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Toward an Effective Crime Mapping Solution for Nigeria: Leveraging Emerging Mobile Platforms

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Abstract - In this study we focused on a system designed for the Law Enforcement Agents to empower their officers to create and maintain crime and accident reports more effectively and more efficiently by improving the current paper based measures. Beyond the digitalization of existing forms, the activity of creating new reports in the field is enhanced through a mobile application that utilizes built-in sensors in mobile devices such as tablet computers and smart phones to capture location and other relative information together with rich media such as pictures and videos. A central repository is used to allow fast and easy access for relevant stakeholders, and we demonstrate how this repository can be used together with GIS data to create powerful crime mapping tools. While in the early phases we reveal the feasibility of the proposed solution through implementation of prototypes and isolated studies of core modules in the architecture and a first iteration of the interface design based on interviews with stakeholders in the organization and analysis of the current workflows.

Keywords: Crime accident reporting, ePolicing, Crime mapping, Spatial databases, Geographic profiling

1. Introduction

1.1 Background Study

Widespread use of Information and Communication Technologies (ICTs) for Law Enforcement Agents is common in developed countries and is also finding its way into developing contexts. Often this is manifested in integrated solutions that aim to modernize and support their workflows of the agencies through digitalization of knowledge and information with regards to Law Enforcement matters and procedures. Ideally this enables more effective and efficient policing through optimized access to relevant information with regard to each case and facilitating communication among appropriate stakeholders. Sometimes such solution further extends into what is commonly referred to as "ePolicing" or electronic policing. Often so-called ePolicing systems include citizen information and services. For instance, the LAPD (Los Angeles Police Department) in California has implemented a website onto which citizens can sign up to receive e-mails with new police information such as newsletters, crime trends as well as crime mapping [1]. Hence, ePolicing in the broader sense has many dimensions including community involvement and public dissemination of relevant information, but in this study we focus on few core police activities, namely crime and accident reporting and how such reports can be tracked and used by different people in the organization. Distinctively, we will discuss how systematic reporting directly from the field using mobile devices can be integrated with geo-spatial data through GIS system to provide timely overviews to decision-makers at various levels in the organization [2].

Through formal and informal interviews with Law Enforcement officers at different levels and through analysis of documents currently in use we have mapped out essential parts of the workflow of Law Enforcement Agents with regards to crime and accident reports. The Nigeria Police currently collect crime data with the use of paper forms. These so-called 'dockets' are then circulated around to members of the police with the authority to validate the data as well as to make these data forms available to all stake holders. Afterwards, the data is then stored in central filing facility called the Crime Register.

1.2 ePolicing for Africa

To our knowledge, few large scale systems have been embraced by countries in Africa so far. As one of the few, Nigeria has implemented an ePolicing solution “as part of efforts to combat crime and meet up with world's standard of policing ... to enable the average policeman and Nigerians access its data base from any part of the country”. From our interactions with various stakeholders in the Nigeria Police system there is generally a positive attitude towards technology, and it is thus timely to investigate how such systems should be designed, implemented and deployed [3]. In this paper, we argue that Nigeria and other emerging economies have a chance of leapfrogging the incremental technological development that many Western countries have gone through and learn from these experiences; especially how organizations can

move from paper-based systems towards more advanced ICT solutions to optimize the efficiency and effectiveness of policing by leveraging the emerging mobile platforms.

We look at crime mapping as an example of state-of-the-art crime solving technology used in the developed countries that can readily be implemented in developing countries together with a mobile crime and accident reporting system without the need for advanced infrastructures. To our knowledge crime mapping has not yet been implemented and used in Africa, but there are many other examples, e.g. the CPS system where crime mapping has been deployed in an ePolicing solution through a web application providing information to the public on the locations of certain crimes. This web application is displaying the different crimes with unique colors to allow an easy overview. That information is derived from a central server onto which crime data is stored. The end users has the choice of choosing exactly which types of crimes they wants to see, from which area and for which period [1].

1.3 Crime Mapping

Both location and time play a vital role in understanding crime and how crime can be tackled. The urge to understand crime locations and their spatial dimensions to crime began to be more fully explored during the late 1970s [4]. Geographic Information Systems (GIS) can be used as powerful tools for tracking crime trends and highlighting crime hotspots. Visual information in the form of maps overlaid with thematic data, are defining concepts of geographic information systems, and making GIS a valuable tool for crime fighting. A GIS is a system of hardware and software used for the storage, retrieval, mapping and analysis of geographical data. It is a tool for revealing what is otherwise invisible in geographical information. In order to recognize patterns of crime that police officers may not necessarily be aware of, GIS is employed to map crime. GIS allows effective integration and analysis of data leading to the identification, apprehension, and prosecution of suspects; it also helps the law enforcing agency to work against crime through effective allocation of resources [5]. Law enforcement agents would use GIS to visualise, analyse and explain the criminal activities in a spatial context. When analysing crime data, the effect of the physical layout of the areas, proximity to various services and land forms should be taken into account since these natural and man-made factors influence criminal behavior [6].

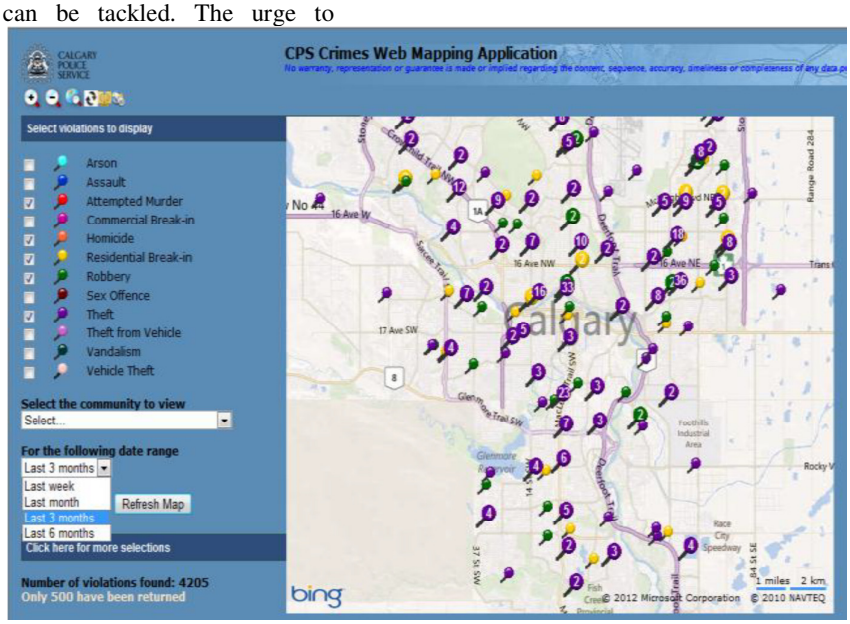

Figure 1: Screenshot from the CPS application which is managed by the Calgary Police Service

Analysing the relationship between crime and place is not a new phenomenon. In the 19th century, scholars focused on the variation of crime in large administrative districts like provinces and countries. At the turn of the 20th century, a group of sociologists took the initiative to undertake new research on urban problems which centred in part on crime. Thus crime and place research was now focusing on comparisons within cities. Techniques that can be used include identifying patterns and concentrations of crime, exploring the relationship between crime and the environment including the compelling socio-economic aspects. Analysis of individual criminal events and of individual persons, building or street victimization studies provides a starting point for fighting crime but for practical purposes individual criminal events must be aggregated in

order to assess patterns and devise methods for addressing them [7].

Law enforcement is a relative latecomer to the use of GIS. Typical use entails using base map components such as streets, land parcels, and aerial photography. The addition of dispatch records, incident records, citations and intelligence reports would then follow. This will not only uncover the patterns in collected crime data and drive new ways to view the criminal justice system, it will also change the way many in criminal justice are doing business. Crime analysis is greatly advanced by having automated crime maps that are easily updated and mapped using customisable search algorithms which are tailored to the specific needs of a user. The United States' National Institute of Justice championed the use of crime mapping in other countries like the United Kingdom, Australia, South Africa and across South America [7]. Applications of crime mapping include recording and mapping of police activities, information dissemination in the police force, identifying hotspots, monitoring the impact of crime reduction initiatives and aiding decision making in resource allocation.

Other developed countries have also adopted Crime mapping as part of their overall set of crime fighting tools. The New South Wales Police Service in Sydney, Australia, projects maps of crime distribution onto a large screen for management and senior police executives to determine policing strategy. In the UK, the Crime and Disorder Act (Home Office 1998) makes it mandatory for every police service and local authority to produce a crime and disorder audit. This has had a significant role in bringing crime mapping to the forefront in the crime and disorder arena [8]. From this it follows that the active use of crime mapping even in modern countries have only relatively recently taken off. Developing countries such as Nigeria would implement crime mapping systems based on these experiences; essentially having the cutting-edge tools for crime solving, decision and policy making [9].

2. Toward A Mobile Policing Solution

We are exploring mobile solutions for many reasons, but mainly it is due to the ubiquity and mobility of these computing platforms. A mobile solution enable law enforcement officers to report crime on location and incident details in real-time using GPS and wireless data networks to potentially enable quick and accurate response to crime scenes and accidents. The GPS allow the officers to capture accurate co-ordinates for the incidents and the networks allow the information to be uploaded back to the central database in near-real time. Of course, the uploading of information can also be done at the office when the officer returns. The use of mobile devices thus can lead to benefits such as improving the end-to-end cycle of reporting an incident to taking action. Capturing and storing data with geographical metadata would enable the data to be analysed to identify trends within and across district's boundaries [10]. Modern mobile devices also have many functions that can aid in the data collection process. Some of these functions are:

- Camera for taking pictures and video for later evidence, e.g. of cars involved in a car accident.
- Microphone and voice recorder for taking statements from witnesses at the scene of a crime
- GPS for exact location of the crime, but also for geo-referencing the collected digital evidence.
- Wireless networks for uploading and downloading data from the central servers
- Relatively long battery time life possibility for recharging though a car charger

These functions will be used to ensure that all the necessary data pertaining to the crime and crime scene is collected.

2.1 Feasibility through Available and Affordable Mobile Technology

For the sustainability and scalability of the solution it is imperative to consider the cost-effectiveness. While the added gain and effectiveness has been argued above the cost perspective must also be considered. The solution calls for a certain sophistication of mobile devices and more than a few devices to be acquired. However, all trends point towards more powerful devices and lower costs; a development that has already spawned a new wave of low-cost high-capability devices that are now finding their way into emerging markets [11]. Thus we have reasons to believe that the near-future will bring a plethora of affordable and useful mobile devices to the African markets. In countries like Nigeria, the mobile networking infrastructure is there but data connectivity is still prohibitively expensive. Again there is reason to be hopeful for a near-future with data plans and air time that are more affordable. However, the situation forces us to design the system to be able to operate in an environment of slow, costly and sporadic network connections [11].

2.1.1 Related Work

Smaller mobile devices like tablets and smart phones are highly suitable for field work where the officers need to move around and interact with people and objects. Mobile data capture has been used in African countries in many other application domains such as healthcare, education, business, rural innovation and governance.

ODK (Open Data Kit) is a prominent example of an open source solution that has been applied in such domains with success [12]. It is designed to be generally applicable, easily configurable and deployable way to collect field data, but for our purpose the problem with ODK is that

data handling is a one way process, i.e. field data is collected through forms and uploaded to central repositories. It is not possible to interact directly with this data again or share it between multiple mobile clients. This seems to be a general tendency among tools and platforms developed for mobile data capture, including more sophisticated tools with automated capture of contextual data through the built in sensors. While we can learn much from the experiences of these projects in terms of the actual field data capture process, we will need rethink how such data can be shared and continuously updated with multiple stakeholders involved. We also need a specific and integrated solution that supports the workflow of the police officers [12].

Figure 2: Affordable low-end high capability devices with GPS, camera, microphone and other sensors.

2.2 Methodology

We are applying an iterative user-centered design methodology in which we strive to involve the intended end-users as early and often as possible to ensure that the eventual system will be acceptable and suitable. For each iteration we develop prototypes with increasing fidelity and functionality and in this paper we report only up until the first design of the mobile user interfaces as a mock-up to communicate the design and intended functionality. We have done requirements gathering and analysis of the current work flow with regards to crime and accident reporting. For this we have used semi-structured interviews in formal settings and informal open interviews. Police officers have been interviewed face to face to help the research team understand the current processes in order to come up with a better way of collecting data with the use of mobile devices without hindering the police mandate. The formal interviews were scheduled with the interviewee and after an interview is conducted, the data collected is then documented and forwarded to the interviewee to verify.

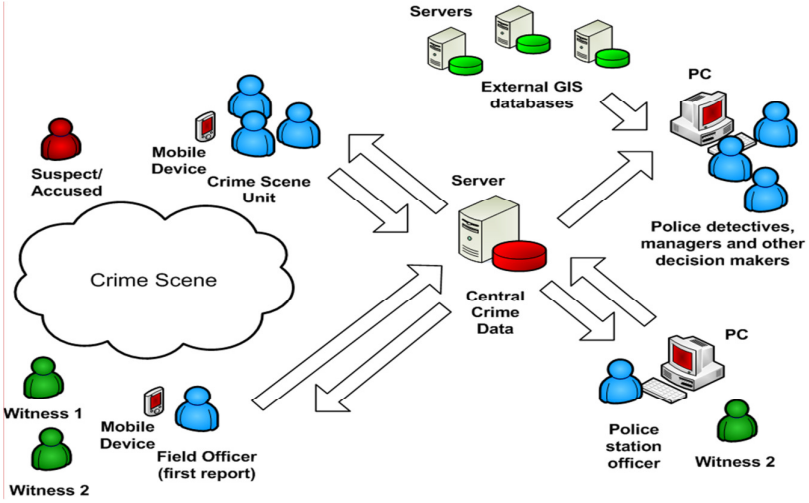

Figure 3: Conceptual System Architecture

2.3 System Design And Architecture

The main objective in this paper is to gradually migrate from the current paper-based solution to an electronic solution and to introduce mobile interfaces for field officers to improve the effectiveness and efficiency of their work. For this purpose we are developing an electronic mobile system, CARAT (Crime/Accident Reporting and Tracking). It is designed to collect crime and accident data at any scene of incident. It will use by both regular and specialized field police officers who collect data from the crime scene and file the initial report (docket) [13].

2.4 Concept

The proposed solution incorporates the use of mobile devices into a holistic system for crime and accident reporting as shown in figure 4. As the paper based solution is implemented throughout the organization the procedures have been adapted and optimized for this. Thus, our solution for digitalizing crime and accident data has to be incorporated throughout as well. The emphasis in this paper is mainly on the mobile components and how crime mapping can be introduced with the use of geo-spatially tagged data. With existing paper based procedures we have identified a number of inadequacies and threats: Risk of losing dockets., lack of proper version control of docket information, various officers are able to edit the document leading to potential errors, inability to quickly locate a desired docket due to the size of archives and physical distribution of the dockets, inability to search for dockets matching specified criteria, a time delay in transferring dockets from one station to another,
Dockets are exposed to various physical hazards such as fire and flooding, inability to capture and store statistical data for decision-makers. Information such as crime/accident patterns and trends within certain geographical areas are not captured by the paper-based system. Such information resides with the police officers who have been stationed in that area over a period of time. The latency in sharing information through physical documents imposes delays on the decisions making abilities of police, hence affecting their response and preemptive abilities regarding crimes and accidents. The above issues are some of the main reasons for making the records electronic and accessible to the right persons throughout the organization. It also underpins the utility of crime mapping as a tool for extracting patterns in the occurrence of crimes if a central electronic crime repository can be established. CARAT allows the collection of richer data sets than normal procedures through use of the phone sensors in addition to human text input fields of the dockets. This is essentially additional evidence and can be captured at the scene of the crime or accident by the first-responding unit. Such rich data includes: **Pictures:** To show immovable evidence from the scene, e.g. a broken window, beaten victim, or dented car. **Videos:** Recordings of the scene while the police officer explains or the victim explains what occurred. Videos can also be used for recording of statements from witnesses. **Audio recordings:** Recordings of witnesses - with build in audio processing this could be used to allow anonymous statements. Richer data can allow for better scene reconstruction, i.e. the crime scene can be reconstructed during trial or even for other stakeholders like the insurance companies for claims. The additional data collected with the mobile device (such as pictures, videos, statements and location information) should prove to be more descriptive than data collected only through paper forms. Also, for the tracking of reports and procedures following the initial reporting of an incident, the proposed solution has a number of benefits throughout the organization: **Access:** Easy access to the data for those authorized enabling better decision making. **Search:** Complex queries and matching of records in the database. Identification of crime patterns: due to all the information being electronic, it will be easier to identify the witnesses who keep appearing at the same scene, suspects leaving signatures and similar venues of crime. **Analysis**: With backend logic it will be relatively easy to conduct real-time analysis of the data collected which will ensure fast availability of statistics and reports thus empowering detectives to make more informed decisions during their investigations**. Process stability:** Control measures can be put in place to ensure that the actions to be taken are part of a process and that process has to be followed properly otherwise some actions will not be executed. **Effective deployment of resources:** With the available statistical information from CARAT, decision makers will be empowered to deploy police resources in a more efficient and effective manner. It could also aid road authorities in decisions concerning the establishment of traffic control measures in high accident areas. From a data integrity and reliability point of view, the data will be stored in a very secure database system which will be backed up according to the policies implemented by the Nigeria Police and will be validated accordingly. Also, all the officers who work with this data will have user accounts and an audit process will run in the background to keep record of all the actions taken towards the data as well as the user account of the officer who took the action and when [13].

2.5 System Architecture and Main Components

The system will be comprised of the following combination of mobile and computer technologies to facilitate more efficient crime and accident data capture as shown in figure 3:

- Mobile Devices Central Crime Database.
- External GIS databases.
- PC Terminals.
- Data communication framework

The overall goal is to introduce these technologies at various points in the crime/accident reporting workflow in order to make it more efficient. Mobile devices will be used to capture rich data from crime/accident scenes by field officers. They will also serve as information portals for officers on the field to aid in their analysis of the situation. Once information has been captured it will be relayed back to the central crime database for purposes of record keeping and information sharing. Initially it will not replace paper-based systems but will work alongside them. Police officers at the station will have PC terminals allowing them to access and update captured crime/accident data throughout the course of the investigation. Once all this information is in place the crime/accident data will be combined with data from external GIS Databases thus allowing a visual overview of crime/accidents in a specific area. This visual overview will also be available as a networked application accessible via authorized Pc terminals on the network. All of the communication will do done via the PolyMORF platform.

2.5.1 Mobile Devices

Mobile devices will be used to improve the field reporting aspect of this whole process. Situational information is usually gathered by field officers through the use of paper based methods (forms, etc.). As said, these are limited in that they cannot capture data such as images, audio and video. Mobile devices on the other hand through various sensor technologies (accelerometer, camera, GPS) are able to capture rich media and sensor data and are therefore appropriate for enhancing the task. For this project mobile devices using the android OS are the focus as they provide an extensive API for interacting with the devices various sensors and support a very large range of devices. These devices will contain applications that mimic and improve upon forms used to gather regular situational information and images, recordings and etc. Once captured, data is then transmitted via Wifi to the crime database server. Furthermore, these mobile devices will serve as information portals for the crime scene unit as they further investigate the reported crime. This will allow them to have more contextual information regarding the crime, accident, victim and/or suspect being dealt with. Information such as victim or suspect's past incidents with the law and frequency of crime /accidents in that area will be available to field officers on scene.

2.5.2 PC Terminals

At least two PC terminals running custom developed applications will be present at the station. Applications running on these terminals will provide interfaces similar to paper-based forms allowing verification and updating of mobile reports. Additionally, PC terminals will also serve as a information access point for officers and detectives to the case data within the server. Detectives will be able access all relevant case information (such as photo evidence, witness interviews and observation notes) during the investigation process. Using the main database, the detective can access victim's or suspects history or past cases related to the same crime etc. Additionally, PC terminals will also serve as a information access point for officers and detectives to the case data within the server. Detectives will be able access all relevant case information (such as photo evidence, witness interviews and observation notes) during the investigation process. Using the main database, the detective can access victim's or suspects history or past cases related to the same crime etc

2.5.3 Central Crime Database Server

As stated earlier this crime database will be used as a central repository for all crime/accident related data between all stations and units in the system. Information captured via mobile devices will be transferred to this crime database through secured networks. For our test system, the crime database server consists of a webserver hosting custom developed web services connected to a postgresql database. The web server hosts applications that will receive data captured from mobile devices, process them and store them in the database. The hosted web applications will also provide secure access to all crime/accident data for authorized police personnel. This will be done through special terminals made available at the various police stations as explained above. Furthermore, the crime database will also store and maintain GIS data related to each crime. This will make valuable information such as crime trends in certain geographical areas available to investigators and decision makers.

2.6 PolyMORF platform

The PolyMORF platform is designed for facilitating communication between web servers and Android devices. It is being developed for tackling a number of local aspects such as lacking stability of mobile data networks and data tariff challenges present in Nigeria. The architecture also aims to provide libraries/components to support the rapid development of similar Android applications (figure 5) that consume data from web services. It is the enabler for the communication between the mobile data capture devices and the crime database server. This platform consists of a web server component designed to expose data contained within the web server where it is deployed and a network-sensitive Android component designed to intelligently communicate with the server component. Both components are provided to developers, who can use them to rapidly develop a variety of applications. Data exchange between the server and the android device is done via the use of JSON (JavaScript Object Notation) objects over https. JSON was chosen as a result of its small footprint, thus resulting in a cost-efficient communication.

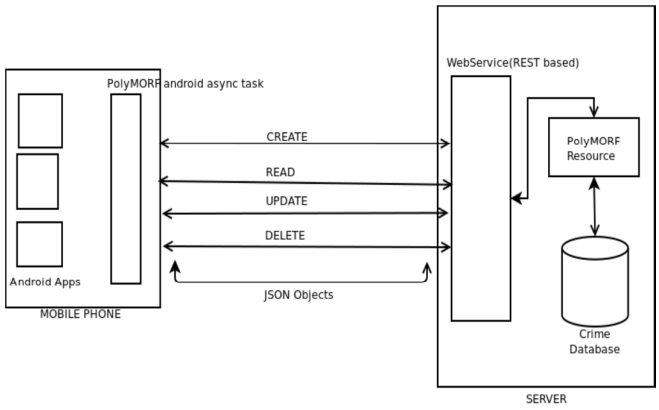

Figure 4: Communication over REST with PolyMORF Client and Server components

2.7 GIS Server

The GIS server is integrating the GIS data from external sources. Currently we are operating with a number of types of information that can be used to improve the crime mapping. **Table 1:** lists some key GIS data and the source where it can be obtained.

Table 1: Useful types of GIS data and where they can be obtained

GIS Data	**Source**
Household Income	National Household Income Survey
Zoning	City Town Planning Maps
Population Demographics	National Population Census
Street Maps	City Street Maps
Schools	City Street Maps
Home Ownership	City Valuation Roll
Street Lighting	City Street Maps
Sheebens	City Town Planning Map
Boundaries of Police Districts	Police District Maps
Public Open Spaces	City Town Planning Maps

Location of ATM's	Banks
Digital Terrain Models	Available for download from the internet

A GIS primarily handles spatial data. Geospatial data is positional data collected about geographical phenomena. Assigning a location component to crime data will enable the overlaying of this crime data with base maps and other geographic data of the area where the crime data is associated.

Prominent among the geographical data would be the population demographics of the area. Demographics are the most recent statistical characteristics of a population. Commonly examined demographics include gender, race, age, disabilities, mobility, home ownership, employment status, etc. Using GIS, crime analysts can overlay other datasets such as census demographics, locations such as shops, schools and industrial complexes to better understand the underlying causes of crime and help law enforcement administrators to devise strategies to deal with the problem. GIS is also useful for law enforcement operations, such as allocating police officers and dispatching to emergencies [8].

The Digital Terrain Models would be used in analysing the location of the crime in 3-D. Possible witness positions would be tested in order to be sure that the timing of events and lines of sight are consistent.

Geographic profiling is a criminal investigative methodology that relates the locations of a linked series of offenses to determine the most probable area an offender resides in. Coupled with both qualitative and quantitative methods, geographic profiling assists in understanding spatial behaviour of an offender and in focusing the investigation to a smaller area of the community. It also helps investigators to prioritize information in large-scale major crime investigations that often involve hundreds or thousands of suspects and tips. Several fields of study focus on the relationship between crime and the location [14]. Environmental criminology focuses on criminal patterns within particular built environments and analyses the impacts of these external variables on people's cognitive behaviour. Another application which looks at situational factors is the Crime prevention through environmental design (CPTED). This is based on the idea that situational factors such as poor lighting can make crime more likely to occur at a particular time and place [15].

3. Preliminairy Results

In this section we report preliminary results from implementing and studying core components of the CARAT system: data capture through mobile devices, the communication framework and the crime mapping server and interface. We also discuss the first iteration of the mobile interface design through a mock-up prototype.

3.1 Interface Design

From the information gained through interviews and analysis of official documents we have completed the first iteration of the mobile interface design. It is a hierarchical structure of input screens that allow the user to fill in all the segments of the existing forms, but also allows for extra data and use of sensors to create richer representations of the crimes and accidents.

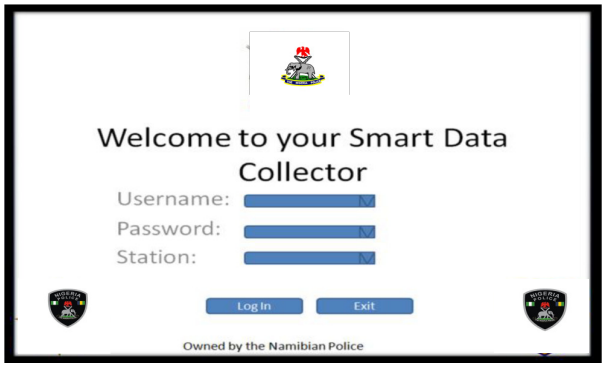

Figure 5: Login/authentication Screen

Figure 6 shows the design of the first screen which authenticates the field officer so that he can access or enter data. A unique username and password should be provided to all field agents who need to collect the data. This will enable the system to keep record of all the field agents who are collecting data and also to keep record of all the changes they make to the data, and for tracking purposes it will serve to ensure that an agent can only access reports that he or she is authorized to see.

Figure 6: Main menu (simplified)

Once the field officers are authenticated they will be presented with the main menu screen (figure 7) which will give them the choice of action next, for each choice a new screen will pop up with further details on how to continue or what fields they need to fill. If they do not wish to continue, they can exit the application.

Once the field officer chooses e.g. the crime report (CR), he or she proceeds to an overview of the components that make up the crime report as shown in figure 8. The officer then goes through these in sequence as these entire field need to be filled to make the crime report complete. If they wish to continue later, they can exit the application, but the status of that specific report will specify pending.

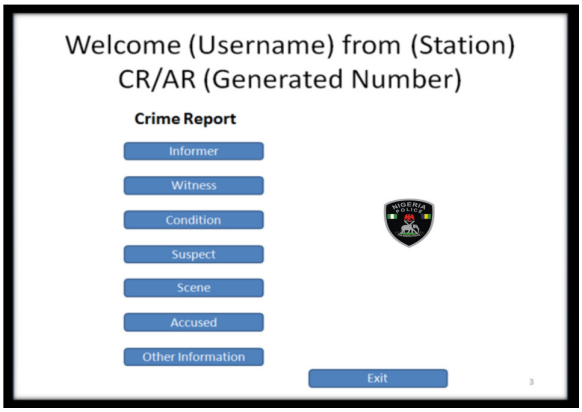

Figure 7: Screen for interacting with crime report data categories

One of the components that need to be filled out as part of the crime report is witness details as shown in figure 8. As can be seen, this screen allows the field officer to not only record and write down the witness's statement but also to take a picture of the witness with the front camera of the mobile device. Also the application allows the field officer to check the witness's ID number against the central database, and if the witness already exists in the database, all the fields will be filled automatically and the field officer will only confirm if those details are still the correct. This empowers the field officer to do his work more efficiently. Once the field officers are done capturing the data, they save it and go back to the crime report list of components and choose one to continue capturing until the crime report is complete. For inputting other details such as place of a crime scene, the GPS of the device is used to automatically add the location and potentially street address to the form.

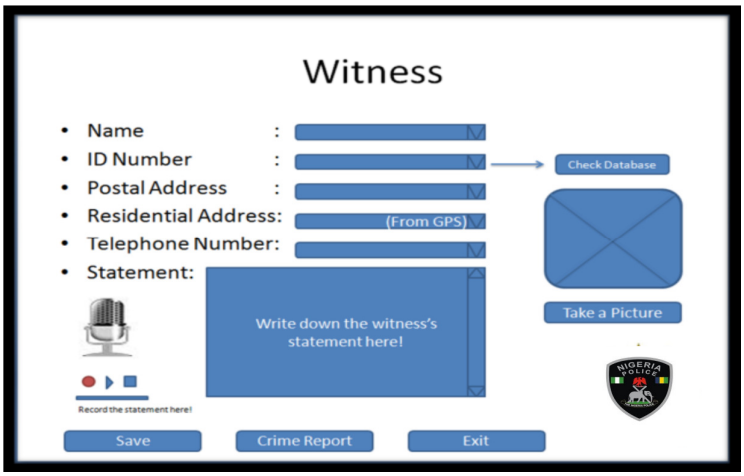

Figure 8: Witness data input with mix of user input, input through sensors (such as GPS) and input through media capture such as audio (microphone) and picture (camera)

3.2 Mobile Data Capture Prototype

We rely on results from a parallel research project to test whether it is possible and feasible to gather larger amounts of geo-tagged data in the field through mobile devices.
The PolyMORF platform (Poly Mobile Online Resource Framework) as introduced earlier is the base platform for communication. It provides the mechanism for sending data collected by the mobile devices and "pushing" it to the database. Though still in the early stages of development it supports the pushing and retrieving data from the database through mobile devices on a local server. The platform consists of a mobile library called the PolyMORF client (for android devices), a web service and a library for interacting with the database called the PolyMORF Resource. PolyMORF Resource The platform was developed with re-use as one of its primary goals, in order to achieve that communication between the mobile client, web service and database needed to be achieved. The PolyMORF Resource provides uniform access to data stored in any table within the database through its simple accessor methods, such as inserting and deleting data. WebService: The web service is designed according to the principles of REST as it advocated the use of Http request methods for predictable and uniform access to a web services data making it extensible for future components, such as interfaces for the general public to report crimes and accidents. PolyMORF Client Applications running on the mobile device act as both data providers and consumers for the web service. All this is done through the PolyMORF Client. It encapsulates all the details involved in communicating with the service by providing a simple set of methods. Through these the client applications are decoupled from the web service. Details such as establishing the connection and interacting with the web are encapsulated.

3.3 GIS Server and Interface Prototype

As a proof-of-concept we have integrated fictional crime data (containing coordinates of the crime location) and geographical data into a geo-database.

4. Discussion and Conclusions

Through this paper we have looked at crime and accident reporting using mobile devices; the digitalization of a paper based system toward a system with a centrally managed repository; and shown how this together with GIS data can be used to create interactive crime maps to aid decision makers in the Police organization. We argue that if a full scale system were to be implemented throughout a police organization it would have massive benefits over a paper based systems both with regards to effectiveness and efficiency. We also argue that the necessary technology is available and will only get better and cheaper. Thus we believe that moving towards an effective crime mapping solution is a scalable and sustainable approach - with huge potential in leapfrogging the "heavy" integrated ICT systems and infrastructures that are usually put in place to establish such functionality. But there are still many challenges to be addressed, not least those that arise at the human-computer interfaces. Through isolated tests and evaluations of a range of prototypes representing the core components of the solution we have demonstrated that the functionality can be implemented, and from this we rationalize that it will be technically possible to implement the overall system. With the positive feedback we have had with various stakeholders in the police organizations, we will continue to work towards and end-to-end prototype that we can evaluate with Nigeria Police to see if this can truly improve effectiveness and efficiency. As stated this is still in a relatively early phase, and there are still many aspects to investigate before we can conclude that this solution would eventually work. We

will have to look into usability, robustness, fault tolerance, safety and security of data within and around the system, and then there is an organizational, legal, social, cultural, ethical and other aspect that must also be factored in. The solution is highly modular, so more functionality can be added to support other processes such as dispatching units or coordinating actions. Also, while the CARAT system is now initially designed for the Nigeria police, it is highly flexible and can be modified to fit other data collection and visualization settings.

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