USABILITY OF MOBILE BASED PARTICIPATORY SENSING APPLICATION USING INTELLIGENT AGENTS

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DECLARATION

I declare that this Dissertation is my original research work and has not been previously published or submitted elsewhere for award of a degree. I also declare that this Research project contains no material written or published in any other university except where due reference is made and author duly acknowledged.

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And I have certified that all revisions that the research project panel and examiners recommended have been adequately addressed.

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DEDICATION

I dedicate this work to my lovely wife Purity Muthoni and my caring mother Rose Wanjiru and siblings Jane and Alex. Your continued inspiration and encouragement has been of enormous blessing to me.

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I would like to acknowledge my supervisor, Prof Ddembe, for his timely guidance and prized feedback in helping me accomplish my project. I also appreciate Dr. Mwangi H. for the constant advice.

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ABSTRACT

Citizens can act as sensors in crises management and volunteers for Geographic information and their surroundings. The proliferation of mobile phone in the developing countries sets a stage for the users to become participants in sensing their environment. A feat that was previously a preserve of specialized and hard coded sensors. Today's mobile phone is equipped with numerous sensors ranging from the camera, the gyroscope, GPS, thermometer, barometer, accelerometer and the microphone. Whenever participants are engaged to crowd source data, they start with zeal but later drop out before sufficient data is gathered for accurate analysis. This project carries the objective of designing and developing an enhanced participatory sensing (PS) tool that will expand usability and entrench subtle incentive mechanism through porting intelligent agents. Experimental research design was used to ensure collaboration with volunteering participants of the tool in its development. The resulting tool is used to crowd source data form volunteering participants, which is analyzed and compared with data from non-enhanced tool. Data from the enhanced PS tool has accuracy levels of 86.6% as compared to 50% from non-enhanced tool under the SMART framework. However, very consistent participants even with the non-enhanced tool, showed an 85% data accuracy levels. This indicated the leveraging power of mediation of intelligent agents in PS tools.

Keywords: Smart phones, Participatory sensing (PS), Intelligent agents, Social media.

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ACRONYMS AND ABBREVIATIONS

APIs- Application Programming Interfaces

CENS- Center for Embedded Network Sensing

DCs- Data Collection Points

GIS- Geospatial Information System

GPS- Global Positioning System

LBSs- Location-based Services

NC- Node controller

OS - Operating system

PDV- Personal Data Vault

PEIR- Personal Environmental Impact Report

GSN- Geo-social networks

PS- Participatory Sensing

SMEQ- Subjective Mental Effort Questionnaire

UI- User Interface

UX- User experience

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Various features of Smartphone make them good candidates for the delivery of behavioral interventions. First, as portable devices that are highly valued by individuals, secondly they tend to be switched on and remain with the owner throughout the day. The two interesting characteristics offer the opportunity to bring behavioral interventions into important real-life contexts where people make decisions about their wellbeing and encounter barriers to behavior change (Denison 2013).

Overall, a global median of 43% say that they own a cell phone that is a Smartphone, which is defined as a cell phone that can access the internet and apps, such as an IPhone or an Android. An additional 45% across the 40 countries say they have a cell phone that is not a Smartphone. A median of only 12% among respondents say that they do not own a cell phone of any kind(Poushter, 2016).

The highest rates of Smartphone ownership are among the richer economies surveyed. This includes 88% of South Koreans, 77% of Australians, 74% of Israelis, 72% of Americans and 71% of Spaniards. Beyond the advanced economies surveyed, Smartphone ownership is also relatively high in Malaysia (65%), Chile (65%), Turkey (59%) and the world's largest Smartphone market, China (58%)(Poushter, 2016).

The uptake of mobile services by Kenyans continued to grow during the first quarter of the 2015/16 Financial year spanning July to September 2015. According to the quarterly sector statistics report by the Communications Authority of Kenya (CA, 2016), at the end of the quarter, mobile penetration stood at 88.1per cent with 37.8million subscribers up from 36.1 million in the previous quarter.

Billions of mobile phones form a great platform for gathering data. Mobile phones could become tools for activism, helping individuals analyze routines and enabling community documentation and participation in decision making or these devices could facilitate the largest surveillance system on the planet (Shilton, 2009). Environmental and user-centric sensor data of consummate quantity and quality can be captured and reported by a possible user base of billions of mobile phone subscribers worldwide Arguably the obtainability of multi-modal sensors on current mobile phones enables a broad range of novel mobile applications.

Contemporary social media systems, supported by use by mobile devices have an 'always on' functionality, and this means being able to exchange one-to-one messages in real-time. Smartphones and other mobile devices enable much more immediate one-to-one communication than previously (Steele, 2013).

Research that uses mobile phones to collect data for personal or social projects is called mobile, urban, or participatory sensing (Eagle, 2008) furthermore collecting data is a major potential source of innovation and knowledge generation, but can be invasive and thus the use of 'Participatory sensing' in situations of crisis management becomes an interesting case study wanting to find the boundary between decision support system and control or surveillance (Massimiliano Tarquini, 2013). In scenarios when an individual or a community uses their mobile phone linked to a cloud service to gather, analyze and present data for discovery, that in essence is the epitome of participatory sensing according to (Tarquinii, 2013). An important trend is data management from such crowdsourcing application that are held by a myriad of users in offline (installed applications) and online (social media) modes, so as to extract useful information while safe guarding the users' privacy.

There are many possibilities that exist for participatory sensing sprees of which (Burke et al., 2006) gives these categories: Individuals, health care providers, and community / government organizations could initiate opt-in activities to evaluate and support individualized and preventative care regimens, gather data for retrospective analysis of causes of chronic and environmentally affected health issues, and generally to collect a wide range of high-fidelity health and environmental statistics for a population of interest.

In various peri-urban areas especially in developing countries, communicable diseases primarily through contaminated water and polluted air are commonplace as ousted by the WHO report of 2015. The citizenly of such areas, pass through such predisposing environments and blame their local governments for inaction to correct the situation. Unaware of the power they carry every day in their smartphones for public health advocacy and action demand from such local governments. Participatory sensing is noted by (Estrin, 2012) to offers a powerful "make a case" technique to support advocacy and civic engagement. It can provide a framework in which citizens can bring to light a civic bottleneck, hazard, personal-safety concern, cultural asset, or other data relevant to urban and natural-resources planning and services, all using data that are systematic and can be validated. However, where there exist such tools adoption rates are low due to varying factors.

1.2 Problem Statement

The challenge and the promise of participatory sensing emerge from involving people in the sensing process (Burke et al., 2006) and thus the likelihood of public apathy to pro-environmental activities as studied by (Massung, 2013). One of the most effective way of improving both efficiency and quality of data and analytic tools to discover areas that require scrutiny or modification, however, only a small percentage of organizations do this (Park, 2015), Whereas people can deliberately increase data accuracy by making well thought out decisions, the lack of timely supporting feedback from PS tools leads to varied performance from participant to participant. Collected data can hence be incomplete, biased and noisy. The use of 'Participatory sensing' in situations of crisis management becomes an interesting case study wanting to find the boundary between decision support system and control or surveillance (Massimiliano Tarquini, 2013)

In Citizen Science and Participatory Urbanism literature, (Kim, 2011) and (Rotman, 2012) cite the key challenges in engaging contributors – namely how to recruit them, and how to get them to make an active ongoing contribution. Most participatory sensing applications have failed to make a lasting impact, due to two main reasons. First, the applications are often in prototype stage and targeted towards a more technical crowd. Second, participatory sensing – especially for environmental monitoring – requires a lot of time and dedication from the user and hence Both issues prevent scalability and wide acceptance by the lay masses (Christian et. al., 2013)

There are ethical issues concerning gathering and processing of data form PS tools namely ; Privacy, consent and equity. Fortunately, the SMART framework for PS tools by (Massimiliano 2013) has sufficiently covered privacy and consent but the equity (fairness, incentive and justice) is participants is still a gap. This has been evaluated by (Sasank et al. 2014) as a major reason for low completion rate of PS data collection goals.

1.3 Overall Objectives

The main aim of this research will be to develop an enhanced mobile participatory sensing tool.

1.4 Specific Objectives

The following specific objectives will guide this research:

1. Study the level of use of participatory sensing tools
2. Design a participatory sensing tool under agile methods.
3. Develop an enhanced PS tool integrating intelligent agents
4. Test and validate the tool.

1.5 Scope of the Study

The study used the developed tool to evaluate the improved user experience in using participatory sensing tool towards collecting data efficiently in Murang'a County targeting environmental and public health concerns as the main area of focus. The evaluation will be correlated against existing literature of similar expeditions.

To keep the scope of this study lean, open source intelligent agents were selected modified and ported to the PS tool. This ensured that the study did not spiral away from the main focus area.

1.6 Motivation of the study

It was very interesting to note that Smartphone ownership in the developing world is rapidly increasing and especially on the front of internet penetration. According to Communications Authority of Kenya (CA, 2016) the first quarter of 2015 registered a growth of 8.5 percent in internet/data subscriptions to stand at 21.6 million up from 19.9 million subscriptions recorded in the previous quarter. Subsequently, the number of estimated internet/data users grew by 7.8 percent to stand at 31.9 million users. Mobile data/internet subscriptions contributed 99 per cent of the total Internet subscriptions with the quarter under review registering 21.5 million subscriptions.

This particular research project was sparked by a visit to Murang'a county waste management office. A review of documents revealed the disconnect between public complaint data and the workers dispatch schedules and response system that the county had established yet the statistics display in earnest the penetration of mobile phone with data capabilities at the hand of the citizens which they could turn to a tool of advocacy o]and electronic citizen participation within the county framework.

1.7 Significance of the Study

An outright reason directing research as accentuated by (Ian F, 2007)is "to build the evidence base to inform strategic or policy directions. "In addition, an exploration of alternative learning mechanisms including discovery is a basic scientific objective of research as is discussed by (R.S. Michalski, 2013).

This particular research is of substantial implication to practice, policy and future research. With regards to practice the study will give a novice way to leverage mobile participatory sensing and harmonizing nature of human and machine learning intelligence (Bin Guo, 2015). In policy this study will complement other studies that seek to strengthen the place of participatory sensing as trustworthy way of crowdsourcing quality data and experimented and asserted by (Dorothy Kalui, 2016). Future researchers can base their work on the gaps identified by this study especially on the use of efficient agents to improve data management and feedback in participatory sensing tools.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter is dedicated to literature review is the systematic, explicit, and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars and practitioners (Fink, A. (2013).

Guided by Fink's definition of literature review, tremendous amount of time will forthwith go to peruse the growing body of evidence in the area of participatory sensing, its maturity and challenges as well as its enhancement using intelligent agents. Further works will go into determining the niche of interfaces needed to inform citizens and foster civic engagement through use of modern technology. The requirements of multi-channel communication, the presentation of issues, the validation and processing of citizens' messages, and the effective interaction of the administration, civil society and local media place high demands on project design and local capacity development. However, the fact that the use of crowd sourcing has been developed for public accountability and development cooperation in Kenya, together with the growing number of successful solutions and examples from all development cooperation sectors demonstrates that these challenges are surmountable (Bott, 2013). mobile communications in promotion of quality healthcare services even in remote and resource-poor environments (Lemaire, 2011) so has the advancement of mobile phone capabilities brought both potential and challenge for using them to improving our daily lives.

This chapter will focus on the evolving concept of participatory sensing and its enhancement for improved usability among the targeted populace. Usability and user experience (UX) are not the same thing: the usability of a product is a crucial part that shapes its UX, and hence falls under the umbrella of UX. While many might think that usability is solely about the “ease of use” of a product, it’s actually more than that.

The ISO 9421-11 standard on usability describes it as: "The extent to which a product can be used by specified users to achieve specified goals, with effectiveness, efficiency and satisfaction in a specified context of use." Usability is hence more than just about whether users can perform tasks easily (ease-of-use), but also concerned with user satisfaction—for a website to be usable, it has to be engaging and aesthetically pleasing, too.

2.2 State of the art in participatory sensing

With the advent of mobile technology, the area of participatory sensing (PS) according to (Burke et al 2006) has attracted many researchers in different domains such as public health, urban planning, and traffic. The goal is to leverage sensor equipped mobile devices to collect and share data, which can later be utilized for analysis, mining, prediction or any other type of data processing. While many unsolicited PS systems exist (e.g., Flickr, YouTube), in which users participate by arbitrarily collecting data, other PS systems are campaign-based, which require a coordinated effort of the participants to collect a particular set of data that the server requires for any purpose.

Some real-world examples of PS campaigns include a distributed mobile sensing computer system by Zhang et al, Mohan et al traffic condition monitoring using Smartphone and the University of California Berkeley traffic monitoring and trends app where users leverage their mobile devices to collect traffic information. In CycleSense a project supported by CENS, bikers document their trajectories along with other data modalities (e.g., pollution, traffic, accidents). In GIS project to explore the urban texture by (Shirani-Mehr 2009), the focus is on participatory texture documentation, where users, in a coordinated effort, aim to collect maximum amount of urban texture information from a set of predefined locations.

According to the survey conducted by (Reinhardt et.al., 2015), an extensive range of sensing applications have been as a result of the emerging participatory sensing paradigm. It is also noted that the introduction of mobile technology has played a major role in defining the pattern taken in the area of participatory sensing. With such level of development, a significant number of researchers have been attracted to venture in different fields including traffic, public health, and urban planning. This has been and is still being conducted with the objective of leveraging the sensor equipped mobile devices that can be used in collecting and sharing data. It is with such data that can be utilized in participatory sensing related decisions, mainly through different data processing techniques which may include analyzing, mining, and predicting. The reality is that participatory sensing has been taking the advantage of increasing mobile devices in creating participatory sensor networks that are interactive.

With mobile participatory sensing, professionals as well as ordinary people are being empowered in collecting, analyzing, and sharing information about different occurrences. Categorization of mobile sensing applications is based on the type of parameters that form the basis of their use. They include people-centric sensing applications which focus on recording activities such as sport experiences and analyzing of the behavior of individuals, such as eating disorder. The other category is the environment-centric sensing applications which are utilized in the collection of environmental parameters such as noise pollution and quality of air (Estrin et al., 2010). The sensing modalities used in most of the mobile sensing applications provide another significant platform of deriving a general system model that is employed in machine learning.

Based on (Emiliano 2012) PARC research the following are the main Participatory Sensing Components. A typical PS infrastructure involves (at least) the following parties: Mobile Node which is the union of a carrier (i.e., a user) with a sensor installed on a mobile phone or other portable, wireless-enabled device. They provide reports and form the basis of any PS application. *Queriers* subscribe to information collected in a PS application (e.g., “temperature in Irvine, CA”) and obtain corresponding reports. Network Operators manage the network used to collect and deliver sensor measurements, e.g., they maintain GSM and/or 3G/4G networks. Service Providers act as intermediaries between *Queriers* and Mobile Nodes, in order to deliver report of interest to *Queriers.*

2.3 Architecture of PS tools

One of the long-time adherent of participatory sensing, (Deborah 2010) tells us of the central role of data in the PS tools and how the initiators of such crowd sourcing tools such take keen interest in the data. Incorporate big data analytics and eventually high scale machine learning to make sense of complex and hidden patterns has to be leveraged.

The developing field of Geospatial information systems (GIS) has gained considerable boost by having location transmitting sensor and location based services enabled in mobile devices.

The ever-dynamic social web 2.0 has not been left out in PS tools as participants seek to share their discoveries and explorations with their networks and to the public through such platforms as twitter ©, Facebook©, Instagram and Pinterest. The most common architectural components for participatory-sensing applications, includes mobile device data capture, personal data stream storage, and leveraged data processing.

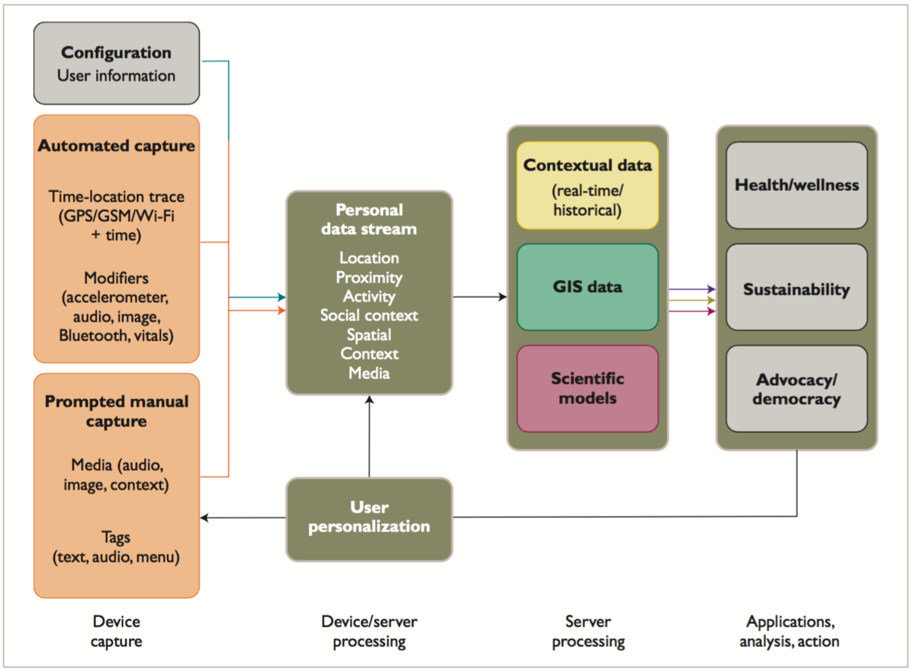


Figure 1 Architecture of a PS application

The architecture adopted for most of the participatory sensing applications sets its foundation on the fields that are utilized. The distinctive architectural components that are familiar with the participatory sensing applications have been identified in Figure 1 above. It provides a deeper understanding of the components' functions as they have been integrated through a general system model (Estrin et al., 2010). The components above have been organized and integrated into client-server architecture with the key focus being on the mobile devices. The presentation includes the interaction that takes place from the sensing process to the actualization of the results amongst the end users of the participatory sensing applications (Macias, Lloret, Suarez, & Garcia, 2012). The following is a highlight into different components of participatory sensing applications.

2.3.1 Sensing component

This is a critical component that is located on the mobile device of a participant and is used in capturing a variety of biometric data, sensor data, barometric pressure, prevalently time, sound samples, pictures, pollution data, location, and accelerometer data. Different participatory sensing modes can be utilized in capturing sensor data: context-aware, automatic, and manual. There are key characteristics that make these sensing modes to be different in their utilization. A relevant example is in relation to participant integration. In the manual sensing mode, the collection of sensor data is triggered by participants in relation to relevant events. Traffic congestion and noise pollution are good illustrations of how this sensing mode is conducted (Reinhardt et al., 2011). Therefore, there is direct engagement of participants in the sensing process.

In contrast, context-aware and automatic sensing modes do not engage participants directly in the sensing process. Also referred to as continuous mode, automatic sensing mode involves a constant sampling frequency while collecting sensor readings. On the other hand, Context-aware mode is also referred to as opportunistic sensing

2.3.2 The tasking component

It is another important component that works by supporting the above discussed sensing component. With this component, the sensing tasks are appropriately distributed to the relevant mobile phones. The sensing modalities are specified by the defined tasks and this is based on the key requirements of the application including the criteria of starting the capture, sampling frequency and sensors utilized. A practical example could be a case of having a mobile device that has an embedded 3 megapixel cameras and operational with GPS (Cardinaux, Bromwich, Abhayaratne, & Hawley, 2011). Information concerning time frame and location of the specific interest is also included in the defined tasks.

2.3.3 The reporting component

This ensures that the collected sensor readings are transmitted to the application server. Most of the communication infrastructure that are utilized in mobile phones, including 3G/GSM/GPRS or Wireless LAN connectivity, are used in transferring the collected data. A practical example is the use of remote procedure calls, TCP connections, or SMS in transmitting the recorded sensor readings to the designated server (Reinhardt et al., 2011).

2.3.4 The storage component

All the collected data (on a mobile phone) and reported data (on the relevant server) need to be stored in a database for easy accessibility and processing. Short-term data storage can be facilitated on the mobile phone while waiting to be transmitted to the server or to be processed. As for long-term storage purposes, reported data can be managed effectively by the use of the server, whereby relational databases will be used storing data. Databases are supposed to be adapted for the purpose of managing the sensor readings, including the SensorBase or sensedDB, and this should be conducted in line with the expectations of managing the collected data (Reinhardt et al., 2011).

2.3.5 The processing component

After data has been stored, the process component is used in extracting relevant features of importance from the data. This can be done at a larger scale on the server or directly at the individual scale on the mobile phones. With this component, the relevant data reported to the designated server can be analyzed and prepared to be feed into the presentation component (Reinhardt et al., 2011).

2.3.6 The presentation component

With this component, all results attained by the processing components will be presented to the end users. The presentation of such results is conducted through web-portals to be accessed by a larger public or through phones display so that only the participants can access them. The presentation of results is mainly in raw form so that the end users can conduct the process of analyzing (Reinhardt et al., 2011).

2.4 Managing data gathered from participatory sensing devices

Data quality is usually defined as the degree of how fit the data is for its intended uses in operations, decision making, and planning. In other words, low-quality data is user-related data collected regardless of fitness for use. Hitherto, the involvement of human participation brings forth critical challenges to the data quality of systems. For example, PS participants may send incorrect or low-quality data to the backend server (Zhang et al. 2014c), data contributed by different people may be redundant or inconsistent (Uddin et al. 2011), and the same device might be used to record the same activity under distinct sensing conditions (e.g., sensing ambient noise when placing the mobile phone in a pocket or at hand). Therefore, *data selection* is often needed to improve data quality, and we should explore methods on fault filtering, quality estimation, expert contributor encouragement, and so forth.

Management of data is an illustrative function that cannot be separated from participatory sensing applications as they are used in machine learning. After the relevant data has been collected from participatory sensing devices, finding the appropriate approach of managing it is imperative in setting an efficient platform of deriving key insights. This involves the capacity of reviewing the same data for the purpose of verifying and judging the suitability of the shared information (Ganti, Ye, & Lei, 2011). In management of the collected data, it is important to determine the presence of inappropriate or privacy-sensitive items so that they can be separated before being reported to the designated application server. There should also be a reassurance on the disclosure of the collected data so that unauthorized third parties do not gain accessibility to such key information.

2.5 Artificial intelligence in mobile devices

To motivate full-scaled user participation and enhance user experience, MCSC systems should be developed in a human-centric manner so as to address the issues of Motivation of human participation, user security and privacy, and human-machine intelligence(Gou et al, 2015).

A robust motivation of devising and developing novel mobile services and software techniques has been as a result of the recent developments experienced in wireless communications and small mobile devices. With the rising demand of quality service delivery with regard to all-encompassing healthcare computing, the need for improved artificial intelligence in mobile devices has been on the increase (Hoseini-Tabatabaei, Gluhak, & Tafazolli, 2013). A practical example is the existence of the artificial neural networks, which represent the systems patterned as a result of the organization and operation of human brain's neurons (Kamat, 2012). It involves a relevant process of utilizing pattern recognition and, hence, forms the basis of undertaking critical developments in the healthcare sector. In understanding how this concept has been adopted in different areas of concern, the focus should be directed at the integration of artificial neural networks in mobile devices and artificial neural network algorithm used in managing data (Gurrin et al., 2013).

Over the last two decades, the concept of machine learning has gained its strong ground with regard to different applications of participatory sensing. This is linked to the capability of allowing adopted computer applications to unearth hidden insights without explicit programming of where such process should take place (Boulos, Wheeler, Tavares, & Jones, 2011). It is noted that the growing body of evidence has demonstrated the potential of mobile communications in promotion of quality healthcare services even in remote and resource-poor environments (Haché, Lemaire, & Baddour, 2011). Such a potential is associated with the advancement of mobile phone capabilities that have brought both potential and challenge for using them to improving our daily lives. The reality is that machine learning has defined a constructive and structural path taken for participatory sensing, including mobile participatory sensing. In this chapter, the focus is on the evolving concept of mobile participatory sensing with ANN algorithm to manage data gathered from participatory sensing applications.

2.4 State of practice: intelligent participatory sensing applications

Making cell phones to be more equipped in terms of resources, especially on their display, processing power, and the memory, has turned out to be a bridge for supporting more complex applications (Heathers, 2013). The concept of intelligence has been integrated in the participatory sensing applications and their efficiency can be associated with how relevant data can be collected and analyzed appropriately. A good real-world example is Intelligent Transportation Systems (ITS), which are considered to be advanced applications. These applications seek to provide inventive services that are associated with various modes of traffic management and transport. It is through such intelligence participatory sensing application that different users are informed in the most appropriate ways and hence become more coordinated and safer when using roads (Acampora, Cook, Rashidi, & Vasilakos, 2013).

Participatory sensing fused with intelligent agents is a new large-scale sensing paradigm based on the power of user-companioned devices, including mobile phones, smart vehicles, wearable devices, and so on (Guo et al. 2014). The infused intelligent agents allow the increasing number of mobile phone users to share local knowledge (e.g., local information, ambient context, noise level, and traffic conditions) acquired by their sensor-enhanced devices, and the information can be further aggregated in the cloud for large-scale sensing and community intelligence mining (Zhang et al. 2011). The mobility of large-scale mobile users makes this a versatile platform that can often replace static sensing infrastructures. A broad range of applications are thus enabled, including traffic planning, environment monitoring, mobile social recommendation, public safety, and so on.

2.6.1 Crowd intelligence extraction and usage

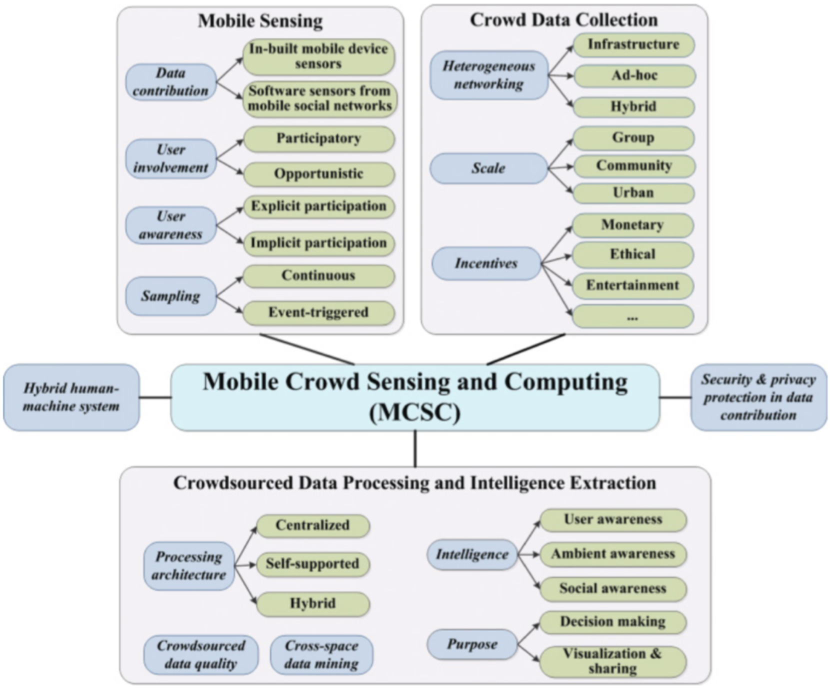
There are three main types of crowd intelligence: *user*, *ambient*, and *social awareness* (Guo et al. 2015). The learned crowd intelligence can be used by authorities, public institutions, and ordinary citizens in different application domains, for example, public health, urban planning, and environmental protection. We further derive the two major purposes of PS application as: *decision making* and *visualization and sharing*. For decision making, it refers to making decisions (e.g., object classification/recognition, event prediction/replay, policy making) or cueing recommendations according to the learned knowledge. For visualization and sharing, the collected information is visualized and shared among citizens.

2.6.2 Fusion of PS and intelligent agents

In computing, bots are referred to as autonomous program on a network that can interact with computer systems or users, especially one designed to respond or behave like a player in an adventure game. This generic definition sets the stage for introduction of intelligent agents in mobile participatory sensing applications. (Jennis, Sycara & Wookbridge 1998, Zhang et al. 2011).

An improvement of the architecture given in Figure 1 is made by (Guo et al. 2015) so as to include intelligence to the existing component that allow human participation.

Figure 2: Improved architecture of PS tools



2.5 Critique of the Literature

There are a number of unanswered questions in participatory sensing that require continued engagement between technology development and ethics. A continued focus on privacy requires the design and field testing of privacy-friendly participatory sensing systems.

Researchers might conduct user studies to evaluate how participants understand and use their privacy choices, or study how combining multiple data collections might complicate privacy concerns. Researchers focused on access and equity can analyze the lines of power and participation in existing and emerging participatory sensing projects. They might collect demographic information on the populations participating in, and affected by, pervasive personal data projects, or interview stakeholders and understand the mix of organizational and informal publics involved in data collection projects

By querying and shaping how pervasive personal data are organized and managed; how privacy, consent, and participation are handled in pervasive systems; how pervasive personal data affects the balance of power in an information economy; and how such systems impact social and institutional memory and forgetting, ethicists and engineers can help to shape this emerging information landscape through building systems, constructing information policy, and shaping values in participatory sensing design.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology that was followed in this research project. The term methodology refers to the 'overall approaches and perspectives to the research process as a whole' and is concerned with why certain data was collected, what data was collected, where and how it was collected, and how it was analyzed(Neville, 2007; Kothari, 2004). In line with this, the research purpose; conceptual framework; research approach and strategy; and data collection and analysis methods are discussed.

It is the assertion of Saunders and his cohort in (Saunders, 2015) that a basic but important choice all researchers face when designing their research: whether to use a quantitative method or methods, a qualitative method or methods, or a mixture of both. Researchers can choose to use a single data collection technique and corresponding analysis procedure, either a mono method quantitative design (for example, data collected using a questionnaire, analyzed statistically) or a mono method qualitative design (for example, data collected through in depth interviews, analyzed as narratives). Alternatively, they can use multiple methods. In multimethod quantitative designs the researcher uses more than one quantitative data collection technique (for example, a questionnaire and structured observation) with associated statistical analysis procedures. For multimethod qualitative designs, she or he uses more than one qualitative data collection technique (for example, in-depth interviews and diary accounts) are used with associated analysis procedures. A mixed methods design combines both qualitative and quantitative data collection techniques and analysis procedures. This means the researcher could start with a qualitative data collection and analysis (for example, a series of focus groups to help determine the breadth of possible factors) and follow this with quantitative data collection and analysis (for example, a questionnaire to determine the relative frequency of these different factors); a mixed method simple design. Alternatively, they could choose to use quantitative analysis techniques to analyze qualitative data quantitatively (for example comparing statistically the frequency of occurrence of different concepts in in-depth interview transcripts between different groups) or vice versa; a mixed method complex design

3.2 Evaluation of Current Research Methodologies

It is the assertion of Saunders and his cohort in (Saunders, 2015) that a basic but important choice all researchers face when designing their research: whether to use a quantitative method or methods, a qualitative method or methods, or a mixture of both. Researchers can choose to use a single data collection technique and corresponding analysis procedure, either a mono method quantitative design or a mono method qualitative design. Alternatively, they can use multiple methods. In multimethod quantitative designs the researcher uses more than one quantitative data collection technique with associated statistical analysis procedures. For multimethod qualitative designs, she or he uses more than one qualitative data collection technique are used with associated analysis procedures.

A mixed methods design combines both qualitative and quantitative data collection techniques and analysis procedures. This means the researcher could start with a qualitative data collection and analysis and follow this with quantitative data collection and analysis; a mixed method simple design. Alternatively, they could choose to use quantitative analysis techniques to analyze qualitative data quantitatively (for example comparing statistically the frequency of occurrence of different concepts in in-depth interview transcripts between different groups) or vice versa; a mixed method complex design. This research used mixed method research design, where qualitative survey method was employed. The selection was necessitated by the qualitative and empirical type of data that was intended by the objective of the research.

3.2.1 Research Strategy

The selection of a strategy is influenced by the researcher's goals and nature of research topic. Each strategy can be used for exploratory, explanatory, or descriptive purposes (Yin 1981). The direction of this research is exploratory and it is used in order to understand the relationships between variables, such as those revealed from a descriptive study of literature. The various research strategies include experiment, survey, archival research, case study, ethnography, action research, grounded theory, and narrative enquiry. Experiment method was chosen. A good experiment design is often characterized by adjectives like flexible, appropriate, efficient, economical and so on. Generally, the design which minimises bias and maximizes the reliability of the data collected and analyzed is considered a good design (Kothari, 2004). The design which gives the smallest experimental error is supposed to be the best design in many investigations. Similarly, a design which yields maximal information and provides an opportunity for considering many different aspects of a problem is considered most appropriate and efficient design in respect of many research problems.

3.2.2 Data collection methods

Questionnaire as a method of data collection has being adopted by private individuals, research workers, private and public organizations and even by governments. In this method a questionnaire is sent (usually by post) to the persons concerned with a request to answer the questions and return the questionnaire(Kothari, 2004). A questionnaire consists of a number of questions printed or typed in a definite order on a form or set of forms. The questionnaire is mailed to respondents who are expected to read and understand the questions and write down the reply in the space meant for the purpose in the questionnaire itself.

In the context of Crowdsourcing discussed in the previous section, a citizen Science data collection project is based on conducting an open call for individuals to collect and submit data. Thus, the data would not be collected only by a specific group of experts but by anyone interested and able to participate in the project. Several projects follow this paradigm, such as The *Great SunFlower* project, whose participants must submit data on the number of bees visiting the sunflower to analyze data on pollination, the *eBird project*, where the goal is to collect information on the location and species of sighted birds (Luiza, 2014)

3.3 Evaluation of Development methodology

Many organizations consider it beneficial to utilize standardized number of steps, called system development methodology (Jeffrey Hoofer, 2014). The systems development life cycle (SDLC) being a common methodology for many organizations. However, there is a cited decline in rigid adherence to large scale full blown methods and instead hybrid methodologies are gaining traction in the development of modern systems (Mark Lejk, 2002).

Mobile Participatory sensing tools are encircled in the realm of mobile applications and further to this (Budiu, 2013) classifies mobile applications into: Native, Web and Hybrid.

Native applications are sentient on the device to be opened via icons on the home screen of the device. Web applications are websites usually based in HTML5 that are optimized to work and feel like native live-in applications. There is an agreed consensus as retold by (Hunt, 2015) that hybrid applications are like native apps that run on the device and are written with web technologies. This classification will help the study to streamline the comparison of methodologies that are best suited to wards mobile applications up and against the proposed methodology.

In broad area of ubiquitous mobile computing there are methodologies that have been advanced and have been successful at varying percentages depending on the project and related tasks. These methodologies are: System Development Life Cycle (SDLC), Rapid Application Development (RAD), Object Oriented analysis and design (OOAD), Agile Methodologies.

A tabulated summary of the methodologies is depicted here showing their strength and weaknesses and suitability to the research project.

Factor	Definition of Critical success factors	Agile Methods	SDLC	OODC	RAD
Size	Well matched to small products and team	√		√	√
Criticality	Untested on safety critical products		√	√	
Dynamism	Modest designs and continuous refactoring	√			√
Adaptability	Succeeds in projects where requirement are not fully discovered at beginning of the project	√			

Table 1: Tabulated summary of methodologies

3.4 Proposed Development methodology

This study will use Agile software development methodology. The agile methodologies aim at facilitating application development processes where changes are acceptable at any stage and provide a structure for highly collaborative application development (Harleen, 2013).A working definition as provided by (Abrahamson et al, 2004) is that the method is an agile development method is cooperative (a strong cooperation between developer and client), straightforward (easy to understand and modify), incremental (multiple releases) and adaptive (allowing for frequent changes).

Agile methodologies are among the best application development apply at times, when customer's requirements are not exact, or when the deadlines and budgets are tight. However, besides the benefits allied in employing agile technologies in mobile application development there are issues that raise concern in reporting gains in quality, productivity and business satisfaction by different groups. It has been reported that agile methods had been successful in delivering in majority of cases whereas there are conflicting reports that claim that the methodology is still too young to require extensive academic proof of their success. This paper is an attempt to review the published literature on application of the agile approaches for the development of mobile application as the researchers believe that agile innovations offer a solution to mobile specific applications that requires high quality development processes.

Mobile Process	Mobile Development Process Description	Year	Techniques
Mobile D	An Agile Approach for Mobile Application Development	2004	XP, Crystal, RUP
Rapid	Rapid Production of Documentation 7 step	2005	AM
Hybrid Methodology Design	Design an Agile Methodology for Mobile Software Development –A Hybrid Method Engineering Approach	2007	ASD, NPD
MASAM	Development Process of Mobile Application SW Based on Agile Methodology	2008	XP, RUP, SPEM
SLeSS	A Scrum and Lean six Sigma Integration Approach for the Development of Software Customization for Mobile Phone	2011	Scrum, Lean Six Sigma

Table 2: Mobile Application Development Process using Agile Methods

Agile works well with highly volatile requirements of mobile apps: Highly volatile requirements of mobile apps require adaptive software development methods. Agile is ideal for projects with high levels of uncertainty or variability and are appropriate for mobile app development. Agile enables easy accommodating of change requests, frequent interaction with clients, and helps in unifying the business requirements across teams by assigning the right priorities and focuses. (Harleen Flora, 2014) Agile is most suitable to address the issues related to inadequate memory; data storage capability; slower devices; security; online/offline capability; and ever-evolving types of devices, operating systems, and development environments.

Agile development encourages stakeholder involvement in mobile projects: Stakeholder engagement in mobile projects enables monitoring of activities which improves increases productivity, profit, and sustainability. Agile development principles encourage active user involvement throughout product development and a very cooperative collaborative environment. This provides excellent visibility for key stakeholders, enables rapid accommodation of stakeholder feedback, and helps in rapidly rolling out suggested new features, and ensuring that expectations are effectively managed. Agile increases reliability and leads to continued use of mobile apps: Mobile users are usually less tolerant of errors and crashes in mobile apps. If an app crashes a few times, the mobile user will easily switch an alternative app as they have many choices available. Agile development with its iterative testing and quality assurance practices assists developers to build in more quality and reliability through repeated cycles of testing.

Agile development empowers user experience for mobile Apps: Mobile apps run in limited environments and there are restrictions when downloading apps. If downloading an application takes several minutes, the user may try other apps instead. Agile development enables thoughtful user experiences and allows developers to experiment different options in subsequent sprints and adjust the design and features of apps to make the user experience is quick, smooth, and seamless. Agile fits incomplete requirement nature of mobile projects:

Mobile projects typically have deadlines and a quick turnaround time for market release. However, the initial requirements of mobile apps are generally incomplete, unclear, insufficient, uncertain, and change considerably during the development process. Developers will commonly put out an app with a limited set of features in the first release and update it in later versions. This nature of mobile applications development fits with the iterative nature of Agile.(Harleen Flora, 2014)

Agile development fits the experimentation & adaptation of mobile apps: Mobile apps become better with each release. The process of refining and improving a mobile app is accomplished with the help of customer feedback. Agile gives early visibility to users and fits this necessary need for iteration.

Agile helps in identifying the risk in mobile projects at early stage: (Harleen Flora, 2014) The release cycles for mobile app development projects are getting shorter and there is possibility of greater risks involved when dealing with tight releases. Small incremental releases made visible to the product owner and product team through its development help to identify any issues early in the project as they arise, making it much easier to respond to change. An adaptive approach and the clear visibility in Agile development adds value to the business by identifying risks and ensuring that any necessary decision can be taken at the earliest possible opportunity.

Agile is best suitable for quick delivery and short development lifecycle of mobile apps: Mobile applications are often characterized by an array of limitations such as rapid development and short development lifecycle. For initial release, a minimum viable product with prioritized features is built and delivered as fast as possible, followed by additional features in later versions. The bug-free quick delivery of product is well supported by Agile. Mobile apps are downloaded and updated quickly, they need to seamlessly interact with back end servers whenever required which can be accomplished with numerous alterations and adjustments along with the way. Using Agile development approaches with sprints, enhanced quality assurance and multiple test cycles aids in successful development of mobile projects (Harleen Flora, 2014).

The use of agile methodology also recognized the act that an architecture was needed. An architecture provides the foundation from which systems are built and an architectural model defines the vision on which your architecture is based. The scope of architecture can be that of a single application, of a family of applications, for an organization, or for an infrastructure such as the Internet that is shared by many organizations. Regardless of the scope, my experience is that you can take an agile approach to the modeling, development, and evolution of an architecture.

Mobile D approach observes the following principles: Phasing and Placing, Architecture Line, Mobile Test-Driven Development, Continuous Integration, Pair Programming, Metrics, Agile Software Process Improvement, Off-Site Customer, User-Centered Focus.

3.4.1 Mobile D approach

This approach is founded on Extreme Programming, Crystal methodologies (method scalability), and Rational Unified Process (life-cycle coverage). The authors (Abrahamson, et al., 2004), strongly recommend the Mobile-D process to be used by a team of about ten application developers or coders, geared towards a product delivery within ten weeks.

There are five phases associated with the mobile D approach as expressed by n (VTT Electronics, 2006) as *Explore, Initialize, Productionize, Stabilize,* and *System Test & Fix*. The figure given herein, shows how the phases and stages fit in with one another.

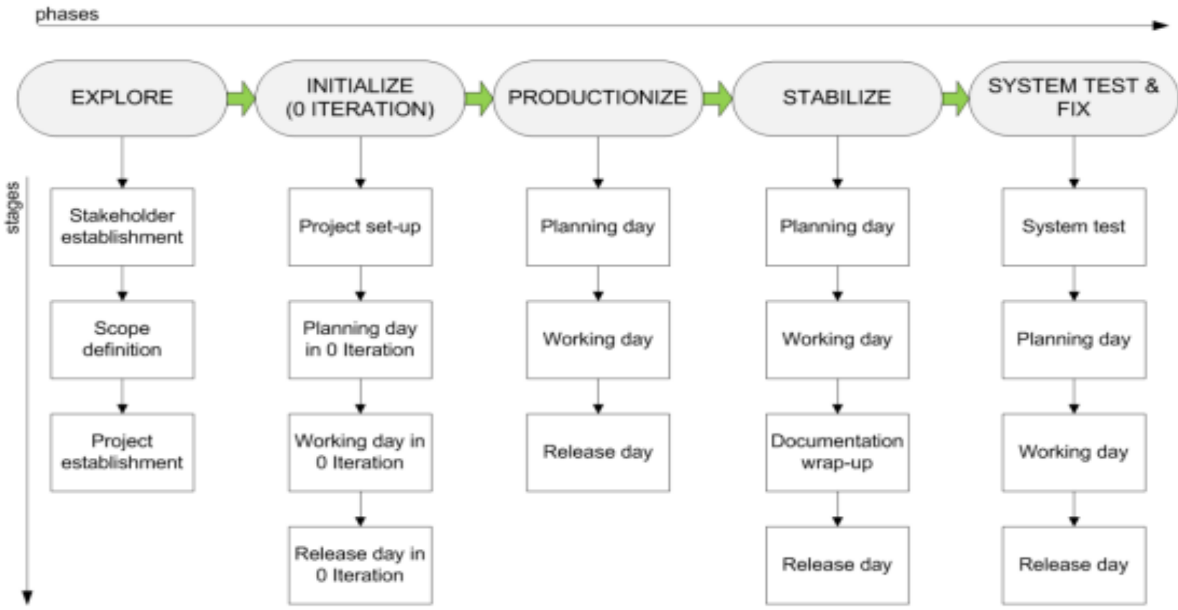


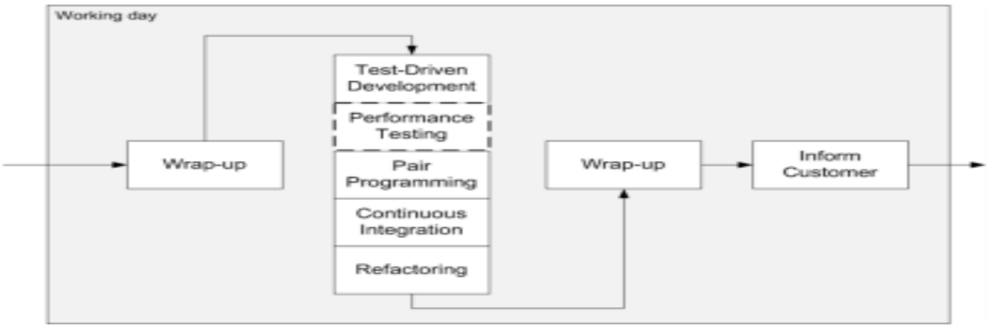
Figure 3: Phases of Mobile D Approach

The first phase has three major stages of establishing the stakeholders, defining the scope and making terms of reference on the established consensus of the project way forward. The second phase, is usually done in loops/iterations with improvements.

The third and fourth phases, productionize and stabilize respectively are simply the execution of the code. This allows the developer to see the outcome of the iteration done previously in phase two.

The fifth step allowed for a full system test. Bugs, errors and exception are handed in the fifth phase. In this project, the integration of machine learning APIs was done at this phase. Major errors included unhandled threads and stack overflows. Depicted here is the included TDD technique in Mobile D.

Figure 3 TDD Technique



The use of the Java Reflection API method provided a reflection of errors. After successfully reaching the execution point that was logged as an error, it is up to developers to analyze the causes of this behavior. The test case as articulated by (Spataru, 2010)fails if method reflection or invocation fails or if the method throws an exception when invoked, and passes if the method has been successfully invoked with the retrieved parameters. If the test passes and the logged execution point is not reached, it is an indication that method parameters were not the cause of the behavior, and other sources must be investigated.

Usability inspection methods have roots in the 1980s (Nielsen & Mack, 1994Nielsen, J., & Mack, R. L. (1994).Usability inspection methods have evolved over the decades to the processes of expert review, heuristic review, and cognitive walkthrough. In this issue, Bias, Moon, and Hoffman propose a new inspection method based on methodology of Concept Mapping and provide an initial assessment of its utility when adapted into a usability inspection method.

Agile and lean methodologies have made their way into mainstream software development methodology. Despite the purported advantages of these methods, it can be difficult to incorporate the user experience (UX) practices that are part of more traditional development methodologies. During interviews and analyses of the fitness of agile (scrum) and lean (Kanban) to incorporate UX methodologies, Law and Lárusdóttir describe the strengths and weaknesses of scrum and Kanban and discuss the potential consequences of developer confusion regarding the “user” and the “customer” when working in the context of these customer-centric development methodologies.

The evolution of usability test methods has led to more and more accurate results that depict a clear picture of the user experience (Lewis, 2015). This research project used the system usability system test morphed into online post-use survey in google forms©. According to usability expert Jakobe Nielsen, it is wrong to assume that: “The best results come from testing no more than 5 users and running as many small tests as you can afford.” The basic premise behind Nielsen’s assertion is that testing with no users gives you zero insights while testing with just one gives you an exponential increase on that. Each additional test user brings an increasing number of repetitious insights, and a decreasing number of original insights. Nielsen illustrates this with a nice graph curve. A sample of 50 participants answered the questionnaire online to completion. The results were mined for special patterns using Weka open source mining software.

CHAPTER FOUR: CONCEPTUAL DESIGN

4.1 Introduction

This chapter describes the conceptual model, the selected framework through which ensured the objectives of this research were best achieved.

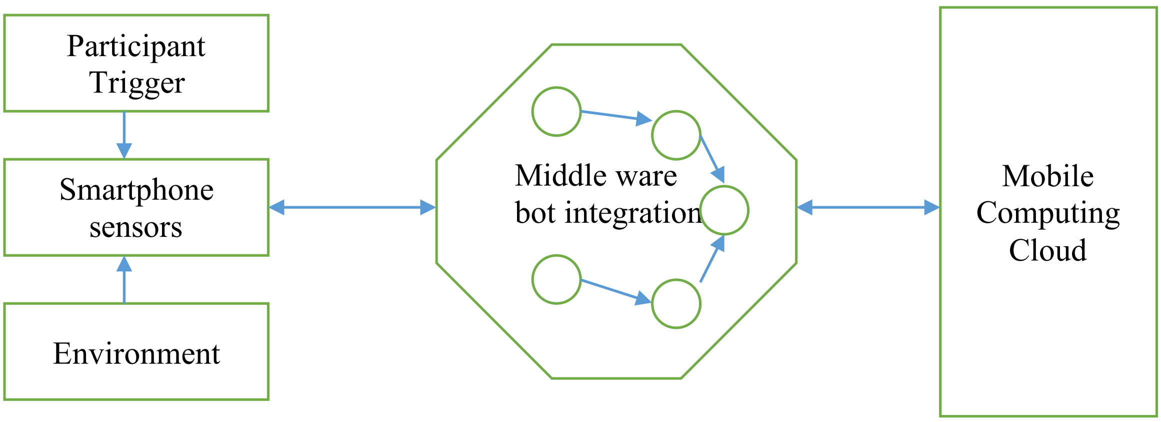
Conceptual framework encompasses the researcher's understanding of how the particular variables in his study connect with each other. Thus, it identifies the variables required in the research investigation. It is the researcher's "map" in pursuing the investigation (Patrick, 2015). Furthermore, the conceptual framework "sets the stage" for the presentation of the particular research question that drives the investigation being reported based on the problem statement as asserted by McGaghie et al. (2001)

Within the agile methodology, the Mobile D approach was selected. The selection was based upon compliance to the SMART framework that allowed for metrics of performance of the application as each feature was added on to the PS tool.

4.2 Conceptual Model

The PS application main objective is to collect data and environmental occurrence surrounding the sensors and route data to the Base station over GSM or WIFI internet. Intelligent agents in the form of bots are actuated when the participant enters a given location geotagged as a potential hazard area or when a new notification of pollution is reported via social media platforms

Figure 4: Conceptual Model



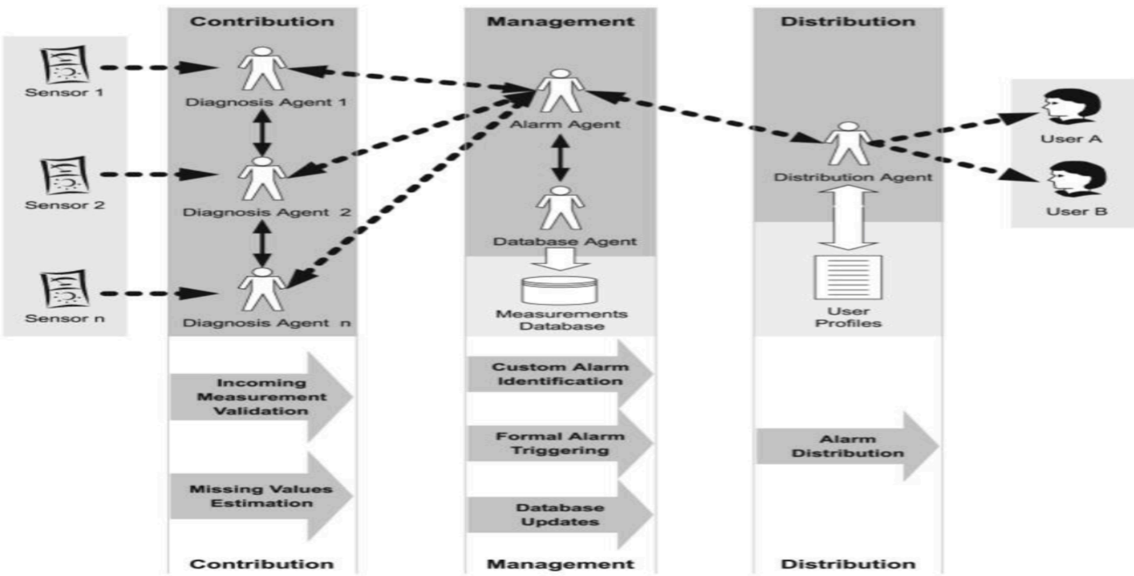
The PS tool is enhanced using agents that are integrated as bots in social media applications. The interaction shapes the models that are stored in the database. This is after interaction with the environment and data stream form social media cloud. The database is hosted in the server and is used to store all media streams and the metadata that is useful in shaping the models and in analysis and visualization of data.

The participant based on a given environment triggers data capture using a myriad of smartphone sensors. When the data matches with trigger point in the middle-ware bot integration then such data is filtered using the privacy filters of SMART framework so forwarding to the computing cloud. This forms a backdrop for a tool that lack bot integration agent of artificial intelligence hence setting a platform for the experiment.

4.3 Participatory Tool and agent interaction architecture

Figure 5 below describes the PS tool and intelligent agents' interaction. It has been used to explain the PS tool enhanced action environment.

Figure 5 SMART Framework



4.3.1 Design of the tool

In building M-safi a classic iterative design process was deployed as guided by the mobile agile development methodology. The application was then subjected to contextual inquiry interviews from key informants to mark the first draft version. The team gave a positive feedback and minor changes were made to the workflow and interface appearance.

An in-house usability evaluation with three Android users was done to remove bugs and correct user interface challenges. Several additional problems including background colors, text size and spacing for easier typing and selecting menu items were corrected.

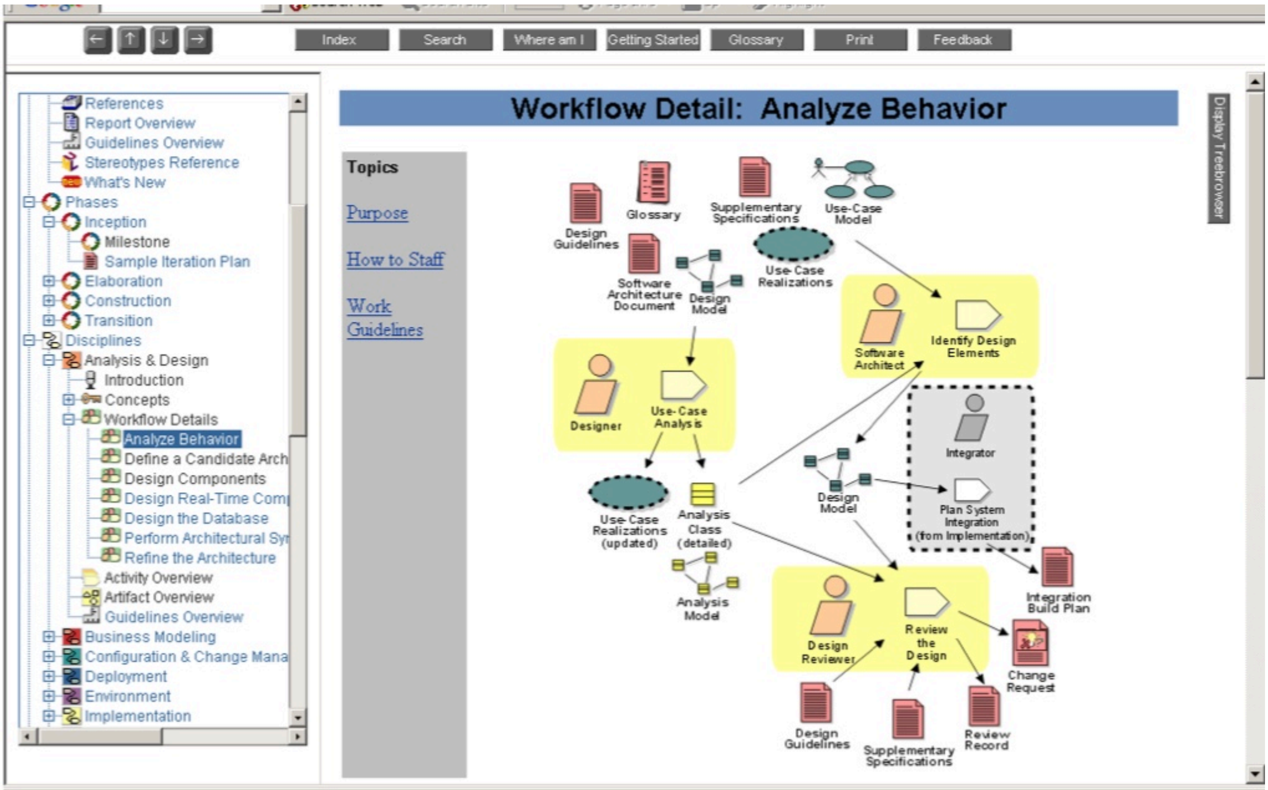
The Rational Unified Process of the Mobile D approach activities was used to create and maintain models. Rather than focusing on the production of large amount of paper documents, the Unified Process emphasized the development and maintenance of models—semantically rich representations of the software system under development.

4.3.2 Visual Modelling

The design model serves as an abstraction of the source code; that is, the design model acts as a 'blueprint' of how the source code is structured and written. The design model consists of design classes structured into design packages and design subsystems with well- defined interfaces, representing what will become components in the implementation. It also contains descriptions of how objects of these design classes collaborate to perform use cases. The next figure shows part of a sample design model for the recycling-machine system in the use-case model shown in the previous figure.

The design activities are centered around the notion of architecture. The production and validation of this architecture is the main focus of early design iterations. Architecture is represented by a number of architectural views. Web- based visual modelling tool was used to generate model and code

Figure 6 Visual Model for developing system



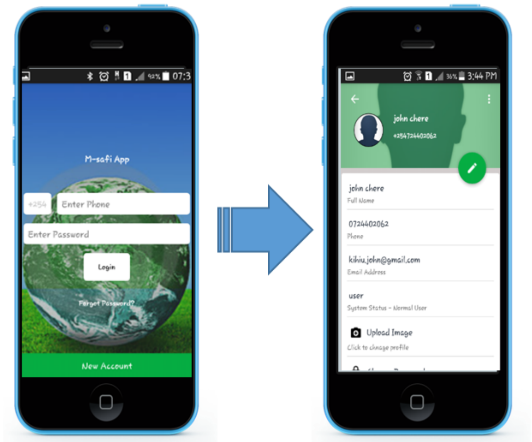
4.4 M-Safi Participatory sensing tool

The name *Safi* is borrowed from the Swahili language of East and central Africa which means clean, seeing that the tool was poised towards environmental hygiene and sanitation. The prefix “M” is short for mobile just like M-learning or M-commerce. The application is a hybrid mobile application that can be used in online and offline modes. The offline mode however has limited functionalities due to the requirement of Geocoding the input to ensure complete processing. The users were allowed to download and install the application on the android based device and emulators.

With the ported machine learning API one can get information about visual content found in an image. Use tagging, descriptions, and domain-specific models to identify content and label it with confidence. Apply the adult/racy settings to enable automated restriction of adult content. Identify image types and color schemes in pictures.

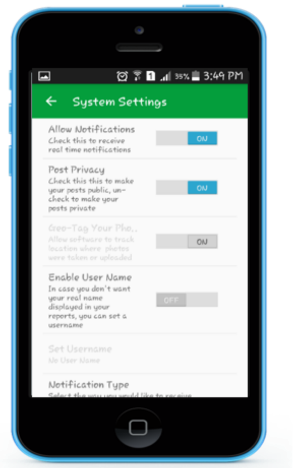
Login screen

Figure 7 Login screenshot



When the user is registered successfully they proceeded to create their profiles. The SMART framework has its tenets on security and hence the settings are intuitive to the user. The privacy setting allowed the user to select whether to use real names or pseudo-name or to be completely anonymous. The settings tab.

Figure 8 Privacy settings screenshot



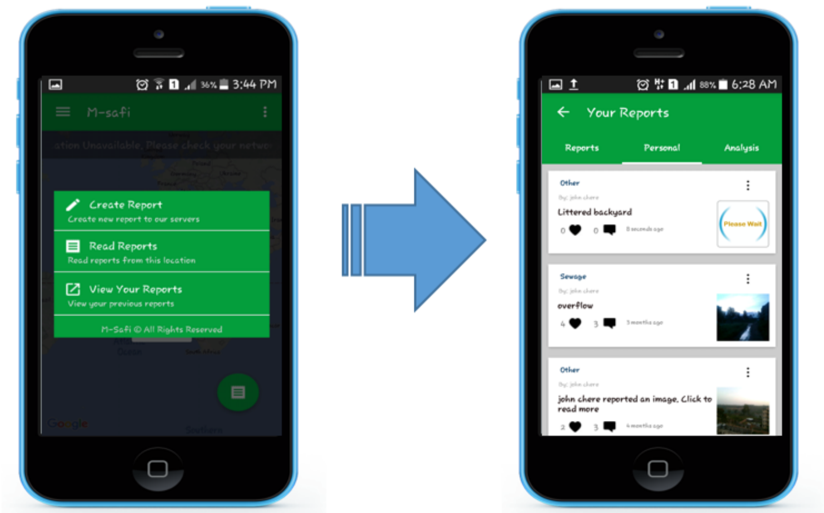
4.5 Fused Intelligent Agents Capabilities

Crowdsourcing,(Brabham, 2013)says, is an online, distributed problem solving and production model that leverages the collective intelligence of online communities for specific purposes set forth by a crowdsourcing organization -- corporate, government, or volunteer. Uniquely, it combines a bottom-up, open, creative process with top-down organizational goals. The gist of our application is thereby capture by the ability to allow volunteer online community to gather and share data at low cost overhead as opposed to proprietary projects.

The application allows user to create reports about environmental pollution concerns. According to the author (Melosi, 2008) the major concerns are smog, sewage, spilling water, Littered streets and uncollected garbage among others. The concerns are capture in the report tab of M-Safi application. Once the user starts the creation process the broker intelligent agents start the authentication and interaction session to make the user experienced more enhanced.

The agents are activated once the geo-fenced area is recorded by phone GSM module or GPS location lock.

Figure 9 Report Caption

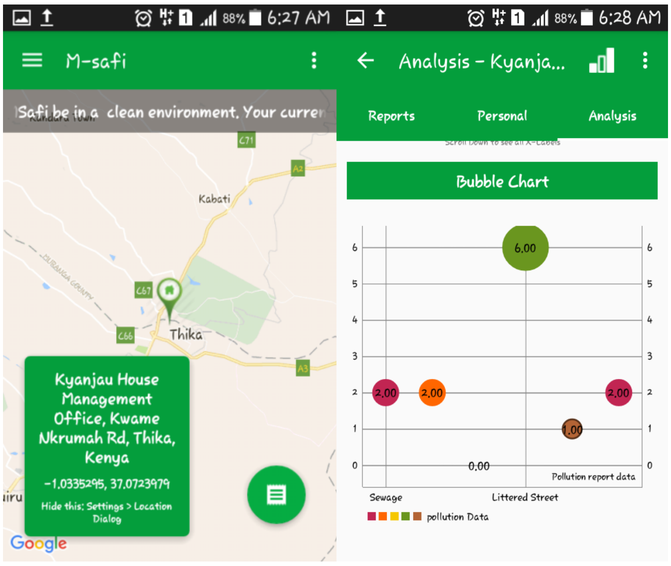


4.6 Data Analysis and Visualization

M-Safi provided a simple to use navigation interface to the analysis and visualizations functionalities. When the report of different types is uploaded by the application they were immediately visible to the registered users of the application. Agent Collaboration which is described as the ability to request and respond to requests for establishing a meeting with another agent. Agents should also have the ability to begin and end meetings with other agents and enforce rules for the meetings, is activated and gets other active broker agents to place pins and pollution density maps on the tool map interface.The of role based access enable the partitioning of administrator and typical user rights.

A task can pass through four main states(Bernhard, 2013): When a task is not started yet (NOT STARTED), when a task is started and its user is interacting to achieve the goal of the task (STARTED), when a task is started but its user is not interacting to achieve it (PAUSED) and when the task is finally terminated (END). After seeing the main states, we will see several events which can be triggered to change the state of a task, these events should be generated by the mobile applications using the plugin functions. During a task performance a user can trigger two main events: START_TASK (at the beginning of the task: *log_start_task*) and END_TASK (at the end of the task: *log_end_task*). Additionally, but not compulsory there exist two others: if user leaves the task (e.g. because of an incoming phone call) PAUSE_TASK event (*log_pause_task*) is produced. Where user decides to continue the task RESUME_TASK event (*log_resume_task*) is triggered. When a task is started two events related to the interaction of the user can be triggered. The INTERACTION event (*log_interaction*) means that a user is interacting in the right way. This event should be triggered when a user is achieving little micro challenges inside the goal of the task. The ERROR event (*log_error*) means that a user has made a mistake during the interaction process.

Figure 10 Geotagging and analysis



The geotagging uses Google Maps© to give accurate positioning. In this application the streets and names are displayed and an accuracy pin inserted to guide the effectors of the concern to locate the area more precisely.

CHAPTER FIVE: PRESENTATION AND DISCUSSION OF FINDINGS

5.1Introduction

This chapter gives a clear presentation of the findings and discusses the findings in relation to the objectives of this research project

5.2 Testing and Implementation of the Tool

The tool runs on the android platform and for this study mobile phone with Android versions 3.0 up to Android marshmallow version 6.0.1 were supported.

5.2.1 Coding, Testing and Installation Process

In this project coding was done in an integrated environment in Android Studio©. Testing of the code was done in parallel especially the unit tests. In some cases, especially on the design of interfaces, potential users of the tool were involved in user acceptance testing. The aforementioned environment provided a packaging.

Using Android Studio© emulators the code was tested and various wireframes were selected and adapted to various screen sizes and configurations. To reduce the complexity of adding more feature and the paring of agents, refactoring was done and version control ensured easy rollback when the vigilant debugging failed. The PS tool has the following major features: The profile manager, Report (Creation, view analysis and share), Settings, Geocoding integrated intelligent agent.

Unit, system and acceptance testing were done in different scenarios. The test cases provide the specified scenario, queries and navigation paths to normal, abnormal and critical uses of the developed system. The Mobile Test-Driven Development (MTTD) practice used in Mobile-D encompassed writing tests before actual implementation, automating unit testing procedures, and acceptance testing all features with the customer(Abrahamson et al, 2004).

The chosen approach (Mobile D) did not inherently have a testing plan within it and hence a recommendation by (Johnson, et al, 2007), served to ensure the inclusion of Test-driven-development (TDD) and test-first-development (TFD).

5.3 Design of Experiment

Experiment is a classical form of research that owes much to the natural sciences, although it features strongly in much social science research, particularly psychology. The purpose of an experiment is to study causal links; whether a change in one independent variable produces a change in another dependent variable (Hakim, 2000) The experimental study to establish the impact of the enhancement of the PS tool was carried out in Kenya using students from a university in Kenya. The students were studying Diploma in Information technology and therefore had a good backing of information systems.

The participants were 30 in number and they formed 15 groups with each group entailing 2 members. The groups were then randomly assigned to the treatment group such that each group had an equal chance of being selected.

Each of the subgroup was de-briefed about the tool and how it works. To commence the experiment, the researcher informed the participants of the expectations and the bet practices to capture high quality data. The log of activities of the experiments were captured in the log files in main server. The time taken by the experiment was 30 minutes in the areas around a peri-urban area.

Table 3: Experimental design showing treatment and outcome

Group	Treatment	Outcome
Group 1	Agent enabled-X_1	Outcome-O_1
Control group		Outcome-O_2

Treatment: the members of group one had the application installed in their phones and the agents enabled while the control group had the agents disabled. The participants were then given five tasks that they were to do and fill a self-test questionnaire.

5.4 Validity of Results

Measures were taken to ensure that the results were valid and consistent with each experimental trial that was done. These measure included:

i. Members assigned at random to each. This means the two groups will be exactly similar in all aspects relevant to the research other than whether or not they are exposed to the planned intervention or manipulation.

ii. Equal time allocated to each discussion group to solve the group task

iii. Each of the discussion groups was not able to access or mingle with others during the discussion duration.

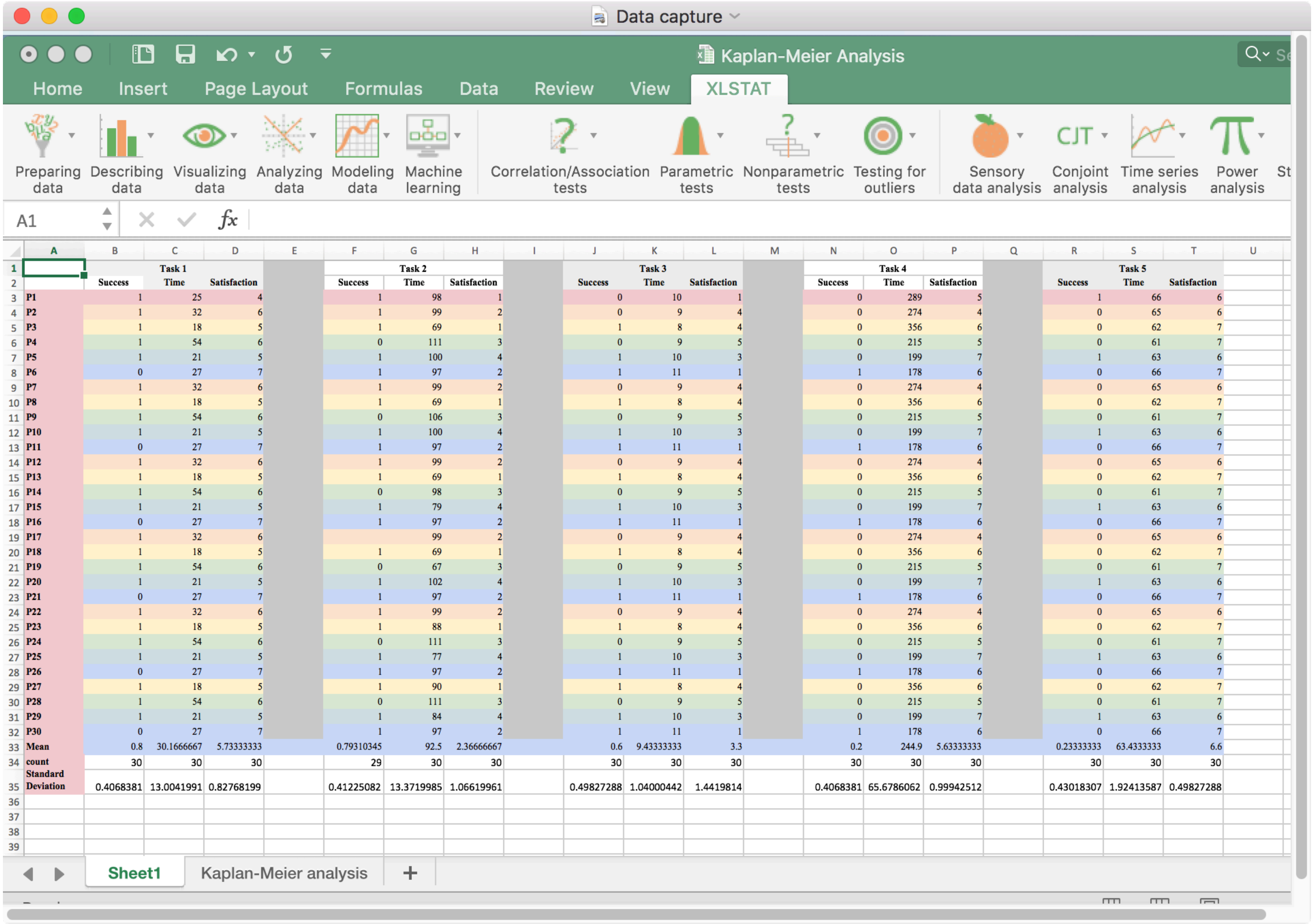
5.5 Experimental study Results

This data was fed into Excel© with Xlstat© plugin using three variables (ParticipantID, Success, Time and Satisfaction). The pattern- rates for both raters were calculated using the COUNTIFS () function in Microsoft Excel and entered to assist in calculating the Kappa value using weighted cases. The sample data entered into SPSS for analysis

Nearby service discovery: The dimension founds on the categories Spontaneous Execution and Service Actuation. As mobile services are much stronger correlated with the daily life of end-users an important requirement is to raise their attention to an adequate service offer in a seaming less manner. A successful implementation depends on the reasoning power (that compare the current users' context and the intended service context) and the number of directly consumed services (reasoning success).

The consistent participants even with the non-enhanced tool, showed an 85% data accuracy levels. This indicated the leveraging power of machine learning in PS tools. The results are gathered from the online survey and analyzed using a statistical package.

Figure 11Data capture



	Task 1			Task 2			Task 3			Task 4			Task 5		
	Success	Time	Satisfaction	Success	Time	Satisfaction	Success	Time	Satisfaction	Success	Time	Satisfaction	Success	Time	Satisfaction
P1	1	25	4	1	98	1	0	10	1	0	289	5	1	66	6
P2	1	32	6	1	99	2	0	9	4	0	274	4	0	65	6
P3	1	18	5	1	69	1	1	8	4	0	356	6	0	62	7
P4	1	54	6	0	111	3	0	9	5	0	215	5	0	61	7
P5	1	21	5	1	100	4	1	10	3	0	199	7	1	63	6
P6	0	27	7	1	97	2	1	11	1	1	178	6	0	66	7
P7	1	32	6	1	99	2	0	9	4	0	274	4	0	65	6
P8	1	18	5	1	69	1	1	8	4	0	356	6	0	62	7
P9	1	54	6	0	106	3	0	9	5	0	215	5	0	61	7
P10	1	21	5	1	100	4	1	10	3	0	199	7	1	63	6
P11	0	27	7	1	97	2	1	11	1	1	178	6	0	66	7
P12	1	32	6	1	99	2	0	9	4	0	274	4	0	65	6
P13	1	18	5	1	69	1	1	8	4	0	356	6	0	62	7
P14	1	54	6	0	98	3	0	9	5	0	215	5	0	61	7
P15	1	21	5	1	79	4	1	10	3	0	199	7	1	63	6
P16	0	27	7	1	97	2	1	11	1	1	178	6	0	66	7
P17	1	32	6		99	2	0	9	4	0	274	4	0	65	6
P18	1	18	5	1	69	1	1	8	4	0	356	6	0	62	7
P19	1	54	6	0	67	3	0	9	5	0	215	5	0	61	7
P20	1	21	5	1	102	4	1	10	3	0	199	7	1	63	6
P21	0	27	7	1	97	2	1	11	1	1	178	6	0	66	7
P22	1	32	6	1	99	2	0	9	4	0	274	4	0	65	6
P23	1	18	5	1	88	1	1	8	4	0	356	6	0	62	7
P24	1	54	6	0	111	3	0	9	5	0	215	5	0	61	7
P25	1	21	5	1	77	4	1	10	3	0	199	7	1	63	6
P26	0	27	7	1	97	2	1	11	1	1	178	6	0	66	7
P27	1	18	5	1	90	1	1	8	4	0	356	6	0	62	7
P28	1	54	6	0	111	3	0	9	5	0	215	5	0	61	7
P29	1	21	5	1	84	4	1	10	3	0	199	7	1	63	6
P30	0	27	7	1	97	2	1	11	1	1	178	6	0	66	7
Mean	0.8	30.1666667	5.73333333	0.79310345	92.5	2.36666667	0.6	9.43333333	3.3	0.2	244.9	5.63333333	0.23333333	63.4333333	6.6
count	30	30	30	29	30	30	30	30	30	30	30	30	30	30	30
Standard Deviation	0.4068381	13.0041991	0.82768199	0.41225082	13.3719985	1.06619961	0.49827288	1.04000442	1.4419814	0.4068381	65.6786062	0.99942512	0.43018307	1.92413587	0.49827288

The first illustration chart comprised of all the questions that were asked and responded to. It is marched against the standard score in usability. Online surveys will involve using a questionnaire combined with automated data collection reflecting the user's actual behavior. They are designed to answer the questions; "What do users think of our product? What do they perceive the value to be?"

Online surveys are incredibly cost-effective and can create large amounts of data on a geographically diverse basis which, in turn, leads to statistically significant sample sizes and results.

Usability Criteria was based on user profile, usability goals and test tasks, we set three criteria, including learnability, efficiency and effectiveness, and two questionnaires such as System Usability Scale and Satisfaction Scale.

Table 4 Subjective Mental Effort Questionnaire (SMEQ)

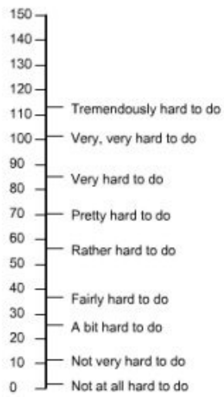


Figure 2. The SMEQ.

Table 4Usability results

Column1	Learnability	Efficiency	effectiveness	satisfaction
Criteria	40%	0.27	100%	
Camera	42%	0.27	86%	74.60%
Notification	39%	0.307	93.30%	62%
Report	38%	7.19	75%	56%
Analysis	41%	7.29	68%	
share	39%	4.03	91.50%	69.50%

A second test on the user experience was done and compared with the usability index from data collected. This was to show a strong correlation of the usability index and the user experience ion that they go hand in hand.

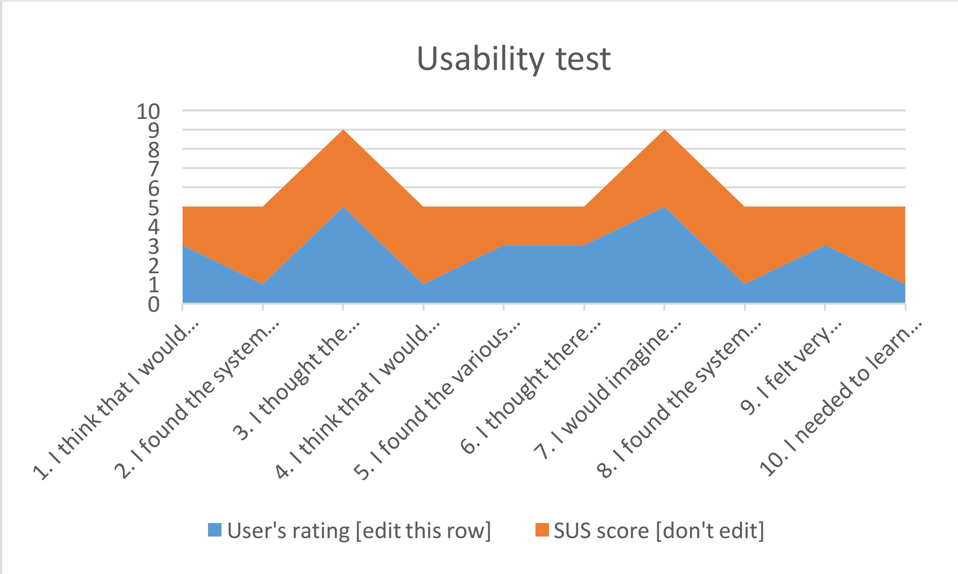


Figure 12 user experience Results

Another way to answer the "how do people user our app?" question is through automated logging – that records events that are generated on the mobile device and without user input. This is a very good way to ensure that interaction data is objective and consistent. Like behavioral analysis, automated logging is limited in the ability to interrogate context or intent.

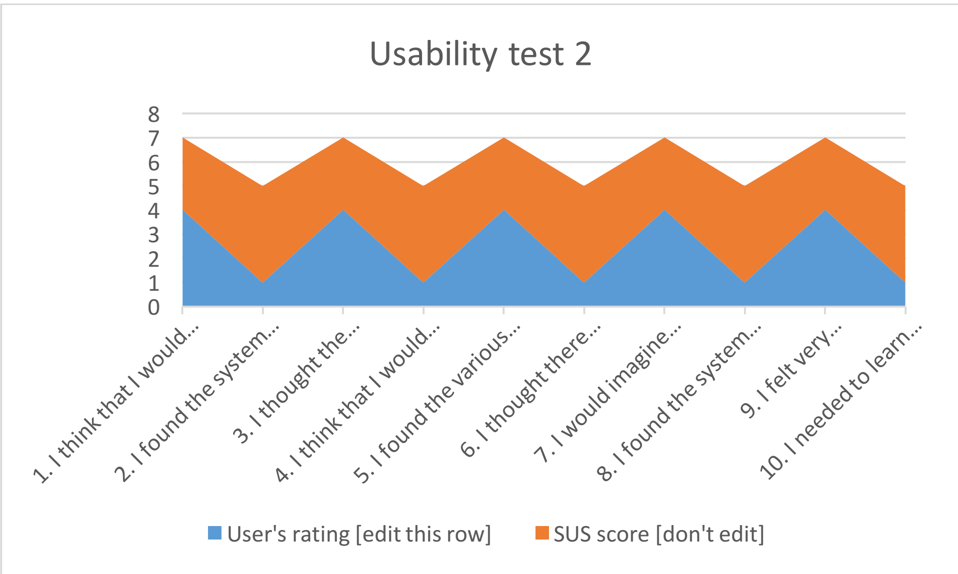
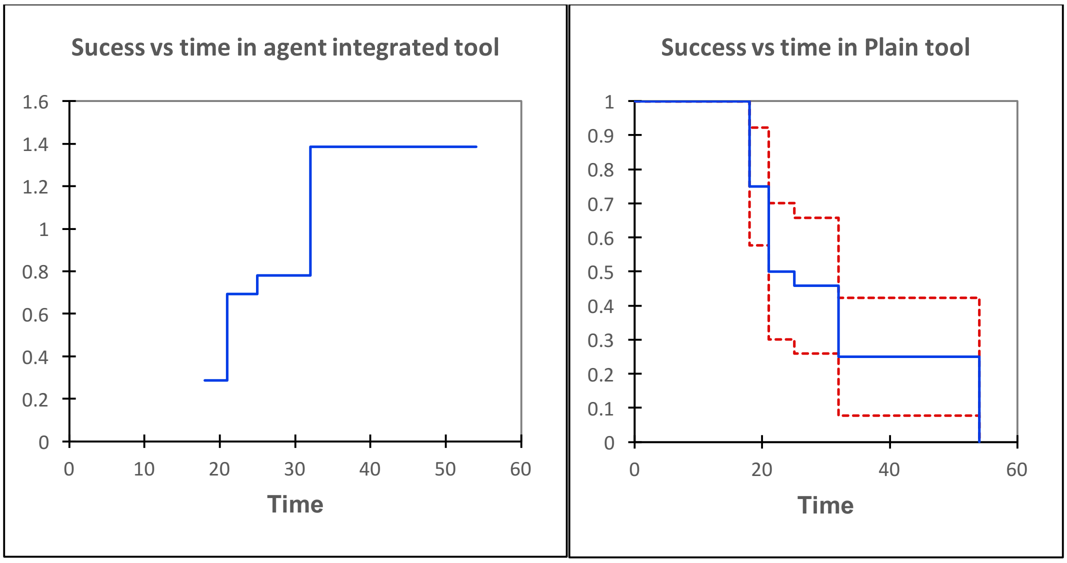


Figure 13 User experience of enhanced app

Figure 14 Graph showing comparison of tools



After all the usability test sessions have been completed, you need to go through all the data, compile it, analyze it and present it in a way that it contains actionable recommendations.

In Learnability, the averages the mobile applications are higher than the criteria, which mean that they are easy to learn. Conversely, the averages of other two mobile are lower than the criteria, which mean that they are not learned easily.

In Efficiency, the averages of components of mobile applications are lower than the criteria, which mean that the two ones are quick to be executed. Conversely, the averages of other two mobile applications are higher than the criteria, which mean that they are not executed quickly.

In Effectiveness, only the average is above 66%, which means tasks are completed with high quality. Conversely, the averages of other three mobile applications are lower than the criteria, which mean that the tasks of three ones are not completed well.

In the experiment, users' subjective satisfaction with the new design was 66% higher than the old design

I gave the same weight to all the usability metrics. Thus, in the experiment, the geometric mean averages the set of scores as: sqrt (2.50*1.66)=2.04. In other words, the new design scores 204% compared with the baseline score of 100% for the control condition (non-enhanced tool). The new design thus has 104% higher usability than the old one.

This result does not surprise me: It is common for usability to double as a result of a redesign. In fact, whenever you redesign a website that was created without a systematic usability process, you can often improve measured usability even more. However, the first numbers you should focus on are those in your budget. Only when those figures are sufficiently large should you make metrics a part of your usability improvement strategy.

Success rate Although numbers can help you communicate usability status and the need for improvements, the true purpose of usability is to set the design direction, not to generate numbers for reports and presentations. In addition, the best methods for usability testing conflict with the demands of metrics collection.

To collect metrics, I used a simple usability measure: the user success rate; defined the rate as the percentage of tasks that users complete correctly. This is an admittedly coarse metric; it says nothing about why users fail or how well they perform the tasks they did complete.

In total, we observed 30 attempts to perform the tasks. Of those attempts, 9 were successful and 4 were partially successful. For this particular site, we gave each partial success half a point. In general, 50% credit works well if you have no compelling reasons to give different types of errors especially high or low scores. In this example, the success rate was (9+(4*0.5))/30 = 36%.

Satisfaction

The Subjective Mental Effort Questionnaire (SMEQ) is made up of just one scale, and it measures the mental effort that people feel was involved in a certain task. According to Sauro (2017) in Quantifying the User Experience, SMEQ correlates highly with SUS scores, as well as completion time, completion rates, and errors.

CHAPTER SIX: CONCLUSION AND FURTHER WORK

6.1 Introduction

In this chapter of the study, a summary of the other chapters is laid and rounding up of the literature review and analysis of the findings. This chapter also provides the overview of the overall project objective and the extent to which each specific objective was met. The objective of the study is revisited and the suitability of the methodology applied is discussed. This part also highlights the recommendation for future research.

6.2 Overview

The popularity of mobile devices and applications, the applications have become more and more important in the world. Through a wide range of mobile applications, users can not only purchase them and share the audio-visual files, but also search or exchange the related information or knowledge. As a result, how to design the mobile application interface to fulfill users' needs has become the most important thing in the field of contemporary mobile application design and development.

The project attempted to enhance a mobile participatory tool that was capturing environmental pollution concerns in a peri-urban area by including machine learning agents made by open source community of Tensor Flow.

Usability an aspect of the user experience which was especially focused on the effect adding agent to improve usability without necessarily making the application more complex. In this test report, we select four mobile applications to implement the complete usability tests; according to the interview, user profiles, task-designed, usability criteria and subjects recruited, we found a lot of human computer interaction or usability issues between users and mobile applications.

Understanding these issues in-depth displayed users' usability patterns and habits which were spotted by the application designer and developer, and then put forward recommendations on the improvement.

For any application to be more well-functional and well-usable; in the future, we not only can validate its functionality such as network connectivity and local close beta test, but we can also propose the usability test, evaluation and competitive analysis which are closely related to the real users.

The first chapter gave the background of participatory sensing and the capability of such a tool in the hand of citizen in improving their lifestyles. This capability was juxtaposed to the low take-off of PS tool in the problem statement. The project specific objectives therefore to design develop and improve this tool.
The second chapter placed in literature and supported it with theoretical underpinnings. The chapter introduced the devices that use this tool i.e. mobile phones and also the software that is used. The inclusion of machine learning in literature review was to capture its role in improving this tool and how developers have leveraged ion the power of AI to bring previously complex analysis into simple and intuitive solutions.

The third chapter introduced the existing methodologies in the domain of mobile application development. This included the System Development Life Cycle, Object Oriented Design Concept and Rapid Application Development. It is in this milieu that Agile methodology was fronted and consequently selected as the most appropriate for the project. The Mobile D approach, being a very elaborate way to handle this project was used. Due to the guideline s of the SMART framework, continuous testing was necessary and hence Test Driven Development (TDD) and test-first-development (TFD) were included. A plugin in the Android SDK was used to measure the performance of the developed application at each improvement iteration and after any major refactoring.

The fourth chapter has its focus on the implementation of the tool that was developed under the agile methods and ported to ANN APIs for enhanced collection and analysis of data. Android studio SDK was used to package the code ready for installation in devices and also hosting in the Google Play store for free downloads by participants, testers or special authorities like the Murang'a County Government.

The fiith chapter hosts the discussion the findings and the recommendation of future research works and projects.

6.3 Discussion

The main objective of this study being stated as ". *enhancing mobile participatory sensing application using intelligent agents*" guided this study. The PS tool was developed in the agile methodology and in the improvement phase, an open source machine learning API (Tensor Flow) was ported to the developed tool. It was from this enhancement that the usability of the tool was evaluated.

Using the agile methodology, Mobile D approach ensured that design, development and integration of machine learning Application Program Interface was seamless and successful. This made achievement of the first and second objectives possible. Once the developed tool was hosted in the cloud (Commercial host Servers), the application was available for download by users. Infrastructure as a service (IaaS) provided by the need processing power for the machine learning function. Localization of geotagging, collecting and sharing reports and visualizations ensured a lean and lightweight application for the mobile devices. This met the third and fourth objective satisfactorily.

User experience is a subjective feeling, as each individual experiences the world through their own lens. The total experience of each user could depend on a variety of external factors, like how they began their day to their mood to their socio-economic status and so on.

Still, though, there are a variety of valid ways to measure usability and the overall user experience, and how people are interacting with each part of your site as well as holistically. Albeit satisfaction isn't 100% correlated with objective usability metrics." Actually, users prefer the design with the highest usability metrics 70% of the time.

I would therefore be rightly said that the overall objective of the project was achieved. The limitations and challenges encountered other than budget constraints were technological in nature and are subsequently given as potential areas for further study.

6.4 Future works

Having successfully ported machine learning to the participatory sensing tool, further studies to integrating machine learning to the tool is recommended. The GIS location based tagging of images, sound and text is an area that will need refinement to optimize the use of data especially over metered internet in mobile devices.

Future studies should explore the area of user experience with a mind of security and privacy where big data requirement of knowing as much about the participant is a quest to moderate.

Participatory sensing should also be spread across all human concerns and in developing economies.

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APPENDIX 1

Google forms© Online Survey Question

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

Notes

80.3 or higher is an A. People love your site and will recommend it to their friends 68 or thereabouts gets you a C. You're doing OK but could improve 51 or under gets you a big fat F. Make usability your priority now and fix this fast.