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Mobile GIS for Cadastral Data Collection in Ghana

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1 Introduction

With the development of Web GIS and the emergence of Mobile GIS new possibilities of data capture and maintenance of geographic information have evolved. One of the categories of geographic information that can benefit from this especially is *cadastral* information, especially in places where there is no long–established, well–funded, digital cadastral data acquisition system, as is the case in many developing countries.

This study's main objective was to design a system of Mobile GIS suitable for building and revising a cadastral database. Up–to–date collection and revision of cadastral data is a key necessity for national advancement. The West–African country of Ghana was used as the case study area. The steps taken in this study to realize this were:

1. To analyze possible *approaches* for online editing, update and transfer processes of cadastral data in a mobile GIS environment and choose the most appropriate one for the use case;
2. To develop *process models* for the chosen approach in editing, updating and online transfer over a mobile GIS network;
3. To design and implement a *prototype* based on the proposed models, and then test for its effectiveness and usability.

This paper will go into more details for the three steps mentioned above. Special attention will be given to the needs and requirements for Cadastral systems in a country like Ghana and the consequences this had on the conceptual design. We will also highlight the important benefits that a mobile GIS–based cadastral system could have over the current practice.

Finally, we will present the prototype system as a 'best practice' example, and explain how we intend to make it available for experimentation and testing. People will be able to download the client components and test it against the server components running on a public website. In that light we plan to further develop the system to use Open Source components on both the client– and server–side.

2 Approaches for mobile cadastral GIS

As a first step, an extensive literature review was undertaken into the theoretical foundations of mobile GIS technologies and system modelling using object–oriented software engineering concepts. Quite a lot of work has been done on data collection and maintenance in many fields within the framework of the mobile GIS technology. For example, Brentjens (2004) looked at updating capabilities in a distributed OpenGIS Web Feature

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Service. Thompson (2002) focused on traffic data collection for travel time analysis by developing a prototype that integrated GPS and GIS technologies. Tsou (2004) also developed a mobile GIS prototype that allows multiple park rangers to access large-size, remotely sensed images and GIS layers from a web server mounted in a vehicle. In Vivoni & Camilli (2003), the development of a prototype mobile GIS environmental field data collec-tion system for two way transfer and display of collected data between field site and remote location server was highlighted. Finally Kang & Li (2005) presented a framework mecha-nism which deals with the maintenance of topological consistencies in updating map data. In all of these works and many more, mobile GIS and data collection applications have been developed in various disciplines but little mention has been made of practical applica-tion in cadastral data acquisition in a developing country setting. This gap is what our re-search aimed to address.

3 Modelling the cadastral processes in Ghana

Ghana, in her quest to improve on her land delivery system, is implementing a project known as the Land Administration Project, aimed at making the collection, maintenance and dissemination of cadastral data more efficient and rapid, while maintaining the necessary level of accuracy. The cadastral business processes in Ghana were studied and user requirements for the Cadastral system were gathered. Subsequently we modelled these processes using the Unified Modelling Language (UML), employing activity diagrams, use case diagrams, class diagrams and sequence diagrams. These can be found, with an extended discussion (in Mensah-Okantey, 2007), available on the project's website (ITC, 2008). The practical application of these business processes has been limited: Currently almost the whole of the capital city Accra has been covered with cadastral maps and cadastral database, and title registration is in progress on pilot bases. For other regions only sporadic surveys are being carried out and cadastral data collection, mapping, creation and maintenance of databases for many more regions remains to be done. So looking into the potential to speed up this process using mobile GIS was a logical step. Compared to traditional cadastral survey methods, the use of mobile GIS would allow attribute information to be collected and recorded simultaneously with their corresponding spatial parcel data. Field data collected and recorded can be communicated quickly to central office for further processing. This would involve reliance on two relatively new technologies: *GPS* surveying and *mobile communications*.

The potentially lower accuracy of *GPS* as opposed to traditional survey methods is only a relative problem: Firstly, for cadastral systems based on general boundary such as hedges and fences, only relative positioning is important, so GPS techniques with lower positional accuracies can be employed. Secondly, even low–cost GPS devices nowadays can employ *differential GPS* technology to improve the accuracy.

Whereas most people might not perceive developing countries such as Ghana as places where *mobile communications* networks are readily available, the country already has five operators, with 7.6 million customers, which equates to a population penetration level of 33%. Moreover, this amounts to 84.4% of the total telephone subscribers (which for example in Austria is only 67.8%), making mobile communications relatively the most important (ITU, 2004). Ghana was among the first countries in Africa connected to the

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Internet and to introduce ADSL broadband services. The rapid growth in this sector in recent years is set to continue (Budde.com, 2007). Fixed internet connections might be less available for the general public then in most Western countries, but certainly government offices are becoming more and more connected to the Internet.

The next step was to develop various models as a *conceptual design* for enhancing the Cadastral data gathering process using Mobile GIS components. Again these are available on the website, and an example can be seen in figure 1.

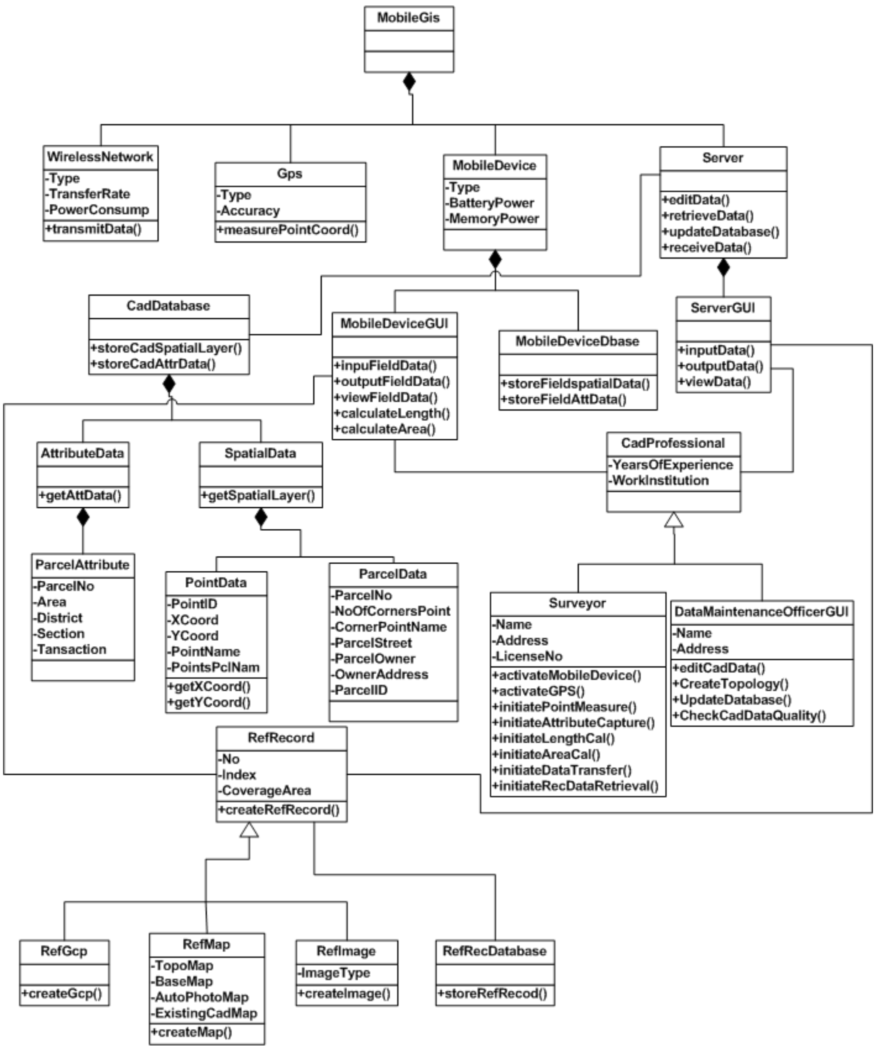

Fig. 1: Example outcome of the conceptual design phase – Class diagram of the proposed system (Mensah-Okantey, 2007).

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4 Proof–of–concept prototype

The conceptual design was partly realised in a *proof–of–concept prototype*. A multi–tiered client–server architecture (see figure 2), was developed and implemented, tailored for cadastral data collection and maintenance. In this first implementation, the graphic user interface was developed in ESRI’s ArcPad Application Builder (ESRI, 2008) and deployed on a Windows Mobile Personal Digital Assistant connected to a GPS. The interface was structured to facilitate collection of cadastral data in the field, and subsequently using the collected data to insert into and/or update a cadastral database, implemented in PostGIS (Refractions, 2008). This can be done real–time if a wireless connection to the Internet is present, or later from a field office with a fixed connection. This is important, as the availability of wireless networks is always uncertain.

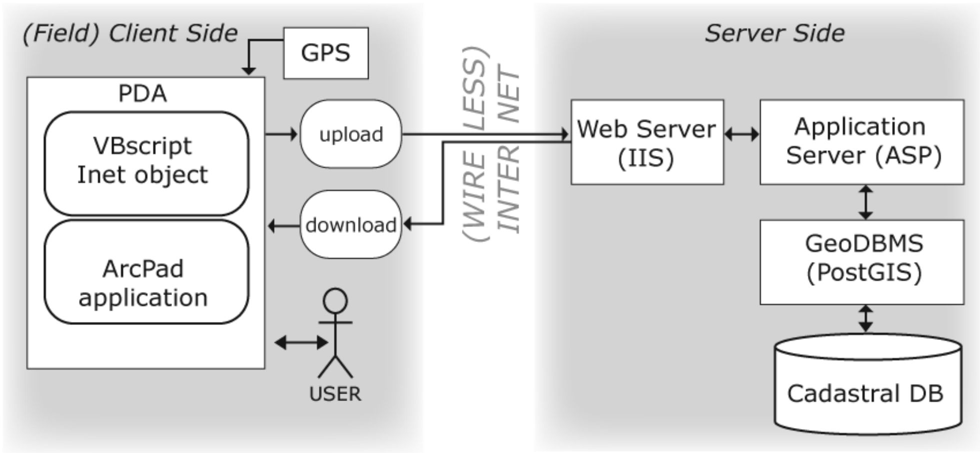

Fig. 2: Architecture of the current proof–of–concept prototype.

One of the challenges in this work was the development of a transfer system to move data from the mobile field client to the server. This required some data transfer coding on the field client to upload data, as well as functionality to receive the data on the server. The latter was implemented using Microsoft Active Server Pages scripting. For the former, a number of data transfer procedures on the client side were explored. The procedure we chose is that a Visual Basic *Inet Object* establishes a hypertext transfer protocol (HTTP) connection with the server and uses a request and response mechanism to make the application server append values found in the data entry forms in ArcPad to the database. ASP scripts with request and response, as well as Structured Query Language (SQL) "INSERT" and "UPDATE" commands were written in JavaScript, using Open Database Connectivity (ODBC) code. The purpose for these ASP scripts was to receive parcel data from the field client and post them into database table. ODBC provides the connection between the server and the database (see figure 3).

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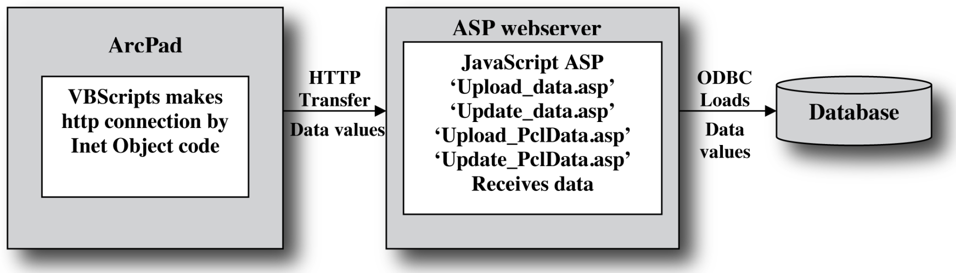

Fig. 3: Data transfer mechanism between field client, application server and database (Mensah-Okantey, 2007)

System functionality tests were carried out on all units of the system separately, as well as an integration test of the combined system, through which part of the existing cadastral map of part of Enschede was updated. Due to time and practical constraints, testing has not yet been done in a real world cadastral field data collection environment. Also missing are user acceptance and usability tests. This has been one of the factors in our decision to try to get a larger user community involved in the further development of our ideas, by means of the Mobile Cadastre Testbed.

5 Outlook: the Mobile Cadastre Testbed

The idea of this testbed is to present the prototype system as a 'best practice' example, and to make it available for experimentation and testing. On the testbed's website at `http://geoserver.itc.nl/mobilecad/`, people will be able to download the client components and test it against the publicly available server–side. This could also provide us with valuable user feedback, hopefully from real–world use cases.

To make the usefulness of the components as generic as possible, we plan to further develop the system to use open source components on both the client– and server–side and to make the system adhere to relevant open standards from the Open Geospatial Consortium (OGC). At the moment, the database tier is already using Open Source software (PostGIS), as well as complying to relevant Open Standards (Simple Features for SQL). Although the application server tier is running on proprietary software (Microsoft IIS and ASP scripting), the scripts themselves are written in JavaScript and thus can be easily deployed on other platforms. To enhance platform–independency as well as performance, we probably will port them in the near future to Java Server Pages running in the open source Apache Tomcat servlet engine. In the longer term, the use of OGC Web Feature Services will be considered. The ArcPad client application currently is fully proprietary. Changing this to a more open system will require a substantial effort, although at ITC we have some experience in this, using for example Scalable Vector Graphics to build applications on mobile devices (Latini & Köbben, 2005).

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All in all, we hope that the Mobile Cadastral Testbed will become a focal point in a user community interested in mobile cadastral data acquisition system in developing countries.

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