MERGING DTM AND CAD DATA FOR 3D MODELLING PURPOSES OF URBAN AREAS

Siyka Zlatanova Nedkova*, Michael Gruber and Michael Kofler****

*International Institute for Aerospace Survey and Earth Sciences
7500 AA Enschede, The Nederlands
**Institute for Computer Graphics
Graz University of Technology
Münzgrabenstr. 11, A-8010 Graz, Austria

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Abstract

We present in this paper a method for merging terrain data from DTM and CAD data. The method uses data from DTM which are reorganized to a set of 3D polygon in a TIN representation. The CAD objects, i.e. buildings and surface features, are fused with DTM after applying a special procedure.

The used techniques ensure the consistency of the data model in terms of avoiding undesirable gaps and occlusions between the DTM and CAD features. A partial simplification of the buildings facilitates the process of texturing and manipulating the data.

In the next steps we will strive fore possible automation of the entire procedure. This shall support a more or less autonomous and cheap manner for building 3D photo realistic models of urban aereas.

1.Introduction.

Three dimensional (3D) digital models became a very important issue in the last few decades due to the increasing demand for a realistic presentation of the real world. A 3D model gives better presentation and facilitates the processes of planning, controlling and decision making especially in the urban areas. Furthermore modern graphics workstations which are available on the market allow already to handle and visualize large amounts of data. Since there is need for 3D models and sufficient hardware, the task of the researchers now is to develop technologies for automatic construction of 3D models using different data sources.

Speaking about 3D models, it is always of great importance to clarify what is the purpose of the model, or in other words, what is the area of expected applications. The organization of the data in the model can be totally different if one needs only a realistic view of the real world with additional tools for flying trough, etc., compare to needs, for example, spatial analysis to be provided. Another aspect which cannot be forgotten is the accuracy of the data. Depending on the application, it may appear that there is no need for very accurate data and there is a possibility for simplification of the data sets. This, without any doubts, will facilitate the process of data handling. The goal of this paper is to contribute a part to the technology for building a 3D city model, namely the merging of terrain data and objects for photo realistic visualization and manipulation, which will supply users with:

- photorealistic presentation with possibilities for navigation through the model;
- abilities to model, design and analyze the data of a city scape, e.g. arrange buildings and man-made objects, allow queries, etc.

The investigations are focussed into two important tasks. Broadly speaking, the first task is to construct geometry and second one is to texture the model. The aim of the approach is to make use of various data sets comming from different sources, e.g. 2D maps, aereal images, Digital Terrain Model (DTM), etc. The joint efforts of the researchers at the International Institute for Aerospace Survey and Earth Sciences(ITC), Enschede and the Institute for Computer Graphics (ICG), Graz will result finally in a automatic or semi-automatic procedure for creating, storing, manipulating and analyzing 3D city models.

2. Data sets

Various methods for constructing 3D models are object of studies and different approaches concerning data extraction and data merging are developed (see [2,5,7,11]). The way of constructing the 3D model depends on the data sets which are used. For example, the work carried out in ITC, is on the construction of models only from aerophoto images, applying 3D digitizing for gathering the required information. Existing DTM, 2D CAD data and aerophoto images are the source data used at the ICG.

The method presented here, uses three major groups of data:

- Digital Terrain Data (i.e. DTM)
- Geometric 3D objects, e.g. buildings
- Man-made objects on the surface, e.g. passways, patches, etc.

2.1 DTM

Two basic methods can be used for the representation of the relief, namely a regular grid (Raster DTM) and Triangular Irregular Network (TIN). Generally speaking, the grid presentation describes the terrain at a regular grid with even distances between mashes. This will cause smoothing effects and may be insufficient at large scale applications. However, the raster-grid presentation allows an easy way of handling and storing the data. The uniform grid has a benefit of offering simple and easy to automate methods for creating Levels Of Detail (LODs) which is important for fast visualization of huge amount of data (cf. [6]).

Many investigations have been done on polygonization of the surface using TIN (cf. [3]). TIN gives the best presentation of the relief in case of a rough terrain, with many important features. Unfortunately, TIN presentation is quite difficult structure for updating. Each modification of the surface usually requires re-triangulation of the whole TIN. Indeed, there are approaches (cf. [8, 11]) which allow a re-triangulation only in those restricted areas where the changes are made. However, in this case information about constraining polygons should be introduced and maintained. Another drawback of TIN is a quite complex manner of creating LOD (cf. [13]) and for this reason there are still no algorithms and software developed which use TIN presentation for a real-time visualization.

The type of DTM presentation is an essential aspect of the 3D construction of city models. Several important considerations influence the choice. The urban areas, consisting only of terrain features, are relatively small compared to the areas outside the city. The surface is basically covered with building and man-made objects and only small parts of the surface are purely natural terrain areas. The expectations are that these drawbacks of TIN will not disturb the modelling process. The reason is that very small areas have to be re-triangulated in case of changes of the surface or for applying LOD in real time.

Another significant consideration is the importance of the terrain features in the urban areas. It appears that parts which are not man-made or man-reconstructed objects are of historical or natural importance for the town, requires a precise description of the surface.

The reasoning discussed above leads to the conclusion that the TIN presentation is more suitable structure for the urban areas than the grid presentation. Therefore TIN is used as a surface description in the approach described below. The manner of gathering data for constructing TIN does not matter for the suggested method. The data can be obtained either from surveying, or photogrammetry, or existing 2D maps with distinguished elevation data.

2.2 Geometric objects

The most important geometric objects in the towns are buildings. The major efforts of the researchers working on this topic, are devoted to their construction from the row data and their storage.

Two possible ways of describing are:

- simplexes
- parametric description.

Simplexes can be points, lines, faces, tetrahedrons, etc. In the common case buildings are described using faces. Faces are required for rendering and texturing purposes. This method allows topology to be introduced and maintained (cf. [11]). The gain of using topology is the ability to share metric information by using explicitly described spatial relationships. Topology ensures geometric consistency of the data model.

The second method assumes some simplification of the row data in order to be obtained regular "boxes". Then these boxes can be described using height, width and length. Thus for each particular building it is necessary to be known one point with its coordinates and sufficient parameters for the description of the size and shape of the buildings. This method reduces to certain degree the amount of data which have to be stored in the data base in case of relatively simple constructions. However, additional computations for constructing the faces are required in the process of visualization.

The information necessary for describing geometric objects can be collected from 2D maps (footprints of buildings), aerial images (roof outlines, chimneys), terrestrial images (facades' details), measurements from surveying, etc.

2.3 Surface objects.

Surface objects are all man-made and natural features which lie on the surface, e.g. streets, paths, passways, etc. The case, when man-made objects are included into the DTM, is clear and further processing is not necessary. DTMs without information about surface features have to be merged with additional data from 2D maps or measurements. Thus one significant question appears, i.e. how to merge the two data sets. The slope of man-made objects differs from the slope of the terrain and this fact requires a terrain modelling to be applied during data merging.

2.4 Photo realistic texture.

Photo realistic texture is another important point in the process of constructing 3D city models. There are discussions in the literature about the need of photo realistic texture. The experimental work in ICG Graz (cf. [2]) shows that more than 90% of data belong to the phototextures. There are at least two quite significant reasons:

- Photorealistic texturing applied to 3D models gives a most realistic presentation of the real world.
- Texture presents details and matereial properties, which are not content of the geoemtry.

One always has to take care about the degree of resolution which is reasonably acceptable to maintain. Some small details from the facades may occur very expensive for collection in terms of time, human efforts and money. Photo realistic texture allows very complex elements, from geometrical point of view, to be presented quite easily.

Essentialy there are two data sources which can be used for photo texturing:

- aerial images for the terrain and roofs of the buildings;
- terrestrial images, taken from street level for the buildingsí facades and other vertical faces.

3. Merging the data from various data sets.

Bearing in mind the topics discussed above, the following data sets are used in the work on constructing 3D models of the cities:

- digital terrain model
- 2D information about surface features and footprints of the buildings
- aerial and terrestrial images

A DTM is used for modelling the surface of the constructed scene. Information from 2D maps is used for deriving the footprints of the buildings. Various images provide information about the height of the buildings and data for phototexturing.

The suggested technology for construction of the geometry can be separated into several important steps:

1. Polygonization of the surface, applying the Delaunay triangulation (cf. [11])
2. Computation of the footprints of the buildings using the data from 2D maps and DTM. The process, in fact, is an interpolation of z-coordinates for each point.
3. Re-triangulation of the TIN using the footprints as a constraints. The re-triangulation can be carry out either for the whole surface or only for restricted regions. An entire re-triangulation is necessary for the initial constructing of the model, while a partitioned re-triangulation can be applied in case of local changes with the geometric objects.
4. Creation of the building boxes and posing at the minimum position of the footprints area (fig.1).

Intersection of the surface objects with the DTM and modelling the horizontalness of the patches and passways (fig. 2). This operation imposes changes in the surface which require modelling the sides slopes along the linear objects.

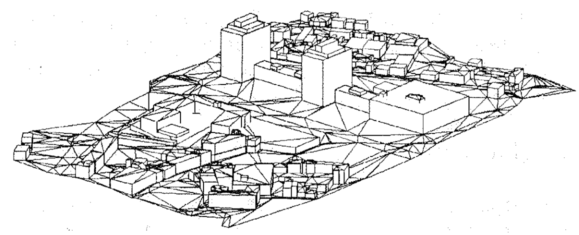

Fig. 1, Building boxes are posed at minimum hight of the footprint area onto the binDTM

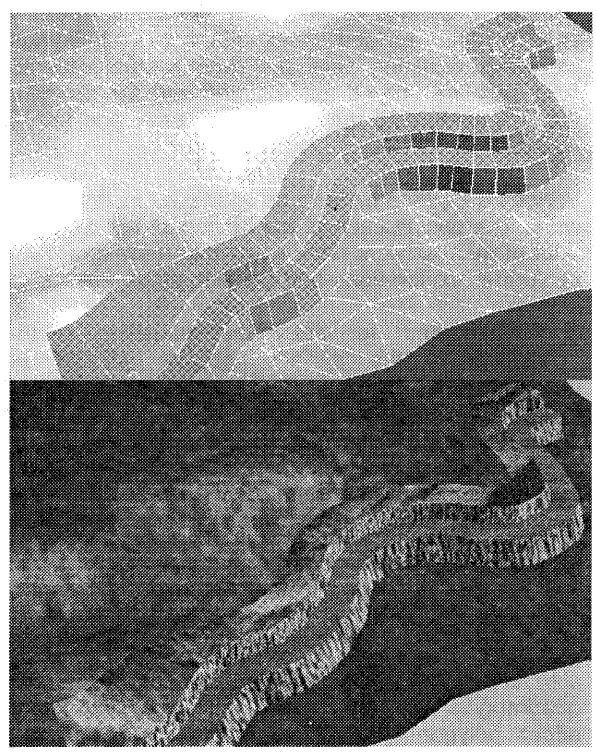

Fig. 2 Merging of terrain data and CAD data of a pathway

The idea of the method is to handle and maintain the reconstructed surface and every particular building as a separate objects. It can be realized that some points of the building occur below the ground surface, i.e. the buildings "sink" in the terrain. However, this approach shows several advantages:

- The walls of the building remain rectangular which facilitates the texturing process.
- Geometric objects remain easy objects for a manipulation. They can be removed
- Since the building boxes are set out at the point with minimum height, the
- correspondence between the surface and each building is ensured. There are not occlusions and holes occurred around the buildings.
- Rectangularity of the buildings allows a parametric description of the buildings.
- Detailed attribute information can be embedded to each of the separate objects (buildings, man-made objects, etc), which will allow queries about the model to be carried out.

4.Test area and future work

The ongoing work is based on two test areas from the central part of Enschede, The Netherlands and Graz, Austria. The first data set is from relatively flat area and is used for investigation of triangulation and re-triangulation of the surface. The second data set is from that part of Graz which is dominated by the Schlossberg. This hill offers a very rough surface and numerous buildings, pathways, retaining walls and various other objects. This data are utilized for texturing and for studying the way of merging the surface features and terrain mesh.

Various questions have to be answered in the future work. The construction of the 3D model still involves a lot of manual work. The most important directions for further explorations and developments are:

1. An algorithm for automatic modelling of the slopes of the surface objects should be developed. All the slopes along passways and patches are created manually in the examples presented in this paper.

2. Algorithms for automatic creation of different levels of detail for fast visualization have to be created.

The concept of LOD comprises both aspects of 3D visualization, i.e. geometry and photo texture. The geometry in urban areas consists of objects which are described by set of triangles (surface), quadrangles (walls of the buildings, etc) and multi-edges polygons (balconies, ornaments, etc).There are algorithms developed already for LOD for a surface presented by grid structure (cf. [5]), however, still there is no worked out concept for geometric objects (buildings) and surface features (passways, etc) laying on the ground. The complexity of the 3D data elements yields the following questions:

- How many levels of detail are reasonably to create? The expectations are four LODs for the building, 3 for the surface and three LODs for the photo texture.

- What kind of data structure should be used for storing the different LOD? The research work in this area gives some possible solution like quadtree (cf. [5]), BSP (cf. [9]) or R-tree (cf. [10]). In any case the tree-structure is considered to be the most suitable data structure for visualization.

- What kind of thresholds should be used for choosing the necessary LOD during the process of visualization? Since the thresholds for switching the LOD might be different for geometry and texture, a correspondence amongst the LOD must be established. The distance from the viewer is a compulsory threshold for both geometry and texture. Another threshold could be the current camera position and roughness of the relief.

- How to automate the process of creating different LODs? The construction of different LOD seems to be a part of the work which will involve a lot of time and efforts. Special investigations should be carried out to determine the necessary techniques. The basic questions is what criterions should be chosen for feature generalizations.

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