Innovation of botany education by cloud-based geoinformatics system

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Abstract: The paper describes the educational portal BotanGIS. It is an innovative geographical information system developed to improve botany education. It is divided into two main parts. The database contains more than 50 characteristics of about 500 plants from the Botanical Garden in Olomouc, the Czech Republic. In the database, students can search and filter and, with the help of an interactive map, locate plants on the map. From a technical point of view, it is built on the rich internet application concept, which enables the creation of a sophisticated online application. The cloud computing interface provides an innovative approach for students' education because the BotanGIS portal is available online. It offers an effective and attractive way to study botany and geoinformatics utilising modern web technologies.

Keywords: botany; geoinformatics; cloud computing; rich internet application; RIA; education.

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1   Introduction

The worldwide development of information technologies brings with it the possibility that Geographic Information Systems (GIS) could be applied in almost every field of science, including biological fields. The field of botany takes benefit of information technology through the creation of evidence and management of large amounts of data in the form of spatial and attributes databases.

Most botanical organisations manage their own records of plants in digital form. A large number of descriptions about the plants are presented to the public and the experts via local databases or websites, but mostly without any spatial localisation of the plants on the map. Therefore, the current trend is towards the development of WebGIS applications that facilitate management, analysis and visualisation of data in different formats (text, photo, maps, etc.).

The traditional desktop approach of providing and working with the GIS still has numerous limitations, especially with regard to spatial data and programmes which a user needs 'physically' stored in a local computer. The general trend in all areas of information technologies is relocation, sharing and centralised distribution of both data and programmes via the internet environment. This solution is possible especially due to the cloud computing approach nowadays. Moreover, in the field of GIS it is supplemented by the rich internet application (RIA) concept, which allows the use of conventions from the desktop platform in online solutions.

The paper describes the online educational portal called BotanGIS to improve botanical, geoinformatical and pedagogical education. The BotanGIS project was developed by the Faculty of Science of Palacký University in Olomouc in collaboration with the Botanical Garden in Olomouc. The main purpose is to make the study of Botany and Geoinformatics much more attractive and accessible.

Just using new internet technologies provides an innovative learning method, because the cloud computing technology simplifies designing and working with the application significantly. The application is available in both online and offline mode on the computer as well as on the mobile platform (iPad and smartphone). It offers an innovative and modern way to study effectively, through the connection of field research and digital multimedia sources. Compared to other learning systems like the learning management system, the designed solution is developed specifically for students of Botany, based on their requirements (Němcová et al., 2011). The main part of the BotanGIS portal is the botanical information system, which serves as an interface for the presentation of plants in Botanical garden.

2   Objectives

With the absence of any modern education material to supplement the study of botany, including all specialised information about the plants in the Botanical Garden in Olomouc, the students and lecturers required, there was a need to create a comprehensive information system of the Botanical Garden because it is a primary source of information for both students and lecturers in all fields of botany. As such, it was a unique opportunity to consolidate botanical data with modern geospatial technologies for academics, and it can be used by employers and visitors as well.

Based on the mentioned necessities the research project called 'Innovation and increasing the attractiveness of botany study using geoinformation technologies – BotanGIS' began in 2010 (Dobesova, 2012). The project was established through the collaboration of the Departments of Geoinformatics and Botany (both from the Faculty of Science, Palacký University) with the Botanical Garden in Olomouc. The aim of the BotanGIS project is to improve the teaching of botanical, geoinformatical and pedagogical subjects through modern online methods.

The previous material used for educational purposes was an outdated list of plants with basic characteristics; the labels were localised for only 20% of plants; and, the photographic documentation was not sufficient in various stages of growth or parts of the plants (habitus, flower, leaf, fruit, bar on a trunk). It was not possible to search for herbs or trees in the analogue plans. Consequently, these were the reasons that helped justify the need to create a complex database with descriptive, geographical and visual information of the plants.

Nowadays, the technical developments can facilitate the creation of a sophisticated system with accurate classification, localisation, description and photo documentation for study requirements. It could be extended to technical parameters like biological and chemical characteristics, the origin and expansion of plants, the conditions and other details, and, above all, the searching and filtering is much more effective. The application has been developed according to the comments and real requirements of employees and lecturers.

3 Technologies

The BotanGIS application takes advantage of innovative WebGIS solutions, especially it is based on the combination of RIA and Cloud computing.

3.1 WebGIS

Besides the analogue maps, nowadays there is a popular group of digital maps, which can be defined as maps based on the visualisation of spatial databases stored in digital form. A typical digital map combines more geoinformation technologies and contains geolocalised information (Voženílek, 2007). The last step in digital map evolution are web maps because maps on the internet platform provide more options and are becoming popular all over the world due to the ease in the collection of information over the maps. Moreover, an interactive map allows a user to easily gain additional information or data linked to the map background (text, attributes, tables, images, video, animation, hyperlink, etc).

Classical web maps are based on the method of visualising geographic data using a server application. On the server side, a web server responsible for handling basic request/response paradigm via the http protocol is located. The map server communicates with a web server and simultaneously processes data from the data repository according to the requirements. The geographic data, the web server and map server are stored on the server side. The web browser with X(HTML) page is located just on the client side, which defines the requirements. Every new action (map movement, zoom, query, and click) requires a new request for the server, which sends back a new response.

Interactive web mapping is adding interactive elements like Java Script, Java applets, ActiveX controls or plug-ins into the map application. They are handled in the client side at runtime and allow users to interact directly with spatial data (Voženílek, 2007). This solution has not been sufficient enough due to many constraints, such as interoperability among different web browsers and unsupported platform independence. The elimination of all disadvantages and asynchronous processing are the reasons why RIA concept is significant for web maps.

3.2   Rich internet application

The latest trend in publishing and working with WebGIS are solutions based on the concept of RIA. It is a web application that brings the tools, practices and conventions from the desktop platform into interactive web applications for everyone and everywhere, providing greater user comfort. It requires a specific environment for the transmission of client requests to the server.

From the technical principle, it is a web application which is not strictly based on the traditional request-response paradigm. Conventional websites are created on the client side by (X)HTML code, which is directly interpreted by a web browser. Every interaction means sending a new request to the server. It returns the response as a code which is interpreted by the browser. This is not necessary in the RIA concept because only the remaining part is completed independently and/or asynchronously with the other content (Meier et al., 2008). Moreover, RIAs are typically characterised by 'elegant' design, because of their focus on aesthetic features. The term 'RIA' is not a concrete technology; it is a general concept, on which some typical technologies are based on. There are a number of RIA technologies like Asynchronous JavaScript and XML (AJAX), Microsoft Silverlight, Openlaszlo, JavaFX, Adobe/Apache Flex, HTML5/CSS3, etc. RIA was mentioned for the first time by Allaire (2002).

In the common geoinformatics applications, the Flex technology is considered to be the most widespread, through which you can build highly interactive web map applications (Johansson, 2010). Novák (2009, p.43) confirms that "Adobe Flex provides an excellent technology that is currently one of the most important RIA technologies". Flex technology is an environment for creating RIA applications that are compiled into the same format as the popular Adobe Flash and runs in the same runtime environment. That brings a significant benefit. To run the application developed on Flex, only a suitable environment is necessary: Adobe AIR in case of a desktop application (typically for development) or Adobe Flash Player in case of a web browser. The great advantage of this approach is that the Flash Player plug-in is already installed as an inherent part in almost all web browsers because it is required by many other online features (videos, ads, games, banners, animations, etc.).

On the one hand, Flex takes from Flash only the best features – runtime environment, programming language ActionScript and tries to add new features. On the other hand, it is an open-source project with a broad space for development of applications. It is important to mention that the Flex is not the same as the Flash. In fact, the Flex is different from Flash! Flex technology is categorised as 'a smart client' (between think and thick client) represented by extension of the web browser by the runtime environment. Applications are embedded in an HTML document, and its implementation manages a runtime environment (Flash Player). It is not necessary to customise the application to a different platform, so only one version is necessary to validate.

Compared to the thin client, this solution provides greater technical and performance possibilities (Pun-Cheng and Shea, 2004). RIA is generally characterised by:

- run in the web browser (both online and offline)

- combine properties from desktop applications into web interface

- no installation process required (if Flash Player is available)

- immediate feedback, refresh is not required

- rich content (video, sound, animation, vectors, drag and drop, keyboard navigation, ...)

- platform independent

- faster processing of requests

- rich user interface

- focus on aesthetic design

- easy distribution and start-up

- mobile applications are fully supported

- open source

- wide possibility of customisation.

The worldwide leader in GIS software, the Esri company, developed its own Flex client called 'ArcGIS Viewer for Flex'. This solution is implemented for the BotanGIS project. It enables the management of geospatial data, with the aim of creating highly interactive web map applications. It supports visualisation of spatial and attributes data, interactive query, data extraction and editing on the screen, geocoding, identification, printing, etc. It is a free, ready-to-deploy Application Programming Interface (API), which is designed for developers that want to customise the appearance, functionality and content of their applications.

Developers can combine predefined functionality and/or services with their own map content in ArcGIS Viewer for Flex. The functionality of applications is ensured by the main XML configuration file 'config.xml'. There are several XML tags which refer to some widgets. The widget is a tool that enhances the functionality of the application; in fact, every function is a separate widget. The map content could be generated by a complicated server solution or via an innovative cloud computing environment. Just with the RIA solution, it is possible to create a smart application according to concrete needs. The simplicity, aesthetics design and innovative approach are advantages. It provides features and practices from robust server solutions into the internet environment; moreover, it enables high user interactivity, support of multimedia components and customisation. Finally, it provides the benefit that the map application may be displayed on a mobile device as well as on a desktop computer, which is helpful to education in the field.

3.3   *Cloud computing and ArcGIS online*

Cloud computing is a model based on the use of computer technology via the internet. In fact, it enables provision of services, data or programmes which are stored on other servers. Users have access to data or programmes via a web browser anywhere all over the world, but in fact, they do not know exactly where the data or applications are stored. They are 'somewhere in the cloud', therefore, the term cloud computing. Generally, it takes advantage of the Service Oriented Architecture (SOA). SOA provides the benefits of web services which allow the centralisation and standardisation of any process. In fact, developing and updating of any application based on cloud computing and SOA is faster, cheaper and more effective.

The choice of cloud applications is unlimited; in fact the applications like Google Docs, Twitter or DropBox are based just on the cloud computing solution. On the one hand, there is an occasion to rent a commercial cloud environment (e.g., Amazon EC2, GoGrid, Skygone Cloud) and install the available GIS program there. On the other hand, there are available services focused on spatial data processing like 'GIS Cloud', 'GeoCommons', 'Skygone' or 'ArcGIS Online'. These services allow visualising, analysing and sharing spatial data fully via the internet. Compared to the standard WebGIS, cloud computing eliminates duplicated data storage on the server and local computers. Besides the large number of public functions, it allows you to use secure private services. This way you can share private data and spatial analysis tools anytime and anywhere (Xu et al., 2004). The approach is based on the publishing spatial data via cloud computing model, in combination with the concept of RIA applications, providing a powerful tool in current WebGIS.

Figure 1   ArcGIS online as a WebGIS based on the cloud computing approach (see online version for colours)
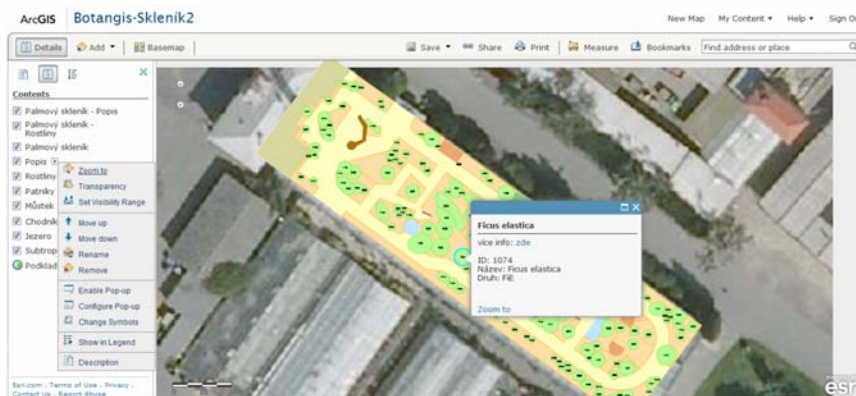
The 'ArcGIS Online' is a cloud solution from Esri Company (Figure 1). It allows the publication of data and working with map content via a web browser only; any GIS software or plug-in is not required. First of all, it works with a default data format called SHP (shapefile) or by default web services through Representational State Transfer (REST). Although built-in viewer allows you to add and edit your own data, it can also be generated from a CSV file. The ArcGIS Online enables users to manage maps, applications and data that are stored in a secure cloud environment (authentication is

required) for free. Moreover, it serves as a repository of a huge amount of created maps, datasets and tools from all over the world on a global and local scale. It means that the user can search among these sources and add it into his own map. In fact, the user joins for a service (not for an original data) which is a SOA principle.

There is an advantage that the data are centralised in one place, and wasteful data duplication is eliminated. That is the reason why ArcGIS Online has been used for the BotanGIS project because students and/or lecturers need only to access by login and password. They do not need to download any data, software or any other tools into their computer. Moreover, sharing data via ArcGIS Online brings the benefit that any data change made by a lecturer is reflected immediately into the application for students, the application is still up-to-date. Final maps and applications can be shared with the public, whether as a map project or as an interactive map application inserted into an HTML page. ArcGIS Online enables the creation of maps, map composition and map applications through simple predefined templates. The BotanGIS project takes advantage of this feature because the content from ArcGIS Online is automatically displayed in the framework of ArcGIS Viewer for Flex.

4   The BotanGIS application

The BotanGIS is a geographical information system focused on the innovation of Botany and Geoinformatics education. The aim has been to improve teaching by using an interactive web application. The BotanGIS application is available on http://www.botangis.upol.cz (Figure 2). The user interface of the educational portal is available to all students and visitors without login into a user account, and it is for free. Primarily, it should serve as a basic study material for students in botanical, geoinformatical and pedagogical fields (Dobesova, 2012). Furthermore, it is designed as a complex database of plants for the employees of the Botanical Garden and lastly, it is intended for the public and visitors as an attractive presentation of the Botanical Garden.

Figure 2   Homepage of the educational portal BotanGIS (see online version for colours)

For students, the portal is separated into database and map sections. Students and visitors can switch between these sections, because they are interactively connected. It means that if a student localises any plant on the map, he or she can show all plant characteristics in one click. If the student searches for some plants by filtering the database, there is a possibility to localise plants in the map every time.

4.1   *The Botanical Garden of Palacký University in Olomouc*

The Botanical Garden of the Faculty of Science, Palacký University in Olomouc is the second oldest botanical garden in the Czech Republic. The first mention about the botanical garden in Olomouc was from the year 1787. It was established for teaching at medical school. In the spring of 1901, building a botanical garden began in its current location. The construction was supported by the city of Olomouc. A pharmacist Edmund Tuma and gardener Charles Pohl had a significant influence on the construction and the arrangement of the garden. The Botanical Garden is located next to Fairgrounds Flora Olomouc. There are four connected greenhouses beside the outdoor garden. There are palm, cactus, tropical and subtropical plants used for education and exhibitions, but administratively belong to Fairgrounds Flora Olomouc, JSC.

The garden has been operated under the administration of the Department of Botany since 1959, when the Faculty of Science was funded. The garden is located in a flat terrain of about 210 m above see level, and it covers an area about 0.65 hectares. The garden is divided into several parts. The park is the most valuable part; it consists of grasses and trees. Some of them were planted in the 18th century and reach over 30m in height. The main part with the beds is located in the middle of the garden. Regularly arranged flowerbeds are used by lecturers and students in the study of the botany system. The other part of the Botanical Garden includes water areas and rocks located near the garden house. In 2003, two lakes called 'smohe' were located in the middle of the park part of the garden.

The significant changes in the structure of the garden were made in 2010 during the reconstruction based on educational projects. The lake near the garden house was rebuilt, a new area for students' needs and a relaxation zone was made. These changes were designed to attract new visitors to the garden, but it also welcomes exhibitions, lecturers and other events for students and visitors just in the area of Botanical Garden.

There are approximately 500 items of plants in the garden, especially herbs, grasses, shrubs, lower sub-shrubs and trees. Based on the changes, there was a need to develop a sophisticated information system for education and for the visitors.

4.2   *Database section*

In the database section, all plants in the Botanical Garden, including their characteristics and pictures, are recorded. The plants are shown as a structured list with interactive filtering and searching tools. The detailed characteristics or location in the map can be displayed according to students' requirements. These actions are done by clicking on the icon information (detail) or the globe icon (map). There is a useful tool that sorts entries in ascending or descending alphabetical order. Fifty three botany characteristics are recorded for every plant on the detailed page (Figure 3). In case of non-authorised students, the environment is designed only for the visualisation of characteristics.

All data are structured into basic characteristics (basic passport) and extended characteristics (extended passport). The passport is the basic technical and operational document for the subsequent management and maintenance process. The basic passport contains entries about the name (family, genus, etc.) in Czech and Latin language. Depending on the level of botany education, students can be familiar with basic or both passports because extended passport contains taxon characteristics and other more specialised details. If any student is not familiar with the meaning of each entry, there is a 'pop-up' description of each characteristic available as well. There is a photo gallery of each plant at the bottom of each page. After clicking on the thumbnail, the photo will automatically appear in the Lightbox Web Photo viewer.

Apart from the non-authorised access, there is a secured administration in the cloud environment. The admin environment is designed for lecturers and advanced students (PhD students only), who have sufficient botany knowledge to add new entries. In every case, their changes must be approved by the superadmin – a botany administrator expert. This double review process guarantees data correctness. If a new plant is added into the database, its exact localisation by clicking on the map is required. The reason is to match the database and the map section with a unique ID. In general, the database section is used often by Botany students while the map section is preferred by students of Geoinformatics.

**Figure 3** Database section of BotanGIS (see online version for colours)

4.3   Map section

The area of the Botanical Garden occupies an outdoor garden as well as four indoor greenhouses. The map section of the BotanGIS reflects dissimilarity of outdoor and indoor plants and that is the reason why two maps with the same functionality are available. All spatial data displayed in the BotanGIS are available through the principle of smart client ArcGIS Viewer for Flex (Figure 4). It means that it is possible to conduct an analysis onscreen or identify the attribute element linked to its spatial localisation. The data are intended for visualisation only; edit or download data is not allowed. Due to the selected solution based on the ArcGIS Viewer for Flex, the original data were stored in shapefile format (*. SHP) in the Department of Geoinformatics.

First of all, the data were topologically prepared and then uploaded into ArcGIS Online. Every subsequent modification in topology (geometry) and symbology (design) has been made via ArcGIS Online interface. In the common WebGIS it is necessary to generate symbology in case of layer replacement. Standardised legend, which is automatically updated for all layers, is another benefit of the selected solution. As a background layer for orientation in the map, the satellite image (World Imagery) was chosen. It is available as the Basemap service on ArcGIS Online. It is a seamless aerial image with a spatial accuracy of 50 cm. Any standardised Web Mapping Service (WMS) can be used as a background or thematic layer in the future, as well. The thematic map content responds to a standardised legend of cartographic work in the Czech Republic. It is divided into:

- park areas (light green)

- water areas (blue)

- paths (light yellow)

- rock (dark green)

- buildings (grey)

- beds (orange)

- localisation of plants (colour point symbol or green polygons).

Figure 4   Map section interface takes advantage of RIA (see online version for colours)
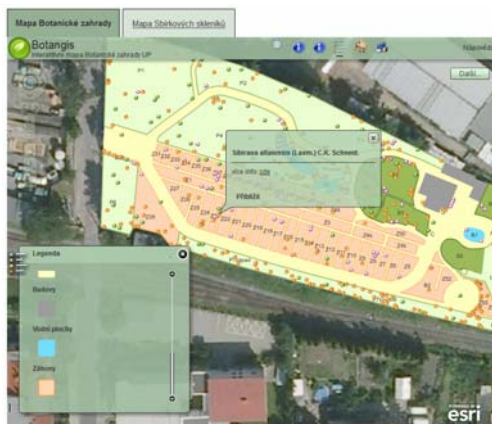
Actually, all data used in BotanGIS are available as a mapping service through the REST interface (http://virtus.upol.cz/ArcGIS/rest/services/botangis). These services are possible to find with the tag 'botangis' and a user can add them into another application made by ArcGIS Online. With the chosen technology, security of the original data is provided. They can be edited only in ArcGIS Online storage by an authorised user (lecturer, PhD student); any other case of editing is not allowed. The map content and the map functionality are strictly separated due to the sophisticated development of the BotanGIS. While the map content is available via 'open' cloud interface (ArcGIS Online) and could be changed, the tools and functions are controlled by admin in a detached cloud interface (ArcGIS Viewer for Flex). The advantage of this innovative solution is that it ensures that programme is running smoothly while the content is updated. Similarly as the content can be edited, the functionality can be extended by using additional widgets. The result is a customised map application that brings conventions and tools from the desktop platform, but runs fully on the internet.

4.4 Testing and managing

The data backup is guaranteed by automatic backup, which makes a copy of database, photo files and map content every week. It is a fully online application, which means that a web browser with Flash support is required for its correct running. The application has been successfully tested in several browsers (Firefox, Internet Explorer, Opera, Safari and Chrome) in different versions without any problems. For the technological requirements, the BotanGIS unconditionally required a web browser with a Flash plug-in. However, the Flash platform is required for many other web pages (ads, games, videos, etc.), so it is usually readily available in web browsers.

The main constraint in choosing the technology was the security of updates. In the case of the cloud solution, more than one person is available to edit data. This has been eliminated by creating access for the 'superadmin'. It allows confirming or rejecting suggested changes by students. In fact, there are five persons with superadmin access who are responsible for the correctness of the database. In case there are new suggested changes, superadmins receive automatic reminders by e-mail. With the cloud approach, the database is still updated with correct data. Of course, there are still opportunities for improvement in the future. It would be appropriate to add the print modules for printing selected outputs and create localisation in the English language.

5 Impact on education

The BotanGIS educational system innovates the study of three totally different study disciplines. Originally, the aim was focused on the fields of Botany and Geoinformatics, but in practice the educational system is suitable for the education of pedagogues as well. The first attached field is the study programme for Geoinformatics for both bachelor and master degrees. Another group is composed of students from the Botany Department in several specialisations. The last group consists of students from the Pedagogical Faculty with a focus on Botanical classes, who usually take classes in the Botanical Garden as well.

Several classes have been improved in the mentioned disciplines. The experiences from the design and implementation of the GIS in the cloud environment are reflected in the modified Geoinformatics courses. Furthermore, the practical use, including a lot of botany characteristics, is beneficial to botany subjects. The major advantage is that the BotanGIS is a real customised information system and not just a theoretical training example. It is an example of a collaboration of experts from different fields during the development. Consequently, the output serves as an educational portal providing a place for study material, literature or links targeted for students.

5.1   Botany education

The main objective of the project was to innovate and improve the teaching of Botanical subjects at Palacký University, Olomouc. The database consists of 500 plants with 53 characteristics. Besides the BotanGIS application, the digital learning materials to support education have been created. It makes it possible to learn in a modern way. The methodology to create the database system for the botanical garden has been prepared as well. That is a very useful document in case of similar project in the future. These materials can be used directly in practical education in the garden as well as for training before teaching. It can also be used for subsequent updates on the studied plants. The materials will improve the professionalism of students for university studies and increase their competitiveness and skills for future jobs. Moreover, it will significantly increase their ability to work with the GIS, which is usually outside of their interests.

At the Botany Department, Palacký University in Olomouc some compulsory and obligatory subjects have been innovated. More than one hundred students of the first class attends the compulsory subject 'BOT/CTPX Field Botany' every year as a basic subject at the beginning of the study. The main classes take place in the Botanical Garden at the spring period. Another subject is 'BOT/DEN Dendrology' attended over 40 students. They study and select real woods, bushes with special characteristics. Microbiota decussate (originally from Siberia) that is planted in the Botanical garden is studied in dendrology for the smallest fruit – cone with only one seed. This information is stored in attribute 'interesting information' in the BotanGIS database, students can search it anytime.

The education is supplemented by facultative subjects. E.g., subject 'BOT/PRAP Cultivation of experimental plants' takes place in the garden and greenhouses. About 30 students get experience how to select, obtain, grow, take care and regenerate the plant material for their experiments. The selection of suitable plants to collect cuttings for plant propagation is searched in the database. Additionally, some facultative subjects take place only in greenhouses: 'EKO/TRBOT – Tropical botany', 'EKO/MASO – Carnivorous plants' and 'KPR/BPESC – Cultivation'. Subjects are attended by students of different study programmes: Systematic Biology, Ecology and Environmental Protection. Furthermore, the subject 'BOT/BRYSB – Bryology' was supported with a new publication 'Mosses in Botanical Garden' and practical field work in the Botanical Garden.

Students are satisfied by information in BotanGIS database, they can collect information about real plants which is effective way of learning. The acquisition of information is very quickly at one complex information source. Very valuable are photographs with details of flowers, fruits, leaves and also barks beside the habitus of whole plant in different seasons of the year.

The web application allows for the utilisation of modern technologies in education. Students can visualise the Botanical Garden and the plants on the computer and be prepared before they go to work in the field. That is the reason why subjects with field exercises are popular. The main benefits for Botany education are:

- presentation of all plants in the garden

- searching in descriptive information about the plants

- filtering in taxonomy and morphology of the plants

- localisation on the map

- extensive photo gallery

- the combination of theoretical information with practical training

- digital materials like digital herbal.

5.2 Geoinformatics education

Based on the practical development of an information system, the methodology has been compiled. It is focused on the creation of a geographical information system for a small area. The methodology describes the implementation of cloud computing and RIA technologies, and it serves the students of Geography, Cartography and Geoinformatics. The text of this methodology has been prepared by the research team members responsible for the BotanGIS development; it captures all the steps of the creation process. A comprehensive study is divided into chapters for a bachelor's program in Geoinformatics and Geography and a master's program in Geoinformatics. Practical lessons with BotanGIS projects are taken in several subjects. The lessons are focused on operating with a cloud computing solution, especially on ArcGIS Online. There are practically demonstrated opportunities which the cloud computing brings into the GIS solutions.

Several courses have been innovated by using BotanGIS: 'KGI/INFUZ Land Information Systems', 'KGI/POKA Computer Cartography', 'KGI/CAD CAD Systems', 'KGI/DASY Database Systems', 'KGI/GISLES GIS Online', 'KGI/GISIT Geoinformation Technology'. Additionally, some of the cartographic and geodetic subjects can also be involved. For example, cartographic symbology is design by 'KGI/TEKA Thematical Cartography'; the exact survey in the field for cadastre map is supported by 'KGI/ZGEOD Geodesy'. Due to the fact that BotanGIS application has been developed at the Department of Geoinformatics, there is an opportunity to develop additional features as a bachelor/master thesis there. Currently, two new widgets (diagrams, and taxonomy dials) are being developed as a bachelor thesis.

Students at the Department of Geoinformatics participate in the development, which brings a lot of information benefits for their education. As mentioned, the main focus from an educational point of view is to implement an innovative cloud computing approach. With the ArcGIS Online, students can make a 'live' copy of the BotanGIS application for themselves. This 'test copy' enables the study of all steps of the development and changes everything. In fact, they work with the real application and can recognise theoretical knowledge using a practical example. Students gain practical experience in creating a database or discover new botanical objects with an attractive

cartographic presentation. Finally, students gain new experience in collaboration and working in a team.

5.3   Pedagogy education

Despite the fact that the project was not originally designed for pedagogical students, it is frequently used by the Pedagogical Faculty of Palacký University in Olomouc as well. It serves the education of future teachers in primary and secondary schools with a focus on Nature and Biological subjects. With the combination of modern technologies, they acquire new methods of teaching.

Basic facts are gained from the database for the study of subjects 'KPR/BBOOC – Higher Plants' and 'KPR/BSEVC – Plant System and Ecology' at the Pedagogical Faculty. These subjects attend more than 40 students every year. Students of other disciplines also have the opportunity to attend subjects within the credit system. It means that subjects are available for students from all faculties of Palacký University.

5.4   Employees and visitors

The BotanGIS project plays a very important role for employees of the Botanical Garden because it provides a complex and updated database of all plants. Compared to the previous analogue system (paper cards), the BotanGIS revolutionised the management. The administration is used by employees, who are able to add, edit and delete plant entries and photos. Furthermore, the admins may insert messages, news or documents which are published on the website for the public. Nowadays, the database is administered by five experts and this list of plants is continuously updated.

With the web portal available for free on the internet, it provides a great opportunity to use it as web presentation for visitors. Public visitors can find information and news about the garden here. In case of interest, the guest can go through the database and identify plants. If users prefer 3D reality than 2D map, they can display the garden house as a 3D interactive model implemented map. Lastly, it serves as an attractive way to promote activities and events like 'Fascination of Plants Day' or 'GISday'. Since the BotanGIS system is ready, it has been presented in several events. The presentation and use of modern technology lures new visitors to come there, otherwise, they would not come.

6   Discussion

A fundamental step in the development process of the educational portal was discussions with botany experts. The portal has been created under their requirements and in collaboration with them. It eliminates constraints associated with developers being ignorant authors in the field of botany. As a matter of fact, there were technical solutions suggested that guarantee the correctness and functionality of the information system and included their requirements. The primary requirements for evidence were to show textual information for teaching. The administrators can take advantage of the private notes in a secured section. These notes allow writing non-public comments like 'On March 2012, the trimming was made'. This feature extended the applicability of the information system for management.

There is the restriction of limited functionality in the offline mode. It means that only browsing is allowed offline. There are future plans to enable full functionality in both online and offline mode, especially with a focus on mobile devices (smartphones and tablets). It could be a technical issue based on post-synchronisation because it required switch into online mode anyway. Moreover, there are greenhouses and some non-public areas that are not recorded in BotanGIS, which means that the system could be extended in the near future. However, from the technical point of view it will not be a problem because the BotanGIS is designed as extensible system.

According to Dobesova (2012, p.1) "the BotanGIS differs from other plant databases that collect information systematically about whole families, genuses, taxa. Systematic plant databases have no connection to real individual plant in wild and their real location". It means that the system describes real plants by real characteristics and authentic photos. Compared to other botany system mentioned approach is divergent. On one hand, there are many databases or management systems with a focus on botany features, on the other hand some botanical garden used Geographical Information Systems. But in fact, the interconnection of complex database component with spatial localisation is not implemented frequently. One of the most sophisticated system in this field is 'Tropicos' website (http://www.tropicos.org). It is a register of records, descriptive characteristics and photographs of plants from all over the world. The Tropicos database contains specimens, bibliography and terminology for last 25 years. In total, there are over 1.2 million scientific names and 4 million records. It offers to search by scientific names, by images or by specific characteristics (family, genus, species, etc.). The only option of GIS implementation is the possibility of generating worldwide plant occurrence into KML file for Google Earth. The 'Plant Database' (http://www.plants.usda.gov) is the botanical website of US Department of Agriculture. It is focused on North America only, and it offers several approaches of searching (simple, full-text search, advanced by more than 50 conditions). From the spatial point of view, there is the condition that shows country of plants occurrence. The 'International Plant Names Index' (http://www.ipni.org) is another worldwide database of plant names ant its characteristics. This database is widely used for academic purposes because it was created in cooperation of the Royal Botanic Gardens in Kew and Harvard University. 'Botanical Research and Herbarium Management System (BRAHMS)' (http://herbaria.plants.ox.ac.uk/bol/) is an innovative way how manage data and images from herbarium specimens, botanical surveys, field observations, or seed banks and literature for the widest possible range of curation and research services and outputs. It is developed at the Department of Plant Sciences, University of Oxford and it is used in 60 countries. BRAHMS is the unique system because it provides tools to query, report, map and publish outputs. Due to online services there is the possibility to generate outputs for GIS solution. In fact, it is visualisation tool only, map modifications are not enabled. Any of mentioned examples not allow spatial editing of plant location via the map interface directly. That is the reason why BotanGIS is the unique solution.

7 Conclusions

Based on the requirements of the Botanical Garden in Olomouc, an educational online portal called BotanGIS has been developed. The BotanGIS project is an innovative comprehensive botanical system that involves all plants from the Botanical Garden. It

takes advantage of the WebGIS solution and aims to collect a large amount of information in descriptive, image and spatial formats. It provides students with an effective, interactive and attractive way of learning and sharing knowledge about plants. The innovative solution is based on the combination of RIA with cloud computing technology. It provides access to materials in digital form via web browser both on the desktop and/or mobile device. Compared to other learning systems, the BotanGIS provides a handle of taxonomical characteristics with spatial localisation in the field. If the student receives descriptive information about the plant, its localisation over the map can be displayed every time.

The designed system allows searching and filtering by attributes in the database, which effectively supports education. It is much more effective to use filter (e.g., show all plants from family Cycadacae) than to look for the same task in analogue materials. The target group of botanical students will increase botanical knowledge because they can use the application in the field as well. Moreover, they will improve their practical technical skills after working with the modern GIS. Similarly, the students of Geoinformatics gain practical experience with creating a real system for practise built with the latest GIS technology. Furthermore, they become familiar identifying some plants. The application is platform and browser independent and can be extended by the use of widgets. Due to the cloud computing approach the application is still updated. Finally, the design of user interface is modern and intuitive, which positively affects the use of the application by the public. The BotanGIS education portal is available for free at http://www.botangis.upol.cz.

Acknowledgements

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