Publication of Geodetic Documentation Center Resources on Internet

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Abstract. Geodetic Documentation Centers collect geodetic and cartographic resources. The resources include spatial data and their metadata. European Union INSPIRE directive imposes an obligation on GDC to publish selected data in the Internet. In this paper, an adequate form of publication is discussed on the base of iGeoMap application.

The Internet application iGeoMap merges data from various resources. Depending on the data to present, different types of resources are used. The application can publish spatial data from files (text or binary), a database specialized in spatial data service (PostgreSQL, ORACLE), or web services (Web Map Service, Web Feature Service). Utilization of various data sources by the application is presented in this paper.

As a part of the subject, searches of the most popular data (parcels, address points, and control points) are discussed. Various data sources and searching mechanisms involved by the searches in iGeoMap are presented in use cases.

Keywords: E–Government, Spatial data, Web Mapping, Web Map Service, Web Feature Service.

1 Introduction

Geodetic Documentation Centers collect geodetic and cartographic resources. The resources include spatial data and their description. European Union INSPIRE [1] directive imposes an obligation on the centers to publish selected data on the Internet.

The centers manage data in various forms. Usually, spatial data is collected as files in vector or raster format. Sometimes databases with spatial data support, such as Oracle or Postgres, are used. Publication on the Internet is usually performed using a dedicated application compatible with internal data format. However, in recent years web services have been used more widely for such

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purposes. Such form of publication is more user-friendly since it allows the data to be referenced in personal resources.

In this paper, an Internet application iGeoMap is presented as a tool for spatial data publication. The application supports several types of data sources. Spatial data can be acquired from files, databases, and web services.

In subsequent sections there are presented sources of spatial data utilized in Geodetic Documentation Centers (Section 2) and iGeoMap application for a data publication in the Internet. For this application several typical use cases, encompassing various data types, are discussed (Section 3). Finally, the conclusions are presented (Section 4).

2 Sources of Data

Geodetic Documentation Centers utilize various types of resources. The centers collect spatial data mainly as files in a closed, proprietary data format enforced by the data management softaware in use.

For example, the centers, which use iGeoMap, utilize a mapfile format. Usually final users do not have adequate software to read such files and a conversion to the most popular and open data formats such as GPX and KML is necessary.

In worse scenario, the centers only have graphical data available in the form of scanned map sheets. However, such files can be also published if additional georeference information is given. In the worst case, local centers do not have any data in digital form, but this situation will not be discussed here.

Several centers, mostly in big agglomerations, collect data in databases. This situation is typical when more than one application have to access the same data. For spatial data dedicated systems should be used (Oracle, Postgres). For security reasons, database engines cannot be made directly accessible to end users and the data must be accessed via an authorized application or a web service instead.

Among web services there exist some dedicated to spatial data publication. The most important is theWebMap Service, which creates an image of the requested area. This service has a limited ability to generate spatial objects descriptions.

When detailed geospatial data is necessary, the Web Feature Service should be used instead. Finally, overloaded WMS can be replaced with the Tile Map Service, which delivers pre–generated tiles.

A detailed description of the above-mentioned data sources together with information on how iGeoMap application supports them are given in the following sections.

2.1 Files

The iGeoMap application is able to read files in mapfile format. This format is used by Geodetic Documentation Centers on daily basis. The format is dedicated to presentation of spatial data collected by a local government administration.

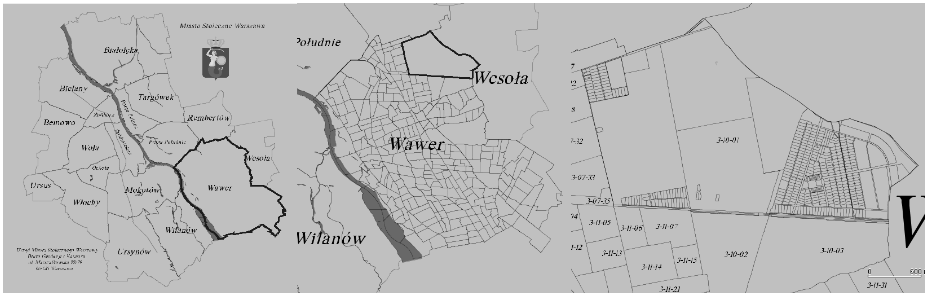


Fig. 1. A hierarchical administrative structure mapped into a mapfiles structure (from the left: a district, a region, parcels). Links are presented as a bold boundary.

The application allows its user to export selected data in common file formats. The KML format is used for a presentation of 3D objects. The GPX format is used for import data into GPS devices.

These files store formatted text. However, spatial data can be also collected in binary sources. The first example are shapefiles as a commonly used and supported source of spatial data. The second, image files, are very often the only digital source of some data in centers and can be published if georeferences for images are given.

Mapfile. The mapfile format is a text format describing spatial data. A single file contains a list of objects. Each object is described by the object geometry and a set of descriptive features. An example is given below.

Example of an area object from mapfile

```
*5213 0 19 0
:A2[146516_8]
:A3[Wilanow]
:TX[@Obreby/Obreby_Wilanow.MAP]
P 1 -9701.560 3538.640 ,20121
P 1 -9676.950 3520.410 ,20120
P 1 -9646.360 3511.880 ,20118
P 1 -9642.500 3482.740 ,20117
P 0 -9701.560 3538.640 ,20121
```

In this example, the Wilanow district is described. The object geometry is a list of points. Each point is given by a labeled pair of coordinates in a local metric system. Different centers use different systems. It impedes the exchange of data between centers.

Descriptive features are stored in attributes. The district is characterized by a unique number called teryt (stored in the attribute A2) and holds links to objects from lower administrative level (in the attribute TX). These two attributes allow administrative structure to be mapped into file structure.

Fig. 2. Information about buildings exported into a KML file

The number called teryt holds information about position of the object in a local government administrative structure. The first two digits determine the first level voivodeship. The next two digits correspond to the administrative level of Geodetic Documentation Centers. The remaining digits define the district and its type (agglomeration or country).

Districts group regions denoted with numbers, which are unique only in the context of the teryt. In the example presented above the file that represents an administrative level of Geodetic Documentation Centers contains an object that is described by the teryt as a district. This object has a link to the next file. This successor includes a set of regions. The following links bring user to a demanded level of the local administration, as it is presented in Fig. 1.

The mapfile format is used in all Geodetic Documentation Centers, which publish spatial data in Internet using iGeoMap. Each day the data from the internal geospatial system are exported as mapfiles. These files contain information about parcels, buildings, and others.

Text files are not the best solution for publication of large data sets on the Internet because of transmission bandwidth limits. For this reason, the data is published as gzip files. For the final user, which uses Java applet this compression is imperceptible, because Java supports compressed streams.

XML Based Files. Formats, which are based on the syntax and file format of XML, such as Keyhole Markup Language (KML) and The GPS Exchange Format (GPX) are used to export selected data from the application.

Keyhole Markup Language is a descriptive language developed by Google Company. KML complements Geography Markup Language [11] (standard defined by Open Geospatial Consortium) as a format for describing and storing geographical information including threedimensional objects.

The format was developed for Google Earth. In Google Earth, user–data is presented against a background of satellite photos, a three–dimensional Earths model, and third-party data. Google Earth brings user–friendly interface, which enables presentation of data as a layered structure. A user can modify various aspects of data presentation including zoom, position of the camera, and a visibility of layers. The format can be successfully applied in various GIS tasks [18,9].

In the centers, the KML format is used for the presentation of selected resources as a three–dimensional model. A visualization of buildings is given in Fig. 2. The model can be generated only by officials and cannot be generated via Internet.

The GPS Exchange Format [16] is a lightweight XML data format for the interchange of GPS data (waypoints, routes, and tracks) between applications and Web services on the Internet.

In the centers, the GPX format is used to export specific data. The result files can be loaded into a GPS device. Such approach makes localization of characteristic point in the terrain easy. A control point representation in the GPX format is given below. The file can be generated on demand by registered users.

Example of a control point in a GPX file

```
<gpx xmlns="http://www.topografix.com/GPX/1/1" creator="iGeoMap">
 <wpt lat="52.35376381765543" lon="20.873053706771273">
 <time>2011-02-28T09:54:17Z</time>
 <name>423.1288</name>
 <desc>Control point</desc>
 <sym>default</sym>
 </wpt>
</gpx>
```

Both types of files (KML and GPX) are based on the syntax and file format of XML. For that reason, the size of file is larger than in case of the mapfile. This problem can be reduced using compression.

Coordinates of points in exported formats are given in latitude/longitude convention. The coordinates are placed on an ellipsoid. A conversion, which bases on a complex transformation from a plain metric system is necessary.

Shapefiles. A shapefile [4] stores geometry and attribute information for the spatial features in the data set. The feature geometry is stored as a shape comprising a set of vector coordinates. Shapefiles are very popular in spatial data presentation but have several limitations [17].

Shapefiles have a relatively fast drawing speed and editing capabilities. Shapefiles can handle single features that overlap or are non–contiguous. Typically they also require less disk space to store. On the other hand, a single shapefile can store only one type of geometry at the same time.

Shapefiles support point, line, and area objects. Attributes are stored in a dBASE format file. This format is somewhat outdated, but can be sufficient in typical applications. Each attribute record has a one-to-one relationship with the associated shape record. The length of attribute names is limited. Only Integer, Real, String and Date field types are supported. Various list and binary field types cannot be created.

A representative shapefile consists of three files: a main file SHP, an index SHX and a database table DBF. This division makes distribution of files on the Internet difficult.

The Shapefile format explicitly uses 32-bit addressing and thus cannot go over 8GB. In addition, there is a 2 GB size limit for any Shapefile component file, which translates to a maximum of roughly 70 million point features.

Because of its popularity, shapfiles are used to transfer data between various spatial applications in Geodetic Documentation Centers.

Image Files. Images can be published as spatial data when georeference files are attached. The georeference file has the same name as the image file and an extension constructed as the first and the last letter of an image extension with an additional *w* letter. For example, the name of a georeference file for a file *image.jpg* is *image.jgw*.

The georeference file gives information about pixel size in map units (usually in meters) in both directions. Coordinates of the first pixel are also given. The last georeference element is the rotation angle about two axes.

Image files are mostly used to present archival data, which are not longer modified.

2.2 Databases

Databases are usually better sources of data than files. However, for spatial data a specialized database has to be used. PostgreSQL with Postgis extension allows to store spatial data. The same is with ORACLE. iGeoMap can work with both databases directly or via PHP interface.

ORACLE database may be too expensive for local centers and the free PostgreSQL database is preferred.

PostgreSQL and PostGIS. PostgreSQL is an object-relational database management system. This open source system can successfully compete against other commercial databases. PostgreSQL with PostGIS extension is dedicated for spatial data managing [19].

Unlike dBASE, PostgreSQL supports not only basic types of data but also, with PostGIS extension, spatial data types, such as point, line, polygon, and so.

PostgreSQL can continue to maintain good performance, even when the database size reaches 100GB. A communication with the database can be performed on the Internet through script languages, like PHP.

PostGIS is an extension to PostgreSQL dedicated to spatial data. PostGIS supports storing and using spatial data, as well as improves capabilities of managing spatial data. Spatial data and attribute data are stored in the database by PostGIS. With specialized functions, relationships between entities of spatial data can be easily analyzed.

The SQL language can be used to directly query both spatial data and attribute data, so it is very easy to provide a variety of database services or web services. In case of data stored in files, when a user wants to look through data from a Geodetic Documentation Center, he has to download either all the data of selected type (for shapefiles) or all the data from a district (for mapfiles). When data are stored in a database a query may be limited to single objects. Moreover, PostGis extension can limit data only to a current view.

A downside of the approach is that data are downloaded once again when the view is revisited. To avoid this, the data may be cached in local memory and a database manager has to synchronize data from a database with local data.

2.3 Web Services

Web services are dedicated for data publication in Internet. Spatial data can be exposed as a Web Map Service. This service returns spatial data as an image. When vector data is required Web Feature Service has to be used instead. Both services are supported by iGeoMap as well as Tile Map Service, which delivers data divided into tiles.

Web Map Service. A Web Map Service [13] produces a visual representation of spatial data, which is not the data itself. A result map is an image in one of popular formats, such as PNG, GIF, or JPEG.

The specification of the service defines three operations: *GetCapabilities*, *GetMap* and *GetFeatureInfo*. All of them are encoded as a URL that is invoked on the WMS using HTTP GET and POST operations.

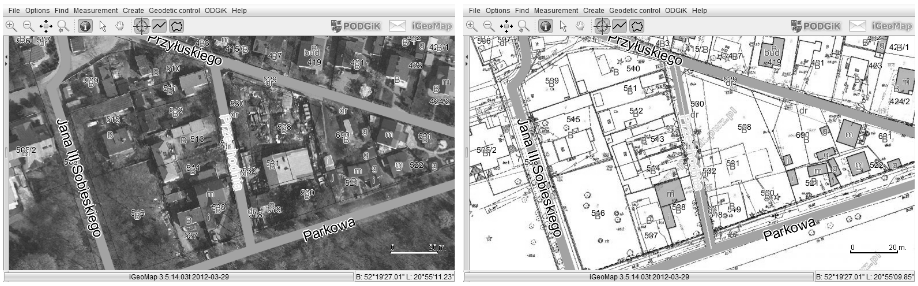
Every WMS server supports *GetCapabilities* operation. *GetCapabilities* operation returns general information about the service itself and specific information about the available maps.

GetMap operation produces a pictorial map image whose geospatial and dimensional parameters are defined by request parameters. This map is defined to be either a pictorial image or a set of graphical elements.

Unlike *GetCapabilities* and *GetMap*, *GetFeatureInfo* is an optional operation. It provides information about features in the maps that were returned by previous *GetMap* requests. This operation provides only information about an object defined by coordinates in the image. WMS service does not have advanced search engine itself [2].

In Geodetic Documentation Centers, WMS services are usually used to generate background for vector data. For example, airplane and satellite photos are presented as JPEGs generated by WMS server. Very often, connected WMS servers generate images from thirdparty resources.

Not all map resources have been converted into the vector format yet. For this reason, the resources are presented using a hybrid technique. Existing vector data are presented as objects from mapfiles. The rest of data is presented as an image



(a) (b)

Fig. 3. Various utilizations of WMS. An opaque airplane photo as a background for vector data 3(a) and a non–opaque PNG image as an extension of vector data 3(b).

generated by a WMS service. In this case, a non–opaque PNG image is generated to merge both sources. Utilization of WMS is presented in Fig. 3.

Images are generated for a current view only. As in the case of PostGIS this approach limits the amount of downloaded data. Once again the problem of revisited area arises. In this case however, because of memory limitation of Java Virtual Machine, downloaded images cannot be stored and managed on a client–side. When the view is changing, the image memory has to be deallocated and a new request is generated even if the view is revisited.

Web Feature Service. Web Feature Service [12] enables the client to retrieve geospatial data through HTTP protocol [3]. It allows clients and servers to share data without having to convert data between proprietary formats [15]. WFS server provide an interface (defined in XML) for online data access. A request sent to a WFS server is a query for features. The result is encoded in Geography Markup Language [11].

In Geodetic Documentation Centers, WFS services are used as an interface for the data. The same data are a source for WMS service. Data delivered as an image can be managed by the client application. Examples are presented in the following sections.

Tile Map Service. Tile Map Service [10] works as WMS. However, data is presented as tiles determined by the grid from TMS specification. Each tile has the same size. A request that miss tiles defined generates an error. Tiles are defined on several levels. This allows generation of images on different levels of details [20].

The main problem with TMS is that the construction of adequate image from tiles has to be done by the client application. For fixed tiles with limited number of scales, it is not a trivial task. The main advantage of TMS is lower generation time than for WMS technique [14].

In Geodetic Documentation Centers TMS is used instead of WMS for data, which are frequently requested from the server.

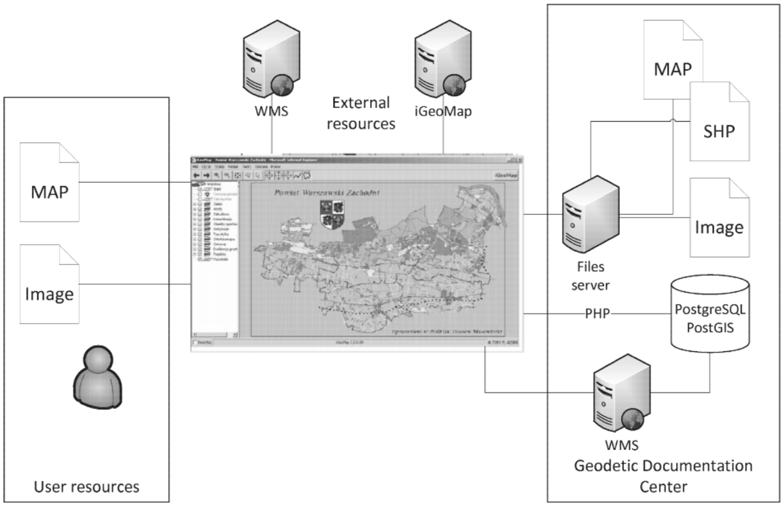


Fig. 4. Various sources for the iGeoMap application

3 iGeoMap

An Internet application iGeoMap [5] for presentation of Geodetic Documentation Center resources is developed in Java as an applet. The application groups data from various types of files (mapfiles, shapefiles and XML based files), databases (PostgreSQL and ORACLE), and web services (Web Map Service, Web Feature Service, and Tile Map Service). Data collected from all connected sources are presented in a tree structure as layers.

Apart from Geodetic Documentation Center resources the application may presents external data or user data. As an external source WMS servers may be used, for example, a national geoportal. Other centers that use iGeoMap can make their own data structure available. Users may add own mapfiles or images with georeference. An appropriate diagram is presented in Fig. 4.

Theoretically, the implementation in Java produces a multilanguage and multiplatform solution, which runs in most Internet browsers and operating systems. It is not true in practice. The interface is in fact multilanguage, but presented data from centers are described only in Polish. Moreover, data export based on IO operations is limited to Microsoft Windows systems

The application presents spatial data to two groups of users. Common citizens may get unrestricted information about parcels, buildings, and address points. Registered geodesists can also access restricted information such as control points description, geodetic maps, and registered geodetic works.

The following sections present typical use cases for both groups. The presented cases use data from various types of resources. The resource types were selected to optimize performance.

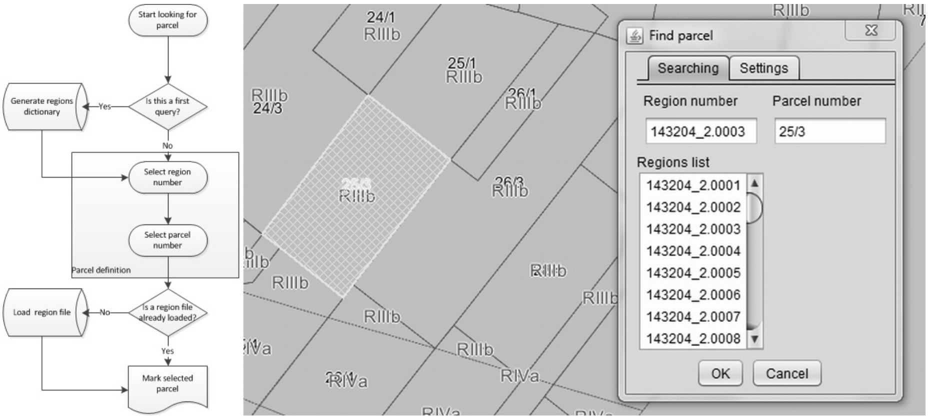


Fig. 5. A search of a parcel on the base of a region number and a parcel number

3.1 Use Cases

The most popular data are parcels, address points, and control points. A typical user looks mostly for these data. What is important for each of these user groups a different data source and searching mechanism is used.

Parcels. A parcel can be found when region and parcel numbers are known. The region number should be prefixed with the whole teryt number. This is not a problem for a geodesist. Common users can use usual names attached to regions.

Initially, parcels are not downloaded. The application can be started on two different administrative levels. In the first case, preloaded file contains districts.

In the second case, a frame of regions is created. In both cases, the preloaded file is a mapfile. The structure of a mapfile enables identification of districts or regions on the base of the teryt number. An identified object has information about linked files.

If the application starts on the district level, a dictionary of available regions can be created. Otherwise, the user should know the complete teryt number. In both cases, the region object holds information about linked parcels file.

This file is downloaded and the requested parcel is identified among downloaded objects. The procedure described is presented in Fig. 5.

The downloaded file stays in the memory and future queries concerning parcels from the region will be accomplished locally. Downloaded files maintain hierarchy so the queries among local data will be limited to the given region.

In this approach, downloaded data is limited only to essential information. In most cases, users are focused on the selected region or nearest neighborhood of the parcel. For that reason, detailed data from different administrative levels are not necessary. On the other hand, once downloaded, data may be freely managed in the client application. Such approach eliminates the repetitive downloading problem.

Fig. 6. A search of an address point on the base of a street name and a number

Address Points. An address point defines the spatial localization of an address.

In country districts, it is given by a city name, a street name, and a building number. In agglomerations, the city name is ignored. In both cases, all parameters should be known by the user, but the system enables also localization with partial data only. This possibility may be useful for ambiguous values such as *15a* or *15A* in the building number.

The main problem is the number of address points. In big agglomerations, the whole set of the address points cannot be displayed at once. To solve this problem two approaches are proposed. In the first one, the detailed information about address points are distributed among files. When a user starts a search for an address point a dictionary of streets is created on the base of a special file. Each position in the dictionary is mapped to a file. Such file contains a subset of address points limited to a few streets and if the street name is selected an appropriate file is downloaded. The main disadvantage of this approach is the limitation of the points presented only to downloaded streets. It is not a problem when the user wants to find a specific address, but a whole view of the addresses in the defined neighborhood cannot be presented.

In the second approach, WMS is used. The address points are drawn as an image. All address points in the current view are presented. In this case obtaining detailed data about presented points is more complicated.

The detailed information about a single address point can be obtained using *GetFeatureInfo* operation. For the selected address point visible in the image from WMS, the information about mapped object are presented.

The search procedure is more complex. When a user asks system addresses for the first time in a session, a street dictionary is generated from the database. It is not necessary in the following questions. The same dictionary can be used again. For the selected street and a building number, an SQL query is generated. The query can be sent to the database via PHP or as a WFS request. As a result, a localization of the address point is generated. The application focuses

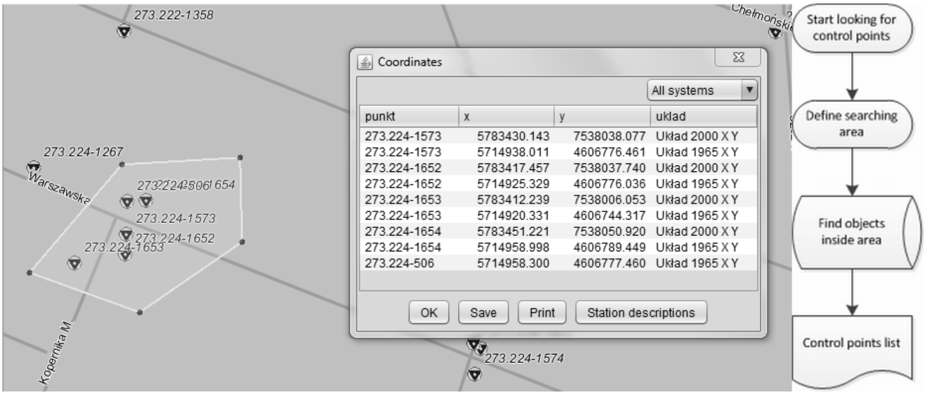


Fig. 7. A search of detailed information about control points on the base of the localization

the view on the localization and an appropriate WMS image is generated. The image presents all address points in the view, but selected ones are marked. The described procedure with search parameters and the result is presented in Fig. 6.

Control Points. A control point presents information about coordinates of the point. The coordinates are given in several systems. For this reason, this information cannot be presented directly on a map.

Mostly geodesists are interested in control points, since information about coordinates is necessary in surveys. The control points have unique numbers and the description of a single point can be obtained basing on this identifier. However, the geodesist mostly needs information about all points in the surveyor's works area.

In the application, the user has to mark an area of interest. If the control points were downloaded as a mapfile and appropriate objects are inside the marked area, unique points numbers would be extracted from the objects. The numbers are primary keys in the database, so detailed information can be obtained on their base.

In this approach, only base data (localization and a number) are downloaded as a file. Detailed information is generated only on special request. The described procedure Fig. 7.

In case of control points, the same problem as with address points occurs. In large areas, the number of points is significant. In such case, the control points may be represented by a WMS image. A marker is created and described as a PostGiS geometry. Using PostGiS functions, points inside this geometry are localized in the PostgresSQL database. The result brings detailed information about points.

3.2 Comparison with Other Approaches

Despite the fact that iGeoMap is a good solution to publish spatial data on the Internet a different approach to the problem can be chosen. Two of them, based on Google Earth and PHP scripts will be briefly presented.

Google Earth. One of the best applications for spatial data presentation is Google Earth. The application presents fast loading satellite and aerial images. It has also layers that contain geodetic data discussed in this paper such as streets and administrative objects.

Geodetic Documentation Centers can publish its data in Google Earth as KML files or WMS services. However, this form of publication can be unsuitable for restricted information such as detail information about control points. End users can also add local KML files to create a visualization of their spatial data against the background of the Centers data. The visualization may include 3D objects and time–based data [9]. Such effects cannot be achieved in iGeoMap.

The problem with Google Earth as a form of data publication lies in its search engine. The search is limited to the internal application layers. User cannot search added data.

The only exception are the information from Geodetic Documentation Centers published as a part of Google Earth layers, for example address points. However, such data are not transferred directly from the centers and can be outdated.

In sum, Google Earth should be preferred when a visualization is the main aim of the data presentation. However, iGeoMap is a better solution when a validity of data is crucial.

PHP Scripts. iGeoMap is a Java applet. This can be a problem for some groups of users. There are systems and mobile devices that do not support Java. In institutions with significant number of computers but without IT support it can be a problem to install Java Virtual Machine.

In such cases, a better solution is a publication based on PHP scripts. This form was selected in several projects including WebEWID [8], eMapa [6], and Geoportal 2 [7]. All above-mentioned projects use a WMS to produce a visual representation of spatial data. For this reason, navigation over the map results in a significant lag. Moreover, search engines are very limited. WebEWID and eMapa have search engines to look for parcels and addresses, but do not have tools for marking groups of objects similar to the mechanism described in the section 3.1. All the deficiencies pointed out are consequences of WMS limitations.

Search engines in the project discussed can be improved if conclusions from the presented search cases are drawn. There should not be any technical problems in application of solutions presented in the section 3.1 to PHP projects.

On the other hand, a serious technical problems occur when a thin html client is used instead of a Java applet. Unlike PHP, iGeoMap supports an import of multi–file structures such as SHP sources and a streams compression.

Fig. 8. Geodetic Documentation Centers, which use iGeoMap system

3.3 Reception

The iGeoMap application was introduced in several Geodetic Documentation Centers. Implementation locations are presented in Fig. 8. Among these centers are both ones from country districts as well as from major agglomeration such as Warsaw and Poznan.

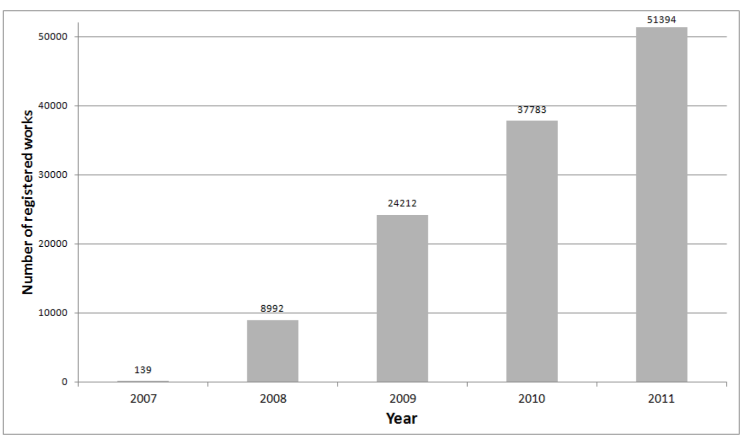


Fig. 9. Registered geodetic works illustrating a development of the application

A part of the published data is not available to common users. Geodetic Centers are obliged by the law to limit access to detailed information about geodetic data. For this reason, a description of control points can be exported only by a geodesist who has registered work in the area. Under this obligation geodesists have to register works in a system. The number of registered works illustrates the development of the system. Collected data, presented in Fig. 9, shows popularity of this solution among specialists.

The solution based on iGeoMap introduced in The Center of Geodetic and Cartographical Documentation in Warszawski Zachodni District was rewarded with The Best SDI Practice Award 2009 during eSDI-NET+ domestic competition.

4 Conclusions

In this paper, the problem of Internet publication of resources managed in Geodetic Documentation Centers was discussed. The main difficulty is a variety of spatial data sources. The centers manage files and databases, which can be made available as web services. All sources have their advantages and disadvantages, some of them were described in the paper, but the solution that publish resources on the Internet should work with all of them.

The proposed solution is iGeoMap. This application, developed as a Java applet, manages the resources mentioned. The application utilizes a mapfile format, which can be used to map levels of a local government administration into a files structure. The reception of the system shows that the solution gas been accepted among specialists.

Different types of data sources are managed in an effective way. In the typical use cases, the selection of data source that limits number of downloaded data without limitation of functionality was presented.

The presented solutions can be use to develop applications based on PHP scripts. Such applications are popular because of portability and small technical requirements. However, search engines used in the existing projects are very limited. A search for spatial data in the projects can be improved when schemas presented in this paper and created on the base of our experiences with iGeoMap will be adopted.

References

1. Directive 2007/2/ec of the european parliament and of the council of 14 march 2007 establishing an infrastructure for spatial information in the european community (inspire). Official Journal of the European Union 50 (April 2007)
2. Bai, Y., Yang, C., Guo, L., Cheng, Q.: Opengis wms-based prototype system of spatial information search engine. In: Proceedings of IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2003., vol. 6, pp. 3558–3560 (July 2003)
3. Chunithipaisan, S., Supavetch, S.: The development of web processing service using the power of spatial database. In: 2009 2nd International Conference on Emerging Trends in Engineering and Technology (ICETET), pp. 832–837 (December 2009)

4. Environmental Systems Research Institute, Inc.: ESRI Shapefile TechnicalDescription (1998)
5. Geo–System (2011), http://www.igeomap.pl
6. Geo–System (2011), http://e-mapa.net/
7. GeoBid (2011), http://www.geoportal2.pl/
8. Geomatyka (2011), http://geomatyka-krakow.pl/
9. Grzenda, M., Kaczmarski, K., Kobos, M., Luckner, M.: Geospatial presentation of purchase transactions data. In: Ganzha, M., Maciaszek, L.A., Paprzycki, M. (eds.) FedCSIS, pp. 291–296 (2011), http://dblp.uni-trier.de/db/conf/fedcsis/fedcsis2011.html#GrzendaKKL11
10. Liu, Z., Pierce, M., Fox, G., Devadasan, N.: Implementing a caching and tiling map server: a web 2.0 case study. In: International Symposium on Collaborative Technologies and Systems, CTS 2007, pp. 247–256 (May 2007)
11. Open Geospatial Consortium: OpenGIS Geography Markup Language (GML) Encoding Standard(Version 3.2.1) [EB/OL] (2007)
12. Open Geospatial Consortium: OpenGIS Web Feature Service (WFS) Implementation Specification Version 1.1.0 (2009)
13. Open Geospatial Consortium: OpenGIS Web Map Service (WMS) Implementation Specification Version 1.3.0 (2009)
14. Qun, L.: Key technologies on rapid web publication of spatial data. In: 2010 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT), vol. 7, pp. 282–285 (July 2010)
15. Ribeiro, J., de Farias, O., Roque, L.: A syntactic and lexicon analyzer for the geography markup language (gml). In: Proceedings of IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2004, vol. 5, pp. 2896–2899 (September 2004)
16. TopoGrafix: GPX: the GPS Exchange Format (2007), http://www.topografix.com/gpx.asp
17. Ye, L., Mao, J.: Spatial analysis on sql geography and geometry data. In: 2010 International Conference on Audio Language and Image Processing (ICALIP), pp. 1749–1752 (November 2010)
18. Ying-jun, D., Chong-chong, Y., Jie, L.: A study of gis development based on kml and google earth. In: INC, IMS and IDC, 2009, NCM 2009, pp. 1581–1585 (2009)
19. Zhang, L., Yi, J.: Management methods of spatial data based on postgis. In: 2010 Second Pacific-Asia Conference on Circuits,Communications and System (PACCS), vol. 1, pp. 410–413 (August 2010)
20. Zhang, Y., Li, D., Zhu, Z.: A server side caching system for efficient web map services. In: International Conference on Embedded Software and Systems Symposia, ICESS Symposia 2008, pp. 32–37 (July 2008)