

DESIGNING SOFTWARE TO GENERATE MESH MODEL AS A DIGITAL ELEVATION MODEL USING ENGINEERING SURVEY DATA AND PERFORMING 3D HYDROGRAPHIC ANALYSIS

K.L.P. Hemantha¹, J.A.S. Jayakody², I.A. Kalani S Illeperuma³, A.C.P.K. Siriwardhana⁴

¹ Divisional Survey Office, No. 24/32, Sangaraja Mawatha, Kandy, Sri Lanka.

Email: hemanthaklp@gmail.com

^{2, 3, 4} Department of Remote Sensing & GIS, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka,

P.O. Box 02, Belihuloya, Sri Lanka.

Email: swarna@geo.sab.ac.lk

Email: kalani@geo.sab.ac.lk

Email: acpsiri@gmail.com

Keywords: Software, Digital Elevation Model, 3D Hydrographic Analysis, Script.

Abstract: This research was conducted for designing a new plugin software, which will generate DEM using grid format Data such as Engineering Survey Data. This study was mainly focused on generating Mesh Model as a Digital Elevation Model (DEM), Mesh Model is a continues vector model. This new software named “DemCAD”, contains set of programs which will allow user to input grid data, after that it will performed data processing and analysis, finally a script file will be made, which contains instructions to automatically plot required model. Then user has to run this script file in AutoCAD 2D/3D Environment. This script contains set of commands which will be recorded in particular sequence and pattern, also to get complete DEM in AutoCAD Script file have to run on AutoCAD without interrupting.

The most important fact in this study was, Mesh DEM can be used to perform various type 3D Hydrographical analyses, such as Flow Direction Mapping, Flow Accumulation Mapping, Flow Path Tracing, etc. There are software like ArcGIS that have ability to perform Hydrographical analyses for 2D DEMs. In that, input grid data was processed in a specific way then data will be passed to another executable file which will use that data and perform 3D analysis process. In this procedure functions were designed for kernel operations and various kinds of calculations such as calculating distance, Bearing, Interpolate Coordinates, etc.

Even though in this study, only land surveying data was used to generate DEMs, any grid format data sources such as Laser Scanning Remote Sensing Data, Radar Data, and even Close Range Photogrammetry stereo pair data, can be used as data sources after some pre-preparation. Future more this mesh model and 3D hydrographic analysis can be used by many professions such as Land Surveying, Quantity Surveying, Irrigation, Engineering, and even military services to plan and perform their day to day work easily.

1.0 INTRODUCTION

1.1 Background of the Study

Digital representation of terrain elevation in particular area with a digital model can be call as Digital Elevation Modeling. Digital Elevation Models play a major role in representing terrain or surface in computers. Most of the time, data collecting to create Digital Elevation Models are done by Photogrammetry or Remote Sensing. The only DEM, created by collecting land survey data is Contour model, other DEMs are used rarely. In this research study, an effort was made to create as many DEMs as possible using land surveying data.

Even though in the drawing software like AutoCAD contains such three dimension environment facilities, still surveyors rarely use three dimension environment facilities, to fulfill their drawing and analytical requirements. Therefore in this research project, an effort was made to find out how 3D environment facilities in AutoCAD can be modified and improved according to surveyor's requirements. Usually AutoCAD software modifications were mainly done using Auto Lisp or Visual Lisp programming language facilities provided by AutoCAD itself. But in this study, most of the modifications were done using C++ programming language and only linking C++ executable files to AutoCAD, was done by using Auto Lisp scripts.

1.2 Mesh Digital Elevation Model

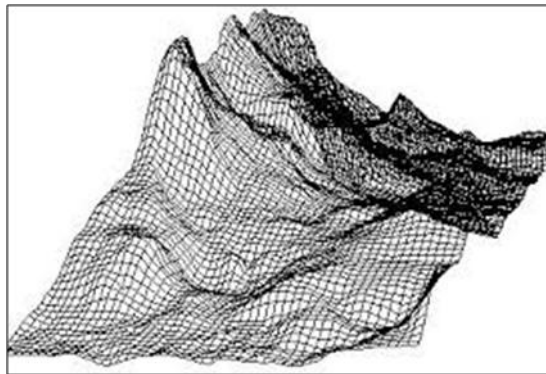


Figure 1- Mesh Digital Elevation Model

Figure 1 shows Mesh DEM and it displays topography features in terrain using 3D environment. Even though this model is real 3D vector model, this model can be used as continues surface (with farther modifications). Mesh DEM was designed according to our own concept. The experience had when designing contour model was lead to designing Mesh DEM. Points and splines were used as the basic drawing elements to design the DEM. Due to use of spline the resulted DEM appears smoothly.

1.3 AutoCAD software

1.3.1 Use of Script Files in AutoCAD: A script is a macro, a list of commands that user can run all at once, and as many times as necessary. Script files allows user to automate tasks that would take a long time if they were done manually. Scripts can be very powerful and user can run them on objects in one drawing, or on many drawings.

1.3.2 Developing Plugin for AutoCAD: Different types of plugin can be developed to automate various tasks in AutoCAD. As an example it is possible to design a plugin for generate contour models in AutoCAD. There are few basic plugin types used in AutoCAD. They are

1. AutoLisp
2. .Net
3. ObjectARX
4. AutoCAD VBA

AutoLisp can be used to accomplish or automate a task using Script file or macro. But .Net, AutoCAD VBA and ObjectARX environments are more powerful. They allows programmer to create his own entities and more advanced behavior. ObjectARX is a C++ interface. The .NET classes are actually wrappers to the ObjectARX interface. AutoCAD VBA is Visual Basic interface with object oriented capabilities. (AutoCAD Help Menu)

1.4 Use of Microsoft Visual Studio

This software will be used to develop the Graphical User Interface (GUI) for the developing software. GUI allows the user to interact with graphical icons when using the software. Creating GUI for particular software will increase the efficiency and ease of use rather than a Command Line Interface (CLI).

In addition to Visual Studio, Dev C++ software was used to develop Command Line Interface needed for this software.

2.0 OBJECTIVE OF THE STUDY

The main objective in this research study is to introduce new free and open source software for generating Mesh DEM in AutoCAD environment. Other objectives are to provide local oriented software which have capabilities to perform Hydrographic Analysis to Local Authorities like Survey Department, Department of Irrigation, etc. Promoting AutoCAD 3D environmental operations and analysis among professionals who are not using them already and let them have the advantages of those facilities.

3.0 DATA COLLECTION AND RELATED THEORIES

3.1 Data Collection

Secondary data was used for this study. Originally, this data was collected using Engineering Survey methods and for Mesh DEM that data were used. Before feed that files to Mesh DEM program, data files have to be analyzed and filtered, so that those data files are in correct grid format.

Data files which are in space delimited, comma delimited and tab delimited formats can be used for this software.

3.2 Related Theories

3.2.1 Interpolation: Interpolation is considered as an approximation problem in mathematics. In digital terrain modeling, interpolation techniques are used to determine the height values of points using the known heights of neighboring points. There are two main assumptions in interpolation techniques. It is considered that the terrain surface is continuous and smooth as well as there is a high correlation between the neighboring data points.

3.2.2 Simple linear interpolation: By using three points it is possible to determine a plane. One example for such a surface is triangular facet. The mathematical function for a plane is as follows.

$$z_i = a_0 + a_1x + a_2y \quad (1)$$

Where a_0 , a_1 , a_2 are the three coefficients and (x, y, z) are the set of coordinates of a surface points. Three reference points with known coordinates are required to compute these three coefficients. After determining the three coefficients, the height z_i of any point i with a given (x_i, y_i) pair of coordinates can be obtained.

3.2.3 Flow Direction Map: One of the keys to deriving hydrologic characteristics of continuous surface is the ability to determine the direction of flow from every cell in the raster (ArcGIS web site-Flow Direction). Even though this theory was applied with raster format data, after few modifications this theory can be applied to vector models such as Mesh DEM model, as well. This is done with the Flow Direction command in Hydrography tool bar. Here instead of Digital Number in Raster format, mean elevation was calculated for each mesh square using heights of four corners.

As shown in figure 2, there are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight-direction (D8) flow model. However, as shown in figure 2, Direction coding that used for Determining flow path of Mesh DEM was different from convention. This modification was done because it is easier for computer programmer to handle. Figure 3 shows technique used in ArcGIS to generate Flow Direction Map from Elevation surface and figure 4 shows technique used in DemCAD to generate Flow Direction Map from Elevation surface.



Figure 2- Direction Coding used in ArcGIS and AutoCAD

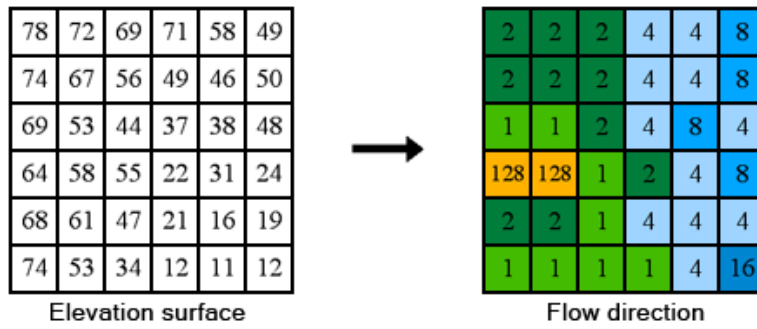


Figure 3- Elevation surface and resulted Flow direction in ArcGIS

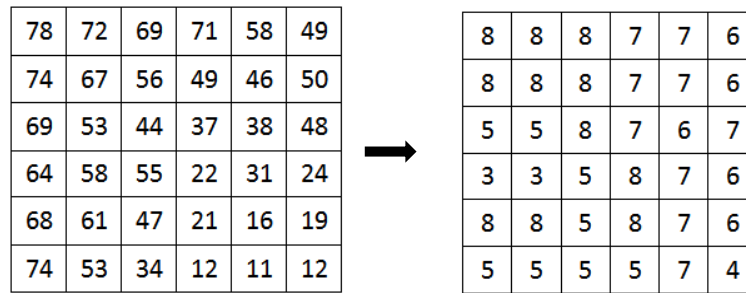


Figure 4- Elevation surface and resulted Flow direction in DemCAD

3.2.4 Flow Accumulation Map: The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell.

In the figure 5 (a) image shows the direction of travel from each cell and the figure 5 (b) shows the accumulated number of cells that flow into each cell. Figure 6 shows the method of ArcGIS applies that theory (ArcGIS web site-Flow Accumulation). Figure 7 shows the method of DemCAD software generates Flow Direction Map to Flow Accumulation Map.

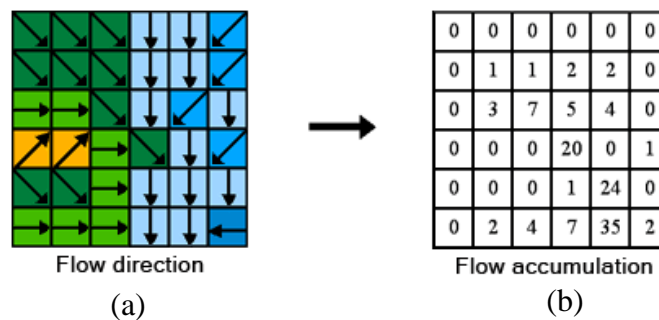


Figure 5-Theoretical conversion from Flow Direction Map to Flow Accumulation Map

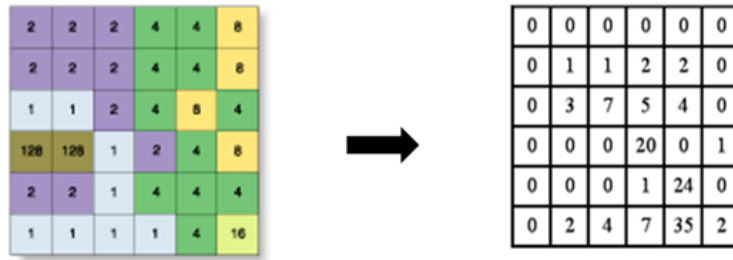


Figure 6-Conversion from Flow Direction Map to Flow Accumulation Map in ArcGIS

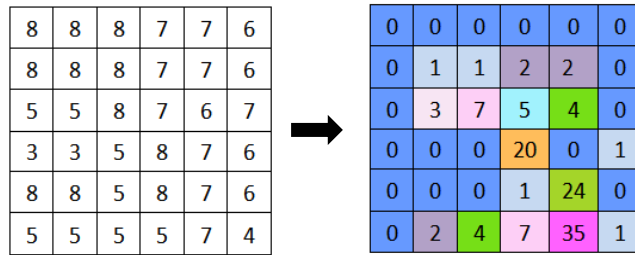


Figure 7- Flow Direction Map and resulted Flow Accumulation in DemCAD

3.2.5 Zero Cell Padding: As shown in Figure 8 and 9, Zero Cell Padding makes possible running a kernel through the edge of the Map. Without Zero Cell Padding DN values located in the edge of the map will be neglected. Path of the kernel will be shown in red arrows in the figures 8 and 9.

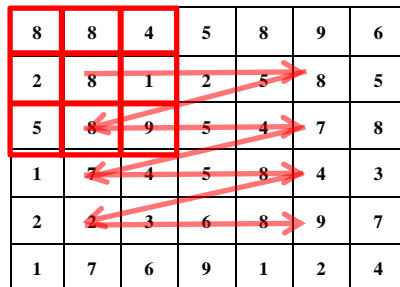


Figure 8- Without Zero Cell Padding

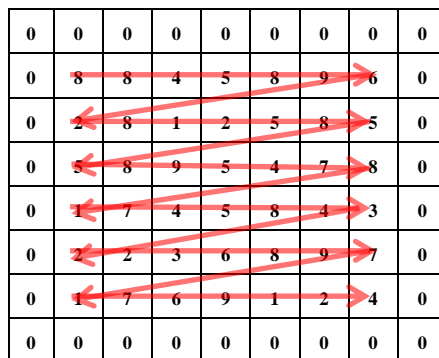


Figure 9- With Zero Cell Padding

4.0 METHODOLOGY

During this study, C++ codes were designed to automatically generate Mesh DEM in AutoCAD.

To develop software for generating Digital Elevation Models, it is required vast theoretical knowledge in digital elevation modeling and computer programming. The analysis was done using different kind of software, to study how above theories were applied in software, to learn what kind of tactics that were used in that software for achieving quality result.

4.1 Mesh DEM Model

This software generates a detailed mesh surface using Engineering survey data using linear interpolation in AutoCAD three dimension environment. Using this software, user can have a good idea about land parcel's topography. This DEM surface model can be further used to do surface analysis operations such as determining flow accumulation path, inter visibility check.

4.1.1 Methodology for Mesh DEM Model

1. The data file was input.
2. The Maximum and minimum values of X, Y, Z data were calculated.
3. The Grid intervals were calculated (Horizontal and Vertical interval).
4. As shown in figure 10, interpolating along all four grid edges was done.

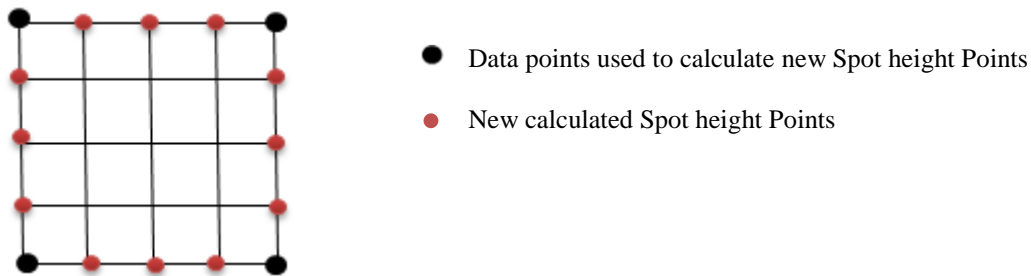


Figure 10- Interpolation Step one

5. Then using upper and lower edge spot heights in-between spot height points were interpolated. This is shown in figure 11.

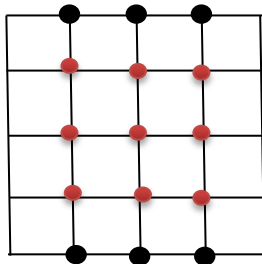


Figure 11- Interpolation Step two

6. Then code was designed to write instructions on script file for connecting interpolated spot heights using spline in North-South direction and East-West direction.
7. Later, code was designed to output script file ScrPDEM and it contains instructions to plot Mesh DEM Model.
8. Finally by clicking the command to run above script file, end user can plot a mesh DEM as a result.

4.1.2 Generating Mesh DEM

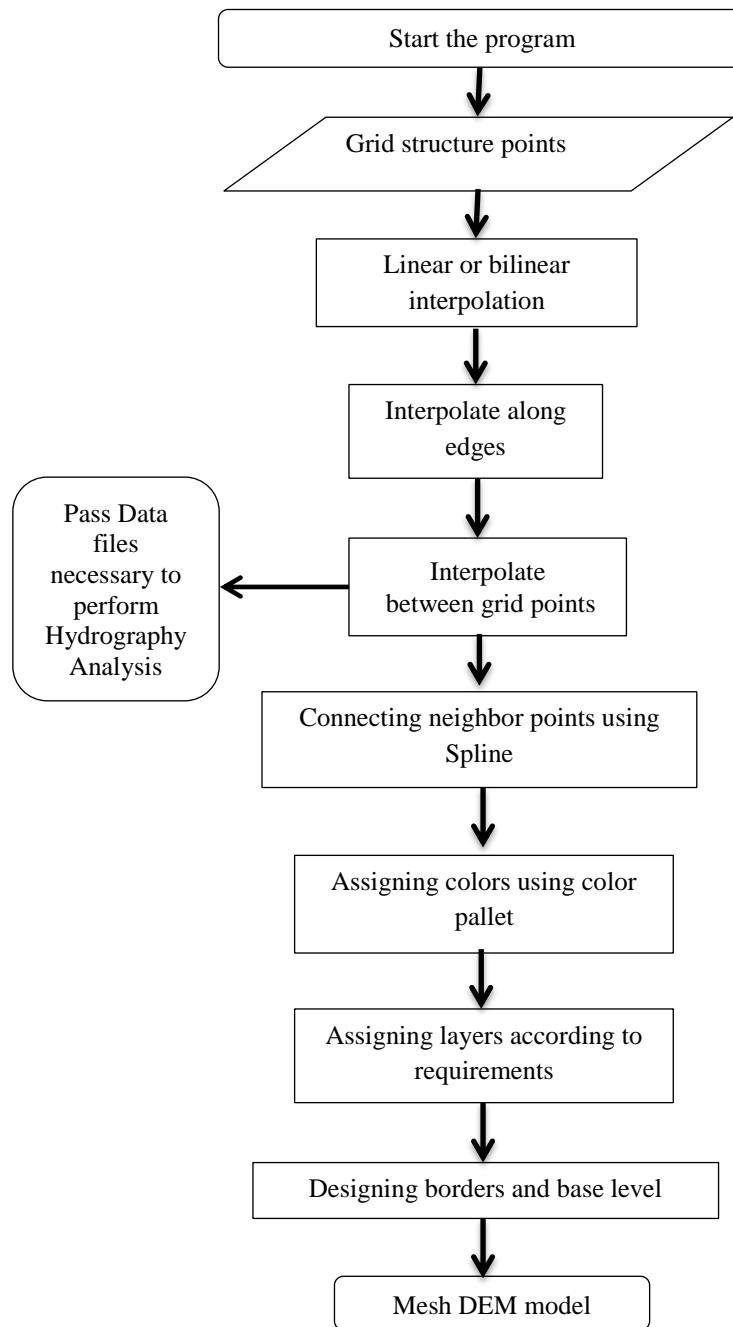


Figure 12- Methodology for Mesh DEM

Figure 12 explains briefly, method of the DemCAD software perform internally when generating Mesh DEM from input grid data sets.

4.1.3 Performing Hydrographic Analysis

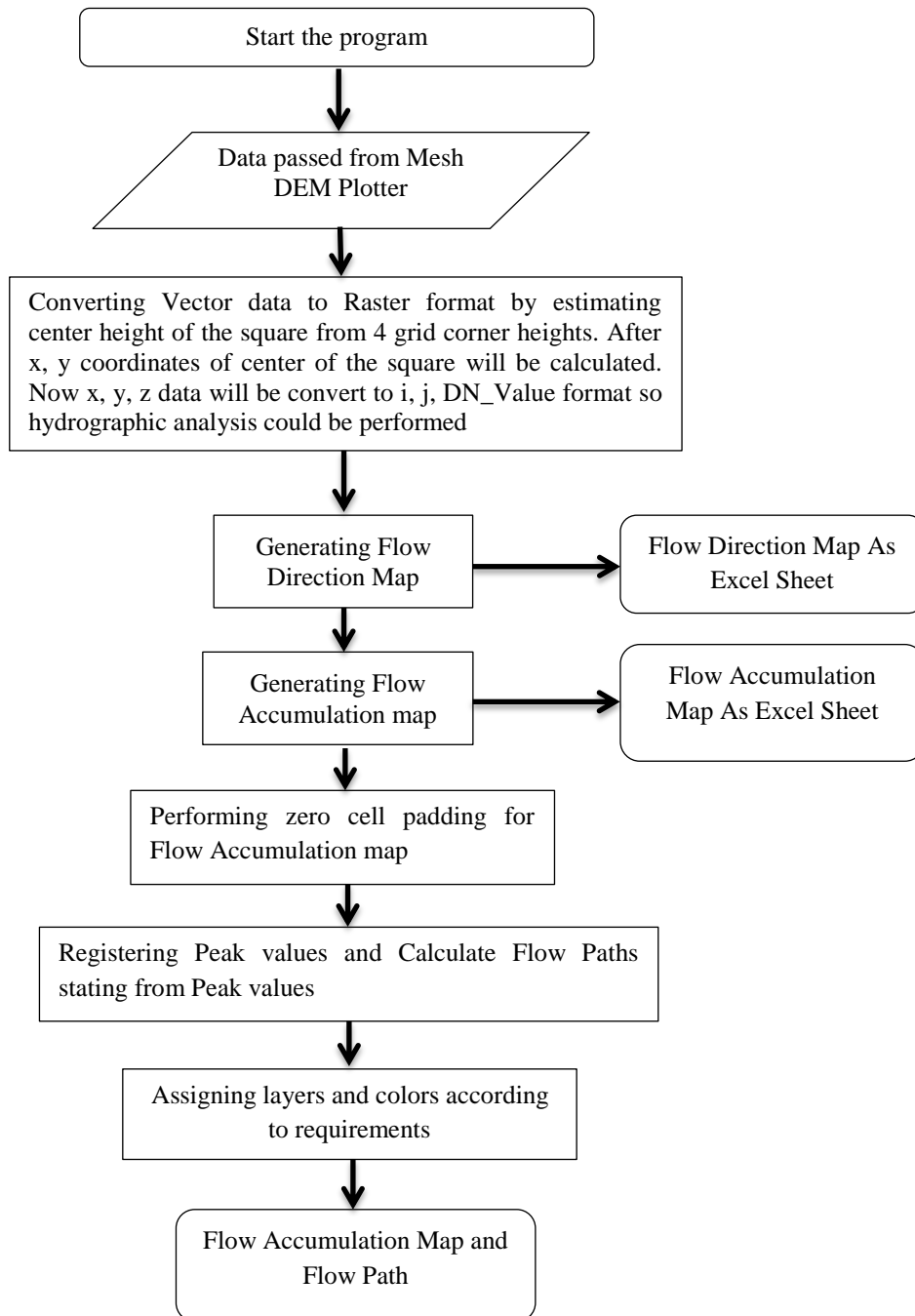


Figure 13- Methodology for performing Hydrographic Analysis

Figure 13 shows, how DemCAD software function when it performs hydrographic analysis internally by generating Flow Direction Map, generating Flow Accumulation Map and tracing Flow Path. In this program, user do not have to input data again, program will use prossesed data passed by previous Mesh DEM plotting program.

5.0 RESULTS AND DISCUSSION

As shown in figure 13 and 14, this new software can generate Mesh DEM model and that can be further used to generate Flow Direction Map, Flow Accumulation Map, Finding Peak values and finally for finding possible Flow Paths for area covered by DEM. Using new DemCad-Grid tool box user can perform all the above operations easily with Graphical User Interface designed specially for this software.

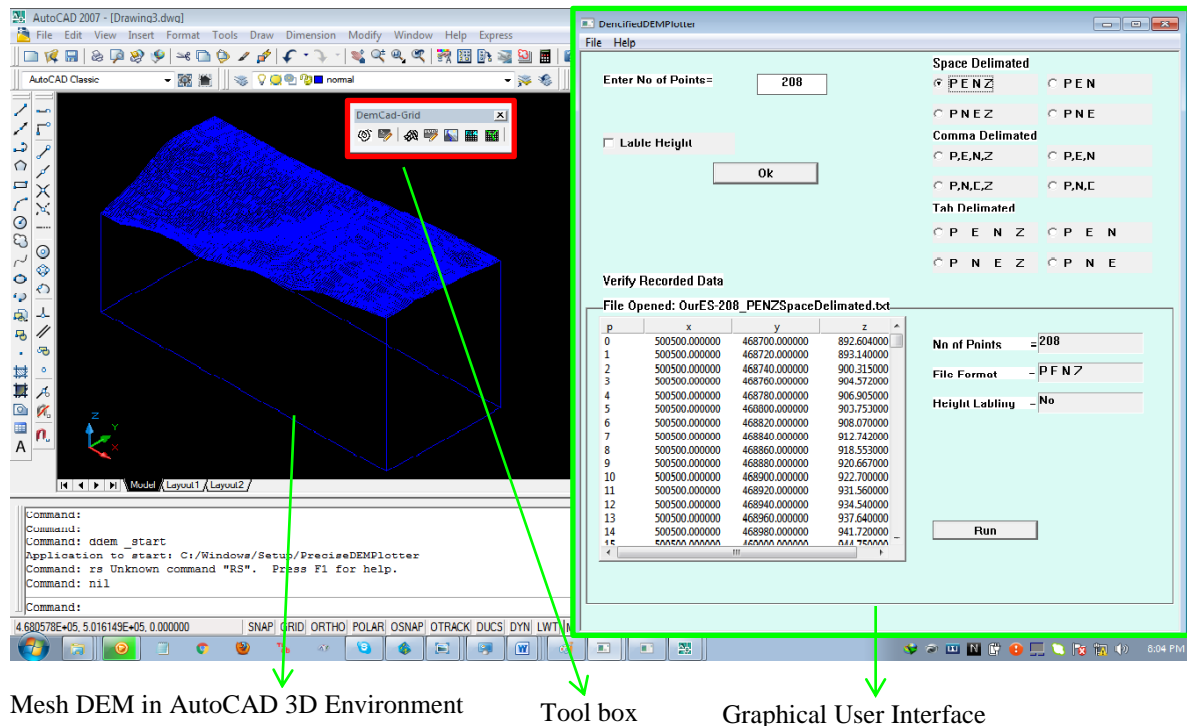


Figure 13- Generated Mesh DEM, Tool box and Graphical User

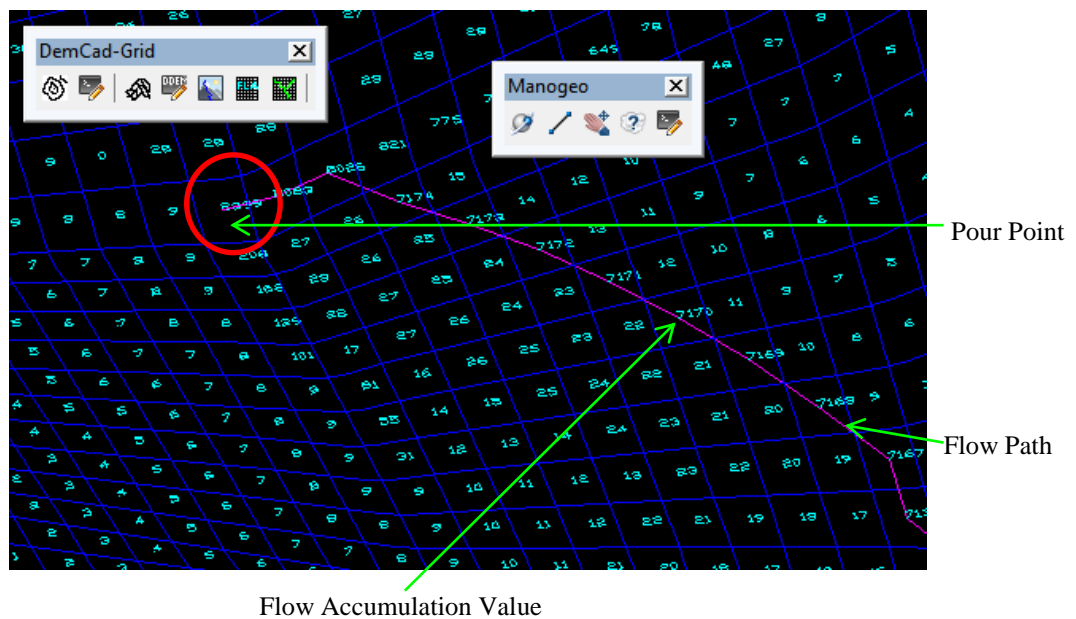


Figure 14- Generated Mesh DEM, Flow Accumulation Map, Flow Path and Pour Point

6.0 CONCLUSION AND RECOMMENDATIONS

Generating Mesh DEM model for any kind of grid format data set and performing hydrographic analysis for that data was achieved, finally assumption could be made that the software development for Mesh DEM was a success.

6.1 Conclusion

All the operations i.e. Generating Mesh DEM Model, Generating Flow Direction Map, Generating Flow Accumulation Map and Plotting Flow Path were successfully and automatically carried out by DemCAD software.

Another special characteristic of this Mesh DEM is even though it is a vector model with the Flow Direction Map, Flow Accumulation Map it will inherit some features of raster model. In other words Total model of Mesh DEM with Flow Accumulation Map becomes a combination of vector and raster model. The user can gain advantages of both vector model and raster model.

However there are some further developments that could be done, one of them is even though DemCAD software plot few possible flow paths it do not plot all the possible flow paths. This is a further development for this software. Another limitation for this software is, it only works with grid data format. If a user need to perform a hydrographic analysis to random data set the user first have to perform random to grid interpolation using an another software like MATLAB and then resulted grid data set have to be feed to DemCAD software for required analysis. In this process accuracy of the original data set will be reduced. As a solution, in the next study software will be designed to generate Triangular Irregular Network model using random data set and then performing hydrographic analysis.

6.2 Recommendations

To understanding topographical features in Conventional DEM such as contour model sound knowledge and experience is required. But since this Mesh DEM model is already on 3D environment with simple AutoCAD commands like “3D Orbit” “Zoom In & Out” user can easily understand topographic features such as peak points, pour points, mountains, vales etc. In additional to that this Mesh DEM Model can be used to perform different kind of surface analysis such as inter visibility check.

Hydrographic analysis done by DemCAD software will be very useful for professionals like Irrigation Engineers, Surveyors and Architects in various projects like designing drainage systems for a specific area, designing a dams etc.

7.0 REFERENCES

ArcGIS web site-Flow Direction Retrieved August 13, 2016

from : <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-flow-direction-works.htm>

ArcGIS web site-Flow Accumulation Retrieved August 13, 2016

from : <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/flow-accumulation.htm>

AutoCAD 2007 Help Menu (inbuilt offline help)

David Francis Maune, 2007. Digital Elevation Model Technologies and Applications: The DEM User’s Manual.

Wikipedia web site –Digital Elevation Model Retrieved January 10, 2016

from : https://en.wikipedia.org/wiki/Digital_elevation_model

Zhilin Li, Christopher Zhu, Chris Gold, 1990. Digital Terrain Modeling: Principles and Methodology.