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EFFECTIVE COLLABORATIVE MAPPING BASED ON MOBILE DEVICES

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Abstract

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There are numerous situations when it is utmost important to share efficiently some spatial data among a group of people. Floods can be taken as an obvious example. Many stakeholders including mayor or rescue service workers must have actual information about the conditions in the terrain. And most importantly, all of these can contribute to the information. Among these situations involving the crisis management, we dare to mention especially the inventory process. Traffic signs, road lanes, trees, lights and many other different object must be regularly maintained. Most of the organizations use some kind of geographical information system to keep the information about the maintained property. Our article is focused on development of mobile application that allows to acquire spatial data that are later used in these information systems. Thanks to real-time data synchronization between multiple devices, field workers can cooperate and share data immediately to an operating center or with the other workers. We describe the design of our mobile mapping application, comparison with other existing solutions and problems of real-time synchronization between different devices. Finally, we provide details about application usage in different municipalities.

Keywords: mobile application, inventory, synchronization, mobile mapping, GIS, crisis management

INTRODUCTION

Every administrator must be aware of the actual state of maintained property. For instance, the governments and local administration must analyze the land use plans, crime rate and many other factors that have an influence on the life in the municipality. We can find numerous examples even from distant past (Wright, 1937; Barnes, 1929), but even in recent history, we can find many interesting analyses based on spatial data. Very similar tasks are carried out by executive officers of many companies, especially these that are connected with agriculture or forestry. We must keep records of tree growth, production of the fields, etc.

Certainly, many of these tasks are nowadays substantially simplified thanks to satellite navigation, remote sensing, GIS and many other information and communication technologies. Nonetheless, there is another important aspect. These tasks involve a broad group of stakeholders. Citizens want to participate in the urban management, decisions connected to land use planning involve many departments, many different forces must be coordinated during rescue operations, etc. (Ghosh, 2016) This places emphasis on fast and effective obtaining and especially sharing of spatial data that provide the basis for further decisions.

Spatial data can be obtained mainly through direct measurement (e.g. usage of a mobile device equipped with GPS in the terrain), from some specific sensor networks (meteorological stations), or indirectly from other spatial data (e.g. vectorization of satellite images, point clouds generated by LiDAR). (Puente, 2013) The last mentioned approach, derivation of information from existing spatial data, is of particular importance in the case of large area processing. The examples include preparation of vector map layer of the road network for navigation, already mentioned forest inventory (Mikita *et al.*, 2016), evaluation of deforestation (Ramachandran, 2017), etc.

Nonetheless, we focus on direct data measurement in this article. Therefore, the situation when an operator with appropriate equipment must perform field measurement. This approach is necessary especially when detail data are required (e.g. precise vendor and the state of the public lights). We provide a brief review of existing solutions for mobile mapping and summarize their advantages and flaws. Further, we explain the design of our mobile mapping application and its implementation. Finally, we describe several examples of its usage for inventory of public property.

Review of Existing Solutions

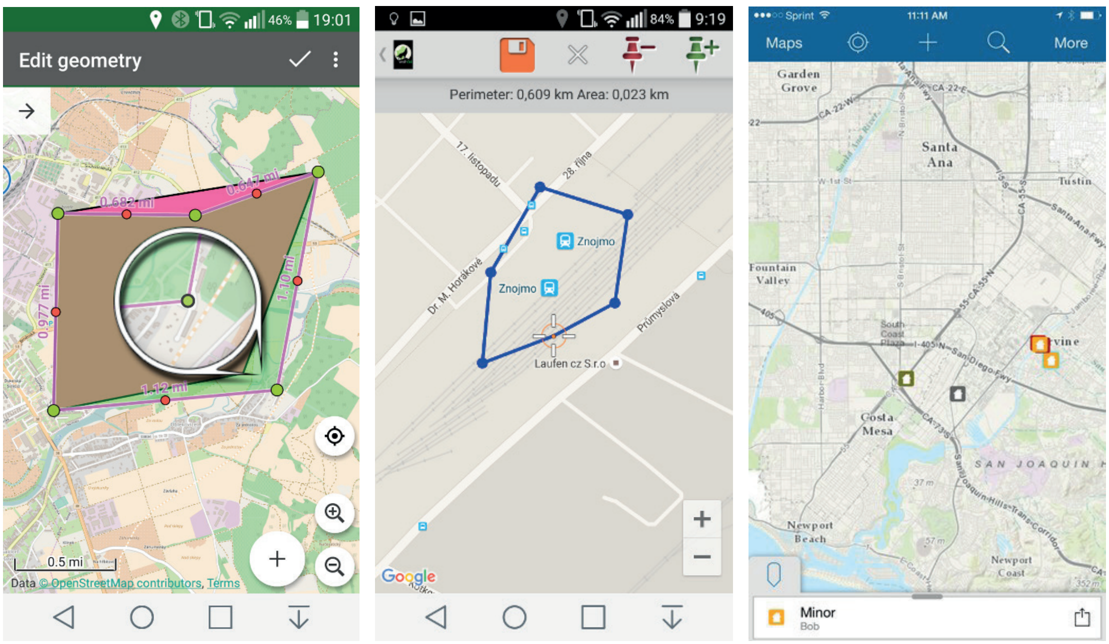
There are a few existing solutions for mobile mapping on the market. We can find them on *Google Play* on *Android* or in *Apple store* on *iOS* platform. Frequently used are *Esri* tools that support their *ArcGIS* solution for GIS professionals (*Collector for ArcGIS*, *Explorer for ArcGIS*, *Survey123 for ArcGIS*, *Snap2Data*). There are however many good rated applications even from other companies in the application stores. We selected several applications that are close to our own application: *MapIt*, *Map Plus*, *Mappt*, *Map Plus*, *NextGIS* Mobile, *Wolf-GIS* or *LocusGIS* (Google Play, 2015; iTunes, 2015). Following comparison is based on documentation to the applications as well as on our own testing. During the testing, we focused mainly on the usability for field measurement and synchronization of the measured data into some service.

The *Explorer* for *ArcGIS* is aimed at viewing existing maps. The *Collector for ArcGIS* is focused, as is evident from its name, on data collection for maps. One of the key flaws is that data structure editing is not supported in device. The *Survey123* application can be used for gathering information through forms. All mentioned applications are using *ArcGIS* online services for synchronization. Nonetheless, the synchronization is not bi-directional.

The *Map Plus* application supports data measurement, import, export, however, there is no synchronization. Similarly, the *NextGIS Mobile* does not support the synchronization too. In *Wolf-GIS*, one can create only polygons. This application is focused primarily on allotments mapping.

The *MapIt* application is most similar to our application. It allows creating map layers with objects described by different attributes directly in the mobile device. The spatial objects have colors and descriptions assigned but cannot have some specific custom symbols. The application user friendliness is generally on a high level. It supports offline maps and allows to export or import the data too. However, full synchronization is not supported.

Another very interesting application is *LocusGIS*. Although the project is still in a beta version (Jan 16), it supports map projects, layers and contains a lot of customization options, e.g. selection which attribute will be visible on the map. It has its own *Locus Store* with additions, materials, and functions, including synchronization functions. An external GPS module can be connected via Bluetooth. Many formats of spatial data are supported including KML, SHP,



1: *Left image presents the LocusGIS beta with intuitive user interface and many functions. The middle image shows the Wolf-GIS that is aimed at allotment mapping. The right image is from the Collector for ArcGIS that is focused on collecting data for maps. (Source: Google Play, 2015; iTunes, 2015)*

GPX and hundreds of different coordinate systems. The user interface is very friendly and intuitive. Once the application will be finished we will see how it will work and how the synchronization will be implemented.

All described applications communicate with some server; nonetheless, they are mainly oriented on viewing existing maps or collection of required data into prepared maps and forms. Possibilities of creating new maps or map layers in a mobile device are limited. The data synchronization is limited too – none of the described applications has real-time bi-directional synchronization between multiple mobile devices. Our application, therefore, aims to overcome mentioned drawbacks. It supports management of map projects, map layers and spatial objects (points, lines, and polygons). All of these can be created or edited right on the mobile device. Most importantly, our application supports real-time bi-directional synchronization between multiple mobile devices and a server.

Methodology

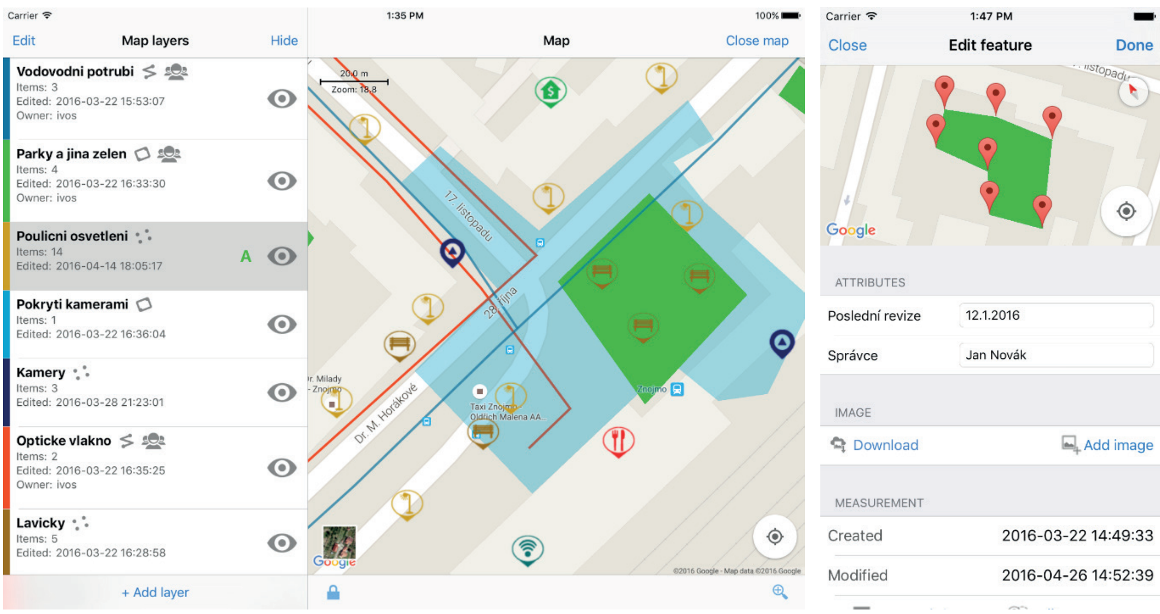
Development of the mapping application has two fundamental aspects: design of the mobile application with the focus on high user experience and implementation of the service for synchronization of measured data.

User Interface

All data in the application are divided into different map projects. Therefore, the user usually creates a new map project each time he/she wants to start a new field measurement. Each project is composed of map layers. A map layer is an overlay of a specified type (point, line or polygon). The layer has defined color, symbol, transparency level and required attributes. The layer consists of objects. Each object holds its attribute values and, if it is desired, a camera image. These map objects can be placed into the map layer manually by picking the appropriate location on the background map, or the users can put the new object on the position given by GPS. Created object, layers and maps can be later edited according to the user needs. This structure has been chosen because it is entirely compatible with the major geographical information system such as *Esri ArcGIS* and *QGIS*. Naturally, data exported into KML can be viewed even with common tools like *Google Earth*. The application interface was designed according to the design patterns for *Android* (Google, 2017) and *iOS* platform (Apple, 2017).

Synchronization

We use own server service for data synchronization. This feature allows keeping the data on all devices up to date even in case the users are working on the same map project or even with the same map layer. We designed two types of synchronization: full and differential one. The full synchronization is used during the first login of the user or if the user was not logged in for an extended period. The complete synchronization downloads all user data at once. On the other hand, the differential synchronization runs periodically. Its purpose is to download only changes in spatial data to spare the data traffic. The differential synchronization is run periodically in the defined interval (default is 30 seconds). All changes that are made on the device are usually uploaded immediately. Just in case of disconnection from



2: *The left image presents an overview of a city property inventory. Each object on the map can have attributes like a date of the last revision or a name of the object's administrator. The right image shows the adjustment of a polygon shape. One can see also the adaptive behavior of user interface – the left image is from a larger screen on iPad, the right one is from a smaller screen on iPhone.*

the network, the changes are queued on the device and uploaded after reconnection.

When two or more users change or delete the same object, a conflict occurs. In our application, the rule of the first is used. Hence, the first change that arrives on the server is performed, the other is discarded and the user is informed.

Nonetheless, synchronization is not an obligatory function. Users can work in the so-called *offline mode* that provides the same functionality, just without the synchronization mechanism. Without synchronization data are stored solely in the device and can be exported to GeoJSON or KML format.

RESULTS

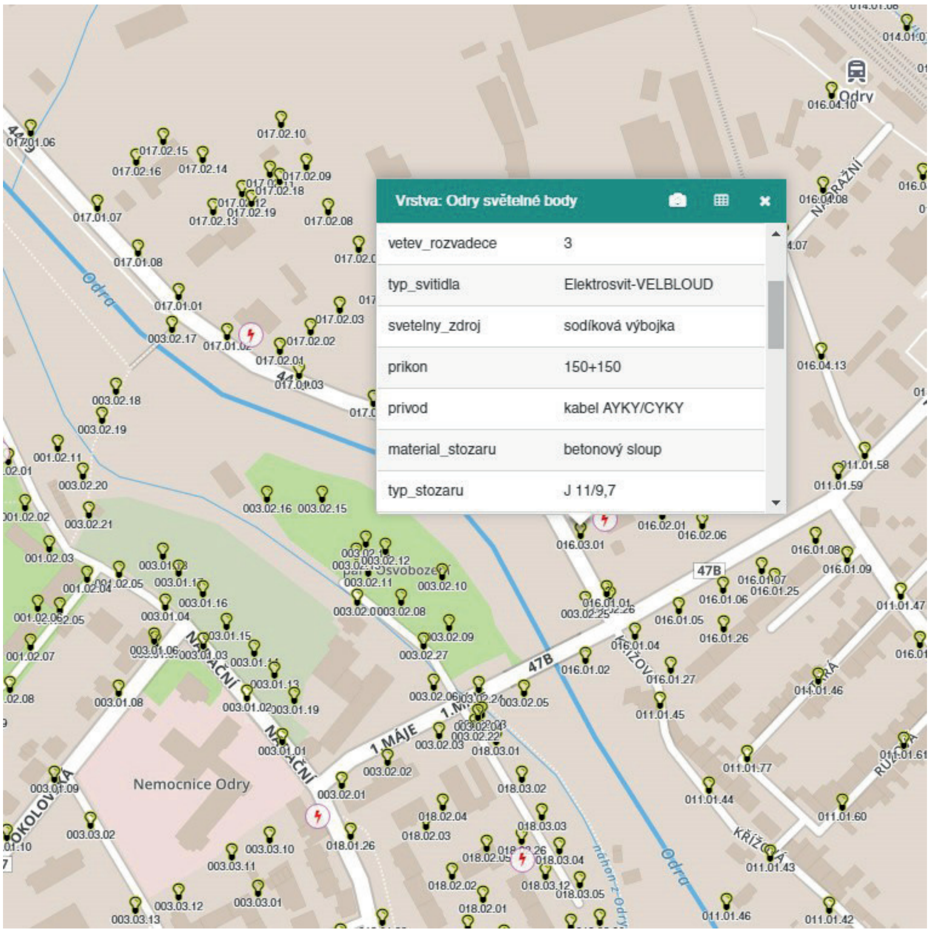
Our target platforms are both *iOS* and *Android* operating systems. For *iOS* development, integrated development environment *Xcode* is used. The whole application is written in *Swift 3* language which is modern, safe and progressively developing language massively supported by *Apple*. For *Android* development, *Android Studio* and *Java* language are used. Both applications are therefore built as native applications based mainly on standard tools and libraries from *Apple* and *Google*. The server-side solution is based on *Python* language. The data are stored in the *PostgreSQL* database with *PostGIS* extension.

Testing in Real Use

We tested our application for over than year with the ENVIPARTNER company. The company is focused especially on local flood management plan preparation and related public property inventory. As mentioned, municipalities maintain plenty of properties. We can name trees in parks, public lights, town flats, parking places, etc. It is utmost important to have precise data about all these properties. Accurate and actual data can substantially simplify planning, maintenance, damage reporting, etc. Following two example describes deployment of our application for such property inventory.

Public Lights Inventory

The application was used for inventory of public lighting in the city of Odry. The existing solution was based on CAD drawings in DWG format. The users exported these drawings that described placement of individual lights into *ESRI Shapefile*. Using *QGIS* application, the exported data was connected with required attributes (initially stored in XLS format). Such map layers were then imported into our application. After that, our application was used



3: *The image presents the final result of public lights inventory in the city of Odry. (Source: ENVIPARTNER company)* to update stored data in the field. The precision of GPS positioning varies a lot with different devices. To obtaining more accurate light positions, the mobile device with our application connected to *GNSS Spectra Precision Pro Mark 700* receiver (Spectra Precision, 2017). This solution allowed to achieve a precision of 70 cm without using any RTK (real-time kinetics) service. Better precision can be achieved using a RTK service, or by taking more measurements and subsequently averaging the point location on the map.

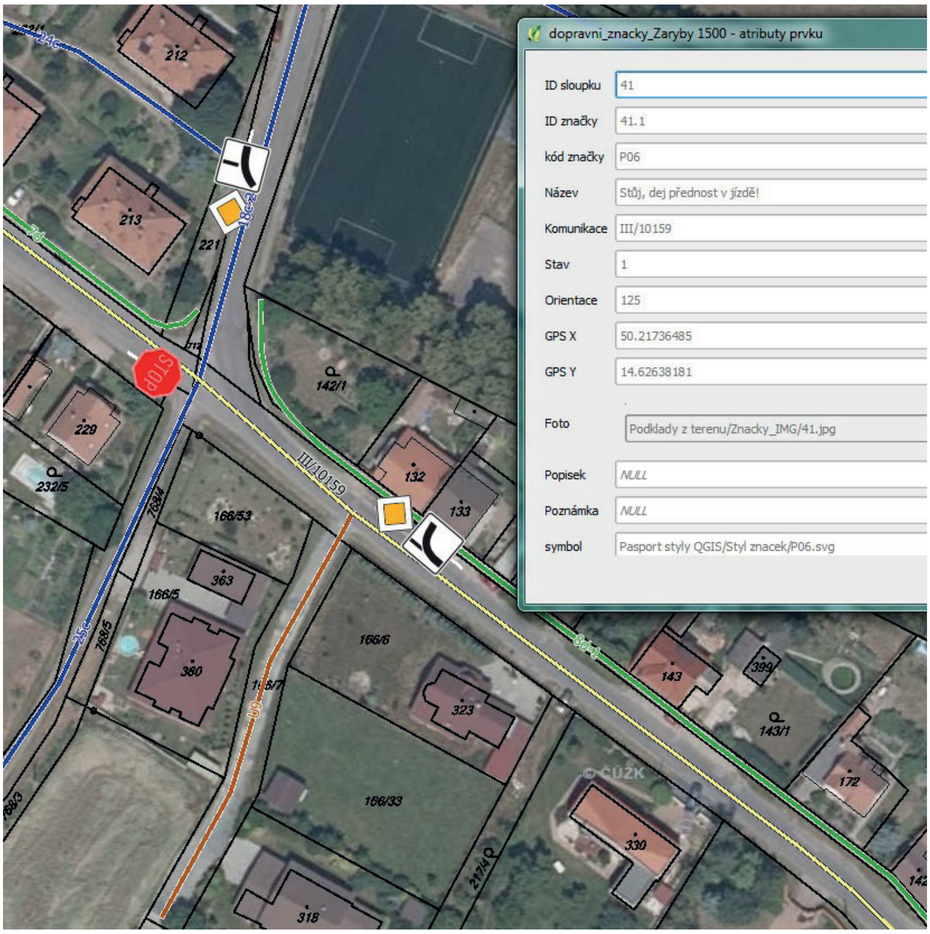
Therefore, the actual position of the individual light poles and switchboards was verified in the field. Further, attributes of each element were updated (used light source, power consumption, overall status, etc.) and photographs were added to each light. The application was mainly working in offline mode because of a vast number of elements in individual layers and mobile internet connection instability in some locations.

The updated information about public lights was exported in the KML format and then processed again in *QGIS* application. There took place the attribute control and data consistency verification. After this post-processing, the collected data were transferred into a *PostGIS* database for further usage.

Road Signs Inventory

Our second case study is the inventory of local roads and traffic signs in the village of Záryby. The village had no previous records of this kind, so the application was used to produce the records completely from the beginning. The data collection in the field consisted of mapping all traffic signs in the village. For each sign was registered its kind and further attributes. The records were supplemented with photographs. Measurements of local roads supplemented these traffic sign records. Similarly, to the previous case, states of the road and photos were recorded. For the inventory a portable device was used. The device provided sufficient precision of measurements with integrated GPS module.

Collected data were later processed with *QGIS* application, which helped to verify and correct some inaccuracies. In the case of traffic signs, a mapping project has been created that includes symbology with road signs corresponding to reality. Local roads parameters were determined according to the act of public communications. The output of *QGIS* was a set of maps with roads and road markings in the scales of 1:1500 to 1:5500.



4: *The image represents an example of road and traffic sign inventory in village of Záryby. (Source: ENVIPARTNER company)*

CONCLUSION

We detected several drawbacks during the testing period. Following text describes the key issues. First of all, manual adjustment of the object's geometry is quite uncomfortable on small screens. Although we made several improvements, it is still incomparable with precise work on a desktop computer. Next problem is related to cooperation of multiple users on the same project. They need to be informed about basic principles of data synchronization. Otherwise, they could overwrite data measured by other workers during a careless action. Hence, they should negotiate conditions before the start of the measurement. Finally, stable internet connection is required for trouble-free collaboration. Data are not lost in case of connection failure. However, after reconnection, many conflicts can occur. It can lead to confusion of workers and duplicated measurements.

Even though mentioned issues, our application can massively simplify the inventory process. It can save costs by improvement of data precision, shortening the time that is necessary for collaboration of the stakeholders and the management decisions can be more precise and well-timed. The advantage of our solution is that all necessary hardware is multifunctional (common cell phones or tablets) and can be used for other purposes, or one can use devices that are already bought in the company. That reduces primary costs significantly.

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