Designing A Prototype Mobile GIS to Support Cadastral Data Collection in Ghana

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Designing A Prototype Mobile GIS to Support Cadastral Data Collection in Ghana

by

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Abstract

With the development of Web GIS and subsequent emergence of Mobile GIS new possibilities of data capturing and maintenance of geographic information have also evolved. One of such geographic information that can benefit from this is Cadastral information. Cadastral data is different from other geographic data due to the fact of its spatial and non-spatial parts being transferable. As such frequent collection of new cadastral data and revision of old ones are very necessary for national advancement.

This study aimed at designing a system of mobile GIS suitable for gathering and revising a cadastral database. Ghana was used as the case study area. For that the cadastral business processes in Ghana was studied and user requirements gathered. Based on these user requirements object-oriented Unified Modeling Language (UML) in the form of activity diagrams, use case diagrams, class diagrams and sequence diagrams was employed to design models. Thereafter Mobile GIS components needed to be added and developed to enhance cadastral data gathering and also its maintenance were identified. A final conceptually designed model was proposed as the prototype. A two-clients and server architecture, user interfaces as well as reference data request were developed and implemented as the final physical prototype tailored for cadastral data collection and maintenance. In the implementation, user interfaces were developed in ArcPad Application Builder and deployed into ArcPad. The interfaces were structured to facilitate collection of cadastral data and transfer (insert and update) into PostgreSQL / PostGIS database management system (DBMS) on the ITC Geoserver (geoserver.itc.nl).

Keywords

Cadastral data, Cadastral database, Client-Server architecture, Field client, Office client, UML, Data transfer, Functionality test
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Dedicated to my wife, son and parents
Chapter 1

Introduction

1.1 Background

GIS applications and technological trends have over the past years seen a rapid advancement, and this has become so largely due to the emergence and the success of the World Wide Web. We have seen geoinformation technology emerging from mainframe computers to stand alone desktop computer GIS through to local networking GIS, to the Web GIS and now Mobile GIS where maps are displayed and processed on small mobile devices like Personal Digital Assistants (PDA) and Mobile Phones (Rajinder, 2004). Interoperability of spatial data means that supporting systems of web and mobile applications as well as the spatial data must be prepared to ensure that it can be transferred, shared, access, processed and updated (Vckovski, 1999) for rapid development.

With the emergence of mobile GIS new ways and possibilities of geoinformation data collection, processing, maintenance and dissemination are emerging. Web and digital maps which can be assessed and disseminated rapidly through the internet on Personal computers are popular but these maps are not mobile (Reichenbacher, 2001), largely due to the immobility of the Personal computers and also the wire nature of the internet technology involved for map transfer and sharing. Gone are the days where paper maps sometimes manually prepared following cartographic rules, are physically disseminated and handled in the field for revision and updates Wireless mobile GIS has this advantage over the wired internet GIS due to the fact that spatial information can be accessed and visualized anywhere for usage.

The mobile handheld devices may have their limitations like their small screen display, small bandwidth, colour resolution and its limited application capabilities, even though most are being overcome by improvements in their technol-
ogy (Vckovski, 1999). However spatial data collection, processing and dissemination of large amount of geographic data are becoming possible due to recent developments we have seen in internet and mobile GIS technology (Kraak, 2002).

Cadastral map data is very significant in every Land Information system in that it forms the bedrock upon which the system is based. Two types of data types constitute Cadastral data; the spatial or graphical representations that describe property parcels, and then the cadastral attribute or non-graphic data that gives additional information about the property parcels. The property parcels are defined sometimes by only boundaries or topologically closed polygons defined by lines known as property boundaries or by objects such as buildings in a 3D cadastre. The property boundaries consist of monumental corner points whose coordinates are determined and updated by cadastral surveying. The cadastral data might further include data like Public Land Survey records, political sub-division boundaries (i.e. city, town), ownership information (both public and private), and comprehensive plan and zoning district data.

Cadastral data are different from other data such as topographic data, land use data and civil registration data among others due to the fact that its spatial and non-spatial parts which can be transferred from one person to another has legal implications. As such their collection and updating are to be done in accordance with these legal constraints such as maintenance of topological relationships between parcels (Group, 1998), (Commitee, 2002). It demands high accuracies (Roberts, 2005) because of the fact that it is the bases for registering rights and ownerships with its accompanying legalities. Although requirements for geometric precision varies from one country to the other, it requires frequent updates and revisions as ownerships and their accompanying rights change from one person to the other and parcels sometimes has to be sub-divided or splitted, merged or new ones created. This is where mobile GIS, a new technology can be applied.

1.2 Problem statement

In Ghana, cadastral survey of land parcels is done by Land surveyors from Survey Department, the National Mapping Agency, and licensed surveyors while the attributes information of the mapped parcels are collected by the Land Title Registration office which is also the body responsible for registration of ownerships with their associated rights of the cadastral parcels. The two datasets are then finally integrated into one central database and maintained.

Increasing demands for cadastral information therefore requires that its data sets collection, maintenance and dissemination should be rapid and with some level of accuracy in order to enhance efficiency in land administration and satisfaction of landed property owners. Ghana in her quest to improve on her land delivery system is implementing a project known as the Land Administration Project. One of its objectives is efficient delivery of cadastral maps. As such the
database has to be regularly updated for changes. Some scenarios which justify proper online editing and updating procedures of cadastral datasets in a mobile internet setup are:

- When a cadastral surveyor collecting data of an area at a remote location, data uploading into office database before editing becomes difficult especially when longer periods will have to be spent in the field.
- Ownership and rights of cadastral parcels are always changing hands from one person to another through sales, lease and mortgages and so on. The database in the office has to be updated with the new changes such as sub-divisions, merging and creation of new ones.

The problem therefore is how the cadastral data can be collected and modeled for editing and updating into the database using mobile GIS technology.

1.3 Objectives

The main objective of this study is to "design a mobile GIS for collection and maintenance of cadastral data". The sub-objectives in order to realize this main objective are:

- To analyze approaches for online editing, updates and transfer process of cadastral data in a mobile GIS environment.
- To develop process models for editing, updating and online transfer over a mobile GIS network.
- To design and implement a prototype based on the proposed improvement methods, and then test for its effectiveness and usability.

1.4 Research questions

The research will be guided by the following questions:

1. What are the user requirements for the process of data collection, editing and updating a cadastral database within a mobile GIS setup?
2. What method can be employed to model the process mentioned in 1?
3. How can the model mentioned in 2 be implemented in a prototype system? This research question will include several technical sub-questions:
   - Which part of the functionality should be client-side and which part server-side?
1.5 Innovation aimed at

- How should client- and server-side be interfaced?
- What format should interfaces employ, and to what extent will that format affect online editing and updating capabilities?
- What update and editing techniques are available and how should they be modified for online editing and transfer.

4. How can the prototype cadastral data editing and updating system within a mobile GIS setup be demonstrated and by what criteria?

1.5 Innovation aimed at

Even though some amount of work has been done in the area of editing of databases in various fields, this research work will result into improved data editing and updating methods for cadastral purposes. The work should result in data being collected and fashioned in a way uniquely suited to cadastral data that will allow edits and mobile transfer.

1.6 Related work

Some relative amount of work has been done on data collection and maintenance in many fields within the framework of the mobile GIS technology. Brentjens (Brentjens, 2004) looked at updating capabilities in a distributed OpenGIS web Feature Service. However topology of geometric features was not taken into consideration in his work. Thompson (Thompson, 2002) focused on traffic data collection for travel time analysis by developing a prototype that integrated GPS and GIS technologies. Tsou (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. Real time spatial updates are done over wireless LAN. In (Vivoni and Camilli, 2003), the development of a prototype mobile GIS environmental field data collection system for two way transfer and display of collected data between field site and remote location server was highlighted. Finally Kang and Li (Kang and Li, 2005) presented a framework mechanism which deals with the maintenance of topological consistencies in updating a 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 cadastral data, modeling in map updating when it is being collected and what mobile GIS infrastructure it can fit. This is what this research proposes to do.
The research methods is mainly constituted into three phases which are Literature review, system modeling (comprising of business process modeling, spatial data transfer format analysis and designing prototype) and developing and testing of the prototype system.

The tasks tailored to answer the research questions are stated below each research question

1. What are the user requirements for the process of data collection, editing and updating a cadastral database within a mobile GIS setup?

Task 1: To answer this question I intend to do a thorough literature review of books and articles, and also to consult experts at the Dutch Kadaster here in the Netherlands on the subject. General user requirements knowledge as far as editing and updating cadastral database is concerned will be obtained from that. I also intend to consult experts in Ghana to know the user requirements in that environment.

2. What method can be used to model the processes mentioned in 1?
1.7. Methodology

Task 2: This question will be answered by looking at the various data modeling techniques and how well they will be suited for data editing and updates when the data is being remotely transferred within a mobile internet. Spatial and modeling techniques will be analyzed with respect to the following modeling characteristics: "Unified Modeling Language (UML)"

- 3. How can the model mentioned in 2 be implemented in a prototype system?

Task 3: Based on the proposed data collection and updating model proposed in 2, the model will now be physically designed and developed by accessing various functions and components for integration, to answer the question. This research question will include several technical sub-questions:

- 3a. Which part of the functionality should be client-side and which part server-side?

Task 3a: Editing and updating possibilities at both client and server sides will be assessed through literature review and the best option adopted, designed and developed. Technologies like thick and thin client processing will be assessed.

- 3b. How should client and server-side be interfaced?

Task 3b: This question will be addressed by assessing, designing and developing fitting client and/or server-side interfaces for uploads and downloads with respect to the cadastral data collecting and updating model proposed?

- 3c. What data transfer format should interface employ, and to what extent will that format affect online editing and updating capabilities?

Task 3c: Various data transfer format technologies will be addressed and the best suited for cadastral data online updating proposed. Criteria for proposing will be based on the flexibility in terms of online editing and updating.

- What update and editing techniques are available and how should they be modified for online editing and transfer?

Task 3d: Online editing and updating techniques in the light of the data transfer formats addresses in 3c such as Structured Query Language (SQL) commands and Geographic Markup Language (GML) will be assessed and developed to suite the model proposed in 2.

- 4. How can the cadastral data editing and updating within a mobile GIS setup be demonstrated and by what criteria?
Chapter 1. Introduction

Task 4. This question will be answered by performing a usability test based on answers provided in the previous questions, to evaluate usefulness of the system. The criteria for the testing will be based on the functionality and effectiveness of the online editing and updating capabilities of the system. (Fall, 2004).

1.7.1 Literature review

The purpose of literature review is to obtain the theoretical foundations that would be required for the research. It will be as follows:

1. The concepts of GIS, internet and mobile GIS technologies,

2. System modeling by the object-oriented software engineering concept. This concept is adopted for the design and prototype of the cadastral mobile GIS system and the reasons being that

   • Objected-oriented modeling always lend itself for support by way of tools which is one of its biggest advantages (Damm et al., 2000). This renders the possibility of being able to understand and formulate the problem domain of the system to be built.
   
   • The prospective users of the system must be satisfied hence their desires and the way the want the system to behave must be considered in the designing of the system, which object-oriented modeling does in user requirements in sorting the views of the users.
   
   • To guarantee to some extent the quality of the system, Object orient-ed engineering ensures that the modeling and design process is completed before the implementation. This ensures that all necessary difficulties are recognized and corrected before implementation.

1.7.2 System modeling, design and development

The system modeling aspect involves user requirement analysis, process modeling, analysis and the designing conceptual system. User requirements study provides inputs into the system modeling. Iteration operations are enforced till a refined system is achieved. Thereafter the static characteristics of process would be modeled using use case, class and sequence models.

1.8 Thesis structure

The thesis contains six chapters namely: introduction as chapter 1; literature review of internet and mobile GIS technologies and system design process as chapter 2; cadastral systems and cadastral mapping in Ghana as chapter 3; modeling,
design and development of prototype mobile GIS for cadastral data acquisition and maintenance as chapter 4; implementation and testing as chapter 5, and finally conclusions and recommendations as chapter 6.

Chapter 1 elaborates on the research background as well as the research objectives, research questions, and the methodology.

Chapter 2 gives a presentation on the concepts of internet and mobile GIS technologies. These concepts are relevant to the modeling and design of the mobile GIS system proposed. System design concepts are as well discussed in this chapter.

Chapter 3 explains the current cadastral system and cadastral surveying and mapping within the case study area Ghana. It also discusses the problems within the cadastral surveying and mapping domain and the need for the use of mobile GIS as a solution.

Chapter 4 analyzes the user requirements, business processes involved in the modeling and designing of the prototype mobile GIS for the cadastral data collection and maintenance, as well as the data transfer process.

Chapter 5 describes the development, implementation and testing of the design of the system. A mobile GIS architecture and interfaces of the system are established and the prototype is developed and tested.

Chapter 6 gives the conclusions and recommendation as regards to overview of research questions and also further future research work.
Chapter 2

Literature Review: mobile GIS technology, system development process

2.1 Introduction

Our world is dynamic and users of geographic information such as cadastral data are demanding timely provision of such data. It is therefore incumbent upon the information providers to look into their business processes of data collection and updating, and explore new ways of rapid and efficient acquisition of such data within the environment of the new emerging technologies. Over the past years a number of technologies such as Geographic Information System (GIS), Global Positioning System (GPS), the Internet, wireless communication and portable computing solutions have changed the way data is collected and managed. These technologies which hitherto and even still, are used individually have now been converged to what is now known as mobile GIS (Tang and Selwood, 2003). This has brought possibilities of rapid and efficient data collection and updating.

The objective of this chapter is to review the concepts of GIS, internet GIS as well as mobile GIS. Comparison between mobile GIS and traditional GIS technologies are also presented with focus on cadastral data collection and updating. The chapter will also review some system design and development paradigms and propose the best for this research.

2.2 Concepts of Geographic information system

Geographic information system (GIS) can be looked at as an information system that is used to retrieve, manipulate, store and analyze geographic information for decision making, or as Cowen (Cowen, 1988) puts it, it is "a decision sup-
2.3 Concepts of Internet GIS

The internet is described as a worldwide telecommunication network (Peng and Tsou, 2003). The demand for geographic data access and transfer necessitated the integration together the technologies of the internet and GIS to what is known as internet GIS. As described by Peng and Tsou (Peng and Tsou, 2003), "internet GIS is the framework of network-GIS that utilizes the Internet to access remote geographic information and geoprocessing tool”

Internet GIS data assessing and transfer developed from the usage of mainframe computers to desktop computers and to the internet as shown in Figure 2.1. Users can receive and send data by the use of the internet. Previously, one has to install GIS software on a computer system before being able to process geographic data. Now internet GIS development is gradually moving towards distributed GIS where it is no more necessary to buy and install GIS software and tool for GI processing but one can have access to them through a distributed system.
2.3.1 Internet GIS architecture

The architectural components of internet GIS vary according to the demand and specific area of application and the problem it is intended to solve. Generally the components are made up of the client, the server and the wired internet communication network. The client normally comprises of a desktop or laptop with a web browser interface for presenting, requesting, accessing and transferring data to the server which then performs processes and analysis of data and generate output. The wired internet provides the platform for the communication between the client and the server by the use of TCP/IP and HTTP protocols (Figure 2.2), or other standard protocols which provides the standards for communication.

![Diagram of Generic internet GIS architecture](image)

**Figure 2.2: Generic internet GIS architecture**

2.3.2 Thin and thick client-server architecture

The architecture of an internet GIS can be of a thin or thick client-server depending on the area of application for which the system is being designed. Thin client-server architecture is a situation where the client has limited applications, and processing capabilities and activities reside in the server. The client can only access and view the data. Some obvious advantages of thin client-server are the less bandwidth needed for data transfer and less processing power of client devices.

For the thick client architecture on the other hand the client device is embedded with GIS applications for data processing. Geographic data is only retrieved from the server by the client. Some advantages are the low level performance requirement of the server resulting in less server load, quicker response time and being able to be assessed by more clients at the same time.
2.3. Concepts of Internet GIS

2.3.3 Further client-server architecture issues

The elements of client-server architecture are further explained here to present the concept of client-server architecture used in this research. The concepts in this section are derived from (Peng and Tsou, 2003)

The client-server architecture system is partitioned into three functional elements namely Presentation; which is the user interface functionality which includes inputs and outputs, Logic; which is the processing functionality and Data; which is the database management system. These functional elements when assigned to a client and a server computers make the architecture range from very thin to very thick.

- Distributed presentation: A very thin client-server architecture in which the client device has only the responsibility to present (interface) the infor-
Chapter 2. Literature Review: mobile GIS technology, system development process

...mation while the server is responsible for processing (logic) and managing the database (data) (Figure 2.5).

- Distributed function: In this architecture the processing element is divided between the client and server (Figure 2.6). Some amounts of processing functions are done by the client while the server performs the greater and powerful part of the processing and also managing the DBMS.

- Remote data access: The presentation and processing are completely the functions perform by the client while the server only handles the DBMS. The client-server architecture here is thick (Figure 2.7). Example, GeoMedia Enterprise in internet GIS is able to access remote data from a data server.

- Distributed database: the DBMS functionality is divided between the client and the server, while the client performs presentation and processing functions as well (Figure 2.8). In this case architecture is very thick. Example is a feature server in ArcIMS which is able to stream vector data to client.

- Tier structure: The partitioned functional elements are concerned with the logical part of the system while the tier structure is concerned with the of physical hardware arrangement system for which the functional elements are located. For instance architecture is two-tier if it involves hardware/software client that does the presentation and one hardware/software server responsible for processing and data management. On the other hand, a architecture is three-tier if it involves a client device with presentation software and either two hardware systems each with a server software for processing and data management respectively, or one hardware system but with two server software each performing processing and data management functions. Figure 2.9(a) is a three tier architecture both physically and logically while (b) is physically two-tier but logically it is three-tier.

![Partitioning point of distributed presentation](image1)

*Figure 2.5: Partitioning point of distributed presentation. (Source: (Peng and Tsou, 2003))*

![Distributed function partitioning point](image2)

*Figure 2.6: Distributed function partitioning point. (Source: (Peng and Tsou, 2003))*
2.4 Concepts of Mobile GIS

The concepts explained in this section are relevant in the design and development of the mobile GIS model for this research.

Mobile GIS is a recent technology that extends from wired internet GIS see Figure 2.5. It was not until the 1980s that the advancement in Global Positioning Technology (GPS) and wireless communication inspired its research and development, which has offered new dimension to the use of geographic information system. Mobile GIS as Peng and Tsou (Peng and Tsou, 2003) put it, "is the GIS through the use of wireless devices such as laptop computers, PDA and cellular phone". Also Tsou (?) defines it as "an integrated software/hardware framework for the access of geospatial data and services through mobile devices via wire line or wireless network”.

2.4.1 Mobile GIS architecture

Its main architecture is similar to internet GIS except that its communication network between client and server is wireless. The client side components are
the mobile client (laptop computer or PDA or mobile phone), a mobile GIS software or browser depending on whether the architecture is thin or thick and a Global Position System (GPS) attached to the mobile client, while the server side components are generally made up of one or more GIS software and one or more different databases. A wireless communication network ensures communication between the client and the server for data uploads and downloads, or information requests and responses (Figure 2.6). Recent development of the GPS technology has resulted in precise location information for use within the mobile GIS environment.

2.4.2 Role of GPS in mobile GIS

Global Positioning System (GPS) has revolutionized GIS in the wake of increase in demand for real-time location and field-based information. It is a positioning system whose working principle is that signals are received by a GPS receiver from four or more satellites whose positions are known. The receiver then com-
2.4. Concepts of Mobile GIS

Computes its geographic position of the location of the receiver knowing the travel time of signal transmission and the satellite positions. It is one of the components of mobile GIS and it is used in two different applications:

- Location-based service (LBS) application provides GIS and spatial information via mobile and field units. With the use of GPS the wireless network system locates the client to which the spatial location information is to be provided. An example is route finding or location of a hospital.

- Field-based application in which the GPS is used as a spatial data collection tool for field collection of spatial and attribute data of geographic entity. The use of GPS for cadastral data gathering and transfer is a field-base application.

2.4.3 Wireless communication in mobile GIS

Wireless communication is a major component of mobile GIS. This section discusses some of the technologies that make up wireless communication with focus on the data transfer in a client-server mobile GIS environment.

Wireless communication simply in mobile GIS means transmission of signals embedded with geographic information between portable mobile client-server or vice versa over invisible radio waves, microwave, infrared or laser. The technology can be organized under four networks namely: Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN) and Wireless Wide Area Network (WWAN). The general summary of various characteristics of these networks are given in the table below:

2.4.4 Data transfer formats standards in mobile GIS

Data exchange between client-server and vice versa has been promoted by development of data formats standards especially now in the face of the large bandwidth and consequently fast data transfer rate that the wire and wireless internet has brought. The Open Geospatial Consortium (OGC) develops standards to ensure interoperability between clients and server (OGC, 1998).

Geographic Markup Language (GML): GML is one of the many extensional applications of XML purposely designed to structure geographic information data for transfer between client-server internet and mobile GIS environment. It enables accurate structuring and coding of complex vector models of the real world (Tsoulos, 2006) such line points, lines, polygons and geographic coordinate systems.

Structured Query Language (SQL): SQL is a standard computer language used to retrieve, update and delete data from a database. It has been standardized by
Table 2.1: Characteristics of Wireless networks (Source: (Quinn et al., 2005))

<table>
<thead>
<tr>
<th>Network</th>
<th>Example of Technology</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| WPAN    | Bluetooth             | - High data transfer rate  
          |                       | - Has a short range (10m)  
          |                       | - Low power consumption  
          |                       | - Communicate between devices within the operating space  
          |                       | - Small networks      |
| WLAN    | WiFi                  | - Higher data transfer rate  
          |                       | - Has a short range (10m)  
          |                       | - Low power consumption  
          |                       | - Communicate between devices within the operating space  
          |                       | - Small networks      |
| WMAN    | WiMax                 | - Covers large geographic area (kilometers)  
          |                       | - High power consumption  
          |                       | - Frequency is 2–11 GHz  
          |                       | - Higher bandwidth than WiFi meaning more data transfer  
          |                       | - Higher data transfer rate    |
| WWAN    | GSM, CDMA             | - Global network  
          |                       | - Communicates between devices  
          |                       | - Faster data transfer rate  
          |                       | - Battery power depends on the device but typically limited to a day of normal work      |

by the American National Standards Intitutes (ANSI) and International Standards Organization (ISO).

### 2.5 System design and development Process

Many system design and development schemes and methodologies have been proposed and applied especially in the area of software designing and engineering. It has been discovered that the concepts of system design is as well applicable in the designing of any system aside software designing domain (which has its origin) and has been used extensively in those areas. This section discusses the concepts of system designs and development and provides an overview of some system design and development models available, their advantages and weaknesses and thereafter the best design model that can be employed for the design of the mobile GIS cadastral data and maintenance system.

Some definitions regarding system designing are given below to explain the con-
cepts used in this research. These definitions are derived from (Morales, 2004):

- A System is the collection of independent artifacts that interact and form a coherent entity that performs a function that is unachievable by any of the artifacts in isolation.

- System development process involves the activities that a designer follows to transfer and transform a set of customer requirements into a system.

- System abstraction is the process of selecting and representing some aspects of the system that are relevant at a particular phase of the process and ignoring other details that are also needed but irrelevant at that phase of the process. System abstraction is the process of selecting and representing some aspects of the system that are relevant at a particular phase of the process and ignoring other details that are also needed but irrelevant at that phase of the process.

- System model is the output model obtained from the selection and representation of the relevant aspects of the system. In other words, it is the result of the abstraction process.

Adding to the above definitions, Egan (Egan, 2003) also describes design system as a process whereby a set of functional activities, their specifications and interactions are conceptualized so as to produce the required system performance. Yodor (Yodor, 1997) described that as a logical sequence of major steps. The processes and methodologies in system design have been made in order to assist designers deal with the complications that may arise during the process of
design. Designing an effective and quality system depends on the many factors such as the type of design model employed and also the point of views of users and managers of the system. While managers are keen on defining activities and making sure that the project is executed and final product ready for usage, the system user’s viewpoint is that it would render flexibility, effectiveness and user friendliness. The system designer therefore has to take these viewpoints into consideration in designing and developing the system.

2.6 Design and development models

Several design and development models have been proposed and applied in many areas. A few of them such as the Waterfall model, the Incremental model and the Object-oriented model are reviewed in this sub-section

2.6.1 Waterfall model

This is the oldest traditional model most widely used by system developers in the early stages of system design and development. Its developmental phases are generally made of the requirements, design, specification, implementation and testing phases (see Figure 2.14). Its unique characteristic is the sequential flow of phases of development in which one phase only begins at the endpoint of the previous phase. One other characteristic also is the assumption that user requirements are known and well understood already from the beginning and do not change through the design and development process.

In spite of the fact that it provides a template for designing and development, its unchanged user requirements through the development process flaws its usage. Often it resulted into systems that do not meet the users’ requirements and because it takes so long to build there is always a change in requirement by the time the system is complete rendering it unusable.
2.6. Design and development models

2.6.2 Iterative and incremental model

Due to the setbacks of the waterfall development process and essentially the fact that by the time the system becomes complete users' needs has changed, early designers decided to add new methodologies to enhance its efficiency by iterating the developmental phases in a continues manner till the system is refined. The iterative and incremental model as Larman and Kruchten in (Larman and Kruchten, 2002) put it, is "a development model based on the successive enlargement and refinement of a system through multiple iterations, with cyclic feedback and adaptation as core drivers to converge upon a suitable system. The system grows incrementally over time, iteration by iteration". This implies that the iteration goes through small incremental process till the system is refined. That defines iteration as the repetitiveness of the process and incremental as the growth of the functionalities from a less complex to a more complex one.
Chapter 2. Literature Review: mobile GIS technology, system development process

The iterative and incremental model also means that there is a cyclic development of the functional versions which are repeated until all the functions are fully refined and developed. The user is allowed to provide a feedback during a development cycle.

2.6.3 Object-oriented model

Object-oriented modeling is extensively employed in software application development and the development of other systems. Its flexibility and dynamic nature renders it one of the most used system development models in many applications. It is seen by (Damm et al., 2000) as a development process which essentially provides a conceptual framework that render good understanding of system development and modeling. It is also defined in (Zhao, 2002) as a "system whose basic structuring is around things rather than around actions". In object-oriented approach, there is the abstract focus which is on the analysis and design process and the main focus which is on the identification of the processes and who accomplishes them (Mwakapuja, 2003).

The object-oriented approach has the object as its basic element. Objects are the things or entities that we see around us or those can be conceptualized. Houses, organizations, software, machines and even events are all examples of objects. All objects has attributes that describes them. These attributes are said to be the 'state' of the object and this provides information about the objects. Objects themselves are static but their states or activities within them change. The state can be passive; i.e. when it does not change (static) unless coerced to do so or active; i.e. if the object can change their own state.

Some definitions of important terms employed in object-oriented modeling derived from (Zhao, 2002) are given below:

![Diagram](image-url)
2.6. Design and development models

• A Class is a category of structurally similar items grouped together with similar attributes and behaviors. That is within the bigger entity we call object there are sub-entities which have similar and specific patterns and these are what is referred to as classes. An object can therefore be defined as an instance of classes.

• An Attribute is the property that describes the state of an object

• An Operation is a function or transformation applicable to objects of a class and objects of other classes.

• An Interface is a collection of operations that a class(s) or an object(s) execute(s) out linking one to the other. It is the point of entry where users of the system implement objects and classes in the system without knowing how they work. It is only the designer of the system who knows the internal construction and implementation.

• Aggregation is the process where two or more objects are brought together to create new objects. That is an object can be composed of two or more objects.

• Generalization is the case where one object obtains the characteristics of another object. For instance a building is a generalization of a bungalow and a flat. All the characteristics of the building are inherited by the bungalow and the flat.

• Object Coupling gives a measure of the logical relationship between the objects or the classes. It gives a description of the connection among the objects or the classes within the system. High coupling ensures strong relationship while low coupling means the objects or classes within the system are somehow independent.

• Cohesion is a measure of the related responsibilities among classes. High cohesion means that the responsibilities are concerned with one particular functionality and the vice versa is low cohesion.

• Encapsulation is a situation where data models and operational functionalities are embodied in objects and classes forming modules. This is one of the strongest advantages on object-oriented approach to system development.

Even though the object-oriented approach goes through the processes as shown in Figure 2.13, its main focus is the analysis and design phases, where models at different levels of details are created. Major tasks executed in the object-oriented approach as stated by (Fall, 2004) are as follows:

• User requirements gathering

• Description of scenarios “Identification of candidate domain of objects, their meanings and responsibilities
• Establishment of relationship between the objects
• Process iteration
• Relationship definition defining
• Identification of existing or previous implemented objects
• Refinement of objects to determine their internal structure
• Iteration

2.6.4 Comparison between modeling approaches

By far the object-oriented approach stands out among the others due to its concept of objects and classes. We see and interact with objects around us and we naturally categorize them into meaning knowledge. For instance we can look at a town as a concept of districts within which there are land sections, parcels and lots. This idea of natural categorization of objects is all that object-oriented modeling is about.

Other system modeling development methods lack the concept of Encapsulation. Encapsulation by objects renders implementational functionalities to be modeled into modules allowing reuse of any existing part of the system and making it flexible. There is also the lack of modeling tools in other modeling methods which are available in the object-oriented method, rendering it supportive to modeling.

In other modeling methods the overall system is hard to maintain due to the fact that their concepts are mixed up and not straight forward. General benefits of objected-oriented system development approach are captured as follows:

• Objected-oriented modeling always lend itself for support by way of tools which is one of its biggest advantages (Damm et al., 2000). This renders the possibility of being able to understand and formulate the problem domain of the system to be built.

• The prospective users of the system must be satisfied hence their desires and the way they want the system to behave must be considered in the designing of the system, which object-oriented modeling does in user requirements in sorting the views of the users.

• To guarantee to some extent the quality of the system, Object-oriented approach ensures that the modeling and design process is completed before the implementation. This ensures that all necessary difficulties are recognized and corrected before implementation.

The disadvantage of object-oriented approach is that it takes a number of models to express the state of the objects (i.e. the static state by class diagrams, the dynamic state by activity diagrams and the behaviour state by use case diagrams) but this has been taken care of by the effective tools that UML provides.
The above benefits discussed however lead to a system which is able to organize data effectively and efficiently and can easily adjust to changing requirements of users.

A mobile GIS for data cadastral collection system needs to be flexible, efficient and maintainable and it should also be supportive by of object identification, (for instance parcel ID). Object-oriented approach provides these elements to system development and therefore would be employed for the system development process in this research.

### 2.6.5 Use of Unified Modeling Language (UML) for system modeling

Due to the increase in the employment of object-orientation in system development, a lot of object-oriented methods emerged. To create a common platform and to end the different uniformity of this method of system development UML was developed. UML is simply a language for modeling objects. It provides a standard notation for modeling and design, and it ensures ease of communication between designer and users (Zhao, 2002). As an important part of the object-oriented development process, UML is used as a standard graphical notation to create, visualize and document abstract models of a system. It is extensible, meaning that it lends itself for customization, and provides an expressive modeling language. The main reason for employing UML in this research is that the analysis and design models can directly be implemented with the same modeling method (Mwakapuja, 2003).

There are many diagrams associated with UML, some of which are relevant for the developments of the system in this research are discussed below.

#### Use case diagram

Used cases are mechanisms developed for user requirements gathering and analysis. They are the basis upon which the system reacts with external forces which are the users, other systems and other factors. They are the point of view of the users with respect to the system and how they interact with it described in text form. The graphic representation of these interactions between the users (actors) and the system is known as the use case diagram (Figure 2.17).

#### Class diagram

The class diagram models the static structure of the system. Static; in the sense that it does not describe the dynamics nature of the system. In other words it does not describe the temporal behaviour of the system. They are mainly constructed as classes and their relationships with one another. Properties and
operations of a class as well as constraints on how objects are connected are shown on class diagrams. Generalization and aggregation (defined in sub-section 2.6.3) are some of the relationships between the classes. They are constructed in compartments namely: names, attributes and operations (Figure 2.18)

![Figure 2.18: Class diagram showing relationship. (Source: (Mwakapuja, 2003))](image)

**Activity diagram**

Activities are set of actions executed to cause to bring results or course a change in the system. Activity diagrams show the workflow activities in the system. They are graphical flowcharts essentially used to describe the various activities that are performed in a process. Just as use cases diagrams model system’s static structure and portray the interactions of objects or classes in the system, activity diagrams model the dynamic structure and portray the activity or action flow within the system (Papajiojorgi and Pardalos, 2005).

Activity diagram normally begins with a start state which is represented by a solid filled rounded bullet, arrows representing the transfer from activity to activity represented by rounded rectangles and ends an end state again repre-
2.6. Design and development models

presented by a solid filled rounded bullet surrounded with a ring. Decisions are shown by diamond symbols and concurrent activities are represented by solid filled rectangles (Figure 2.19).

![Activity Diagram](image)

Figure 2.19: Example of an activity diagram.

**Sequence diagram**

Sequence diagram shows how objects within a system communicate or interact with each other and in the order the interaction is occurring. Figure 2-20 is an example of a sequence diagram.

**Analysis and design of mobile GIS system with UML**

To recall, it is observed that all system design methods one way or the other run through the phases of analysis, design, testing and implementation. What object-oriented analysis sought to do is to analyze requirements from user about the mobile GIS data collection system while design provides design solutions.
Object-oriented use case, class and activity diagrams are the key modeling tools to be used.

In the analysis stage of the development of the mobile GIS system, use cases would be developed in the extraction of the requirements from main players in the cadastral data collection and maintenance domain and modeled with use case diagrams.

Various objects and classes and the relationships between each other would then be identified and modeled using class diagrams to design the system. Activities of players or actors like surveyors who will be using the system and cadastral organizations would be modeled with activity diagrams. An overall design of the mobile GIS system for the cadastral data collection and maintenance would be achieved by the integration of these models.

Interface is the user’s point of interaction with the system. Its design would therefore be in accordance with the user’s requirements and also based on user interface principles such as simple dialogues and screen layouts to ensure user friendliness.

2.7 Conclusion: why mobile GIS for cadastral field data collection

It is very common that data needed for field work, like an existing base map or controls network data, has to be pre-downloaded unto a field device hardisk...
memory. This poses a problem especially because spatial and graphical data require bigger memory capacity (Rudrappa, 2003). This is solved when field workers download data needed to be used in the fieldwork and upload the cadastral data collected on the field in real-time. Again conventionally cadastral data collected in the field is manually uploaded later after the data has been collected before validation is done later. No real-time connection exist for transfer of data to be made readily available in the database for users (Peng and Tsou, 2003).

The following are is a list of some advantages of mobile GIS for cadastral data collection and also for the maintenance of the data:

- Cadastral data can be collected, updated and validated real-time right in the field to ensure removal of errors.
- Field edits can be performed.
- Data collected and updated data can be made available for other uses and applications through the wireless communication.
- Time-critical field work such as dispute cases where composite plans prepared from cadastral data are needed for quick adjudication can be executed with a mobile GIS.

However, there are disadvantages that are associated with mobile GIS. Below are highlights of some of them:

- Spatial data presentation limitation due to small screen of client mobile device
- Smaller memory capacity of client mobile device.
- Low processing power of client mobile device.
- Low battery power of client mobile device.
- Slow spatial data transmission due to low bandwidth.

### 2.8 Chapter summary

To summarize, this chapter explained the basic technologies and concepts to be employed for the development of mobile GIS system. These include internet and mobile GIS technologies and their architectural setups, data transfer format which are essential in transporting data from client to server and vice versa. Wireless technology was as well discussed. The chapter also took an overview of system design and development processes and models and raised the need for the employment of the object-oriented approach for the design and development of the mobile GIS for cadastral data collection and maintenance system to be designed in this research. Lastly in its conclusion, it justified the need for use of mobile GIS in collecting cadastral data and maintaining it.
# Chapter 2. Literature Review: mobile GIS technology, system development process

## Table 2.2: Comparing advantages and disadvantages of the different models

<table>
<thead>
<tr>
<th>Type of design and development model</th>
<th>Characteristics</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waterfall</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear development phases</td>
<td></td>
<td>Allows testing at every stage</td>
<td>Assumes user requirements do not change</td>
</tr>
<tr>
<td>Unchanged user requirements</td>
<td></td>
<td>Checking at every stage enforce discipline</td>
<td>Problem of redesign</td>
</tr>
<tr>
<td>No feedback between phases</td>
<td></td>
<td>Allows good track of progress</td>
<td></td>
</tr>
<tr>
<td>One phase begins when another phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Iterative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phases are executed in incremental manner</td>
<td>Ensures up-to-date information gathering</td>
<td>Difficult to define deliverables</td>
<td></td>
</tr>
<tr>
<td>Every iteration goes through the development phases</td>
<td>Ensures correctness of information by verification</td>
<td>Difficult to manage</td>
<td></td>
</tr>
<tr>
<td>Additional functionalities considered as new iterations are performed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Object-oriented</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Based on objects as basic entities</td>
<td></td>
<td>Provide flexible and efficient tools</td>
<td>Requires a number of models to express object</td>
</tr>
<tr>
<td>Encapsulation property</td>
<td></td>
<td>Easy maintenance of model</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability of tools to support modeling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reusability due to encapsulation</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 3

Cadastral system and cadastral mapping, the Ghana case

3.1 Introduction

Having reviewed the concepts of internet and mobile GIS and have also suggested object-oriented development process of modeling as the design paradigm for the design of the cadastral data collection and maintenance system, this chapter discusses the general cadastral system in Ghana with particularly focus on cadastral spatial data collection and maintenance. In Ghana, Land administration in general and cadastral system in particular involves land institutions such as the offices of the Land Title Registry (LTR), Lands Commission (LT) and Department of Town and Country Planning (TCP) (Figure 3.1). All these institutions are under the umbrella of Ministry of Land, Forestry and Mining except LTP. The chapter will briefly discuss the activities of these institutions but the focus will much more be on the activities of Survey Department since it is the national mapping agency responsible for production and maintenance of spatially referenced cadastral data. It is also intended to discuss the current cadastral data acquisition processes and techniques, highlight on some of the problems and put forward the benefits that can be obtained in the use of mobile GIS in cadastral business processes with respect to data acquisition and maintenance.

3.1.1 Case study area-Ghana

The area under study for this research is Ghana, a country in West Africa. It lies between latitude 4° 44’ N and 11° 11’ N and longitude 3° 06’ W and 4° 44’ E. Administratively, the country has been subdivided into 10 regions (Figure 3.2) and the regions have also been subdivided into a total of 138 districts. For
cadastral mapping purposes, the districts have again been subdivided into sections to allow cadastral data collection and mapping to be executed section by section. 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 which have not been covered with cadastral map yet, sporadic cadastral surveys are being carried out occasionally for provisional registration upon application by parcel owners. This therefore implies that cadastral data collection, mapping, creation and maintenance of databases for many more regions are yet to be done.
Chapter 3. Cadastral system and cadastral mapping, the Ghana case

3.2 Land registration in Ghana

After independence in 1957, two laws were passed to regulate the administration and transactions of land in the Ghana. These are the Registry Act 122 and the Survey Act 127. However it was not until recently that major weaknesses were detected in the Land Registry Act which did not allow it to yield the expected result. Most important among them is the fact that only instruments (legal document) were registered with the absence of maps of sufficient scientific accuracy to enable parcels of land to be identified and their boundaries ascertained. The result of this is multiple claims of land ownership and rampant litigations because of the fact that there were no documentary proofs by way of title to ownership of a particular well described parcel.

The Survey Act fashioned to serve the Registry Act also contributed in making the Registry Act ineffective. This is because it allowed two sets of cadastral records to be created; one certified by a licensed surveyor without approval by the chief survey officer, called Certified Plan and the other certified by a licensed surveyor with approval by the chief survey officer. The effect of this is the fact that plans certified by licensed surveyors are most of the time not accurate due to the fact of improper survey and tracing from small scale topographic maps (Fosu and Derby, 2006).

It is against this background and couple with the fact that parcel-based title registration is seen as one of the best form of land registration (Williamson, 1981), that in 1986 the Land Title Registration law was established to allow certified maps approved by the chief survey officer alone to be attached to instruments for registration to achieve its main objective of giving proof of certainty of title to ownership. This therefore means that cadastral maps are done with sufficient positional accuracy to forestall dispute of boundaries (Fosu and Derby, 2006).

3.3 Organizations involved in Land Administration

3.3.1 Ministry of Land Forestry and Mining (MLFM)

As far as cadastral system is concerned under the Land Administration Project (LAP) sub-sector, all land agencies are managed under the MLFM except Department of Town and Country Planning which is administratively under the Ministry of Environment Science and Technology. MLFM is the body responsible for the formulation of policies, monitoring and evaluation of the performance of the land sector and the impact of land policies and development efforts in the country.

Its vision and mission within the land domain is to ensure that land is sustainably managed and utilized to ensure socio-economic growth and development, and this is to be achieved through efficient policy formulation and implemen-
3.3. Organizations involved in Land Administration

tation, and through an efficient land delivery system. As such its aim among others as far as land is concerned are to develop and manage sustainable land to develop and maintained effective institutional capacity for land delivery service to review, update, harmonize existing legislations and policies affecting land. These responsibilities on the shoulders of the MLFM are carried out by the land institutions mentioned earlier and whose individual mandate is discussed further on.

Under the current Land title registration law the minister in consultation with the Chief Registrar of the Land Title Registry and the Director of Survey of the Survey Department has the mandate to declare districts to be demarcated and surveyed for title registration. When this is done, the way is then paved for cadastral data collection of that area and for subsequent creation of cadastral layers into the central cadastral database for the title registration.

3.3.2 Town and Country Planning department (TCP)

Town and Country Planning is administratively not under the land sector ministry but has been included as one of the land agencies due to the role it plays as far as cadastral mapping is concerned. It is basically charged with the duty of preparing land use layout schemes drawn on large scale topographic maps prepared by the national mapping agency or a licensed surveyor, for area planning. Demarcation and cadastral survey of the boundaries as shown on the scheme is executed by cadastral surveyors on the ground based on the layout scheme (Fosu and Derby, 2006).

3.3.3 Lands Commission Secretariat

Land commission was established under Land registry Act 122, and essentially charged with the responsibility among many others, to register deeds of instruments in order to record the sequence of property history. It is also responsible for administering lands acquired by the state. Currently, Land Commission executes Deeds registration which is running concurrently with the new Land Title registration. It is not directly involved in cadastral data collection but rather request clients registering their documents, to have the lands involved spatially referenced and described on cadastral plans certified by a licensed surveyor. These are to be attached to their deeds documents before registration can be take effect. Land Commission is therefore a service provider, a responsibility which it does by the use of cadastral data.
3.3.4 Land Title Registry (LTR)

LTR was established when the need for a new system of registration was seen after difficulties of the Deeds system of registration were realized. The essential part of this system is that title and interest to land are registered instead of the registration of only deeds documents as in the case of the earlier form of registration. Its purpose is in two fold; first to give certainty and facilitate proof of title and secondly to prevent fraudulent deals in land (Sittie, 2006). Land parcellation from cadastral survey is the key element in this type of registration.

To register a title to a parcel of land, the land must be properly surveyed with sufficient accuracy and spatially referenced showing the extent and the area and also duly approved by the chief survey officer. This implies that LTR is not directly into cadastral survey and field data collection but are involved in maintaining cadastral spatial and non-spatial data for the purpose of title registration.

3.3.5 Survey Department (SD)

The Survey Department of Ghana headed by the Director of Survey is regulated by the Survey Act 127. It is the national mapping agency mandated by law for the provision of all geographic information in Ghana, and it is at the centre of land administration in the country. Its mandate includes cadastral, geodetic and topographic surveying as well as maintenance of geographic databases such as national geodetic controls, both horizontal and vertical; topographic and cadastral databases (Arko-Adjei, 2001). Demarcation of layout schemes prepared by town and country planning before executing a cadastral survey is another task of the department. Its other responsibility is to regulate all survey activities by any other survey organizations or by licensed surveyors. This is done by regularly checking surveys and cadastral mapping executed by licensed surveys and also setting survey standards by which surveyors would abide. It is also responsible for licensing and revoking licenses of surveyors.

Survey Department has a central head office where the Director of Surveys operates from and he is currently represented in all regional offices by regional surveyors who are also represented in the districts by the district surveyors. It is intended under the land title law to decentralize the cadastral system to the district level but currently that has not been achieved in its entirety. It is currently functionally organized into five sections which coordinate together in map production including cadastral maps (Figure 3.3), as described below:

- The Head office where the Director of surveys and deputies are located. It is where the day to day administration of the department is run from
- The Examination and computing section is where all national mapping records and cadastral records are checked and archived. The checking is to
make sure that their quality is acceptable and within the national mapping standards. This also where surveyors engaging in cadastral data collection from the field are.

- Digital mapping section is responsible for the digital plotting and the creation of databases of all geographic data. These databases are used as data source for creation of plans and maps such as cadastral maps and plans.

- Cartographic section is responsible for drawing maps and plans. They also check all maps and plans to make sure that they are drawn according to national and international cartographic rules and standards.

- Photogrammetry section is responsible for map production by the use of aerial photographs. Currently it is engaged in producing orthophotos for cadastral map preparation.

Figure 3.3: Functional structure of Survey Department

3.4 Cadastral data collection and maintenance

Under the current land titling system of registration which is parcel-based, Survey Department plays a pivotal role as it is the provider of cadastral database needed for registration. As such it is the body that engages in cadastral data collection and maintenance either directly or sublet the collection part on contract to licensed surveyors but with Survey Department’s supervision. Therefore Survey Department works hand-in-hand with LTR in the process of land title registration delivery to the public.
Chapter 3. Cadastral system and cadastral mapping, the Ghana case

3.5 Methods of cadastral data collection

In this subsection some of the techniques employed for cadastral data collection are discussed. These are digitizing from existing large scale maps for areas which have already been surveyed, the use of Total stations, GPS or Aerial Photographs for areas which have not been surveyed and therefore do not have existing maps

3.5.1 Digitizing from existing maps

Digitization is a process of converting a map from a hardcopy format into a digital format so that the data can be stored and manipulated on a computer. Some areas have already been surveyed and therefore large-scale topographic maps exist for those areas. In such cases boundaries of area and parcels within can be digitize into the cadastral database with unique identifications. The only field data collection required in this case is when there is the need for updating.

3.5.2 Ground Survey method by Total Station

Total station instruments have over the years been used in the acquisition of 3-dimensional coordinates of ground features for various types of mapping including cadastral mapping. It is employed as a field-based technique for geographic positioning in which it is vertically set on ground control points (GCPs) from which positions of point features on the ground are measured and recorded based on a geodetic control network. For quality and accurate positioning measurements of points, measurements are sometimes done from at least two different control points.

Recent total stations come with electronic field books for data collection, recording and coordinate geometry computations. The problem with this as far as cadastral data collection is concerned is that, no one electronic data collection and recording system exists that satisfies the cadastral needs of a part of a particular country. This is because cadastral systems are different for different countries and therefore there is no one interface model to suit them all.

3.5.3 Aerial photography

Measurements of ground features from the air, is another method of dataset collection for mapping. Photographs of overlapping areas are taken normally from an aircraft platform at a flying height depending on the scale of the map to be produced, and points identified in the overlap region are transformed into ground position coordinates by mathematical calculations using ground control
3.5. Methods of cadastral data collection

points tied to the national control network.

As far as cadastral data collection is concerned this technique has not proven to be very effective and therefore has not been extensively used due to the invisibility of cadastral boundaries. It is favourable however in circumstances where land or parcel boundaries are well marked by walls or hedges, or boundary corner points are well marked with monuments that can be visible on the aerial photographs. For it to be employed for cadastral data collection, more ground checking has to be included to supplement the data from the photographs.

3.5.4 Ground surveying method by GPS positioning

As explained in chapter 2, a GPS receiver gathers all needed positional and range information from satellite to determine its own position. A wide variety of GPS receivers are available for use depending on the type of application and the required standard of accuracy. Some are double frequency receivers, which means that they receive signals from satellites on double frequencies (called L1 and L2), while some are single frequency receivers (L1). Double frequency receivers yield higher positional accuracies than single frequency receivers.

The positioning system in wide usage today is the Navigation Signal Timing and Ranging Global Positioning System (NAVSTAR) which is a US military navigational system. Selective Availability (SA) is a 100m positional error that the controllers of NAVSTAR intentionally introduced into the system for US security purposes. SA has now been permanently turned off by the order of the US government. The Russian Glonass is in operation and the European Galileo which is civil, will soon be in operation. These will provide alternatives to the US military NAVSTAR. In the event that the SA is turned on again which can affect geographic data collection (including cadastral data) accuracies with GPS, the Glonass and the Galileo will provide alternatives.

For cadastral data collection application, every country has its required accuracy standard because cadastral systems differ from country to country. For example, for a guaranteed fixed boundary cadastral system where there are monuments at every boundary turning point, absolute accuracies of the points are expected to be high so that boundary points can be re-determined in case they are lost. In this case higher accuracy GPS and observational techniques are employed to yield higher accuracies. On the other hand for cadastral systems based on general boundary such as hedges and fences and where relative accuracies are important, GPS with lower positional accuracies and techniques can be employed. Some GPS positioning techniques and the accuracies they give are discussed below:

- **Absolute positioning**: This is characterized by a single receiver centered on the station whose position is to be determined, and receiving signals
from four or more satellite at a given observation time (van Sickle and van Sickle, 2001). The accuracy of this method of positioning depends on the time and satellites position accuracies received by the GPS receiver. The accuracy of this positioning method is now 10 to 20 metres without selective availability. The accuracy of this technique can also be improved by waiting longer at a station to observe many readings which is then averaged.

- **Relative positioning**: In this kind of positioning method, also called Differential Positioning, two or more receivers are employed for observing the same satellites (four or more) simultaneously to determine their relative coordinates. One receiver is used as a reference receiver which is stationed at a point of precisely known coordinates whiles the other receivers may or may not be stationary but being cited on points whose coordinates are to be determined. Coordinates of the unknown points are resolved based on the coordinates of the known station. This method yields higher accuracies (sub metre) than the absolute positioning technique. It is employed sometimes for cadastral survey works which demands high accuracies.

- **Differential GPS**: This is a modification of the relative positioning method. In this method, the receiver on the known base station is equipped with a transmitter which transmits radio signals of its satellite observations including the station coordinates on real-time to the receivers whose positions are to be determined. The unknown point receivers then compute their locations coordinates based on the transmitted information and their satellites observations. This technique can be employed for L1 lower accuracy receivers such as the Bluetooth GlobalSat 338 handheld receiver to improve the accuracy depending the application for which it is being used. (See Figure 3.4)

### 3.5.5 Current methods in use

The methods currently in use today in Ghana are the Ground survey by Total station in combination with GPS. The GPS is mainly to provide control points while the Total station for actual survey of boundaries and parcels. Arial photography has been used for some areas but not extensively. The main setbacks of these methods are the inability to capture spatial and attribute cadastral data at the same time, and the huge work labour needed. As new technology emerges the future plan is to have a method that can overcome these setbacks.

### 3.6 Cadastral business processes

Business process can be said to be a group of activities or a description of tasks that an organization goes through in order to achieve a goal. A business process has inputs which are the requirements that are put into place, the methods
which are the ways activities are performed, and the output which is the final product or the achieved goal. The inputs make way for the methods to be implemented to achieve the goal. In the cadastral domain, the requirements needed to be put in place and the methods in the form of activities that can be employed to collect cadastral data and maintain it in a database and finally produce cadastral maps and disseminate to users can be said to be a cadastral business process. Some current common cadastral processes in Ghana are shown in the next sub-sections.

### 3.6.1 Dutch Cadastral parcel sub-division/consolidation process

The Dutch cadastral system unlike Ghana is the Deed type with the general boundary system. As such accuracies of cadastral parcels relative to others are of prime importance rather than absolute accuracies. Methods used in data capture are ground surveying with tacheometer and tape, aerial photographs, digitizing and scanning where there are existing maps. The difference between the data capture and maintenance processes in Netherlands and Ghana is that in Netherlands most of the processes are fully automated. For example as the boundary data is being collected, the Surveying and Cartographic Information System (SCIS) is being automatically updated with the survey results (Figure 3.5).
3.6.2 Current cadastral plan preparation process in Ghana

The current general cadastral plan preparation process by Survey Department for Land title registration as derived from (Arko-Adjei, 2001) are as shown below. (See Figure 3.6). This is after cadastral data collection of an area has been completed and the digital layer is being maintained in the database.

1. Land title registry submits request for preparation of cadastral plan on behalf of client to Survey department.
2. Client pays the appropriate fees.
3. Surveyor appointed to identify the parcel on the ground with client, execute and record necessary changes in parcel boundary geometry as agreed by clients and neighbours.
4. Surveyor extracts parcel coordinates from database or computes coordinates if there are changes in parcel geometry or boundaries points.
5. Surveyor opens file to which all related records are kept.
3.6. Cadastral business processes

7. Director of Surveys gives his final approval to plan by way of signing.
8. Plan is submitted to Land Title registry for subsequent title registration

3.6.3 Current parcel sub-division/consolidation process in Ghana

The scenario is that a parcel owner in agreement with a prospective buyer decides to sell part of his parcel of land to the buyer. The owner has already registered the parcel with the Title Registry. The parcel therefore has to be subdivided and the new parcel registered in the name of the new owner. The buyer forwards an application to the Title Registry requesting for a subdivision survey and subsequent title registration of the new parcel in his name. The sequence of activities is as follows:

1. Title Registry acknowledges receipt of application, checks whether seller is the legal owner and is entitle to sell it.
2. Title Registry approves if seller is the legal owner, and forwards application to Survey Department requesting it to perform a subdivision survey and prepare a cadastral plan/map of the new parcel in the new owner’s name,
3. Survey Department appoints one of its Cadastral surveyors or contracts a licensed surveyor to carry out the subdivision survey,

4. The Cadastral surveyor carries out the processes of subdivision,

5. Survey Department approves cadastral map/plan and forwards it with the report to Title Registry,

6. Title register updates the Title register and issues a title certificate to buyer/applicant,

7. Buyer/applicant collects the title certificate on payment.

The data collection process

In the sub-division example illustrated in sub-section 3.6.3, the surveyor performs certain sub-division processes. These processes are further shown bellow:

1. Manually searches and collects reference data for use in the field.

2. Establishes the boundaries on the ground.

3. Measures angles/distances of boundary lines with Total Station or coordinates of boundary points with GPS.

4. Records and stores raw field data into a field book (analogue).

5. Transport data to office for entry into a compute.

6. Perform Coordinate adjustment.

7. Enters adjusted coordinates into a Parcel Management System to update cadastral database.

8. Prepares a cadastral map/plan with new attribute information.

9. Prepares a detailed report and submits to head of survey Department.

3.6.4 Problems with current cadastral processes in Ghana

The cadastral processes currently existing in Ghana especially in the area of acquisition of the data, storing and updating are bedeviled with many problems which are undermining the efficient operations and delivery of cadastral services. Some of these problems which it is hoped mobile GIS can help solve are discussed below.
• Very often the process of data capture is not supported by the recording procedures which are on paper. Even graphical user interfaces of data loggers of electronic instruments have not completely been modeled to support cadastral data recording.

• There is completely no linkage between field workers and the central office database and it is also not possible to communicate field observations to the central office. It is as well very difficult to access office information such as control points locations or existing topographic map of the working area for use as reference map for cadastral surveying, especially when the working area is very remote from the central office.

• Currently coding and attribute information such as parcel identification number, parcel area of location and many more are not captured alongside the spatial data on the field due to the fact that the process of data capture and recording has not been structured to support that. These informations are captured at a latter date retarding efficiency. Creation and maintenance of attribute information therefore becomes difficult.

• Again currently, the analogue and not very well structured format of cadastral data recording, coupled with the absence of linkage between field and central office do not allow field data editing, updates and data validation for checking quality of the data while in the field.

### 3.6.5 Benefits of mobile GIS to cadastral business processes in Ghana

With mobile GIS, a graphical user interface can be modeled and designed to support cadastral data collection and recording. This can also allow attribute information to be collected and recorded with their corresponding parcel spatial data simultaneously on the field. Also with mobile GIS, field editing and validation of data is possible to forestall situations where cadastral data has to be validated at later date. Above all with internet connection between field and central office, communication between the two is achieved. Field data collected and recorded can be communicated to central office for further processing and also information needed to be used on the field to enhance the collection of the data can be accessed with mobile GIS.

### 3.7 Chapter summary

This chapter outlined the activities of the agencies involved in acquisition as well as maintenance and usage of cadastral in Ghana. A comparison of sub-division processes of cadastral mapping in Ghana and the Netherlands were given, identifying the differences particularly within the spatial data capture and maintenance aspects. Finally some problems in the current cadastral processes in
Ghana were highlighted to bring into fore the areas in the business processing where mobile GIS can be employed to help solve.
3.7. Chapter summary
Chapter 4

Mobile GIS for Cadastral data acquisition and maintenance, System process modeling and design

4.1 Introductions

In this chapter, user requirement analysis, conceptual modeling and design of the mobile GIS for cadastral data collection and maintenance system processes is developed. Object-oriented development process is used as the modeling method with UML as the tool for the modeling and designing. An activity diagram captures the current cadastral data collection and maintenance business processes in Ghana leading to a high-level class diagram. The business processes are obtained through a user requirement study conducted in Ghana and the Netherlands. Upon analysis, a use case diagram is developed to identify the various actors and also to capture their use cases. The use cases are further fleshed out to identify the various components needed to enhance the system, leading also to the enhancement of the high-level class diagram. Finally, sequence diagrams are developed to show the interactions among the components of the new system.

Object oriented method of system process development is chosen as the paradigm for the development of this system process due to its obvious advantages as noted in chapter 2. Object-oriented modeling process comes in many different guideline flavours, some of which are: Object-oriented analysis (OOA) (Coad and Yourdon, 1990), Object-oriented design (OOD) (Coad and Yourdon, 1991), Object-oriented analysis and design application (OOADA) (Booch, 1993), Guidelines for rapid application engineering (GRAPPLE) (Schmuller, 1999)

The object-oriented process guidelines used in this research is the GRAPPLE
4.2 Requirement gathering

guidelines provided by (Schmuller, 1999). The reason for choosing this method is that as much as all the methods use UML, GRAPPLE provides clear, understandable easy-to-use UML graphical notations and systematic system processes through the design and development stages.

The GRAPPLE guidelines involve gathering of user requirements, analysis, the system design and system testing. These will be discussed even more in the subsequent sections of this chapter as we delve into the design of the system.

4.2 Requirement gathering

User requirements gathering involves identifying the business processes within the domain of cadastral data collection and maintenance, performance of the domain analysis and identifying the system requirements. Requirements gathering give the knowledge of the specific processes that will require improvements and the operations of those processes. Essentially, the users’ domain and accompanying problems are the primary subject of interest (Mutamo, 2003).

User requirement interviews were conducted with domain experts from Survey Department, Ghana through phone calls and the electronic mails. The objective is to acquire knowledge in the current business processes involved in cadastral data collection and maintenance and the components involved, and the need for enhancement. I communicated with Mr. Jones Ofori-Boadu, Head of Examination Section through electronic mail on the 6th of October, 2006. Answers to the questions posed to him were validated by Mr. Alex Kutu, a Cadastral Surveyor and Mr. Justice Quansah, a Cadastral Maintenance officer, the two of which I contacted through phone calls. Questions that were posed included

1. How is cadastral spatial data acquired from the field and how is it maintained?
2. Is the spatial data and associated attribute data kept in the same database or kept apart?
3. What methods are employed in the data acquisition and by which survey instruments?
4. How are field measurements recorded?
5. How are cadastral data transferred to the office? Is the data processed fully, partially or not at all processed in the field before transferring to office or processed in the office?
6. What staff are involved in the cadastral data collection and maintenance?
7. What maintenance processes does the cadastral data go through?
A further personal discussion was conducted with an expert, Mr. van Osch of the Dutch Kadaster-Apeldoorn, the Netherlands on the 20th November, 2006. The objective was to acquire general cadastral business process knowledge. The questions asked centered on cadastral field office for cadastral data acquisition, subdivision process, cadastral database links to field surveyors, and which functionalities should a field cadastral surveyor have.

Answers to these issues were collaborated with those from the domain expects from Ghana. The current cadastral business processes in Ghana captured by the interviews have been modeled in Figure 4.1.

4.2.1 Business Process identification

The purpose of the business process identification is to obtain knowledge and understanding of the current cadastral business process domain in Ghana as far as data collection and maintenance is concerned, in order to subsequently propose enhancements to the system processes. Business processes are well modeled by UML Activity diagrams. They give good impressions of the system and help communicate better understanding of the business processes and the parties involved.

The activity diagram (Figure 4.1) models the current cadastral data collection and maintenance procedure in Ghana. It involves essentially the Surveyor who does the field spatial data collection, the Examination section which checks the quality of the surveys, the Data Maintenance officer, who constructs, edits and updates the spatial database with the new data and the Cadastral data user who request cadastral data and then collects and adds its own attributes to it.

Since the core of this research is centered on cadastral data collection and maintenance, cadastral data dissemination, which comes with the usage, is beyond the scope of this research. It is therefore only mentioned but will not analyzed.

4.2.2 Domain analysis

The purpose of the domain analysis is to identify, collect and organize the relevant objects within the business process. This is to give further understanding of the current system to make way for proposal of a better system. In pursuance of this, all relevant objects within the prevailing system are identified and grouped into classes, which are later in the development process further developed.

The preliminary identified objects and their relationships within the domain of the current cadastral data collection and maintenance are shown in Figure 4.2. The objects are as follows:

1. CadDatabase: Cadastral database
4.2. Requirement gathering

2. **SpatialLayer**: Spatial Layer

3. **AttributeData**: Information associated to spatial data

4. **RefRecordData**: Survey reference record data. Different types of reference data such as topographic map used for orientation in cadastral survey

5. **Survey Instrument**: field instruments used in undertaking cadastral survey

6. **Computations**: Reduction of raw field measurements

7. **FieldBook**: Survey field book in which field measurements are recorded

8. **CadProfessional**: Cadastral professionals
Chapter 4. Mobile GIS for Cadastral data acquisition and maintenance, System process modeling and design

Figure 4.2: High-level class diagram of current process in Ghana

9. Surveyor: The professional who undertakes cadastral measurements in the field

10. DataMaintenanceOfficerGUI: Defines the interface of cadastral data maintenance officer in charge of editing cadastral data

11. CadUserBody: Cadastral user bodies like Land Title Registry and Land Commission

12. GCP: Ground Control Points use as Geodetic network controls for cadastral survey

13. TopoMap: Topographic map used as reference map for orientation

4.2.3 Requirements identification

In the first two stages of the requirement gathering, the current business process system of the cadastral data collection and maintenance was modeled using the activity diagram, and high-leveled class diagram developed. This is the conceptual modeling of the system. Requirement identification deals with the system
4.3 Analysis and design

itself. Its purpose is to discover what users want out from the system in order to fashion out enhancements to the system. In other words it is to identify what the users want the system to do for them. Use case packages are used to group the system functionalities with respect to the actors.

The knowledge to be obtained from the business processes and professionals within the cadastral domain, coupled with the mobile GIS technology will be used in the enhancement of the system.

It is important to note that identification of actors and analysis of their use cases will bring out more new classes. Some of the classes in Figure 4.2 which are not deemed to be useful for the new system will then be eliminated.

**Developing the requirements**

As can be seen from the current business processes in Ghana (explained in subsection 4.2.1, Figure 4.1 (page 50), some aspects of the cadastral data collection and maintenance activities can be enhanced with new methods. The core components of cadastral data which are the spatial land parcels and their associated attribute data are currently not being collected together at the same time due to the fact that methods and technologies used do not allow that. (These have already been outlined in chapter 3).

Again currently, the database existing and being maintained is only the spatial database without their associate attribute data. This is because attributes are collected by cadastral user organizations (like Land Title Registry) only when there is the need to use a cadastral plan. In the proposed mobile GIS system, there has to be a method of data collection in which the two core cadastral data can be collected as the same time and maintained in the same database.

The problem of reference data access and cadastral data collection editing and updating of the database can be tackled by the new desired system with the use of wireless network for online transfer of data. The proposed mobile GIS system is also intended to cut off the situation of manual paper recording of field observations.

From the activity diagram in (Figure 4.1), the main actors as far as core cadastral data collection and maintenance are concerned, and which are and will form the functionality of the enhanced system are identified and modeled in the use case package in Figure 4.3. Their use case package functionality can be seen in Figure 4.4 (page 54).

4.3 Analysis and design

This phase of the object oriented modeling is a further analysis of the requirement gathering phase. Its main purpose is to give further understanding of the system to be designed by analyzing the requirements gathered, and then expand
into the required refined system. The phases involved in the analysis stage of object oriented modeling according to (Schmuller, 1999) are given as follows:

- Understanding the system usage
- Fleshing out the Use cases
- Refining the high-level class diagrams
- Define the interaction among objects

### 4.3.1 Understanding system usage

In this section of the design process, the actors (persons or systems) who initiate each of the use cases in the requirement gathering stage are discovered. Use case diagrams will be used to model the actors and their use cases. The discovering of the actors is based on the interviews with domain experts as to who does what during the business processes.

The actors from both Cadastral data Collection package and maintenance package use cases are identified as seen below. The model of these actors and their use cases can be seen in Figure 4.4 (page 54).

1. Surveyor
2. Data maintenance officer
3. Cadastral User Agency
4.3 Analysis and design

4.3.2 Fleshing out the use cases

After identifying the actors who execute the use cases, the next stage is to analyze each use case into detail in order to put flesh around it. This gives a good picture of what the system will do. It is done by writing in text form the sequence of steps of each use case scenario. According to (Schmuller, 1999), for each use case, it is important to list out these information:

1. brief description of the scenario
2. Assumptions for the use case
3. The actor who initiates the use case
4. Preconditions for the use case
5. System-relates steps in the scenario
6. Post-conditions when the scenario is complete
7. The actor who benefited from the use case

Note that Pre-conditions are the conditions that needed to be fulfilled (be in place) before the operation of the use case can be executed to guarantee the Post-condition. Post-conditions describe the system condition after the use case has been executed. That is they describe the results to be expected.
Assumptions are very important. They tell which conditions must be in place for the post-condition of the use case to be achieved. Assumptions give the proposed design consideration of the system.

**Fleshing out the 'Download record' use case:**

Description: This use case is to download reference records such as the existing cadastral map to be updated, reference control points coordinates and topographic, photograph or satellite image to be used as background orientation for the cadastral survey.

Initiating Actor: Surveyor

Assumptions:

- There is a database of such records on the office server.
- Database accessible to the mobile device on the field through the wireless network within the working area.

Preconditions: Data collection is to be started.

Post-conditions: The reference records such as cadastral map to be updated or an image of working area for first survey have been downloaded for use on the site.

Steps:

1. Surveyor activates the mobile device interface for data request
2. He specifies the type of record he is looking for and his working area.
3. Request is sent to the office server.
4. Server searches for specified record and transmits back to mobile device
5. Surveyor views record on screen of mobile device for use

**Fleshing out the 'Collect data' use case:**

Description: The surveyor on the field initiates the GPS and mobile device to start collecting cadastral points and parcel polygons.

Initiating Actor: Surveyor

Assumptions:

- GPS connected to a mobile device.
- Mobile device has interface structured to capture cadastral spatial and attribute data.
• Reference record data such as existing cadastral map, control points data and area topographic or base map has been retrieved.

Preconditions: cadastral boundaries corner points can be identified. Cadastral data has not been collected.

Post-conditions: Spatial and attribute data collected in a structured manner.

Steps:

• Surveyor activates GPS and initiates it for data collection
• GPS creates point and parcel data object by measuring point coordinates
• Point and parcel data are displayed on the mobile device user interface (GUI)
• Point and parcel data are stored on the mobile device spatial database
• Mobile device job detail interface captures associated attribute data.
• Attribute data are stored into mobile device attribute database

**Fleshing out the 'Transfer data' use case:**

Description: The surveyor initiates the data transfer process

Initiating Actor: Surveyor

Assumptions:

• There is a wireless network connection between the mobile device and a remote office server.
• Cadastral data can be transmitted in their transfer format.

Preconditions: Data collected and captured on mobile device. Data not transferred to office.

Post-conditions: Cadastral data transmitted to remote office server online from field.

Steps:

1. Surveyor activates mobile device for data transfer
2. Surveyor activates wireless communication link between mobile device and server
3. Mobile device communicates with remote server through the protocol and indicates link with server.

4. Mobile device transmits collected cadastral data to server through the wireless communication link.

5. Data arrives in the server and it is stored for further processing.

Figure 4.5: Use case diagram of Cadastral data collection and maintenance

**Fleshing out the 'Update database' use case:**

Description: This use case is the processes in updating the cadastral database on the server side from the field.
4.3. Analysis and design

Initiating Actor: Surveyor

Assumptions:

• The existing cadastral database is accessible through a server from the field by a wireless link

Preconditions: Parcels geometric changes has occurred on the ground as a result of subdivision or merging

Post-conditions: The spatial database is to be updated with the new changes

Steps:

1. Surveyor activates mobile device to download existing map record to be updated
2. Mobile device interface sends request for transmission to server
3. Wireless network transmits request to server
4. Server sends reference map for transmission
5. Wireless network transmit to mobile device interface
6. Mobile device interface sets reference map layer as background
7. GPS observe new points and store them in database of mobile device
8. On the mobile device interface captures cadastral data (PointData and ParcelData)
9. Wireless network re-transmits new changes to server
10. Data Maintenance officer interface loads data to his system interface for further editing
11. Upon satisfaction completion, Data maintenance officer sends new data to update cadastral database.

In all of the above use cases, the benefiting actor is the 'Cadastral User Body' who is the final user of the cadastral data.

It should be noted that the remaining two use cases, 'Mark off boundary' and 'Disseminate Data,' even though important, are beyond the scope of this thesis and therefore not fleshed out.
System components

It can be observed in the ‘Assumptions’ part of the fleshing out of the use case scenarios that the components and functionalities which are supposed to enhance the system are emerging.

For example it is clear that a wireless network between a mobile device used to capture the cadastral data will be needed to ensure data exchange between the mobile device and an office server. It can also be seen that a mobile device is needed for data capture in the field and it should be equipped with interfaces for capturing the cadastral data; both spatial and attributes.

It would be necessary to have a page interface within which all the capturing page interfaces are embedded. The need for a mobile device database would also be needed for storing both spatial and attribute data before transferring to the remote office server.

On the server side a cadastral database on top of a database management system will be needed as part of the server components.

4.3.3 Refining the class diagram

Analysis and fleshing out of the use cases has brought about new classes. The initial class diagram from the business process domain analysis (Figure 4.2) therefore has to be refined. New classes that came up from the use case analysis has been included and fleshed out to reflect the enhanced system. The overall classes and their meanings for the enhanced system are listed below in Figure 4.6, page 61.

1. MobileGis: Mobile GIS which defines the major components of data capture and transfer
2. MobileDevice: Mobile device operated in the field to capture cadastral spatial and attribute data
3. GPS: measures the coordinates of parcel boundary corner points
4. Server: defines the software on the office computer which communicate with field worker
5. WirelessNetwork: defines the wireless network for data transfer
6. MobileDeviceGUI: defines the graphical user interfaces of the mobile device through which surveyor communicates with the device
7. ServerGUI: defines the server interface through which Data maintenance officer communicates with server
8. MobileDeviceDbase: defines the database model on the mobile device for data capture
9. CadDatabase: defines the Cadastral database
10. SpatialLayer: defines the spatial layer in the database
11. AttributeData: defines the attribute data associated to a spatial data
12. PointData: defines the point data of parcels
13. ParcalData: defines the data of parcels (polygons)
14. PointAttribute: defines the attributes of point data
15. ParcelAttribute: defines the attributes of constructed parcels
16. CadProfessional: defines the professionals in the cadastral data collection and maintenance domain
17. Surveyor: defines the field worker who collects cadastral data
18. DataMaintenanceOfficerGUI: defines the interface of data maintenance officer
19. RefRecord: defines the survey reference records needed for changes and as reference for spatial data collection
20. RefRecDatabase: defines the databases of the survey reference records
21. RefGcp: defines the ground control points records for cadastral survey
22. RefMap: defines topographic map reference records use as referenced background map
23. RefImage: defines the satellite image records use as reference background image

4.3.4 Define interaction among objects

This stage of the design and development process focuses on showing the interactions among the working parts of the new proposed system. This is achieved by using sequence diagrams to model the components suggested by the use case package and which was fleshed out. The sequence diagrams on pages 62-64 model interactions among the components. In 'Download Record' sequence diagram the Surveyor with the use of the mobile device interface activates and sends a download request to server, retrieves record and sends it back to the mobile device interface (Figures 4.7). In the 'Collect data' sequence diagram, (Figure 4.8)the Surveyor with the GPS and mobile device interfaces collects cadastral data into device database. In the 'Transfer data' sequence diagram (Figure 4.9)
the Surveyor using the mobile device interface transmits collected data through the wireless network to server. The 'Update database' sequence diagram in Figure 4.10 embodied the other use cases. It models the update process through the collection and transmission process.

4.4 Chapter summary

To summarize, this chapter which is the nucleus of this research is centered on the conceptual design of the new system for cadastral data collection. The new enhancements as a result of the user requirement gathering and analysis brought about the use of mobile GIS to facilitate the field collection and mainte-
nance process of the cadastral data. Various UML diagrams were used to model the system processes from the current state to the newly proposed and enhanced system. The next chapter of this research will focus on the physical development and implementation of the proposed mobile GIS system based on the derived components obtained from this chapter.
Chapter 4. Mobile GIS for Cadastral data acquisition and maintenance, System process modeling and design

Figure 4.8: Sequence diagram for ‘Collect data’ use case

Figure 4.9: Sequence diagram for ‘Transfer data’ use case
Figure 4.10: Sequence diagram for 'Update database' use case
Chapter 5

Prototype implementation and testing

5.1 Introduction

This chapter discusses issues relating to the implementation of the conceptual model of the prototype mobile GIS designed in chapter 4. Key elements to be implemented among others in the conceptual model are the client-server architecture developed, the mobile device (clients) components in terms of devices and user-interface customization for collection, transfer process of cadastral data to remote database, as well as the download of record data as background orientation. The preparation of the server to receive data and insert into database by way of programming scripts as well as issues relating to testing of the first prototype are also discussed.

User requirement analysis and further conceptual modeling resulted in a number of use cases for the system. These are generally the Download Record, the Collect data, the Transfer data and the Update database use cases (see chapter 4, section 4.3). Within each of these uses case are the system objects that mould the system. Those ones that run through all the use cases and which are implemented in this section are:

- Client: defines the type of client to be implemented in the system
- MobileDeviceGUI: defines the user interfaces to be developed and implemented
- Server; defines the remote server components
• AttributeData: which defines the attribute information of the cadastral data
• PointData and ParcelData: which defines points and parcel data
• GPS: which defines the GPS device
• WirelessNetwork: which defines the wireless internet connection between client and server.
• RefRecord: defines the reference record data for referencing
• DataMaintenanceOfficerGUI: which defines the interface of the cadastral data maintenance officer

The other classes and their definitions can be found in chapter 4 subsection 4.3.3

5.2 Prototype implementation

5.2.1 Software, hardware and scripts developed

A number of software, hardware and programming languages were used in the development of the actual prototype. Table 5.1 summarizes the software and hardware tools made available for the building of the prototype, while Table 5.2 summarizes the programming languages used.

5.2.2 Prototype architecture

Figure 5.1 gives the architecture of the system. It presents the various hardware and software components making up the system and how they interact. In the conceptual model in chapter 4, the 'Client' component of the system was modeled as a single component. For practical implementation, the 'Client' was divided into Field Client and Office Client. The reason for this is that ArcPad does not have much data editing tools and functionalities needed to process the cadastral data into a topologically cleaned cadastral map. This is to be done in ArcMap on the Office Client.

• Field Client.

The field client was designed and purported to be used on the field for collection of cadastral information. It is mobile and its components consists of ArcPad software running on a Personal Digital Assistance (PDA). The communication connection between the office client and the server is by wireless internet connection. The user interfaces developed in ArcPad Studio structured for cadastral
Chapter 5. Prototype implementation and testing

Table 5.1: Software and Hardware used in prototype implementation

<table>
<thead>
<tr>
<th>SOFTWARE/HARDWARE</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| ArcPad 6.0.3       | - A platform for capturing cadastral data  
|                    | - Also the platform from which data is uploaded  
|                    | - It runs on the mobile device as well as desktop computer |
| ArcPad Studio 6.0 (Application Builder) | - Used for customization of ArcPad |
| ArcMap             | - Used in processing field uploaded cadastral data  
|                    | - Use to view the data |
| ArcCatalog         | - Used in creating shapefiles to be deployed on mobile device |
| Feature Manipulation Engine (FME) | - An extension in ArcMap  
|                    | - Used in connecting ArcMap to DBMS |
| PostgreSQL / PostGIS database management system (DBMS) | - Used as the DBMS with a spatial database extension  
|                    | - It runs on the geosever.itc.nl server |
| PDA                | - The field mobile device  
|                    | - With Wi-fi internet communication link  
|                    | - With Bluetooth |
| GPS                | - GlobalSat BT 338 Handheld receiver  
|                    | - With Bluetooth  
|                    | - With 20-channel satellite tracking |

data gathering, has been deployed unto the ArcPad and is to be used to capture the cadastral data. The field client has a GPS receiver connected to it for positional fixing of the cadastral points.

- Office Client.

The main functionalities of the office client is to load cadastral data that has been uploaded into the server PostgreSQL/PostGIS DBMS by the field client, back unto its interface, perform spatial editing which could not be done on the field client’s ArcPad, after which the finished processed data is saved back into the DBMS ready for dissemination. Its components consisted of desktop computer, ArcMap with a Feature Manipulation Engine (FME) for connection, loading and saving cadastral data from and to the server DBMS. Communication between office client and server is by wired internet connection.

The office client functionalities could later on be implemented on a PDA so that field client could directly communicate with server and perform edits directly from the site.

- Server.
### 5.2. Prototype implementation

#### Table 5.2: Programming languages used in prototype implementation

<table>
<thead>
<tr>
<th>PROGRAMMING LANGUAGE</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| VBScript and JavaScript         | - For interface customization  
                                 | - Use for developing Active Server Pages (ASP)                           |
| Windows command Batch scripts   | - Developed for map/image downloading                                    |
|                                 | - For file format conversion and loading                                 |

The server ITC geoserver.itc.nl consists of the ASP webserver and the PostgreSQL / PostGIS DBMS running on it. The main function of the ITC ASP webserver is to receive uploaded data and then subsequently load them into the DBMS via the application server.

### 5.2.3 Technical description of prototype functionality

When all components such as the client’s user interfaces deployed unto Field client’s ArcPad, server side scripts deployed unto the server, GPS connected to mobile device as well as wireless internet connection in place, the initial step is to open the ArcPad interface of the field client which serves as the main user interface. For cadastral point data collection, the ‘Cadastral Point Data form’ interface is activated and entry fields capture point information. Collected data are uploaded by the upload functionality on the page by the Inet Object codes, to the geoserver.itc.nl server. The ASP script on server designated to receive point data receives and posts data into the cadastral database through the application server.
server. The application server is the ASP application server, and the database is on the PostgreSQL/PostGIS DBMS. Parcel data are collected by using the ‘Cadastral Parcel Data’ interfaces. Just like points data, ASP script designated for polygons receives and posts into database via the web server and the application server. A HyperText Markup Language (HTML) page is sent from server to client notifying of data upload (Figure 5.3).

The Office client through the use of FME (see table 5-2) in ArcMap interface selects the data output format, connects to the database through an ODBC connectivity and loads for viewing and processing. The processed and cleaned cadastral data is saved back into database. For a clear picture of how the prototype works, a schematic diagram of the mechanism is shown in Figure 5.2.

**Figure 5.2: Schematic diagram of Mechanism of prototype.**

### 5.3 Developing and Testing Prototype

In designing and developing a system, testing is one of the process phases. The main purpose of testing a system is to demonstrate how it operates, to evaluate how practical it can be and to gather feedback for future development. It is not
to prove the system but to improve it (Lewis and Reiman, 1993).

For this research, the prototype is tested by these criteria: the functionality of the system, whether it is easy or difficult to understand the system, whether or not it is easy to operate it and whether the system will allow user’s errors to be avoided. The phases of the testing are adapted from (Pham, 2000). These phases were chosen because of the fact that problems found during testing are localized and can be detected easily as each component of the system is tested independently before integration. The phases are discussed below:

**Developer’s unit test phase**

The developer test is performed by the developer to ascertain the system’s performance. Firstly each unit component is tested in isolation from the others using actual inputs and then the units are integrated together into the whole system and tested again. This is to ensure that the system requirements in terms of functionality are fulfilled.

As has been mentioned earlier on in chapter 1, the main objective of this work is to develop a system that can conveniently be used to acquire cadastral data and be able to dynamically transfer, edit data and update a remote server with the cadastral data collected. The final product should be a clean cadastral map kept in the Cadastral database ready to be disseminated. The various components of the prototype tested comprise of the Field client interfaces, the Office client components, the data transfer processes, Server components

**1. Developing and testing Field Client interfaces:**

The ArcPad user interfaces were designed using ArcPad Studio powered by VBScripts. A customized interface in ArcPad consists of one or more forms. A form consists also of pages which can also be one or more. A page harbours control
entry fields which accept inputs and execute functions. Every part of the form and page interface has titles to describe the functionality they are purported to perform.

For this project, the ArcPad graphical interface that appears when ArcPad is loaded is the main interface, into which all the other interfaces were built. Two main interface forms were built: the "Cadastral Points Data Form" interface for point data collection and the "Cadastral Parcel Data Form" interface for cadastral data collection. Within each form interface were built page interfaces. "Cadastral Points Data Form" interface contains two pages; the "Capture Data" and "Update" pages. The "Capture Data" page contains entry fields that capture the cadastral point information such as point id, point name and measured GPS coordinate values, all of which were to be transferred (Figure 5.4a). VBScripts running under the "Click to Upload data" button and containing data transfer code was developed to do the data transfer to server.

The Update page interface was purposely designed to allow old data in the database to be replaced with new collected data. It contains an ID entry field and the Update button. Again VBScripts were developed to run under the Update button which does the data transfer update (Figure 5.4b).

The "Cadastral Parcel Data Form" interface has four main pages, two "Parcel Attribute" pages, the "Upload" and the "Update" pages. The "Parcel Attribute" pages were developed to capture cadastral parcel attribute data such as the Parcel identification number, the Location of the parcel, the name of the street along which the parcel is, the transaction affecting the parcel such as whether reg-
5.3. Developing and Testing Prototype

istered or not, district and section numbers (Figure 5.5). Attributes of cadastral parcels may be different from country to country implementing cadastral systems, and may depend on the information they may want in their cadastral register. The attributes information developed here are those peculiar to Ghana where regions have been divided into districts and districts further divided into sections, each district and section having a district and section number respectively.

Figure 5.5: Parcel data attribute interfaces.

The "Upload" page of the "Cadastral Parcel Data Form" interface has coordinate fields that captures the measured GPS coordinates of the parcel corners when GPS is activated for polygon measurement, and two other button; the "Get Coords" and "Upload Data" buttons. Again VBScripts developed to run under the "Get Coords" button displays the parcel corner points coordinates in the coordinate fields while that under the "Upload Data" button does the data transfer to server (Figure 5.6a). The "Update" page, just like updating point, was developed to update an old parcel data in the database with a new captured data using the identification number of the old record. The "Click to Update" button runs a VBScript to effect data transfer and update (Figure 5.6b).

At every stage of the development of these interfaces, each interface was tested to make sure that scripts were running well to give the desired interface. The testing was done by running each interface script. A few times, errors occurred or scripts did not give the required results but these errors were debugged. An iterative process of running, finding errors and debugging was done until the required interfaces for both point’s data and parcel data were achieved.

2. Developing and testing of database:
Chapter 5. Prototype implementation and testing

Figure 5.6: Get parcel point’s coordinates, upload and update interface.

The PostgreSQL/PostGIS database management system (DBMS) and ITC ASP webserver are running on the ITC geoserver.itc.nl (called the geoserver). The database dubbed "mobilecad" was created in the DBMS. This database was populated with two tables. "Cadpointsdata" table was meant to receive uploaded point data whereas "cadparceldata" was meant to receive uploaded parcel data. In creating the tables, point and polygon (for parcels) shapefiles datasets were first created in ArcCatalog. A Batch script written in batch commands was then run to converts the shapefiles into PostgreSQL/PostGIS (.sql) format and then loaded into the database. The tables were now ready to receive collected cadastral data field from site.

It must be noted here that in this work it was assumed that the spatial reference coordinate system of the cadastral data within the data base is the same as the GPS spatial reference system. Otherwise the GPS collected spatial data would have to be converted into the database reference coordinate system.

3. Developing and testing data transfer components:

One of the major challenges in this work is the development of a transfer system to move data from the mobile field client to the server. This required some amount of data transfer coding on the field client to upload data, as well as Active Server Page (ASP) scripting on the server. A number of general data transfer procedures on the client side were explored but two were chosen to be explored further due to the fact that they had the potential to work well in ArcPad.
The first procedure was developed with batch scripts which contain Windows commands. Two batch scripts and a server ASP script were developed. The "Transfer.bat" batch script transfers ArcPad shapefiles to the server. The "ConvLoad2db.bat" batch script was activated in the "UploadSQL.asp" ASP script on the server as soon as the shapefiles were transferred, which converted the shapefiles into the database (.sql) format and then loaded the data into the database. Figure 5-7 illustrates how this procedure works.

A functionality test was conducted on this data transfer procedure on an ArcPad-running desktop computer to simulate field condition. The aim is to determine whether scripts would run well and also whether data transfer would be successful. Once again some initial coding syntax errors were observed in the VBScripts but they were debugged. However this data transfer system was not adopted because of the difficulties discussed below.

The major difficulty with the batch script procedure was that it requires script access to the server's operating system (OS) which could potentially harm the server's operation. It was therefore considered unsafe to be implemented in this prototype. Another problem was that it loads the shapefiles (.shp, .shx, .dbf) within the ArcPad record set and not the data values captures in the ArcPad data entry fields. There is therefore the problem of appending or updating old record set with new ones in the database. Another difficulty is that batch scripts cannot run on the Windows CE operating system (OS) of the PDA used. Such OS in this case cannot be used as the mobile device. Only mobile devices with OS which run batch sscripts have the potential to be use. The batch script procedure has the advantage of not needing wireless connection to server before uploading data, as data is stored in the ArcPad shapefile recordset (.dbf) database. Uploading can then be done at a later date when data collection has completed and at location where there is network connection between mobile device and server.

The second developed procedure is that an Inet Object code snippet that establishes a hypertext transfer protocol (HTTP) connection with the server and uses a request and response mechanism to append values in the data entry controls in ArcPad to the database in the server. The Inet Object HTTP data transfer code was created with VBScripts in ArcPad Studio and deployed into ArcPad. Four ASP scripts with request and response, as well as Structured Query Language (SQL) "INSERT" and "UPDATE" commands were written in JavaScript. "Insertdata.asp" and 'Updatedata.asp' for point's data, and "InsertPclData.asp"
and "UpdatePclData.asp" for parcel data respectively, all using Open Database Connectivity (ODBC) code, were written and deployed on the server. The purpose for these ASP scripts was to receive point and parcel data respectively from field client and post them into database table. ODBC provide the connection between the server and the database (Figure 5.8).

Testing was conducted on the developed data transfer components of the system against functionality and reliability criteria. In Arcpad on a desktop computer with internet connection, data values were obtained by screen digitizing from a map and the data sent. This is to test how the scripts will behave and also to find out whether data can be transferred to database. There were a few problems with the SQL commands in the ASP scripts initially making downloading difficult. However, debugging and trying several times solved the problem. The whole transfer system was tested again within the open central circle of ITC building (where there is an intermittent wireless internet connection at some parts), after deploying the VBScripts unto a PDA connected with a GPS, and ASP scripts also deployed on the ITC geoserver.itc.nl server. The system was able to establish HTTP connection to transfer data to the database in the ITC geoserver.itc.nl server.

To develop and implement the Download Record use case modeled in chapter 4 Figure 4-7, a 'Record Download' form interface was developed in ArcPad with a "Download Background Record" button. The record to be downloaded could be an existing cadastral map or an image of the working area (to be updated) and which was to be used as a background reference.

The scripts developed for operation of the download is VBScripts which activates batch script "Downloadrecord.bat" with a windows OS "get" command to get the records from the server. (See appendix for scripts)

![Figure 5.8: Data transfer by HTTP.](image)

The inability of batch scripts to run on PDA was the difficulty of this operation. However it was tested on the desktop with a server connection by downloading image files from the server without much difficulty. Implementing this system on the field require the use of a mobile computer.

4. Developing and testing office client interface:

As mentioned in subsection 5.2.2 in this chapter, the office clients is responsible
5.3. Developing and Testing Prototype

for loading cadastral data from the database, perform edits and save the edited cadastral data back into the database in the form of a cadastral map. The office client uses ArcMap as its interface (Figure 5.10) with an FME extension connection to the database for loading and saving (Figure 5.11.)

The interface uses tools such as joining points by lines, snapping points and boundary lines, topology creation and removing overlapping boundary lines. Performing a functionality test on this part of the system, a connection was made to the cadastral database table “cadparceldata” with cadastral parcel data and was loaded into the ArcMap interface as shown in Figure 5.9. It was loaded back after editing. The loading and performance of editing such as removing of overlapping boundary lines, as well as saving to database again proved to be successful.

5.3.1 Developer’s integration test phase

The integration test performed by the developer brings together all the components or subsystems that have already been developed, into the required system. This is to test the functionality of the overall system. The testing scenario discussed under System Functionality Testing gives a step-by-step illustration as to how this test was performed.

The difficulty encountered in this testing scenario was that it could not be done in real world cadastral field data collection environment. This was because of the fact that having a wireless internet connection beyond the immediate surroundings of the ITC building could not be arranged because of time constraints.
The GPS component could not be used since it needs open skies to operate. Therefore in doing the test, ArcPad field client data collection components were simulated on a desktop computer which has an internet connection to the ITC geoserver.itc.nl server. The points and parcel corner points coordinates to be measured by GPS were also simulated by creating points and parcel coordinates information on an existing cadastral map of part of Enschede, the Netherlands, through on-screen digitizing.

- **System functionality testing**

With all the various components of the system tested and put together, the steps taken to run the system to test the overall functionality are discussed below. It was envisaged that the results will be a clean cadastral map kept in the cadastral database.

1. As stated earlier, a desktop computer with a wired internet connection to server was used to simulate a PDA or other mobile device as the field client.
In ArcPad the main ArcPad interface (within which the data capture interfaces operate) was brought to view.

2. On clicking on a toolbar button, the 'Record Download' interface was loaded to view. The 'Download Record' button executes the downloading of the existing cadastral map from the server to ArcPad, and then loaded to view. This was used as the background reference record upon which point and polygon layers would be laid for the cadastral data collection.

3. The point and polygon layers to capture their respective points and parcel information to be measured and recorded were then selected and made editable.

4. Cadastral points’ data were acquired first by making its layer the first editable layer. On clicking on a cadastral parcel corner point. The 'Cadastral Point Data Form' interface popped up with the points coordinates (would have been GPS points coordinates if GPS had been used) registered in the coordinate fields of the 'Data Capture' page (Figure 5.4). 'Click to upload data' button send files to server and then to data base. An html page was received confirming data transfer (Figure 5.3). Each selected cadastral point was visited, repeating the same process until twenty four (24) points data were transferred.
5. To test the functionality of the Point Update process, the identification number (ID) of the point whose record was to be updated needed to be known, as the process replaces an old record in the database with a newly collected record. For that a point of ID number 7 (seven) already existing in the database was chosen to be updated. On measuring a point and entering the attributes into the 'Capture data' page interface, the 'Update' page was brought into view by using the left and right arrow. The ID field was entered with the number 7 (seven). On clicking the 'Click to Update Point Record' button the new data replaced the old one in the database with ID number of 7 (seven).

6. After points' data had been collected, the parcel layer was then made the first editable layer. Cadastral parcel data in the form of polygons and its attributes were collected for each parcel whose corner points' data has been obtained. Each parcel corner was visited again but this time as a close polygon. On clicking of the a parcel corner points and closing the polygon, the 'Cadastral Parcel Data Form' interface popped up requesting for parcel attributes entry into fields of 'Attribute' pages. The 'Get coords' button brought to view all the polygon's corner point coordinates as shown in Figure 5-6a. The parcel information was then uploaded into the ITC ASP webservice and then into the database, all within geoserver.itc.nl server. An html confirmation notification was returned indicating that data has been transferred successfully. A total of fifteen (15) spatial parcels (polygons) with their attribute information were collected and uploaded into database.

7. At this stage the cadastral points and cadastral parcels data were respectively in the 'cadpointsdata' and 'cadparceldata2' table in the PostgreSQL/PostGIS database management system and can be viewed through the Squirrel software interface. Figures 5-12 and 5-13 show points and parcels data respectively, viewed a text SQL interface. The office client using the ArcMap interface, connects to the to the database management system through the Feature Manipulation Engine extension and loaded the data into ArcMap for editing (Figure 5.14).

8. Major editing performed was on the parcel spatial data, by way of snapping together boundary lines which were overlapping, and cleaning unneeded lines and points. Other spatial editing such as creation of topology could be done, but this was not done because of time constraint. The cleaned edited cadastral map (Figure 5.15) was then saved back into the database ready to be disseminated to users.

The system has been able to collect and upload cadastral points and parcel data, edit and kept them as a cadastral map in the database. This proved its functionality.
5.3. Developing and Testing Prototype

5.3.2 User’s Acceptance test phase

The purpose of this test is that it acts as a validation to the previous tests. For this the users test the system in a working or simulated environment where the system would be working. This test helps developer quickly debug prototype by observing people use them and remarking on it. Testing is also paramount to ensure that required functionalities and effectiveness users require are met as the users test it. For this prototype, user testing is needed but could not be done because of time constraints. However some users’ acceptance testing techniques and the best that was intended to be used if the test on this system was to be conducted has been discussed below:

Evaluation of User’s test techniques:

Various user tests or what is referred to as usability evaluation techniques has been developed, as the way humans interact with systems becomes a study of interest. These techniques can generally be divided into quantitative and qualitative methods. According to (Shrinivasan, 2005), the quantitative method “sum-
marizes the evaluation using statistics or numbers, abstracting the cognitive process behind the evaluation whereas the qualitative method "brings out the cognitive process behind the evaluation process". The cognitive process means that the test person interacts, knows, share his thoughts and judge the performance of the system. The quantitative evaluation method involves survey of larger group of people in and out of the subject domain while some qualitative approach focuses on potential users of the system for the system testing. The qualitative approach is summarized as query techniques (involving interviews, focus groups and questionnaires), the observational technique (involving think aloud with retrospect, field description of activities) and documentation method (written materials and other documents) (Patton, 2002).

For this work, think aloud with retrospect technique of system testing under qualitative evaluation was to be adopted. In this technique, potential users are allowed to use the system to solve a problem as they verbalize their thoughts. Audio-visual techniques are then used to record the verbalizations. The whole testing process is then reviewed by the developer together with the test person as the audio-visual recording is being played back.

Reason for this choice is to allow users think, learn and judge the functionalities of the system as they go through the testing process. Again users do not need to remember the operations they perform and having to describe their thoughts about the system performance afterwards. This reduces the risk of memory failure of users when their thoughts are sought after the test (Young, 2005). Figure 5.16 summarizes the think aloud process that was to be used.

The think aloud evaluation process was intended to follow four steps; first, creation of a scenario, then briefing section, then the think loud section and the retrospect section. The testing could be done in a cadastral data collection environment where there is a wireless internet connection or simulated ArcPad on a
5.3. Developing and Testing Prototype

Figure 5.15: The resulted cleaned cadastral map to be saved

desktop computer with an internet connection.

- Scenario creation

A cadastral data collection scenario would be created and test person would be allowed to go through the cognitive process by the use of the system to test and evaluate it. A scenario of cadastral data collection would be as follows:

Some parcels of land have already been surveyed and the cadastral map of those parcels of land existed in the cadastral database. Recently part of these parcels were demarcated, sub-divided into plots and sold to people who wanted to put up residential buildings. The cadastral office was then requested to survey these new changes to update the cadastral database so that the new changes can be disseminated for title registration.

- Briefing section

In this section the test person would be briefed about the system interfaces and other components, and also generally about how the system works. He would then be allowed to familiarize himself with it. He should be free to pose any question as to the functionalities of the system. A user’s guide could not be prepared because of lack of time.
Chapter 5. Prototype implementation and testing

5.4 Chapter summary

The conceptual prototype designed in chapter 4 has been developed into its physical form and implemented in the chapter. The components implemented were the clients’ interfaces, the server-database components as well as the transfer processes. The graphical user interfaces were developed tailored for cadastral data capture. The architecture employed in the implementation is two-client
5.4. Chapter summary

server architecture. The field client uses PDA or mobile computer as its mobile device and was responsible for field collection and uploading of cadastral data into the database management system running on the ITC Geoserver. For the implementation of batch scripts in ArcPad, the mobile device would have to be a mobile computer as batch scripts cannot run on PDA. The office client has the responsibility of loading data from database, performs edits and loads the clean cadastral data back into the database after processing, ready for dissemination. All units of the system were tested by developer before an integration test of the combined system through which the existing cadastral map of part of Enschede was updated into a clean cadastral map ready to be disseminated. A user’s acceptance test could not be done, however the ‘think aloud’ method of evaluating a system was proposed to be used to test the system in future.
Chapter 6

Conclusion and recommendations

6.1 Review of research objectives and questions

This research has its main objective as the design of a prototype mobile GIS, a system that can be employed for cadastral data collection and maintenance. The sub-objectives designed to guide the achievement of the main objective were:

1. To analyze the approaches for online editing, updates and transfer process of cadastral data in a mobile GIS environment.

2. To develop process models for editing, updating and online transfer over a mobile GIS network.

3. To design and implement a prototype based on the proposed improvement methods, and then test for its effectiveness and usability.

Within the framework of the above research objectives, the research questions asked at the beginning of this research and their corresponding answers have been discussed below:

1. What are the user requirements for the processes of data collection, editing and updating a cadastral database within a mobile GIS setup?

The research used the cadastral data collection and dissemination situation in Ghana as the case study. As such the business processes involved in the cadastral data collection in Ghana were examined. This was done through interaction with domain expect in the cadastral business in Ghana and the results were
validated with other interaction with experts in the Netherlands. The purpose of this was to gather user requirements, analyze them and propose a system to enhance the cadastral work. The user requirements therefore gathered are summarized as follows:

- To have an integrated spatial and attributes cadastral data gathering and maintenance mechanism.

- To have a user-friendly, simple and yet effective system of recording cadastral data and a means of processing it to a final product within the shortest possible time to enhance efficiency.

- The system should be able to effectively update a cadastral database regularly without the need for many hands.

2. What method can be used to model the processes mentioned in 1?

Some system modeling techniques were reviewed in chapter 2. In chapter 4, the object-oriented technique with its accompanying Unified Modeling Language was employed due to its discussed advantages over the others, to model the cadastral data collection and maintenance processes based on the user requirements derived. An enhanced conceptual mobile system was proposed and its components modeled. The details can be seen in chapter 4.

3. How can the model mentioned in 2 be implemented in a prototype system?

This question was intended for the development and implementation of the conceptual system designed in the previously and to determine client and server functionalities as far as the cadastral data collection, transfer, processing and database updating is concerned. In answering this question in this work, the system was physically developed and implemented. Those parts that were implemented were the client connected with GPS and server interfaces and functionalities, transfer of cadastral data to and from database as well as background reference data download. These are described in chapter 5.

4. How can the system of cadastral data editing and updating within a mobile GIS setup be demonstrated and by what criteria?

The task proposed to answer this question is to perform a usability test on the designed and developed system. Two types of test procedures were designed; the Developer’s acceptance test and the User’s acceptance test. Developer’s acceptance test was performed on each component of the system in iteration as it was being developed. User’s acceptance test could not be performed because of time limitation. Details can be obtained in chapter 5.
6.2 Conclusion

Cadastral data is an important asset to national development. It therefore needs proper collection mechanism and good maintenance process. There have already been existing conventional methods of cadastral data collection like the use of total station instruments and office data downloading, but these do not take into consideration the combined collection of both spatial and accompanying attribute cadastral data. This research came out with methods within the mobile GIS system to solve that problem and to enhance the overall data gathering process. It can be said that all the research questions were adequately addressed in this research.

There were however some limitations in this work. The 'download record' could not be fully implemented on a PDA with the transfer processed used in this work. Again in the system implementation, data of parcels with only four boundaries can be collected. Extension to boundaries more than four could not be possible due to time limitation. Another limitation is about the fact that the system could not be tested outside in a real world cadastral data collection environment due to lack of wireless internet connection.

6.3 Recommendations

For future work these recommendations are made:

- It was assumed in this work that both the spatial data collected and the existing data in the database has the same spatial coordinate system. In most cases spatial data collected with GPS is always in the World Geodetic System 1984 (WGS84) while cadastral spatial databases are in other coordinate systems. Further research should be made as to spatial data reference systems integration within the domain of cadastral spatial data collection with mobile GIS.

- This work did not look into the dissemination aspect of cadastral data after it has been maintained in the database. The research can be extended into how the the prototype can be employed to disseminate cadastral information.

- In the cadastral world, fixed and general boundary systems are implemented depending on the choice. These obviously go with required positional accuracies of parcels. Within this framework further research could be conducted in the light of web services in general and mobile GIS in particular.

- The system should be extended for collection of data for parcels which have more than four boundaries.
• Time constraints did not allow a user’s acceptance test to be performed for the mobile GIS cadastral data gathering and maintenance prototype system developed. It is recommended to be done.
Chapter 7

Bibliography


Appendix A

Visual basic scripts

A.1 Parcel transfer and User interface development codes

Option Explicit
Dim objSelLayer, objRS, objSH
Dim lngSHType, arrSys, intJ, DimobjPart
Dim objVertex, intI
Dim X(6), Y(6), I, X1, X2, X3
Dim X4, Y1, Y2, Y3, Y4, X5, Y5
Dim objEFPageOneControl
Dim objEFPagethreeControls, objEditForm
Dim ID, pclID, PclLocatn, Distr
Dim Sectn, objEFPagetwoControls
Dim Transactn, Street, Owner, Address
Dim objEFPagefourControls

Sub InitializeForm 'Do any form initialization in this sub
    Set objEditForm=ThisEvent.Object
    Set objEFPageOneControls=_
    objEditForm.Pages("PAGE1").Controls
    Set objEFPagetwo Controls=_
    objEditForm.Pages("PAGE2").Controls
    'Disable the Parcel ID edit box
    objEFPageOneControls("txtparcelID").Enabled = False
    'Initialization
    'for form when adding new records
    If objEditForm.Mode = 3 Then
        Dim objParcelRS Set objParcelRS = Layer.Records
        'Update the Parcel
objEFPageOneControls("txtparcelID").Value =_
ReturnNextID(objParcelRS, "ID")
'Add <NONE> to both comboboxes
objEFPageOneControls("comtransactn").AddItem -1, "<NONE>"
End If
'Free objects
Set objEFPageOneControls = Nothing
Set objEditForm = Nothing
Set objParcelRS = Nothing
End Sub

Function ReturnNextID (objRS, strFieldName
Dim intMax
objRS.MoveFirst
'Initialize the max value to the first record
intMax=CInt(objRS.Fields(strFieldName).Value)
Dim intCurrVal
While Not objRS.EOF
intCurrVal=CInt(objRS.Fields(strFieldName).Value)
If (intCurrVal>intMax) Then
intMax = intCurrVal
End If
objRS.MoveNext
Wend
ReturnNextID = intMax + 1
End Function

Sub Upload
Dim objNet, strURL, varData, objEditForm, lngSHType
Dim SelLyr, ShpRs
Dim ObjShp
Set objEFPageOneControls =
Layers("CadPcl").Forms("EDITFORM").Pages("PAGE1").Controls
Set objEFPagetwoControls = Layers("CadPcl").Forms_(_("EDITFORM")) Pages("PAGE2") . Controls
Set objEFPagethreeControls = Layers("CadPcl").Forms_(_("EDITFORM") ). Pages("PAGE3") . Controls
'If objEFPagethreeControls("txtx1").value = "" Then
'objEFPagethreeControls("butupload").Call = False
'MsgBox "Please click the GET_ 
COORDS button to get parcel coordinates"
'End If
Set SelLyr = Application.Map.SelectionLayer
'If Not SelLyr Is Nothing Then
'MsgBox "No feature is selected"
'Exit Sub
'End If
Set ShpRs = SelLyr.Records
Appendix A. Visual basic scripts

Set ObjShp = ShpRs.Fields.Shape
' Getting the data from the input form fields
pclID = objEFPageOneControls("txtparcelID").Value
PclLocatn = objEFPageOneControls("txtpcllocation").Value
Distr = objEFPageOneControls("comdistrict").Value
Sectn = objEFPageOneControls("comsection").Value
Transactn = objEFPageOneControls("comtransactn").Value
Street = objEFPagetwoControls("txtpclstreet").Value
Owner = objEFPagetwoControls("txtowner").Value
Address = objEFPagetwoControls("txtaddress").Value
X1 = objEFPagethreeControls("txtx1").Value
Y1 = objEFPagethreeControls("txty1").Value
X2 = objEFPagethreeControls("txtx2").Value
Y2 = objEFPagethreeControls("txty2").Value
X3 = objEFPagethreeControls("txtx3").Value
Y3 = objEFPagethreeControls("txty3").Value
X4 = objEFPagethreeControls("txtx4").Value
Y4 = objEFPagethreeControls("txty4").Value
X5 = objEFPagethreeControls("txtx5").Value
Y5 = objEFPagethreeControls("txty5").Value

' Creating INET object
Set objNet = Application.CreateAppObject("INET")
' creating URL to send to server
strURL = "http://geoserver.itc.nl/mobilecad_ /Insert_PclData.asp? pclID=" & pclID & "&PclLocatn=" & PclLocatn & "&Distr=" & Distr & "&Sectn=" & Sectn & "&Owner=" & Owner & "&Address=" & Address & "&Street=" & Street & "&Transactn=" & Transactn & "&X1=" & X1 & "&Y1=" & Y1 & "&X2=" & X2 & "&Y2=" & Y2 & "&X3=" & X3 & "&Y3=" & Y3 & "&X4=" & X4 & "&Y4=" & Y4 & "&X5=" & X5 & "&Y5=
MsgBox "Sending : " & strURL
' Display the host name in a messagebox
MsgBox objNet.HostName, vbOKOnly, "HostName"
varData = objNet.OpenURL(strURL)
' Display the data in a message box.
MsgBox varData, vbOKOnly, strURL
Set objNet = Nothing
End Sub

Sub GetPolygonCoords
' Dim objSelLayer, objRS, objSH, lngSHType
Dim arrSys, intJ, intI
' Dim objPart, objVertex
Set objSelLayer = Application.Map.SelectionLayer
' Get the selected feature’s geometric shape.
Set objRS = objSelLayer.Records

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A.1. Parcel transfer and User interface development codes

```vba
objRS.Bookmark = Application.Map.SelectionBookmark
Set objSH = objRS.Fields.Shape intJ = 1
For Each objPart in objSH.Parts
    MsgBox "Part " & intJ & " contains " & objPart.Count_ & " vertices.", vbOKOnly, "Vertex Count"
    intI = 1
    For Each objVertex in objPart
        Call PntInfo1(objVertex)
        intI = intI + 1
    Next
    intJ = intJ + 1
Next
Set objSH = Nothing Set objRS = Nothing
End Sub

Sub PntInfo1(objSH)
    X(intI) = objSH.X
    Y(intI) = objSH.Y
    MsgBox "The coordinate information for the current point or vertex is: " & _
        vbCrLf & X(1) & " , " & Y(1), vbCrLf & X(2) & " , " & Y(2), vbCrLf & X(3) & " , " & Y(3), vbCrLf & X(4) & " , " & Y(4), vbCrLf & X(5) & " , " & Y(5), vbOKOnly, _
    "Coordinate Information."
    Set objEFPagethreeControls = Layers("CadPcl").Forms("EDITFORM").Pages("PAGE3").Controls
    objEFPagethreeControls("txtx1").Value = X(1)
    objEFPagethreeControls("txty1").Value = Y(1)
    objEFPagethreeControls("txtx2").Value = X(2)
    objEFPagethreeControls("txty2").Value = Y(2)
    objEFPagethreeControls("txtx3").Value = X(3)
    objEFPagethreeControls("txty3").Value = Y(3)
    objEFPagethreeControls("txtx4").Value = X(4)
    objEFPagethreeControls("txty4").Value = Y(4)
    objEFPagethreeControls("txtx5").Value = X(5)
    objEFPagethreeControls("txty5").Value = Y(5)
End Sub

Sub UpdatePclData
    Dim objNet, strURL, varData, objEditForm, lngSHType
    Dim SelLyr, ShpRs, ObjShp
    Set objEFPagethreeControls = _
    Layers("CadPcl").Forms("EDITFORM").Pages("PAGE3").Controls
End Sub
```

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Appendix A. Visual basic scripts

Set objEFPagethreeControls = _
Layers("CadPcl").Forms("EDITFORM").Pages("PAGE3").Controls
Set objEFPagefourControls = _
Layers("CadPcl").Forms("EDITFORM").Pages("PAGE4").Controls
Set SelLyr = Application.Map.SelectionLayer
' If Not SelLyr Is Nothing Then ' MsgBox
"No feature is selected"
' Exit Sub
' End If
Set ShpRs = SelLyr.Records ShpRS.Bookmark = _
Application.Map.SelectionBookmark
Set ObjShp = ShpRs.Fields.Shape
' Getting the data from the input form fields
pclID=objEFPagefourControls("txtupdateid").Value
varDate=CDate(objEFPagetwoControls("txtdtpDate").Value)
PclLocatn=objEFPageOneControls("txtpcllocation").Value
Distr=objEFPageOneControls("comdistrict").Value
Sectn=objEFPageOneControls("comsection").Value
Transactn=objEFPageOneControls("comtransactn").Value
Street=objEFPageTwoControls("txtpcliststreet").Value
Owner=objEFPageTwoControls("txtowner").Value
Address=objEFPageTwoControls("txtaddress").Value
X1=objEFPageThreeControls("txtx1").Value
Y1=objEFPageThreeControls("txty1").Value
X2=objEFPageThreeControls("txtx2").Value
Y2=objEFPageThreeControls("txty2").Value
X3=objEFPageThreeControls("txtx3").Value
Y3=objEFPageThreeControls("txty3").Value
X4=objEFPageThreeControls("txtx4").Value
Y4=objEFPageThreeControls("txty4").Value
X5=objEFPageThreeControls("txtx5").Value
Y5=objEFPageThreeControls("txty5").Value
' Creating INET object Set objNet = Application.CreateAppObject("INET")
strURL=_"http://geoserver.itc.nl/mobilecad/_
UpdatePc1Data.asp?pclID="&pclID& "&PclLocatn="&PclLocatn&_ 
"&Distr="&Distr& "&Sectn="&Sectn& "&Owner="&Owner&_ 
"&Address="&Address&"&Street="&Street&"&Transactn="& 
"&X1="&X1&"&Y1="&Y1&"&X2="&X2& 
"&Y2="&Y2&"&X3="&X3&" &Y3="&X4&"&X4="&Y4& 
"&Y4="&X5&"&Y5="&Y5
MsgBox "Sending : " & strURL
' Display the host name in a message box
MsgBox objNet.HostName, vbOKOnly, "HostName"_
varData = objNet.OpenURL(strURL)
' Display the data in a message box.
A.1. Parcel transfer and User interface development codes

MsgBox varData, vbOKOnly, strURL
Set objNet = Nothing
End Sub

Sub VerifyLocation
If ThisEvent.Object.Value = vbNull Then
ThisEvent.Result = False
ThisEvent.MessageText = "Please enter LOCATION NAME"
ThisEvent.MessageType = 48
End If
End Sub

Sub VerifyDistr
If ThisEvent.Object.Value = vbNull Then
ThisEvent.Result = False
ThisEvent.MessageText = "Please enter DISTRICT NUMBER"
ThisEvent.MessageType = 48
End If
End Sub

Sub VerifySection
If ThisEvent.Object.Value = vbNull Then
ThisEvent.Result = False
ThisEvent.MessageText = "Please enter SECTION NUMBER"
ThisEvent.MessageType = 48
End If
End Sub

Sub VerifyTransaction
If ThisEvent.Object.Value = vbNull Then
ThisEvent.Result = False
ThisEvent.MessageText = "Please enter TRANSACTION TYPE"
ThisEvent.MessageType = 48
End If
End Sub

Sub VerifyStreet
If ThisEvent.Object.Value = vbNull Then
ThisEvent.Result = False
ThisEvent.MessageText = "Please enter STREET NAME"
ThisEvent.MessageType = 48
End If
End Sub

Sub VerifyOwner
If ThisEvent.Object.Value = vbNull Then
ThisEvent.Result=False
ThisEvent.MessageText = "Please enter OWNER’S NAME"
ThisEvent.MessageType = 48
End If
End Sub

Sub VerifyAddress
If ThisEvent.Object.Value = "" Then
ThisEvent.Result = False
ThisEvent.MessageText = "Please enter OWNER’S ADDRESS"
ThisEvent.MessageType = 48
End If
End Sub

A.2 Points transfer and User interface development codes

Option Explicit
Sub InitializeForm
' Do any form initialization in this sub
Dim objEFPageOneControls,
Dim objEFPageTwoControls objEditForm
Set objEditForm=ThisEvent.Object
Set objEFPageOneControls=objEditForm.Pages("PAGE1").Controls
' Initialization for form in any mode
' Disable the Point ID edit box
objEFPageOneControls("txtptID").Enabled = False
' Disable X Coord and Y Coord edit boxes
objEFPageOneControls("txtgpsx").Enabled = False
objEFPageOneControls("txtgpsy").Enabled = False
' enter coords into edit boxes
objEFPageoneControls("txtgpsx").Value=GPS.X
objEFPageoneControls("txtgpsy").Value=GPS.Y
' Initialization for form when adding new records
If objEditForm.Mode=3Then
Dim objRS
Set objRS = Layer.Records
' Update the Point ID objEFPageOneControls("txtptID").Value = _
ReturnNextID (objRS, "ID")
End If
' Free objects
Set objEFPageOneControls=Nothing
Set objEFPageTwoControls=Nothing
A.2. Points transfer and User interface development codes

Set objEditForm = Nothing
Set objRS = Nothing
End Sub

Function ReturnNextID (objRS, strFieldName)
Dim intMax
'Get the first record
objRS.MoveFirst
'Initialize the max value to the first record
intMax = CInt(objRS.Fields(strFieldName).Value)
Dim intCurrVal
While Not objRS.EOF
intCurrVal = CInt(objRS.Fields(strFieldName).Value)
If (intCurrVal > intMax) Then
intMax = intCurrVal
End If
objRS.MoveNext
Wend
ReturnNextID = intMax + 1
End Function

'Verify Point Num field Sub VerifyPointName If
ThisEvent.Object.Value = "" Then ThisEvent.Result = False
ThisEvent.MessageText = "Must enter value into Point Num field"
ThisEvent.MessageType = 48 End If End Sub

'Verify Parcel to which point belong’s field
Sub VerifyPointPclID
If ThisEvent.Object.Value = "" Then
ThisEvent.Result = False
ThisEvent.MessageText = "Must enter value into Point’s Parcel ID field"
thisEvent.MessageType = 48
End If
End Sub

Sub Upload
Dim Date, PtPclNam, GPSx, GPSy, PtNam, ID
Dim objNet, strURL, varData, objEditForm, varPtNam
Dim SelLyr, ShpRs, ObjShp, objEFPageOneControls
Set objEFPageOneControls =
    Layers("Recent").Forms("EDITFORM").Pages("PAGE1").Controls
Set SelLyr = Application.Map.SelectionLayer
Set ShpRs = SelLyr.Records
ShpRS.Bookmark = Application.Map.SelectionBookmark
Set ObjShp = ShpRs.Fields.Shape
Appendix A. Visual basic scripts

' Getting the data from the input form fields
ID = CInt(objEFPageOneControls("txtptID").Value)
'Date = CDate(objEFPageOneControls("dtpdate").Value)
PtNam = objEFPageOneControls("txtptname").Value
PtPclNam = objEFPageOneControls("txtptpclname").Value
GPSx = objEFPageOneControls("txtgpsx").Value
GPSy = objEFPageOneControls("txtgpsy").Value
'varSurveyorName =
objEFPageTwoControls("txtsurveyorname").Value
'varSurveyorQuali =
objEFPageTwoControls("txtsurveyorquali").Value
' Creating INET object
Set objNet = Application.CreateAppObject("INET")
' creating URL to send to server
strURL = "http://geoserver.itc.nl_
/mobilecad/Insert_data.asp?ID=" &ID & "&PtNam="_
&PtNam& "&PtPclNam=" &PtPclNam& "&GPSx=" &GPSx&_
"&GPSy=" &GPSy& "&X=" &ObjShp.X & "&Y=" &ObjShp.Y
MsgBox "Sending : " & strURL
' Display the host name in a message box MsgBox
objNet.HostName, vbOKOnly, "HostName"
varData = objNet.OpenURL(strURL)_
' Display the data in a message box.
MsgBox varData, vbOKOnly, strURL
Set objNet = Nothing
End Sub

Sub Update
Dim Date, PtPclNam, GPSx, GPSy, PtNam, ID
Dim objNet, strURL, varData, objEditForm, varPtNam
Dim SelLyr, ShpRs, ObjShp, objEFPageTwoControls
Dim objEFPageOneControls, objEFPageThreeControls

'Set objEFPageTwoControls =
Layers("Recent").Forms("EDITFORM").Pages("PAGE2").Controls
Set objEFPageOneControls =
Layers("Recent").Forms("EDITFORM").Pages("PAGE1").Controls
Set objEFPageThreeControls =
Layers("Recent").Forms("EDITFORM").Pages("PAGE3").Controls
Set SelLyr = Application.Map.SelectionLayer
Set ShpRs = SelLyr.Records
ShpRs.Bookmark = Application.Map.SelectionBookmark
Set ObjShp = ShpRs.Fields.Shape
' Getting the data from the input form fields
ID = CInt(objEFPageThreeControls("txtupdateID").Value)
'Date = CDate(objEFPageOneControls("dtpdate").Value)
PtNam = objEFPageOneControls("txtptname").Value
A.2. Points transfer and User interface development codes

PtPclNam = objEFPageOneControls("txtptpclname").Value
GPSx = objEFPageOneControls("txtgpsx").Value
GPSy = objEFPageOneControls("txtgpsy").Value
' Creating INET object
Set objNet = Application.CreateAppObject("INET")
strURL = "http://geoserver.itc.nl/mobilecad/
/Update_data.asp?ID=
&ID & "PtNam" &PtPclNam&_"&GPSx=" &GPSx&
"&GPSy" &GPSy& "&X" &ObjShp.X & "&Y" &ObjShp.Y
MsgBox "Sending : " & strURL_
box MsgBox objNet.HostName, vbOKOnly, "HostName"
varData = objNet.OpenURL(strURL) . MsgBox varData,_
vbOKOnly, strURL
Set objNet_= Nothing
End Sub
Appendix B

ASP JAVAScripts

B.1 'Insertdata.asp' codes

<%@Language="JAVAScript"%>

The data you sent is:
ID=<%= Request.QueryString("ID") %>;  
Pt NAME=<%= Request.QueryString("PtNam") %>;  
PT’s PCL NAME= <%= Request.QueryString("PtPclNam") %>;  
GPS X=<%= Request.QueryString("GPSx") %>;  
GPS Y=<%= Request.QueryString("GPSy") %>;  
X=<%= Request.QueryString("X") %>;  
Y=<%= Request.QueryString("Y") %>;  

<%  
ID= Request.Form("ID");  
PtNam= Request.Form("PtNam");  
PtPclNam=Request.Form("PtPclNam");  
GPSx=Request.Form("GPSx");  
GPSy=Request.Form("GPSy");  
X=Request.Form("X");  
Y=Request.Form("Y");  
conn = Server.CreateObject("ADODB.Connection");  
conn.ConnectionTimeout = 10; conn.CommandTimeout = 20;  
Rs=Server.CreateObject("ADODB.Recordset");  
conn.Open = "DRIVER={PostgreSQL Unicode};"  
conn.Open = "DRIVER={PostgreSQL Unicode};SERVER=localhost;DATABASE=mobilecad;Uid=mobilecad;PWD=ericus;OPTION=3;":  
SQLcmd = Server.CreateObject("ADODB.Command");  
SQLcmd.ActiveConnection = conn;  
ID = Request.QueryString("ID");  
PtNam=Request.QueryString("PtNam");
B.2 'Updatedata.asp' codes

```javascript
// The data you sent is:
ID=<%= Request.QueryString("ID") %>;  
PT NAME=<%= Request.QueryString("PtNam") %>; 
PT's PCL NAME= <%= Request.QueryString("PtPclNam") %>; 
GPS X= <%= Request.QueryString("GPSx") %>;   
GPS Y= <%= Request.QueryString("GPSy") %>;  
X= <%= Request.QueryString("X") %>; 
Y= <%= Request.QueryString("Y") %>; 

ID = Request.Form("ID");  
PtNam=Request.Form("PtNam");  
PtPclNam=Request.Form("PtPclNam");  
GPSx=Request.Form("GPSx");    
GPSy=Request.Form("GPSy");  
X=Request.Form("X"); 
Y=Request.Form("Y");  

conn = Server.CreateObject("ADODB.Connection"); 
conn.ConnectionTimeout = 10; 
conn.CommandTimeout=20; 
Rs=Server.CreateObject("ADODB.Recordset");  
conn.Open="DRIVER={PostgreSQL Unicode};SERVER=localhost;DATABASE=mobilecad;Uid=mobilecad;PWD=ericus;OPTION=3;"; 
SQLcmd=Server.CreateObject("ADODB.Command");  
SQLcmd.ActiveConnection=conn; 
ID=Request.QueryString("ID"); 
PtNam=Request.QueryString("PtNam"); 
PtPclNam=Request.QueryString("PtPclNam"); 
GPSx=Request.QueryString("GPSx"); 
GPSy=Request.QueryString("GPSy"); 
sql= "UPDATE recent5 SET pt_name='"+PtNam+"', pt_pcl_name='"+PtPclNam+"', _
 GeometryFromText('POINT("+ GPSx+" "+ GPSy +")', -1)"; _
SQLcmd.CommandText = sql; RecSet1 = SQLcmd.Execute(); _
```
Appendix B. ASP JAVAScripts

gpsx = "+GPSx+", gpsy = "+GPSy+", the_geom =_
GeometryFromText ("POINT (" +GPSx + " " +GPSy + ")", -1) _
WHERE id = "+ID++";
SQLcmd.CommandText = sql;
RecSet1 = SQLcmd.Execute;
%>

B.3 'InsertPclData.asp' codes

<%@Language=JavaScript%>

Parcel data uploaded to PostGIS/PostgreSQL database
PCL ID = <%= Request.QueryString("pclID") %>.
PCL LOCATN = <%= Request.QueryString("PclLocatn") %>.
DISTRICT NUM = <%= Request.QueryString("Distr") %>.
SECTION = <%= Request.QueryString("Sectn") %>.
OWNER NAME = <%= Request.QueryString("Owner") %>.
OWNER’S ADDRESS = <%= Request.QueryString("Address") %>.
PCL STREET NAME = <%= Request.QueryString("Street") %>.
TRANSACTN TYPE = <%= Request.QueryString("Transactn") %>.
X1= <%= Request.QueryString("X1") %>.
Y1= <%= Request.QueryString("Y1") %>.
X2= <%= Request.QueryString("X2") %>.
Y2= <%= Request.QueryString("Y2") %>.
X3= <%= Request.QueryString("X3") %>.
Y3= <%= Request.QueryString("Y3") %>.
X4= <%= Request.QueryString("X4") %>.
Y4= <%= Request.QueryString("Y4") %>.
X5= <%= Request.QueryString("X5") %>.
Y5= <%= Request.QueryString("Y5") %>.
<% pclID = Request.Form("pclID");
PclLocatn=Request.Form("PclLocatn");
Distr=Request.Form("Distr");
Sectn=Request.Form("Sectn");
Owner=Request.Form("Owner");
Address=Request.Form("Address");
Street=Request.Form("Street");
Transactn=Request.Form("Transactn");
X1=Request.Form("X1");
Y1=Request.Form("Y1");
X2=Request.Form("X2");
Y2=Request.Form("Y2");
X3=Request.Form("X3");
Y3=Request.Form("Y3");}
X4=Request.Form("X4");
Y4=Request.Form("Y4");
X5=Request.Form("X5");
Y5=Request.Form("Y5");
conn = Server.CreateObject("ADODB.Connection");
conn.ConnectionTimeout=10;
conn.CommandTimeout=20;
Rs=Server.CreateObject("ADODB.Recordset");
conn.Open="DRIVER={PostgreSQL Unicode};
SERVER=localhost;DATABASE=mobilecad;
Uid=mobilecad;PWD=ericus;
OPTION=3;";
SQLcmd=Server.CreateObject("ADODB.Command");
SQLcmd.ActiveConnection=conn;
pclID=Request.QueryString("pclID");
PclLocatn=Request.QueryString("PclLocatn");
Distr=Request.QueryString("Distr");
Sectn=Request.QueryString("Sectn");
Owner=Request.QueryString("Owner");
Address=Request.QueryString("Address");
Street=Request.QueryString("Street");
Transactn=Request.QueryString("Transactn");
X1=Request.QueryString("X1");
Y1=Request.QueryString("Y1");
X2=Request.QueryString("X2");
Y2=Request.QueryString("Y2");
X3=Request.QueryString("X3");
Y3=Request.QueryString("Y3");
X4=Request.QueryString("X4");
Y4=Request.QueryString("Y4");
X5=Request.QueryString("X5");
ysql="INSERT INTO cadparceldata2_ (id, pcl_locatn, distr_num, sectn_num, owner_name, owner_addr, pcl_str_na, pcl_transa, the_geom) VALUES ("+pclID+", "+PclLocatn+", "+Distr+", "+Sectn+", "+Transactn+", "+Street+", "+Owner+", "+Address+", GeometryFromText('MULTIPOLYGON(("+X1+" "+Y1+", "+X2+" "+Y2+", "+X3+" "+Y3+", "+X4+" "+Y4+", "+X5+" "+Y5+")))', -1 ));
SQLcmd.CommandText = sql;
RecSet1 = SQLcmd.Execute;

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\section*{2nd section here if any}
\section*{3rd section here if any}
\chapter{Name of appendix B here}
Appendix B. ASP JAVASCripts

B.4 'UpdatePclData.asp' codes

```jsp
<%@Language=JavaScript%>
The data you sent was:<p>
PCL ID= <%= Request.QueryString("pclID") %>.  
PCL LOCATN= <%= Request.QueryString("PclLocatn") %>.  
DISTRICT NUM= <%= Request.QueryString("Distr") %>.  
SECTION= <%= Request.QueryString("Sectn") %>.  
OWNER NAME= <%= Request.QueryString("Owner") %>.  
OWNER ADDRESS= <%= Request.QueryString("Address") %>.  
PCL STREET NAME= <%= Request.QueryString("Street") %>.  
TRANSACTN TYPE= <%= Request.QueryString("Transactn") %>.  
X1= <%= Request.QueryString("X1") %>.  
Y1= <%= Request.QueryString("Y1") %>.  
X2= <%= Request.QueryString("X2") %>.  
Y2= <%= Request.QueryString("Y2") %>.  
X3= <%= Request.QueryString("X3") %>.  
Y3= <%= Request.QueryString("Y3") %>.  
X4= <%= Request.QueryString("X4") %>.  
Y4= <%= Request.QueryString("Y4") %>.  
X5= Request.Form("X5");  
Y5= Request.Form("Y5");  
<%
pclID = Request.Form("pclID");  
PclLocatn=Request.Form("varPclLocatn");  
Distr=Request.Form("Distr");  
Sectn=Request.Form("Sectn");  
Owner=Request.Form("Owner");  
Address=Request.Form("Address");  
Street=Request.Form("Street");  
Transactn=Request.Form("Transactn");  
X1=Request.Form("X1");  
Y1=Request.Form("Y1");  
X2=Request.Form("X2");  
Y2=Request.Form("Y2");  
X3=Request.Form("X3");  
Y3=Request.Form("Y3");  
X4=Request.Form("X4");  
Y4=Request.Form("Y4");  
X5=Request.Form("X5");  
Y5=Request.Form("Y5");  
conn = Server.CreateObject("ADODB.Connection");  
conn.ConnectionTimeout = 10; conn.CommandTimeout=20;  
Rs=Server.CreateObject("ADODB.Recordset");  
conn.Open = "DRIVER={PostgreSQL
```
B.5 'UploadSQL.asp' codes

<%@Language=VBscript%>
<%
DIM WShell Response.Write "starting..." Set WShell = Server.CreateObject("WScript.Shell")
Response.Write "<p>alright until ere..." WShell.Run("D:\Inetpub\geoserver\mobilecad\ConvLoad2db.bat",1,True)
set WShell = nothing Response.Write "Points shapefile added to mobilecad"
%>
Appendix C

Batch scripts

C.1 ‘Transfer.bat’ commands

ftp -s:m:\config\Desktop\mobilecad\Transfer.bat open geoserver.itc.nl mobilecad ericus put m:\config\Desktop\batch\Points.dbf put m:\config\Desktop\batch\Points.shx put m:\config\Desktop\batch\Points.shp ls bye

C.2 ‘ConvLoad2db.bat’ commands

D:\mobilecad_batch\tools\shp2pgsql mobilecadpts.shp_ CadPtTable12 > cadpts12.sql | psql -d mobilecad -h pubnt03.itc.nl -f cadpts12.sql -U mobilecad
Appendix D

Testing

D.1 Developer’s test of prototype
D.1. Developer’s test of prototype

Figure D.1: Developer system functionality testing of prototype at open skies of central ITC building