USAGE OF CAD/CAM SYSTEMS FOR MANUFACTURING OF SOLID RELIEF MAPS

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ABSTRACT:

Relief maps are generally required for military purposes, land use and town planning works. These maps are generally prepared as solid blocks, and are hand made. Some difficulties and impossibilities due to sharp height differences may be inescapable in the course of production of these maps. Therefore; some exaggerations may have been done to get a smooth surface appearance.

On the other hand, the use of CAD/CAM systems for 3D designing and manufacturing of models for automotive, aircraft, aerospace, medical and other several industrial applications is quite well known and spread out. This paper addresses our studies about the usage of CAD/CAM systems for manufacturing of solid relief maps, and presents production of a prototype.

1. INTRODUCTION

Solid relief maps, which presents 3D model of a part of a terrain are generally required for military purposes, land use and town planning works. These maps are usually prepared as solid blocks, and their production are usually done by hand. Therefore; their metric correctness, soundness and production time entirely depends on human factor and the base material being used. During the production of these maps, presentation of very small details such as sharp changes in height may require some exaggerations due to difficulties in cutting, carving and sticking the materials.

Systems which are used for designing 3D spatial model on the bases of graphical data, and are used for producing solid models using CNC machine tools are referred to as Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM) systems. Pro-Engineer, Uni-Graphics, Catia are some of the well-known softwares which are used in these systems (Cripps, 2003), (Chen and Wang, 2001).

Although these systems' use in industry is very common, their usage for relief mapping and architectural town planning modeling are not seen in practice.

This paper addresses the way of using CAD/CAM systems for production of solid relief maps.

2. RE-FORMATTING CARTOGRAPHIC DATA FOR CAD MODELLING

For this research work, cartographic data of a sample Digital Elevation Model(DEM) produced by Microstation program was used (Krishnan and Taylor, 2002) as shown in Figure 1. At first, the DEM's triangulated data was exported for transformations into various formats which can be suitable for general CAD programs.

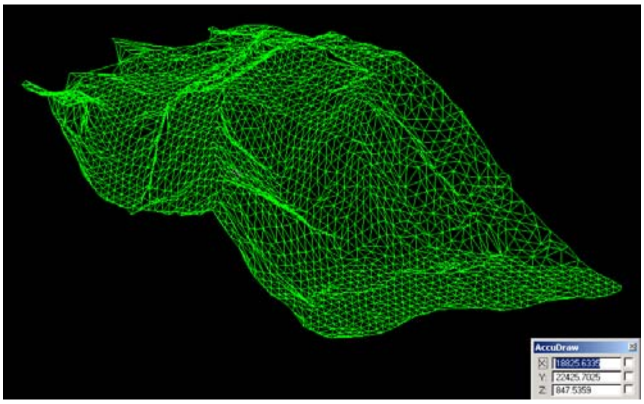

Figure 1. A Sample Digital Elevation Model Produced by Microstation

Since it is very hard and certain to have some problems using triangulated data especially for CAM applications, IGES (Initial Graphics Exchange Specification) data format was chosen. As known, it is possible to apply point, curve and even surface information with several formats in the IGES data (Mansour, 2002).

In this experiment, point formatted data structure has been preferred because of the ability of changing some parameters to create complex surfaces from the points. Consequently, some different parameters were experienced.

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Thereafter having the cartographic data in point format the following steps were carried out for reformatting the data that is suitable for computer aided manufacturing.

a) Repeated corner points and coordinate data of triangles were wiped out so that appearance of a single point data in the file had been limited to once.

b) The original terrain model was reduced to a scale model about solid relief map's scale (1/20000).

c) The redacted data structure was saved in IGES as shown in Figure 2.

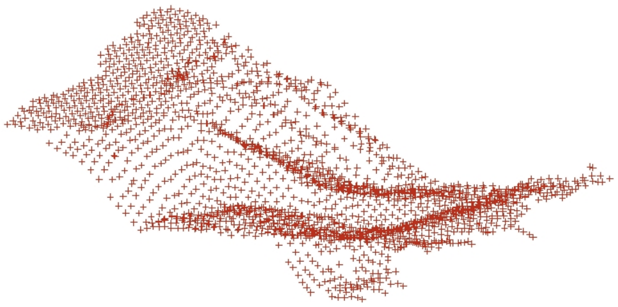


Figure 2. IGES data is created by Microstation program

In this manner, the reformatting of the DEM data that is suitable for CAD/CAM processing was successfully concluded.

3. PREPARING CAD MODEL

After reformatting process of the cartographic data was completed, following steps were carried out to prepare a CAD model that is suitable for CAM processing.

a) Redesign of the cartographic data had been done by Unigraphics CAD software and manufacturing data had been prepared and simulated by Unigraphics CAM software. New generated point formatted IGES data was imported to UniGraphics CAD software. This imported and opened data to the UG CAD software can be seen in Figure 3 (Chen and Wang, 2001).

b) First of all, Work Coordinate System (WCS) was reoriented according to opened form of the data structure in the UG CAD software. Coordinates of the WCS are called work coordinates, and are denoted by XC, YC, and ZC. The XC-YC plane is horizontal and is called the work plane.

c) Boundaries of the area in which the CAD model would have been manufactured were defined as perpendicular to the work plane.

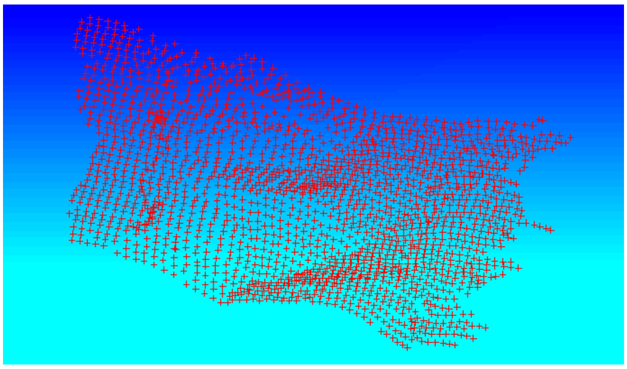


Figure 3. IGES data is imported by UG CAD software

d) Point Cloud selection was used to create a new surface from the points within the defined boundaries. With the use of Point Cloud selection, surface fitting process to the data was carried out by applying high degree polynomials. A 7th degree polynomial was found out as the most suitable mathematical model to fit the data's surface. With this surface fitting, mean deviation 0.3 mm (5.72 m.) and high deviation 2.33 mm (44.47 m.) in Z direction were achieved. The result of the polynomial surface fitting process is shown in Figure 4. Extreme outside points of the data have been ignored because they caused disarrangement in creation of the surface according to some specified parameters like curvature of the surface related to the points. Although this attempt, some problems were still observed at the surrounding section of the surface that extended to infinity because of the disordered points at the overall sides of the area defined by the boundaries. These problems also can be seen in Figure 4.

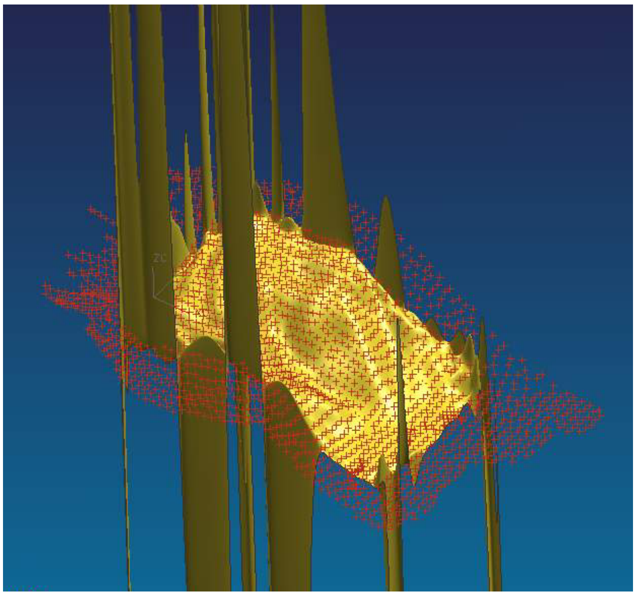
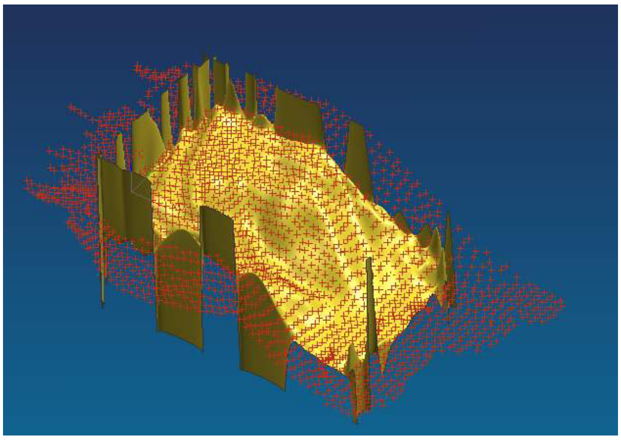


Figure 4. Image of surface creation by Point Cloud Selection

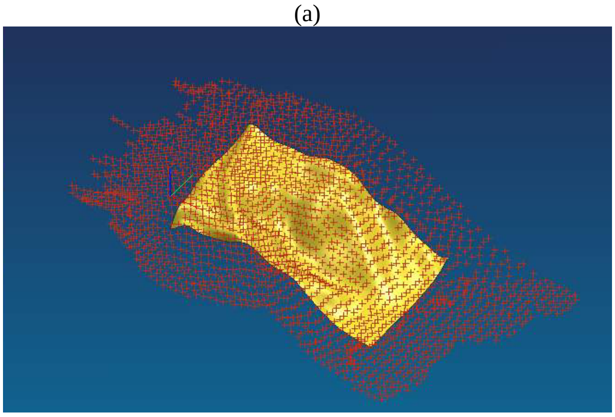
e) In succession steps, these bad sections were clipped out to get a suitable model for manufacturing process. The results of this process is shown in Figure 5-a.

f) Subsequently, to be able to work on a regularly shaped material, a rectangular shaped area in the surface was chosen by clipping out the outer surface data as shown in

Figure 5-b. Here, sizes of the rectangle were defined as same as size of the manufacturing work piece.



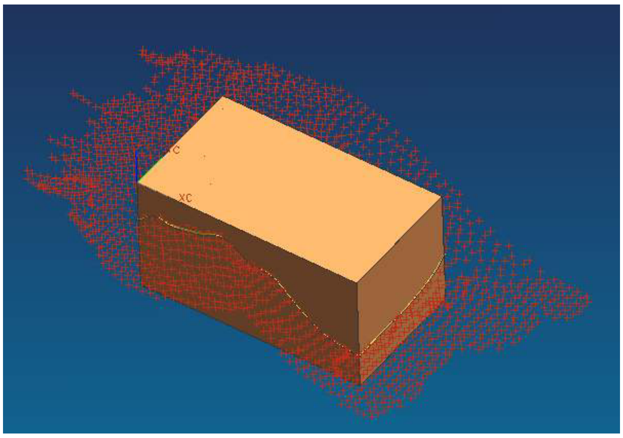
(a)



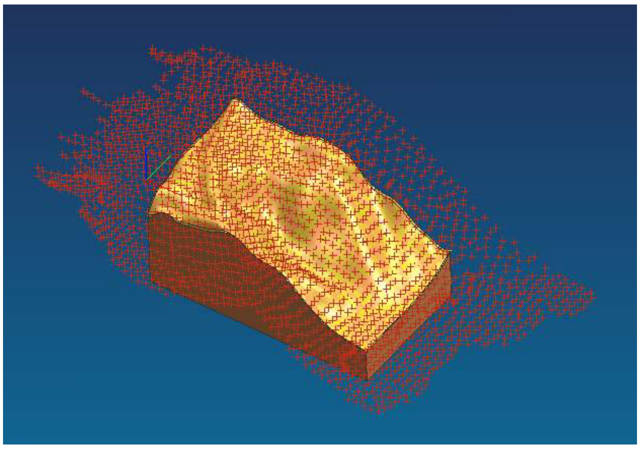
(b)

Figure 5. Cleaning steps for the disordered surface

g) This latest rectangular shaped model data was transferred onto a rectangular prism to make the model as solid state. This step can be seen in Figure 6-a. Subsequently, this prism was cut by the DEM surface, like as shown in Figure 6-b.



(a)



(b)

Figure 6. Solid model creating steps from the constructed surface

h) For final CAM process, a solid model was formed by transferring this latest model to Unigraphics' Manufacturing Module.

4. MANUFACTURING PROCESS

A 5 axes CNC milling center which is called as Deckel Maho DMU 60P was used for manufacturing of the scaled model of the terrain (User Manual, 1998). A picture of this machine can be seen in Figure 7. This kind of machines provide to manufacture complex shaped geometries which are important especially for the automotive and aircraft industry (Chen and Wang, 2001), (Baptista, and Simoes, 2000), (Kim et al., 2001).

A raw material made of hard plastic in rectangular prism shape was chosen as work piece and fixed at the worktable of the machine. Manufacturing process is explained in the following steps.

Figure 7. A picture of Deckel Maho DMU 60P 5 axis milling center

a) First of all, rectangular prism shaped model was created and fitted with the solid model according to raw material's dimensions in CAM module. This model will be used to simulate the operations in the computer as if it is in real situation. This is necessary to see all about the cutting process before doing real milling operations. The model obtained in this way is called as workpiece and it is shown in Figure 8.

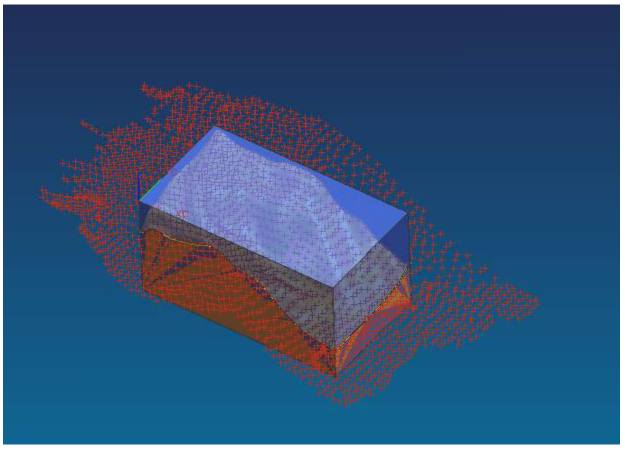


Figure 8. Workpiece model has same dimensions with raw material

b) Afterwards, cutting process started at first with a spherical shaped cutter which is called as ball end milling cutter and has a big diameter. First of all, some filling were removed from the material, assuming that surface of the model consists of curves. Cutting process was started from the curve with the highest elevation and ended at the curve with the lowest elevation. So, a rough profile of manufacturing model of a solid relief map was obtained. Related to this, Figure 9 and Figure 10 illustrate simulations of the cutting process and the manufactured rough model, respectively.

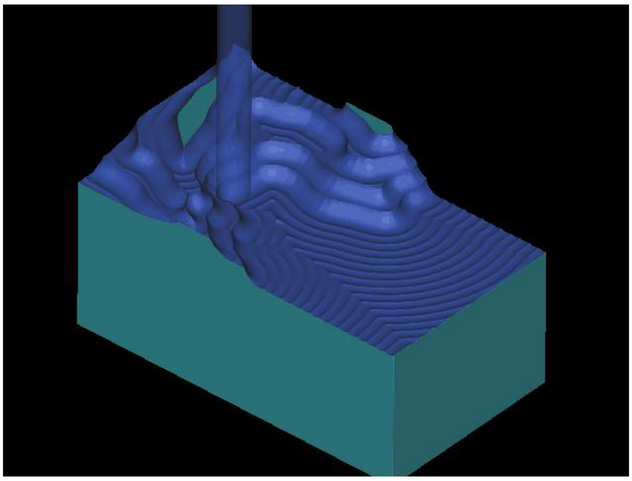


Figure 9. Process simulation of first rough cutting

c) A second order rough cutting was carried out after the first rough cutting. At this stage, smaller diameter ball end milling cutter was used for in a similar manner to previous operation. Contrary to the first process, here cutting of the model was carried out by moving the cutter in one direction over the roughly modeled material. Accordingly, distances between cutting passes were smaller than the previous operation. Figure 11 and Figure 12 illustrate the simulations of cutting process and the latest manufactured model, respectively.

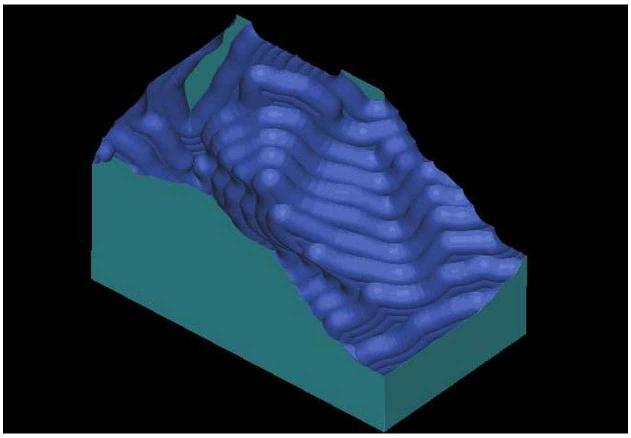


Figure 10. Simulation of end of the first rough cutting operation

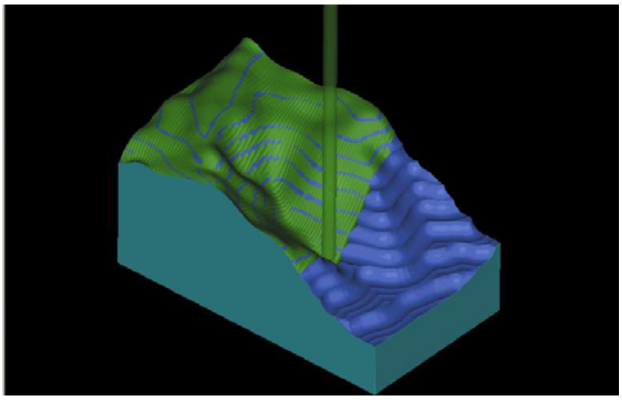


Figure 11. Process simulation of second rough cutting

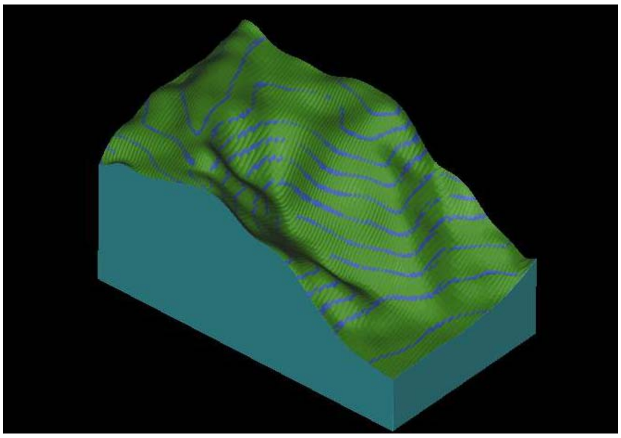


Figure 12. Simulation of end of the second rough cutting operation

d) Lastly, as in the previous process, smaller diameter ball end milling cutter with more smaller distanced cutting process was used for smoothing the model surface. Figure 13 and Figure 14 illustrate the simulations of the cutting process and latest product, respectively.

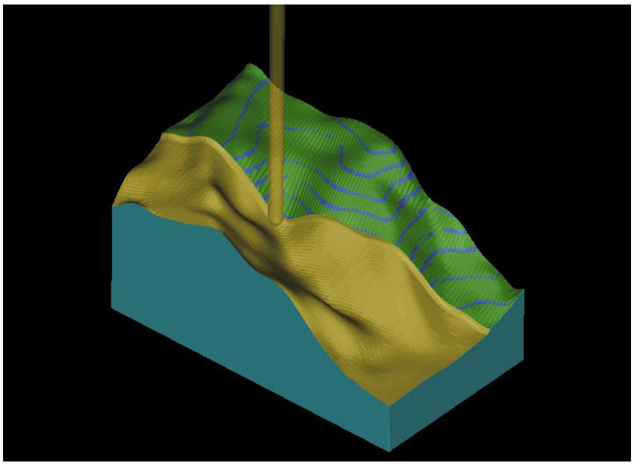


Figure 13. Process simulation of finish cutting

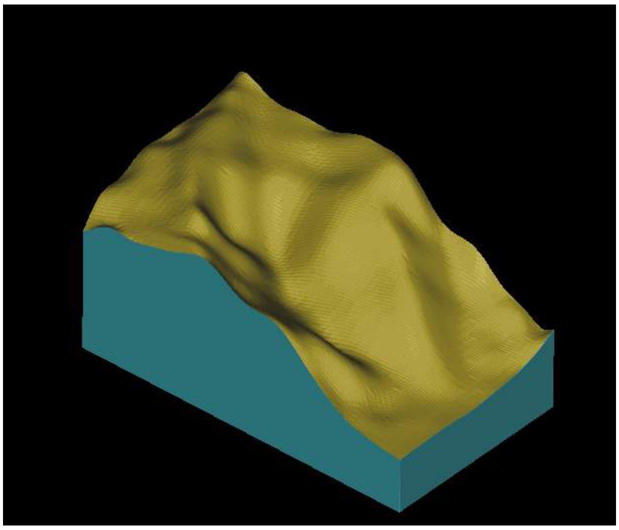


Figure 14. Simulation of end of the finish cutting operation

5. CONCLUSION

Although, the use of CAD/CAM systems for designing and manufacturing of many materials in industrial projects is very well known, its usage for designing and manufacturing of solid relief maps is not seen in practice. Results of this research work have shown that CAD/CAM systems can successively be used for that purposes, too.

The results also showed that the procedures and approaches used in this research work can also be applied for solid model production in architecture and town planning works.

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