

# GENERATING PRECISE AND ACCURATE 3D CITY MODELS USING PHOTOGRAMMETRIC DATA

O.Emem\*, F.Batuk,

YTU, Division of Photogrammetry and Remote Sensing, Beşiktaş Istanbul, Turkey- (oemem, batuk)@yildiz.edu.tr

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## ABSTRACT:

This paper presents a study, which aims to generate 3D city models from existing 2,5D maps. A 3D city model is generated via CAD software using the existing photogrammetric 2,5D maps of a chosen pilot area. 3940 buildings, 8000 trees, 810 streetlight lamps are modeled in the scope of the project. Two 1/5000 scaled orthophotos are used for visualization of the surroundings. In order to reach the high vertical accuracy for buildings, extra editing processes are applied to the all buildings in the project area. Therefore, the vertical errors of buildings were corrected on 2.5D photogrammetric maps. Finally a precise and an accurate 3D city model of Beşiktaş Region is generated and converted into VRML. Using VRML format, it is also possible to visualize and animate the 3D city model on the internet.

## 1. INTRODUCTION

Developments in computer technologies supplies us new tools, which can be used for administration, planning, applications and making things easier in daily life. Furthermore these tools are used to increase the quality of daily life and to save the nature. The names of these tools are CAD, GIS, GPS, laser scanning, radar, digital photogrammetry, 3D city modeling from the point of view of measuring, evaluation and presentation. These tools have been developed since 1960's. Instead of using the hard-copy maps, new technologies such as visualizing the improvements of city on the display and having a tour on a 3D virtual city make things easier for architects and city administrators, and these abilities let them decide effectively and consistently.

While the applications in digital environment were investigations of possession, taxing etc. in 80s; those applications were moved to planning and preserving habitat in 90s. Nowadays it is possible take a tour around cities in virtual reality models, and those models give opportunity to make measurements and to design new concepts.

The 3D city models, which generated by different methods can be transferred into GIS easily and used as a base for GIS. In addition, it is possible also to make queries on the 3D city models, and these 3D city models can be published on internet for civilian users (Zlatanova, 2000).

Nowadays, 3D city models are generated using 3 main approaches: automatic, semi-automatic and manual. Thus, existing 2D and 2.5D maps are bases for semi-automatic and manual 3D city model generation.

Photogrammetry is an appropriate tool to provide information about man-made objects, vegetation cover and the like (Gruen, 1999). Photogrammetry and digital image processing techniques play important role to make visualization technology practical and cost effective. In the 3D city modeling, simulation is done by using true information via photogrammetry. Photogrammetry appears to provide the only economic means to acquire truly 3D city

data (Förstner, 1999). By means of true information in the content of the precision and accuracy, the 3D city models can be used for simulation and analysis from visualization and animation (Emem, 2002b).

In spite of high vertical and horizontal accuracy of photogrammetric maps, it is not possible to use them directly in the 3D city modeling. Especially the buildings on the digital maps have some vertical errors, when we examine them from the perspective view. Hence, these perspective errors should be edited before using them in the 3D city models (Emem, 2002a).

In this paper, a manual 3D city model generation using existing 2.5D maps project is presented. But this paper mainly focuses on editing the height differences on buildings.

## 2. METHODOLOGY

In this study, some certain methods are applied for the 3D model generation as follows:

- Examining of 2.5D maps for elimination of the data which is not used
- Generation of DTM
- Editing the vertical differences of the buildings and solid modeling of buildings
- Preparation of the 3D cell libraries and locating them on DTM
- Visualization
- Virtual reality on the web.

The modelings of roof of the buildings are not aim of this study. Because, modeling of the roofs requires extra data, which does not exist in the 2.5D photogrammetric maps.

## 3. DATA FOR THE 3D CITY MODELS

The 3D city models contain data, which is related to the spatial objects. Those objects might be located over the surface, on or under the surface, and those are includes the details, which has certain shape and location. Those objects

are generally topography, buildings, transportation, plant cover, infrastructure and other details related to the goal of application.

Actually, the 3D city models are focused on buildings; however it may contain roads, green cover, trees etc. according to the usage of model.

The data is most essential component of the 3D city models. Therefore, data should be in appropriate form and accuracy. If the data was collected as a purpose of generation of the 3D model, it will largely be suitable for use. But, when we consider using the existing data, the extra editing jobs will be inevitable.

The 3D city models are highly useful for city administration however; collecting required data is costly and very hard. Therefore, using existing data for model generation is cheaper and practical. Especially existing maps produced by photogrammetry is much more suitable for 3D city model generation (see Figure 1, 2).

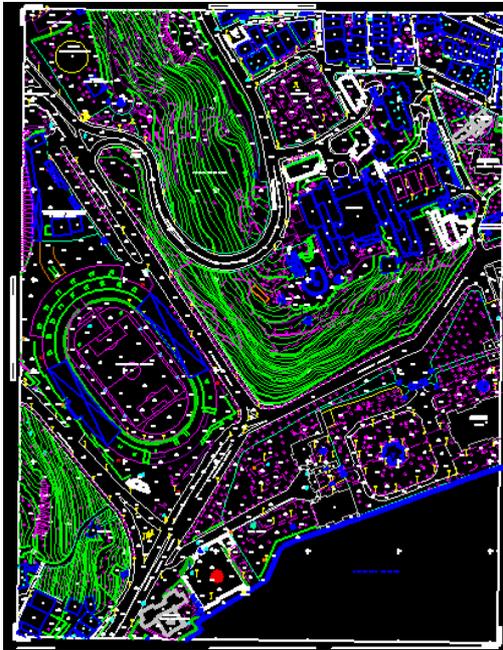


Figure 1. Top view of digital photogrammetric map

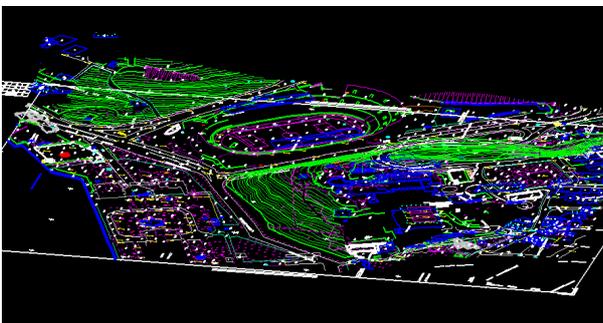


Figure 2. Perspective view of digital map

In addition to the maps, orthophotos and rectified image of the building facades are used for visualization of the 3D model. These images are draped and rendered on surfaces for photo-realistic view.

#### 4. THE DATA PREPARATION

In this study, 1/1000-scaled digital maps are used. In order to reduce the mess, some unnecessary data such as administrative boundaries, walls, railways etc. is eliminated from the maps. Selected 53 object types are selected and used. Some of those objects are as follows:

- DTM points
- Breaklines
- Sea and lake boundaries
- Sea ports
- Buildings
- Roads
- Plant cover boundaries
- Trees and lamps

After elimination, those data are classified according to its type (see Figure 3). For instance all the buildings types such as residential building, mosque, factory etc. are classified in the same level. This class is used for generation of the solid models of the buildings. Some certain classes are constituted for all data types.

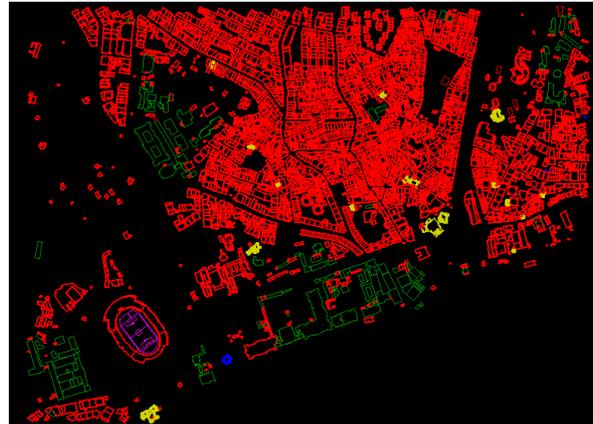


Figure 3. Buildings

##### 4.1 Generation of DTM

In order to generate DTM, related object's level is used. This level contains features and height points, which can define the topography of the area. These features are DTM points, declivities, contour lines, boundaries etc. All these features are converted to the points. Finally terrain was triangulated with these points. But some of these points have wrong z values and needs to be eliminated. During the production of the maps, human made mistakes causes this wrong z values. Sometimes operator can measure the heights incorrectly. Therefore these values should be edited or deleted from the data during the process.

In order to correct them, manual or automatic procedures can be applied. In manual way, this problem is solved interactive control and editing (Yastikli, 2002). Operator triangulates the surface and examines the triangles visually. But this method causes neglect of the lower errors and time consuming.

Automatic methods are editing the points automatically with selected parameters (Yastikli, 2002). But using this method can cause losing the small details on the surface. In this project both of these methods are used for best result. Thus, height errors and faulty triangles are corrected or deleted in order to reach the precise DTM (see Figure 4). Triangulated

surface is converted to 250.000 sampling points and grid/lattice (see Figure 5).

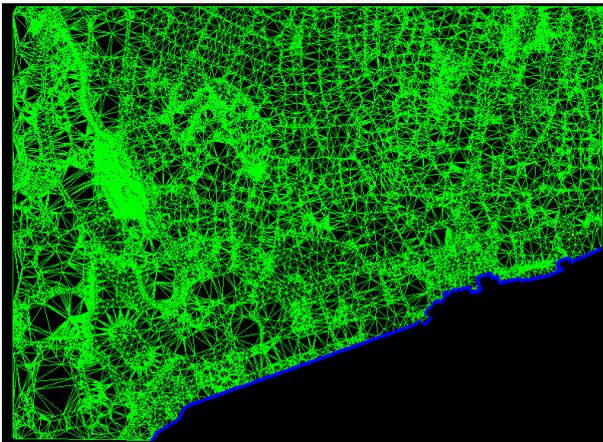


Figure 4. Triangulated surface

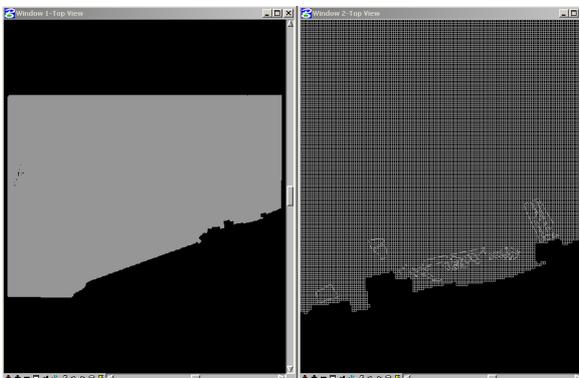


Figure 5. Lattice of the surface

#### 4.2 Editing The Vertical Differences of The Buildings and Solid Modeling the Buildings

Like the z errors in the point clouds, the buildings have height errors in it as well. The reason of these errors is again arises during stereo compilation like other z errors. Operators sometimes see different points other then the roof corners of the building (Figure 6). Even if they compile it with true z value, it appears as an error when seen from the perspective. For instance he/she can set the floating mark on the surface instead of roof. They can not be realized from the top view (see Figure 6). So that errors can not be edited during 2D editing phase. This kind of errors is very rare, but can be encountered and needs high attention (Emem, 2002a).

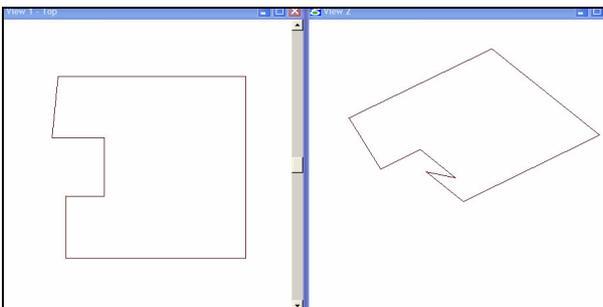


Figure 6. Wrong point compilation error

The other error arises because of the roof corner height differences. Despite the operator compiles the building correctly, this error comes from the nature of the view and it

is inevitable. Normally the height of the building corners should have the same height value. But some buildings which have triangle roof types are compiled with different height values (see Figure 7).

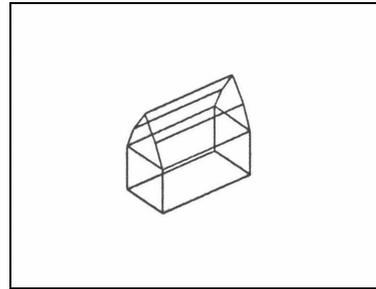


Figure 7. Triangle roof

This kind of buildings can not be realized like the preceding error during the 2D editing phase (Figure 8).

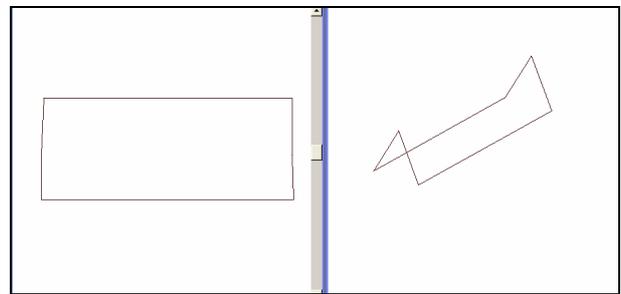


Figure 8. Height difference of the roof

Even if both errors are not critical for conventional usage of maps, they are important errors for 3D city modeling. Therefore these errors should be corrected before solid modeling the buildings.

If we consider the compilation process of buildings, the operator starts from a corner of the upper point of the building. Therefore, there are 2 ways to correct height differences on the buildings. First, accepting the arithmetical average value of the building data points. But this assumption causes changes on the values from the real values. Other way is to assume the correct value as the first compilation data point the building. Because, operators generally fix the parallax on the first data point correctly and more carefully in addition the most of them start to compilation from upper point of the building instead of the roof corner (Emem, 2002a). In this study, the first data point of the building is assumed as the correct value. Therefore all the buildings on the project area were edited with the accepted height values (see Figure 9, 10). Some buildings on the project area such as stadium and complex shaped hotel were edited separately from others.

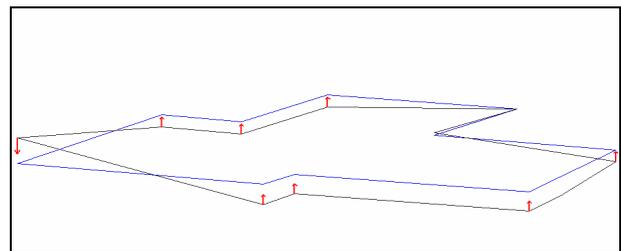


Figure 9. Correcting values according to accepted value

After editing, the entire buildings are solid modeled by extruding them down to the DTM (see Figure 11, 12, 13).

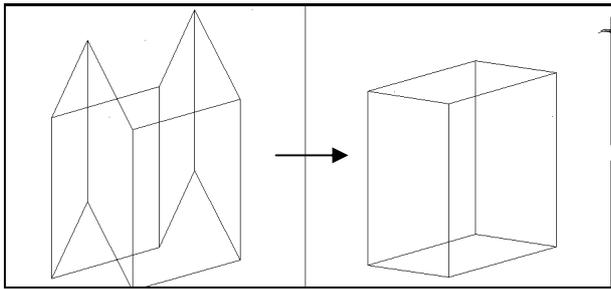


Figure 10. Before editing and after editing

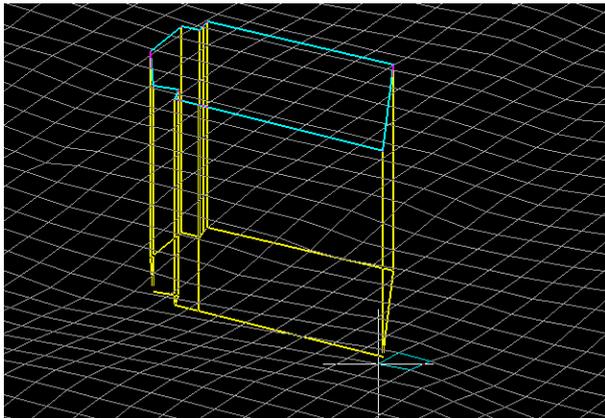


Figure 11. Extruding the building

This height correction process provides buildings to be better shaped for the 3D city models. Since it is hard and expensive process to extract roofs from the existing maps, the roofs of the buildings are neglected. Editing of the height differences on the buildings are done automatically.

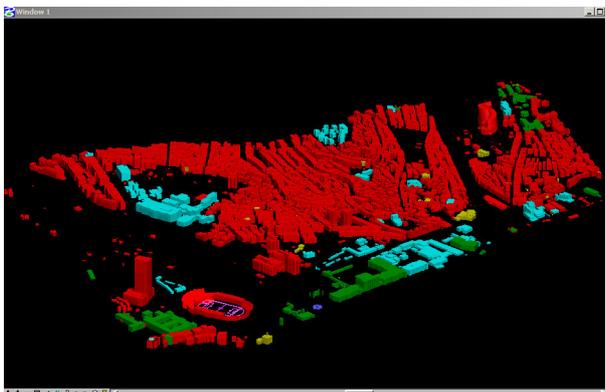


Figure 12. Solid models of buildings

#### 4.3 Preparation of the 3D cell libraries and locating them on DTM

In this study, a symbology library is prepared for two kinds of trees and street lamps. Those symbologies are converted to the cells to use them in the 3D city model. The heights of the trees and lamps are assumed as same values (see Figure 13, 14, 15). Therefore, these 3D cells are placed just for visualization of the 3D city model.

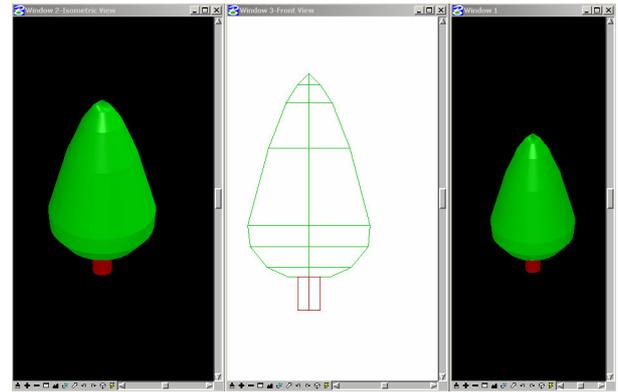


Figure 13. Pine tree symbol

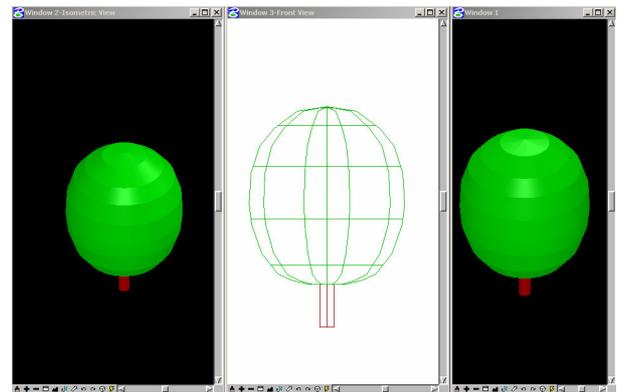


Figure 14. Symbol for other tree species

The trees on the existing map, which is used for this study contains two species of tree. These are pine trees and other species. Therefore, two types of tree symbols are used in this study. One symbol is designed for street lamps (Figure 15).

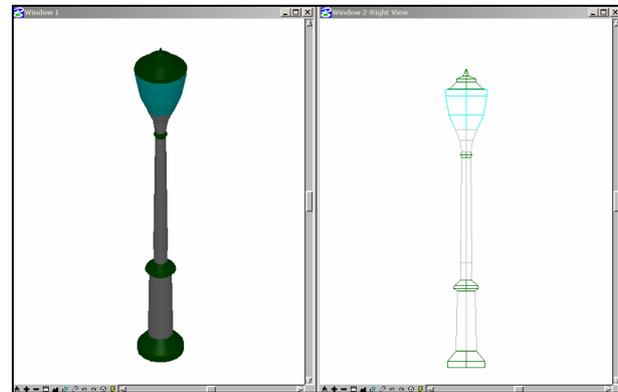


Figure 15. Street lamp symbol

However, the trees and the lamps are displayed as planar objects in the digital maps, they contain height values. They are compiled from the intersection point with the surface if possible. In the 3D city model, those 3D cells are placed instead of the planar objects on the map.

#### 4.4 Visualization

In this study, two different visualized city models are generated. First, the orthophotos of the project area are used. Orthophotos are draped on the DTM, thus photo-realistic view of the surface is generated (see Figure 16).

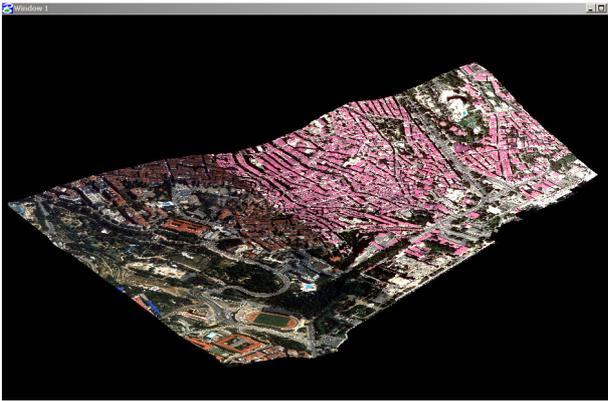


Figure 16. Photo-realistic view of the surface

After draping solid modeled buildings are merged with this view (Figure 17).

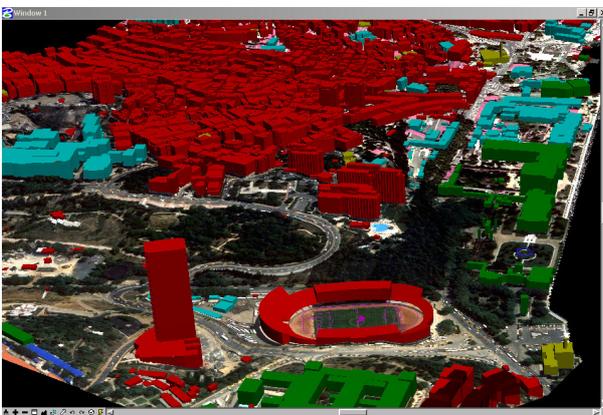


Figure 17. 3D city model

Secondly, the 3D cells and colored DTM is used. Primarily green cover areas and watery areas are determined and these areas are painted green and blue (Figure 18).

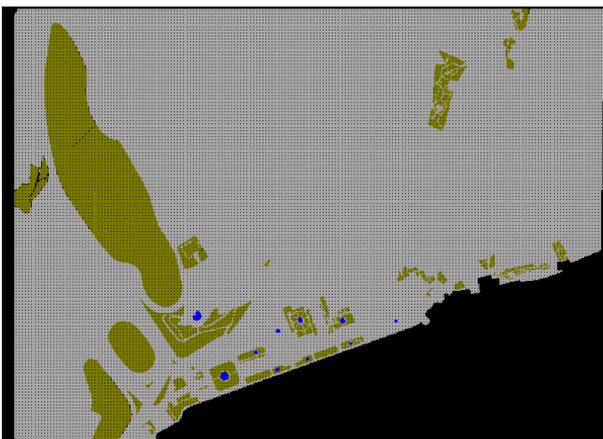


Figure 18. Colored DTM

Then, 3D cells are placed and merged with the solid buildings. Additionally roads and green covers areas are merged with the other files. Finally, two different visualized 3D city models are generated (see Figure 19,20).

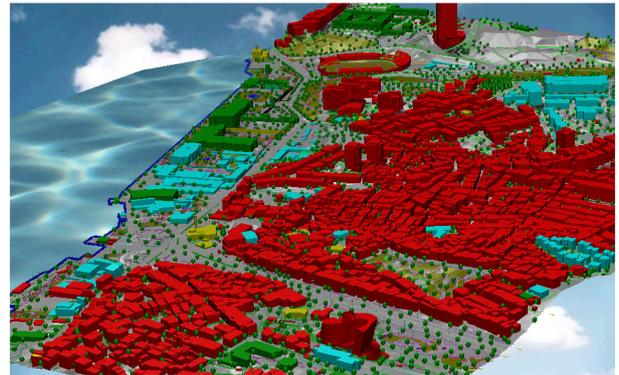


Figure 19. 3D city model with 3D cells

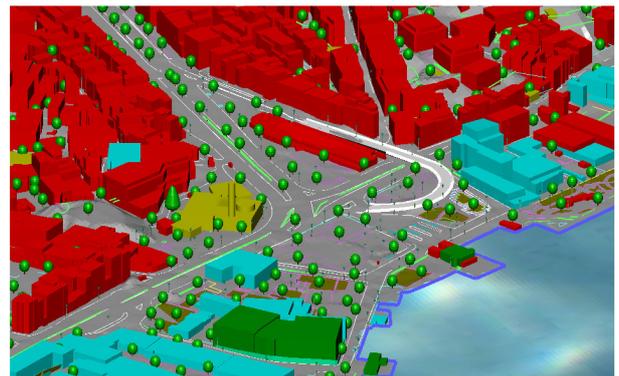


Figure 20. 3D city model

#### 4.4 Virtual Reality

After generation of the 3D city model, it is aimed to submit the model to the citizens on internet (Özmutlu, 2001). Thus, VRML is chosen to achieve this purpose (Zlatanova, 2000). Therefore, the 3D city model is converted to VRM language. MicroStation Software is used for conversion. Finally, the 3D city model is published as VRML via web page (see Figure 21).

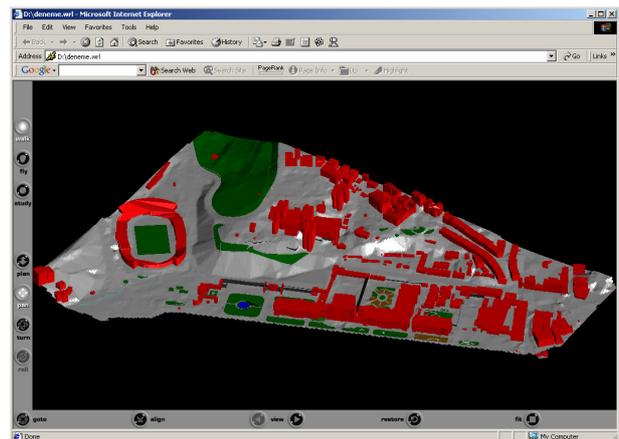


Figure 21. VRML view

#### 5. CONCLUSION

Developments in computer technologies have improved new tools, which can be used for administration, planning, applications and making things easier in daily life. Furthermore these tools are used to increase the quality and to save the nature.

Photogrammetry is economical way to provide true height values, which is required for 3D city modeling. Since, collecting the data is costly and very hard, 2D and 2.5D photogrammetric maps are used as base. Therefore, accuracy of the city model is based on the accuracy of the base map. Since existing maps are not containing data about the roofs of the building, it is recommended to gather required data during production of the maps and to take this as a common rule. Otherwise same procedure will be done repeatedly and data will be duplicated.

Because, the collection of the data required for the 3D city models is very costly, using existing data is became current issue. But using existing data directly in 3D model generation might be full of errors. Especially buildings, which are the main objects of the 3D city models, have distinct errors. Using the data without editing will cause X, Y and Z errors in the 3D city models. Additionally, view of the model will be different from the real world shapes.

In order to generate accurate and precise 3D city models from the existing photogrammetric maps, the data should be edited as required.

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