DIGITAL TERRAIN MODEL APPLICATION IN ROAD PLANNING AND DESIGN

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Abstract

Development of CAD applications as well as an increasing availability of detailed data of the terrain characteristics provides new possibilities in the road design process. 3D modeling of line and surface objects, unlike the "classic" design, has the uniqueness expressed through the amount of data being processed and the interaction of the buildings and the terrain with the existing and planned facilities. This paper presents an example of creation and usage of a relatively large DTM and route of the road. Eight alternative solutions of about 6.5 kilometers long road and its corresponding road junctions were designed and evaluated. Digital terrain model size of 2.4 x 6.6 kilometers was designed and used for testing and evaluating alternative solutions of the road. In making solutions, data from different sources and different levels of treatment was used and then included in a complete 3D model by using several CAD applications. The paper discussed the problems of modeling a large object whose model not only had to meet the accuracy criteria but whose geometry file record size had to be acceptable in order to perform the computer processing in real time. The paper also offers an overview of detailed photorealistic visualization made for the acquired variant from the point of meeting the created model precision requirements (obtained by using vector and raster geodetic bases and their overlap) along with the met requirement of finding the criterion between the sufficient amount of details and adequately small file records. The paper presents the experience, observations and methods useful for future similar activities in the road design process as well as some features of 3D modeling that can affect the choice of the route and road junction technical elements.

Keywords: CAD, 3D modeling, DTM, roads, visualisation

1 Introduction

The quality surveying data definitely makes the basis for setting and selecting alternative solutions in the design. This paper presents a case whose task was to make alternative solutions of a road route trasition from a 285,5m high plateau to the 227,5m high valley and make road junctions with the existing roads. After the optimal solution was adopted, a project had to be made. While planning the above mentioned road route, both the 1:5000 state map as well as quality geodetic vectorical basis in two variants were at disposal. Considering that the 8 alternative solutions of the road were suggested and evaluaed on a corridor size of 15,8 km^2, it can be said that a relatively large vectorical database was saved in one file as 3D points and polylines. Not only time limits but hardware and sotware limits as well chalenge us in finding methods by which computer resource can be used better but, at the same time, due to eficiency and increased working speed, the project quality and precision must not be compromised. Hereafter, procedures for choosing methods for terrain and road 3D modelling will be described in a few steps.

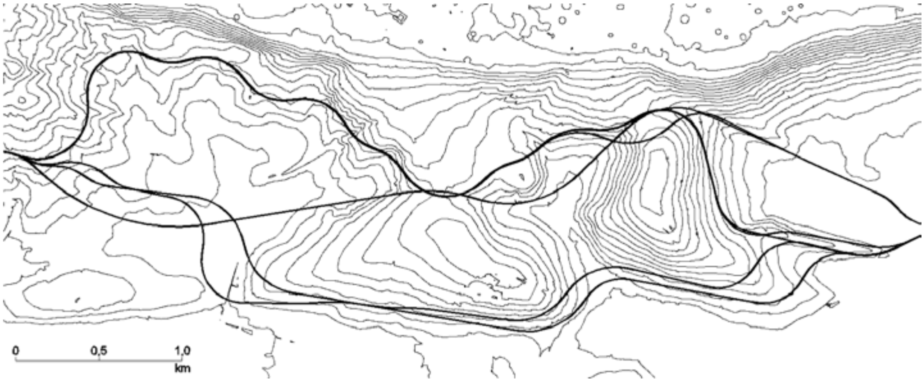

Figure 1 Alternative solutions of the road route.

2 DTM creation

For DTM creation, access to a vectorical data describing the terrain configuration is needed. The data include any entity described with x, y and z coordinates. Before the beginning of the modeling process and depending on the available data type it is very important to choose the best method. In our case, two different vectorical terrain presentations existed. The first one included a vectorised 1:5000 state map, presented only through contour lines, as shown in Fig. 2. The second one included a carefully categorised minimal number of 3D points and polylines as a contour plan and breakline segments, which were representative for terrain configuration description at the same time (Fig. 3). When comparing Fig. 2 and Fig. 3 it is immediately obvious that the terrain description through vectorised contour plan only contains more contour lines and breaklines than the other one. On the contrary, it does not contain points at all, while the other one does (on a 50 x 50m grid). For the advantages and disadvantages comparison of the above mentioned DTM creation basis, two test DTMs of 1 x 1km in size were created (subsequently Test 1 and Test 2) and had the same 3D network building conditions. In both cases TIN model was used because neither regular nor hybrid grid networks were applicable according to low redundancy of available data and noumerous breaklines. The results were compared through the total number of 3D network triangles, the file size record and visual presentation precision grade criteria.

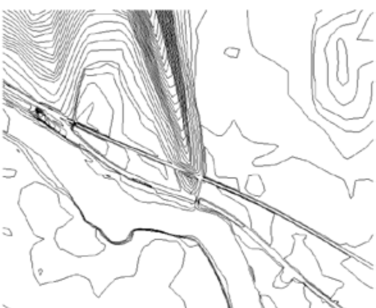

Figure 2 Test 1 - Contour lines

Figure 3 Test 2 - Breaklines,contours and points

The generated Test 1 DTM contained 9923 triangles and the file size was 0,99 MB, while the generated Test 2 DTM contained 3578 trangles and the file size was 0,65 MB. However, it is possible to reduce or increase a number of triangles and the file size as well by changing TIN constructon conditions (triangle size lenght or angle range limits). If that is the case, then the visual presentation precision grade criterion comes out, by which the triangle number decreasment of the Test 1 DTM affected the poor detail level and 3D representation precision. On the other hand, the triangle number increasment did not improve either sharp edges representation or sudden changes in terrain configuration, but a non-characteristic smoothing of the observed terrain occured.
The test 2 DTM, on the contrary, showed quality 3D representation of all of terrain configuration characterists, so that the TIN mesh smoothing was not necessary. For example, there are clearly visible sharp transitions of the river bed edges as well as the existing road and railway contours, while the flat parts are coverd with minimum triangles needed, as shown in Fig. 4. The 3D representation quality can be improved by draping the orthophoto image over TIN surface (Fig. 5.) which further verifies the accuracy of DTM. The visual presentation accuracy can be tested by zooming the characteristic parts of the model or ortophoto image. For the purposes of such verification sharp edges and transitions in the terrain were taken as representative. According to all of these criteria, Test 2 DTM was adopted as the more favorable one.

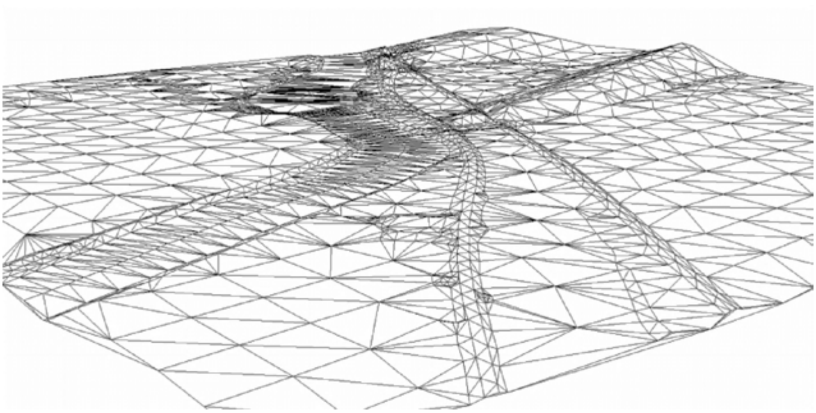

Figure 4 TIN based Test 2 DTM.

Figure 5 Ortophoto over Test 2 DTM overlap.

3 Road model creation

Horizontal and vertical road axis settlement in most of specialized softwares implies some kind of automation in setting up lines and curves. Faster designing is manifested through automated creation of terrain and road profiles and cross sections, work amount calculation, etc., especially for the open parts of the route (parts without frequent changes in cross-sections). The above mentioned software advantages were used in this work for selecting the optimal corridor and route solution. The design of road junctions, especially grade separated ones (which include road objects as well), appears to be questionable so it was not performed in individual variants. Algorithms that manage the programming routines for designing the grade separated road junctions generally do not exist as integrated software parts. When they do, they can not predict all the possibilities or possible irregularites. Within the project, it was necessary to design two grade separated junctions and then – since the DTM and the road were created in 3D, it was apropriate to create them in 3D as well.

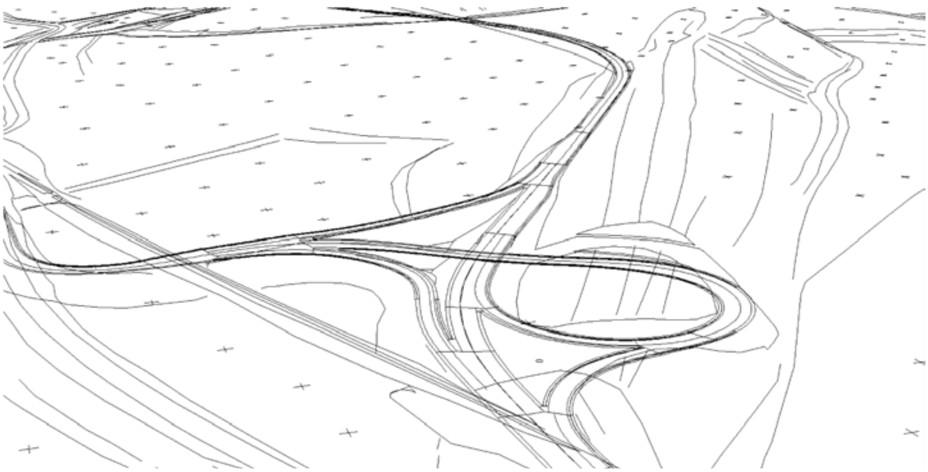

Figure 6 Basis for DTM and 3D road model creation.

Methods used for creating 3d road model and its corresponding road junctions included the rules adopted during DTM creation, previously explained in this paper. Relating to access to 3d polylines of all the relevant road axes, the vectorical data for roadway, ditch and shoulder edges had to be obtained as well as the intersectional lines between terrain and back slope/fill slope. Accordingly, the road junction model was based on 3d polylines with minimum necessary number of points which were at the same time sufficiently accurate for different roadway edge curvatures. A significantly denser dot structural pattern was used for road junctions where there were greater curvatures of roadway edges than those in open road sections. 3d polylines were created as ASCII files with a special application which uses ground plan and height position data of a road axis and warping of a roadway surface. Furthermore, those files were treated as any other DTM database. Intersectional lines between back slope/fill slope and terrain were mostly the result of a specialized software. Those polylines could partly be adopted as breaklines and used as a DTM component. The rest of edges related to the road, ditches and shoulders were simply used for creation of 2nd grade ruled surfaces so that the edges were used as n generatrices with m fillings. In areas with greater curvatures greater number of fillings m were used. Fig. 7. shows grade separated road junction created by previously adopted rules. DTM was cut by intersectional back slope/fill slope breaklines and presented through a 3d grided visual style which provides a better intuitive visual perception of the terrain while road junction elements were modelled as a 2nd grade ruled surface.

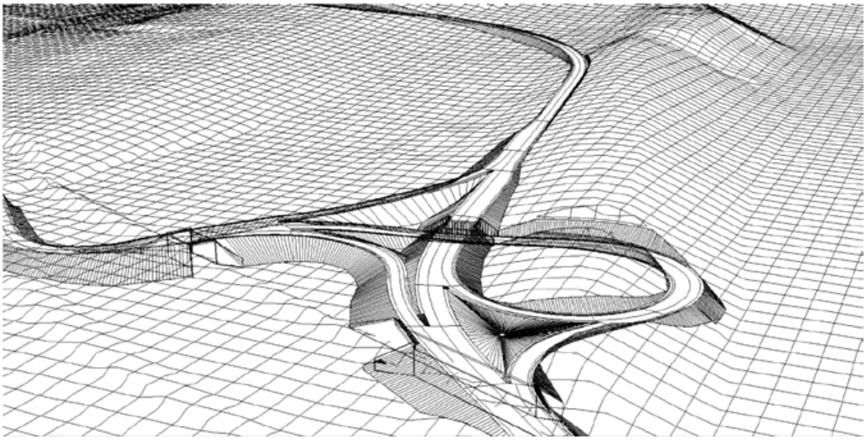

Figure 7 Road junction 3D model on DTM.

4 Visualisation

Creating a photorealistic visualization of a designed object is a common practice today. Quality aproach to the preferred detail level is here of crucial importance. It is neccessary to identify importance of a particular part of the provided model visualization in order not to unnecessarily lose software and hardware resources and time. In creating a visualization, a case where it is the only aspect of project presentation and where basis for its creation has no reference in design must be differed from a case where visualization is based on a model obtained as a designing result. In the latter case, the level of detail is already expressed through designed road elements to a large extent (horizontal and vertical elements of a road route, transverse slope, back slope/fill slope and shoulder placement detail). Thereafter, a basic dataset, in form of associating the appropriate material texture bitmaps (asphalt, concrete, vegetation etc.), horizontal road signs, public lighting, houses and vegetation placed near the road route, etc.), is required for visualization creation purposes. At the same time, what can be omitted are the material glare and shading effects (as a results of a time-consuming raytracing or rendering), relating to the final level which is to be achieved in visualization of a road design - a driving animation, where the earlier mentioned detail level would be lost (due to a fast passing near objects).

Figure 8 3D terrain and road junction model visualisation.

5 Conclusion

Due to their "comprehensiveness", the integral software solutions specialized in a specific engineering field design can sometimes be a kind of a trap. Namely, the whole design procedure, from vectorization, the DTM and the road model, to, finally, visualization could be performed within the single software. Since the software is capable of processing different level and quality data, the DTM creation could be performed by using a basic contour plan and both significantly strain the model and slow down the data processing. A creation of a 3D road model in the grade-separated road junctions would be very demanding and the integration of some of the details almost impossible even by using the progressive tools at disposal. Finally, the straining of such complete 3D model by a detailed visualization and by stressing the elements which would eventually be unnoticeable to the final user could lead to the drastically aggravated work with the database and to losing the point of providing a higher design software level than the basically required one. Therefore, the automation of a specific software should not be allowed to „perform" the data processing in such segments which require design engineer intervention and supervision. While doing so, the same processing level depending on final product requirements should be applied through all the design phases. A quality selection of minimal required DTM creation vector data and their proper categorization and usage will provide a small enough database with a sufficiently precise model for a start. By using such model we will not restrict ourselves exclusively to the installled road modelling software support but also intervene by using appropriate program routines which would provide the minimum data number for creating the required surfaces. Finally, the basic required visualization elements can be easily added to such a precise and, from the database point of view, small model.

Figure 9 Road junction model visualisation detail.

This enables us not to be restricted to using a single software or all the installed software options for all the required DTM and road elements. Regardless of the daily growing possiblities and capacities of today's computer data processing speed and their availability it is not the same whether even a few percentages of less or more time are spent on data processing in recurrent procedures. This can be the key factor in achieving the required design level by using 3D modelling within the longer design time frame.

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