up.

The CEDRA Solution

Shown in Figure 1 is the {Contouring commands} combo-box, which possesses a number of tools that assist the user in creating contours for a set of x,y,z points. This combo-box can be found in the **CEDRA-AVland-ContouringMenus** toolbar in the CEDRA-AVland software.
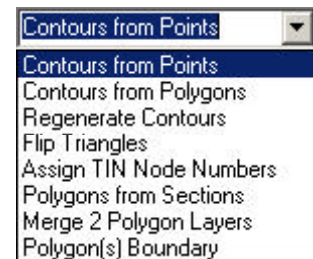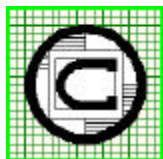

Figure 1
Contouring Commands Combo-Box

Regarding the various commands in this combo-box, note the following:

- The [Contours from Points] command creates the TIN and associated contours from a set of random x,y,z points, while the [Polygons from Sections] command only creates the TIN from a set cross section x,y,z points along a predefined center or base line, where x is a measure along the center or base line, y is the left (negative) or right (positive) offset of the point from the predefined alignment, and z is the elevation. This month we will address the former command. We will reserve the latter for another issue.

- Once the TIN has been created, the user may delete and/or create new triangles, or change the diagonal

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(common side) formed by two adjacent triangles with the [Flip Triangles] command.

• If a TIN has been modified such as triangles being added or deleted, point elevations altered, etc., then the [Contours from Polygons] command should be used to create a new set of contours.

• If a TIN has not been modified, and the user simply wishes to change one or more of the contour attributes (interval, smoothness, etc.), the [Regenerate Contours] command can be used to create a new set of contours.

The other commands of this combo-box either do not pertain to this bulletin, or are addressed below.

Note that a CEDRA TIN is actually a point layer and a polygon layer with the polygon layer containing references to specific points in the point layer. Furthermore, each polygon in the polygon layer is triangular in shape and that each vertex in the polygon must touch a point feature in the point layer.

Import Of The Set Of Terrain Points

The base information for developing contours, which describe the terrain of a project, is to have available x,y,z points. These points can be obtained by field pickup, photogrammetric means, digitized from a hard copy map, or any other means. The objective is to have available an ASCII file containing, at the least, each of the x, y and z values.
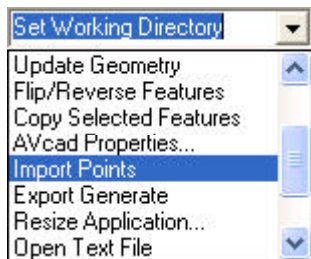

Figure 2
CEDRA Commands Combo-Box

To import an ASCII based point file into CEDRA-AVland the user can employ the [Import Points] command under the {CEDRA commands} combo-box (see Figure 2). This combo-box can be found in the **CEDRA-AVcad-Menus** toolbar. The operational steps to perform this task would consist of the following:

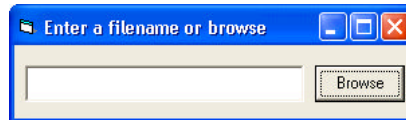• Select the [Import Points] command to display the browsing window of Figure 3.

Figure 3
Browse For The Set Of Terrain Points

• Click at the Browse button to display the conventional Windows file navigation dialog box, navigate to the directory of the file to be imported, select the file and click the OK button. The choice list box of Figure 4 is displayed containing the available point input formats.
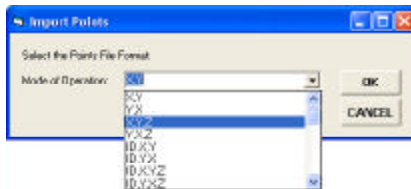

Figure 4
Format Of The Set Of Terrain Points

• Select the applicable format, and click the OK button to read the file, create the shapefile of the points that were read, and display a message box identifying the file that was read, and the number of points that were introduced (see Figure 5).
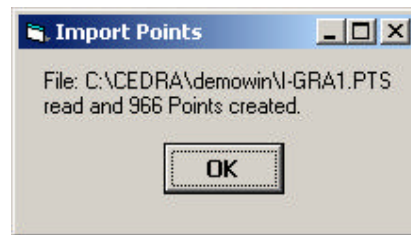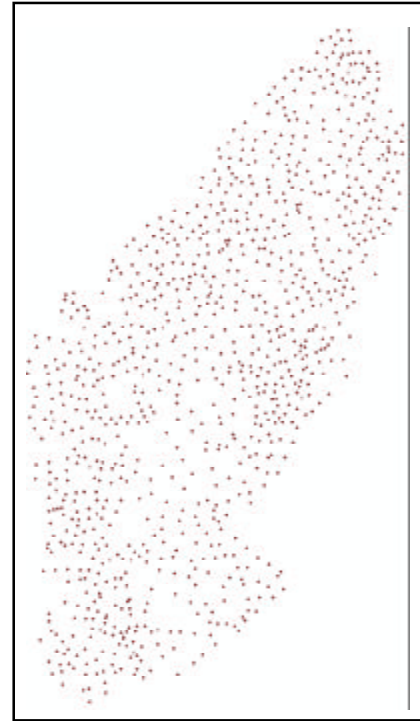

Figure 5
Import Points Results Message Box

Figure 6
Sample of Imported Terrain Points

• Note the number of points that were introduced and click at the OK button. The points are now displayed (see Figure 6), and the name of the shapefile is introduced in the table of contents (TOC). The name of the shapefile is the same as that of the input file with the letters "pn" appended thereto. The "pn" extension denotes a point layer.

• Verify that the number of points displayed in the above message box is the same as the number of points that are contained in the file that was read. If it is not, then there may be syntax error somewhere within the file. In this case, check the input file, correct any typographic errors, and repeat the above process.

• You may wish at this time to click at the black dot below the shapefile label in the TOC and modify the symbol and color of the points.

• Finally, stop the editor and save the edits.

Create The Contours

Having read the random points of the subject terrain, we are now ready to generate the contours. In generating contours from random points, the [Contour from Points] command will create polyline, polygon and annotation features. These features will be stored in a Personal GeoDatabase (PGD) using the name of the current active layer as the name of the PGD.

So that the first step in the contour generation process is the setting of the current active layer. As such:

- Select the [Set Active Layer] command under the {CEDRA commands} combo-box.

- Select the Entering New Layer Name option from the choice-list drop down that appears in the first data field.

- Enter the appropriate False X, False Y and False XY units values.

    The reader is referred to the May issue of Command of the Month for detail information describing these parameters. However, summarizing, the False X and False Y values pertain to the coordinates of the low left corner of a rectangle which encloses the points being imported. These values should be such that no data will fall below or to the left of this point.

    The False XY units value controls the number of digits to the right of the decimal point that are stored in the PGD for coordinate values. An adequate value for the False XY units parameter would be 10000, which indicates 4 digits to the right of the decimal point will be stored, while a value of 1000 indicates 3 digits. This parameter also controls the upper right corner coordinates of the PGD's extent. A value of 10000 for the False XY units parameter denotes that the upper right

corner coordinates of the PGD's extent can be computed by adding 214,748.3647 to each of the False X and Y coordinate values (for a 32 bit computer).

- Select the OK button.

- Enter an appropriate layer name such as TIN, followed by selecting the OK button.

The current active layer has now been defined. Note, this process needs to be performed only once prior to the generation of the contours. Once the current active layer has been set, it remains intact, unless changed by the user.

To begin the contour generation process, the user should:

- Activate the layer containing the points to be processed in the Table of Contents (TOC) and then select those points which are to be used in the contour generation.

- Before continuing, you may wish to open the table of these points and identify the data field (attribute) that contains the elevation.

- In the {Contouring commands} combo-box of Figure 1 click at the [Contour from Points] command to display the dialog box of Figure 7 containing two choice data fields with scroll down arrows.
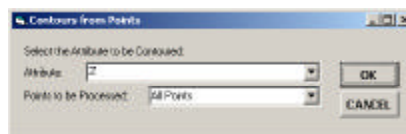

Figure 7
Points And Attribute To Be Contoured

- Scroll down in the first data field and select the attribute in the points layer that contains the elevation.

- Scroll down in the second data field and select the All Points or the Selected Points option, and then click

at the OK button. As can be seen, the user is able to process all points in the layer or just a selected set of points. So that, if a large set of points are to be processed, the user has the ability to perform the contouring in batches or sets.

Once the OK button is selected, the dialog box of Figure 8, which contains 8 input data fields and two scroll down choice data fields, will appear.
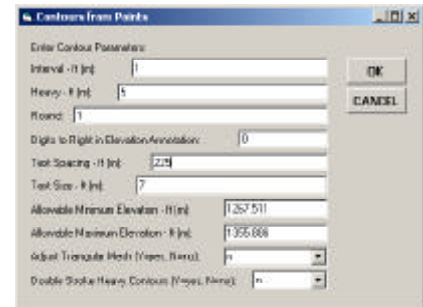

Figure 8
Contour Specifications Dialog Box

- Enter in the *Interval - ft (m)* data field the interval at which contours are to be created.

- Enter in the *Heavy - ft (m)* data field the interval of the contours to be drawn with heavier lines.

    A heavier line is denoted by having a PEN attribute value of 2 assigned to it, while an intermediate contour will be assigned a PEN attribute value of 1.

- Enter in the *Round* data field a value of 1 or higher. A value of 1 does not introducing any rounding to the contours. One might want to use this when contouring a strip of a roadway. The higher the number entered, the rounder or smoother the contours will look.

- Enter in the *Digits to Right in Elevation Annotation* data field the number of decimal digits to be displayed in the annotation of the contour elevations. In most cases

this number will be zero, and the contour annotation will be like 343, 529 and so forth. However, in very flat terrains, one may wish to draw contours at intervals of less than a foot (meter). In such cases, one may wish to annotate contours to the nearest tenth, hundredth, or whatever may be desired.

- Enter in the *Text Spacing - ft (m)* data field how far apart, in world units, a heavy contour is to be annotated with its elevation. Note that only the heavy contours are annotated.

- Enter in the *Text Size - ft (m)* data field the size, in world units, of the contour annotation (elevation).

- Accept, or modify as required, the default values displayed in the *Allowable Minimum Elevation - ft (m)* data field and in the *Allowable Maximum Elevation - ft (m)* data field. The program will exclude from the contouring process any point whose elevation is outside the above two limits.

- Scroll down in the *Adjust Triangular Mesh (Y=yes, N=no)* data field, and select the desired choice. A response of *Y* results in the program trying to avoid the creation of triangles with acute angles (that is, long slender triangles).

- Scroll down in the *Double Stroke Heavy Contours (Y=yes, N=no)* data field and select the desired choice. By selecting a positive response, the program will double stroke each heavy contour instead of using a heavier line. That is, two lines, which are slightly apart, will be created rather than one.

- Click at the OK button for the program to commence the development of the TIN and of the contours. You may notice the progress bar and the operations being performed at the bottom of the screen.

When the TIN and the contours have been created they are displayed in the map area, and three new layers are added to the current active data frame. These layers are the:
- LAYERtx containing the contour annotation features, the
- LAYERpl containing the contour lines, and the
- LAYERpg containing the triangles or polygons of the TIN,

where LAYER is the name of the current active layer. Shown in Figure 9 are the 5 foot contours created for the points of Figure 6, while Figure 10 displays a portion of Figure 9 at a larger scale.

Figure 9
Contours Of The Sample Terrain

You may wish to stop the editor at this time and save the edits, unless of course you are certain that some contour parameters should be changed.

As a suggestion, it is recommended that in the initial contour generation, the user specify a course contour interval, as well as, a course heavy contour interval. As an example, let us assume that 1' contours are to be created with

Figure 10
Blowup Of A Portion Of The Sample Contours

the heavy contours appearing at 5' intervals. Rather than using these values initially, it is suggested that 5' contours be created with a heavy contour interval of 10'. The reason being, is that, using course contour parameters results in faster contour generation. The triangles which are created will be the same regardless of whether the contour parameters are course or not. As such, why waste time in creating a lot of contours when, initially, the user is interested in seeing how the triangles are developed. Once the triangles are developed, they can be modified as appropriate, after which, refined contours can be generated.

Manipulating Contours

Having created the TIN and contours, it is time to zoom in and scroll in all directions to peruse the contours and identify any areas that might not be the way the user desires. As such, the user may want to: (a) redefine the TIN by having the program try to remove skinny triangles, (b) modify certain triangles by flipping common sides, (c) delete and/or add new triangles, or (d) change any of the parameters specified in the dialog box of Figure 8. In performing such contour editing, the user should be aware of the following rules:

1. If the TIN is not to be altered, the user should:

   (a) Select in the TOC, the layer containing the terrain points and the layer containing the TIN triangles (polygons) so as to activate both layers.

   (b) Select the [Regenerate Contours] command in the {Contouring commands} combo-box of Figure 1.

   (c) Make any changes to the parameters in the displayed dialog box of Figure 11, which is similar to that of Figure 8 but without the data fields that affect the TIN.
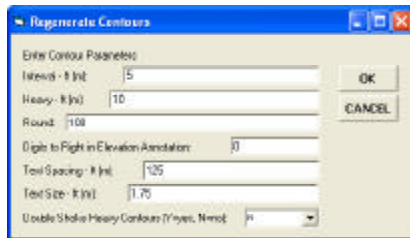

Figure 11
Dialog Box For Editing Contours

   (d) Click the OK button to carry out the changes.

If the current active layer does not contain any contour information (lines and/or annotation), the command will display the newly regenerated contours, after the changes have been applied.

If the current active layer does contain existing contour information (lines and/or annotation), the user will be asked if the existing contour information is to be deleted or appended to. Shown in Figure 12 is an example of how this query is posed.

In so doing, the user has the ability to replace the existing contour information with new contour information without having to manually delete the existing contour data.
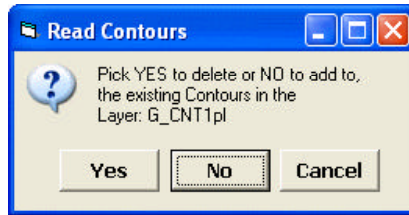

Figure 12
Add / Replace Existing Contours Query

   (e) Select the Yes button to delete the existing contour information (lines and annotation), the No button to add to the existing contour information, or the Cancel button to abort the regeneration of the contours.

Figure 13 displays a blowup of the low-right corner of Figure 10 with a 2 foot contour interval. Disregard the green lines for the time being.
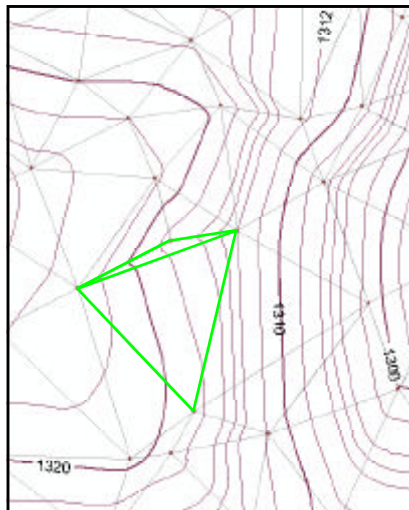

Figure 13
Blowup Area With 2 Foot Contours

2. If the TIN is to be altered by flipping the common side of two TIN triangles (refer to the two triangles in Figure 13 highlighted in green), the user should:

   (a) Select in the TOC the layer that contains the contour annotations.

   (b) Select the *Switch Selection* tool to select all contour annotations in the annotations layer,

and then click at the *Delete Selected Features* tool and confirm to carry out the deletion.

   (c) Select in the TOC the layer that contains the contour lines.

   (d) Select the *Switch Selection* tool to select all contour lines in the polyline layer, and then click at the *Delete Selected Features* tool and confirm to carry out the deletion.

Note that in Step 2(a) the user could have selected the layer that contains the contour annotations and the contour lines, together, by holding down the Ctrl keyboard key and selecting the layers, after which, Step 2(b) could be performed. In so doing, both the annotation and the lines could have been deleted in one operation.

   (e) Select in the TOC, the layer containing the terrain points and the layer containing the TIN triangles (polygons) so as to activate both layers.

   (f) Select the *Select Features from Active Layers* tool, and then select two triangles whose common side is to be flipped.

   (g) In the {Contouring commands} combo-box of Figure 1 click at the [Flip Triangles] command. The common side instead of being a line proceeding in a northeasterly direction (see Figure 13), is now almost a vertical line. This is because the command flips the common side to connect the two vertices of the triangles which are not connected.

The user can now select another pair of triangles, after which, the [Flip Triangles] command can be re-selected at

which point the common side between the two triangles will be flipped. Note that only two triangles can be selected, if more than two are selected, an appropriate error message will be displayed.

(h) In the {Contouring commands} combo-box of Figure 1 click at the [Contours from Polygons] command to display a dialog box containing two choice data fields with scroll down arrows similar to that of Figure 7.

(i) Make certain the All Polygons option is displayed in the second data field, and click at the OK button to highlight all triangles and display the dialog box of Figure 8, thus giving the user another chance to edit the contour parameters.

(j) Click at the OK button to begin the generation of the new contours and annotation thereof (see Figure 14).

Figure 14
Contours After Flipping Triangles

Since we deleted the existing contour information (lines and annotation), in Steps 2(a) through 2(d), the query message box of Figure 12 will not be displayed. So that, the user

has the option of deleting the contour information manually before performing the triangle flipping, or having the program perform the deletion at the time the contours are to be regenerated.

At this time it may be a good idea to stop the editor and save the edits before proceeding with any additional edits.

3. If the TIN is to be altered by deleting one or more TIN triangles, the user should repeat the preceding process with the exception that in Step 2(f) the user should select the polygon or polygons to be deleted.

Usually this editing method is used around the boundaries of the terrain where there are no terrain points.

4. In addition to modifying the TIN as indicated above, the user may:

- Introduce new points and assign elevations by using any of the available CEDRA-AVland point commands. Note that elevations may be entered when creating points by selecting in the {CEDRA commands} combo-box the [AVland Properties] command, and activating the *Enter Extended Data* check box. When this property is checked, any command which creates a point feature will prompt the user to specify an elevation for the point.

In addition, elevation values of existing point features can be modified by using the EF command which can be found in the **CEDRA-EditFeature-Tools** toolbar. In using this command, the user simply selects the point to be processed, after which, a dialog box containing the current values of the various attributes associated with the feature will ap-

pear. The user then enters the new desired information for the elevation attribute or any other attribute, for that matter of fact, and clicks the OK button.

- Delete a point, and then use the *Move endpoint or keynode of a feature* tool to modify the vertices of the triangles that had the deleted point as a vertex. Note that each vertex of a triangle (polygon) must touch a point feature.

- Delete a group of adjacent triangles, and then use the *Discrete lines, polylines or polygons* tool to create new triangles by connecting the various points.

- Reshape the current TIN by any of the methods that were described above.

Note

When adding new triangles (polygons) or reshaping existing triangles, the user must update the OIDs which are associated with the vertices of the triangles. This can be accomplished by using the [Assign TIN Node Numbers] command in the {Contouring commands} combo-box of Figure 1. In using this command, the user should:

(a) Select in the TOC, the layer containing the terrain points and the layer containing the TIN triangles (polygons) so as to activate both layers.

(b) Select the polygon(s) to be processed.

(c) Activate the [Assign TIN Node Numbers] command in the {Contouring commands} combo-box of Figure 1.

The command will then determine which point is closest to the individual vertices of the triangle and assign the OID of the point to the appropriate attribute for the polygon. As a point of information,

within the polygon layer there will be three attributes called NODE1, NODE2 and NODE3. These attributes contain the OID of the point that is assigned to the vertex of the polygon. To ensure proper OID assignment, it is recommended that the Editor be stopped prior to using this command.

Summary

As seen above, it takes but a few steps to create a contour map. Since rarely two persons will develop identical contours given the same set of points, the program provides adequate flexibility to modify the TIN and thus change the contours.

In addition, the ability to develop a TIN from a selected set of points is very useful and should be taken advantage of by the user. In so doing, triangles can be developed from a small manageable set of points rather than having to deal with a large number of point.

Once the contours have been created, the user may use other CEDRA-AVland commands to extract profiles and cross sections for roadways, channels, levees and the like.

In another issue of the Command of the Month we will return to the subject of contours to discuss additional features.

If you have a request for Command Of The Month, feel free to phone, fax or e-mail your request to The CEDRA Corporation.