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Web-Based GIS System for Real-Time Field Data Collection Using a Personal Mobile Phone

Ko Ko Lwin, Yuji Murayama
Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Japan
E-mail: kokolwin@live.com, mura1@sakura.cc.tsukuba.ac.jp
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Abstract

Recently, the use of mobile communication devices, such as smart phones and cellular phones, in field data collection is increasing due to the emergence of embedded Global Position Systems (GPS) and Wi-Fi Internet access. Accurate, timely and handy field data collection is required for disaster management and quick response during emergencies. In this article, we introduce a web-based GIS system to collect the field data from personal mobile phones through a Post Office Protocol POP3 mail server. The main objective of this work is to demonstrate a real-time field data collection method to students using their mobile phones to collect field data in a timely and handy manner, either in individual or group surveys at local or global scale research.

Keywords: Web-Based GIS System, Real-Time Field Data Collection, Personal Mobile Phone, POP3 Mail Server

1. Introduction

Geospatial data collection is one of the important tasks for many spatial information users. Geospatial data collection may include remote sensing data, field data and other in-house GIS data conversion processes (*i.e.* scanning, georeferencing, digitizing, etc.). Among them, field data collection is one of the first steps for spatial information users, especially for geographers, geologists, biologists, crop scientists, ecologists, etc. Field data collection is required for several reasons, such as collecting Ground Control Points (GCPs), ground truth data collection for result validation, collecting soil contaminated sites, plant or animal species, and gathering public opinions for retail market analysis in order to analyze the spatial distribution patterns of objects and information on their associated attributes. Accurate field data collection is also necessary for adequate spatial data analysis and proper decision making.

Traditional field data collection (*i.e.* pen-and-paper based) is a time consuming and bulky task. For example, we need to prepare basemaps, collect an ancillary dataset, and other paperwork. This is not practical to use in real-time disaster information collection, which occurs in unpredictable places and requires a quick emergency response. However, recent developments in mobile communication, Global Navigation Systems, the Internet and portable computational devices such as Netbooks or Ultra Mobile Personal Computers (UMPC) allow us to conduct field data collection in a timely manner. Moreover, under the client-server setting for field data collection, a field user may take advantage of digital repositories prepared for data collection (*i.e.* basemaps, satellite images and other ancillary data), as well as information resources more generally available via the Web [1]. For example, use of Web Map Service (WMS) to access Google Maps or Microsoft Bing Maps data from GIS applications via a HTTP interface. It can provide Google Map or Microsoft Bing Maps image data to any GIS applications that can use a WMS service for raster data. This can eliminate the time for basemap preparation and other image processing tasks.

Perhaps the most exciting area of computer system development continues to be in hand-held devices such as personal digital assistants (PDA), UMPCs, Netbooks and smart phones. A smartphone is a mobile phone that offers a more advanced computing ability and connectivity than a phone with contemporary features. They are much more efficient in form factor (size, shape, weight, etc.), chip type, internal storage capacity, battery lifetime and operating system compared to desktop computers. Along with hardware development, the operation systems used in smart phones are becoming more and more compact and functional such as iPhone (Apple Inc.) and Android (Google). Computer scientists at the University of Washington have used Android, the open-source mobile operating system provided by Google, to turn a cell phone into a versatile data collection device by collecting deforested area and instantly submitting that information to a global environmental database in a flexible manner [2]. In the meantime, world cellular mobile phone subscribers are increasing year by year. According to the International Telecommunication Union ITU's 2010 report, by the end of 2009 there were an estimated 4.6 billion mobile cellular subscriptions, globally corresponding to 67 per 100 inhabitants [3]. Recently, a couple of studies have demonstrated field data collection with mobile phones in both the educational and industry sectors [4,5].

On the other hand, the increasing popularity of the Internet and user-friendly web-based GIS applications such as the Google Maps/Earth and Microsoft Bing Maps platform have made GIS an integral part of life today, for finding the closet facilities, driving routes and so on. For example in Tsukuba City, Japan, local residents and green exercise takers can search for the shortest or greenest route between multistop trips through a smart phone while walking down the street by accessing the Eco-friendly Walk Score Calculator web-based GIS [6]. However, PDAs, Netbooks and smartphones are sometimes considered as costly, including both device and wireless access service charges, not suitable to use in student field survey project. Moreover, mobile field computing environments vary widely, but generally offer extremely limited computing resources, visual displays, and bandwidths relative to the usual resources required for distributed geospatial data [7].

In this paper, we discuss the collection of field data by a GPS embedded personal mobile phone and POP3 mail service. We also construct a Web-based GIS system to integrate, store, share and retrieve the collected data in real-time, which could be used for example in metrological data collection (*i.e.* surface temperature, wind speed/direction) and damage information in disaster areas at various locations. The main objective of this development is to collect the field data in a timely, handy and cost effective manner.

2. Web-Based GIS System and Real-Time Field Data Collection

2.1. How It Works

We have developed a personal field data collection software called Ultra Mobile Field GIS (UM-FieldGIS) for the UMPC or Netbook computer, to collect field data using either Google Maps or a pre-installed map (PIM) [8]. UM-FieldGIS allows users to create, edit and modify the survey items and attach multimedia information. However, UMPC or Netbook computers and Wi-Fi Internet access services are expensive and not suitable for students. We need to find an alternate way to collect field data in a handy and timely manner at low cost, such as using a personal mobile phone.

Figure 1 shows the detailed system design of field data collection using a personal mobile phone. Basically this system can be divided into three sections; named Field Data Collection, Automation Process and End Users. Field Data Collection includes a GPS embedded mobile phone or GPS plus mobile phone. All functions of receiving mails, data injection and format conversion processes will be performed automatically, called the Automation Process. Finally the End Users Section interfaces with the Web-GIS for survey data downloading, GIS data visualization and performing spatial analysis functions through a web-GIS browser at low cost, such as by using a personal mobile phone.

Field Data Collection: We utilized a GPS embedded mobile phone which typically supports additional services such as Short Messaging Service (SMS), Multi Messaging Service (MMS), e-mail and Internet access; short-range wireless (infrared or Bluetooth) communications; as well as business and gaming applications, and photography. Users are required to type predefined text format for collecting the data. For example, the user needs to add the "/" character between fields and add "," between attribute values (**Figure 2**). This text message will be sent to a predefined mail address with a predefined subject. The user can also attach photos, as many as required.

Automation Process: This text message is read by a POP3 mail server and then converted into Microsoft Access Database format. Under the Web-GIS system, this MS Access Database is converted into an ESRI Shape file and integrated with another GIS dataset, such as roads, building footprints, aerial images, etc.

End Users: Users can download up-to-date survey data in an ESRI Shape file format through their Web-GIS browser. User can also perform basic GIS functions such as distance measurement, finding the closet facilities within user defined search distances, labeling of attribute names, linking between survey records and maps, and viewing the attached image files through a Web-GIS browser (**Figure 3**).

The overall system is built on Microsoft ASP.NET with an AJAX Extension and VDS Technologies (Web Mapping Components for ASP.NET). ASP.NET is a web application framework marketed by Microsoft that programmers can use to build dynamic websites, web applications and XML web services. AJAX (short for Asynchronous Java Script and XML) is a group of interrelated web-development techniques used on the client side to create interactive web applications. With AJAX, web applications can asynchronously retrieve data from the server in the background without interfering with the display and behavior of the existing page. The use of AJAX techniques has led to an increase in interactive and dynamic interfaces on web pages. AspMap for .NET from VDS Technologies is a set of high performance web mapping components and controls for embedding maps in ASP.NET applications (Web Forms).

2.2. Survey Modes

This system can be used either for individual or a group surveys (**Figure 4**). The individual survey mode is ideal for each user to collect their own field survey data for a specific purpose, and the group survey mode is ideal for real-time information collection such as surface temperature, wind speed/direction, earthquake damage information, etc., and can be switched between simply by changing the "Type" field. For example, for an individual survey the "Type" field may be the individual's initial name and later they can extract their own data using this value field. For a group survey, the "Type" field may be the category which is being surveyed, such as temperature, land use type, rock or soil properties, etc.

3. A Case Study

Every year, students conduct a field survey to collect information about public facilities such as bicycle stands and their capacity, car parking lots, sidewalk condition,

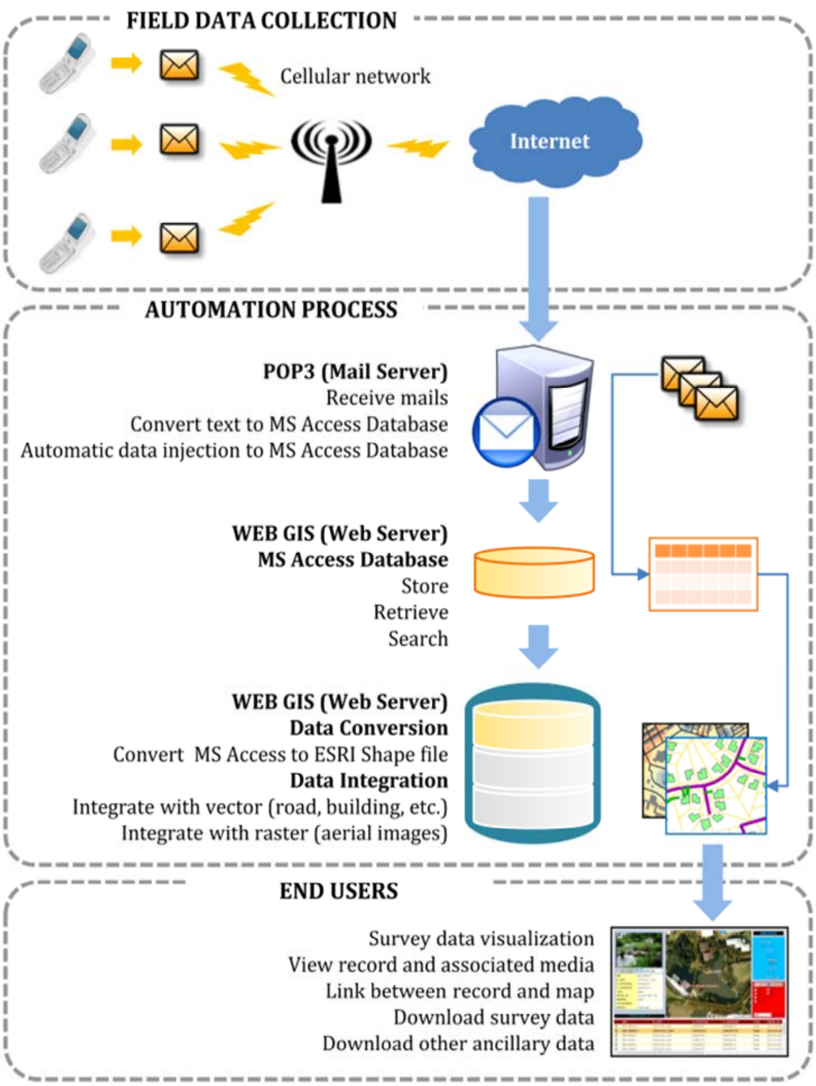

Figure 1. Details of the system for field data collection using a personal mobile phone.

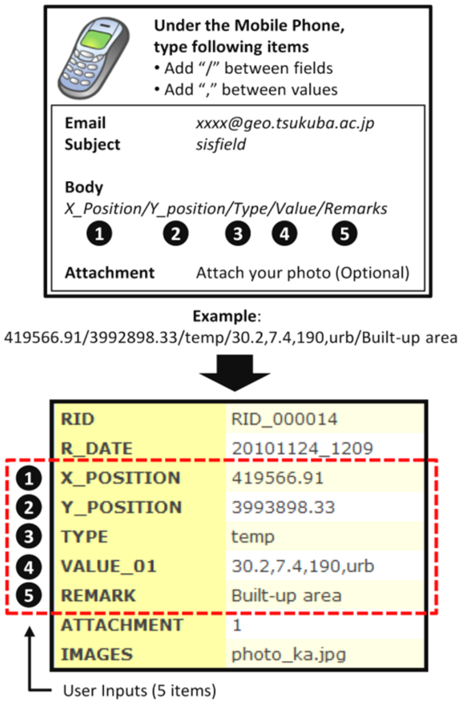

Figure 2. Format conversion between text message and MS Access Database.

illegal garbage dumps and other environmental data. This year, we introduced this system to the students for their field survey course, which is a part of the University Campus GIS project. In this two-day field course, we conducted both individual and group surveys. For the individual survey, students individually collected information on location of Automated External Defibrillator (AED), illegal garbage dumps, illegal bike parking places, graffiti in public places, broken pavements, man-made footprints caused by people walking on the grass and passing inside the trees instead of using legal paths. Later this information was used by university administrators for maintaining the campus landscape and managing the student facilities. With respect to the group survey, we collected real-time surface temperatures with other attribute information, such as wind speed/direction and surrounding land use type. In this case study, four faculty members and sixteen students from the University of Tsukuba, Japan, and two faculty members and nine students from the South China Normal University, China, participated.

3.1. Prior to the Field Work

Planning ahead is important for an adequate and successful field data collection. Spatial planning and sampling design include setting where and what attribution information to be collected. It is difficult or impossible to collect again after the field work has been done. We also demonstrated handling of GPS and other field survey instruments (**Figure 5**).

Figure 3. End user interface of Web-GIS for field survey data visualization in real-time.

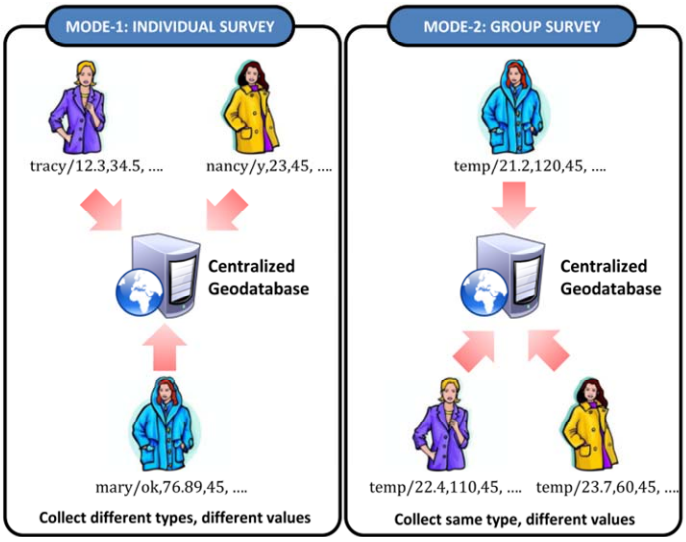

Figure 4. Modes of survey: individual or group.

Figure 5. (a) Planning ahead; (b) GPS training; (c) Learning about real-time automatic metrological data collection.

3.2. During the Field Work

During the field work, students are required to send field survey data by using their GPS embedded mobile phone or reading coordinates from a Garmin handheld GPS. For the individual surveys (**Figure 6(a)** and **(b)**), all students collected the data inside the campus based on specific information (*i.e.* location of garbage boxes, parking lots, etc.). For the group survey (**Figure 6(c)**), we divided the survey area into student groups. Each group is required to collect temperature, wind speed/direction and land use type information in thirty minute intervals. Faculty members were also monitoring their status using a Netbook computer with wireless Internet access along with them (**Figure 7**). Faculty members were also offering advise to the students through mobile phone communication.

3.3. After the Field Work

After the field work, students are required to download the survey data through Web-GIS and open in ESRI ArcMap in the laboratory (**Figure 8**). This process includes downloading the data, importing, formatting and visualizing the data in ArcMap. We used Visual Basic for Applications (VBA) script to convert the comma separated values into attribute fields (**Figure 9**).

Figure 6. (a) and (b) Individual survey of graffiti in public places and illegal garbage dumps; (c) Group survey of surface temperature collection.

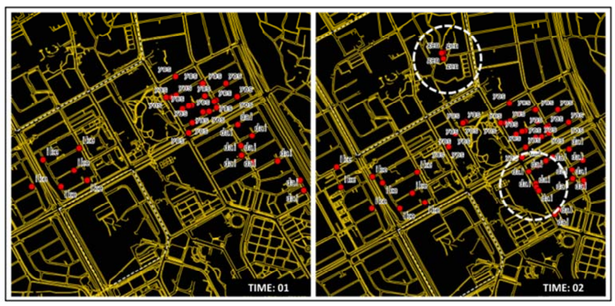

Figure 7. Monitoring of real-time data injection by individual student (Individual survey mode).

Figure 8. Field data visualization and downloaded from Web-GIS in the laboratory.

String substitution is also carried out by VBA Script to replace the short text to full text, such as “urb” to “Urban”. This is because sometimes students collect the data using short text messages to reduce typing errors and time. Furthermore, students were also able to select their own data by choosing their name in the “Type” field.

Following is the VBA script code for columns separation and formatting in ArcGIS using Field Calculator function.

```
'Column Separation by Specific Character (,)
    Dim tString() As String
    tString = Split( [VALUE_01], ",")
    tString(0)
Do again for other fields by changing the index
    tString(1)
    tString(2)
Trim(tString(3)) for text attribute field.
Trim removes the space before and after words.
```

```
'Substitution by string
Dim tString As String
tString = Replace([C4], “ubn”, “Urban”)
tString
```

4. Results and Discussion

Figure 10 shows the results of a student’s individual field survey data, such as determining the location of AED, bike parking places and capacity, benches, lamp posts, illegal foot paths, etc. This result will be used by the university administrators to improve the campus and students‟ daily lives. Students can also find the closet facilities by user defined search distance, known as closet facility analysis. **Figure 11** shows the results of a survey of surface temperature and associated surrounding conditions, such as wind speed/direction and land use type, taken at thirty minutes intervals in a group survey.

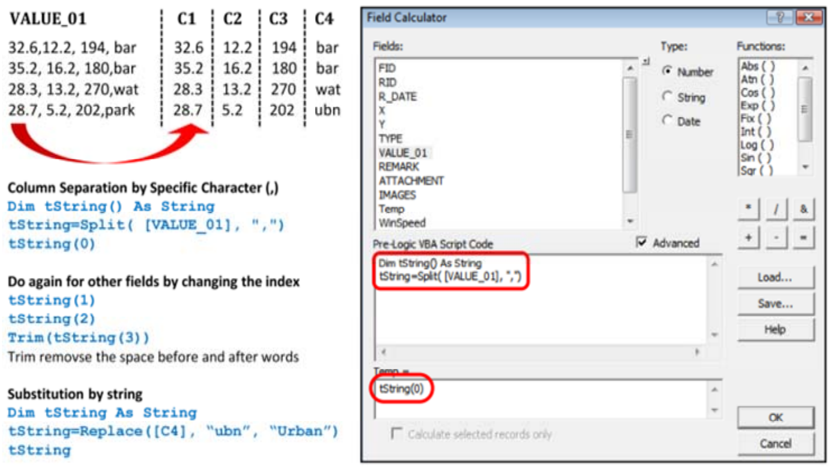

Figure 9. Columns separation and formatting of the survey data in ArcGIS using Visual Basic for Applications (VBA) script.

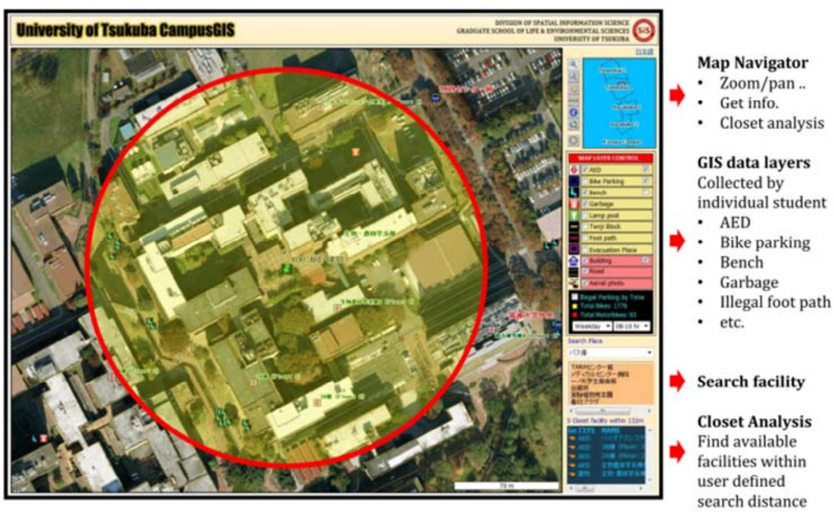

Figure 10. Web-based campus GIS built on student individual field survey data. http://land.geo.tsukuba.ac.jp/campusgis/.

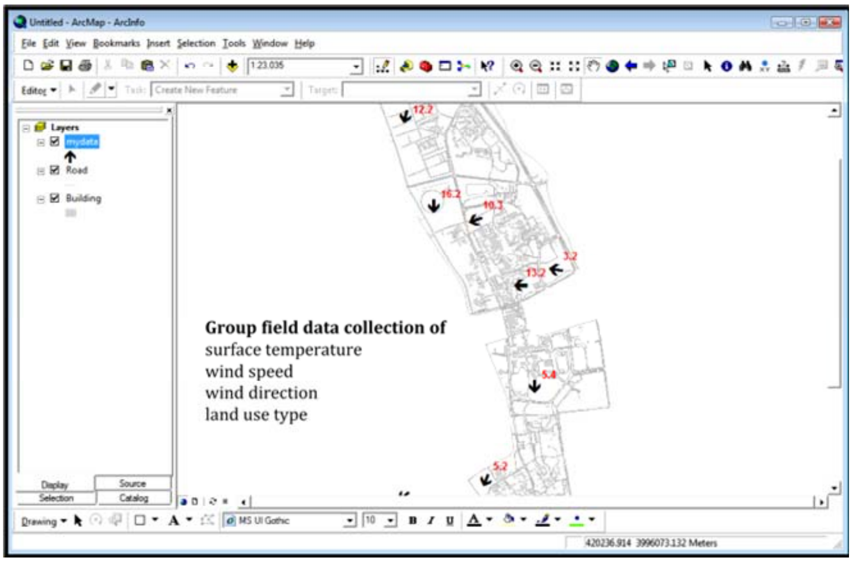

Figure 11. Mapping the surface temperature, and wind speed/direction in ArcMap based on student group survey data.

These factors can vary quantity of surface temperature. By importing the group survey data into ArcGIS program, student can perform more a number of spatial analysis functions.

5. Conclusions

Although we have developed a Web-GIS system for field data collection which allows users to directly view the basemaps, get coordinates from the map, create new survey items and input the data through a web browser by using wireless Internet access services and Netbook computers, until now Netbook computers, smart phones and wireless Internet access services are expensive and not suitable for educational uses. In this paper, we introduced a novel approach for field data collection using a GPS embedded mobile phone and POP3 mail server to collect the real-time geospatial information from individual or group surveys. All survey data are collected, stored, shared and retrieved via the Web-GIS system for further analysis. This is ideal for student research activities in order to practice their research work and improve their understanding of spatial distribution patterns and their associated attribute information.

6. Acknowledgements

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