A GIS Based Parking Management and Dissemination System

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Abstract: *Parking is dynamic. One minute a parking space is engaged and the next ten or so minutes its vacant. Finding a parking space has thus become a nightmare in many cities. There are many Parking Guidance Information Systems, PGIS meant to alleviate a driver's pain of finding or reserving a parking space but they operate as standalone systems and therefore disseminate information only to a selected few at a given time. The aim of this study is to have a Geographic Information System, GIS that will enhance the components of a PGIS so that it runs on a mobile phone platform thereby allowing a driver to access parking information whenever and wherever he is. The GIS-based PGIS will provide the driver with a view of the near real time parking situation of his destination, allow him to reserve a space as well as have his smart phone enabled to notify him once he approaches a vacant space or even perform routing functions. Thirty parking spaces were collected within Jomo Kenyatta University of Agriculture and Technology, J.K.U.A.T classified, mapped and published in a web map server. A Quick Response Code, QR was installed on each parking space and a SMS server established to monitor the reports and requests of drivers. An Android smart phone application was created that was able to reap parking information from the map server. The system greatly reduced the trial and error involved while in search of a parking space thus increasing a driver's confidence, cutting down on the amount of parking time and the emotional stress associated with finding a parking space.*

Keywords: Android, Parking, PGIS, QR Codes.

1. Introduction

The number of automobiles in many nations is becoming larger and larger and it's increasingly difficult to park. The Global Parking Survey, 2011, conducted by the International Business Machines, IBM showed that drivers in 20 international cities face a daily struggle in finding a parking space. Six out of 10 drivers abandoned their search for a space at least once. The report also revealed that over 30 percent of traffic in a city is caused by drivers searching for a parking spot. Over half of all drivers in 16 of the 20 cities surveyed reported that they have been frustrated enough that they gave up looking for a parking space and simply drove somewhere else. Parking is dynamic; an aspect which many traditional. Parking Guidance Information Systems, PGIS are failing to address [1]. Figure 1 shows a typical PGIS display that only serves a selected few road users at a given time. A good solution for the pressing parking problem would be to increase the number of parking spaces and enlarge parking lots but this will involve gigantic investments [2]. However better management of the existing parking facilities is seen as a wise stop gap measure. Many drivers find themselves making guess work while looking for parking space simply because they are not aware of the parking situation in their immediate environment. To disseminate parking information which is ever changing, one would require a fast medium of communication like the internet. The internet has revolutionized the world of communication [3] and many people are using the internet as their main source of information. Moreover, the internet has already been incorporated into developed nations' societies and is quickly penetrating developing ones too [4]. The widespread internet access since the 1990's have not only thinned the line separating office and home, but substantially contributed to the increasing mobility of our working and everyday life [5]. This is especially so with the advent of smart phones which virtually enables the user to 'carry' the internet with him wherever he goes. The increased use of handheld mobile devices including Personal Data Assistant and mobile phones has been likened to "Putting yourself in the world and world in your palm" [5]. A map which was only viewable on desktop computer can now be seen in many screens connected to the over the World Wide Web including smart phones. Currently there is a proliferation of virtual maps including Google Maps, Bing Maps, ESRI Maps and Apple Maps. With these maps many have been able to find places, directions, geo tag their pictures get distances, etc. in their phones.

Figure 1: A typical Parking Guidance Information System

2. Mobile Maps and Devices

Maps in the pre-internet times can be grouped into three categories: view only maps, analytical maps and explorative maps. Though maps still remain the most popular communication language of spatial information the internet and advances in technology has necessitated a creation new kind of maps that will serve the same use as the old maps as well as incorporate dynamism and mobility. Modern maps are no longer used for mere presentation but for interactive and individual exploration of temporal and non-temporal spatial data. The internet has revolutionized the distribution of screen maps with the web-based maps being seen as a

metaphor to spatialize the information space and as a collaborative thinking instrument shared by spatially separated users. The realization of wireless internet access has brought web maps back to mobile environments where they are most needed. Figure 2 illustrates the operations of a mobile GIS platform.
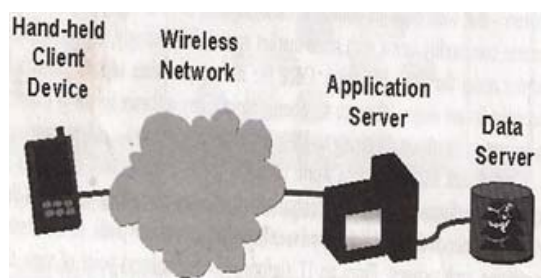

Figure 2: Handheld mobile GIS platform

Unlike web-maps, mobile maps are more personal and provide better platform to relay spatial information especially of a temporal nature. A mobile map is somewhat like a snapshot of an environment around a certain location and time, but with highly selective information and integrated intelligence. Most of our daily activities require us to be in motion and driving is no exception. With parking spaces being engaged on and off, a static or a standalone system, like the case of most PGIS would seem handicapped in relaying parking information. Mobility is unquestionably a fundamental aspect of contemporary life. With mobile maps modern mobile people (drivers) will be better informed of the events from near and far, past, present and future; ensuring they are better prepared for their tasks. There is a wide array of hand-held devices that can be classified into three types based on weight, power, cost and functional capabilities. These are Portable PCs, PDAs and mobile phones. This study focuses on the mobile phone since currently it's the most used type, versatile and most applicable for disseminating parking information to many users at a time. Moreover, a key feature of mobile phones is that they have the ability to determine their location using Global Positioning Systems, GPS embedded in them. Other characteristics that make mobile phones better suited for mobile GIS include; high mobility, dynamism and ability to operate in real time, supports applications and ability to sense locational information. It's because of the above reasons that such mobile phones have been branded a new name: Smart phones. Smart phones have hit the market with huge sales. Unlike standard cell phones they have additional features that allow the user to do a lot of things on and off the internet. An operating system like Android enables one to log in the internet and install applications suited for his needs. For instance, Quick Response (QR) Codes and Quick Response Readers are features that are gaining popularity across the nations. A smart phone equipped with a QR Reader application is able to decode information encrypted in QR Code and prompt the phone to do necessary action as directed by the QR Code. Figure 3 shows how a smart phone scans a QR Code.

Figure 3: A QR Code and a smart phone with QR Reader

There are codes that prompt the phone to make a call to a specific number, open the default browser of the phone and visit a particular website, display a message or even prompt the user to send a message to a particular number upon populating the Short Message Service, SMS function of the phone. The SMS-QR Code type is used in this study. The idea is to automate the message sending function of the phone thus reduce time and effort in relaying a SMS.

3. Parking Guidance and Information System

Parking Guidance Information System (PGIS) is also known as Advanced Parking Information System (APIS) It is to promote the effective utilization of parking lot and adjacent roads, to provide parking location, condition, road traffic routes and other information related by variety ways to induce the driver to find the parking most effectively. The objectives of the system can be summarized into the followings [6]. The angle of road use: helping drivers find parking as soon as possible to shorten the parade time, depress invalid traffic of finding parking, improve road usage. To a certain extent, the pressure of Guidance area traffic can be eased. Thereby, the situation of urban traffic congestion can be improved. The angle of parking facilities: reducing the vacancy rate, promoting balanced use of parking, improving parking turnover rate, protecting the economic benefits of car parks and promoting the economic vitality of commercial facilities within the system.

The angle of parking manager: optimizing parking environment, reducing the phenomenon of illegal parking. It requires a high level of car park construction and management for induction system implementation, helping to improve overall function and management level of parking services. The angle of city management: parking space can be found quickly by real-time parking guidance. Thus, the energy waste, air pollution and noise pollution can be reduced.

3.1 Analysis on Functions of Parking Guidance Information System

Parking guidance information system plays a very important role in regulating parking demand in time and space, improving the parking facility utilization, reducing the road traffic arising from searching for parking, improving the efficiency of the transportation system, improving operation conditions and increasing economic vitality of business areas and so on. With the purpose of the system, parking guidance information system need to meet the requirements of functions as follows [7].

a) The system should collect real-time information about the status of the car park accurately, and delivery to the management center timely. It should achieve interaction of all car parks within the planning region and management center, that is, to achieve the integration about physical facilities and management center of the existing management systems and parking guidance information system center software of a single point parking lot, and to ensure that the design number of parking can be expanded.

b) The system should imply automated management of car park, including charging systems, computerized management and rapid query, statistics and analysis of data. It also has extension functions that connecting with other intelligent transportation system urban.

c) The management center of the system has strong functions of statistic data and information processing, storage, the integration of parking management information, and the reliability processing of the release data information. It also should include traffic flow reporting system, storage and statistics of parking registration information table, statistics of signs registered information table, and storage and statistics of vehicle information table within the parking.

d) It can use the information released screen to supply the information of parking location and status of parking space for the drivers when they come into the induction area.

e) Parking spaces information should be queried in the information management center of this system, including the real-time parking information and daily flow of cars at the parking lot.

3.2 Design of Parking Guidance Information System Framework

Logical structure is an auxiliary tool of organizing complex entities and relationships, which focuses on the functionality processing and information flow of the system. The function of each subsystem and the linkages between these subsystems and interaction relationships can be seen through the logical structure of parking guidance information system.

System information collection, processing, distribution, transmission in the system should be integrated calculated rationally in the parking guidance information system. Also, the other external conditions outside the system such as driver behavior analysis, network traffic control and management, parking operation should be integrated calculated to strengthen the utility and effectiveness based on correctness of software systems. In the parking guidance information system, the data processing of information is the key to the whole system. System software can predict the change of parking utilization through data processing, comprehensive analysis of the basis of data collected and the static data set before, state of road network, and parking facilities.

3.3 Analysis on System Function Module

A direct function of parking guidance information system is to provide parking information for parking demander and traffic manager. Analyzed from Information transmission process of parking, parking guidance information system should have four functional modules, which are information collection, information processing, information transmission, and information dissemination. The release of stopping information can be achieved from interdependence and interaction of the four function modules [8].

a) Information collection module

Information collection module can capture real-time information on parking usage accurately and transmit to the management center timely. Via remote monitoring devices and sensing devices, parking information can be collected. The parking traffic information can also be obtained through traffic information collection system.

b) Information processing module

c) Information processing module is responsible for processing information such as surrounding road information and the state of parking into appropriate form that can be provided to drivers. The information such as parking spaces, remaining car places, congestion condition of distribution road and so on can be processed. The module also can store parking information, predict available parking, and process the changes of parking patterns. These features are basis for future services such as the forecast of the parking demand conditions, parking information inquiry, parking scheduled. Information processing is mainly made by management center hardware and system software.

d) Information transmission module

e) The basic task of information transmission module is to ensure that the flow that from the information collecting system to the information processing system and then to the information release system is smooth. Then, the data can be exchanged within the client of collection, management and distribution center.

f) Information dissemination module

g) The task of information dissemination is to release information processed by information processed systems to the outside in an appropriate manner. Information dissemination system includes a variety of publishing tools, such as the LED screen, traffic information broadcasting and television, Internet and other networks and phone inquiries, geographic information system and car navigation system. Released information includes parking position, parking number or occupancy and the distribution of parking facilities in surrounding.

4. Methodology

Jomo Kenyatta University of Agriculture and Technology is one of the public universities in Kenya. Its mainstay is Agriculture and Technology. It's located in Juja Town which is about 50 Km from Nairobi. The institution has a geographical extent of 9,878,000-9,880,000 south and 278,000- 280,000 east, UTM Arc1960. Figure 4 shows the extent of the study area.

Figure 4: A topographical map showing JKUAT

It harbors a student population of approximately 5000 with quite a large number of teaching and non-teaching staff some of whom use the parking facilities daily. According to the recent survey conducted by institution's Estates department, the university records the highest number of cars every Monday and Friday with a total of number of not less than a thousand cars. The average number of cars for the others days of the week is six hundred. With only a few numbers of parking lots, some drivers are forced to park in undesignated areas like gardens and under tree shades. The situation gets worse during graduation events.

Figure 5 shows how the system is assembled which starts with mapping of parking spaces in the study area. Each parking space is uniquely identified with a special number and QR code generated for each space. The code also includes the dispatcher's mobile number. A database showing all the mapped parking spaces with their attributes is created. A SMS server is established that forms a link between the parking spaces and the geodatabase. A web server Application Programming Interface, API is established and published over the internet which can be accessed and analyzed by an Android smart phone application.

The system offers several options through which the user, a driver, can use to access and report parking information. It has three basic components viz, the driver's smart phone, internet and QR codes that are connected via a spatial database or geo-database. The smart phone allows the driver to request, book for a parking space, report his occupancy at a given as well as receive confirmations of any transactions. These are enabled by the SMS function of the smart phone. In addition to these, one can use the smart phone to have a bird's eye view of the parking areas and also use the phone as a guidance tool. The internet is used as the communication medium that links the activities on parking lots, the geo-database and the driver's smart phones.
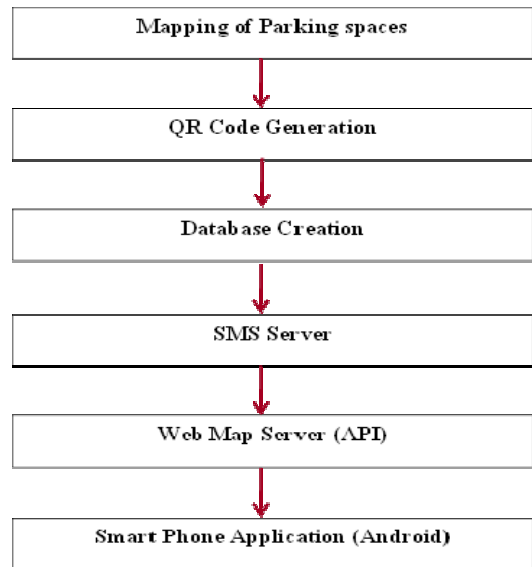

Figure 5: System flow chart

Parking spaces are spatial objects with different coordinates and attributes. Jomo Kenyatta University has several park lots to cater for the ever growing number of cars. These parking spaces are normally named after the building they are installed at and have different properties. . Some spaces are dedicated to drivers with disabilities and some for long vehicles. Considering that the system will finally run on Android smart phone, a special data application was created that was able to use a smart phone's GPS, pick the parking spaces and send the coordinates plus attributes to an online database via the phone's default pocket data function, see Figure 6.

Figure 6: Smart phone mapping application

Attributes for the parking spaces were the type of parking, whether Normal, Long/High or Disabled, the region and location of the parking lot. Once the data was entered on the field and sent over the internet, the online database was automatically populated. A SMS type of QR code was generated using the Quantum QR generator. A QR code for each parking space is generated where the unique identification number is encoded. The dispatcher's cell phone is also included in each QR code. Therefore on each parking a QR code having the parking space number and the dispatcher's mobile number is installed. All the parking spaces in the study area are installed outdoors. Thus the QR affixed on the parking space will be exposed to different weather conditions including scorching sun, rain and dust. The QR was thus printed on metallic plate since metal will endure these weather conditions. This is as shown in Figure 7. Moreover, there is surety that the QR print will not erase easily on the metallic plate. Most parking spaces have

already round metal bars marking the end of the space. Screwing a QR code on a metallic plate was also easy and a permanent way of placing the QR code. This QR will pre-populate a driver's SMS function of his phone with the parking space unique number and prompt him to put his cars registration and then send the message to control room.

Diafaan SMS server was used to form a link between the drivers' messages and the geo-database. The server receives requests, reports and bookings from the drivers, replies automatically to respective drivers and filters the messages to get the unique numbers which will be used to update the database and consequently the web map. An extent defining the study area was defined in Google Maps and customization of the web page done. The mapped parking spaces were published to the internet and appeared on this extent having their unique attributes i.e. Normal, Disabled and Long/High. A facility for booking was also installed that will allow one to zoom in a specific parking space and leave his personal details. The web page has both the list of all the parking lots and a web map which displays the same. If a parking space is vacant then it is visible on the web map but if its booked or occupied, then it will disappear from the screen until it's declared vacant again.

Figure 7: A QR Code affixed to a parking barrier

Figure 8 above shows how the QR Code was installed on a parking lot. Using Java programming for Android, a customized application was assembled that is installable in an Android based smart phone. The application connects with the GPS and pocket data functions of the phone. There is a welcoming page that directs the user to a short menu. Here one is given the option to have a view of the available parking spaces displayed as a list or alternatively launch the phone's browser hence display scaled version of the web map. A booking facility is also put in place that allows the driver to send his car's registration number. A SMS will be sent to the driver

Figure 8: A car parked by a parking barrier with a QR Code

5. Results

5.1 Web Interface Visual Display and Parking Reservation

A web map page for Jomo Kenyatta University was created showing vacant parking spaces as shown in Figure 9.

Figure 9: Web map page for JKUAT

This web interface operates on a near-real time mode since it will automatically update itself and reflect the situation on the park lots. The interface is connected to SMS server hence every request, booking or report will be recorded and reflected on the web map. The web map is also tied to the Android web application in such a way that whatever happens on it is published to the smart phone application via internet. The web page allows one to have a near-real time visual look of the parking situation within the university. This is a crucial element since one will make a better decision about his desired parking. On the web page there is a list of the available parking spaces which one can upon click on one, make a booking. There's also a map showing the parking spaces listed on the left. A legend showing the types of parking spaces is also included. Here one can flip through the various base maps to suit his interests. For instance one can switch to satellite view to have a look of the parking space against the satellite view of the institution as shown in Figure 10. The web interface provides a facility to make bookings of the desired parking space. Here a driver accessing the web page identifies a parking space of his choice clicks on it and enters his personal details in the pop up window. Figure 11 shows the booking facility of the web map. A message of confirmation is send back to the driver telling him the particular spot has been reserved and will expire after 30 minutes. Another message is also send to the parking attendant alerting him of the booking.
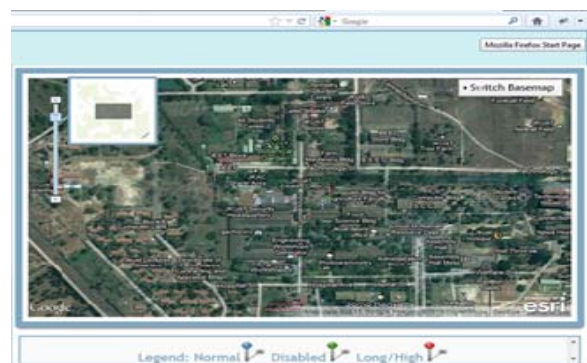

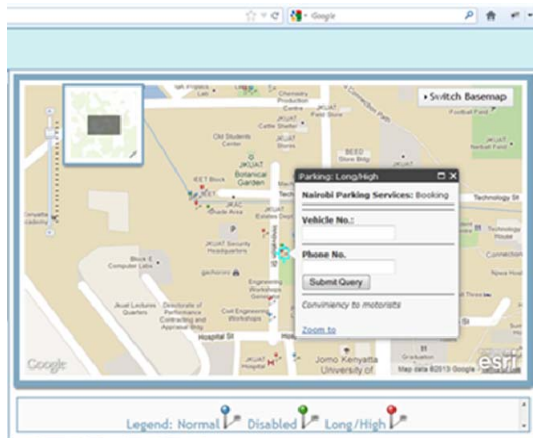**Figure 10:** Web map with satellite view as the base map

Figure 11: The booking facility of the web map

5.2 Smart phone Application

The web interface was scaled down to a format installable in an Android smart phone. The application was published in the Google Store market where one can download and install for free. A shortcut icon appears in the main menu of the phone which once clicked leads one to the sub menu of the application. Figure 12 shows a smart phone having the application shortcut marked with a letter 'P'. The display of the available parking spaces was done using two ways; by listing available parking or an online map.

Figure 12: Menu of a smart phone showing the smart phone application short cut icon marked with the letter 'P'

Figure 13 below shows the welcoming page that comes on when one initiates the smart phone application

Figure 13: The welcoming page of the application

The map and list options are as shown by figure 14. The list option leads one to a list of the available parking spaces which one can choose from as shown in Figure 15. Figure 16

shows a booking facility for reserving a particular space in the Android application. A pop window appears when one selects a parking space prompting him to enter his personal details. A confirmation message is reverted back to the driver and the particular lot removed both from the list and on the map
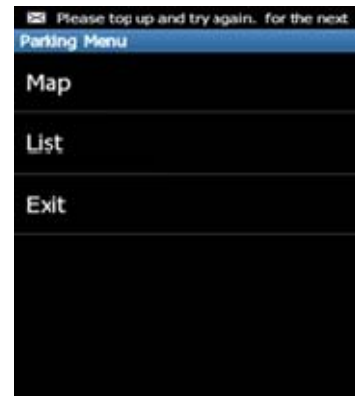

Figure 14: The map and List options of the smart phone application

Figure 15: List of vacant parking spaces

Figure 16: The booking facility of the smart phone application

The map option displays the available parking spaces. This is as shown in Figure 17. It allows one to hover around the study area by touch of button or swipe of the screen. The properties of a particular parking space are displayed once it's clicked as shown in Figure 18.

Figure 17: The Map option of the smart phone application

Figure 18: A parking space in the Workshop area of JKUAT

6. Conclusion

GIS was seen as a good tool to better the services of a parking guidance information system especially if it's a mobile GIS. Traditional methods of relaying parking information which included road signs and off-road visual displays were rather limited in that only a portion of road users could access the information at a time. A PGIS powered with a mobile GIS can deliver such information to as many road users one can think of at a time despite their location. Additional advantages of the system over traditional PGIS dissemination methods include;

a) Traditional PGIS dissemination methods only showed the status of a parking lot i.e. the number of occupied and vacant parking spaces. This mobile GIS PGIS allows the driver not only to know the number of vacant spaces but also other information e.g. road names for foreigners, booking facility and other important details derived from the base maps.
b) The system can further provide vital information like indicating driving directions for the driver. This is made possible since the system is connected to the GPS facility of the smart phone.
c) Having a system that gives a visual display of the current parking situation eliminates the puzzle a driver finds himself in while looking for a parking space. It enhances his decision making ability while he is still on the move thus cuts down the amount of time spent in finding a parking spot, reduces traffic snarl ups and ultimately lowers fuel consumption. Such a display shows the driver a vacant parking closest to him or her at an instance hence reducing driving time drastically. With such capabilities it

can be said that a smart phone can be used as a park finder.

7. Recommendations

a) Notifications: Due to the fact the use of cell phones while driving is a crime in most nations, it is recommended that the smart phone application be expanded to allow the driver be notified once he is within several meters away from a vacant parking space. The notification may be inform of a loud beep or vibration of the phone. Thus it won't be necessary for the driver to interact with the phone directly.
b) Billing: Parking fees is a source of revenue for most municipalities. Having 100 percent collection of parking fee near impossible. But with such an automation of the parking system and elimination of the parking attendant as the municipal's trustee to collect the fees, one can go a long way in maximizing fee collection. The system also can be enhanced by connecting it to the various mobile money transfer services.

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