Finding Your Way Around Heritage Sites: the Delivery of Digital Information to Mobile Devices

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An information enriched 3D digital city model connected wirelessly with the real-time user interaction has the potential to deliver an effective piece in the pervasive computing jigsaw. Real-time location awareness can contribute to the effective delivery of 3D digital city models and associated information to small mobile devices. Location awareness is also one of the vital elements of ubiquitous computing systems; together the mobile hardware and its interactive contents can be thought of as 'everyware' [1] . This paper describes the work - undertaken with different technological systems that have potential for pedestrian location sensing connecting the pedestrian user with real and virtual environments simultaneously. In particular we look at how users can be correctly located and efficiently informed about buildings and artefacts that are part of the spectrum of built forms that together are referred to as Architectural Heritage sites.

1. INTRODUCTION

The paper investigates the use of satellite navigation technology, enhanced with RF systems and barcodes to facilitate access to information on sites of architectural significance in the city via a portable, wireless and handheld device. It explores the virtue and shortcomings of each in order to determine the best possible integrated solution.

The work is part of a broader "city in the palm of your hand" research project that is aimed at real-time connection to city representation and information systems. The project focuses on Liverpool as a test bed for the technologies and techniques. In 2004, Liverpool Maritime Mercantile City was inscribed as a UNESCO World Heritage Site, and the particular area of focus for application of the techniques that we have looked at is that site and other parts of the city of Liverpool with significant historic buildings.

The project utilizes a 3D digital city model and an associated city information database, connected in real-time. The paper concludes with the remarks on the use of GPS and other navigation technologies and describes a system that integrates RF or barcodes systems with WiFi technology for real-time location awareness for a pedestrian user accessing a mobile 3D digital urban model on a handheld device. The suggested integration will locate the pedestrian user in the 3D virtual city representation on location, and inform the user about the key information relating to the site where they are currently located.

Mobile devices are being used by a broader section of society and technical features of mobile devices are constantly improving. Mobile devices with GPS, Bluetooth, WLAN, Camera, and RFID and barcode readers have been around for some time. The advent of these and other new features provide opportunities for exploitation in Architecture, and other fields such as city planning. The work presented here focuses on the use of these features of mobile devices to facilitate the pedestrian user's access to city architecture information on the location. We present a method for pedestrian users to connect what they see in the real world with what is being displayed on their handheld devices. Once correctly located, users can then be presented with additional textual and graphic information on the building or the part o the city where they are located.

There has been experimentation and development of mobile city guides that provide location based information and routing functionality [2], [3], [4], [5]. A mobile digital city model with connected database of information can be exploited for a number of purposes like visualisation, development, planning, commerce, transport, tourist information and for discovering the city for a wide variety of users, both professional and non-professional [6], [5], [2], [7], [4]. Currently, significant research being targeted on applying ideas relating to ubiquitous computing technology in the field of architecture. The work described here is a contribution to that field of development.

The past few decades have seen explosive growth in the deployment of satellite navigation technologies on land, air and water. Consequently there has been a drop in price and increase in the availability of both hardware and software to take advantage of the Satellite navigation technology. Opportunities are now presented in the field of Architecture and Planning. As part of this work, a number of experiments were conducted in carefully selected areas of Liverpool to get an idea of a conventional GPS receiver's accuracy for a pedestrian user in the city of Liverpool. Results show many problems with using GPS in an urban environment for this purpose, due to the variable nature of GPS's accuracy and availability. This paper gives an analysis of GPS receiver's reliability and accuracy for pedestrian location in urban places by comparing placement of the user in a 3D digital representation of the city with the actual location.

The features of automatic positioning within a 3D digital city model in the hand-held device require a certain degree of sensitivity; however satellite navigation technology at its present stage is not always accurate enough in this regard. Consequently we have considered enhancing GPS location accuracy by twinning it with other technologies. RFID systems have the potential to be a hugely significant technology within the ubiquitous computing vision [8]. NFC systems, based on RF technology, enable users to pick up information from their environment, conventionally from everyday objects; but why not buildings too? Similarly we have become familiar with the bar coding of products to give them a unique identifier; again could we use bar coding to identify a building and deliver information on that building. Conceptually, bar coding and RFID are quite similar; both are intended to provide rapid and reliable information about physical object on which they are affixed. Both, RF and barcode technologies have the potential to widen their sphere of application to digital city models to augment real-time location awareness. The 'City in the Palm' project aims to combine user's real world contextual information with associated city architecture information on a digital handheld device - and technological glue is needed to combine real and virtual worlds' information on the fly. So, the main purpose of an RFID tag/barcode is to act as technological/digital glue to join physical objects to a remotely located computer network [8].

In addition Liverpool is among those cities of UK that have been selected for an initial implementation of a comprehensive wireless infrastructure. The wireless net access will be available across broad swathes of Liverpool [9]. Knowledge of, and reference to local wireless broadcast points have the potential to add a further technique to help locate a pedestrian user 'on the fly'.

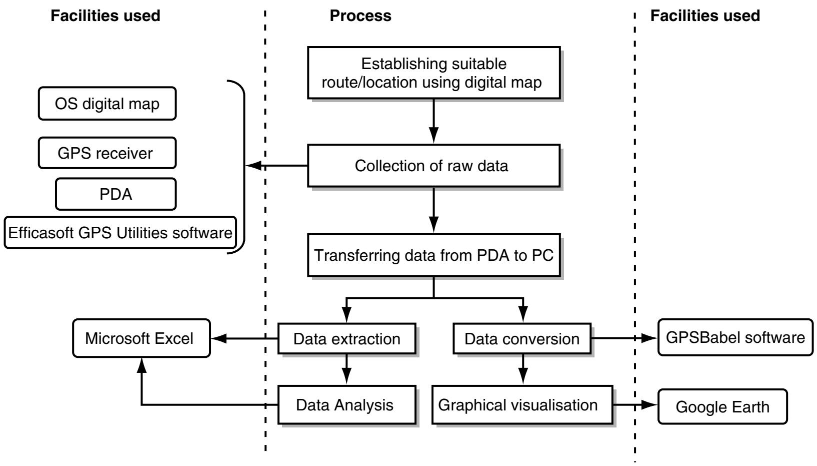
2. SATELLITE NAVIGATION

Satellite navigation and positioning systems are an area of growing significance in the field of wireless communications. The Global Navigation Satellite System (GNSS) is a network of satellites that transmits high-frequency radio signals containing time and distance data that can be picked up by a receiver, allowing the user to pinpoint their location anywhere around the globe. There are two GNSSs currently in operation; the United States Global Positioning System (GPS) and the Russian GLObal NAvigation Satellite System (GLONASS) [10]. Since it has only twelve active satellites as of 2004, the GLONASS system has been generally considered of limited usefulness; however it is expected to extend coverage from Russian territory and parts of adjacent Europe and Asia currently, to global coverage by 2009 in partnership with India. GPS is the only fully functional global satellite navigation system as of 2006. GNSS is a rapidly growing field and systems continue to be refined. The technology is now readily available at low cost via different forms of devices used daily, such as mobile phones, GPS enabled hand-held devices, Palmtops and PDAs. These potentials have made satellite navigation technology open for exploitation for real-time location awareness in applications requiring the user to be located in a city map or model in real time. Previous work in this regard undertaken by the CAAD research unit (Liverpool) at the University of Liverpool had considered the use of GPS technology for real time location awareness of pedestrian user in 3D digital city model on a handheld device [11], [12]. In our work GPS interaction with a 3D digital city model offers the potential for automatic real-time location awareness rather than users having to find their location manually. Wireless connection to a server means that data (textual, numeric, image and video) can be downloaded, on the fly, for the building or location where the user is currently present.

Basic GPS has become an extremely valuable radio-based navigation system - suitable for most, but not all, applications. There are number of problems with using GPS technology in urban environments due to the variable nature of a GPS receiver's accuracy and availability dictated by the number of satellites that the device can connect to. So, various issues associated with navigation using GPS receivers have to be addressed to achieve acceptable results. Through experiments with GPS receivers in carefully selected areas of Liverpool the study sought to get an idea of current GPS accuracy particularly in problematic areas of Liverpool city, such as urban canyons. One of the values measured is Dilution of Precision (DOP), and this is a value, recorded by the GPS device (but not normally seen by the user), that indicates the number of satellites that the GPS device can 'see'. With a large number of high angle (in relation to the ground plane) satellites accuracy is good. Accuracy is impaired as the number and angle reduces.

2.1. Experimental Details

The work examined and analysed a GPS receiver's data that was intended to interact with a 3D model of the city of Liverpool. Seven experiments were conducted in different locations, open and obscured, and with different receiver conditions; both stationary and moving.



◀ Figure 1. Procedure flow chart.

In order to make these experiments more easily interpreted we adopted a technique that permitted graphical visualization and analysis of GPS receiver data. The information from these experiments was used to establish a range of errors that GPS-linked PDAs experience in urban locations.

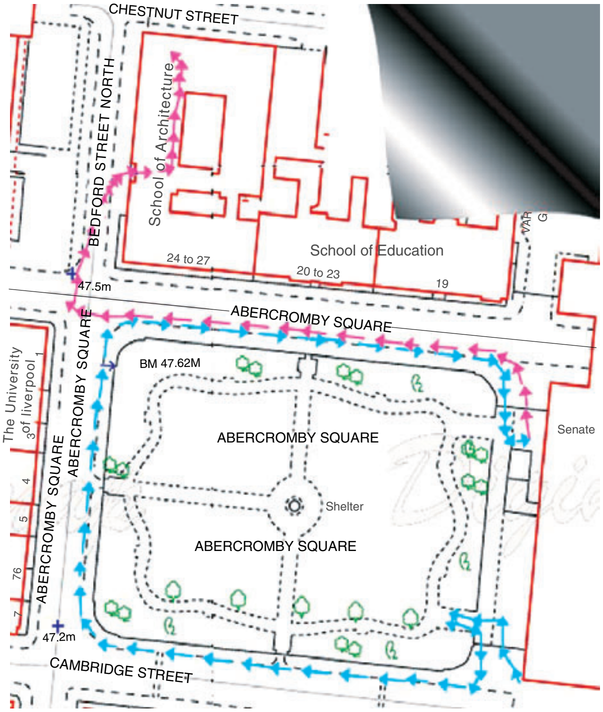
The data files recorded by the GPS receiver were opened as text files, when copied from the PDA to PC. The data files were converted into KML files through the GPSBabel software before importing them as a graphical plot into a map or aerial photo (such as Ordnance Survey maps or Google Earth images). Apart from exporting data files to Google Earth to give a visual representation of errors, the latitude, longitude, altitude, number of satellites in use and DOP information was also extracted from the GPS receiver raw data. This data was in the form of NMEA0183 sentences; and these were imported into Microsoft Excel for analysis. Figure 1 shows a representation of the processes involved.

This information was used to establish a range of errors that GPS-linked PDAs experience in urban locations. Potentially, a GPS-enabled PDA should allow its user to be located accurately in the model, but others have reported that GPS receiver location is only accurate to a few metres [13]. Our readings showed that there were typical errors, as expected from GPS receiver's inaccuracy but there were occasions when GPS receiver gave gross errors. The arrowed lines in figure 2 show actual path followed in 2 experiments conducted at different times while the lines in figure 3 show the path calculated by the GPS receiver.

The results show that paths calculated by GPS receiver are different from the actual paths followed and Figure 3 gives an visual indication of the size of the errors. The graphs in figures 4, 5 and 6 show the errors in horizontal and vertical positioning information of a GPS receiver.

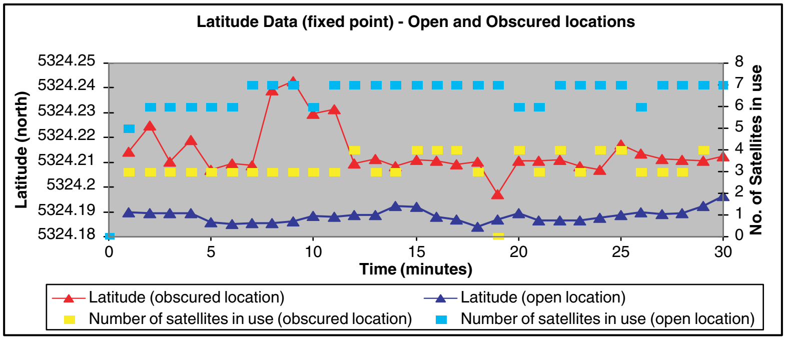
The GPS measured values for latitude data are shown in Figures 4 and 5. In Figures 4 and 5 the triangles show the GPS measured values, and the

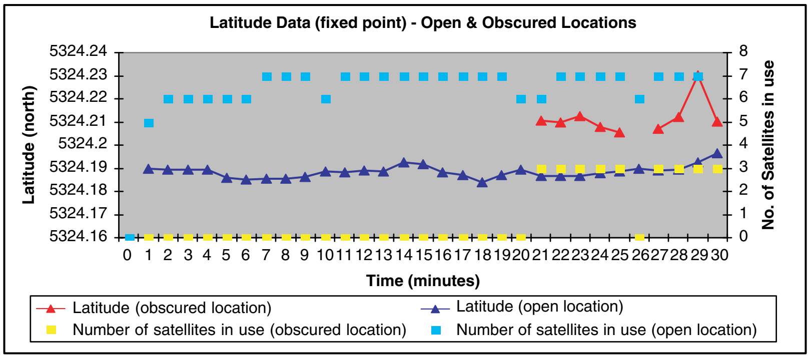
► Figure 2. Map of the actual path followed.



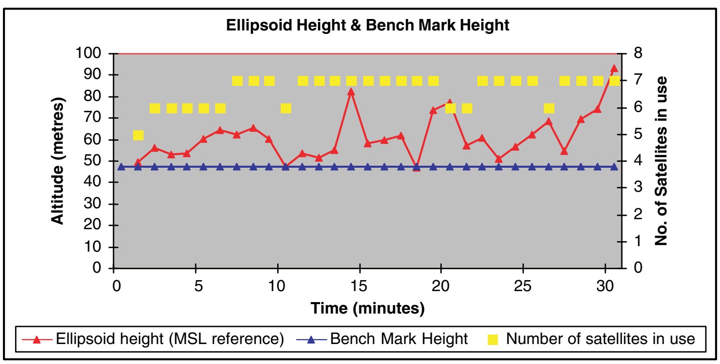
► Figure 3. Route indicated by GPS receiver overlain on aerial photo.

squares show the number of satellites that the receiver could 'see'. The measured values show that readings in an 'open' location are more consistent and reliable than those from a partly obscured location. For the typical test in a partly obscured location, for two thirds of the 30 minute test period no satellites were visible. For the remainder of the time only 3





◀ Figures 4 and 5. Typical Latitude Readings in Open and Obscured locations.



◀ Figure 6. Altitude Data.

satellites were in view, compared to the 7 typically in view in the more open location. Consequently no readings were available for 20 minutes in the partly obscured location and the GPS device could not get a 'fix' on the user's position. The buildings in this location were not exceptionally high so this indicated the importance of augmenting GPS positional information for pedestrian users.

The readings plotted in Figure 6 show that the variability in GPS altitude readings can be considerable. The horizontal line indicates the actual altitude (by referring to a known benchmark height at the site). Readings from the GPS recorder are shown by the triangles. Despite there being a large number of satellites available the variability and error in height calculation was significant.

2.2. Outcome

This work provides an idea of reliability and accuracy of a stand alone GPS receiver's data for use in conjunction with 3D digital urban models for pedestrian users. It was found that although the GPS technology has come into extensive use for vehicle navigation system, this technology at its current stage can not fulfill all the requirements that a 3D interactive, and remotely accessible, digital city model with associated information, for pedestrian users demands. A basic GPS system can be one of the best options as far as its availability alone and with handheld devices is concerned however technology is not sensitive enough at its current arena that it can be used for pedestrian users of mobile hand held devices like one aimed in the "City in the palm of your hand" project. However, the development of new satellite-based navigation systems and modernisation plans in existing ones have opened a new era in the research of satellite-based global positioning and navigation systems. Users will see a further jump in performance with the introduction of next generation of GPS system and launch of Galileo will improve the accuracy in urban canyons [14]. Future developments and easy availability will make satellite navigation technology one of the best solutions in near future for the purpose described above.

3. ENHANCING TECHNOLOGIES

In order to avoid sole reliance on GPS location ongoing research and further work that we have undertaken has explored other wireless technologies to be used to enhance GPS positioning information to provide more precise, acceptable and reliable dynamic interaction on location with a 3D urban model and an associated city information database.

3.1. Automatic Identification System

Automatic contactless identification system has emerged as one of the dominant technology trends of last few decades. Contactless systems use radio frequency (RF) for the transfer of power and data, and are hence called RFID systems (Radio Frequency Identification). This allows real-time data exchange between a source and a receiver over a relatively short range. An RF reader does not need a direct line of sight in order to work.

RFID

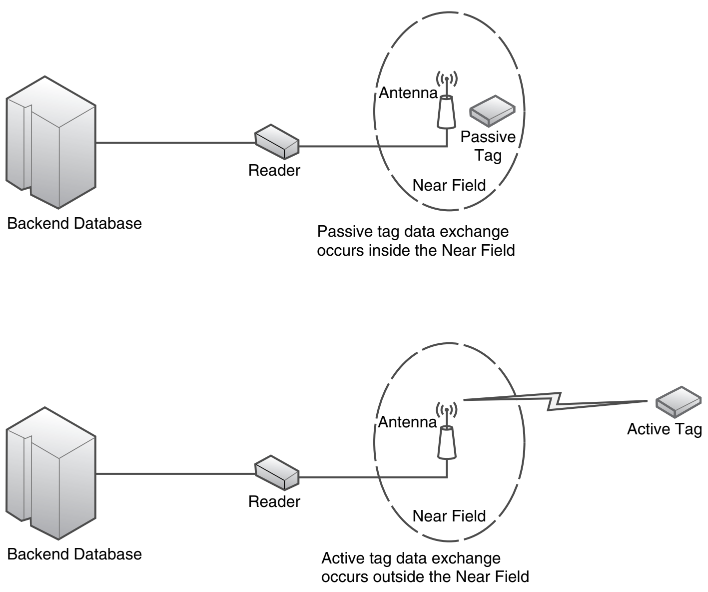
Radio frequency identification is a general term for a set of technologies that use radio frequency (RF) to communicate data [15]. Radio frequency, or RF, refers to that portion of the electromagnetic spectrum in which electromagnetic waves can be generated by alternating current which is fed to an antenna. The technology has been advancing over the past several years, and the application space has been broadening. RFID has been used for a range of activities from pinpointing the position of runners in marathons to tracking livestock to automating supply chains and assisting in inventory management for major retail vendors.

RFID systems comprise readers and tags along with a backend infrastructure for data management.

An RFID system is always made up of two components

1. The transponder (RF tag)
2. The interrogator (RF reader) – in our case a mobile phone or pda

Transponders used in RFID are commonly called tags, chips, or labels, which are largely interchangeable, although "chip" implies a smaller unit, and "tag" is used for larger devices. The data capacities of RFID transponders normally range from a few bytes to several kilobytes [17]. Tags can be extremely small, thin and easily embedded within packaging, plastic cards, tickets, books or signs, for instance. [8]. Many models of reader are handheld devices, but readers can also be fixed in place (e.g. on buildings or in doorways) and even hidden, embedded into ceilings or walls. There are also readers that can be incorporated into handheld devices such as PDAs and mobile phones [8]. The reader queries the tag, obtains a small packet of information, and then takes action based on that information. That action may display a number on a handheld device, or it may pass information, or communicate it to backend databases and systems thousands of miles away.



◀ Figure 8. Passive and active tag processes [17].

One very important feature of RFID systems is the power supply to the transponder. Passive transponders do not have their own power supply, and therefore radio frequency is used to deliver power to the transponders. They can only operate in the presence of a reader. Obtaining power from the reader device is accomplished using an electromagnetic property known as the Near Field. The Near Field is a phenomenon that occurs in a radio transmission, where the magnetic portion of the electromagnetic field is strong enough to induce an electrical field in a coil. As the name implies, the device must be relatively near the reader in order to work. The alternative to a passive tag is an active tag that incorporates a very small battery, which supplies all or part of the power for the operation of a microchip. Active transponders are not limited to operating within the Near Field.

As passive tags do not require a continuous power source they have a much longer life, and because of extremely small size they are much cheaper to produce. For active tags the range increases and reliability improves [8]. The achievable range of the system varies from a few millimetres to above 15m.

NFC

Near-field communications (NFC) combines two established technologies: radio frequency identification (RFID) tags and wireless readers. Similar technology is used in electronic highway toll systems, and in passports. And it's now being introduced into mobile phones, given their ubiquity and ability to have more features packed inside them [18]. It enables communication between electronic devices in close proximity. It provides a seamless medium for secure data transfer. This enables users to perform intuitive, safe, contactless transactions, access digital content and connect electronic devices simply by touching or bringing devices into close proximity. NFC operates in the standard unlicensed 13.56MHz frequency band over a distance of up to around 20 centimeters. Currently it offers data transfer rates of 106kbit/s, 212kbit/s and 424kbit/s, and higher rates are expected in the future. For two devices to communicate using NFC one device must have an NFC reader/writer and one must have an NFC tag. The tag contains data, connected to an antenna that can be read and written by the reader. An NFC tag is typically a passive device that stores data that can be read by an NFC-enabled device. The passive mode of communication is very important for battery-powered devices like mobile phones and PDAs that need to prioritize energy use [19].

NFC is a versatile technology and its uses are growing rapidly. In an era where we all using different computing technologies at one time, life will be much simpler once devices are capable of knowing when we want them to talk to their environment - and then doing it automatically. NFC technology can be used as to unlock and open doors of information. NFC technology enables communication between a device and an information provider.

NFC removes the need for the user to perform complex manual configurations. Once the connection is established – within milliseconds – information can be exchanged between the two devices using either NFC directly or via another wireless technology like WiFi, Bluetooth. Projections are that half of all cell phones will support NFC technology by the end of 2009 [20].

At a high level, RFID technologies can be viewed as a way to bring together the physical and the informational environment together in many different contexts. RFID is an enabling technology towards the achievement of seamless and calm vision of Ubiquitous computing [8]. NFC tags have already reached a price point where it is feasible to print off batches of NFC stickers that enable users to create customised links [19].

Our 'City in the Palm' project aims to use an RF system to augment real-time location awareness of a pedestrian user when interacting with a city navigation system. This can be achieved by storing numerical coordinates of the building's position in RFID tags along with other useful information and attaching them to buildings. These tags will allow physical buildings to speak out of their presence when readers interrogate them. As the user walks through the city passing by different buildings, the user can use the NFC/RFID-enabled device to query tags, posted on the buildings throughout the city, for information.

The NFC chip is able to initiate a wireless link from the phone/pda to a remote server with a database. The database contains two key pieces of information. First it stores information on the building to which the NFC chip is attached (in our case, primarily heritage related information). Secondly the coordinate information acts as a check on, or correction to, GPS location data. This is particularly valuable in potentially obscured locations such as entrances to Heritage buildings.

3.2. Barcodes

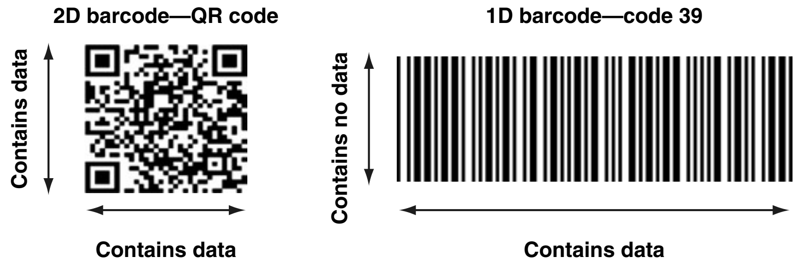
In today's world, almost every consumer product in the market has a barcode. They've become an accepted part of our everyday lives. A barcode typically has ID data encoded in it, and that data is used by a computer to look up all specific information associated with the data [21].

Camera Phone and Barcodes

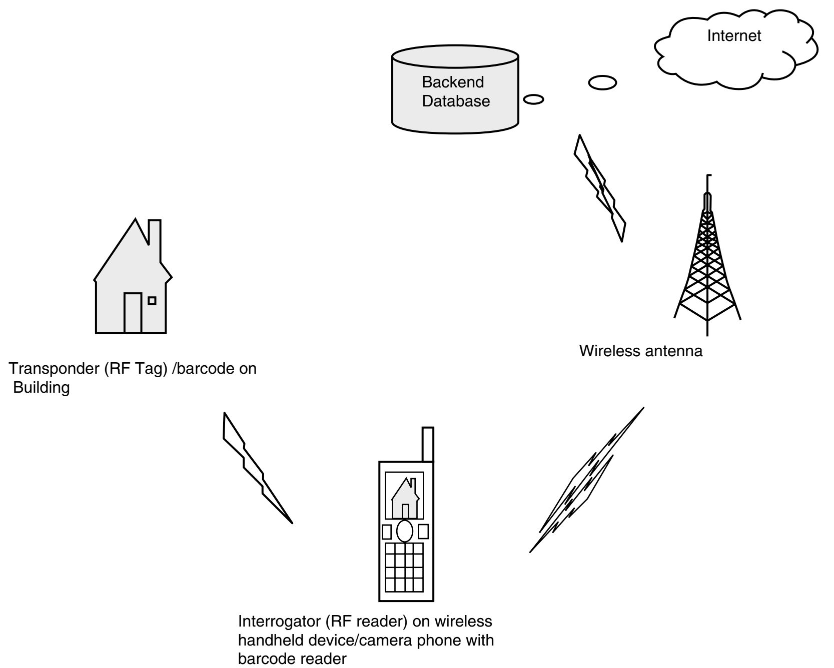
Mobile phones and barcode technologies have been combined to the advantage of user. The phone, programmed to interpret barcode images, will generate the barcode value which is used to identify the object. By connecting online, user can then get access to a wealth of information about the object. As with an RFID device a connection can be initiated to a remote database from which building information and map location corrections can be downloaded with minimal user input.

Recently, mobile telephone operators began including QR code reading software on camera phones. A QR code stores data in 2D rather than the conventional 1D (see Figure 9). The mobile phone barcode reading software can also be downloaded to mobile phones from different websites. Users photograph a barcode and their camera phones decode the text embedded in the codes and display, manipulate, and store the information associated with that barcode on their mobile devices [22]. An email address, URL or plain text can be generated in such an operation. After scanning it with camera phone, user will have instant access to the encoded information straight on the display of mobile device. Again, remotely located data on the Heritage site where the barcode is located, can be accessed.

► Figure 9. 2D and 1D barcodes.



► Figure 10. A schematic flow diagram of the projected system for connecting real and virtual worlds on location.



4. WIFI + RFID/BARCODE SYSTEM – CONNECTING REAL & VIRTUAL WORLDS

The addition of the RFID and barcode technologies mentioned above allows us to enhance a handheld digital device with more precisely located and customised information on a Heritage Site. As a test bed objects/buildings in the city have been affixed with RFID tags/barcodes. These can therefore be identified by RF or barcode readers attached with an enabled handheld device. Once the digital device has read the ID number of a building, it resolves the number and uses that data to make a connection that can locate the user in a map/model representation on the device, and can also be used to access information on the current site (see Figures 10 and 11).

◀ Figure 11. City in the Palm of your Hand system following wireless download to a PDA.

Liverpool is among those cities of UK which have been selected as pilots for a comprehensive wireless infrastructure. British Telecom (BT) is developing a high-speed Wireless Broadband (WiFi) network within city of Liverpool. As Heritage Site locations, such as the one in Liverpool, gain coverage as part of WiFi networks the opportunity for greater speed and flexibility in making the connection to remote information and mapping systems increases. This information, can be sent to a backend infrastructure via the WiFi enabled handheld device, and thus the user is able to receive context related information in real time.

5. CONCLUDING REMARKS

Over the past few years, GPS technology has come into extensive use for vehicle navigation systems. However this technology at its current stage can not fulfill all the requirements that a 3D interactive, and remotely accessible, digital city model with associated information, for pedestrian users demands. Basic GPS system can be one of the best options as far as its availability alone and with handheld devices is concerned. However the technology is not sensitive enough currently that it can be used at all times for pedestrian users of mobile hand held devices accessing information such as that presented by the "City in the palm of your hand" project.

This work provides an idea of reliability and accuracy of a GPS receiver's data for use in 3D digital urban models. It was found that;

(i) Errors and error intensities of GPS receiver's data are different for different areas. Some areas (such as obscured locations) tend to give larger errors than open areas.

(ii) A GPS receiver often fails to deliver continuous positioning information in urban canyons and obscured locations. The more obscured the location, the greater the 'down time' where no readings are available.

(iii) The latitude and longitude accuracy of the GPS receiver is far better than altitude accuracy. Deviations in latitude, longitude and altitude are found in both open and obscured locations.

(iv) The measures of Dilution of Precision, PDOP, HDOP and VDOP, remained less than 6 in experiments, suggesting a high degree of accuracy in position information, however constant, abrupt and sometimes huge changes in positional information were noticed.

All the above points are factual nevertheless a fact that the GNSS is a rapidly growing field can not be ignored. The development of new satellite-based navigation systems and modernization plans in existing ones have opened a new era in the research of satellite-based global positioning and navigation systems. Users will see a further jump in performance with the introduction of next generation of GPS system and launch of Galileo will improve the accuracy in urban canyons [14]. Future developments and easy availability will make satellite navigation technology one of the best solutions in near future for the purpose described above. However, RF and barcode technologies have been shown to provide useful backup and correcting information when located at a known location on a Heritage Site.

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