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3D Visualisation in location-based services

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3D Visualisation in location-based services

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ABSTRACT

This research aims to increase insight in the development and application of 3d location-based services on handheld devices. The general research objective is: ‘To explore how a location-based application can be set up to support 3d visualization on a mobile computing device.’

Location-based applications use the geographical position of a device to deliver to add value to their functionality. The use of three dimensional (3d) visualisation can improve comprehension of objects or space. Navigation in such a visualisation can prove difficult especially on a mobile device where a mouse is usually not available. An auto navigating visualisation can solve this.

Software development is often prone to delay. To reduce the risk of this delay during development the Waterfall software development model is used allowing for a structured development. The model is sequential driven, this meaning that for a phase to be started all previous stages need to be finished completely. This allows each development stage to begin when all the necessary preparation is done. The development framework in which the software is developed is Microsoft’s .NET framework.

The applications requirements are amongst others: are a built in questioning system capable of rendering questions specific to a users position, an auto-navigating visualisation and an automated answering system capable of storing answers either on the XDA or online. The functional design comprises of three layers. The first layer, the application layer holds the application on the XDA. The second layer, the business layer holds a WWW-server supporting ASP.NET and the third, data layer. This layer, comprising of a SQL server, holds a database with the 3d data. Complex requests can be rendered by the WWW-server using ASP.NET and processed by the SQL server.
The implementation design is simplified to a two layer application. The business layer is not fully implemented; the application loads a web form when the answering function is pressed. The implemented positioning system uses a GPS receiver connected to the XDA for positioning.

The use of GPS for positioning is preferred because of its precision. Although a combination of a browser-based and a terminal based application is preferred a solely terminal-based pilot application is developed. The .Net compact framework has proven to be useful but does need third party solutions to implement the applications main elements.

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ACRONYMS AND DEFINITIONS

ASP.NET	Active Server Pages (Microsoft); server-side technology for dynamically-generated web pages. With full support for .NET languages such as Visual Basic .NET and C#.
Batch processing	the sequential execution of a series of programs (or ‘jobs’) on a computer [1].
CELL-ID	Cell Identity
CHTML	Compact HTML; a (fully compatible) subset of HTML and supported by Pocket Internet Explorer.
CPU	Central Processing Unit; the part of a computer that interprets and carries out the instructions contained in the software [1].
EGNOS	European geostationary navigation overlay system; developed to supplement the GPS system, increasing positioning reliability and accuracy to within 2 meters. It is similar to the North American WAAS and is scheduled to launch fully operational in 2005.
E-OTD	Enhanced Observed Time Difference
GPRS	General Packet Radio Service; a mobile communication technology designed tot transport data.
GPS	Global positioning system.
GSM	Global System for Mobile communications or Group Speciale Mobiles; standard for mobile phones.
GUI	Graphical User Interface; a method of interacting with a computer through a metaphor of direct manipulation of graphical images and widgets in addition to text [1].
HTTP	Hypertext Transfer Protocol; the commonly used way to transport information on the World Wide Web.
Kbps	kilobits per second; 1 kbps is equal to one thousand bits per second
Mbps	Megabits per second; 1 Mbps is equal to 1 million bits per second
MB	Megabyte; equal to 1024 bytes or 8192 bits.
NMEA-0183	a standard for data communication, for instance between a GPS receiver and a PDA, developed by the National Marine Electronics Association.
PDA	Personal digital assistant; a type of handheld computer.
Pocket PC	A special version of Microsoft’s Windows Compact Edition (Windows CE) enabled with cellular phone and text messaging features. There are three versions of Pocket PC 2000, 2002 and 2003.
RAM	Random Access Memory; is used to hold the program code and data during execution.

ROM	Read Only Memory; is used to store programs and cannot be written to as easily as RAM.
RS-232	Is a standard for serial binary data interchange commonly used in personal computer serial ports. It can for instance be used to interchange data with a GPS receiver.
SD card	Secure Digital card; a flash storage card
Time sharing	Time-sharing is an approach to interactive computing in which a single computer is used to provide apparently simultaneous interactive general-purpose computing to multiple users by sharing processor time
USB	Universal Serial Bus
VRML	Virtual Reality Modelling Language
WAP	Wireless Application Protocol; protocol using WML as its primary language
WAAS	Wide Area Augmentation System; developed to supplement the GPS system, increasing positioning reliability and accuracy both horizontally and vertically.
WML	Wireless Mark-up Language
XDA	eXtended Digital Assistant, brand name of O2. The XDA is a PDA that integrates a cell phone with GSM and GPRS connectivity.
X3D	the successor of VRML, ISO standard defined by the Web 3D Consortium

1 INTRODUCTION

1.1 CONTEXT AND BACKGROUND

In the early days of computing a user needed to be located physically near the computer to be able to use it. The computing resource could not be used by more than one user. Batch processing solved the latter problem but the user still needed to be near the computer resource to use it. With the introduction of time sharing it became possible to actually physically be somewhere else and still be able to use the computer resource. With the rise of conventional networking and local area networks the physical freedom became even larger. Enabling a large amount of computers, for instance on a university campus, to be connected to each other. However, there is still a limitation to these networks in terms of physical freedom. Therefore it seems only logical that computing evolves further bringing freedom to use of a computing device when and wherever users choose to [2]. Mobile networks can provide such freedom.

In the 1980's there were only local cellular solutions all using different techniques that made them incompatible. Facing an increasing internationalisation and an increasing demand for a single standard, the mobile network the Group Speciale Mobile was created by the 26 European mobile state companies in 1982. One of the cornerstones of GSM network is roaming, enabling a user to use his mobile device outside his own operator area. GSM was launched in 1992, already serving more than a million subscribers at the end of 1993. In 1995 the amount of customers had grown to 12 million spread over 86 countries [3]. The GSM standard enables the mobile phone manufacturers to earn back their research and development costs rapidly. This in turn pushes the development of phones with full colour screens, organisers and built in cameras. Modern mobile devices are starting to look like computers more and more [3].

While standards for mobile communication are proofing useful, a wide scalar of wireless standards are trying to fulfil the need to access information online without the need for cables. These wireless standards often use small networks that are wireless but not mobile. With the integration of wireless capabilities computing has entered the mobile domain. There is a difference between wireless and mobile the latter means that a device can be moved, or is not static. This doesn't mean that the device is necessarily wireless, many older PDA's need to be synchronized by use of a cable. On the other hand a wireless device such as a computer with a wireless LAN connection is not mobile either. The progression in computing and mobile and wireless networks as described above can be seen as steps in evolution in use of computing resources leading to freedom from collocation and a true flexible usage of computing devices, see figure 1 'The evolution of computing'.

The developments in computing and in mobile communication described above provide new opportunities to commercial enterprises and also to education. About 80% of fixed Internet users are also using mobile communications thus it can be expected that they also want to get these services on their mobile devices [4]. In combination with Internet mobile and wireless technology gains even more potential. Wireless (and mobile) services are also appealing to education. *'Mobile computing devices and wireless internet promise to revolutionise the delivery of educational materials' [5]*. Wireless and mobile services can for example provide additional information during fieldwork assignments. The possibilities of mobile and wireless learning have been tested extensively [6, 7].

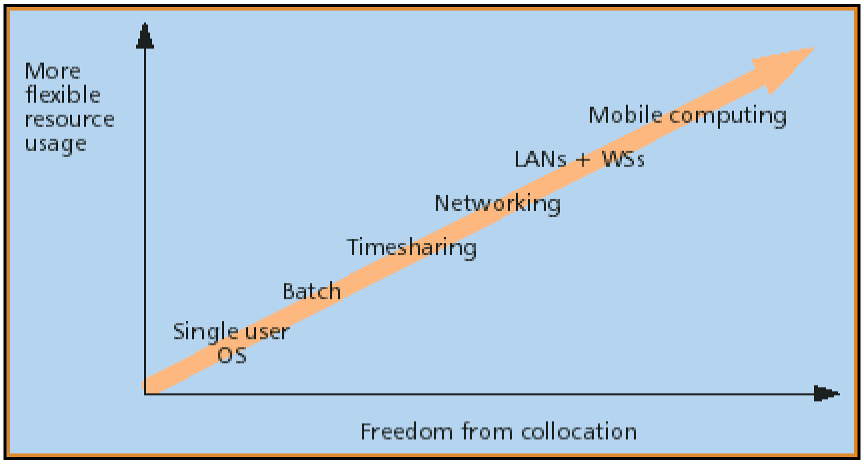

Figure 1 the evolution of computing

Fieldwork is often seen as the ultimate form of education [8]. Mobile services can provide a student with location based information or can provide a connection with the teacher who is located at another place. But location based services can also provide a way to register data digitally during the fieldwork. PDA's provide several advantages to education by providing a motivational stimulus, offering ease of storage and portability contributing to improved written work. Furthermore PDA's make it easier to produce written work, increase knowledge of computers and are readily available anytime, anywhere. A comprehensive literature review in m-learning is done by Saville-Smith and Kent [7].

1.2 PROBLEM DEFINITION

In 2004 the Vrije Unversiteit Amsterdam and Wageningen University started a joined project called MANOLO [9]. One of the main goals of the project is the use of digital media, especially w- and m-learning, to support communication and community-forming in the digital learning environment. One of the way's to achieve this main goal is by the development of examples of w- and m-learning applications.

As part of a course, students are taking inquiries to collect resident's opinion about planned changes in their surroundings. The inquiries are performed by filling out a questionnaire. The planned changes are shown to the residents through photo prints showing the landscape after the planned changes. This methodology has several disadvantages. Photos are showing the changes from a fixed position and angle. In this way it is often hard for a resident to interpret the changes shown on the photos. And because the photos are static it is impossible to choose which view the image shows while each resident will often have his own preferences.

What is needed is a visualisation able to optimise a view for each user. In other words a viewer that is capable of showing a visualisation from different perspectives. One of the basic limitations of photo's is that they display a two dimensional (2d) view. The objects or landscapes and the planned changes are three dimensional (3d). A 3d view display increases perception, this is especially useful when changes are complex and hard to imagine for an inhabitant. 3D views enable more realistic representations of changes. In the case where inhabitants are confronted with future development plans of their surroundings existing objects that will not change can help orientation in view. A location aware (or location-based) 3d visualisation can combines the advantages of a three dimensional visualisation with the position of the device it is shown on [10, 11].

Because students need to take inquiries in the field the three dimensional visualisation needs to be shown on a mobile device. There is currently no location-based service available able to render 3d maps on some sort of handheld device. A handheld device can either be a PDA, mobile phone or a tablet pc. To make it even easier to interpret the 3d visualisation, the location-based service can be fitted with orientation awareness. This is awareness of the compass direction to which the projecting device is held. In this way the resident can look at the current situation and the 3d visualisation from different directions and from different positions without the need to navigate on the visualisation.

1.3 RESEARCH OBJECTIVE

The general research objective is:

'To explore how a location-based application can be set up to support 3d visualisation on a mobile computing device.'

The general research objective is divided into research questions:

1. What components of the location-based application are desired?
2. What type of application can be used best to set up this location-based application?
3. How can an application that contains part of the components from the first research question be implemented?
4. How can the application, resulting from the third research question be tested to asses to what extent it offers the desired components?

1.4 REPORT OUTLINE

Due to the large technology and terms used in this report a list of of abbreviations and acronyms is preceding the first chapter.

In chapter two ‘Theory’ location-based services are further explained a definition is chosen and the influence of law on this kind of services is explained. Also several positioning techniques and mobile networks are treated. A basic introduction in 3d visualisation is given by the final paragraph.

Chapter three ‘Methodology’ explains what challenges are present in development of mobile applications, a software development is adapted and the framework in which the design and implementation will take place is described. Finally two types of applications are explained and compared.

In chapter four ‘Design’ a list of requirements to the location-based application is given and a functional design is given. The following paragraphs introduce the hardware available to the study. Two 3d viewers are compared to choose one that can be used by the application. The available data is also discussed.

Chapter five ‘Implementation design and testing’ starts with an overview of all features that will be implemented in the pilot application. The implementation is presented and its use is explained. And finally the test results are discussed.

The sixth and last chapter the results are discussed, conclusions and recommendations are given.

2 THEORY

To be able to answer the research questions, the concept of a location-based service needs to be clear. Therefore an introduction of location-based services is given including some application examples. A definition for location-based services is adopted. European law dictating what location-based services can and cannot do is explained. Location-based services rely on geographical information and uses positioning techniques to acquire this information, some of these techniques are treated in paragraph 2.2. Mobile networks are often used to access data or to enable positioning techniques; several generations of mobile networks and different techniques are discussed in paragraph three. Finally in paragraph four discusses 3d visualisation with special emphasis on its use on mobile devices also several 3d standards are discussed.

2.1 INTRODUCTION

2.1.1 Description

Location-based services may be new to the public, but with the completion of the United States Defence GPS network in the 1970's, the first of these services were in use already. When the U.S. government decided to permit free use of the network in the 1980's the first GPS receivers started to become available to other industries. These location-based applications were mostly positioning services.

With the advent of location-based functionality computer programs become aware of the users geographical location. This knowledge can be used to provide a service tailored to the user's position without interference of the user. The in-car route planner is probably the most used location-based service. However there are many more services that call benefit from location awareness to improve there service level. In the United States emergency services use an auto tracking service to locate people that can the emergency services. Transport companies started to use location-based services to track cargo and to locate trucks. Location-based services use location information to provide a better service to its users.

Location-based services come in different shapes and sizes. There are different way's to classify a location-based service. A location-based service can be person oriented or device oriented. When it is a person oriented service, it is designed to enhance a specific service by knowing the users geographical position. A device oriented location-based service can be oriented on the user's position but doesn't have to. It can for instance be a cargo tracking application or a friend finder application that tracks a friend's position.

Another way to classify location-based services is in push and pull services. A push service gives information to its users without the user's direct request for it. For instance a notification of a diner's coffee discount when a user approaches its vicinity or a notification of an approaching friend. A pull service requires the users active request for information that is enhanced with the users position, for instance a request to find the nearest diner [12]. Because a location-based service adds location awareness to a service it is not likely to become a separate service category but rather an extra feature of existing services. Table 1 gives an overview of different locations-based services.

Table 1 Overview of location-based services [13]

Trigger services e-commerce, payment information, Advertising	**Tracking and monitoring** Routing Navigation proximity
Location-based information Fleet management Asset tracking People finding LB tracking games	**Assistance services** Emergency Roadside assistance Health care

2.1.2 Defining location-based services

Due to its diver's nature the concept of a location-based service knows many definitions. Because the main objective of this research is to explore how a location-based service can be set up, there is a need for a clear definition used in this research. Schiller and Voisard [12] define location services as: *'Services that integrate a mobile device's location or position with other information so as to provide added value to a user.'* This is a clear but general description of location (based) services. Smith, Kealy and Williamson [14] make a distinction between location services and location-based applications: *'Location services deliver information about the geographic location of mobile telecommunications devices. This includes mobile telephones, mobile interactive browsers and devices attached to other moveable items such as people, packages and vehicles. Location based services deliver end-user applications based on location services.'* This definition enables a more clear delineation of the goals of this research; therefore it will serve as definition for location-based services throughout this study.

2.1.3 Location-based services and privacy regulations

When a person calls an emergency number a mobile phone is often used. Because of the emergency and the fact that the caller did not plan to make the call it is can be hard to establish the exact location of the caller. Because of this the US Federal Communications Commission (FCC) obligated wireless carriers to provide the callers location in 911 emergency calls. The European Union with an even higher percentage of mobile phone calls to emergency services did not follow in this approach. The possibility to localize mobile phone users opens the possibility to location-based spam on mobile phones. The concern is a spamming problem on the mobile network similar to the spamming problem currently experienced on the internet. Because of this the use of location data is regulated a EU directive on Privacy and Electronic Communications [12]. In the EU location data may only be processed anonymous or with the consent of the user for the duration necessary for the provision of the service. Also the location service must inform the user, what kind of location data will be processed and whether it will be transmitted to a third party. Users need to be able to withdraw from the service at any time. And users need to be able to refuse the service for each connection to the network [15].

2.2 POSITIONING TECHNIQUES

There are several technologies that can determine the position of a mobile device. They can be divided into two groups; network based and handset based. In network based positioning the mobile network determines the position of the mobile device and handset based techniques rely on handsets or mobile devices to determine the position. A combination of both handset and network based technology is also possible. The main positioning techniques are discussed in the following paragraphs.

2.2.1 Cell-ID

Cell identity in short Cell-ID is a network based positioning system. It determines in which cell the device is within the wireless network it's used in, see figure 11 'Cell-ID positioning system'. The boundaries of a cell are made up of base stations that have a known and fixed position.

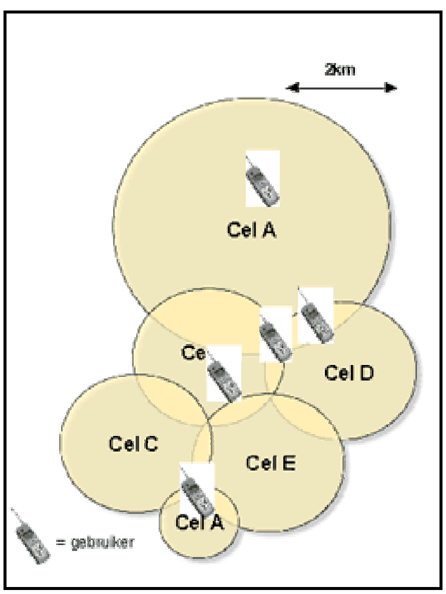

Figure 2 Cell-ID positioning system [16]

This positioning technique is easy to implement for mobile operators and does not require an upgrade of the network. The downside of this technique is its accuracy. The diameter of a cell ranges from several hundreds of meters in urban areas to three kilometres in agricultural areas. Sometimes a cell can be divided into sections enabling a reduced cell size of up to two thirds. This however requires a high density of base stations which can be found in for instance built up areas. A more accurate position can be determined when Timing Advanced is used. The technique uses the roundtrip time of a signal from a base station to a phone and back, to calculate a more precise position. However timing advance needs a mobile positioning centre such as Microsoft's Mappoint location server.

2.2.2 Time Of Arrival (TOA)

Time of arrival provides higher accuracy than Cell-ID discussed in the last paragraph. It uses several base stations to determine a mobile phone's position. Each available base station calculates the time it takes to receive a signal form the mobile phone. By using the known coordinates of the base stations in combination with the calculated distances a position can be calculated through triangulation. This requires the base stations to be synchronised which can be expensive because it requires each base stations to be fitted with an atomic clock or GPS. This does not require any changes to current mobile phones and reaches an accuracy of about 50 meters in urban areas and 150 meters in rural areas.

2.2.3 Enhanced Observed Time Difference (E-OTD)

E-OTD is a handset based technique; it records the roundtrip time similar to TOA. The difference is that the signal originates at the handset and the calculations are also performed by the mobile device. The base stations need to provide a very accurate time in their response and at least three base stations need to be available in order to get an accurate positioning. The accuracy of this positioning technique is fifty to a hundred fifty meters similar to TOA. This technique is simpler to implement for carriers because it requires less adoptions to the network, also mobile devices require little modification. An advantage to this technique compared to GPS is that it can be used indoors [16, 17].

2.2.4 Global Positioning System (GPS)

GPS is the most precise handset based technology. The GPS system uses satellites that orbit the earth to send signals to a so-called GPS enabled receiver. Signals of at least three satellites are needed to calculate a position through triangulation.

The GPS receiver needs a line of sight with the satellites to receive their signal without disturbances. The signal of GPS satellites is too weak to penetrate buildings, restricting it's usage to outside buildings. When a GPS signal bounces on a building and reaches a GPS receiver the receiver calculates a wrong position.

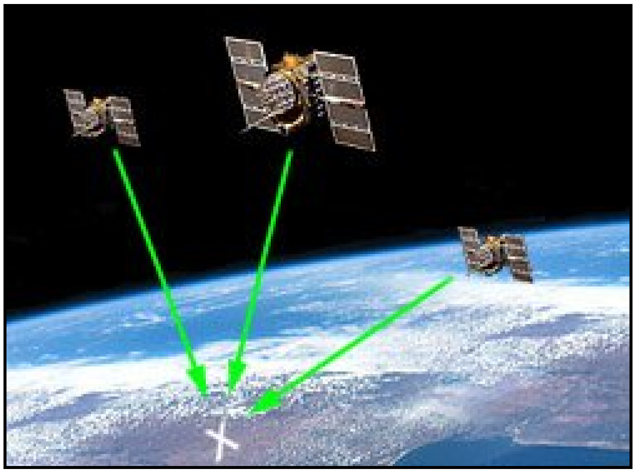

Figure 3 GPS positioning [18]

This is why GPS tends to become less reliable close to high buildings. This is a major drawback of the GPS technology. The calculations of a position with a GPS receiver require considerable processing power. Therefore GPS receivers are often separate units with their own power supply. The general accuracy of a GPS receiver is about five to forty meters, depending on location conditions like weather and the amount of urbanisation where it is used. A higher accuracy can be reached when the receiver is enabled with EGNOS. This European technology, similar to WAAS used in North America increases the accuracy and reliability of a GPS signal. A GPS receiver using EGNOS can reach accuracy within than 3 meters. GPS can also be used in combination with all of the positioning techniques above; this can reduce the start up time of the GPS receiver witch can take up to two minutes. It can also help to lower the GPS's sensitivity to atmospheric disturbances of the GPS signal [17, 19, 20].

2.2.5 Suitability

The use of Cell-ID in combination with a mobile device requires no additional hardware and because the positioning technique is network based it does not put a strain on the devices CPU however it isn't accurate very accurate. TOA and E-OTD are more accurate but still not nearly accurate enough to be useful in the application. The use of GPS requires either a GPS receiver connected to mobile device, or a device with a built in GPS receiver. Besides the higher investment costs for equipment the GPS technology delivers a much higher accuracy. Because the location-based application developed in this research requires high accuracy a GPS receiver will be used to determine the PDA's position.

2.3 MOBILE NETWORKS

This paragraph gives an overview of the different mobile networks and their advantages and disadvantages when used with location-based services. GSM is the most widely used cellular network at this moment and is a second generation network. Before GSM there were several analogue mobile networks. GSM is designed for use as a phone network with a constant data stream used needed with voice communication.

2.3.1 General Packet Radio Service (GPRS)

With the rise of mobile internet and mobile data services, the need for packet data is growing. One of the major advantages for carriers is that data packets allow a more efficient use of the mobile network. Several users can use one data channel and one user can receive data over several channels. In contrast to a stream network where one user requires one channel. GPRS is an example of a 2.5 generation network using data packets. It delivers data transfer rates ten times higher then conventional network up to 144kbps. It must be said though that 144kbps is a theoretical speed in practice a 20-40kbps is reached, which is still much faster than GSM. The advantage of 2.5 generation networks is that they require little physical network upgrades. An attractive aspect for the user is that GPRS allows the mobile device to be connected always. With GSM the charged fee is calculated based on connection time while with GPRS the amount of used data.

2.3.2 Enhanced Data rates (EDGE)

EDGE stands for Enhanced Data rates for GSM Evolution. This technology can be implemented in existing GSM networks and only requires changes to the base stations not to mobile devices. It can be implemented as Enhanced GPRS with speeds from 60Kbps up to 384Kbps but also on GSM networks that do not use GPRS. EDGE can be seen as interim upgrade of existing GSM and GPRS networks until UMTS (see 2.3.5) is introduced. Many operators do not use this technology because UMTS is already being implemented or it is used to complete UMTS coverage in rural areas.

2.3.5 Universal Mobile Telephone Service (UMTS)

UMTS or is a third generation mobile system. The implementation requires a new network witch is currently being deployed in the Netherlands. The system is designed to deliver data at speeds up to 2MBps theoretically. When UMTS was tested it soon appeared that he theoretical speeds where impossible to reach when the network was used intensively. In practice a speed varying from 150 to 384Kbps can be expected. This allows for instance videophone connections but is much lower than the originally anticipated 2Mbps. A new technique called HSDPA or High Speed Downlink Packet Access is capable of increasing UMTS, allowing for an upgrade to theoretical speeds up to 8-10 Mbps. In practice a transfer speed between 400Kbps and 600Kbps is expected [21].

2.4 3D VISUALISATION

In a three dimensional (3d) visualisation geometric shapes can be shown in all three dimensions like in reality. This enables better comprehension of shapes compared to when a 2d visualisation is used. In the past years the use of three dimensional visualisations has been adopted by in applications on desktop computers. They can now be found in games, maps and even electronic ads. It can be especially useful to use 3d visualisation when the interpretation of an object or space is required. For instance to show a construction design of a building or bridge or even a ski slope. On mobile devices the use of three dimensional visualisations is not very common yet. The hardware and software possibilities of mobile device tend to stay behind roughly half a decade. The screen resolution of mobile devices is much lower than that of a desktop pc, which results in a lower demand for hardware speed. Still the lack of an embedded processor with 3d capabilities can limit the mobile device's visualisation capabilities severely depending on the 3d technology used. A lack of RAM memory needed to render a 3d visualisation is also often a limiting factor [22]. There are several ways' to render a 3d visualisation all with different advantages and disadvantages. The next section discusses the most often used technologies.

VRML is a text based modelling language, this means that it can be written and changed in any text editor. VRML does not store pixel and colour data but uses text instead to describe objects. Compiling is not necessary and libraries used with programming languages neither. The VRML viewers can interpret a VRML file directly. VRML is an ISO standard for describing 3d objects and worlds. The specification is being developed by the Web3D Consortium. In video pictures are stored separately in so called frames, these frames are shown at a high rate giving a fluent playing effect. VRML does not work the same; it stores information about objects and constructs a scene when a viewer's eye point (looking direction) is aiming at it.

VRML files are made up by objects who are defined by there edges in points. These points are distributed in a three dimensional space. The width of an object is defined by the x-axis, the height by the y-axis and the depth by the z-axis. The points are linked together by lines forming a wire frame. These frames can then get a surface also called skin in different colours ore textures. Objects can emit light or be lit by a light source. When a source needs to be lit it must also be shaded witch is computational the most demanding part.

When certain geometric objects are used several times in a visualisation, for instance a tree, VRML offers the option to define just one object and create several instances of it. This helps to create a more efficient model and safes space when running the visualisation. VRML models exported from CAD programs often do not implement this feature. This results in a higher less efficient (in space) VRML file.
The newest 3d specification of the Web3D Consortium is called X3D. This successor of VRML is an open standard 3D file format. It is available for all computer platforms and is compatible with VRML75 and offers much more functionality.
Java 3D is developed by SUN Microsystems, it is not a text based modelling language like VRML. It is a collection of Java classes and requires the Java 2 runtime and a plug-in to display in a web browser but it can also be embedded in an application.
Java3D is more complex than VRML and not as easy to learn but can be used to create more complex models. Therefore it is sometimes best to use both language and

combine them. For simple applications VRML can be used best and for more complex models Java3D [22, 23].

3 METHODOLOGY

3.1 CHALLENGES OF WIRELESS APPLICATIONS

In software engineering projects it is not uncommon that timetables are exceeded with 50-80% of the planned time [24]. Therefore a structured approach in the development of an application is essential. This especially applies to wireless applications because developers have to deal with a number of challenges that make it extra difficult to create an application that earns back its developments costs. The network coverage is not a hundred percent and network signal can be lost due to all kinds of factors such as tunnels, buildings etc. The speed of wireless networks is often a limiting factor with newer networks just exceeding a bandwidth of 56 kbps. During peak periods of usage a server can take time to receive and react to a request slowing an application down further. Costs of wireless connectivity are still high compared to pc internet connections which can make applications less attractive to use. There are several types of devices (e.g. smart phones, PDA's etc.) using different protocols (WAP, WML, CHTML etc.) on different platforms (Symbian, Windows CE etc.). This makes it difficult to develop an application that targets al wireless devices. Therefore applications are often only capable of reaching a part of its potential users [19].

3.2 SOFTWARE DEVELOPMENT

To develop software applications in a more structured way a software development model can be used. The use of such a model makes sure that the right processes are done at the right time[1]. The model used in this study is often called 'Waterfall model' but sometimes referred to as 'linear sequential model' or 'the software life cycle'.
The Waterfall model describes software development in a number of phases, see figure 3 'Waterfall software development model'. An explanation of the model will be given below [25, 26].

[1] There are many different software development models such as: V-model, the Spiral model, staged delivery model and so on. Lenz and Moeller give a comprehensive overview of software development models used in .NET application development [26].
There is no perfect model that suits every development project and there are many models. In this study the Waterfall software development model is used. A number of aspects return in each software development project. A software development model can be used as a guideline to develop software in a way that makes sure that al necessary aspects are dealt with and are dealt with at the right phase of the project. It is applied to make sure that the application serves its intended purpose without exceeding available development time and budget. By dealing with the right aspects of software development at the right time the amount of occurring problems can be reduced.

In its first phase, the Concept phase, the goals and limitations of a software development project are discussed. In the first chapter in the problem definition it becomes clear what purpose the application should serve. In the second chapter the concept of location-based services is further explained to delineate the type of technologies available to the application.

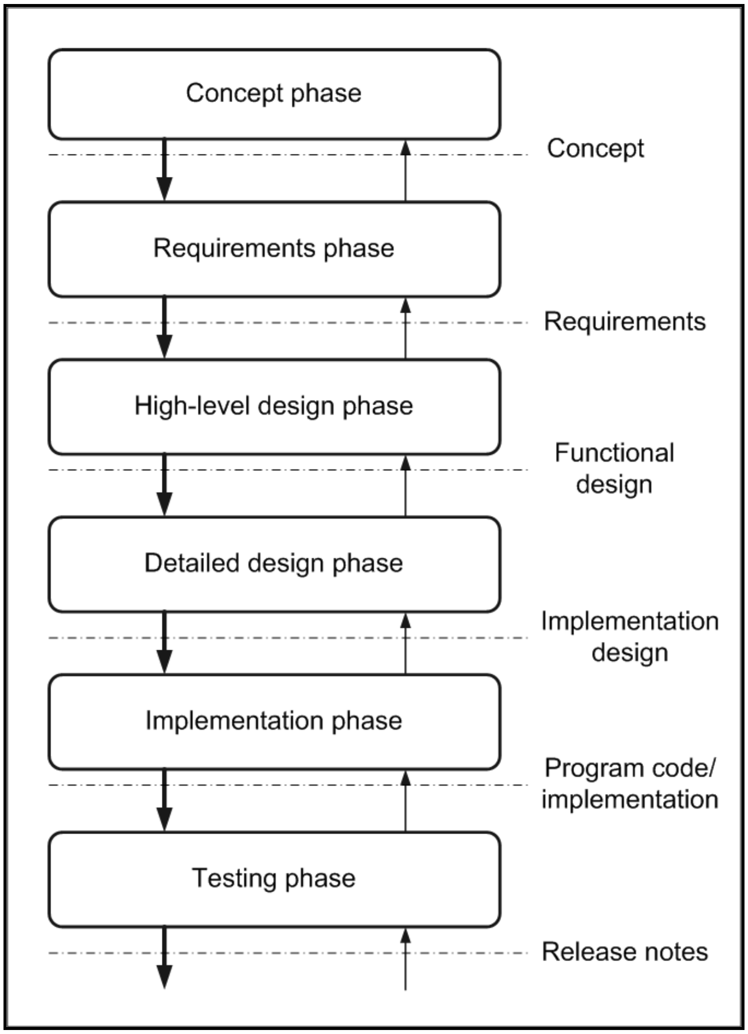

Figure 4 Waterfall software development model, adapted from Lenz and Moeller [26]

In the second phase, the Requirements phase the applications requirements are discussed. The technology that will be used is treated here and the limitations of the proposed technology are discussed. Chapter three discusses some challenges faced in the design of wireless applications in the first paragraph of chapter three. It discusses the development platform in which the application will be designed discussing its advantages and disadvantages. And finally in paragraph four of chapter three two types of applications; browser-based and terminal-based applications are explained and compared. In the first paragraph of chapter four user requirements for the application are discussed.

The third phase is the High-level design phase. In this phase a first design of the application is made. This design shows the technology that can be used, so frameworks and platforms can be found in this design. From the design it becomes clear how the application is built up and, how will be running on the clients computer and if it used external sources to function or not. The functional design can be found in chapter four paragraph two.

The fourth phase, the detailed design phase specifies all parts of the high level design. It does so without showing any code. This is where the application prototype design is constructed. First the hardware available to this study is discussed, then several mobile 3d viewers able to run on the available hardware are discussed, compared and a viewer is picked. The 3d viewer is essential to enable the application with three dimensional visualisation rendering capabilities. In 4.5 the available 3d visualisation is discussed and in 5.1 the Implemented features are discussed

The fifth phase is the Code implementation phase. Here a prototype application is developed to test a number of the functionalities proposed in the design phase. When all the previous phases have been completed well the coding should normally not result in much problems. Code error checking in individual components is also performed in this phase. The prototype is discussed in the second paragraph of chapter five and code examples can be found in the appendixes.

The sixth and last phase is the Test phase. The entire application is now running and will be tested for errors. In this phase it becomes clear if all the components of the applications work well together. The application is used in the field and is tested for errors, the results of this testing is described in the third paragraph of chapter five and leads to recommendations that can be found in chapter six, third paragraph.

The Waterfall model is a so-called sequential driven method. This means that, to be able to begin a new phase in the model the previous phase needs to be completed. Although the Waterfall model is widely used, it has been criticized often. For instance, in a software development project it is not always clear what all of the requirements are at the moment the technical design is finished. So when requirements change during the test phase not only the requirements phase needs to be adjusted and reassessed, all subsequent phases until the test phase need to done again also. Every phase in the model receives feedback from its subsequent phase.

3.3 .NET AND .NET COMPACT FRAMEWORK

The location-based service will be implemented in Microsoft's .NET framework. This implicates several advantages but also limitations concerning with respect to the use of 3d viewers, programming languages etc. This paragraph explains what the .NET framework is and how it will affect the location-based service design in chapter four and the prototype application in chapter five.

3.3.1 .NET framework

Microsoft .Net or the .NET framework was first launched in 2000. Wikipedia (2004) defines .NET as: "… *a Microsoft project to create a new software development platform focused on network transparency, platform independence, and rapid application development"* [1]. The main strategy of the .NET framework is to enable software as a service. It is an operating system platform that incorporates applications, a suite of tools and services and a change in the infrastructure of the company's Web strategy. The .NET framework simplifies Windows software development by enabling developers to build both desktop applications and Web-based applications with a single approach. It enables developers to use the same tools and skills to develop software for a variety of different systems like handheld smart phones and servers.

The .NET framework consists of two main parts: the common language runtime (CLR) and the .NET framework class library. Several major programming languages, such as C#, C and Visual Basic are supported by the .NET framework. A program can be written in one or several of these languages and then automatically converted to the CLR which serves as an intermediate language for all .NET languages. The CLR handles memory management, error handling and security management. Therefore the programming doesn't need to focus on these issues anymore [27, 28]. The .NET framework class library is made up of three main components:

1. ASP.NET helps with build Web applications and Web services
2. Windows Forms facilitates smart client user interface development
3. ADO.NET helps to connect applications to databases

The class library is a collection of reusable classes that can be used to perform most programming jobs.

3.3.2 .NET compact framework

The .NET framework is too large to run on most mobile devices. Therefore a small .NET compliant framework has been developed by Microsoft. It is called the .NET Compact Framework or in short .NET cf and is a subset of the .NET Framework. Before the .NET cf development, for instance on the Windows CE platform, used to require different tools and programming techniques than when programming a for the Windows PC platform. to some extent this is no longer the case in .NET [29]. The .NET cf can be installed on Windows Pocket PC and Windows CE. It is embedded in Windows Pocket PC 2003 and higher. The .NET cf is significantly smaller than the .NET framework with a footprint of about two MB's. This smaller size is reached by the omission of 4700 of the total of 6000 types that are available in the .NET framework. This of course has its impact on the functionalities that are available to the development of applications in the .NET compact framework.

3.4 BROWSER-BASED VERSUS TERMINAL-BASED APPLICATIONS

There are several types of applications with different advantages and disadvantages. The type of application that can be used best differs from case to case. This paragraph serves to give insight in the possibilities to enable a conscious choice for a type of application during application design.

Applications for mobile devices can be browser-based or terminal-based. The browser based application is also called a thin application, while the terminal based application is called a thick application. These names refer to the ability of a developer to change the graphical user interface (GUI) and functionality. A browser-based application uses the browser of the mobile device. The main characteristic of a browser-based application is that it requires no installation and therefore no distribution of software. It runs on the browser. Upgrading the software can be done by upgrading the server. Because the application runs on the browser which makes it platform independent. Browser-based applications execute little code on the mobile device; most of the code is executed on the server side. The speed of the connection and of the server is important to speed of the application. The downside of browser-based applications can be that the limitations of the browser are the limitations of the application. This means that there is for instance not much storage space on the device and there are no possibilities to move graphics

A terminal-based application needs to install software first to be able to function. The download can commence on a browser, for instance trough a webpage. But the application runs on the devices platform not in the browser. Terminal-based applications can execute code on the server but also on the terminal, in this case the mobile device. Software updates need to be distributed and can therefore not be implemented for all users at the same time. This leaves the possibility of several versions of the application existing at the same time, which in turn can complicate the management of the software on the server side [19, 21].

A hybrid application combination with both terminal based and browser-based features is also possible. To view help files the browser can be invokes to display the help menu. The advantage is that help files can be updated in HTML with the need to change code. The HTML can be installed with the program or be located at a HTTP address. The limitations of a browser can be solved for a part by using Active Server Pages (ASP) which enables execution of for instance Visual Basic code server side.

4 DESIGN

The potential user group of the application, as discussed in the first chapter, comprises of Wageningen University students. These students fill out questionnaires with inhabitants of areas that are subject to town and country planning changes. This specific use results in several demands towards the application. The requirements or functionalities for the location-based service are summed up and discussed in the first paragraph. This results in a functional design that is able to comply with the demands which is presented and explained in the second paragraph. The hardware available to this study is discussed in the third paragraph. 3D viewers available for the Pocket PC's are discussed in the fourth paragraph to enable selection of a most suitable viewer. Finally the available 3d model needed to test the application is discussed in paragraph five.

4.1 REQUIREMENTS

The applications users do not have any specific knowledge or experience in working with a PDA, location-based services or GPS. Therefore the application needs to work intuitively. In other words, the users need to be able to use the application with little to no explanation. Where explanation is needed the application should provide it. A location-based application can have many embedded functions adding to its functionality and importance. There are a number of possible functionalities that might be considered in the application, they are summed up below in a number of categories. The functionalities that will be implemented into the concept application will be discussed in 4.5 'Implementation'.

4.1.1 Positioning

From a users perspective a real-time 3d visualization is preferred. Lower refresh rates will make it harder to interpret the 3d visualisation.
A built in questionnaire combined with the 3d visualisation implemented by use of location specific questions is desirable. This means that questions or notifications that pop up when the user is at a specific position

4.1.2 Mobility

A wireless connection can be lost due to circumstances. The application should automatically reconnect when a server connection is lost.
Internet based functionality allows for application updates to be downloaded and installed (automatically) and immediate access to newly available datasets.

4.1.3 Visualisation

The possibility to look at any direction, including up and down, with the 3d visualization following each movement which replacing manual navigation.
An option to shift from the user's position to a 'bird's eye' view. With this is meant a viewing position at 10-20 meters height that matches the user's horizontal position.
A zoom function enabling a user to decide how far he can look into the 3d visualization

4.1.4 Hardware and software

The ability to automatically download and install the application from a website.
Automated storage of a users answer, using the keyboard or audio memo function, in a (remote) database.
User anticipation, loading new 3d data before a user reaches a new position that requires new data to reduce waiting time during use of the application.

4.2 FUNCTIONAL DESIGN

Provided that there are no obstacles in development and hardware resources a functional design of the application can be made. Ideally the application uses an internet server to request the 3d visualisation from the data server. This enables data flexible updates and the program requires minimal space on the mobile device. The internet server uses ASP.NET to allow more complex requests from the data server, this approach helps to keep a low CPU demand on the mobile device running the 3D location-based application. The design showing this implementation is shown below. To enable .NET technology on a Pocket PC 2002 platform the .NET compact framework needs to be installed. On the Pocket PC 2003 and higher platforms .NET compact framework is embedded and requires no extra RAM. The business layer and the data layer are shown as physically separate layers, in practice both layers can exist on one server.

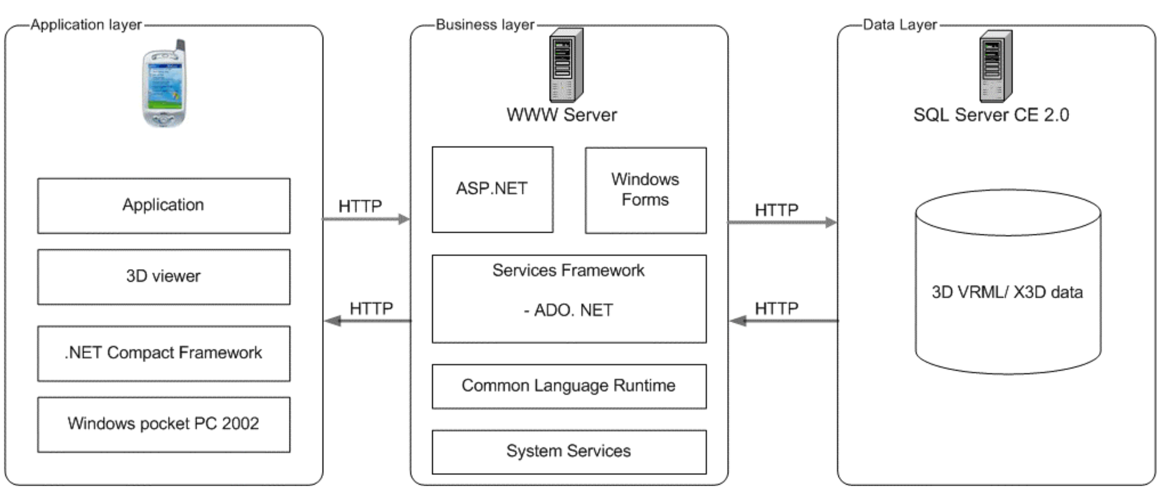

Figure 5 Functional design

4.3 HARDWARE

To be able to test the application a PDA is used, the XDA from O2 is available for testing purposes. To be able to locate the XDA precise location a GPS receiver is used. The Garmin Etrex Summit GPS receiver is used. The XDA and Garmin GPS receiver's specifications can be found in the table below. Development will take place in Visual Studio 2003, this means that the application will be a .NET application and requires the .NET Compact Framework to be installed on the XDA. The disk operating system of the XDA Windows Pocket PC2002, updates for mobile devices are only available through manufacturers. There is no upgrade available for the XDA therefore the software development will be focussed on Windows Pocket PC 2002 platform. The pocket internet explorer does not support VRML therefore a VRML plug-in or browser is needed.

Table 2 Specifications of used hardware [30, 31]

PDA		GPS receiver	
Brand	O2 XDA	Brand	**Garmin**
CPU	Strongarm 206Mhz	Type	**Etrex summit**
Memory	32MB SDRAM 32MB Flash ROM	Features	**compass, altimeter**
LCD Display	240x320 pixels 4096 colours	Precision accuracy	**15 meters**
		Compass accuracy	**5 degrees**
		Update rate	**1/second continuous**
Wireless connectivity	GSM and GPRS		
Operating system	Windows Pocket PC 2002	Interface	**NMEA 0183 RS-232**
Extra features	SD card slot, USB and RS-232 connector,		

The amount of available memory on the XDA is about 25MB of RAM and 25MB of ROM. This can be extended by use of a SD card; this enables an additional 256MB of hard disk space. The Garmin GPS receiver has a built in compass that is used to assist in the device's calculation of a heading. The heading and position can be read by the XDA when connected using the MMC. The heading can be used to establish the compass direction of the user's viewpoint.

4.4 MOBILE 3D VIEWERS

Now that is established which hardware will be used and in which platform the application will be functioning, an appropriate viewer needs to be selected. Viewers which are being developed by individuals on a non-professional basis are excluded. But viewers that are developed in an active web community were considered. The operating systems found on PDA's pose, in combination with limited hardware capabilities, a challenge to develop a 3d viewer. Several dozen 3d viewers are available for the Microsoft Windows only two viewers were found capable of running on the Microsoft's' Pocket PC platform. It appears that most mobile 3D viewers are developed for Palm operating systems or Linux. The two found 3D viewers are IBM's Mobile 3D viewer developed by the T.J. Watson Research centre and Pocket Cortona developed by Parallel Graphics.

IBM's Mobile 3D viewer is still a prototype application. It is capable of showing 3D visualisations in pdb format not in VRML, but a tool is provided to convert VRML to pdb format. Because the viewer is a prototype there is not active support and there is not developers guide either. The viewer uses the Pocket Internet Explorer to show 3D models and is capable of basic transformations such as zoom, rotation movement and lighting of the model shown. The use of the 3D viewer is free but a paid license may become necessary in the future [32].

Parallel Graphics offers Pocket Cortona. This 3D viewer (or 3D browser) is distributed as shareware and requires the user to buy a license after a one month evaluation period. Parallel Graphics offers a standard developers kit that contains Cortona Control. This ActiveX control can be used to provide applications the ability to render 3D models, it also allows VRML automation and user interaction with VRML scenes. Installed on a Pocket PC Cortona control and the Pocket Cortona viewer are capable of rendering VRML models in VRML97 format only. When Pocket Cortona is installed on a pc an add-on can be installed enabling the viewer to render VRML 1.0 models. The use of Cortona Control requires the installation of Pocket Cortona on the Pocket PC [33].

The 3D viewer developed by IBM is available almost with no documentation compared to Pocket Cortona resulting in a higher probability of a successful implementation. Because Parallel Graphics also offers an ActiveX control with a variety of additional functionalities, documented in a developers kit Pocket Cortona will be used to implement 3d scene rendering capabilities in the pilot application.

4.5 DATA

4.5.1 3D model

A 3d visualisation of the planned construction of 'de Born' in Wageningen is available to test the application. De Born is the future campus of Wageningen University.

The visualisation is exported from 3D Studio Max and has a size of approximately 2MB. This means that the dataset can be stored in the PDA's memory. It is not constructed for use on a PDA and therefore does not use any optimalization methods in VRML available for resource restrained devices such as a PDA. Storing the dataset in a database server requires the dataset to be send in parts because the average GPRS connection takes about two minutes to download this amount of data (an average download speed of 20 kbps is assumed). This amount of time is considered unacceptable for a user of the program. However a partial download of the file only showing the required part of the 3d model can be considered. The application should then anticipate the movements of the user by downloading new parts of the model in advance. In other words by downloading a specific part of the 3d model before a user arrives in that part of the model.

4.5.2 National Marine Electronics Association (NMEA)

Besides data describing a three dimensional model as described in the last paragraph positioning data is also needed. When a GPS receiver is used to determine a position the NMEA interface is the most often used protocol for communication between the GPS receiver and the application. There are different NMEA standards, the NMEA 0183 is the most common used.

The positional information that can be found in the NMEA signal useful to the application is described below. The longitude and the latitude help to calculate a position; they give the coordinates of a geographical position and can be found in the NMEA signal.
Latitude; also denoted as φ, gives the location of a place on Earth north or south of the Equator. The equator is an imaginary line between the poles parallel to the earth's axis of rotation. Longitude; also denoted as λ, describes the location of a place on Earth east or west of a north-south line called the Prime Meridian. In contrast to the equator the prime meridian has no natural starting point. Longitude is given as an angular measurement ranging from 0° at the Prime Meridian to +180° eastward and −180° westward.

The GPS receiver also calculates in what direction it travels. This is done by comparing the longitude and latitude signal to derive a travelling route but also use of a digital compass built into the receiver. This is how the course is calculated and send with the NMEA signal. Course is the general term that describes the bearing that needs to be followed in order to move from destination to a target. The bearing or compass bearing is the angle between the direction to an object and a reference direction. The reference direction is usually the magnetic North.

The course does not change when the GPS receiver stops travelling. One of the requested features of the application as described in the first paragraph of this chapter is the ability to allow a user of the location-based application while moving from point A to B to look to his or her left or right with the application adapting its view. This movement different from a course is known in navigation as heading. Heading is the direction a vessel, vehicle or person is pointing towards. It may be necessary to point away from the intended course to counteract the effects of a cross wind, tidal current or some other force. For instance, a ship sometime needs to have a heading of north-northeast to be able to follow a course to the north. Heading is the horizontal direction in which a craft is pointed, expressed as angular distance from a reference direction, usually from 0 degrees at the reference direction clockwise through 360 degrees. Heading is not part of the standard NMEA signal; however some GPS receivers are capable of so called HCHDG sentence, which comprises of the magnetic heading and variation. The Garmin Etrex Summit supports this direct compass output.

5 IMPLEMENTATION DESIGN AND TESTING

To enable the design of the prototype application it is necessary to reflect on the demands that contributed to the functional design and establish which functionalities are most relevant to test. Also the available hardware and data must be considered. The first paragraph of this chapter describes not only which functionalities will be implemented but also what functionalities will be dropped. Sometimes leaving out one features automatically results in the absence of another, for instance when an internet connection is left out, online help not possible either. The functions that will be implemented in the prototype application are described in the first paragraph. The implemented features differ from the requirements described in chapter four to an extent that a new design is needed for the prototype application. This design is treated by the second paragraph which is followed by a paragraph that explains how to use the application. Finally in the fourth paragraph discusses the tests during development and the application is tested on location to detect errors and evaluate its behaviour.

5.1 IMPLEMENTED FEATURES

Therefore the application implemented will run on the XDA using serial communication with the GPS receiver to acquire positioning data. The application will not be using an internet connection or a remote server. This helps to reduce the complexity of the prototype and enables the application to remain as sober as possible to allow for testing of the core functionalities; rendering a 3d visualisation in combination with automated navigation. Also, the absence of a network-based positioning system enables the application to operate outside the sphere of European Union law concerning privacy regulations.

5.1.1 Positioning

Two features related to positioning where mentioned; real-time 3D visualisation and built in, location specific questions. The location aware 3d visualization application will render a 3D model on the screen of the PDA. The coordinates, needed to position the user's current point of view will be extracted from the GPS receiver in an automated process. The 3d visualization will be opened automatically. Once the 3D visualization is started, the direction determined by the GPS receiver will be used to update the 3d visualisation.
A real-time 3D visualisation requires considerable processing power even for a low screen resolution found on a PDA. The XDA does not embed a processor with such capacity. The GPS receiver that is used calculates and sends at position to the XDA with an interval of one second. Therefore an adjustment of the 3d visualisation every two to three seconds is expected at best. The location specific question feature is selected for implementation in the application including an automated answering system.

5.1.2 Mobility

The core concept of the application is that it is location-based and capable or rendering a 3d visualisation. Wireless connectivity is not required enable the core concepts. Therefore the concept application will not incorporate any interaction with a server. This also means that there will not be made use of a (remote) database. The 3d data will be present on the PDA.

5.1.3 Visualisation

The possibility to look up and have the 3d visualization following this movement is not implemented. The onboard compass on the GPS receiver can only register horizontal directions; therefore additional hardware would be required. A bird's eye view will not be optional in the application. A zoom function, allowing the user to decide how far he can watch into the visualisation will not be implemented yet.

5.1.4 Hardware and Software

As mentioned under wireless connection the first application will not feature any internet or network based functionality. Microsoft Pocket PC does not allow automatic downloading and installation of ActiveX Controls. This restricts the possibility to distribute the application through the internet. Therefore automatic updates are not possible through the pocket internet explorer. There will not be a possibility to answer pop up questions in the XDA. Automated storage of a users answer is not implemented. Because the application will be implemented on the PDA only, no database will be used in the prototype.

5.2 IMPLEMENTATION: 3D-LBS

When the selected features in paragraph one are combined with the available hardware (see paragraph three, chapter four) and the dataset (fifth paragraph, chapter four) a more technical design can be made, see figure five 'Implementation design'. The implementation in the .NET compact framework allows for a design of the graphical user interface in Windows Forms. Visual Basic .NET is used as a programming language in the application. Because there is no standard support for serial communication or GPS in Visual Basic .NET a third party library is needed. The Open .NET Compact Framework offers a solution. It is a shared source project that is offered at no costs. Downside of this solution is that it requires the entire Open .NET compact Framework to be installed on the XDA. The installation of the Open NET compact framework caused considerable loss in performance of the XDA which is why an alternative is used. Franson[34] offers a single library that supports both serial communication and the ability to read NMEA-0183 data format, without significant loss of performance.
The downside of this solution is that it is shareware, after two weeks of usage a serial key needs to be purchased. Cortona control is used to embed Pocket Cortona's functionality in the application; this is an ActiveX control see the fourth paragraph of

chapter four. However, the Microsoft .NET compact framework does not support the use of ActiveX controls. To enable this ActiveX support needs to be built into the application.

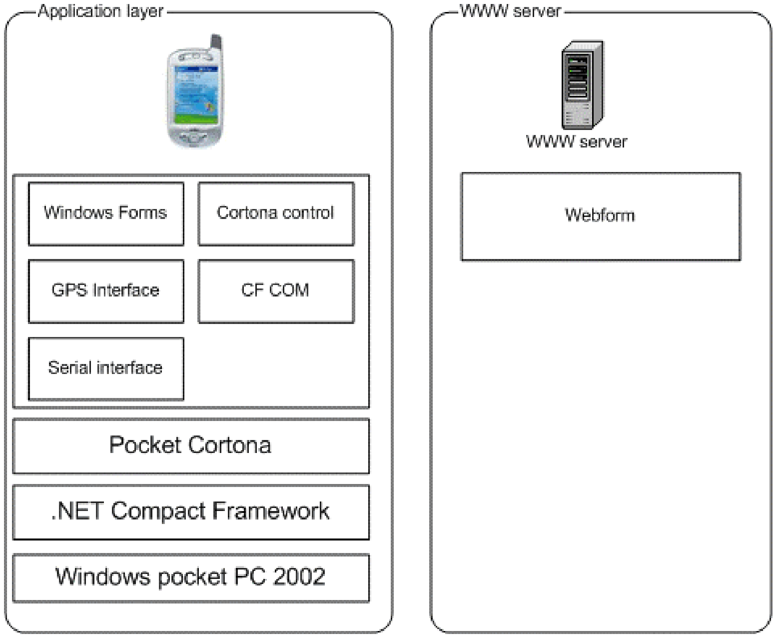

Figure 6 Implementation design

Odyssey Software[35] provides a solution called CFCOM, which will be used for this purpose. CFCOM requires an additional library that will be installed automatically with the applications executable. The GPS library from Franson is also automatically installed with the executable.

5.3 USING 3D-LBS

The application is designed for intuitive use; this means that little or no foreknowledge is needed to use the application. Its composition is optimalised for use on a mobile device. Therefore tabs where used instead of roll down menu's and the available buttons are large to enable easy access with a pen.

The use of 3D-LBS can be defined in three parts:

1. Getting the program up and running
2. Testing and/ or changing (GPS) settings
3. Running the auto-navigating 3d visualisation

The second part is optional, under normal conditions when the GPS receiver is connected and configured properly the application should work without the need for adjustments. When the application is used more often this stage can be skipped. When there are problems with the GPS connection the GPS test console can be used. A walkthrough for each part of the application can be found on the next two pages.

1. When the XDA is turned on 3D-LBS can be found under program files\3D_LBS\.
The start-up screen of 3D-LBS shown in figure 5, shows two tabs and a start button. The picture displayed on the start-up screen is a maquette showing the new campus of Wageningen University and Research. It is also known as 'de Born'.

Figure 7 Start-up screen

2. The 'settings' tab provides information about the interface setting of the GPS receiver. It also contains a button to load the GPS test console (see figure 9). When this console is loaded the top message states: 'no GPS connection'. The Grid, communication port settings and baud rate are preset to be compliant with the XDA used in this study with a dataset compliant to the Dutch grid also known as: 'Rijksdriehoeksstelsel'.

When the start button is pressed the top message should turn to 'GPS connection established'. The GPS receiver sends data packets to the XDA shown by the counter in the bottom left corner.

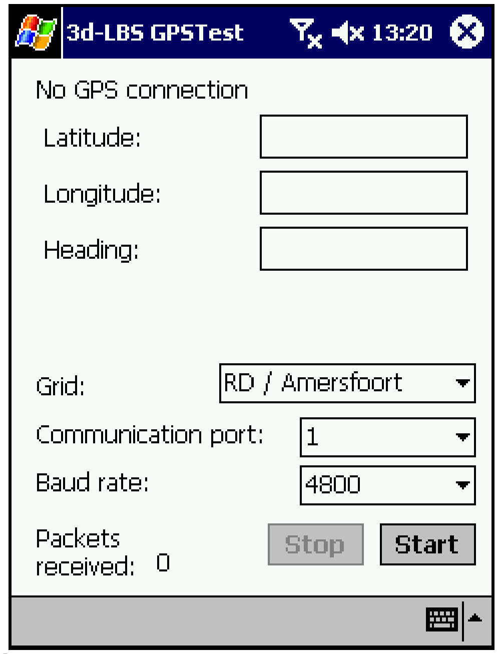

Figure 8 GPS test console

3. When the start button in the start-up screen is pressed the 3D viewer console is loaded. There are two options here:

1) Run starts the 3d visualisation of the future layout of 'De Born' campus of Wageningen University using the GPS receiver for auto navigation.

When running the visualisation the user is required to be on the future campus site. Location-based questions can appear under the visualisation.

2) A demo is also present to show the 3D capabilities of the program. The demo does not require a GPS connection and can be useful to demonstrate or examine the program indoors.

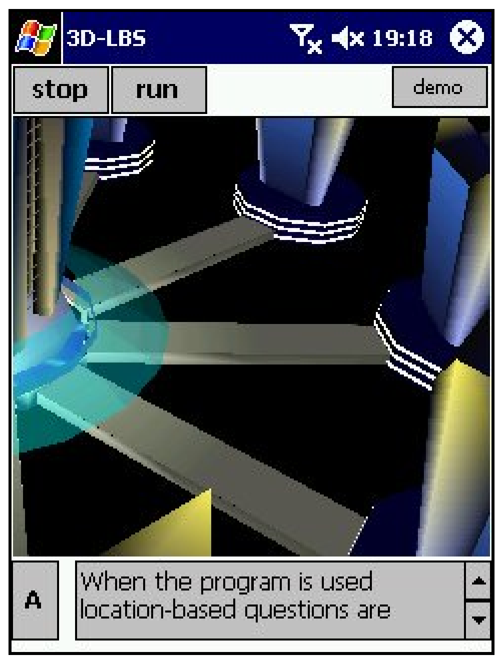

Figure 9 application showing demo

5.3 TESTING

One of the advantages of development in .NET is the possibility to test an application component on the device it is designed for. During development deployment of an intermediate version of the application could be performed to see witch errors where generated. This means that many errors could be resolved during the code implementation phase. This means that most implementation errors where already solved when the code implementation phase was completed. A full test of the application could not be performed because the automated 3d navigation is not fully implemented.

6 DISCUSSION AND CONCLUSION

There are many way's to construct a location-based service. The specifics of a location-based service both in needed functionality and available hardware are often decisive in the choice for a technology. This relativity in choice is reflected in the differences between the functional design and the implementation design. The first paragraph evaluates these choices ordered in the chapter in which they where treated. The next paragraph conclusions are ordered following the research questions. Finally, in recommendation further research and development options are discussed.

6.1 DISCUSSION

The second chapter delineates the concept of location-based services and treats several fundamental technologies that are fundamental. Location-based services require positioning technologies to add location-awareness to the service they deliver. There are several ways' to acquire the position of mobile telecommunication device. Some of them require additional functionality to comply with European laws on privacy, especially network based positioning methods. Because the position of a person is private a user needs to consent with a service requesting a user's position and needs to be able to end the service at any point in time. This is not needed when using a GPS positioning system. Depending on the requirements of a location a GPS receiver is favoured compared to network-based positioning techniques. This requires a GPS receiver which connected to the mobile device. Although use of the GPS system is free, a receiver needs to be purchased requiring a one time investment of approximately one hundred euro. Network based positioning techniques are less accurate than GPS. However they offer several advantages; when there is network coverage positioning can take place and services require no computational effort of the mobile device, it just needs to present the surface, thus a browser application will do in most cases resulting in platform independence of the location-based service. GPS does not work inside buildings and becomes increasingly unreliable close to large constructions. The favoured technology depends on the specifics of the location-based service. The different types of mobiles networks are developing without many surprising leaps. In general it can be said; the newer the technology the higher the bandwidth. The differences in bandwidth are often too small initially to convince a massive transition of users to the new technology. It can be expected to take some time before high speed mobile networks are in use. This reduces the potential of network based services and especially when a fragmented market due to different mobile platforms, devices and protocols is also taken in mind.

To help answer both the second and the third research question a software development model is used. There are many of these models, all with there advantages and disadvantages. The Waterfall software development model that is used is very general but developed to come too a functional design of an application that is subsequently translated in a more technical design. In this study the more technical design does not reflect the functional design; in fact it is different in many perspectives. This is not a problem but it does undermine its reliability. The Waterfall model is sequential driven, meaning that when something changes in a certain phase every next phase needs to be re-evaluated. The differences between the functional design and the implementation design would have made this difficult, potentially impossible. A non-sequential driven model might have been more appropriate. However, in this case no changes to the first three phases where made after completion.

Besides a software development model to guide a structured approach a platform needs to be chosen. Because the available hardware runs Windows Pocket PC 2002 a windows based development is chosen. Microsoft often the traditional windows environment and since 2000 the .NET framework. Mobile devices use a subset of the platform called .NET compact framework. The Pocket PC 2002 platform does not embed this compact framework but it can be installed additionally. The use of the framework offers many advantages and is promoted by Microsoft as the framework to use in application development. One of the main advantages is that .NET libraries consist of managed code which allows runtime memory management. Also, .NET allows for different .NET languages to be used in the same development project. Because it is a relatively new concept many functions are not available in the first .NET compact framework. Unfortunately this often results in the need to use workarounds to solve not available functionalities which add to an increased complexity. One of the plainest examples is the lack of COM control support by the .NET compact framework requiring a third party solution. Also the use of a third party library is needed to open a serial port. The true compatible development environment, offering all standard programming tasks through a development framework consisting of standard libraries, envisioned by Microsoft with the launch of the .NET framework is not reached yet. However considerable improvements have been made in the .NET compact framework 2.0 version introducing support for COM controls amongst other things. This new version of the .NET compact framework is expected in the second half of 2005. Because the available hardware limits the choice in platform to either Windows based or .NET based. A solid comparison between different operating systems such as Symbian and Pocket PC cannot be made. As a result no conclusions can be drawn with respect to what operating system is most suitable.

The functional design in the fourth chapter is mainly driven by the choice to develop in .NET. This three tier application design is promoted heavily in .NET. Although this approach has many advantages it also implies the use of several servers and often paid online services. For instance, the need for both a ISS web server and a SQL server comes. The used 3d viewer, Pocket Cortona comes with a developer's kit. This kit is not designed to support .NET developers although the Cortona control can be implemented. This lack of support and examples results in a more difficult development traject. Despite this fact Pocket Cortona and Cortona control are considered the best option to render and automate VRML scenes; there are no known alternatives in .NET for mobile devices.

The core functionalities of rendering a locations-based 3d visualisation in combination with location-based questions were selected for implementation in the application. In combination with a system to raise questions location-based in combination with an automated answering system. The automated 3d navigation is not fully implemented. The developers kit developers guide is outdated several years, in practice this results in a more time consuming implementation. In combination with .NET cf's need for third party solutions to implement GPS functionality and COM control support a longer implementation phase is required. An answering button next to the question appearing in the application (see figure 9 'application showing demo') is implemented. Pressing this button opens a web form that can be filled out and send to for instance, an email address. A web form is not implemented

The used 3d visualisation is not developed specifically for mobile devices. It is optimalised but it is hard to asses to what extent the model runs slower on the XDA compared to when the model would have been designed specifically for use on the XDA. Therefore the speed with which the application renders the VRML scene and implements position changes can be lower.

6.2 CONCLUSION

The general objective of this study was to explore how a location-based application can be set up to support 3d visualisation on a mobile computing device. The research can be split up in a more theoretical part where technologies where compared to come to a functional design, and a more practical part where a location-based prototype application was implemented. The theoretical part focussed on answering the first two research questions:

1. What components of the location-based application are desired?
2. What type of application can be used best to set up this location-based application?

The second part of this study is more focused on the last two research questions:

3. How can an application that contains part of the components from the first research question be implemented?
4. How can the application, resulting from the third research question be tested to asses to what extent it offers the desired components?

Depending on the requirements of a location a GPS receiver is favoured compared to network-based positioning techniques because it is very accurate and precise. Network based positioning techniques offer coverage almost everywhere in contrast to GPS which is much more sensitive to disturbances and blocking by buildings therefore the most suitable positioning technology depends on what is most important; a positioning technique that is no very precise but does always work or an positioning technology that is precise but does not function often. When a mobile network is used in the location-based application a newer type of network is desired because of higher bandwidth required to transfer 3d scenes.

A browser application is most desirable when a location-based service uses a mobile network. When network reliance is not desired a terminal-based application is more suitable. When the user requirements and existing technology are combined a design arises that combines both terminal application aspects and browser-based aspects. This design leaves more demanding computational parts to servers but supports user interaction that cannot be delivered by a solely browser-based application.

The implementation of 3D-LBS is done in a terminal-based client application form (see 3.4). The 3d visualisation, the automation of the visualisation and the implementation of location-based questions succeeded partially because the required development time exceeds the time schedule. The .NET cf is found to be capable of the implementation intended when two third party solutions (Oddysseys' CFCOM and Fransons' GPS Tools) are added to the .NET cf functionalities. The question and answering functionality is implemented. Because the 3d automation is not implemented fully a test could not be performed in the field. Therefore no conclusions can be drawn concerning the applications behaviour.

6.3 RECOMMENDATION

Because the application is a pilot version in which not all functionalities are implemented yet, further development of the application is recommended. The implementation of an answering system in particular should receive high priority. It is expected that further improvement of 3d support on mobile devices in combination with better optimalised operating systems will add to the applications ability to render increasingly complex 3d scenes.
The use of a 3d application requires a users' acclimatisation to the 3d view witch is in many cases is new to its user. A demo of 'De Born' giving a introduction to the new complex before switching to the automated 3d view mode would be helpful to accommodate this. This also helps users to form a general idea of the construction site before the more detailed, location-based mode is initiated.
The application offers functionalities that require more comprehensive evaluation. This will result in more feedback about the programs features, strong points and weak points and is expected to result in further improvement of the applications usability.

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APPENDIX A INSTALLATION GUIDE

First a number of things need to be checked:

1) The application is designed to run on a PDA running Pocket PC 2002.
   Additionally the .NET cf 1.0 SP2 needs to be installed. This can be downloaded from Microsoft's download centre at:
   http://www.microsoft.com/downloads

2) Pocket cortona is also required two week trial version can be downloaded at:
   http://www.parallelgraphics.com/products/cortonace/download/

3) The library that is used to enable GPS functionality is called GPSlibCE.dll. A .NET cf version of this file, precompiled for the ARM processor (unless the PDA embeds another type of processor) needs to be preinstalled, preferably in the Windows folder of the PDA.

When prerequisites as described above are met the installation of 3D LBS can take place. Copy the installation file to the Pocket PC it is called 3dlbs.cab. This file automatically extracts and installs the program. The program can now be started from / Program Files / 3D LBS
When the program cannot connect to the GPS receiver while all settings seem correct go to settings / Connections/ Beam in Pocket PC, the 'Receiving' checkbox should not be checked