

Defining 2D Parcels in 3D Space by Using Elevation Data

Fatih DONER and Cemal BIYIK, Turkey

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SUMMARY

Until today some countries have developed several works related to 3D cadastre depending on mainly their legal systems and technical needs. Current Turkish cadastral works has been carried out based on the Cadastre Law put into force in 1987. Although the obligation in the Law to sustain cadastral works in 3D, cadastral bases have been produced in 2D so far. There is a lot of information available in 2D such as parcel boundaries and large scale topographic maps. Although it is possible to collect 3D data by means of several techniques, it requires huge amount of time and budget to recollect all the data which is already available today. Hence, integration of 2D cadastral data and height information can be a solution to define parcels in 3D space. This process is also needed to integrate cadastral maps with 3D objects such as tunnels, pipelines, cables.

In this paper, firstly, current status of Turkish cadastre is briefly evaluated in context of multi dimensional registration. Then, 3D data collection techniques and height surface models are examined. On a case study, it is aimed to define 2D parcels in 3D space using a DTM (Digital Terrain Model) represented by a TIN (Triangular Irregular Network). Two types of data set were evaluated to represent height surface. The first is point heights obtained with terrestrial survey and the second is contours gained from a topographic map. Another data set used in the study is 2D parcels. The height surfaces were used to extract z-coordinates for the parcel boundaries. Finally, some spatial analyses and visualization were performed in ESRI's 3D Analyst software package.

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1. INTRODUCTION

Global economic, social, technological factors and need for sustainable development are having a substantial impact on cadastral systems. As a result of this impact, the content and role of cadastre have changed significantly during the last few decades. According to the report of Cadastre 2014, future cadastres will show the complete legal situations of land, including public rights and restrictions (Kaufmann and Steudler, 1998). All these rights, restrictions and responsibilities related to land are often overlapping, therefore, current 2D cadastral systems have shown limitations in certain 3D situations.

From the scientific and technological standpoint, the principal challenge in developing a 3D cadastre lies in collecting, processing and managing the 3D data. Current surveying technologies such as aerial and close range photogrammetry, airborne or ground based laser scanning and GPS enable to be collected the 3D data with high precision. There are also available data sets that include 2D parcel boundaries and height information. In terms of cost and time, resurveying of 2D parcels may not be sensible to locate them in 3D space. Hence, it can be more suitable to integrate current data sets rather than to collect the data which is already available. Lenk (2001) and Stoter and Gorte (2003) are previous studies that performed on the integration of 2D data and height information. In this paper, it is aimed to assign z-coordinates to the boundaries of cadastral parcels by using a DTM. In addition, some spatial analyses and visualization were performed in ESRI's 3D Analyst software package.

Before the technical parts describing of 3D data collection, processing and surface models, this paper commences with a brief review of Turkish cadastre. Then, cadastral recordings related to 3D aspects are described according to current Turkish legislation. After the application stage, this paper ends with conclusion.

2. CADASTRE IN THE TURKEY

The Turkish cadastral system includes land registration and cadastral mapping. Cadastral maps are part of the register and cadastral parcels are basic units in the maps. Land registration and cadastral mapping is maintained by one organization: The General Directorate of the Land Registry and Cadastre (GDLC). Responsibility of the cadastre belongs to the national government (The Ministry of Public Works and Settlement).

Cadastral works in Turkey was started after the foundation of the Republic of Turkey (1923). Early land records, however, existed in the Ottoman Empire period. During this period, lands were registered with detailed information and land boundaries were described in some books as written. This written period continued to the late nineteenth century. The land records which come from Ottoman Empire are still used to solve legal disputes on land (Biyik and

Yomralioglu, 1994). After foundation of the Republic of Turkey, cadastral works began in 1925 based on the Cadastre Law (No. 658). Until 1950, cadastral works carried out only in urban areas. At the end of the World War II, the need for agricultural products and determination of agricultural lands increased the necessity for the cadastral surveys. Thus, the cadastral survey of the whole country was initiated in the early years of 1950's. Until 1987, cadastral works in Turkey were carried out in urban and rural areas based on different laws. In 1987, the Cadastre Law was put into practice and all the cadastral works and regulations were combined under the law (Demir et al., 2003).

There are also some technical problems in Turkish Cadastre. One of them is that cadastral mapping in Turkey has been implemented with using different surveying methods and standards so far. In addition, cadastral maps have been produced different coordinate system, scale and base types. Some of the surveying methods which are used for producing cadastral maps are: graphical, orthogonal, photogrammetric and digital (X,Y,Z). Besides, the obligation to produce cadastral bases in national coordinate system could not be put into practice until 1993 (Demir and Cete, 2004). As of 2005, %97 of cadastral surveying was completed in urban areas. This ratio was %71 for rural areas.

Although the Turkish cadastral maps have been produced by using different surveying methods and standards, content of the maps is similar. Cadastral maps show property boundaries and some cadastral maps also include outlines of buildings in parcels for reference purposes. With the cadastre law (1987), topographical data was added to the content. Thus, the Turkish cadastre has to reflect vertical dimension of the property units on maps. In spite of the legal requirement, cadastral maps have been produced in 2D so far

With the development of technological tools and information technologies, some projects have been developed in Turkey to speed up cadastral works and also to improve cadastral services and accuracy of the cadastral data. One important projects developed by GDLC is the Title and Cadastre Information System (TAKBIS in Turkish).The general objective of this project which was initiated in 2000 is to establish the Turkish Cadastre Information System throughout the country. The pilot area for the project was selected as two districts of the Ankara. The TAKBIS project is still in progress, and consists of three steps: analysis, design, and application development. The main purposes of TAKBIS are (URL1):

- to provide reliable and up-to-date land information required for all land and land-related activities and decision makers,
- to transform cadastral data to a multi purpose land information system,
- to protect the cadastral data in a secure environment and provide secure access the data,
- to accomplish cadastral services within the scope of information technologies,
- to provide standardization in cadastral services.

3. 3D RIGHTS AND RESTRICTIONS IN THE TURKISH LEGISLATION

Like many other countries, civil law is the legal basis in Turkish cadastral registration. Regarding the Turkish Civil Code, the main types of cadastral recordings with a 3D component are (the Turkish terms are added in italic, in brackets):

- Property right (*mülkiyet hakkı*)
- Right of easement (*irtifak hakkı*)
- Right of superficies (*üst hakkı*)
- Condominium right (*kat mülkiyeti*)

3.1 Property right

From the legal standpoint, property on land has a 3D component in Turkey. Article 718 of the Turkish Civil Code (2001) describes the content of the property on land. According to the article, property in land reaches from the middle of the earth up to sky. Also this property comprises building, vegetables and mines. According to the Article 998 of the Turkish Civil Code, followings are registered in land registry as real estate:

- Land
- Individual and permanent rights on real estates
- Individual parts of the building that are subject to condominium

3.2 Right of easement

Article 779 of the Turkish Civil Code defines the right of easement (*irtifak hakkı*). According to the article an easement is charge imposed upon a real estate (serving real estate), in favor of another real estate (dominant real estate). This charge forces the owner of serving real estate to avoid using some benefits of the property right or forces the owner of dominant real estate to use the serving real estate in specific way. The right of easement can be transferred, that is, when the parcel is sold, rights and restrictions of an easement are taken over by the next parcel owner.

3.3 Right of superficies

In Article 726 of the Turkish Civil Code the right of superficies (*üst hakkı*) is defined as: property of constructions that are built permanently under or above of a land owned by someone else belongs to person who has right of easement. In the same article, it is defined that it can not be set a superficies on individual parts of the buildings subject to the Condominium Law. A right of superficies can be used when the owner of the construction is not the same as the owner of the parcel. In the cadastre, no geometry is maintained to reflect spatial extent of the right.

3.4 Condominium right

Another 3D use of space occurs in apartment complexes. From the point of legal context, in Turkey, every apartment owner has the full property of a part of the building (apartment). The

communal areas of the building, such as staircases and elevators are held in co-property. According to the Turkish Civil Code, the registration of individual parts of a building is subject to Condominium Law (in Turkish: *Kat Mülkiyeti Kanunu*). In the cadastre, only the ground parcel of the apartment building is maintained and therefore the individual apartments can not be recognized on the cadastral map. Consequently apartment units cannot spatially be queried.

Another important issue is that underground objects aren't registered in Turkey. This is due to the fact that many underground objects related to infrastructure are located under lands owned by public (e.g. roads). According to the Article 16 of Cadastre Law (1987), these lands which are not subject to private property are only shown on maps and not registered (Tudes and Biyik, 2001).

4. SURFACE MODELS

Surface models are used in 3D cadastre to produce height surfaces of cadastral parcels. This process makes it possible to integrate the property units to other 3D objects and perform certain spatial analyses. In this part of the paper, surface models for 3D cadastre are introduced. A surface is a continuous field of values that may vary over an infinite number of points. For example, points in an area on the earth's surface may vary in elevation, proximity to a feature, or concentration of a particular chemical. Any of these values may be represented on the z-axis in a three-dimensional x,y,z coordinate system, so they are often called z-values. Because a surface contains an infinite number of points, it is impossible to measure and record the z-value at every point. Surface models are needed to stored surface information in a GIS. A surface model approximates a surface by taking a sample of the values at different points on the surface and then interpolating the values between these points.

Two main types of surface models are: rasters and TIN (Triangular Irregular Network)s. Rasters represent a surface as a regular grid of locations with sampled or interpolated values. TINs represent a surface as a set of irregularly located points linked to form a network of triangles with z-values stored at the nodes.

4.1 Raster Surfaces

Raster surfaces are usually stored in grid format. A grid consists of a rectangular array of uniformly spaced cells with z-values. The smaller the cells are, the greater the locational precision of the grid is. It is not possible to locate individual features (for example, the summit of a mountain) any more precisely than the size of the grid cells. Rasters are also used to store images and thematic grid data. Figure 1 shows a raster grid surface in perspective view.

4.2 TIN Surfaces

TINs consist of nodes that store z-values, connected by edges to form contiguous, nonoverlapping triangular facets. The edges in TINs can be used to capture the position of

linear features that play an important role in the surface, such as ridgelines or stream courses. Because the nodes can be placed irregularly over the surface, TINs can have a higher resolution in areas where a surface is highly variable or where more detail is desired and a lower resolution in areas that are less variable or of less interest.

The input features used to create a TIN remain in the same position as nodes or edges in the TIN. This allows a TIN to preserve all of the precision of the input data while simultaneously modeling the values between known points. It is possible to include precisely located features on a surface such as mountain peaks, roads, and streams by using them as input features to the TIN.

TIN models are less widely available than raster surface models and tend to be more expensive to build and process. The cost of obtaining good source data can be high, and processing TINs tends to be less efficient than processing raster data because of their complex data structure. TINs are typically used for high precision modeling of smaller areas, such as in engineering applications, where they are useful because they allow calculations of planimetric area, surface area, and volume.

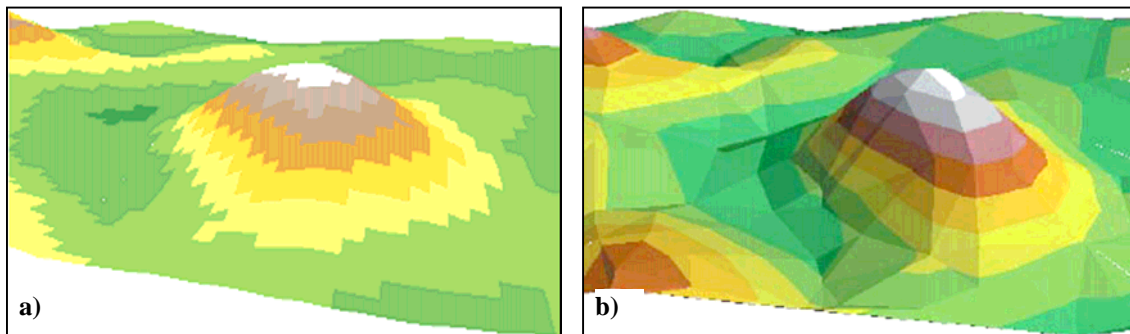


Figure 1: raster (a) and TIN (b) surfaces in perspective view

5. TECHNICAL ASPECT OF 3D DATA ACQUISITION AND PROCESSING

Cadastral is only one of the application areas which 3D data can be used. Similar to other application areas deal with 3D data, the main technological challenge in maintaining a 3D cadastral is related to collecting, maintaining, editing, analyzing and visualizing the data. Significant developments are taking place in surveying technology and it is not very difficult to add z-values to the x and y-values of a coordinate-set. Horizontal and vertical reference systems are nowadays integrated (e.g. WGS84/ETRS), GPS-based survey provides z-values, airborne laser-altimetry (e.g. LIDAR) has become very effective in the collection of elevation data for large regions, and terrestrial laser-scanning is a source of 3D data collection ('3D point clouds'). Although there are several techniques that can be used for data collection, it may not be sensible to collect the 3D data for cadastral purposes alone. Hence, sharing and multipurpose use of data are important topics that should be given extra caution (Lemmen and Oosterom, 2003).

It is important also to examine the state of the art with respect to the relevant software. In the 3D application areas, customized software has frequently been used, because the existing Standard geo-DBMS and GIS/CAD software do not cover the 3D aspects sufficiently. However, significant progress has been made in the recent years. For example, the DBMSs Oracle Spatial, IBM Informix Dynamic Server (IDS) and IBM DB2 Spatial Extender, can all store the third dimension within their point, line and polygon spatial data-types. However, the geometric functions (area, overlap, buffer, etc) are still limited to two dimensions, true 3D volume primitives are not available and there is no 3D standard available like the OpenGIS Simple Feature Specification for 2D data types. The geo-DBMS can be considered as the back-end of geo-information processing. The front-end can either be 'traditional' GIS software (strong in analysis) or CAD software (strong in data editing). In general GIS packages support (2D) editing, analysis and visualization, and in many systems 2.5D functionality is added. However, functional support in true 3D is still very limited. CAD packages on the other hand have supported true 3D editing and visualization for many years, but are limited with respect to analysis of information at geographical scales of measurement. In practice, and in spite of the many possible applications, true 3D geo-information processing has not yet made any great breakthrough, because of limited availability of 3D data and standard 3D software. However, on both fronts the situation is improving rapidly (Lemmen and Oosterom, 2003).

In Zlatanova et al. (2002), some of available software packages (ArcGIS 3D Analyst, ESRI; Imagine VirtualGIS, ERDAS; GeoMedia Terrain, Integraph.Inc etc.) that attempt to provide solution for 3D representation and analysis were evaluated. This paper concludes that most of these packages can efficiently handle 3D data in the 3D visualization aspect but further progress is still needed for true GIS functionality such as 3D structuring, 3D manipulation and 3D analysis.

Consequently, major development has been seen in 3D visualization and editing thanks to advanced computer hardware and graphics achievements. However, 3D functionality is still lacking such as generating and handling (querying) 3D geo-objects, 3D structuring, 3D manipulation and 3D analyses (3D overlay, 3D buffering, 3D shortest route). This is caused by the specific character of 3D data compare to 2D. Bottlenecks are still the 3D object reconstruction, the representation and navigation through large 3D models, editing and organization of the data.

6. CASE STUDY

A case study was carried out to assign height information to 2D parcels and locate the parcels in 3D space. Height values of the parcel boundaries were derived from a terrain elevation model. The terrain elevation model represented by a TIN surface was created by using two different data sets. The first is contour lines derived from a topographic map on scale of 1/25000. The map includes elevation information as contour lines that exist in every 10-meter-elevation interval. The second data set is point heights that collected with terrestrial survey. The last data set, 2D parcels, is from cadastral database. Number of the parcels selected for the study is 2406. Figure 2 shows the data sets used for the study.

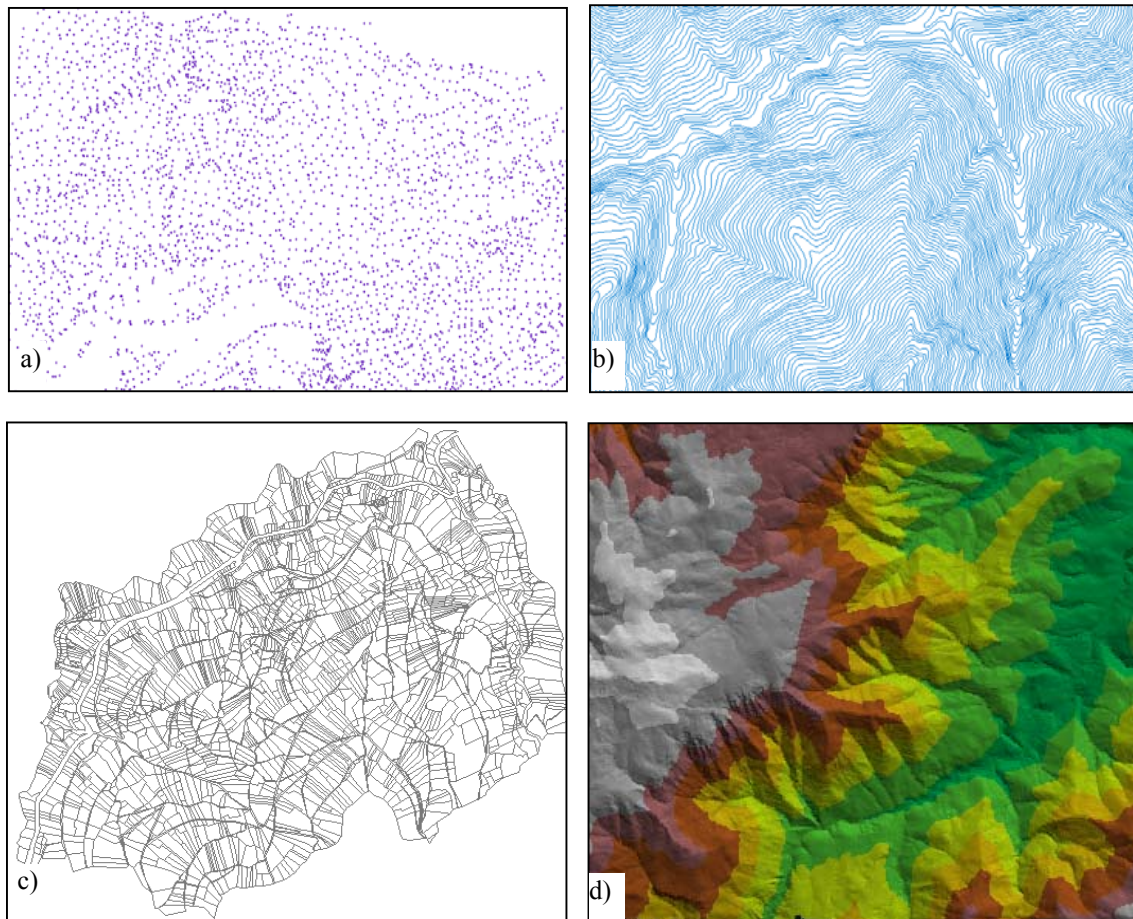


Figure 2: Data sets used a) points with height, b) contour lines, c) 2D cadastral parcels, d) height surface represented by TIN

Parcel boundaries were described in 3D by assigning z-coordinates to the nodes of the parcel boundaries. A DTM represented by a TIN which is based on both point heights and contour lines was used for the extraction of the z-coordinates. By assigning the z-coordinates to the nodes describing parcels boundaries, the cadastral parcels can be represented in 3D and 3D coordinates of the parcels can be computed. Figure 3 shows a 3D scene of 2D and 3D cadastral parcels in national coordinate system. In Figure 3, 2D cadastral parcels are positioned on a plane where z-coordinates equal zero.

Another advantage of integrating the 2D cadastral data and height information is that calculating surface areas of cadastral parcels is possible. The application software, 3D Analyst extension of ArcView, offers an option to add “clip polygons” to existing surfaces that allows calculations to be implemented on only that portion of the surface that lies within the clip polygon. By using this option, 3D area of a parcel in the cadastral database was calculated. In 3D Analyst, the surface area of a parcel is measured along the slope of the surface. The variation in the height of the surface is taken into account. For the case study, the 2D area of the selected parcel is 2066.592 square meters while 3D area of the same parcel is 2209.885 square meters. The difference between these two values is 143.293 square meters. These results verified the fact that the surface area is always greater than the 2D area unless the surface is flat.

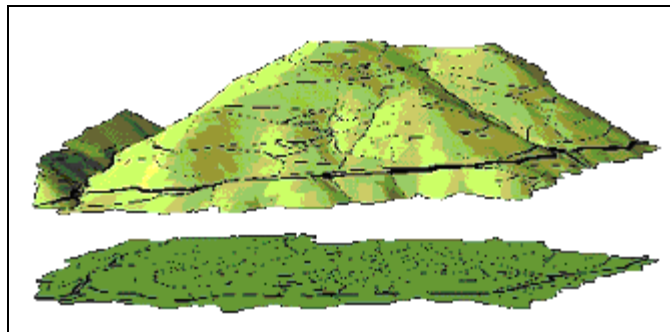


Figure 3: A 3D scene of 2D and 3D cadastral parcels

CONCLUSION

One of the technical challenges in developing 3D cadastre is to relate the third dimension to existing 2D data sets. Combination of 2D cadastral data and height information makes it possible to locate the cadastral parcels in 3D space. In this paper, a case study was carried out to assign z-coordinates to the boundaries of cadastral parcels by using a DTM. The z values of parcel boundaries were derived from the terrain elevation model represented by a TIN surface. In order to create the TIN surface, two different data sets were used: contour lines gained from a topographic map at a scale of 1/25000 and point heights obtained with terrestrial survey. In terms of accuracy, using point heights collected with terrestrial survey is more suitable to build the TIN surface. On the other hand, the way of collecting 3D data is time consuming and the data may not be available for large areas. Height surfaces which are built from both point heights and topographic maps can be used to extract surfaces of the parcels and visualize the 2D cadastral maps in 3D.

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BIOGRAPHICAL NOTES

Fatih Doner is a research assistant at Karadeniz Technical University (KTU), Turkey. He graduated from the Department of Geodesy and Photogrammetry Engineering at KTU in 2002. He received his MSc degree with the thesis entitled “Mobile Geographic Information Systems: Basics and Applications” in August 2005. He is currently studying on his PhD thesis. His research interests are cadastre, land information systems and relevant GIS applications.

Cemal Biyik is a Professor for Cadastral Science in the Department of Geodesy and Photogrammetry Engineering at Karadeniz Technical University, Turkey. He received his PhD degree with the thesis entitled “The Organization of Cadastral Workings in the East Karadeniz Region in Turkey” in April 1987. His research interests are land administration, cadastre, forestry cadastre and project management.

CONTACTS

Fatih Doner

Karadeniz Technical University, Gumushane Faculty of Engineering

Department of Geodesy and Photogrammetry Engineering

29000 Gumushane, TURKEY

Tel. + 90 456 233 7425

Fax + 90 456 233 7427

Email: fatih@ktu.edu.tr

Cemal Biyik

Karadeniz Technical University, Department of Geodesy and Photogrammetry Engineering

61000 Trabzon, TURKEY

Tel. + 90 462 377 2767

Fax + 90 462 328 0918

Email: biyik@ktu.edu.tr