Development of multifunctional realistic 3D model of Municipality of Koper

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ABSTRACT: Municipality of Koper is one of the biggest municipalities in Slovenia. Municipal spatial planners are coming across with various problems because of insufficient and uncertain digital data. Frequently terrain work is unavoidable. To decrease the amount of terrain work, almost whole municipality was scanned with lidar. From obtained data we made a realistic 3D model for various purposes. It includes different vector layers and objects like buildings and trees. Two versions of 3D model are being developed - one less detailed for entire municipality and other more detailed for city centre of Koper.

1 INTRODUCTION

Municipality of Koper is one of the biggest municipalities in Slovenia. It covers an area of 311 km^2. The density of population is 158 people per km^2. The terrain is far from being uniform; it is quite heterogeneous with the heights from 0 to 1028 m.

Municipal spatial planners are dealing with various problems caused by insufficient and uncertain data which leads to extended terrain work. There were various ideas how to make their work easier, but all of them need very precise data collection about the terrain as a starting point. As the DTM sold by Surveying and Mapping Authority of the Republic of Slovenia is not precise enough (resolution 12,5 ×12,5 m), we decided to perform lidar scanning. At the end of the year 2007 and in the beginning of 2008 about 160 km^2 of surface in Municipality of Koper was scanned with lidar. This covers the entire inhabited area in the municipality.

After that we started to use acquired data in various manners. One of them was also the desire of developing the realistic 3D model that would represent entire municipality. This would render possible visualizing the entire municipality as realistically as possible with the buildings, streets, infrastructure etc. The development of the program for visualization of mentioned realistic 3D model was quite complicated, especially because of huge amount of data and limited capacities of computers on which 3D models will be used.

2 THE NEED FOR REALISTIC 3D MODEL

During the last decades, spatial planning and managing has changed a lot, especially because of progressive introduction of digital spatial data and computer programs for their use and development. But actual state is still far from the state in which all the work of municipal spatial planners could be done from the office with the help of computer, digital data and special software. There is still a lot of information that needs to be acquired on terrain with the survey. In some cases planners are dealing with data that is not possible to obtain without terrain examination but in majority of cases is not like that; it is because they are dealing with insufficient or nonexistent data about the terrain or either existing digital spatial data that is not accurate enough and needs to be verified on terrain.

Municipal space planners are practicing terrain work especially for evaluation of parcels, elaboration of space plans, and the assessment of space based taxes or only to get a conception about specific area. If a spatial planner wants to evaluate a parcel from the point of suitability for a specific type of use or to evaluate the value of the parcel, there is some information about it that he can acquire only on terrain. But among this information there are quite a few facts that can also be obtained from a realistic 3D model of the city or municipality that includes all the buildings and infrastructure and allows "to fly" over it and between them.

To diminish their terrain work we already (in the past) made multiple 3D models with the purpose of evaluating the terrain from various points of view (view on sea, hours of sun, slope, etc.) (Žerjal et al., 2007, Kolega et al., 2008). But this 3D models offers only a chance to evaluate the terrain from a specific point of view, they do not give us a conception of the area that we are analyzing. One of the main reasons for developing this realistic 3D model was therefore exactly this chance to get the conception of the area which is more realistic and informative then just looking at ortophotos. With the use of both 3D models there is only a small range of information that needs to be acquired on terrain.

3 DEVELOPMENT OF 3D MODEL

3.1 *Bases*

3D model in our case is a combination of application, 3D model viewer and 3D data. Main sources of data that we started with were DTM (digital terrain model) and digital ortophotos, both acquired by lidar measurements. Measurements were done only on populated areas so we did complete the missing data with information from Surveying and Mapping Authority of the Republic of Slovenia which are less accurate (DTMs with resolution of 12,5 × 12,5 m and 25 × 25 m) and older digital ortophotos (made in years 2006, 2007 and a small part in 2003). But DTMs and ortophotos are only the base. If we want the 3D model to be really helpful for spatial planners it needs to also contain data about buildings, communal infrastructure, roads and all other things that are important when someone is validating or analyzing a specific area or parcel. For the first phase we decided to add data about buildings and communal installations, which include power lines, canalization and water supply. We used the data collections from Surveying and Mapping Authority of the Republic of Slovenia or directly from establishments responsible for determined service. Beside this we also added data about the roads layout, which was acquired directly from the Municipality of Koper.

3.2 *Software*

We started with examination of tools and applications available with a preference for open source projects.

A 3D viewer is a complex computer program and there are few of them on the market. But we did not find any that would fit our needs completely and a second best solution was to find an open source project that is actively developed and to expand its capacities to match our needs. We started with definition of expected qualities:

- open source, no hidden parts that can not be changed
- active, so we do not have to do all the work in the future (larger dataset, other hardware or platform, ...)
- scalable - fast enough today but scalable in the future when we expect even more data
- analogues, close to our kind of problems

We decided that "Virtual Terrain Project" would suite our needs and plans for future development. It has all required qualities, although it's not perfect. Its development is sometimes too active and we could say that some parts of it are complex and really understood only by their authors. But the entire project is modular and if some part would cease its development it could be replaced with a similar one or a new one could be developed.

We decided that our realistic 3D model of Koper will be composed from two separate scenes. One will be the general viewer for the area of whole municipality and the other only for the city centre of Koper. The main difference will be the precision of representing building data. For the municipality 3D model, we used data about buildings from Surveying and Mapping Authority of the Republic of Slovenia. Their data for building includes only few attributes. From those, we used building's ground plan and height. There is no data about roofs or frontage, so we are adding (inventing) roofs, windows and doors to houses, because even if data is fictitious the resulted view is more real then cubes alone. The result is that the user can get an approximate idea about the appearance of the area, but he can not find out for example the colours of buildings etc.

The second scene of 3D model shows (for now) only the city centre of Koper and is more sophisticated. We photographed the buildings, trees and other objects and added pictures to frontages and roofs and other objects. We also modelled the houses with passages, churches and other special buildings. This way the model is much more realistic and the user can get a real sense of the place.

The main "type" of viewing the data is in way that the user can "fly over" an area from the specific height, between 0 and 500 meters from ground, or "take a walk" between the buildings in more detailed model of city centre. There is also a possibility for inquiry when a user "clicks" on specific object.

Figure 1: Example of terrain with "invented" houses in 3D model of whole municipality.


Figures 2 and 3: Examples of detailed buildings with photographs on frontages and trees in centre of Koper.

3.3 *Data management*

Although precision of data acquired with lidar is around point every 20 cm, we decided that a grid of half meter (resolution 0.5 × 0.5 m) will be used as terrain grid. In case of Municipality of Koper the region size is 13 km × 14 km which becomes grid of 26000 × 28000 points. Here we encountered our first problem; we can not load the entire terrain at once. Terrain grids in VTP are square and sizes are powers of 2. A grid of 16384 × 16384 would use approximately 2 GB of RAM (actually 1 GB for heights and 1 GB for texture). In theory we could load such a grid but firstly it would not cover the entire region and secondly its size is too close to the limits of typical computer used in Municipality of Koper (32 bit and about 3 GB of RAM). Some tests showed that limits are even lower. In VTP, maximum size of grid that is usable is 8192 × 8192 points. VTP solution to this problem is the use of tiles, small parts loaded in memory separately and of different grid sizes. But the idea in theory was better than the realization; it is working well only if number of grids is not too high. For complete size terrain use of VTP tiles resulted in slow turning and viewer response.

After a month of testing we decided that we need two layers of details and to switch between them at specific height. For distant view we use the grid of 8 k × 8 k points, which means that points are around 2 m apart. That is 4 times less than what we set as our goal and results in 16 times smaller data files. For a detailed view we started to develop our own tiling. Loading of data had to be fast and loading of 8 k grid takes more than a minute. This is not a problem for initial grid but we cannot wait a minute every time we pas a region boundary. The difference between 2 m grid and 0,5 m grid starts to be visible when we look from around 500 m of height and that is the threshold for switching between layers. Tiles need to be small for loading, but if they are too small, they are hard to manage because of their number. Considering all, we decided for tiles of 256 m (512 × 512 points).

Even loading of small tiles is not fast enough and that is why we added a “trick”. Every tile has two representations. Low quality has same resolution as initial grid and is constructed from it in RAM. High quality is loaded from file. So the detailed layer is constructed from tiles which are of different precision, only the nearest tiles are high quality (and even they may be low quality for few seconds when loading). In this way the moving around highly detailed terrain is fast and pleasant to use. Only a list of tiles is always present in memory, the data is constructed and loaded as needed. We limited the number of tiles in memory to 150 - 250.

3.4 *Adding layers of other data (structures, objects and vector data)*

Data representation in VTP is highly modular. Data loading of terrain is separated from loading structures, objects or vector data. This additional data (additional layers) are loaded locally, usually only in a radius of 2000 m from camera position.

Viewer can read vector data from shape files (points, polygons and polylines). Usage of attributes from shape files is limited; they can be used for colouring, a date, some description and as external links to 3D representation and external data view (on properties page there is a clickable link which executes system associated action to specific file type, for example to view a jpg).

VTP has its own format for buildings (structures) definition that is called VTST format and it is based on GML (it is described on www.opengis.org/gml/). It is an xml format. Buildings have planes (walls) and on planes pictures can be added. But when you add 5 pictures per each building you quickly run out of memory. So for now only smaller regions (city centres) can be equipped this way. With passage to 64bit systems this limitation may be overcame.

Prepared 3D objects of various formats (3ds, obj, etc.) can be loaded and positioned (absolutely or relatively) on terrain.

First time an additional layer is used, a dialog box prompts the user about how the specific layer is going to be used (colours, line widths, etc.) and the user’s response is than saved for automatic loading at next run.

We added a drawing tool for highlighting a region with an annotation, colour and date.

3.5 *Usage and future plans*

The main goal of the 3D model is visualization of various terrain and urban features in 3D. The user should get as realistic as possible representation of terrain, together with additional data like communal infrastructure. The model is not meant for performing “classical” spatial analysis. It can only display prepared spatial layers and in this way also “simulate” the appearance of possible events in realistic 3D space. For example, when the spatial planners on

Municipality of Koper needed to decide where new buildings should be built and where not, we created and added a layer of all potential new buildings (we used the database of applications sent to the municipality by citizens who want to change the land use of their parcels to residential use, which would allowed them to build new houses there). These way spatial planners saw how all this new buildings would look like in landscape, which helped them to decide more easily about each questionable parcel whether or not it is appropriate to change its use to residential.

Since September 2008, first version of realistic 3D model of Municipality of Koper is in phase of experimental use. We expect users (spatial planners on Municipality of Koper) to evaluate the product and to propose ideas about how to expand its usability.

Anyway our plans are to eventually add new layers and data to existing ones. New layers would be: the register of spatial units (which includes house numbers, boundaries of settlements and other spatial entities) and cadastre for sure and probably some others proposed by users.

For now vector data and objects like buildings have only a few attributes (date, description, representation and possibility of external link). Eventually we will add the possibility of a more detailed inquiry. For example, a user will be able to "click" on a road or a building and get information about it, like the name of the street, house number, settlement, etc. We could also expand usage by connecting the viewer with existing databases and display structure data without external applications.

4 CONCLUSION

From the first period of experimental use we established that the application is quite usable. It can diminish terrain work of spatial planners. With time, the 3D model will be progressively developed with new layers of data which will increase its applicability and practicability.

The nature of the application is that it is quite "open" and therefore could be used for representing other types of data as well, for example a model of sea floor that we are also developing.

With time, this kind and amounts of data will become less problematic for viewing in 3D on "everyday" computers, but we must not forget that the quantities of data will also progressively grow at the same time as the number of representing layers and their attributes. We can say that the problem of huge amounts of data remains our constant companion. This means that one of our main goals in the future will also be the development of the application in the sense of enlarging its capabilities and developing new ways of transforming the huge amounts of data so that they can be concurrently visualized in quantities as large as possible.

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