Improving Quality of Geo-data in Electric Utility Companies Using Mobile GIS

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Abstract – **Company's geospatial data precision is the key issue for analysis, decision making and management using Geographic Information Systems (GIS). Mobile GIS applications should provide increased precision of geospatial data acquisition transferring acquisition process directly in the field. Increased geospatial data quality during acquisition could be provided by using mobile device's GPS and communication abilities. In addition, on site data collection can provide better description of the objects of interest. To provide field acquisition of geo-data about power supply network GINISED Mobile is developed, as a component of existing GINISED system. GinisED Mobile is used to improve the quality of geo-data within an electric utility company. It provides users with ability to update existing and collect new geo-data according to the situation on the field. Lineage and better positional accuracy are addressed through integration with GPS of the mobile device and depend only on its precision. In addition, better accuracy of descriptive attributes and context of geo-data are achieved by providing users to define their values directly in the field. This paper presents mobile GIS application's architecture and implementation and defines processes for its use in the field.**

Keywords – **Mobile GIS, Utilities, Field data collection, geo-data.**

I. INTRODUCTION

Nowadays, utility companies are using Geographic Information Systems (GIS) in order to improve management of their large network infrastructure, dispersed on large geographic area. GIS should not be considered mainly as a digital technical documentation but as a central information system, that provides integration of various information in spatial context. The usage of GIS enables utilities to improve investment/maintenance/development planning activities, customer care, network performance analysis, reporting etc. consequently leveraging their overall business performance. GIS enables users to capture, store, analyze, and display geographically referenced information. It allows them to view, understand, query, interpret, and visualize data in a way that is quickly understood and easily shared [1].

Spatial data are used in different analysis within utility companies like asset tracking, losses calculations, quality of service, optimal performing of the utility infrastructure etc. These analyses greatly depend on the accuracy of available spatial data and their attributes. Therefore, the quality of used geo-data plays an important part in utilities [2]. However, in previous period the quality of geo-data has been largely influenced by human factor due to an outdated collection process. It was based on dispatching crews on the field with primary task of determining the approximate location of the real geo-objects (defining geometric attributes) comparing the real world situation in the field against paper maps. Collected data (handwritten on the paper) are then stored in spatial data warehouse, using a specific GIS editor. Next step required qualitative description of collected data trough definition of specific details and possible relations to other data. Previously described geo-data collection process was susceptible to errors due to imprecise and incomplete data, poor interpretation of collected data or lack of collection procedures. This requires usage of new technologies that will positively affect the collection process in terms of quality and simplicity of collection process in the field.

Improved geo-data collection process needs to address better location accuracy of the object of interest, its orientation in relation to the environment and mechanisms to store data about these objects. In addition, qualitative attributes and context of the object are better viewed and collected directly in the field. The availability of GIS applications in the field, allows the elimination of the previously mentioned shortcomings of the collection process. Field GIS application has a limited set of functionality compared to standard GIS applications due to mobile computing devices' limited computing power that are available in the field. The emphasis of these applications is on the orientation, locating the precise position and comfort of work on site. This approach aims at improving the capabilities of verification of already collected geo-data and increasing the quality of new data [3].

The reminder of paper presents the solution for the collection of geo-data in the field, which is an extension of the existing GIS with mobile component. The second chapter gives the basic features that contemporary mobile GIS applications need to provide with strong emphasis on characteristics needed for fieldwork. It also discuss the characteristics of geo-data that must be addressed in order to improve their quality. The third section examines the architecture of GINISED system for recording electric power grid and defines the position of the mobile GIS component. The fourth chapter presents procedure for data preparation, field collection and data verification and provides a detailed insight into the architecture and implementation details of the GINISED Mobile system.

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II. MOBILE GIS FOR FIELDWORK

Mobile GIS and mobile applications in general today represent a trend in the development of information systems [4]. Design and development of such systems is not easy because it requires opposing performance requirements of mobile applications in conditions of limited resources of mobile devices. In addition to the problems that come to mind when developing applications for mobile devices, GIS applications pose additional requirements that must be also accounted such as [5]:

- Information services and distributed processing on the server side,
- Mobile devices' capabilities in terms of communication and geo-location,
- Relational database available on mobile devices and
- Software and hardware characteristics of mobile devices.

During the process of designing mobile GIS for fieldwork, it is necessary to take into account the technical characteristics of the mobile client (hardware capacity constraints, embedded modules for location, communication, etc..) as well as the physical characteristics of the environment and conditions for use (atmospheric conditions, the availability of communication services, etc.). These conditions largely determine the GIS platform requirements and appropriate client devices that can be used. In addition, it is necessary to provide the server side support trough the development of appropriate services and definition of protocols and procedures for synchronization and verification of data collected in the field.

Mobile devices can use different types of communications: Wireless LAN (802.11b / g), packet data networks using mobile telephony (GPRS) or company's radio communications using additional modems [4]. Due to underdeveloped infrastructure, communication is not possible at some locations and in this cases system should be sufficiently adaptive to provide some autonomy. This includes preserving context when working in offline mode, using map caching mechanisms and some kind of persistence storage, preferably mobile database [6].

Positioning using mobile devices is enabled using GPS or mobile network base stations. Today, the coverage of mobile network is good, especially in urban areas but its accuracy is measured in tens of meters. GPS provides much more accurate positioning measured in meters, and the precision can be increased using corrective methods [7]. Professional GPS devices, designed to work in the field have an accuracy of about 0.5 to 5 meters. In many cases, such precision is not enough and better results are achieved using additional antennas that provide better reception of the satellite signal.

Relational database on a mobile device, except as a means of storing data retrieved from the central system, should enable the independence of the device by preserving the state of the application in cases when communication with central system is not available. Mobile database replication has to provide certain parts of the company's central database available on the mobile device. The basic concept is the use of synchronization in which case, data in embedded database are automatically synchronized with main (back-end) database. [6][8]. Another option is direct copying of embedded database files from device to computer, reading data and selective recording in the main database. Later avoids the possibility that "bad" data, resulting from adverse conditions in the field or the human factor, get into the database.

The quality of spatial data is measured trough five characteristic: lineage, positional accuracy, attributes accuracy, logical consistency, and completeness [9]. All accounted criteria are of great importance for electric utility companies. Therefore, mobile GIS has to provide improved quality of geo-data by improving accuracy of each of these five characteristics. Criteria like lineage and positional accuracy are addressed trough accurate positioning using GPS and only depend on the precision that can be achieved with mobile device's GPS receiver and conditions in the field. Attributes accuracy, logical consistency, and completeness primarily depend on the way that user percepts objects in the field and collects data. Therefore, good user experience of mobile GIS needs to be provided through simple and intuitive user interface appropriate for fieldwork.

III. GINISED MOBILE ARCHITECTURE

For the purposes of recording, manipulation, maintenance and analysis of power distribution network, PD Jugoistok Nis in cooperation with the Laboratory for Computer Graphics and GIS, Faculty of Electronics Engineering in Nis continued the process of development of specialized GIS called GINISED [10][11]. GINISED provides mechanisms for recording, manipulation and spatial analysis of data about electric power distribution network. The application has object-oriented GINISED architecture. Its development is largely based on previous work on the development of object-oriented framework for GIS applications [10]. All the tools necessary to manage power distribution network, in GINISED system are implemented as two independent applications [11]:

• GINISED Editor - Specialized tool for creating of spatial data of the electricity distribution network (creation of geographic schemes of electric power distribution network, editing parameters of network elements and defining their interrelationships) and

• GINISED Viewer - WebGIS application with three-tier software architecture that provides efficient mechanisms for viewing and searching of spatial data on the selected part of the electric distribution network.

GINISED Viewer allows users to access spatial data using a thin Web client from any computer, but does not solve the problem of availability of geo-data for workers in the field. In order to enable access to geo-data to users who work in the field, the existing system has been expanded by adding a mobile component called GinisED Mobile.

GINISED Mobile has to enable rapid acquisition of geo-data in all areas covered by PD Jugoistok, which have not yet been entered into the system. It can be used for revision of already entered geo-data according to the real situation on the field. Improving data quality will increase the overall value of the whole GINISED system for the company PD Jugoistok [10].

GINISED Mobile is a three-tier application that consists of:

- GINISED Mobile Editor with mobile database
- GINISED Mobile Server
- Centralized Geospatial Database.

GINISED Mobile Editor is a mobile device application with primary goal to support mobile teams of PD Jugoistok working in the field (Fig. 1.). Online mode is supported through the application component framework Ginis Mobile for working with maps [4]. In addition, GINISED Mobile Editor needs to support users working in offline mode. GINISED Mobile Editor contains the presentation layer with the possibility of working with raster and vector maps and the data logic in the form of mobile databases. The user interface is customized for the better utilization of the map and working with objects.

Fig. 1. GINISED Mobile Editor on mobile device

The second part of the application logic is on the server side. The central database contains all the necessary information on electricity distribution network [10][11]. Component GINISED Mobile Server prepares all the data necessary for the operation of GINISED Mobile editor in offline mode. This implies preparing raster map segments for the area of interest and vector data necessary to complete the task and then transferring them to mobile device. Vector data are only a subset of data that will be updated in the field. All other vector data are used in form of raster in order to speed up the drawing on the screen. In cases where raster maps are not available on the local computer's file system, GINISED Mobile Server uses maps obtained from WMS.

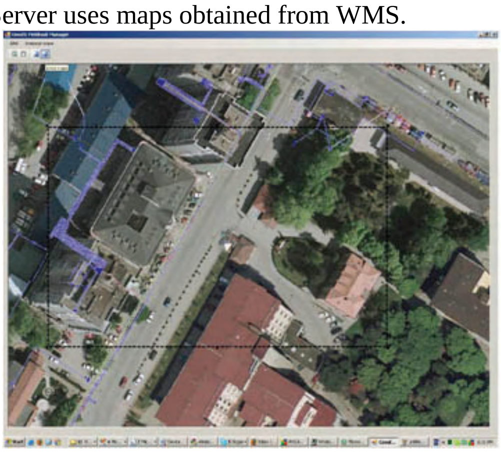

Fig. 2. Selecting area for fieldwork in GINISED Mobile Server

IV. PROCEDURES FOR FIELDWORK AND APPLICATION IMPLEMENTATION

In PD Jugoistok, specific procedure for the use of mobile GIS applications in the field was defined. The fact that in most cases, application will work in offline mode influenced the procedure significantly. Procedure for data collection consists of three steps (Fig. 3.):

- Preparation of data for a defined fieldwork area
- The process of data collection in the field
- The takeover procedure, validation and data entry into the central database

Prior to fieldwork, mobile device needs to be prepared by preparing raster maps and mobile database file with necessary data. The procedure consists of selecting the appropriate area on the map of GINISED Mobile Server (Fig. 2.), and then the selection of geo-data of interest for the defined location. Prepared maps and mobile database file are copied to mobile device. The main objective of this approach is minimizing calculations and processing on the mobile device during drawing of raster map and vector data [10]. Prepared maps are optimized for the device display and for a given area thus reducing occupancy of secondary memory and significantly reducing needed working memory for unnecessary segments of the map. If communication in the field is available, raster map segments are downloaded from WMS. Raster layers that can be selected are retrieved from the response on the *GetCapabilities* request to the WMS. In online mode, data are obtained using synchronization with central database that is natively supported by mobile DBMS (in our case Oracle Lite). Although data update is possible directly from the collection site, all data must first pass validation within company before they are stored in central database.

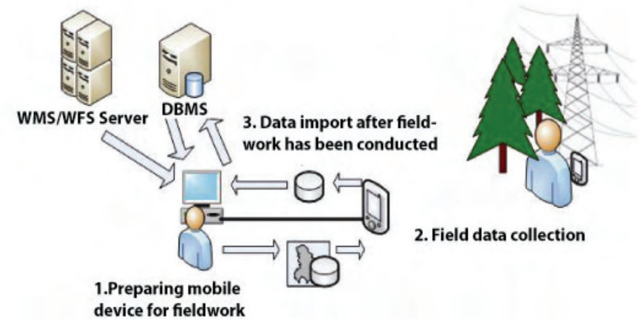

Fig. 3. Geo-data collection process

During fieldwork, users enter new or change existing data. In the process of geo-data collection, it is necessary that person who collects data, stands next to the object of interest in order to acquire its GPS location. Alternatively, user can point to the location on the map, relative to the current position in cases when objects of interest are not accessible. The next step is the selection of the appropriate type of entered object. The final stage is setting the orientation of the object in accordance with actual situation in the field. Optionally it is possible to enter additional description of the object. The process of changing the existing objects requires that they already exist in the mobile database and are shown in vector layer. The basic purpose is to determine the exact location and orientation of the edited object, but it is possible to change its type and attributes too.

After the team returns from the field, data are imported from the device in GINISED Mobile Server and displayed on the map. Depending on the needs, location and orientation of imported objects can be fine-tuned according to raster map (most accurate aero-photo and satellite maps). If the object is valid the authorized person confirms it and enters it into the central database.

GINISED Mobile Editor consists of three subsystems:

• Subsystem for working with raster map
• Subsystem for working with vector layer
• Subsystem for working with database

The entire continuous raster map consists of a matrix of segments raster maps. Given the static nature of the map segment, the optimal approach is to use local cache of raster maps segments that have already been used on the client. This mechanism significantly increases the performance of the map display. Map display is based on two level cache. The first level uses secondary memory to store map segments [4]. In the case of working in offline mode, this cache is used to hold all the necessary map segments for the area of interest. Since the secondary memory has relatively long access times, second level cache is introduced. Because of spatial data locality, it is expected that the user will require map segments adjacent to those segments that were last accessed. The second level cache keeps last N map segments in RAM of the device where N is dynamically calculated based on the currently available memory. When the amount of free memory becomes insufficient for new map segments, algorithm removes old segments from the secondary cache according to the LRU algorithm.

Subsystem for working with vector layer is specific due to constraints of the mobile platform. Therefore, solutions used are different from the usual practice in conventional GIS. Drawing vector layer elements is based on copying of the bitmap prototypes. For each element a bitmap prototype is created such that enables much faster access to bitmap pixels. While drawing, each pixel of the map canvas is mapped to the corresponding pixel of the prototype. This solution enables drawing and rotation of complex symbols that are not natively supported on mobile device. Such drawing is processor-intensive thus the results of mathematical operations are stored in separate structures for later use. The advantage of this drawing approach is the consistent view of vector layers in all GINISED applications.

Subsystem for working with mobile database is based on interfaces for database access. This approach completely separates presentation layer from data access layer. The main advantage of this approach is reduced number of access to mobile database thus reducing the possibility of error.

V. CONCLUSION

The system presented in this paper is a good foundation for further expansion of mobile services for supporting field crews in PD Jugoistok. Monitoring of the collection process will identify the impact of such mobile applications on business processes in PD Jugoistok. In future, the emphasis will be on identifying all potential users of mobile GIS in PD Jugoistok. By upgrading the existing corporate network infrastructure, owned by PD Jugoistok, it will be possible to introduce a high degree of interaction between employees in the field and employees within company. Data communication provided using mobile GIS will provide timely response of repair and maintenance crews. Employees in PD Jugoistok will be able to achieve significant savings reducing time spent on the ground and reducing transport costs through dynamic forwarding of new tasks while the crews are still at locations of interest. Time for development of other mobile applications will be significantly reduced by using presented architecture. Further work is based primarily on improving user interface in accordance with the experiences of the users and improving the presentation layer by improving existing algorithms.

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