Development of HVE 3-D Surface Data through AutoCAD Land Development Desktop

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ABSTRACT:

Engineering Dynamics Corporation's 3-Dimensional Human, Vehicle and Environment (HVE 3-D) analysis package is an ideal tool to evaluate the dynamic response of a vehicle to various environmental conditions. Many different types of 3-Dimensional (3-D) vehicle models are readily available in the HVE 3-D vehicle library. These vehicle models can be customized to match the characteristics of the particular vehicle being evaluated. However, the second important piece of the analysis, the environment, must be record and developed by the user. Many different approaches to the measurement and development of a 3-D surface environment are available. These measurement techniques range from the use of state of the art total station surveying equipment to manually recording measurements of the physical geometry using measuring wheels, measuring tapes and levels. Whatever measurement technique is utilized, the 3-D environment topography or terrain data must be developed and processed into 3-D surface data and thereafter transferred into the HVE 3-D analysis package where it will interact with the HVE 3-D vehicle model. This paper describes an approach for the development and processing of the 3-D environment's topography or terrain data from various sources using a simple spreadsheet. A comma delimited point file is developed for the 3-D surface and the files are imported into AutoCAD® Land Development Desktop (LDD), which is used to develop the various 3-D surfaces associated with the vehicle-environment analysis. Once the terrain model is developed in LDD, it can be exported as a 3-D Studio file into HVE 3-D. A graphical presentation of the analysis can be created using HVE 3-D or the data can be transferred into a high order rendering program to develop the graphical presentation.

INTRODUCTION:

To use the HVE 3-D analysis package to evaluate the dynamic response of a vehicle to a 3-D environmental terrain, the vehicle data and the terrain data must both correctly exist in the HVE 3-D program. The vehicle data is readily available and can be customized to match the particular vehicle being evaluated. While HVE 3-D has many generic 3-D terrain models, their surface data does not match the specific 3-D terrain, real world or proposed site design, which is needed to complete the evaluation. The specific 3-D data must be measured and recorded from the actual world or developed from a set of specifications. Using state of the art total station surveying equipment, coordinates of specific points in the real world environment can be measured very accurately. The surfaces defined by these points define the cross-slope and horizontal curvature of the road surface, the incline of the hill, the change in elevation at the edge of the road, the shape of the ditch and even an isolated rise in the terrain can be accurately recorded for use in a simulation.

However, data from a Total Station is not always available. At times, the only information available may be design drawings, lists of survey data, or hand measurements. These various forms of surface data require an accurate terrain surface development method that will accommodate the forms in which data is typically made available. An additional challenge to having point data available in various forms is that all of these forms of surface point data are typically not in the coordinate axis convention that has been used in HVE 3-D. The typical surveying/measurement coordinate axis must be converted into the HVE 3-D coordinate axis system. One more challenge that complicates the development of surface terrain models for HVE 3-D, which exist between the AutoCAD software and the HVE 3-D software is that the normals (the vectors that are perpendicular to each polygon face on the model) which define the side of the surface that supports the vehicles in HVE 3-D are not always predictable and seem to be dependent on the manner in which the data is collected or organized.

Any of the sources of data mentioned above, that can generate a set of specific points to define the surfaces, can be used to develop 3-D terrain data in AutoCAD® Land Development Desktop. The LDD surface model can then be transferred into HVE 3-D for use in a simulation. This paper addresses one method that accommodates most forms in which real world surface data can become available, and which provides predictable results in a relatively short time.

DISCUSSION:

Point definition:

The first step in this process is to define the points that make up the surfaces in a usable format. Several formats can be used. To simplify this process, we have chosen one. The information that we use for each point is a point number, a northing value, an easting value, an elevation value and a description or code. This format is typically known as PNEZD: point, northing, easting, elevation and description. All five pieces of this information must be placed in the order listed.

The terminology is in typical surveying terms. The point number is a unique number that identifies a particular point. The northing value is the distance from the reference point or origin to the point in a north direction. Negative northing values would be south of the reference point or origin. The easting value is the distance from the reference point or origin to the point in an east direction. Negative easting values would be west of the reference point or origin. The elevation value is the distance from the reference point or origin to the top of the surface (up is typically positive and down is typically negative). The description or code represents a specific series of points, such as the points along the edge of the pavement, the center of the pavement, or the bottom of the ditch. The point description is an important part of the point information. AutoCAD Land Development Desktop will use the point description to organize the points in LDD and to define the surfaces.

We have chosen to use Microsoft® Excel (Excel) to organize our data and convert the coordinate axis system used to collect the data to HVE 3-D's coordinate axis system. The point information can be cut and pasted into Excel or can be typed into Excel depending on the information source available. The point numbers are placed in column A, the northing information is placed in column B, the easting information is placed in column C, the elevation data is placed in column D and the description or code information is placed in column E.

A	B	C	D	E
Point Number	**Northing (Y)**	**Easting (X)**	**Elevation (Z)**	**Description**
1	**30**	**200**	**10**	**EP1**
2	**50**	**400**	**30**	**EP1**
3	**90**	**195**	**10**	**EP2**
4	**100**	**395**	**30**	**EP2**
5	**10**	**200**	**5**	**BDI1**
6	**30**	**400**	**25**	**BDI1**
7	**110**	**190**	**5**	**BDI1**
8	**120**	**390**	**25**	**BDI1**

Table 1: A simple example of surface point data set-up in an Excel spreadsheet. The points data can be pasted into Excel from a total station data file, it can be entered manually from a design drawing, survey list or from hand measurements or it can be brought in from a computer aided drafting file.

Once the point data is entered into Excel in the proper columns, (see Table 1 above) the data can be manipulated in Excel so that it matches the HVE 3-D Coordinate system. It is a good idea at this time to save your data in a master file.

Converting to the HVE 3-D Axis System:

Most surveying systems place the elevations as positive up, but HVE 3-D has adopted the coordinate axis system in SAE Recommended Practice J-670e, Vehicle Dynamics Terminology, which places positive Z in the direction of gravity or down. In other words the conventional X Y Z axis system has been rotated 180 degrees around the X-axis placing positive Z down and positive Y on the opposite side of the X-axis. To get the point data to match the HVE 3-D axis system the signs on the northing values and the elevation values must be reversed. It is also helpful to have the surface data in the first octant of the coordinate axis system and relatively close to the origin. To accomplish this axis change in Excel, simply assume that the positive Y-axis represents north. Multiply each northing entry in column B and each elevation entry in column D by –1 to invert the data. At the same time the point data can be moved back into the first octant by adding the largest positive number from each column. For the simple point file example shown in Table 1, the equation for the B column would be (B*-1)+120 and the equation for the D column would be (D*-1)+30. After these simple conversions have been completed, the surface has been inverted and fits the HVE 3-D coordinate system. (See Table 2)

A	B	C	D	E
Point Number	**Northing (Y)**	**Easting (X)**	**Elevation (Z)**	**Description**
1	**90**	**200**	**20**	**EP1**
2	**70**	**400**	**0**	**EP1**
3	**30**	**195**	**20**	**EP2**
4	**20**	**395**	**0**	**EP2**
5	**110**	**200**	**25**	**BDI1**
6	**90**	**400**	**5**	**BDI1**
7	**10**	**190**	**25**	**BDI1**
8	**0**	**390**	**5**	**BDI1**

Table 2: The northing and elevation data in columns B and D have been inverted by multiplying each value by negative 1 and adding the largest positive number in each value.

While inverting the data in Excel, it is also good practice to move the surface close to the origin in order to facilitate placement of the HVE 3-D vehicles onto the surface. If the first easting, column C, point is a large distance from the origin, it may be difficult to drag the vehicle in HVE 3-D to the surface. It is advantageous to shift the surface toward the origin, keeping the surface in the first octant. In the example, this can be accomplished by subtracting 190 from each of our easting values in column C. (See Table 3)

A	B	C	D	E
Point Number	**Northing (Y)**	**Easting (X)**	**Elevation (Z)**	**Description**
1	**90**	**10**	**20**	**EP1**
2	**70**	**210**	**0**	**EP1**
3	**30**	**5**	**20**	**EP2**
4	**20**	**205**	**0**	**EP2**
5	**110**	**10**	**25**	**BDI1**
6	**90**	**210**	**5**	**BDI1**
7	**10**	**0**	**25**	**BDI1**
8	**0**	**200**	**5**	**BDI1**

Table 3: The easting data in Column C has been shifted closer to the origin by subtracting the smallest positive from each value.

If any of the easting data is negative it is a good practice to shift the data into the first octant by adding the largest negative number to each easting value.

The last organizational item to be considered, before saving the Excel file and transferring the point data into LDD, is the point descriptions. The descriptions will be used with a description key file in LDD to separate the point groups in order to create various surfaces. Each set of points that define an edge of a surface should have a common description. In the example, the EP1 represents one pavement edge, the EP2 represent the opposite pavement edge. A surface can be easily created between these points that will represent the pavement. However, the shoulder areas have the same description for both sides of the road, BDI1, which represents the bottom of the ditch. It will not be easy to set up two separate shoulder surfaces on each side of the road with all the points sharing a common description. The description for points 7 and 8 should be changed to BDI2, to facilitate the creation of these two shoulder surfaces. (See Table 4)

A	B	C	D	E
Point Number	**Northing (Y)**	**Easting (X)**	**Elevation (Z)**	**Description**
1	**30**	**100**	**21**	**EP1**
2	**10**	**300**	**1**	**EP1**
3	**0**	**200**	**0**	**EP2**
4	**20**	**0**	**20**	**EP2**
5	**30**	**200**	**21**	**BDI1**
6	**20**	**300**	**1**	**BDI1**
7	**0**	**100**	**0**	**BDI2**
8	**10**	**0**	**20**	**BDI2**

Table 4: The description for points 7 and 8 have been changed to isolate those points when the points are imported into LDD.

Once the data has been organized and reconfigured in Excel to fit the HVE 3-D coordinate system, and a description system which defines the points that will represent the surfaces, any heading such as the Point Number, Northing (Y), Easting (X), Elevation (Z) and Description should be deleted and the data should be saved as a comma delimited file (.csv) in Excel and Excel should be closed.

Creating Surfaces in LDD

An easy way to facilitate the creation of multi-surface terrain models in LDD is to create a description key file to organize the comma delimited file created in Excel. The description key file places the points on layers dependent on the point's description. The various point layers can then be activated one at a time or in groups to define each surface. A specific group of points will be used to define each surface.

In the example shown in the tables above, the EP1 and EP2 points define a pavement surface. To create this surface, only the EP1 and EP2 points can be active. If the BDI1 and BDI2 points are active, and are not isolated from the group, they will be included in the surface. In this simple example it would not be difficult to isolate the BDI1 and BDI2 points from the EP1 and EP2 points, but on more complex terrain models, involving hundreds of points, curves and localized changes in elevation, it becomes increasingly difficult. In addition to the pavement surface in the example, the EP1 and BDI1 points define a shoulder surface and the EP2 and BDI2 points define the opposite shoulder surface.

An example of how the site measurement task can be organized using point descriptions is shown in Figure 1. Figure 2 shows the surfaces that could be developed from accurately measured field data in LDD. Figure 1 shows a minimal number of points for illustrative purposes. Using only a few points produces a crude surface model. More points produce a finer surface detail and a more accurate surface model. The number of points required to accurately evaluate the dynamic response of a vehicle to the environmental depends on the situation.

In order to set-up HVE 3-D with different friction multipliers on each shoulder surface, the shoulder surfaces must be separate from each other and from the pavement surface. A description key file, with these descriptions defined in the file, will automatically separate the points with identical description onto separate layers when the comma delimited file is imported into LDD. If care is taken to use the same point descriptions each time a site is surveyed or an Excel point file is created, a single standard description key file can be created and used with each point surface data file that is imported into LDD for the creation of a terrain surface model. Example of standard point descriptions are: EP# for pavement edges, TDI# for top of a ditch, BDI# for the bottom of a ditch, and CL# for a pavement centerline. (See Figure 1)

Once a description key file is defined for the terrain surface model, the comma delimited file from Excel is imported into LDD using the Import Points command and selecting the appropriate comma delimited file. After the points are imported, the appropriate layers associated with each surface are activated and point groups for each surface are created using the Point Group manager. In the example the EP1 points would be imported to an EP1 points layer, the EP2 points would be imported to an EP2 points layer, the BDI1 points would be imported to the BDI1 points layer and the BDI2 points would be imported to a BDI2 points layer. To create the points group associated with the pavement between EP1 and EP2, the EP1 and EP2 points layers would be activated and the points group created by selecting those points. The point groups are then used to build the surface.

The Terrain Model Explorer is used to create each surface from the point groups. Three-dimensional lines that connect each point to its nearest neighbor define the surface. This method creates a triangular surface mesh. For the pavement surface, two triangles would be created from the four points.

In situations such as curves and/or intersections where points will connect across the curve or between the two road surfaces, boundaries can be used to define the active area of the surface. Using boundaries will prevent the creation of surface elements in areas where other surfaces will be defined and prevent confusion created with surface overlap. Boundaries are defined by connecting the points on the edge of the surface with a 3-D polyline. The Terrain menu is used to create the 3-D lines. The final step in creating the terrain surfaces in LDD is to display the surface with a poly face mesh. The Terrain menu is used to complete this task. When the mesh is completed each surface should be saved on its own layer. This is easily accomplished by defining the layer while the poly face mesh is being created. Defining the layers can be accomplished automatically by placing an asterisk in the Layer Prefix Box before the poly face mesh is created.

This procedure is repeated for each surface. In our example the EP1 and BDI1 point's layers would be activated to create the shoulder surface between the EP1 points and the BDI1 points and the EP2 and BDI2 points layers would be activated to create the shoulder surface between the EP2 points and the BDI2 points. If there had been other points such as pavement center line points, bottom of ditch points or etc., that needed to be included in the surface, those points layers would need to be activated when the surface was created and the LDD software would include those additional points in the surface.

Exporting and Using the Surface Model:

Before the model is exported to HVE 3-D, all of the surface layers should be activated and all other layers should be turned "off". If the point data was expressed in units of feet the model must be scaled by 12, since HVE 3-D works in inches. Once the surfaces have been scaled appropriately, the surfaces should be exported as a 3-D Studio File (.3DS).

To insure that the normal vectors, which allow the surface to support the vehicle model in the HVE 3-D system, are pointing in the correct direction, rotate the surfaces about the X-axis 180 degrees with the Rotate3-D command. Make sure to change the name on the rotated file so that it is not saved in place of the original file. One of these files should work in the HVE 3-D system.

Transfer both the unrotated and the rotated 3-D Studio files to the HVE 3-D SGI computer and into the environments folder for HVE 3-D. Load the file that was not rotated into HVE 3-D first. This file will be oriented correctly with the HVE 3-D coordinate system. Load the surface and a vehicle file in the Environment Editor. Then, use the Event Editor to set-up an event; any event will work as long as it has at least one vehicle, e.g. EDSMAC4 and a passenger car. Position the vehicle over the environment by dragging it to the surface or enter specific coordinates and drag the vehicle along the environment's 3-D surface, testing various locations for proper normals. If the vehicle's wheels rest on the surfaces, then the surface normals are correctly oriented and the surface model is ready to be used. If the vehicle remains above the surface on the zero plane or penetrates the surface, then the surface normals are not correctly oriented and the surface model is not usable. Monitoring the z coordinate position can allow you to check the vertical position of the vehicle. If the z coordinate value remains constant the vehicle is resting on the zero plane and is not resting on the surface, assuming that your surface is not flat and positioned at the zero plane. The z coordinate value should vary with the surface terrain model.

If the vehicle remains above the surface on the zero plane or penetrates the surface, you will need to open the rotated 3-D Studio file and use the HVE Environment 3-D Editor to rotate each surface 180 degrees about the X axis for the correct orientation. In the Environment 3-D Editor select a surface by clicking on the surface with cross hairs. Change the "Roll" angle to 180 and press return. Repeat this process for each surface in the 3-D Studio environment file. Once all of the surfaces have been rotated, go back to the Event Editor. If the unrotated 3-D Studio surface file did not support the vehicle, this file should work with the HVE 3-D system. After you have evaluated the surface in this manner discard the surface file that did not support the vehicle.

The direction of the normals can also be evaluated in the in the Environment 3-D editor. To display the normal vector for a selected point, simply load the surface in the Environment Editor, click the 3-D Editor button, click on the desired surface, choose "Face" in the Surface Editor's Pick Mode radio button, then click anywhere on the surface, the surface normal vector will be displayed for the point you selected.

Final Comment:

This paper addresses one method of creating surface terrain models for HVE 3-D. Many other ways exist using various tools. This method may seem tedious and time consuming at first glance, but it has been the most repeatable method that works with multiple surface data sources that I have found. I will continue to explore other methods to streamline the process and create accurate surface data. Please, feel free to provide me with your thoughts and ideas.

REFERENCES:

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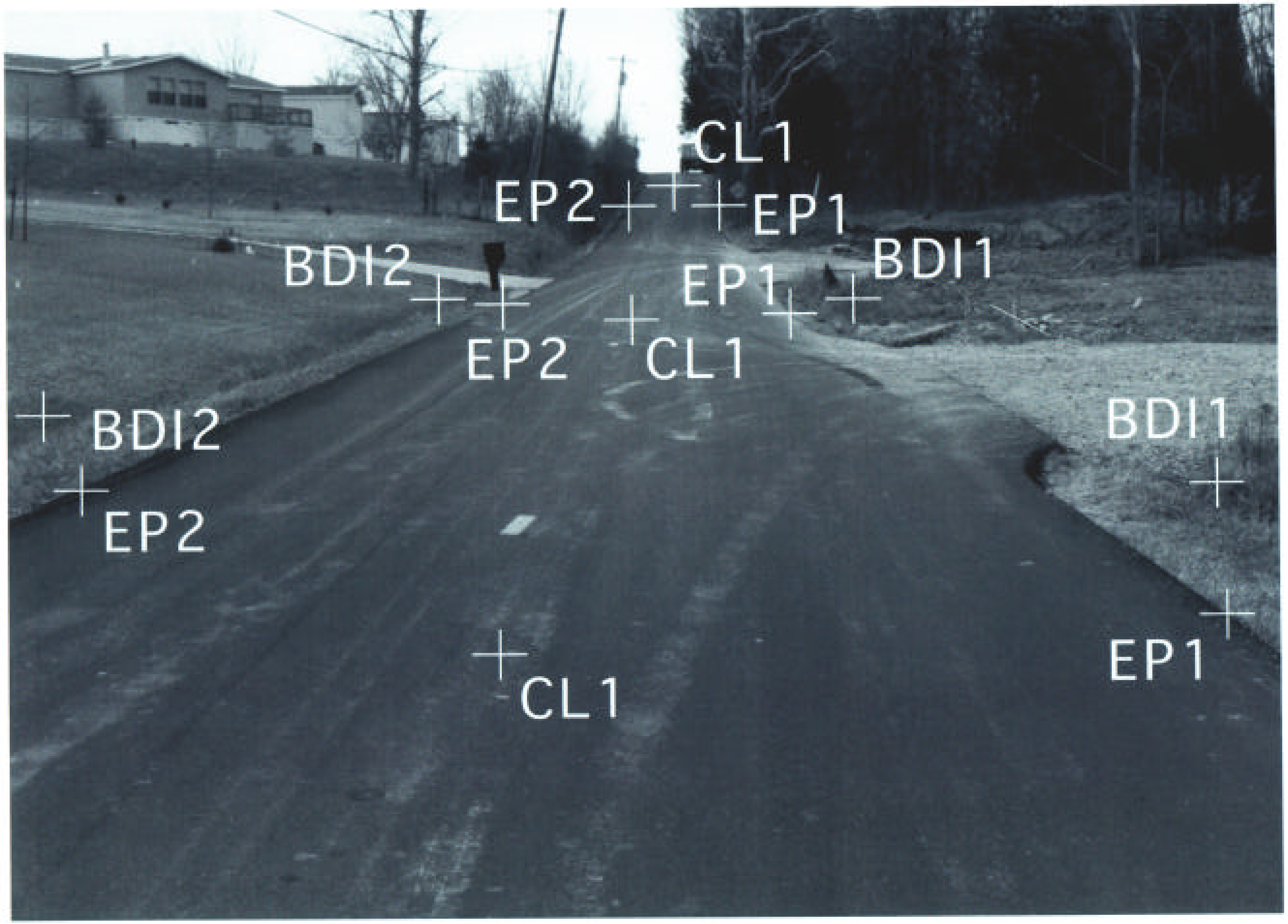

FIGURE 1

FIGURE 2