GEODIVA: A PLATFORM FOR GENERATING CUSTOMIZED MOBILE APPS FOR GEOSPATIAL DATA ENTRY

Sally E. Goldin[1], Natacha Varieras[2], Kemmatat Keawkittikanchana[1] and Kurt T. Rudahl[3]
[1] KMUTT Geospatial Engineering and InnOvation Center, 126 Pracha Uthit Road, Bangkok 10140 THAILAND
Email: sally@cpe.kmutt.ac.th
[2] École supérieure d'informatique, électronique, automatique (ESIEA)
74 bis Avenue Maurice Thorez, 94200 Ivry-sur-Seine FRANCE
Email: varieras@et.esiea.fr
[3] Department of Computer Engineering, KMUTT, 126 Pracha Uthit Road, Bangkok 10140 THAILAND
Email: ktr@goldin-rudahl.com

KEY WORDS: mobile spatial data gathering, open source, application generator, internationalized software

ABSTRACT: Solutions to practically every problem facing society, including biodiversity, health, food security, climate change, and poverty, depend on up-to-date information about biophysical and/or social conditions. In most cases, that information has a spatial component.
Smart mobile devices, equipped with GPS receivers, cameras, accelerometers, and easy-to-handle touch screen interfaces, have tremendous potential as tools for gathering geo-located field data in a wide range of disciplines. In fact, many software packages are currently available for mobile data gathering. Often, however, these applications have characteristics that reduce their effectiveness in the developing world, including high cost, lack of internationalization, use of proprietary data formats, a domain-specific focus and a requirement for network connectivity.
We have developed a system called *GeoDIVA* (*Geo*graphic *D*ata *I*nput and *V*alidation for *A*ll) which remedies these problems. GeoDIVA is a free web platform that allows individuals or groups to generate customized mobile apps for geo-tagged data entry, simply by entering their specifications into a web form and clicking a button. GeoDIVA apps are easy to create, easy to use, available in the user's local language, tailored for the specific problem the user is trying to address, useful without Internet connectivity, and designed to save geographic and attribute data in a simple, standard format that can be imported into many common desktop applications, including both commercial and open-source GIS.
In this paper, we describe the concepts and architecture of GeoDIVA, and demonstrate how it meets the need for specialized mobile data gathering for users in a wide range of disciplines.

1. INTRODUCTION

1.1 Overview

Solutions to practically every problem facing the society—biodiversity, health, food security, climate change, poverty—depend on up-to-date information about biophysical and/or social conditions. In many cases, that information has a spatial component. For instance, biologists want to be able to map the locations where various species have been sighted, as well as to record conditions such as date and time of sighting, number of animals, surrounding vegetation, etc. Public health authorities need to know where cases of infectious disease occur, as well as demographic data about the patients, number of individuals in the household, availability of sanitation and safe drinking water, etc. Food security planners require accurate information on locations and boundaries of fields, crops grown in different fields, crop conditions, water sources for agriculture, etc.

Smart mobile devices have tremendous potential as platforms for gathering geo-located field data, for many purposes. Typically, they have GPS receivers which can deliver near-continuous information about the device's position on the earth, at least when outdoors. They also have cameras that can record still or video images of conditions on the ground. Meanwhile, their touch screen interfaces are relatively easy to learn and use, and reduce the need for typing while moving. The fact that they have local storage means that data gathered can be maintained in persistent form until the users return from the field.

In fact, there are quite a few software packages available for mobile data gathering. However, many of them have critical weaknesses that reduce their effectiveness, especially for organizations on a limited budget, or in the developing world:

- They are too expensive;
- They are not internationalized (translated into local languages);
- They are aimed as specialists and hence too technical and difficult for many people;
- They focus on a specific domain of applications which may not be what the user needs, e.g. census data gathering, infrastructure mapping, etc.;
- They produce output in specialized formats that are only useful in the context of additional GIS or analysis software;
- They require continuous broadband Internet connectivity, which can be a problem in remote areas and lesser-developed countries.

Our solution, ***GeoDIVA*** (***Geo***graphic ***D***ata ***I***nput and ***V***alidation for ***A***ll) aims to remedy these problems by providing a way for individuals or groups to create customized mobile apps for geo-tagged data entry that are easy to create, easy to use, available in the user's local language, tailored for the specific problem the user is trying to address, useful without Internet connectivity, and designed to save data in a simple, standard format that can be imported into many common desktop applications, including both commercial and open-source GIS. GeoDIVA is available free, to anyone who registers and provides complete contact information.

1.2 Existing Solutions for Mobile GIS Data Gathering

Many problems require information about spatially distributed conditions in the real world. The fundamental task in field data collection involves recording the location of some feature or phenomenon (spatial information) along with relevant attributes associated with the location (non-spatial information). The details of this task vary considerably, however, from one discipline and one project to another, in terms of both the spatial and non-spatial information needed.

The promise of using mobile devices for field data gathering has been recognized for more than a decade (e.g. Nusser et al., 2003). Over the past few years, that promise has become a reality, due to the widespread availability of powerful and inexpensive mobile phones and tablets, the introduction of open source operating systems and development frameworks (Goldin et al., 2014), and the promulgation of GIS standards. Most mobile devices now have the ability to record both spatial and associated non-spatial information, as described above.

As might be expected, many applications have been developed to take advantage of these capabilities. In particular, commercial GIS vendors offer mobile data collection apps that interface with their server-based products (ESRI, 2016; GISCloud, 2016; Maptitude, 2016). These tools often provide a high level of functionality (possibly more advanced than needed for many projects), but they require a license for the primary package and/or a monthly fee. Most require Internet connectivity, at least to initialize the application and to transmit the data gathered. In addition, with the exception of ESRI's products, all the apps we have surveyed are available only in English

In response to the expense involved in using proprietary applications, researchers and practitioners sometimes undertake the process of developing their own mobile applications for field data gathering (Abdullah and Muhadi, 2015; de Abreu Freire and Painho, 2014; Lwin and Murayama, 2011). While this approach results in an application that free to use and tailored to the needs of a particular user group, it requires significant time, effort and information technology expertise. Furthermore, that expertise must remain available over time in order to modify the application in response to changing requirements or to serve new projects.

1.3 The History of GeoDIVA

We first conceived of the GeoDIVA project while developing our own customized mobile data gathering app for a project involving the mapping of small waterways in a rural district of Thailand (Duriyapong et al., 2014). As we worked on programming the WaterTrak Android application, we realize that the interaction and architecture could be generalized to create a generic mobile data gathering app schema. The geospatial components of the software, namely, accessing the GPS to acquire up-to-date position information and recording that information in a data file, are common to all such apps. Only the specific attributes to be recorded vary from app to another, as the domain, context or user goals change. Meanwhile, we noticed that the software logic for handling different attributes was very stereotyped. The code for reading, validating and saving an attribute value depended only on its data type: string, integer, real number, free-form text, or list of choices.

Instead of requiring custom programming, we realized we could generate much of the app code from templates. We could ask the user to define the attributes she wanted, using a simple web interface. Then we could use that information to create exactly the data entry screen she needed. By saving the attribute definitions in a data base, we could offer a user the chance to return and modify her app any time this was necessary.

We recruited a team of three undergraduates, who implemented the first generation GeoDIVA website as their capstone senior project. Unfortunately as is often the case with students, the project never quite reached the stage of release. We now have another, more experienced developer working to update and test the application. We hope to make the GeoDIVA website publicly available by January 2017.

2. THE GEODIVA APPROACH

GeoDIVA is a web-based facility for generating mobile data gathering apps, based on user specifications. Currently GeoDIVA produces apps for Android only. We feel that Android is the most appropriate platform for mobile apps aimed at developing countries, due to the low cost of Android devices, the widespread market penetration of the operating system (66.87% of the market, according to NetMarketShare.com), and the lack of proprietary restrictions on app development and distribution. Furthermore, the Android Software Development Kit (SDK) provides command-line based tools which can be invoked from a script running on a server.

Every GeoDIVA app provides the ability to record the geographic coordinates of locations or paths, then to enter information into a form customized for the user's application. For instance, the form associated with a disease incidence mapping app might include patient's age, patient's gender, patient's marital status, a list of possible symptoms, date of symptom onset, etc.

All GeoDIVA apps store the gathered data in text files using a comma-separated value (CSV) format. This simple and generic format can be imported into spreadsheet programs, relational databases, and many GIS software packages.

GeoDIVA apps do not need Internet connectivity. Users can transfer their data files from their mobile devices to other computers or applications using wireless or USB connectivity once they return to their home base. Of course, if Internet service is available, GeoDIVA users can take advantage of this, but the generated apps provide full functionality without it.

2.1 Creating a GeoDIVA Application

To create a new mobile app, a user goes through the following steps:

1. Accesses the GeoDIVA website.

2. Registers as a GeoDIVA user and provides full contact information (so that we can eliminate malicious or frivolous users and also keep in touch with our user base).

3. Logs in to the GeoDIVA website.

4. Clicks Create to create a new app definition and enters a name for the app.

5. Decides whether the app will be point-based or track-based. The former would be appropriate for recording wildlife sightings or disease incidents. The latter would be appropriate for mapping bicycle paths or the locations of irrigation canals. The user interface for these two types of apps is somewhat different. (A future version will also provide area-based apps.) Each GeoDIVA app is specialized for one particular type of spatial feature.

6. Define a set of data entry fields for her application, by specifying the following for each field:
   - A label for the field, in the user's local language. This is what will be shown on the data entry form.
   - A label for the field data in the CSV file (English, optional).
   - The type of information to be entered in the field (text, integer, floating point, single boolean value, set of boolean values, or selection from a set of fixed choices)

- Optional limits on the length of a string or the maximum and minimum values for a numeric field
- Optional default value
- Whether the field is required, that is, whether it must be filled in if the user wants to save the data.

7. Once the user has entered all this information, she clicks on the "Create App" button. The GeoDIVA server will generate code for the new app, compile and package it into an .apk file (Android installation package) and provide a link that will allow the user to download the app to her device and install it.

2.2 Modifying a GeoDIVA Application

The GeoDIVA server retains all the specifications for the user's app in a database. If the user decides at some future point that she needs to modify the user interface for her app, by adding, removing or changing data entry fields, she can simply log in to the GeoDIVA website, choose the app from a list of those she has defined, and edit the specifications. Then she can regenerate a new version of the app which will include the changes.

A user can define any number of apps for different purposes.

3. GEODIVA ARCHITECTURE

The GeoDIVA system is based entirely on free and open source software. Currently the application runs on a Linux server at King Mongkut's University of Technology Thonburi. Once the system is released, we may move it to a commercial hosting platform to provide better scalability.

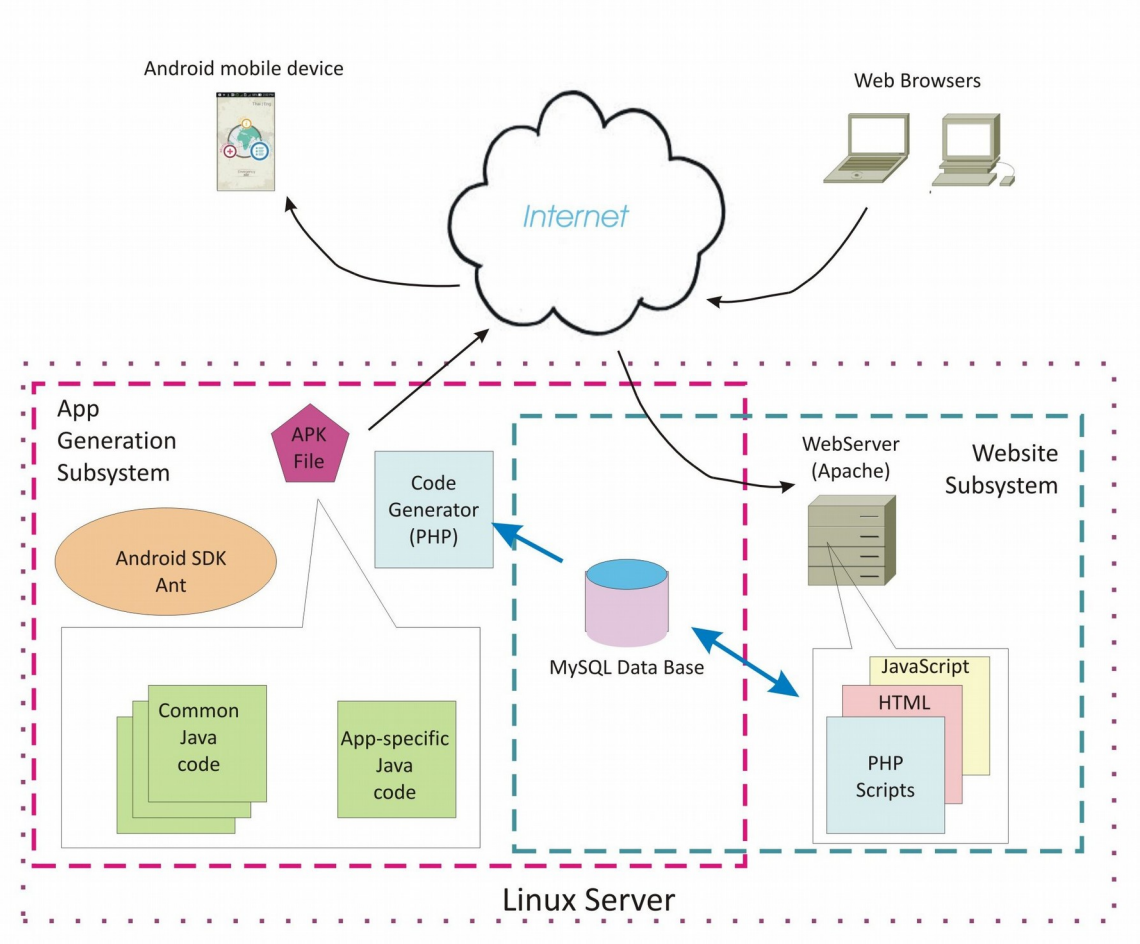

Figure 1. GeoDIVA Architecture

Note that the server is only involved in *defining* and *generating* apps. Once an app has been generated and installed on the user's mobile device, it is totally independent of the server. The GeoDIVA server does not itself host or distribute any sort of geospatial information. It simply provides a platform that helps users to create customized apps without the need to do any computer programming.

Figure 1 illustrates the architecture of the system. The user interface for defining apps is browser-based, and can be accessed from any device with an Internet connection. Both the web site logic and the application generator are written in PHP. User credentials and app definitions are maintained in a MySQL database.

Android applications are typically written in Java. GeoDIVA includes some Java source files (Java classes) that are the same for all generated apps. These handle common functionality such as accessing the GPS and writing to the output file.

The code generator creates additional, customized Java source files based on the field definitions in the database. It also creates XML files to define the user interface (UI) screens for the application. Although Android apps can create user interface controls and layouts programmatically by calling API functions, defining the UI separately from the code is the recommended practice. For code generation, this is particularly convenient.

Once the code for the new app has been generated, the generator invokes Ant, a software build automation tool. Ant in turn runs various command line tools from the Android SDK to compile the app source files and package the final app into an .apk (Android installation) file. The system returns the location of the apk file to the web UI, which displays a link for the user to download the app to her device and install it.

Note that currently if the user has defined the app fields using a desktop or notebook computer, she needs to trigger the generation process from the mobile device where she wants to install it, in order to access the generated app and download it to the target device. Future versions of the system will provide more convenient distribution options, for instance, sending the link to the user by email.

4. INTERNATIONALIZATION

The GeoDIVA web application is fully internationalized. Currently the application can be used in English, Thai and French. Translating it to other languages is straightforward, as all strings are kept separate from the code.

Unlike most of the mobile data gathering apps currently available, which are English-only, the apps created by GeoDIVA can be in any language. The user types in the strings she wants to use as labels for the data entry fields in the app. These can be in Thai, in Devanagiri, in Swahili, or whatever language the user wants. (We have not yet tested any bidirectional language like Hebrew or Arabic.)

Furthermore, the Android application development framework would make it very easy to create multi-lingual apps using GeoDIVA. Android apps typically store their text strings separately from the layout instructions, in a different set of XML files. The operating system provides a scheme for defining multiple string files for different languages. If the programmer follows the operating system naming conventions, the app will automatically use the language the user has chosen via device settings.

5. FUTURE PLANS

As noted above, we hope to make GeoDIVA available to the public, with its current level of functionality, early next year. Meanwhile, we have many plans for additional capabilities that will make the system more flexible and useful.

5.1 App Capabilities

The mobile apps created by version 1 of GeoDIVA are quite basic. We anticipate adding the following enhanced features:

- *Support for area-based apps as well as point- and track-based apps:* This will expand the range of domains and problems where GeoDIVA apps can be helpful.
- *Map display:* We would like it to be possible for a GeoDIVA app to (optionally) show the user's current location on an image or map of the area of interest, and to track the user's position as she moves. This is a popular feature of commercially available apps. Since we do not want to require Internet access, this capability may require the user to download the map or image into the device before data gathering begins.
- *Photo attributes:* In many situations, it may be useful to allow users to associate photos or videos with a logged geospatial feature.

- *User identification:* Currently, GeoDIVA apps do not require any sort of login in order to gather data. However, an organization that creates an app to be used by multiple people may want to identify who gathered each data set. The user defining a GeoDIVA app will have the option to select from a set of predefined fields for a user identification screen. The app user will need to fill in these fields before she can begin gathering data. The identifying data will be stored in the output files created by the user.
- *Support for other platforms:* We are not sure whether the demand for Apple or Windows device support will be large enough to balance the significant develop effort to support these platforms. One possible route would be to rewrite the system to use a cross-platform mobile toolkit like Cordova (Cordova, 2016). However, this might remove some of the advantages of using Android such as command line tools and declarative definition of the UI.

5.2 Web Site Capabilities

GeoDIVA has the potential to become an online community. If we attract enough users, it may be worthwhile to add social networking features such as a forum, messaging, or a blog. We also believe that users may want to share app definitions with other users. Thus we will need to add an ability to "clone" an app definition, including a definition created by another user.

6. CONCLUSION

The concept of geo-tagged mobile data gathering is commonplace. Many companies, research groups and non-profit organizations have developed mobile applications for gathering data about specific phenomena. However, a variety of factors combine to make these apps less useful for and accessible to less technically-sophisticated users and users in the developing world. By providing a simple app framework and an easy-to-use facility for creating new apps that exactly match the user's needs, GeoDIVA will put the power of geospatially-enabled data gathering into the hands of a much wider audience. This, in term, will facilitate the acquisition of information critical to solving a broad range of critical problems in many domains.

7. REFERENCES

Abdullah, A.F. and Muhadi, N.A. 2015. GiS data collection for oil palm (daCOP) mobile application for smart phone. ISPRS annals of the photogrammetry, remote sensing and spatial information sciences, Volume II-2/W2.

Cordova. 2016. Overview. Retrieved September 14, 2016 from https://cordova.apache.org/docs/en/latest/guide/overview/index.html

de Abreu Freire, C.E. and Painho, M. 2014. Development of a mobile mapping solution for spatial data collection using open-source technologies. Procedia Technology 16, pp. 481-490.

Duriyapong, F., Varnakovida, P. and Goldin, S.E. 2014, Development of GIS database for conservation and sustainable use of lampradong: a case study of Amphawa district. Proceedings of 10th International Conference on Asia GIS, June 14-16, 2014, Chiang Mai, Thailand.

ESRI. 2016. Collector for ArcGIS. Retrieved September 14, 2016 from http://doc.arcgis.com/en/collector/

GISCloud. 2016. Mobile data collection. Retrieved on September 14, 2016 from http://www.giscloud.com/apps/mobile-data-collection

Goldin, S.E., Rudahl, K.T., and Intapong, P. 2014. Open source and open standards: tools for rapid development of community-oriented GIS. Proceedings of the 35th Asian Conference on Remote Sensing, October 27-31, 2014, Nay Pyi Taw, Myanmar.

Lwin, K. and Murayama, Y. 2011. Web-based GIS system for real-time field data collection using personal mobile phone. Journal of Geographic Information Systems, 3 (4), pp. 382-389.

Maptitude. 2016. Mobile data collection & field mapping software. Retrieved September 14, 2016 from http://www.caliper.com/Maptitude/solutions/mobile-gis-data-collection.htm

NetMarketShare, 2016. Mobile/Tablet Operating System Market Share. Retrieved September 14. 2016 from https://www.netmarketshare.com/operating-system-market-share.aspx?qprid=8&qpcustomd=1

Nusser, S.M., Miller, L.L., Clarke, K. and Goodchild, M.F. 2003. Geospatial IT for mobile field data collection. Communications of the ACM, 46 (1), pp. 64-65.