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# Use of a progressive web application for working with Earth remote sensing, topographic and cadastral data layers

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**Abstract.** This article proposes the use of the progressive web applications (PWA) for the geographic information systems' (GIS) web user interfaces. The main advantages of this approach for GIS: use of arbitrary mobile and stationary devices; work in conditions of unstable connection to GIS server with fault-tolerant user input data delivery to the server, when the connection is restored; work offline with the information stored on client device, when the server is disconnected, and automatic synchronization of changed data, when the server connection is active; network traffic savings during data transfer. The above mentioned advantages are important for a number of practical applications in cadastral accounting and construction.

## 1. Introduction

A large number of geographic information systems (GIS) with a web interface [1] are used in cadastral registration and construction. These systems work in a web browser and require a constant server connection [2]. This fact does not allow working with such systems on-site under poor or missing Internet connection.

Since the work of construction and cadastral engineers requires filling a large number of documents in situ, on various sites, it is necessary to provide users with the opportunity to work on-site with the same systems that they are used to work with in the office. The presence of a convenient client-server tool for working with geodata that does not require complex installation or special devices [3] would expand the range of geodata consumers and also provide the possibility of entering data into GIS by a wide range of people [4-6].

To do this, it is necessary to provide the ability to operate GIS outside of the offices in places where a stable high speed Internet connection may not be available.

Today the main problems preventing the on-site use of web GIS are the information loss due to failures and interference in wireless data transmission, the need of large data amounts re-download in different sessions of web GIS applications and the constant need for an active server connection. These circumstances have a particularly negative effect when accessing geodata via the Internet, since the probability of interference limits the duration of sessions with data, and the use of web applications excludes the possibility of offline local storage and use of individual datasets for certain users.

The novelty of the proposed approach lies in the carried out study, that takes into account the specifics of geodata (volume, time of relevance, spatial resolution, multilayer structure) and uses the capabilities of the HTML5 standard [7] for creating web applications (mechanisms for offline storing and manipulating data on the client device by means of a web application only).

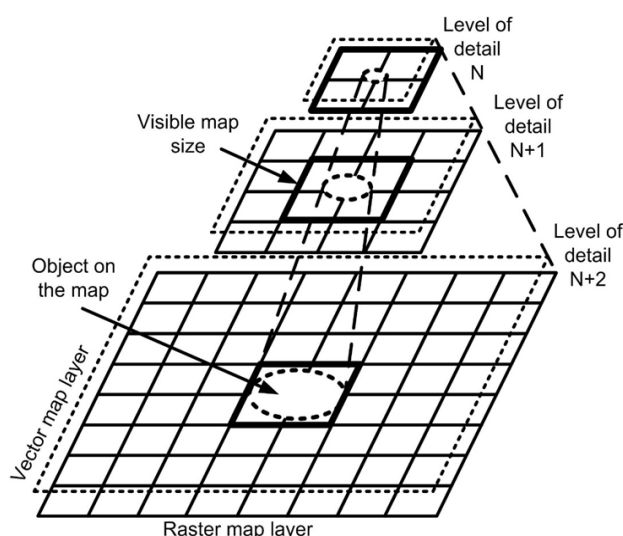


This makes possible the creation of progressive web applications (PWA) for GIS – offline capable fault tolerant web applications, that can work on any stationary or mobile device with HTML5 compliant web browser without any other software.

Let us consider working with a cadastral GIS using PWA as an illustration of the use of PWAs in GIS.

## 2. Solution components

To discuss the offline capable, fault tolerant web GIS we should describe the main elements of web GIS user interface we are going to work with. When loaded to user's device web browser, in addition to management software, modern web GIS contains a combination of layers [8] of raster, vector, and text data loaded with reference to a unified coordinate system (see figure 1).



**Figure 1.** The composition of the elements of a multilayer map.

### 2.1. Raster Data

Raster layers of the map consist of a matrix of points – pixels that transmit information by their color. The raster layers of a map are usually Earth Remote Sensing (ERS) data, aerial photographs, or maps scanned from paper. Raster layers act as a substrate for vector layers or as independent sources of information about the Earth's surface.

Raster layers of the map are created from separately loaded elements – tiles with a resolution of 256x256 pixels and a size of 5-200 kB (the most common size in the GIS are 5-20 kB) each to accelerate the start of the map display to a user.

The scaling of raster layers for enlarging the map is carried out by increasing the number of layer elements by 4 times for each subsequent detail level. Depending on the detail level, a raster layer is created from tiles of various resolutions [9].

In order to ensure a smooth transition between the detail levels before loading the constituent elements of the next level, proportional stretching (or compression when the map is scaled down) of existing map elements is carried out.

Raster map elements are rarely updated, the lower the detail level is, the less often it is updated.

The user's work takes place at detail levels from 14 to 19, therefore, in order to ensure autonomous operation, a certain number of tiles of the raster layer of the map should be locally saved. The amount of saved data is determined by the area of the map section and the number of tiles (table 1).

**Table 1.** The total number of tiles and total amount of data of the raster layer depending on the area of the site in the detail levels from 14 to 19 with the size of one tile being 20 kB.

| The area of the site, sq. km. | Total number of tiles, pcs | Total amount of data, kB |
|-------------------------------|----------------------------|--------------------------|
| 1                             | 267                        | 5,340                    |
| 2                             | 500                        | 10,000                   |
| 4                             | 995                        | 19,900                   |
| 9                             | 2,138                      | 42,760                   |
| 16                            | 3,803                      | 76,060                   |
| 25                            | 5,849                      | 116,980                  |
| 36                            | 8,375                      | 167,500                  |
| 49                            | 11,298                     | 225,960                  |
| 100                           | 23,264                     | 465,280                  |
| 225                           | 51,953                     | 1,039,060                |

## 2.2. Vector and Textual Data

Vector map layers consist of points, polylines, and polygons that form graphic objects of the vector layer, as well as associated textual descriptions or analytical information.

Geospatial and thematic objects with precisely defined boundaries are usually displayed on vector layers, for example: administrative-territorial division, settlements, roads, city and land cadastre, various marks, data on fires, meteorological data etc.

Vector layers are displayed on the map starting from a certain detail level. They are immediately loaded in full if have only a small number of elements on the layer. If there is a large number of elements, the layers are loaded in parts that correspond to the section of the map displayed on the screen and its detail level. This ensures the best perception of the map by a user and good performance of a terminal device.

The amount of data in a vector layer depends on the number and characteristics of the elements displayed on it.

Scaling of vector layers when the map is enlarged (scaled down) is carried out by proportional stretching (compression) and additional loading (removal) of elements displayed with greater (fewer) detail. This is possible due to the specifics of the vector image, as well as the multilayer map structure.

Vector layers can be updated frequently since their updating may not depend on the received ERS data and does not require a lot of server processing. The actual update frequency depends on the content of the displayed information and the period of its relevance and is determined in accordance with the purpose.

## 2.3. PWA GIS Data Caching

Depending on the activity scope, various types of ERS data are required. In order to assess the needs and possibilities of ERS data long-term caching in various tasks, the main common parameters are the spatial resolution (it allows determining what detail levels of the data are needed to be cached to solve a specific task) and the data relevance period (it allows determining the saving traffic possibilities for a specific task).

Various types of geodetic and cadastral tasks are characterized by the ERS data relevance period from 1 month up to 5 years. Therefore, the ERS data can be locally cached by PWAs for their relevance period. For the professional use of ERS data in GIS, not all of the detail levels are used but only the levels from 14 to 19, which provide the necessary spatial resolution of 0.5-10 m. To save local data storage, individual data sets used by specific specialists are subject to caching (with limitations on the

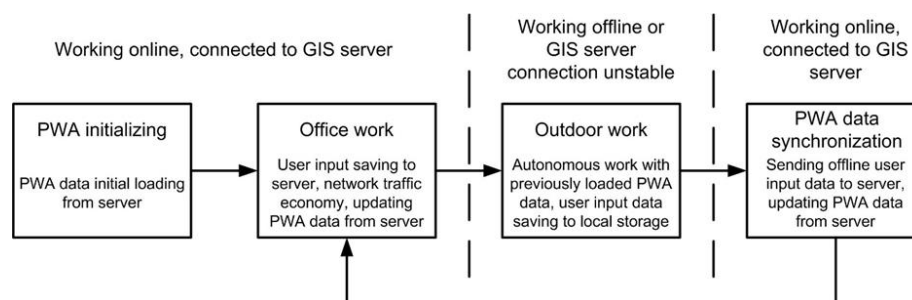
land area and the necessary detail levels) [10]. Since the saved PWA can be launched immediately with the required map detail level, caching of unused detail levels is not required.

Vector layers and text symbols can change during each working day but since there is a territorial division between specialists, changing information by some employees cannot affect the quality of the autonomous operation of other employees. And during synchronization with the GIS server, any and all receive up-to-date information. The client side of the PWA of each employee is synchronized with the GIS server automatically when there is an Internet connection to the server. Elements of vector layers are also cached to save traffic and provide autonomous operation. In this case, the period of relevance is at least one working day.

As for the PWA program code for displaying data layers and ensuring user's interaction with them, it does not change when the displayed data changes, therefore it can be cached for a long time, until the version of the PWA software part changes.

### 3. PWA GIS User work process

The use of PWA in GIS allows the following work process (see figure 2, table 2) for the specialist (a land surveyor or a cadastral engineer) using geodata, mobile devices, and who may need this GIS away from a reliable connection to the GIS server, e.g. when carrying out: topographic survey of the terrain (including various objects of the terrain situation, such as terrain features, vegetation, communications, buildings); adjustment of topographic plans and updating terrain situations; preparation for construction; land boundary coordination; dispute resolution; other types of geodetic and cadastral work.



**Figure 2.** The process of user's work with PWA in GIS.

**Table 2.** The process of user's work with the PWA while working with GIS in comparison with a traditional web application.

| No. | User actions  | PWA  | Traditional web application   |
|-----|---|--|---|
| 1.  | Internet connection online. The first user's visit to the web server from an arbitrary client device with a standard web browser. | Initialization: initial loading of PWA software and data from the server to the local storage of the client device. During initialization, the PWA operates like a traditional web application. User can start working right away. | Loading the main page and the data displayed on it. User can start working right away.  |
| 2.  | Internet connection online. Viewing an interactive map, entering and editing descriptions of map elements. E.g. in the office.    | Check for updates and download changed data from the server, send user input data to the server. Save traffic and protect against connection failures by using data from local storage and backing up user input.                  | Downloading data from the server as the user requests, sending user input data to the server. Server connection failures cause inoperativeness. |
| 3.  | Internet connection offline. Viewing an interactive map, entering and editing   | Autonomous work with previously loaded data, saving user input data in local storage.  | Out of service.   |

|    |  |  |   |
|----|--|--|---|
|    | descriptions of map elements. E.g. on-site outdoors. |  |   |
| 4. | Internet connection is back online.                  | Data Synchronization: sending saved user input data to the server, check for updates, and download changed data from the server. | Reloading of the page, upon displaying of which the connection was lost, and the data corresponding to its address. |
| 5. | Go to step 2.  |  |   |

Before starting on-site work (at a certain section of the area), a specialist from the office or any other place with a reliable Internet connection using a personal device accesses the GIS PWA web server, containing a vector map of this area with a raster substrate from ERS data. After the user authorization, the individually configured PWA is automatically downloaded and saved to the user's device with the necessary data and software for a particular user to work with in offline mode. This is carried out by means of the PWA in a web browser without the need to install any additional software on the user's device. PWA allows using various types of stationary and mobile client devices.

After the initial PWA data loading, the user can work with the saved data and input data to PWA web forms (e.g. for topographic/cadastral/boundary plan: text comments, updates of object attributes, change of object boundaries) having poor or no connection to the GIS web server.

The specialist finds objects in the entrusted area, the boundaries of which on the vector layer do not coincide with the relevant ERS data, marks them in the PWA, e.g. by highlighting or setting new boundaries. If the ERS data is relevant, then new boundaries and all calculations of distances and areas can be carried out without leaving the office. But to eliminate errors, e.g. if there are objects that are hard to distinguish (fences, buildings, etc.), hidden by vegetation, the specialist has to go to the object to clarify details: visual confirmation of the presence of objects and their outlines, the cadastral attributes relevance, GPS coordinates of the points of objects etc. The exact coordinates are determined by specialized equipment, but to search for boundary marks for binding this equipment, preliminary determination of GPS coordinates by means of personal mobile devices can be used. A personal device used on-site (laptop, tablet or even smartphone), when working with the PWA, already contains all the things needed for work, despite the complete or partial lack of connection to the server.

When inspecting the object, the specialist makes notes in the electronic plan, updates the boundaries and attributes of the objects in the personal device, and then returns to the zone of reliable Internet connection to the server (e.g. to the office) to synchronize the data with the server.

The PWA saves all offline user input data and sends it to the server when the Internet connection is back online.

All saved PWA data that has been changed on the server during the client's autonomous operation is automatically updated on the client device when reconnecting to the server. All users have the data updated, so everyone receives relevant information.

The developed software solution [11], [12] allows to upgrade to PWA almost any existing traditional web application based GIS.

#### 4. PWA GIS Network Traffic Comparison to a Traditional Web Application GIS

To get a numerical estimate of GIS network traffic savings and web pages' loading time reduction when using the PWA compared to a traditional web application, let us consider the work of a specialist on a site with an area of 25 sq.km (which is also equivalent to a road or a communications route of 50 km, including 0,25 km of the adjacent territory on both sides of the center line). The considered PWA software solution contains:

- a raster layer of ERS data of detail levels from 14 to 19 that consists of 5,849 tiles, with a total size of 116,980 kB;
- a vector layer that contains 500 objects with a total size of 40,960 kB;
- PWA program code and design elements, including means for displaying data and user interaction, 30 elements with a total size of 5,120 kB;

- a configuration file of 300 kB that controls local caching of received data on the client's side.

During the PWA initial loading (initialization), 163,360 kB = 159.53 MB = 0.16 GB will be downloaded to the user's device.

For the comparison let's assume that the raster layer data is updated completely every 6 months, although, in practice, it can be updated not completely but only in some of its tiles that contain changes for the specified period. Regarding the vector layer, let's assume that 10% of its objects are updated every 3 days. We'll also assume that the PWA program code and design elements are not updated for the period under review. Saved elements are delivered from the local storage on the client side and displayed to the user almost instantly. During each session with the PWA, a configuration file is downloaded from the server. This allows the client part of the PWA to check the relevance of locally stored data and controls the local storage updating.

Thus, the total traffic when working with the PWA will be as follows:

- 173,352 kB – per week (7 days);
- 213,320 kB – per month (31 days).

In order to compare PWA with a traditional web application (that can't work offline and doesn't backup user input data), let's assume that in a traditional web application each session is downloaded no more than 20% of the total amount of raster and vector GIS data (the user works with different sections of the site area), the program code is loaded every time and consists of 25 elements with a total size of 4,800 kB (since it doesn't have PWA features).

Then the total traffic generated by working with a traditional web application will be as follows:

- 254,716 kB – per week (7 days);
- 1,128,028 kB – per month (31 days).

## 5. Conclusion

As a result, network traffic savings when using the PWA compared to the traditional web application in this case are 31.95% (81,364 kB) per week of use and 81.09% (914,708 kB) per month. Besides the network traffic savings, the offline operation, when working with the cached data, and user input data backup abilities are also the huge advantages of the PWA.

Due to the high importance of automation of geodetic, cartographic, and cadastral activities for public administration and construction and wide use of traditional web applications in GIS industry, it is important to upgrade traditional web GIS applications to PWAs to make them more effective and useful.

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