

Evacuation GIS for the TANGO Project

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Abstract. The paper describes an application of ArcGIS Desktop 9.3 and ArcGIS Server 9.2 for creating and testing an evacuation GIS within the EC FP 6 project TANGO (Telecommunication Advanced Networks for GMES Operations). One of the goals of the project was to develop and test different telecommunication solutions for exchange of geographical data in areas where common terrestrial or mobile networks are not available and users have to rely on satellite communication only. The practical demonstration was carried out in the Portuguese island Madeira. Two main application areas of ArcGIS 9.3 within the security work package of the project are presented: creating the geodatabase and the web-portal which main part is represented by a map server built on the ESRI technology. Data in the geodatabase were organized according to the NATO standards for non combatant operations and standard desktop ESRI applications were used for data collection. The sources of geographical data were limited. Visual interpretation of aerial orthoimages and satellite images supplemented with additional sources for obtaining attributes were therefore the main methods of data acquisition. The paper also describes the map server which main purpose was sharing data among users participating in the project. The advantage of the created map server from the user point of view is a possibility to make requests for selected geoprocessing tasks, e.g. searching the shortest route, in a user friendly interface of the web browser. The summary of problems that appeared during the project realisation covering all processing steps from data collection to running the map server are also presented.

Keywords: evacuation GIS, telecommunications, GMES

1 Introduction

Telecommunication Advanced Networks for GMES Operations (TANGO) was an international project running from November 2006 to October 2009 under the 6th Framework Programme of the European Commission and was coordinated by EADS Astrium. In the first stage of the project, the main activities concentrated on specification of needs of GMES users regarding satellite telecommunications and development of suitable solutions. The proposed solutions were then presented and tested during demonstrations connected to different GMES areas such as fisheries monitoring, maritime surveillance, humanitarian aid and security. Details about the project and developed telecom solutions are available on the project website www.teladnetgo.eu.

The Department of Applied Geoinformatics and Cartography of the Faculty of Science of Charles University in Prague belonged among 24 partners from research and industry participating in the project. Its task was to participate in the development and implementation of a GIS solution in the Security Demonstration. This demonstration simulated a situation when EU nationals appeared in a crisis area outside EU borders and their evacuation from a remote place had to be carried out. The exercise took place in the Portuguese island of Madeira. Several partners of the project and end users of GMES services took part in this demonstration both as active participants in the simulated crisis situation or as observers. In general, there were four actors involved – the operation centre (EUSC in Torrejón de Ardoz in Spain), the Joint EU Situation Centre in Brussels, the field base and the field unit in Madeira. Project participants from the European Satellite Center (EUSC), Infoterra France, CNES and Charles University were members of the first and the last two groups. The main tasks of the actors were following:

Operation Centre - collecting latest Earth observation data, updating GIS database, generating possible evacuation routes from the gathering places to the closest evacuation points (airfields, harbors etc.), supporting the field base and the situation centre with updated information (imagery, vector data and attributes)

Situation Centre - decision making regarding the whole evacuation, monitoring the demonstration

Field Base - collecting latest information from the field unit (e.g. obstacles on the evacuation routes), transferring this information to the operation centre and the situation centre via satellite telecommunications

Field unit - leading the evacuation convoy from the gathering places to evacuation points along generated evacuation routes, in situ data collection, sending information about obstacles that appeared to the field base

Text, pictures, vector GIS data as well as voice communication were transferred via satellite telecommunications. Encryption was used for sending critical data concerning security and field operation. The field and base units exchanged information using Risk and Emergency Containers for Valuable and Essential telecom Recovery (RECOVER) developed by CNES and a portable telecommunication solution Eliseo from Infoterra.

In order to make decision about evacuation routes, GIS database containing a road network, possible assembly points and access points to the country (airports, harbors, etc.) had to be designed. The following text describes the content of the created database and basic procedures used for collecting vector data. The next part is devoted to the applied web-GIS solution built on the ArcGIS server and to geoprocessing tasks needed in the evacuation scenario.

2 Data acquisition for evacuation GIS

Geospatial data collected by both EUSC and Charles University represented the essential part of the presented GIS solution. The area of our interest was situated in the southern and southeastern part of Madeira Island. The whole island has inhomogeneous landscape with steep slopes, a lot of tunnels, complicated flyovers etc. (see Fig. 1), which made acquisition of geospatial data a very difficult task. Structure of the data required for evacuation GIS was adapted to NATO standards for noncombatant operation (STANAG 3596).

High resolution orthoimages with pixel size of 40 cm was used as the base for mapping. It was obtained from Portuguese authorities as well as a detailed DTM with 10 m resolution derived from photogrammetric measurements. Another source of information was multispectral satellite imagery from Spot 5 with resolution of 2.5 m. The climatic conditions make use of satellite imagery in Madeira rather problematic. Due to its topography and climate a part of the island is nearly always covered with clouds and it is almost impossible to capture a completely cloud-free scene. Three sources mentioned above provided enough information to extract geometry and some attributes of the most of features required for the evacuation GIS. As a support for attributes' completing, other sources from the Internet were helpful. The out-of-date but very detailed topographic maps of Madeira and Panoramio and Wikimapia providing photos placed at a certain location should be mentioned. The quality of these "anonymous" sources from the internet can be controversial but there is often no other way how to get more information about object recognized by visual interpretation. Although the processing of all sources was made very carefully, some minor corrections had to be done when comparing acquired data to the real situation in Madeira.



Fig. 1. An example of flyovers and tunnels in the steep terrain of Madeira. Area in northeastern part of Funchal. Aerial image by Instituto Geográfico Português, photo from Panoramio.

All collected data was stored in ArcSDE geodatabase [2] in projection UTM (zone 28 N) on local ellipsoid Porto Santo 1934. All data from local authorities were in this coordinate system and had guaranteed accuracy. The conversion to other ellipsoid was not necessary for our purpose and could cause inaccuracy. For integration of point measurements using GPS a software solution for conversion from WGS84 to the local datum was developed and it is available from the TANGO server or on demand. It is a simple tool for conversion of coordinates in text format without a need of any additional software.

The work itself was carried out by five operators, two from EUSC and three from Charles University. EUSC was responsible for route reconnaissance, Charles University for the rest of 18 layers. Details of involvement of EUSC in the Tango project can be found in [1]. Data processing was carried out in ArcMap 9.3 using its comfortable and powerful editor's capabilities. At the beginning of the work, the area of interest was divided into parts and each person was processing only her / his subarea. The data acquired for all these subareas were merged and checked for errors by a coordinator manually (broken line connections, overlapping objects, differences in attributes etc.). Finally, quality control was performed by overlooking the whole area of interest and independent checking of key features.

The acquired data included information about hydrology (coastline, hydro network and water bodies), transport (roads, bridges, coastal infrastructure, airfields), industry (storage and repair installations, electronic installations, water installations, industrial installations and power installations) and other layers (urban areas and headquarters). Visual interpretation was only used for vectorization. Some features were hardly recognizable even though as much supporting information from the Internet as possible was sought. Some experiments were carried out with respect to the automated road extraction using object based classification in the Definiens software package too. The methodology is not ready for operational use yet, therefore it was not applied for the Security Demonstration.

Finally, EUSC created map symbology for acquired data and the result of joint work has been published on the Internet using GIS server based on ESRI technology.

3 GIS solution

GIS system in the background is essential to fulfil all goals of the security demonstration. During the crisis the field unit has to gain information as fast as possible and with minimum efforts. This means that the system has to be easy to maintain and almost near real time. Possible alternatives for geoprocessing queries were tested – on desktop side or on server side. Two main activities included:

- Data processing
- Data dissemination

Except of these activities different types of distribution of the information were evaluated. All access points to the demonstration information are summarized in the Table 1. Up-to-date information about the crisis situation and its changes was accessible from four servers via the internet. All information (reports, data, maps, etc.) was published from one place (Operation Center). Each new item appeared almost at same time on all servers.

Table 1. Information dissemination

Server	Goals & types	Users	Technology
Geoserver	Collect information with up-to-date situation at one side	Public, civil users	Web content manager system
Mapserver	Dissemination of the maps and GIS services	Active actors	ArcGIS Server 9.2
SitCenter II	Publish information within integrated EU crisis web system	EU situation center	Web content manager system with secure improvement
OpsCenter	Server for distributing of the secure information to the field (encrypted)	SatCen and Field Unit	Web content manager system with military encoding subsystem

Data processing, in the means of this paper, is understood as geoprocessing with captured datasets. The security demonstration had to provide information resulting from network analysis. The network was represented with digitalized roads and streets. The attributes contained information about road directions, road categories, slope of road segments, allowed and real estimated vehicle speed. The data as well as the network were stored in ESRI geodatabase format. Therefore the calculation (geoprocessing) was done using ArcGIS engine (Network Analyst). ESRI software was chosen due to its accessibility of all project partners. For geoprocessing two independent tasks (named according to ESRI software convention) were defined – location of the closest evacuation point (calculate closest facility) and finding the most suitable routes based on the field conditions and given restrictions (calculating the best routes).

Data dissemination within this paper is restricted to the terms of spreading out the GIS outputs. GIS servers were used for data dissemination with stress on mapserver capabilities. GIS servers in scenario description guarantee following services: data dissemination, providing reports for field operations, visualizing GIS analysis [3]. Two different independent sources for „GIS“viewer (locally, technologically), namely ESRI and Google, were chosen. A precondition existed requiring that each individual GIS server has to be fully accessible and manipulated by the Operation centre (GIS server's sources provider).

3.1 GIS server solution

From the technological point of view two server types can be distinguished - evacuation web page and GIS server with analysis support. Both of them can be easily managed by one person at one location. The evacuation web page is intended as a gateway for different groups of users. A precondition existed that it has to be an open content manager system with a possible extension and integration within Sit Centre (EU Brussels). Joomla CMS (content manager system) satisfied all conditions and was therefore selected. Joomla is a php based open source content manager system and it can operate with different database systems in the background (MySQL, PostgreSQL, SQLite). This CMS is in accordance with the SitCen system and also with Infoterra's distribution system. Joomla is high configurable, it supports own modules and it has a growing community of users and developers. The most important part of the system for the Tango project was user management, role management (grant access, privileges), upload and download of files. The role management and authentication of the users is most important with respect to security. The system satisfies user requirements for quite easy dissemination of information in case of many types of reports (weather reports, restriction reports, field situation reports, etc.) and output situation maps (predefined maps of selected areas and situation in pdf format). GIS server for analysis support is strictly based on ESRI technology (ArcGIS server, Network Analyst extension, Image server). It provides possibilities to near real time recalculation of the network tasks (alternative evacuation routes, closest facilities). Geoprocessing tasks were calculated with road segments before demonstration for testing of the web geoprocessing services. During the demonstration the roads were calculated on the server side.

3.2 Geoprocessing

Activities connected to geoprocessing tasks have close relations with the data storage (including data editing, data sharing, data access, etc.). PostgreSQL database engine was selected for the TANGO project. Database was connected with ArcGIS through ArcSDE connector [4]. It provides a direct connection to ArcGIS Desktop or ArcGIS Server. All vector data are stored in the database but the raster data (e.g. SPOT images, aerial images) are stored in the file system. Storing data in a common central database provides more benefits for the users – for security reasons access privileges can differ for each person and tasks performed – data editing (e.g. road restrictions) or map publishing (e.g. build map or geoprocessing services). The database is not accessible only via SDE connector. A direct access (PostgreSQL) can be faster for data uploading. This data store contains all up-to-date vector data and it is still accessible from multiple clients.

The purpose of the demonstration was also to integrate tools that are offered in existing software packages. Therefore standard ArcGIS tools were used for quick and easy dissemination of the map and geoprocessing services [5]. There were not special efforts made to customize the GIS server portals (as templates, API, etc.) The geoprocessing services are closely linked to the creation of map services. For the needs of the project four map services were created. The first contains the "underlying, base" data for the map drawing (vectorized data mentioned above). The second one is

represented with the map services to display geoprocessing operations outputs (restrictions on the roads, the calculated optimal route for evacuation, etc.). Raster data were published in the form of two services - first service contains a mosaic of aerial photographs and the second one comprises satellite images from SPOT. Map services were defined in the ESRI map service format and also in the standard WMS. Raster data were published only in the WMS format. The development of these services was done by ArcGIS Desktop (preparation of map services) and ArcGIS Manager Tool (remote access and management of the services for displaying the resulting route). Publishing raster images was carried out using ArcGIS Server Image Extension.

Searching for the best route was calculated within Network Analyst extension. Usage of such a function at the server side needs to build a general model in the Model Builder Environments. Models for searching closest path to the given location (facility) and the fastest route between two given points were created. The inputs for both models can be specified with an uploaded point layer or using cursor to specify points interactively. Definition of the restrictions is used in the same way. The example is shown in Fig. 2.

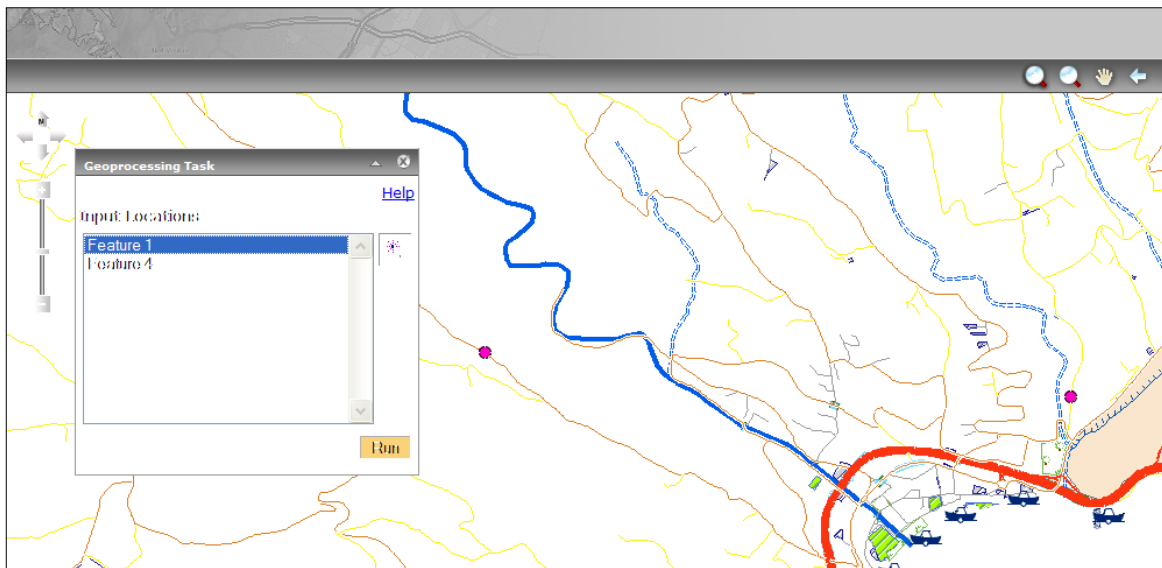


Fig. 2. Interactive inputs of the points for geoprocessing tasks

The calculation provides outputs almost in real time. Two situations were tested. The first one uses only the server capabilities (specification of parameters for the model via web interface and network analysis processing). The second solution consists of sending parameters via satellite telecommunications to the operation center, calculating a suitable route on the desktop, encoding outputs and sending them via encoded satellite link back to the field. Each of these approaches has its benefits and depends on demands of individual cases. In case of the server solution the output (selected route) is delivered faster to the field unit. The results are displayed as a layer within geoprocessing map service on the mapserver or can be downloaded in various formats to the desktop application in the field. Shapefile format was selected because of third party application requirement. The second approach can be more efficient in case that map outputs (e.g. in pdf format) are necessary for headquarters. The output of the calculation can be very fast incorporated to the printable maps with specific tools of ArcGIS and predefined map templates. An example of a subset of an output map (as it was generated into the pdf format) is in Fig. 3.

A mapserver simple application was established to publish map services and results of the geoprocessing. The predefined wizard in ESRI ArcGIS Manager was selected based on the demand for testing "out of the box" solution for future fast building mapserver webpage. The application had to satisfy common control features (zoom, pan, selection of the layer, show scale, etc.) and provide control toolbar for geoprocessing services (uploading a file with points of interest, interactive specifying points or selecting restricted roads, starting calculation, downloading results, etc.). All of these functionalities can be defined via web interface of the ArcGIS Manager. The efficiency of this approach strongly depends on the server performance. At this point it can be concluded that server performance was the weak aspect of the presented solution. It was very helpful to create predefined scale cache for topographic (static) layers. Ten scale levels for vector mapservices and image services were calculated. The results of the geoprocessing were published without cache calculation. This ESRI

solution was created mainly for network calculations but for dissemination of the results different solution based on Google Earth client was also tested. Geoprocessing results were provided to EUSC and published in Google style with more graphic and design features. This client was used to present the immediate situation on maps for public audience.



Fig. 3. Evacuation route map example (published in pdf format)

4 Conclusion

Collecting data for GIS database was time demanding. Nevertheless, up-to-date there is no automated solution that provides results of usable geometric quality. The existing tools require lots of manual editing and post-processing. Collecting additional information (attributes) about the created objects was also tedious and needed field reference in order to achieve required reliability of this information. This approach is rarely possible to apply in a real crisis situation when the teams have to rely on Earth observation data and possibly, if it exists, older information about infrastructure in the crisis area.

It can be concluded that ArcGIS server capabilities were suitable for the purpose of the presented demonstration but for a real crisis situation it would need more server optimization mainly for increasing performance. The described demonstration only required network analysis but for other applications more geoprocessing tasks could be appended to the server in order to better support decision making in headquarters. From the user perspective it can be useful to use ArcGIS Server API for web page integration with already existing crisis decision support webpages (e.g. EU situation centre). Geoprocessing tasks are suitable for GIS clients without license (e.g. Network Analyst function for ArcGIS Desktop without extension). ArcGIS server provides easy way for chaining the services from different sources.

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