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Research Article

REAL TIME VECTOR DATABASE UPDATING SYSTEM: A CASE STUDY FOR TURKISH TOPOGRAPHIC VECTOR DATABASE (TOPOVT)

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ABSTRACT: Turkish Topographic Vector Database (TOPOVT) is a 3D vector database comprising 1:25.000 scale or higher resolution topographic features, contours representing the topography and geographic names. TOPOVT is the basic geographic data source for our country mapping and base for GIS applications covering whole Turkey. So far data collection for TOPOVT has been carried out by General Command of Mapping. Updating of TOPOVT is a continuous process and goes on by annual planning on regional base.

Geospatial data collection, either in the office or in the field, is a hard, costly and time consuming process. Using the existing geospatial data will be a suitable solution for get rid of all these expenses. Governmental institutions and municipalities have their own GIS and collect and update these geospatial data according to their needs. With a close look, these data are similar to TOPOVT data or with a little effort can be converted to TOPOVT model.

TOPOVT Real Time Updating System was designed to provide all governmental institutions and municipalities producing and using geographic information via internet to update and easily access to TOPOVT. TOPOVT Real Time Updating System has been realized to avoid duplicate geographic data production countrywide and reflect the changes in topography to TOPOVT in real time or near real time. This system will enable governmental institutions and municipalities to update TOPOVT in their service areas according to their job definition without needing another software thus providing the TOPOVT users to make use of the up-to-date data.

By this system, all the governmental institutions needing topographic database for their applications will easily reach TOPOVT, make use of the data in their field works and present the data they produced to country use. Also, by avoiding the duplicate geographic data production, national sources will be utilized economically and effectively.

Keywords: *TOPOVT, real time updating, topographic feature, vector database*

1. INTRODUCTION

General Command of Mapping (GCM) is responsible for the production of maps for defense and development purposes and provide geographic data to governmental institutions according to the regulations. In order to realize this responsibility effectively, Turkish Topographic Vector Database (TOPOVT) was established with a model representing the real world continuously with vector data without file base. TOPOVT is the topographic vector database in which the 1:25.000 scale topographic data produced by General Command of Mapping are stored and presented and also standard topographic printed maps are produced.

The vector data in TOPOVT is acquired mainly from stereo aerial photos by digital photogrammetric workstations and then completed in the field by checking the compiled data, correcting the mistakes and collecting the attributes of the features and also the geographic names. After field completion the data are post-processed, topologic rules are controlled and then uploaded to TOPOVT (Canıberk et al. 2014).

At the design stage of TOPOVT, all collected features in classical map production are investigated for their integrity, collection rules and topologic relations. New topographic feature classes and subtypes are determined by making use of VMAP (Vector Map) data model. The attributes and attribute values of these features are also determined; UML (Unified Modelling Language) diagrams are designed showing the topographic features, attributes, lower bounds, attribute values and transformation tables (Canıberk et al. 2014).

UML is a standard that enables visual representation of system components and their relationships. UML is not a programming language but covers the entire system development process. A good modeling during the analysis and design phase prevents many problems that may arise in the software phase (Booch et al. 2005).

The spatial Web standards produced by the Open Geospatial Consortium (OGC) and the systems that work with spatial data generated by different data producers have become interoperable in the Web environment. OGC has published more than 30 standards so far. These are the ones most commonly used for Web mapping; Web Map Service (WMS), Web Feature Service (WFS), Web Catalogue Service (WCS).

With WMS service, it becomes possible to share maps over the network. In this service, the geographical data itself can be shared instead of the maps derived from it. These maps are presented in raster formats such as JPG, PNG and TIF. It can be said that this service is particularly suitable for maps that will be used as a base (Beaujardiere, 2006).

In the WFS service, it is possible to directly share the geographical data over the network itself. Vector data (point-line-polygon) is used instead of raster data. That is, many vector analyzes such as clip, buffer, intersection, shortest path analysis are performed with vector data obtained using WFS (Vretanos, 2005). With WFS, there is no direct data flow from the server to the client, and the client can also transfer to the server as if it were two-way data transfer. Users can make changes to the incoming data (insert, update, delete) and send it to the server and update the data. Such WFS services are called Transactional WFS or WFS-T.

The data need for the applications in which the spatial analyses are carried out are not met by a single producer. These applications need attribute information together with spatial information. The variety of these attributes directly influence the results of the application. The countrywide database are needed for the fulfilment of the requirement to the spatial data and attributes produced by different institutions in order to execute the mentioned applications. The different institutions or sides have to cooperate effectively to share the data they collected for establishing and sustaining these databases.

Today, the spatial information is the base for every kind of planning work. For this reason, the most important factor in healthy decision making is the working on accurate and up-to-date geographic data in planning works. The applicability of the planning is related to the availability and up-to-dateness of the data (Önder, 2000).

Different application fields, such as earth sciences, natural resource management, environmental protection, urban and regional planning, defense, transport, tourism, statistics and education need geographic data, because they require regional or countrywide analyses. Spatial data are generally related to resolution/scale and they have to be analyzed and presented with the resolution/scale that modelled phenomenon and processes were the best understood (Weibel and Dutton, 1998; Başaraner and Selçuk, 2004). In this context, TOPOVT is trying to fulfill the users' spatial data needs according to resolution, scale and up-to-dateness; it also assumes a role in effective use of national sources and avoiding duplicate productions.

Although it is assumed that keeping the national spatial databases up-to-date is the responsibility of national mapping institutions, it is also the responsibility of the partners who need and produce spatial data. The updating process is mainly carried out by photogrammetric compilation and field works. Hanson and Wolff (2010) defined these solutions as time consuming and expensive; thus failing to respond effectively to update requests. Müller and Heipke (2009) have achieved a 65.5% success rate in the method they developed for the semi-automated updating and control of large-scale databases using aerial photos at 10 cm resolution. However, it can be foreseen that it will be difficult to implement it on a country basis because the method they apply will lead to keep the institutional database updated with only institutional capabilities.

Coumans (2016) stated in her article that Ordnance Survey Ireland (OSi) designed a topographic database that 1:1,000,000 cartographic products could be produced from 1:1,000 topographic database in an automated workflow. OSi geared to present real features to the users by combining the efforts to collect data in different scales. OSi has combined efforts to produce spatial data by avoiding duplicate works on different scales.

Ordnance Survey of UK is the national mapping agency of Great Britain. They deal with 234.000 km² area and try to present most up-to-date maps to their customers. They split revision policy into two stages as continuous and cyclic revision. In continuous revision, most important features, namely buildings and roads, are captured in upmost six months' time after the construction. Cyclic revision deals with gradually changing features especially to the national environment. Data capture for cyclic revision is carried out at fixed intervals. Capture priority is also divided into four categories according to cyclic revision periods. More prestigious or important features (such as roads, public places like hospitals, schools and sport areas) for people are captured in short time periods (Ordnance Survey, 2018).

Moore (2013) pointed out that U.S. Geological Survey's (USGS) national 7.5-minute topographic map series was completed in 2000. He asserted that one sheet of map would cost more than $50,000 (in 2007 dollars) and would take 45 years to complete the series in traditional method. By using the available different resolution and different accuracy level GIS sources countrywide, USGS achieved three years updating cycle and cheaper production expenses than the original topographic maps by at least a factor of 100.

A newly emerging paradigm, namely volunteered GIS (VIG) is effecting the geographic information collection phenomenon. This kind of geographic information is derived from ordinary volunteered people, in a sense it is crowd sourced. VIG is executed via web applications or mobile phone applications. One of the most successful VGI application is OpenStreetMap (OSM). OSM produced data in some places are claimed to be more accurate and detailed than the officially produced maps of that place. By the help of the volunteers, the geographic information is collected or updated immediately in urgent circumstances (Fast and Rinner, 2014).

USGS also seeks volunteers to contribute The National Map (TNM). They call the volunteers as The National Map Corps (TNMCorps). In this project USGS urges from TNMCorps to update existing data and collect non existing data. Especially, the volunteers are requested to give the location of community buildings like schools, hospitals, fire stations etc. USGS informs its volunteers that TNM data collected by VIG yields accurate and up-to-date information to the citizens (USGS, 2013).

İşcan and Ilgaz (2017) have analyzed governmental GIS applications and geospatial data. They proposed that all governmental institutions should use same geospatial data model, namely a common geospatial infrastructure.

The tendency in geospatial data production is towards avoiding multi-production efforts on the same location as it is seen in the above mentioned production examples. While the countries are seeking ways to reduce the geospatial data production expenses, they are also trying to save labor and time. As a result of these efforts, they manage to produce more up-to-date geospatial data on broader areas of interest. Consequently, General Command of Mapping, the national mapping agency of Turkey, initiated a project to unite all geospatial data production efforts so as to allow all governmental institutions to share and to contribute Turkey's geospatial data.

This paper defines the problem in the second chapter; propose an updating system design which has already been put into practice in the third chapter; and lastly draw some conclusions and suggests some actions for future works.

2. PROBLEM DEFINITION

Geospatial data collection, either in the office or in the field, is a hard, costly and time consuming process. Using the existing geospatial data will be a suitable solution to get rid of all these expenses. So far, the data collection for TOPOVT has been carried out by General Command of Mapping. Updating of TOPOVT has always been a continuous process and goes on by annual planning on regional base.

Governmental institutions and municipalities have their own GIS and collect and update these geospatial data according to their needs. With a close look, these data are similar to TOPOVT data or with a little effort can be converted to TOPOVT model. The design of the proposed Real Time Updating System is expected to solve to unite nationwide geospatial data collection and updating efforts.

3. REAL TIME UPDATING SYSTEM DESIGN

Not only the creation of the spatial databases is an important and ambitious work, but also to maintain and updating the database (Cömert et al., 2009). The necessity of digital geographical information is in the tendency to increase continuously; by reviewing the digital geographical data produced, the data model used in production needs to be updated according to user needs and the design of geographic databases in accordance with this data model is required. TOPOVT is a structure that can respond to user needs in this context.

With the establishment of TOPOVT, the ability of geographic data production to adapt to the efficiency and technological developments in the map production system has increased. Geospatial data users are provided with the necessary data infrastructure for online geographic data support. Although the definition of the rules for the analysis, design phases and the loading of the database is very important as of the near future, nowadays it is left to update the database. From this perspective, the real-time database update system will take an important step toward reaching institutional targets (Canıberk et al., 2015).

TOPOVT Real Time Updating System was designed to provide all governmental institutions and municipalities producing and using geographic information via internet to update and easily access to TOPOVT which is the basic data source of geographical map and topographic map production, which is the basis for GIS applications. The system has two components as web and mobile applications. TOPOVT Real Time Updating System design is depicted in Figure 1.

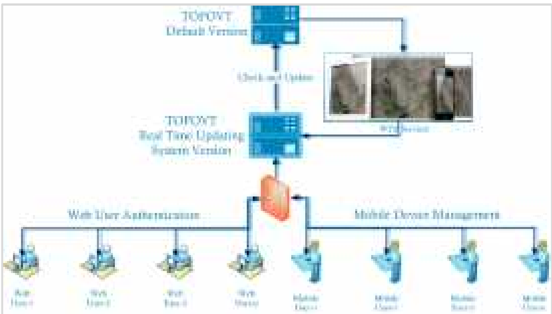

Figure 1. TOPOVT Real Time Updating System

3.1 Web Platform Updating System

The real-time topographic database update system requires the selection of data to be published, the identification of users and groups, and authorization procedures. After this process, the users will be able to connect from different platforms to the database and perform add-delete-update operations.

Only authorized users are allowed to log in to the system via WEB interface provided that IP addresses are defined for the access. In addition, user input traffic is controlled by keeping all input/output records in the system. Thus, the access security of the system is ensured.

The system consists of data management and data transfer, topographic data entry and editing, layer drawing and attribute information entry, mapping, authorization and service integration layers. Welcome page of the system interface is presented in Figure 2.

Figure 2. Welcome page of the system interface (https://topovt.hgk.msb.gov.tr)

This web-based application can be reached through any internet browser. The defined reports, such as production amount of any feature layer or contribution of any user, can be obtained.

The authorization to the users are done according to zone-based (Figure 3) and/or attribute-based. The attribute based authorization gives users the ability to see and/or update the attributes of the authorized features. The ability to add/delete/update features is also defined in this interface.

Figure 3. Zone-based authorization

All geospatial data submissions can be managed via a single platform with internal and external services. Vector data can be viewed and managed from web platforms on map layers; can be reported by hundreds of users within the authorities granted at the same time from the databases. The change of history-based topography can be observed. Also, WMS, WFS, and WCS services can be added dynamically and can be presented based on authority (Figure 4).

Figure 4. Service addition and authorization

System administrator provide public authorities and all other stakeholders to perform updating, addition, deletion and correction operations on the authorized area by performing authorization on the basis of layer, region, province, district, village, neighborhood and attribute. The vector processing required to update TOPOVT from existing geographical data is executed fast, secure and also data integrity is ensured. To this end, tools that work in the internet interface and that can perform many basic geographic operations (cutting, cropping, merging, reshaping, etc.) are integrated into the system. Figure 5 shows the system-integrated geographic editing tools.

Figure 5. Geo-editing tools application

The system also enables the administrators to check and validate the updated data with a control unit. In this unit, all the changes that users made on TOPOVT are controlled one by one basis and validated as “accepted” or “rejected”. So the standardization and integrity of TOPOVT is preserved.

3.2 Mobile (Android) Platform Updating System

TOPOVT android application is designed for users who carry out data collection work in the field. This system will increase the efficiency of the field work, which is one of the TOPOVT data collection steps. The Android application will also be able to serve to the field works of the institutions that will be the stakeholder of the update system.

A mobile platform update system is designed for users to access TOPOVT data with android data tablet computers in the field (Figure 6). The system is managed by Mobile Device Management System (MDM) and can be linked to the TOPOVT update infrastructure. The user access authority to the system is determined by MDM and can work integrated with the real time updating system.

Android data tablets can be controlled remotely via the management console, messages can be sent to the tablet via the management console, such as resetting the system, turning GNSS on/off, locking the device. This ensures that both the tablet and the data in the tablet are safe. At the same time, the data downloaded to the disks of the tablets are protected by encryption algorithms, preventing unauthorized access to the data.

Figure 6. Tablet PC and external GNSS receiver

Software running on the android data tablet platform can access TOPOVT data, just like the software running on the browser, and perform add-delete-update operations within the authorities. Users can work in real time as well as download the data at the same time as the internet connection and send them to TOPOVT at the end of their work and they will be able to work in near real time.

Users see only the mobile update software on their tablets and cannot access any other settings and cannot run any programs. Separately authorized users for each tablet are directed to the main screen to log in to their tablets and the main application screen (Figure 7) is displayed with successful user input.

The main screen consists of four sections. These sections are; Settings Bar (1), Transaction Menu (2), Tools Menu (3), Map Module (4). All functions in these sections are active according to the user's authority.

Figure 7. Mobile application main screen

Mobile application vector contains many tools for data editing. These tools allow the user to edit on the existing geometry on the selected layer. The user can use these tools within his/her authority. Editing tools become active after feature(s) are selected. Single feature editing when a geometry is selected, multiple feature editing tools when multiple geometries are selected. The system has merge, clip, intersect, union, snap from node to node, split functions which are the basic geographic information system functions that facilitate data collection in the user interface (Figure 8).

Figure 8. Geometry editing tools

An external GNSS receiver is plugged into tablets from the micro USB port and thus ensures feature collection at ±3 m spatial accuracy. The GNSS receiver is compatible with Turkish CORS (TUSAGA Aktif). The accuracy can rise up to decimeter level with using Turkish CORS. The tablet application can detect the installed GNSS receiver and work with the external receiver. After connecting the receiver, all the information (satellite number, geometry etc.) from the receiver can be displayed. A new point or vertex can be added with the GNSS receiver, and existing geometries can be arranged according to GNSS coordinates (Figure 9).

Figure 9. Feature collection with GNSS

4. RESULTS AND DISCUSSION

TOPOVT is a database in which 1:25.000 or larger scale topographic vector data produced by the General Command of Mapping is stored and presented, and at the same time standard topographic map production is performed which is one of the most important tasks of the institution.

Rapid development is observed in our country especially in urban areas. As a result of this development, when the newly created, changed or diminished features are transferred to the database in short time intervals, the will of the users who need the up-to-date database will be met. For this reason, the establishment of a real-time updating system is important.

The developed system will provide public institutions, organizations and municipalities direct access to TOPOVT, and will facilitate data sharing among institutions. Thus, institutions will contribute to the updating of TOPOVT in line with their needs, and repetitive productions between institutions will cease to exist. With the real-time updating system, data can be updated at the same time by splitting large areas, integration of data produced or possessed by public institutions and organizations producing topographic data can be provided and all updates can be instantly controlled from a single center, TOPOVT.

With TOPOVT Real Time Updating System;

- The duplicate geospatial data collections of institutions will be avoided,
- The geospatial data will be kept up-to-date with labor and time saved from duplicate transactions,
- Emergency geospatial data needs will be met shortly as there will be no bureaucratic procedures,
- Full and correct geospatial data will be used and shared since missing features and errors are reported and corrected by the related institution.

Thus, TOPOVT can be updated with the geospatial data produced by the public institutions and organizations and the municipalities. In addition, data collection can be carried out between the institutions by collecting detailed geographical features similar to TOPOVT and making necessary changes in feature definitions and attributes to prevent duplication. Organizations will be able to contribute to the correctness and completeness of TOPOVT by noting errors and omissions.

Quality assurance may be provided by TOPOVT management until the users have a certificate at the beginning of their works. Then quality control will be carried out by a certain percentage of the data entered, i.e. 10% of the data. Also the features will have feature level metadata about the owner/updater of the feature. The owner/updater of the data will be responsible. Moreover, during the planned revision of TOPOVT, quality will be assured by GCM either by stereo imagery or by field completion in at most five years changing according to the development level of the region.

Providing geospatial data to TOPOVT is also possible with WFS. In this case, a mutual schema of the features should be agreed in order to easily migrate different kinds of geospatial data.

The limiting accuracy is ±3 m in planimetry and height for TOPOVT. The accuracy of most of TOPOVT data is better than ±3 m. This accuracy might be improved according to the needs of the partners. Especially in urban areas, the accuracy and resolution of the TOPOVT might be greater than 1:5.000 scale maps by designing a multi resolution database.

There are of course challenges for the success of this proposed system. So far governmental institutions gathered geospatial data according to their needs in any available format and model. In fact, it is very difficult to provide these different kind of geospatial data to communicate each other. But this challenge can be overcome by working together on an agreeable schema to exchange geospatial data. Most important factor to make this project come into practice is the mutual will of all the shareholders.

In further studies, the outputs of the system can be discussed. Also, the refinements to the system are put forth.

For further applications, some improvements can be made in the TOPOVT Real Time Updating System to allow VIG to Turkish citizens in order to contribute their observations to a TOPOVT condensed version by their mobile phones. The volunteers can especially be requested to give location and name of the community buildings so as to present up-to-date and accurate information to other citizens.

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