A Location-based Mobile Application for the Police on the Beat

Dissertation Progress Report

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Abstract

The Greater Manchester Police (GMP) has a wide variety of information about victims, suspects, crimes, among others, resulting from their day to day activities. That information is correlated with the location where it was generated. As of today, this location-specific information is not available to the police officer that is patrolling the streets.

To introduce a system that can give up to date information, relevant to the current location of the police officers that use it, can improve the efficiency and effectiveness of the activities performed by them.

The aim of this project is to develop a mobile application that uses location based data provided by the GMP, to display on a mobile device, using user friendly interfaces and using the device’s sensors and features, to enhance the information received by the officer on the beat.

To achieve this goal, an analysis of the needs of the GMP is made. Also, a review of current approaches for location based applications for a variety of entities is constructed. Selection and review of available mobile technologies for implementation is made as well.
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1. Introduction

In recent years, mobile technology has permeated all aspects of human interaction with the world. This interaction ranges from consumer applications, including web-browsing, social media and games, to work-related applications, including financial and systems monitoring, and a wide range of instant communication. The availability of the internet on any location, thanks to data plans on mobile devices, from laptops, tablets and smart phones, has given all consumers the possibility to reach any information they desire from any location.

With the increase of these devices, new ways to increment the productivity and efficiency of workers in all fields has been introduced [1]. From simple text messaging communication (chat, e-mail) to applications catered specifically to a given field of work. These include project scheduling software, remote monitoring applications, and Enterprise Resource Management (ERP) systems among others.

1.1 Current needs from the Greater Manchester Police

The Greater Manchester Police (GMP) is looking for innovative ways to implement technological solutions involving mobile technologies. These solutions aim to increase the efficiency of the work done by police officers during patrol. They are also aimed to complement their current technological infrastructure, and improve the efficiency of their activities on a day to day basis, without incurring in a considerable investment.

GMP expects its officers to use a technological solution to complement their activities, confident that the availability of current, detailed and precise information will increase their effectiveness. The information queried by police officers regarding victims, suspects, arrests, properties, etc, needs to be marked with the precise location of occurrence, in order to be shown to the user in the location where the user is at any time. This information is managed by internal information systems within GMP; however there isn’t an actual system that allows its querying on real time by police officers on the beat. It is expected that a mobile application that uses readily available services and features and low cost of acquisition and maintenance, could help achieve the above needs.

1.2 Aims and objectives

This project will develop a mobile solution for the GMP that allows their police officers patrolling the streets, to query and receive relevant information based on their current location. This
information contains data regarding suspects, victims, properties, etc and their specific geographical position. To allow a greater functionality, the application must capture images taken from the device’s camera, and enhance them with information queried from the GMP’s database.

1.3 Report Outline
To accomplish the project aims and objectives is important to know the current environment and tools that are being used by the police forces. This report contains a study that will help understand the police needs and constraints regarding their field of work.

With that in mind, a review of the mobile technology evolution is made including its characteristics and main functions. It will serve as a starting point to understand the main focus of the dissertation. In the same vein, a review of Augmented Reality (AR) technologies will take place. These technologies, serve to enhance the interaction of the user with the world by embedding computer generated images into the user interface.

A history of the technologies available and its characteristics, and describing the technologies available for implementation is made. This will present a frame of reference that will help shape the final implementation of the mobile application required by the GMP needs.

Once the background review is made, this report will focus on the processes and methodologies that are being followed to develop the mobile application. It describes the software development cycle followed in the implementation, including a description of the tools required for its evaluation once it’s developed and tested. It also includes the plan and schedule that is being followed to execute the dissertation project.

Finally, the report describes all the progress that has been made during the current stage of the project. It includes an overview of the meetings that have taken place with the GMP and the list of requirements gathered from them. A section covering the process of analysis and selection of the development technologies is also included. Over the course of the project some development efforts where carried to implement an early prototype and technology demonstration. These efforts are detailed on the report.
2. **Background**

2.1 **Police environment**

Government entities around the world are looking for solutions to increase their effectiveness while reducing their costs described by Hauner and Kyobe [1]. During the last economic crisis, the budget of government in the UK has been reduced [2], and it has affected all its departments. While it seems that recession continues to affect budgets worldwide; innovative solutions have been looked upon to tackle this environment.

While is the case that private companies are leading the way in terms of technological innovations, it has been seen that government entities are using the same incentives to improve their bottom line [3]. An increase in productiveness and effectiveness for every area of public service is needed to overcome their budget cuts.

Among the departments affected by budget reduction are the police departments in the UK. According to the Her Majesty's Inspectorate of Constabulary (HMIC) [4], the organism in charge to inspect the police forces, budget cuts have affected the number of police men and women patrolling the streets. It has been shown by McCarty and Ren [5] that the overall security of an area is diminished with the reduction of police force, directly affecting the citizens located in the area.

A police officer has a wide variety of duties, ranging from patrolling the streets in case of suspect behaviour to administrative duties to support the policing organization. Other duties concern arresting individuals who have broken the law. While performing said duties, a police officer can conduct investigations, keep records of his/her activities, provide first aid in case of emergency, and testify in court regarding a specific crime. It is expected that a police officer must enforce the letter of the law in an ethical manner while carrying out the orders given by their supervisor [6].

A police officer in the UK can belong to a given number of departments. The law enforcement departments in the UK are diversified according to their function [7]:

- **Territorial Police Force**: Carry out most police duties in the UK. Their duty is to enforce the law, provide security services for all residents of a specific area; prevent crime and damages to property and to improve the quality of life for all. The police forces associated
with this description are deployed within England, Wales, Scotland and Northern Ireland.

- **Special Police Forces**: These are national forces that don’t have a specific area or jurisdiction. They are in charge of specific duties, like policing regular and rail transport, non military nuclear facilities, and drug enforcement, among others.

- **Miscellaneous Police Forces**: Have the responsibility to police certain specific areas, like ports or parks.

In order to perform their duties, police officers have several tools at their disposition. These tools can include cuffs, extendable batons, and incapacitating devices like tasers and incapacitant sprays. Most of the police officers don’t carry firearms, but there are some officers authorized to carry them during special duties and on special patrols [8]. While most of the tools have suffered some changes during their usage in the police duties, this changes seem to be rather evolutionary than revolutionary in nature, and most of the procedures and day to day activities have been the same during this time.

While the information age has permeated all structures of private and public industries, helping data analysis, information retrieval and productivity, most police officers during their regular patrol still rely in the same tools of communication and law enforcement as their peers 20 years ago as specified by UK Legislature [7] [8].

It is expected that with a reduction of the number of police officers patrolling the streets, each officer must cover a wider range of area reducing their effectiveness and increasing the probability of criminal activity. To overcome this situation, it is necessary to envision new tools that can be developed and given to each individual officer so he can maintain, or even increase the productivity and efficiency of each patrol duty.

In order to create such tool, it is imperative to know in detail the regular activities of a police officer on the beat. With such description it will be possible to find the most pressing needs of the police department in this area and design a tool that can be used effectively by the officers.

The main activities done by a police officer encompass the following as described by [9]:

- Search of individuals or vehicles for suspect activities and for keeping record of said searches.
• Arrest, detention and treatment of individuals during criminal activity. This activity can be done with or without a warrant depending on the situation.

• Stop vehicles and review drivers’ documents like drivers licence and insurance. Request a breath test if the driver seems to have been drinking or the driving pattern seems erratic.

• Search premises and seize property found on them.

During the execution of these activities most police officers patrol the streets on foot. In order to effectively execute those activities, it is necessary for them to hold the most relevant information related to their current location. If the police officer has enough current information regarding individuals and premises, it will be possible for the police officer to prioritize the most pressing actions at a given time and location.

While location based technologies have been introduced to the police force in recent years [10], they have mostly been introduced in police vehicles used during patrol (Cars, Helicopters). Assistance for police officers on the beat, offering functionality related to the current location has not been implemented on a worldwide basis.

A device that can recognise a police officer’s location, and offer information regarding updated relevant information regarding criminal offences, suspects, vulnerable individuals, etc. could help officers to engage in their activities with a greater degree of accuracy, saving time and effort for each member and increasing security for the city population. The ability to query other information regarding nearby locations is also needed to increase the efficiency of the police on the beat.

With the continuing advances in mobile technology and the affordability of these devices for the regular population, it would be possible to implement a prototype to display relevant information for the officer on a simple display without a huge increase in costs for the government.

2.1 Evolution of Technology on Mobile devices
It is possible to categorize the handheld transceiver (personal radio transceiver or “walkie-talkie”) as the first mobile device used for communication [11]. The possibility 2 persons to communicate over a large area increased the possibility to coordinate and implement actions without visual contact. Its development dates from the Second World War using batteries and vacuum tubes which made the devices a considerable size. After the war and with the introduction of the
transistor, the handheld transceiver reduced its size and was introduced safely and as a consumer
device for recreation or other activities.

During the 50’s new ways for communication were introduced with the pager. The pager was
introduced as a device to receive phone messages from a limited range, and it was used first by
physicians in New York on a subscription basis as stated in [12]. The technology of the pager also
evolved to acknowledge, and replay received messages. Although by the mid 90’s the availability
of cellular networks displaced the popularity of the pager, this technology is still used in locations
where the simplicity, and cost of the device still offer an advantage over more advanced
technologies, as seen in [13] [14].

Recently, the technology of mobile phones has also evolved. The first mobile calls were
performed on a device placed on a car in St Luis, USA during the first half of the 40’s decade [15].
By the 70’s mobile phone technology started to grain ground based on the advances made by
Motorola Research Laboratories [16] [17], with the first commercially available mobile phone sold
in the first half of the decade. While the phone had severe disadvantages (high price, size, weight
battery duration and charging times), it had a very good consumer reception for the time, with
orders numbering in the thousands [18].

During the 80’s the technology started to be commercialized in the rest of the world. Countries
like Japan and the Nordic countries increased their investment in infrastructure to support the cell
networks needed to support mobile phones [19]. During this time new features were introduced
by the phone manufacturers to increase consumer appeal. Technologies to reduce the batteries’
size (reducing the overall phone size) and the introduction of text messages by the short message
service (SMS) were counted among these advancements. By the middle of the 1990s, mobile
phones were starting to gain ground in the common population. The call and device prices, while
still high, started to be accessible by the majority of the people [20]. With the introduction of
higher processing power and features like games and applications, mobile phone stopped being a
luxury item and started to become tools for efficient communication and collaboration among
their users.

By the 2003, hardware resources where advanced enough to start increasing additional features
on phones. The launch of devices like Blackberry started the era of Smartphones, which increased
mobile phone features, by adding E-mail messaging, internet browsing, and a greater number of
business and consumer applications. By the first half of the decade, it was possible for consumers to acquire smart phone devices with an extend array of sensors and communication technologies (Bluetooth, Wi-Fi) and high quality touch screens. By this time, advances in new Operating Systems (OS) like iOS and Android, made it possible for the general population to start creating applications, taking advantages of the phone’s capabilities, and to commercialize them through vendor-supported marketplaces.

2.3 Overview of available technologies for Implementation

On a current hand held device, like a high end smart phone or tablet, it is possible to find a variety of sensors and technologies that can help the development of a wide range of applications. Global Positioning System (GPS) sensors, network access, gravity and light sensors, accelerometers, gyroscopes, orientation and rotation vectors, high definition screens among others, can be found on most devices. These are the most relevant systems available to create a rich user experience on a mobile display:

- **Global Positioning System (GPS):** System that is composed of an array of over 30 satellites in low earth orbit that provide signals that can be detected by a receiver on the earth’s surface [21]. The system allows any device that has a GPS sensor, and can receive a clear signal from at least 4 satellites, to determine an accurate location of the user, in real time, all over the world. With the use of the satellites’ signal, the receiver can triangulate its location accurately. The system uses the standard coordinate system (longitude and latitude) that can be used on any application or physical map. The ability of any GPS device to infer the user’s location, allows any software to provide any information relevant to it. The system is developed and administered by the Department of Defence of the United States of America.

- **Touch Screens:** Current hand held devices have displays that can be used to interact with the user by haptic sensitive screens. Screens that can perceive the human touch and capacitive devices like stylus pens enable the users to interact with the information displayed in them [22]. These types of screens can be attached to a wide array of devices, ranging from computers and video game consoles to smart phones, helping the development of a great set of consumer and business applications [23]. Touch screens use different technologies, include capacitive sensing (senses electrical conductivity elements like human fingers and conductive pens) [24], resistive sensing (layered conductive
surfaces that react to the position of the interaction) [25] and acoustic recognition (sound wave sensors that digitalize sounds produced by screen touch) [26] are some of the available technologies used to implement interactive screens on current devices.

- **Digital Cameras:** Devices that can sense light sources to produce photographs or video on a digital apparatus using an electronic sensor [27]. These cameras provide the user with a digital view of the world around the person. Using several methods, like single-shot, multi-shot and image scanning, the light sources can be manipulated to display images to the user using different resolutions and filters [28]. While most digital cameras started as single devices, today the largest number of digital cameras can be found in mobile phones [29], thanks to the advancements of electrical manipulation and miniaturization, and improvement in lens technologies.

- **Network Access:** Most hand held devices today have access to a data connection in most places around the world. Hand held devices can use several technologies to interchange data. This extended connectivity can be obtained using Bluetooth, GMS, GPRS, EDGE and LTE networks, Wi-Fi (802.11 IEEE standards), among others. With this capability, any modern hand held device and software can retrieve and upload information from anywhere as long it has a connection available. A data connection improves the amount of interaction that a user can make with the applications and their surrounding environment, due to the possibility to generate and display dynamically any information and to connect to any service reachable on a data connection.

- **Accelerometer:** An accelerometer is a sensor that can measure the acceleration along a given axis on any device that holds it. It is based on the gravity experienced by the weight of a test mass over a point of reference as described in [30]. The accelerometer can use piezoelectric elements (which use electrical charge generated by mechanical stress) and capacitive elements (which use electrical capacitance) to convert the mechanical force produced by gravity into electrical signals that can be read on a device, and perform calculations based on them. Using the accelerator provides a way to measure the direction and pitch of a device, having gravity as a point of reference. Using this sensor, an application can calculate the approximate orientation of a device and display information accordingly.

- **Compass:** The compass is an instrument that can measure the earth’s magnetic fields surrounding it, to display the direction and orientation within a frame of reference.
Compasses on mobile devices help software to use those measurements to provide and display to the user, the direction of the device within the cardinal points of a location and to display it to the user. The compass on a mobile device is implemented via a magnetometer [31], which measures the strength and direction of the magnetic field.

- **Gyroscope:** A device to measure the orientation of the device. A gyroscope uses angular momentum to calculate the rotation and pitch. Several applications can use gyroscopes to provide accurate information to the user, and increase the precision when used with other sensors like accelerometers [32]. Among these applications it is possible to find video gaming, naval navigation, and stabilization of flying vehicles.

Using these available technologies it is possible to create a compelling tool for almost any requirement from a consumer or business application that needs robust location and orientation capabilities. Among the applications that can take advantage of these sensors and tools, are applications that provide a direct view of the world and enhance their view with computer generated information. These kinds of applications are described as Augmented Reality applications.

### 2.4 Augmented Reality overview

Augmented Reality (AR) as described in [33], is the inclusion of computer generated information and widgets over a display of real world images. In this context, the real world view is “augmented” by all the information generated by the computer interface between the view and the user. The information displayed the computer interface can be generated from a variety of inputs, based on the type of application and the device used.

There is a wide range of displays that can provide an AR perspective to the user [34] [35] [36] [37]. Here is a description for some of these devices:

- **Head mounted displays:** Special helmets located on the user’s head that provide an information display to the user. These devices have special sensors that provide a wide range of degrees of freedom and adjust the information according to head movements. An example of this technology can be seen in Air force pilot’s helmets.
- **Eyeglasses:** An evolution from the head mounted display; eyeglasses can provide an augmented display of the real world, using small camera and a range of sensors, displayed
over the lenses of the screen. Lately, Google has been working on the development of this technology in the Project Glass.

- **Handheld devices**: The evolution of smart phones and tablets has allowed the inclusion of different sensors, including cameras, GPS, accelerometers, etc. With the increase of processing power of handheld devices, a wide set of applications is being developed. Companies like Layar have surfaced and they develop applications and services that take advantage of these technologies [38].

- **Spatial Reality**: Instead of displaying information on specific screens, spatial reality devices project the desired information over physical objects. This separates the display from the user, allowing a wider range of users to collaborate on the same space. One of the drawbacks of this type of device is that since it needs a surface to project the desired information, so it cannot offer the same flexibility that user specific devices provide.

- **Next Generation Displays**: The latest generation of displays is being researched around the world, and are based on the direct display of information over user’s retina or contact lenses. Other types of displays are based on the real time processing of light sources to provide an augmented view of a light source that the human eye cannot physically see, for example a clear view of a soldering process that cannot be seen directly by the human eye [39].

AR displays and software can already be found in several fields, from consumer to business applications. Some of the uses for this technology can be described as task support (allowing a performance increase in the execution of a complex task), to educational and recreational. A description of these applications and range of fields is followed in more detail:

- **Task Support**: applications that help the execution of a given task can be found on several fields [40] [41] [42] [43]. Using AR, an architect can help visualize information about construction projects while they are being built, and a consumer can view extended information of a product that the person may want to buy inside a store. AR displays can also be incorporated on assembly lines to improve production line processes. In a military perspective, extended information on the battlefield can help soldiers to assess risk regarding their environment and enable real time communication between the soldiers and the command centre.
• **Educational**: AR can help extend the interaction between the user and the subjects of study as noted by [44] [45] [46]. Textbooks and other related educational material can be scanned using AR displays to increase the information available to that object. Field trips can be enhanced by the use of this technology, by means of increasing the information available on a remote site, and providing simulations of past events on the site.

• **Recreational**: Tourism applications that present interactive information on important sites on different cities can be displayed using these devices [47] [48]. Fans of sports can improve their viewing experience by looking computerized images that extend information on the field of play, examples of these can be found on the “first down” line on American Football transmissions [49], where the TV viewers can see increased information regarding the playing field that is not available for the people at the stadium.

Overall, any task that can be performed using an appropriate display and can be enhanced by availability of increased information regarding said task, is suitable for an AR implementation.

### 2.5 Location based and AR applications for consumer and business entities

With the evolution of mobile technologies, software development has taken advantage of the capabilities offered by those technologies. Application marketplaces have provided a simple way for both consumer and business users to download and use applications, and for developers to distribute them. To give an example, since the introduction of the app store by apple in 2007, more than 800,000 applications are available to download. Their success has been demonstrated by more than 40 billion downloads in the same time frame [50]. This mobile marketplace has led the way for other mobile vendors like Google and Microsoft to create their own platforms for content distribution on their own mobile environments.

The availability of marketplaces and the increasing resources and technologies offered by mobile devices has produced a great number of applications that have been created to cater the needs of a wide range of consumers. One subset of those applications is geared towards location based technologies, in which their use can enrich user interaction and provide reliable location based information for users. Likewise, the increase of the devices’ capabilities to sense and measure their surroundings, has enabled the development of AR applications on a wide range of platforms.

From the consumer standpoint, applications like foursquare, let users check in into businesses and venues based on a GPS based location, are available. On the same social media topic, mobile
Apps for Facebook and Twitter can access the GPS sensors to tag user postings and create a map of the user locations for the user’s friends to see.

Outside the social media environment, consumer applications that enhance the user experience can be found, including applications that let the user decide if a product will look good in his house before buying it [51]. Other consumer applications are based on displaying finished views of boxed products, like Lego’s augmented reality app [52]. Tourism has also been a good source for developing applications, where museums and government entities use mobile applications to display enhanced information on historical landmarks or to display an object in different periods of time.

From a business perspective, several entities have created applications that take advantage of the mobile technologies to create an enhanced user experience [53]. Fleet and sales management apps are being created to keep detailed locations of sales and fleets across a wide area. Other areas in which these technologies are applied are based on asset tracking, work validation and location based search.

The usage of location based applications has been in use on the military since the beginning, and in the case of AR technologies, it was first introduced by military research [54]. However, given the evolution and cost of the technologies, its uses have been restricted to few applications. Research has been done on mobile applications for military use based on detached devices like smartphones that provide a better presentation interface [41].

Regarding the subject of analysis, the GMP has provided an Application Programming Interface (API) that provides location based information for any application that wants to use it [55]. This data contains information about crime statistics at street and neighbourhood level, nearest police stations, among others. There are several applications that use this data in creative ways [56], alerting the users to rough neighbourhoods, and the possibility of locating specific crime in an area. The drawbacks of this public API is that the location information is not as accurate as the one used internally by the GMP and the information may not be up to date.
3.  Research Methods

3.1 Development Process
The project aims to analyze, design and implement an application prototype that meets the needs and requirements of the Greater Manchester Police (GMP) officers on the beat. In order to accomplish this objective it is imperative to define a process in which these requirements will be gathered and studied. This project will follow an iterative process of software development engineering as stated by Larman [57], in which the main phases of the process are described as follows:

- **Inception**: A small study is made to gather the most outstanding requirements from the client (in this case the GMP). This phase is made with the in collaboration with the GMP contact, the project’s supervisor and the student.

- **Elaboration**: The main objectives are laid out and the most pressing needs are stated to give start to the phase. This phase is iterative, with requirements identified and addressed in each iteration. On this project, the client won’t be able to accompany personally during all the iterations, but constant communication with the client is expected throughout the duration of it.

- **Construction**: This phase encompasses coding and testing of the requirements defined for each iteration. During an iteration, the construction phase has the majority of the effort. It is possible that during the course of each phase, the original requirements change, and those changes will be addressed on the following phase.

- **Transition**: Results from the construction phase are analyzed and deployed on the working prototype. Feedback from the client is not expected on each iteration. This phase will be executed by the project supervisor and the student. Once a transition phase is finalized a new elaboration phase begins.

It is expected that a prototype will be constructed during several iterations of the software engineering process. Throughout each cycle or iteration, several artefacts (deliverables of the process) will be constructed. The artefacts that will be delivered by each development cycle are:

- **Design diagrams**: These show the overall design of the applications, they could include the different abstraction layers of the implementation. This set of diagrams can specify static
or dynamic processes of the application. They are intended to give a “bird’s eye” view of the system structure and function.

- **Class Diagrams**: They display the model of the data manipulated by the application. They show the domain model and the class structure for the system. In these diagrams, attributes and operations of each class are shown. It is expected that the model is augmented and refined in each cycle.

- **Vision Document**: This single document specifies the overall goals and objectives of the resulting application. It defines the limits and scope of the effort to be executed on the project. This document is constructed in the initial phase of the project (Inception).

- **Bugtracker**: This document defines all the test cases, and keeps track of the results of each test. It allows monitoring of the real progress of a cycle. The bugtracker specifies all the tests to be made on the application, including functional and non-functional requirements, integration and acceptance tests to be made by the client.

### 3.2 Design Patterns

In order to provide an acceptable result the application should be designed to conform with common design patterns in the code and user interface. As stated by the “gang of four” [58], software design patterns are useful to create reusable and scalable designs. Using design patterns helps the development of the application in an iterative cycle since each pattern allows the separation of function and implementation [59]. This allows the implementation of client requirements in different stages of application development. Design patterns can be categorized into several subsets based on their function and goals:

- **Creational Patterns**: They specify the methods in which some classes of the domain are created. Based on the needs of the model, separating the creation of the classes from their use allows a design to be extensible and reusable within different subsets or layers of the application. Within this category the Abstract Factory, Builder, Factory Method, Singleton patterns among others can be found.

- **Structural Patterns**: They define the overall structure and design of the application, allowing the separation of different layers and views within the application. Adapter, Bridge, Composite, Facade and others are patterns found in this category.

- **Behavioural Patterns**: They define the behaviour of a subset of classes or layers and how they should interact. They allow the possibility of decoupling the implementation from
actual usage, and how a specific class should be treated and managed during the course of a function within the system. Some of the patterns that are described in this category are Command, Iterator, Mediator and State.

For the user interface, it is possible to define some design patterns to be used. Taking into account that the goal of the application is to be hosted on a mobile device, it should follow a number of user design patterns adequate to the medium. The application should behave according to the expected behavioural patterns of the environment where is developed. Layouts, button placement, and user expectations should be taken into account in order to specify the design of the user interface.

For every mobile platform, including Apple’s iOS, Google’s Android, Microsoft’s Windows Mobile and others, there are user interface standards to be applied. It is expected that the application should conform with the standards specified with the selected development environment for the project. At the very minimum it is expected that the application should make appropriate use of the touch screen interface, gestures and overall application lifecycle of the platform.

3.3 Deliverable of the project dissertation
As a result of the project dissertation, a mobile application will be developed. In order to support the required environment, a layered system using a centralized database and information retrieval middleware will also be constructed. This middleware is needed so the mobile application can use its services.

As part of the resulting dissertation, a section covering the evaluation and selection of the technologies to implement the application will be presented. Mobile environments, such as Apple’s iOS, Google’s Android and different mapping technologies will be studied and presented in this section. Technologies related to Augmented Reality, which aim to improve the spatial experiences of the user, will also be evaluated and implemented.

The project will produce a prototype/proof-of-concept rather than a production-level application, in order to show the capabilities of the selected technologies. The resulting application would be evaluated by GMP personnel associated with this project. The evaluation will be based on a survey on which each potential user will evaluate each requirement defined for the prototype. Additional factors including ease of use, responsiveness and performance should be evaluated.
3.4 Out of scope issues
The application is a proof of concept, so the project won’t be designed to function within the actual expected nature of devices in the field, e.g. space age bespoke headset (similar to Google Glass project) which could be argued is a better solution than an ‘off the shelf’ tablet or smartphone.

Security constraints regarding the information available in the application/device will not be addressed, e.g. In-the-field security issues (e.g. loss of device, eavesdropping), suspects and victims, information, etc. Also, security issues around using off-the-shelf technologies for the implementation (e.g. trusting Google with your real data, possibilities of protection/loss via/ despite encryption etc.) will not be addressed. Data mining opportunities around more sophisticated pre-processing of police/other data prior to display on devices will not form part of the development of the application prototype in the project dissertation.

3.5 How the software is going to be evaluated
Since the result of the project dissertation is a working piece of software, a working prototype with its characteristics described in previous sections; the result and functionalities should be evaluated by the final users of the application. For the final software evaluation, two main tests are defined for this purpose; acceptance tests, and usability tests.

The acceptance tests of the project will be evaluated by GMP designated contacts based on the complete fulfilment of the main requirements for the application. The main requirements are defined by the GMP, and these are based on a subset of the use cases defined for the whole project. Other types of requirements (performance, reliability, supportability requirements on the FURPS model) should not be evaluated by the final users unless it is clearly specified by the GMP.

The evaluation method is a weighted average for the subset of functional requirements. It would be based on the following criteria:

Each evaluated requirement will have a defined weight in the overall score. If a requirement of the prototype is met by the standards defined for it, it will be given a score of 1 otherwise, its score will be 0. For a successful result in the acceptance test, the overall score of the full set of the user defined requirements must be above a certain percentage (also defined by the client).

To measure the acceptance tests the formula described as follow should be applied:
Where \( n \) = Total number of requirements on the acceptance test

To describe the above process, let assume that given software project has the following user evaluated requirements and results for an acceptance test, as described in table 3.5.1.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Weight</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Req1 - Acceptance Requirement 1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Req2 - Acceptance Requirement 2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Req1 - Acceptance Requirement 2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Req2 - Acceptance Requirement 3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3.5.1: Example of user tests and results for each requirement

Using the results in the table and applying the equation, the result would be equal to 83%. In this example, if the user defined that the minimum threshold that the project requirements should be 90%, the project would fail the acceptance test, but if the threshold was defined as 80%, the acceptance test is deemed satisfactory. A detailed definition of the requirements for the prototype is specified on the Progress section of this report.

The final product should also be evaluated based on usability tests. Usability testing is the process on which the interaction between the software and the user is evaluated as described by [60]. The goal of usability testing is to receive a direct input of this interaction and to measure the capacity of a given piece of software to meet the user’s expectations. In order to evaluate the final prototype of the application a System Usability Scale (SUS) is going to be used.

The System Usability Scale was developed by John Brooke [61], and aims to evaluate on a scale of agreement the interaction of the users and the software. The valuation is made on a series of questions given to the user after following a predefined interaction. The questions to be asked to the user are specified on the table 3.5.2:
<table>
<thead>
<tr>
<th>Number</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I think that I would like to use this system frequently</td>
</tr>
<tr>
<td>2</td>
<td>I found the system unnecessarily complex</td>
</tr>
<tr>
<td>3</td>
<td>I thought the system was easy to use</td>
</tr>
<tr>
<td>4</td>
<td>I think that I would need the support of a technical person to be able to use this system</td>
</tr>
<tr>
<td>5</td>
<td>I found the various functions in this system were well integrated</td>
</tr>
<tr>
<td>6</td>
<td>I thought there was too much inconsistency in this system</td>
</tr>
<tr>
<td>7</td>
<td>I would imagine that most people would learn to use this system very quickly</td>
</tr>
<tr>
<td>8</td>
<td>I found the system very cumbersome to use</td>
</tr>
<tr>
<td>9</td>
<td>I felt very confident using the system</td>
</tr>
<tr>
<td>10</td>
<td>I needed to learn a lot of things before I could get going with this system</td>
</tr>
</tbody>
</table>

Table 3.5.2: Questions asked to the system evaluator on a SUS [61].

Each of the questions is evaluated on a scale from 1 to 5, where 1 is “Strongly Disagree” and 5 is “Strongly Agree”. The score from each question goes from 0 to 4. The SUS generates a single score representing a measure of the overall usability of the system. (Scores from individual questions are not meaningful on their own). To score the overall SUS score, even questions are graded 1 minus the scale position. Odd imbed questions are graded 5 minus the scale position. All grades are added and multiplied by 2.5 to obtain the overall result. SUS scores have a range from 0 to 100. It is expected that an application that scores over 80 has a good usability. For all applications, the average of SUS evaluation is 68 [62].

The overall evaluation from the project clients will be based on both the requirements and usability tests, and it could show the overall effectiveness of the project result from the GMP perspective.

3.6 Project dissertation Planning
The project dissertation plan has been divided in several subtasks following a standard iterative software development cycle. The Gantt chart for the overall implementation plan is defined on the figure 3.6.1.
The most relevant milestones in the plan, with their deadline dates are described in the table 3.6.2:

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background reading – Technology Selection</td>
<td>31st March 2013</td>
</tr>
<tr>
<td>Progress Report</td>
<td>April 30 2013</td>
</tr>
<tr>
<td>Complete System Design specification Finalized</td>
<td>8th April 2013</td>
</tr>
<tr>
<td>Complete System development finalized</td>
<td>7th June 2013</td>
</tr>
<tr>
<td>User evaluation with Greater Manchester Police</td>
<td>10th August</td>
</tr>
<tr>
<td>Dissertation writing finalized</td>
<td>30th August 2013</td>
</tr>
</tbody>
</table>

Table 3.6.2 List of milestones for the project dissertation

With the current schedule, the remaining outstanding work for the project dissertation is subdivided in the following tasks:

- **Application design Approval**: Following the finalization of the progress report, the detailed technical designs for the application layers will be reviewed with the supervisor for approval.
• **Data Analysis:** The GMP provides anonymous data that can be used during the project development. GMP data will be used to define an appropriate data structure to store and query the information that will be displayed by the mobile application.

• **Application Development:** Once the overall designs for the Database, Middleware and Application layers are approved, the development and coding of the layers will be performed using an iterative development process.

• **User Testing:** Meetings with the GMP persons assigned to the project will take place to test the application. User testing will include usability tests.

• **Dissertation Writing:** The writing for the dissertation report will be made during the months of July and August. During this time frame most of the development should be finalized and the user testing will be executed. This will allow enough time to correct any outstanding errors and to appropriately collect the results from the tests.
4. Progress

There are several activities that have been done so far on the project, based on the standard iterative software development cycle. So far there are several milestones that have been met, and they will be described in each of the following subsections.

4.1 Overview of Student / Supervisor Meetings
Since the project inception, the student has met with the project supervisor to discuss the advancements and progress on a weekly basis. On each meeting there are several subjects that are addressed and at the end of each meeting new tasks and goal are made to be reviewed on the following week. The tasks range from simple activities like reading on a specific subjects or related to a given deliverable of the prototype. The main milestones that have been achieved by during this process are:

Technology review: Since the project inception, the project objective is to implement a mobile application using location based technologies. To ensure a successfully developed application, a formal review of available technologies was needed. A correct implementation needs to take into account readily available technologies based on a multitude of software APIs and Hardware providers. The result of this milestone is reviewed on a more detailed basis in the “Selection of Technology” section.

Overall application design: Based on the objectives dictated by the project description, an overall application design was needed to envision the full extent of the effort needed to complete it. Several designs were made to describe the overall application features and functionality and to describe the layers that will form the full environment. Overall, the layers that were defined for the application were the data layer (covered by a database) a middleware (data gathering, processing and formatting) and mobile application (user facing component of the application; consumes the services provided by the middleware). The result of this milestone is reviewed in the “Application Design” section.

Prototype development: During the init course of the project, efforts were done to start the implementation of the software application. The aim of the initial milestones was to make a proof of concept for several technologies related to the overall goals of the application. Progress was made on several fronts, from map related development, sensor analysis and an initial review of
video overlays for an enhanced world view for the user. Detail of this progress is specified in the “Development” section.

It is expected that the meetings will continue during the project duration and if there are schedule changes, those will be agreed by the interested parties.

4.2 Overview of Meetings with GMP
The prototype that is being developed will need to serve current needs expressed by the GMP. A requirement gathering process was followed to formally retrieve those needs. To achieve this, 2 meetings were held to gather the main and secondary requirements from the GMP. The first meeting was with the main supervisor of the project from the GMP side, (Peter Langmead-Jones) in which the main requirements were laid out. A second meeting was made with another contact form the client (Duncan Stokes) in which requirements were further developed for the project. As a result of the meetings, the requirements were gathered and categorized.

Application/Software Requirements

The project must provide a mobile application that should be able to display 'summary data', originating from a number of sources (GMP databases, public available services), in a visual display that correlates data to an approximately 'photo-realistic' image of its geographical source.

The artefact (software prototype) won’t address security issues, such as legal/regulatory issues, data protection, anonymity, etc. The prototype should show an intelligent enhancement over the services provided by current geo-based services (crime-mapper/police.uk website). The application should behave in a "push"-based interaction with the user, rather than "pull"-based (the application will notify the user rather than the user proactively looking for the information).

The nature of the data retrievable by the constructed system should include crime scenes, suspect and victim locations, vulnerable individuals, information regarding the nearby properties (Key-holders, issues, street furniture), and other relevant data that might help the users of the system to take appropriate and accurate actions. The data to be used on the development of the application should be provided in part by the GMP (providing “dummy”, not real information).

Other information should also be queried from other public available services provided by the local government entities. An appropriate device for the development of the system, according to the technology evaluation, should be provided by GMP.
GMP will provide a limited information set based on the Rusholme area (near the M14 4DJ post code) that will match the current structure of the data managed by GMP’s internal systems. With the data provided, a data management layer must be developed to analyze said data and provide that information to the police officers on the beat, using the most appropriate display like a map based interface and augmented reality display.

4.3 Selection of Technology
To achieve the results specified on the requirements made by GMP, the first step is to select a technology that can appropriately support the selected features. In order to evaluate the technology, key characteristics were analyzed, and compared between the current mobile vendors. The features that were taken into consideration for the evaluation are:

**Map Support**: The availability of a programmable map interface to compose a custom application with related map layers, markers and overlays.

**Video Support**: In order to present the location based information in a photo realistic environment to the user, video support is needed. The ability to programmatically manipulate video displays, add overlay images, and control the on board camera is imperative.

**Sensor Information**: The ability to detect and obtain sensor information to position the user on a realistic location in the world. Sensors like GPS, accelerometers, orientation, gyroscopic and light sensors are needed to correctly locate the user position and direction and present him with the relevant information related to his current location.

**Programmability**: The possibility to develop a multilayered system on the device, able to communicate with external systems, control notifications (in text, light and vibration forms), usage of services (separately running services from the main application). It should be possible to control the application lifecycle in order to reduce energy consumption and appropriate usage of sensor information. Ability to produce an application suited for mobile and tablets without over additional code.

**Price/Licensing**: It should be possible to develop the main application without the need of external licenses, and should be cost free to develop and publish. Usage of free and open source software should be expected for the prototype.
For the evaluation of said features, the biggest mobile vendors were selected based on current market share. These vendors are Google with the Android Mobile Operating System (OS), Apple with iOS and iPhone, iPad mobile devices, and Microsoft Windows Mobile on Supported devices.

Table 4.3.1 shows the comparison of features between the different mobile vendors and the features analyzed.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Apple</th>
<th>Google</th>
<th>Microsoft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Map Support</strong></td>
<td>Introduced Apple Maps on iOS 6. Before that version used google maps API. No restrictions on use.</td>
<td>Offers Map Support through Google Maps API. Free to use if used less than 25000 times per day. Supported natively on all Android phone and Tablets.</td>
<td>Provides Windows MAP API that uses Bing Maps and Nokia services for location based applications. Restricted to use the API on navigational, asset tracking and business applications.</td>
</tr>
<tr>
<td><strong>Video Support</strong></td>
<td>Apple devices provide a wide range of camera devices that can capture the surrounding environment with an appropriate resolution.</td>
<td>Google devices provide a wide range of camera devices that can capture the surrounding environment with an appropriate resolution.</td>
<td>Nokia devices provide a wide range of camera devices that can capture the surrounding environment with an appropriate resolution.</td>
</tr>
<tr>
<td><strong>Sensor Information</strong></td>
<td>Latest iPhone and iPad devices are provided with the following sensors: GPS, Accelerometer, Gyroscope, light sensor, proximity sensor.</td>
<td>The Nexus range of devices provides the following sensors: GPS, Accelerometer, Gyroscope, light sensor, barometer, magnetometer, and proximity sensor.</td>
<td>Top of the line Nokia Lumia devices provide the following sensors: GPS, Accelerometer, Gyroscope, light sensor, magnetometer, proximity sensor.</td>
</tr>
<tr>
<td><strong>Programability</strong></td>
<td>iOS Applications are developed with the Object-C programming language on the Xcode development environment. Development is restricted on Apple Mac devices.</td>
<td>Android apps are created on the Java language using Android development API. Development can be made on windows or Linux platforms using an eclipse IDE plug-in.</td>
<td>Windows 8 Apps are developed on .NET Languages (C#, Visual Basic .Net) and can only be developed on Windows OS.</td>
</tr>
<tr>
<td><strong>Price/Licensing</strong></td>
<td>To deploy an app on the marketplace an application has to be approved by an Internal apple team. A licensing fee of USD$ 99 is needed. It is not possible to legally distribute applications outside the market.</td>
<td>Free application distribution can be done via marketplace or by side-loading directly on the device. There are no restrictions on distribution of apps outside the marketplace.</td>
<td>To deploy an app on the marketplace an application has to be approved by an Internal apple team. A licensing fee of USD$ 99 is needed. It is not possible to legally distribute applications outside the market.</td>
</tr>
</tbody>
</table>

Table 4.3.1: Mobile Vendors characteristics evaluated for the project dissertation
After reviewing all the capabilities offered by the mobile vendors and taking into account the overall cost of implementation, the Android development environment was selected. It is expected that the nature and maturity of the services provided by Google will provide a strong environment to develop the desired application.

The selected tools for the implementation are:

- **Operating System (Development):** Windows 7
- **Development Language:** Java SE 7.
- **Development Environment:** Eclipse Integrated Development Environment (IDE). Includes Android development Plug-in.
- **Mobile Platform:** Android 4.1.1 and above (Jelly Bean).
- **Device:** Samsung Galaxy Nexus.

### 4.4 Application design

In order to meet all the GMP requirements, a design was envisioned to support all the needs of the client. The system and mobile applications designs have to take into account several restrictions from the data management standpoint and from the mobile environment in which it will perform.

From the meetings with the GMP it was noted that all the data information is stored in plain text files, without proper data normalization. Even if the application in the prototype stage will only manage a reduced set of data (centred on the M14 4DJ post code), in the actual running environment it could manage and / or query a much greater set of information. Since the application should perform in a push-based mode (the application should notify the user if there is an important set of locations around the current user position), it should behave like a background service, but using the least amount of power to reduce the energy consumption on the mobile device.

Taking into account those restrictions, a three-layered design was created. The three layers are composed of the Data Layer, System Middleware Layer and Mobile Application Layer.

**Data Layer:** It will map and store the information provided by the GMP. It will consist on a normalized central database that will store the information of the structure needed by the middleware and the mobile application that will consume its services.
**Middleware Layer:** A server side component that will perform 3 basic functions. Provide services to the mobile app, query and manage the data stored in the data layer, and perform the data transformation from the information provided by the GMP and related public available services in the internet.

**Mobile Application Layer:** This is the user-facing part of the application, provides context and location specific data to the client. Shows Map based and augmented reality information to the user. It will follow the application lifecycle of the selected environment, and will provide the necessary tools to query the information to be consumed by the services provided by the middleware layer.

Figure 4.4.1 shows the overall design of the layers and their interactions during the lifecycle of the application. While it provides an overview of the system functionality, each of the layers and their interactions are explained further.

![Diagram of system design](image)

Figure 4.4.1 General system design of the application

The database layer will store all the information related to the GMP data, and will also store application specific data (configuration, data structures, etc). The database design follows normalization rules to ensure reduction of data redundancy and dependencies. The data structures defined in the database are important, since they hold the appropriate definition of the
data to be queried by the app. It will also ensure that data from other sources, other than GMP files, will be stored using a standard structure.

The database layer can only be accessed directly by the Middleware layer. The middleware layer will perform queries and data operations (insertion, updates, deletes) over the information on the database. The middleware layer will also have the function to capture, process and format the information from different sources (GMP files, public available services). After processing the data, the middleware will store the information in the appropriate structure on the database. This function ensures that data from different sources and formats will be available by the mobile app at run-time. The middleware layer uses software design patterns to perform its operations in an extensible way, and uses them to ensure an adequate level of performance, by ensuring proper methods of data processing (e.g. caching, connection pools).

The mobile application layer will consume the services provided by the middleware layer and services from the maps components. The application itself won’t store much information on the device but will use the information from the sensors, to accurately calculate the device’s position and orientation to present relevant data to the user. The middleware application has 3 modes of operation.

- Display of location data relevant to the user’s position on a map interface. This mode will allow the user to use touch gestures to zoom specific locations and display relevant information.
- Display of an augmented reality display, using the device’s camera and overlay markers on top of it, to display on the user’s point of view. The information displayed will be limited to their proximity to the user’s view, which should be around 200 meters around the user’s position.
- The mobile application will also perform queries regarding taking into account the user’s location. This is done through a service to notify the users of important information near its position. The notification would be done via light, sound or vibration, while the user is not actively using the application.

The mobile application should also have some configuration options which will allow the user to specify which kinds of notifications are displayed, and which information will be presented by the application.
4.5 Development
To implement the design several efforts have been done to meet the specification. The implementation effort done has been directed into understanding the implications of such development, including the understanding of the mobile application lifecycle on the selected environment. Work has also been done on implementing the mobile application layer’s modes of operation.

The development effort has been separated on three different aspects, applying the Map interface to the mobile application, creating overlays over live video feed and analyzing sensor data.

Map Interface: The map interface is made using the Google maps component on the user application. The component, named GoogleMap, is a fragment on the Android development environment. Fragments are a portion of a user interface that can be included on an application activity, which is the main class that interact with the user on a given time.

Activities on the Android development environment have a lifecycle that must be understood to properly manage the application resources. Figure 4.5.1 shows all the states and transitions on each activity lifecycle.

The first state is created, which is the state that an application resides after being first instantiated by the system. In this state the basic application operation logic, is done only once during the activity lifecycle. The second state is started, which is the state where the activity is visible for the user. Resumed is the main state of the application, and receives external input from it. Paused is the state where the activity resides once another activity partially obscures the main activity. In this state operation should be made to ensure that only the main resources of the device are kept running. Stopped is the state where another activity is running and being displayed to the user. In this state the application releases all the resources that are being used by the activity and saves all the user information that needs to be stored. The last state is destroyed, and this represents that the activity has been released from the device’s memory.
To reach each of the states, the operating system calls certain methods on the activity class. These methods (onCreate(), onStart(), onResume(), onPause(), onStop(), onDestroy()) represent the transitions between the states. These methods can be overloaded to ensure that the proper operations can be made on the activity on each state.

To create the map mode on the application an Activity was created, and the map fragment was initialized on the onCreate() method. The GoogleMap Fragment holds all the functionality to zoom the map and navigate through the desired position (configured on the instantiation phase). To add functionality to the map, it is possible to add markers on the map at run time. These markers can be configured to be displayed and to respond to user actions once touched.

Figure 4.5.2 shows an android activity configured to display some markers. One of the markers is being touched and it is displaying information about the specific location. Once the official structure of the files presented by the GMP is known, it would be possible to design an appropriate display for each of the markers on the map mode on the mobile application.
Sensor Information: In order to develop a location and orientation aware application, the device’s sensor information needs to be collected. The selected device for the project presents a wide variety of sensor information that can be read to understand the user’s current position and orientation. It is possible to divide the sensor information on the Android OS on Location Sensors and Other Sensors.

Location Sensors: Sensors that provide location specific information of the user’s device. To provide said information, the device uses 2 types of sensors, Global Positioning Service (GPS) and Network Location. The GPS sensor is a much more detailed positioning sensor that Network location sensor, however, if the GPS sensor is not available on the device or if the user is not reachable by the satellite system used by the GPS, the network positioning could replace the functionality (reducing precision). To read the position information on the device, 2 classes are used on the application, LocationManager and the interface LocationListener from the package android.location. LocationManager, as the name implies, manages for the user the sensor information. To update the sensor information, the class receives implementations of the LocationListener class which will receive the updates on the method requestLocationUpdates. The full implementation can be done like this:
First, the `LocationManager` class is instantiated by the System Service of Android OS. Then, through the `requestLocationUpdates` method of `LocationManager`, specific implementations of the `LocationObserver` interface are given as parameters for the method. On the method it is specified which kind of sensor (GPS or Network) is desired. On this example `LocationObserver` is an implementation of the `LocationListener` class. There are several methods that can be implemented of the `LocationListener` class. The most important is `onLocationChanged` which receives a parameter of the class `Location` which holds the latitude and longitude of the device’s position from the `LocationManager`.

**Other Sensors:** To accurately describe the user’s position and orientation, the system needs to read a set of other sensors in the device. The selected device offers a wide array of sensors that could help determine the orientation of the user. To identify the number and characteristics of the sensors available on the device, the Android OS provides a set of instructions to query said information:

The sensor architecture is defined by several classes. The main class is `SensorManager` of the `android.hardware` package. This class is instantiated by the Android’s system service with the instruction:

```java
mSensorManager = (SensorManager) act.getSystemService(Context.SENSOR_SERVICE);
```

Where `mSensorManager` object is an instance of `SensorManager` class. After `SensorManager` is correctly instantiated, it is possible to access its methods. The first, and arguably the most important method is `getSensorList`, which lists all the available sensors on the specific device programmatically. The list returned by the method, hold instances of the class `Sensor`. This class holds several attributes that can help identify each of the device’s sensors, such as the name and precision.
To query the list of available sensors and its names, the following algorithm can be executed:

```java
String result = " ";

//Retrieves the list of available sensors form the SensorManager
List<Sensor> deviceSensors =
    SensorManager.getSensorList(Sensor.TYPE_ALL);

Iterator<Sensor> iter = deviceSensors.iterator();
int i = 1;
//Retrieves the names from the list of available sensors of SensorManager
while(iter.hasNext()){
    Sensor actual = iter.next();
    result = result + "(" + i + ") " + actual.getName() + "; ";
    i+=1;
}
```

Most sensors hold information on 3 available axes (x,y,z). To retrieve the information on each sensor, SensorManager can register an instance of a SensorEventListener. This interface is implemented on the developer's code to receive the sensors values on the onSensorChanged method of the interface. A simple implementation of the interface to retrieve the sensors values can be made in this fashion:

```java
public class SensorListener implements SensorEventListener{

    private String x, y, z;

    @Override
    public void onSensorChanged(SensorEvent event) {
        //The variable "values" holds the sensor’s value in each of
        //the 3 slots of the array
        float[] values = event.values;
        x = values[0] + " Value 1 – X axis";
        y = values[1] + " Value 2 – Y axis";
        z = values[2] + " Value 3 – Z axis";
        //do calculations with x, y and z variables
    }
}
```

The listener registration is made by using the SensorManager methods:

```java
sensorXXX = mSensorManager.getDefaultSensor(Sensor.SENSOR_TYPE);

mSensorManager.registerListener(listener, sensorXXX,
    SensorManager.SENSOR_DELAY_NORMAL);
```

`sensorXXX` is an instance of class Sensor and it is instantiated using SensorManager’s method of `getDefaultSensor` (in an Android device there could be several sensors of the same type). This
method receives a “sensor type” parameter, accessed statically from the Sensor class. Table 4.5.3 shows the types of available sensors that a device could provide. After instantiating the object from Sensor class, the implemented SensorEventListener is registered through SensorManager’s registerListener method.

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE_ACCELEROMETER</td>
<td>A constant describing an accelerometer sensor type.</td>
</tr>
<tr>
<td>TYPE_AMBIENT_TEMPERATURE</td>
<td>A constant describing an ambient temperature sensor type.</td>
</tr>
<tr>
<td>TYPE_GRAVITY</td>
<td>A constant describing a gravity sensor type.</td>
</tr>
<tr>
<td>TYPE_GYROSCOPE</td>
<td>A constant describing a gyroscope sensor type.</td>
</tr>
<tr>
<td>TYPE_LIGHT</td>
<td>A constant describing a light sensor type.</td>
</tr>
<tr>
<td>TYPE_LINEAR_ACCELERATION</td>
<td>A constant describing a linear acceleration sensor type.</td>
</tr>
<tr>
<td>TYPE_MAGNETIC_FIELD</td>
<td>A constant describing a magnetic field sensor type.</td>
</tr>
<tr>
<td>TYPE_ORIENTATION</td>
<td>This constant was deprecated in API level 8. use SensorManager.getOrientation() instead.</td>
</tr>
<tr>
<td>TYPE_PRESSURE</td>
<td>A constant describing a pressure sensor type.</td>
</tr>
<tr>
<td>TYPE_PROXIMITY</td>
<td>A constant describing a proximity sensor type.</td>
</tr>
<tr>
<td>TYPE_RELATIVE_HUMIDITY</td>
<td>A constant describing a relative humidity sensor type.</td>
</tr>
<tr>
<td>TYPE_ROTATION_VECTOR</td>
<td>A constant describing a rotation vector sensor type.</td>
</tr>
<tr>
<td>TYPE_TEMPERATURE</td>
<td>This constant was deprecated in API level 14. use Sensor.TYPE_AMBIENT_TEMPERATURE instead.</td>
</tr>
</tbody>
</table>

Table 4.5.3: Types of sensors available on Android OS [64].

To understand the information read by each sensor, a simple activity was developed that showed each sensor’s output with their values on each axis. Figure 4.5.4 shows this activity displaying the sensor list and some of the sensor’s values.

![Figure 4.5.4: Activity displaying sensor information](image)

**Video Overlays:** To create an augmented reality mode on the prototype, it is necessary to access the device’s camera and display it to the user. On top of the video feed, location sensitive
information must be displayed to the user. These overlays must have the functionality to display information after an user touches it. To access the camera feed, it was necessary to access the specific lens classes in Android OS, including \texttt{Camera} and \texttt{CameraPreview}. These classes provide a View (User Interface class that provide help and interaction to the user) that displays the image that is being detected through the camera lenses on the device.

Once the preview is displayed, images were placed on the top of the video feed. These images were placed using classes of type \texttt{ImageView}. This class provide all the methods to attach gesture functionality (like touch) to the image. Figure 4.5.5 shows a camera preview on the device with image overlays. At this time, the overlays are static over the video feed, however the image position can be changed dynamically so it would be possible to move them with the change on orientation of the device.

![Figure 4.5.5: Video display on Android Device with image overlays](image)

\textbf{Other Work:} Other work has been done over the programming of the mobile application, including creating an about page and splash screen (See Figure 4.5.6). This work has been done to create a more compelling user interaction with the mobile app and to give it a more polished user interface following the design of current mobile applications in the market.
5. Summary and further work

This report contains the progress and effort applied to develop a prototype of a mobile application to query and display relevant location-based information for GMP on real time. Thus far, an analysis of the current GMP needs, requirements and overall project environment is made, along with the technologies that will be used to implement the prototype. A review of the processes and evaluation techniques for implementation is also included. It is expected that following these procedures, a functional, usable and efficient application will be constructed and that it will fulfil the requirements expressed by GMP. The progress made so far include developing separate interfaces for 2 modes of operation of the final mobile application (map view and augmented reality view), and the general design specification of the system.

The remaining effort on the project will focus on finalizing the analysis of the general and layered design of the system, in order to start the development of the prototype. System implementation will follow the iterative development cycle which will allow constant feedback from the project stakeholders. Once the design and implementation of each system layer is finalized, the development will be tested and evaluated according to the evaluation techniques presented in the report. It is expected that the dissertation report will be written during the test and evaluation phases of the project.
6. References


[58] E. Gamma, R. Helm, R. Johnson and J. Vlissides, Design Patterns: Elements of Reusable Object-Oriented Software, Reading, Mass: Addison-Wesley, 1995.


