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A MARKET PARKING SYSTEM USING WIRELESS SENSOR NETWORKS.

By

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Declaration

I hereby declare that this submission is my own work towards the award of the MSc degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which had been accepted for the award of any other degree of the University, except where due acknowledgement had been made in the text.

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"The will of God will never take you where Grace of God will not protect you."
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Dedication

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Abstract

To meet the explosive need of traffic optimization in and around market areas, the Wireless Sensor Networks (WSNs) was adopted to curb this challenge. The WSNs consisting of sensor nodes and networks as we know offers powerful services such as sensing, computing and communicating. Until now, there had been several approaches of vehicle detection, but this work proposes an approach of the Market Parking System (MPS) using WSNs. The system detects vehicle as it approaches the lot, differentiates what vehicle class category it falls under. it also monitors the state of the parking space by already deployed sensor nodes buried in each of the parking space. After accurate detection of the vehicle the Low-energy adaptive clustering hierarchy (LEACH) routing protocol of the WSNs is used to route the information as regard the parking lot to the base station, and the availability of parking spaces would be known by the administrator.

All results, methods and techniques was simulated and verified using MATLAB.

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List of Abbreviations

APS Automated Parking System

CH Cluster Head

CSMA-CA Carrier Sense Multiple Access with Collision Avoidance

DNS Distributed Sensor Network

EM Electro-mechanical

IEEE Institute of Electrical & Electronics Engineering

IETF Internet Engineering Task Force

LEACH Low-energy Adaptive Clustering Hierarchy

LED Light Emitting Diode

LPR Licence Plate Recognition

MEMS Micro-Electro-Mechanical System

MPS Market Parking System

PDF Probability Density Function

PEGASIS Power-Efficient Gathering in Sensor Information System

PGIS Parking Guidance and Information System

PVW Principal Visual Word

RF Radio Frequency

RFID Radio-Frequency Identification

SHM Structural Health Monitoring

SIFT Scale- Invariant Feature Transform

SPS Smart Parking System

TBIS Transit Based Information System

TEEN Threshold-Sensitive Energy Efficient Sensor Network

VMP Visual Matching Problem

VMS Variable Message Display

WHSN Wireless Hetergeneous Sensor Network

WSN Wireless Sensor Network

Chapter 1

Introduction

1.1 Background

Serious concerns have been raised with respect to parking problems and traffic congestions in and around market places. If one ever had to drive around a parking garage in search of that singular spot to park, one would probably have felt his/her own patience slipping away as it could be time wasting and frustrating. Demand pressure for parking and transportation facilities in both the local and state government areas have equally remained high in recent years [1]. This phenomenon has its own associated problems. A 30% estimate of vehicles driving on the roads in the downtown area of major cities are said to be cruising around for a parking spot and this approximately takes an average of not less than 7.8 minutes to find one [2] .

As per the researcher, Smart Parking System (SPS) is a timely intervention to curb this menace. SPS is a standalone- automated system that furnishes information on parking availability to motorists. SPS plays a vital role in ensuring good parking in urban areas [3]. Optimized parking has become a global priority. Smart Parking System aims at satisfying the involved parties (parking service providers and drivers), through the improvement of car park management and drivers' everyday life.

The size of a parking lot depends largely on the number of vehicle it is proposed to accommodate and the size of the kind of business operated there. However, prominent businesses with lots of customers would require a large parking space/ garage, unlike small scale business with lesser patronage [4]. Realizing the difficulty in finding parking areas in some market places, the SPS utilizes variety of technologies to effectively and efficiently manage the parking lot. Wireless Sensor Networks (WSNs) consist of tiny devices known as sensor nodes. For communication to take place, these sensor nodes are set with radio interface thereby forming a network [5] . Each sensor node has more often than not several parts; a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source (i.e. battery or an embedded form of energy harvesting). Sensor nodes are however duty-cycled to be able to save energy. It periodically turns its radio OFF and ON to participate in network communication. Having earned considerable popularity. The WSNs are flexible enough and can be used in resolving problems in different application domains [6] . For WSNs in different applications to be successfully deployed, several parameters depend upon the sensor nodes. The significant parameters ranging from the processing power and memory capacity of the sensor,to the low power consumption/long lifetime, as well as production cost, security, and fault tolerance among others [7].

According to survey estimates, it was shown that in the late 1970s, about 53% of all workers depended on buses to get to their workplaces; whereas one-fifth or 20% commuted by private automobile; another 20% walked to work while less than one percent travelled to work by train or water transport. The number of private cars in Lagos has increased over time; in 1960, 8,800 licensed cars existed in the city; between 1970 and 1974, over 42,000 cars were registered. In 1985, nearly 20,000 minibuses, 6,000 midi-buses, and 30,000 taxis were estimated to run in the metropolis [1].

It is evident in most cases that, finding parking spaces in a typical Nigerian market poses challenges to motorists as the parking lots are always full, and they have to drive around in search of available parking space on the street or at a nearby place. This results not only in traffic congestion but also in traffic jam and struggles amongst incoming vehicles to the parking lot and parked vehicles. Limitation of sign distance and obstructions in clear recovery zone for errant vehicles also results in traffic congestion.

With the continuous growth in the number of automobiles, the situation worsens by the day. This work proposes a system to determine whether a space is occupied or not by detecting the presence of a vehicle. The algorithm deployed is a vehicle detection algorithm.

1.2 Motivation.

The purpose of any technology is to satisfy needs in the best possible way at a minimum cost. As earlier highlighted, we find several smart parking facilities of major cities predominantly in shopping malls. Mostly each and every neighbourhood is unique and have their own peculiar parking issues. However parking issues commonly identified lately among others have been a source of inspiration for this work and they are as follows:

1. Inadequate information for motorists on parking availability.

[1] http://www.city-data.com/world-cities/Lagos.html

2. Inefficient use of existing parking capacity.

3. Excessive automobile use.

4. Confusing parking policies.

1.3 Problem Statement.

With the eminent demand on the judicious use of time for want of success, business owners and customers alike blame most of their slack on traffic congestion. Serious concerns pertaining to parking problems and traffic congestions in and around various market places have been raised. It is in the quest to correct this menace that the researcher resorted to minimizing traffic congestion around market vicinities using WSNs.

1.4 Research Objectives

1.4.1 General Objective

The main objective of this research is to optimize parking by designing a parking scheme using wireless sensor networks to reduce traffic jams/ congestion in market environment and around neighbouring streets.

1.4.2 Specific Objectives

This research work specifically seeks to:

1. Determine the extent to which Parking Spaces are occupied by deploying WSNs.

2. Access how the vehicle detection algorithm can help solve parking issues.

3. Make recommendation(s) from this study.

1.4.3 Research Questions

- To what extent can the WSNs be deployed to identify occupied Parking Spaces?
- How can the vehicle detection algorithm solve parking issues?
- How will the people of the study area benefit from the Market Parking System (MPS)?

1.5 Outline of the Thesis.

The setup of this thesis will be as follows. The First Chapter gives an introduction, motivation and the objective of this work. Chapter Two deals with previous work related to SPS using Image Processing, SPS using Licence Plate Recognition of Vehicle, SPS via Radio Frequency Identification (RFID) and Car Park Occupancy Detection. In Chapter Three, the system model for the proposed technique will be presented. An assessment of the method described in Chapter three will be stated in Chapter Four; by way of simulations. In Chapter Five, the conclusion and recommendation(s) is presented.

Chapter 2

Review of Literature

Due to the economic situations in most developing countries, Ghana as no exceptions. People lay much emphasis on the heady use of time and things being equal opt for services at a relative low cost but gives higher returns and satisfaction. The researcher as far as this research is concerned sort to explore the extent to which the WSNs can be used to effectively curb these slacks associated with time and cost of parking in market vicinities.
Hence in this chapter, the role of WSNs in smart parking is reviewed. Sensing techniques available in literature are described, while research gaps are identified.

2.1 An Overview of a Parking System

Parking lots usually are paved with asphalt, although in some cases they are paved with concrete and many others are coated with gravel. A couple of recently constructed lots their surface with porous pavements. The type of engineering used in constructing the pot lot varies by the different type of parking lot. While parking lots have traditionally been an overlooked element of development projects by governmental oversight, the recent trend has been to provide regulations for the configuration and spacing of parking lots, their landscaping, drainage system and pollution abatement issues. Parking lots near businesses, buildings, or institutions are often implicitly understood or explicitly labelled to be for the use of their respective customers or visitors, often with special vehicle spaces for the owners and employees. Parking lots around apartment buildings are often exclusively intended for parking use of their residents, although sometimes separate spaces may be provided for visitors. Such parking for businesses, offices, and residences is often free to the customers, patrons, or residents.

Virtually parking spots are scarce in some cases, and in such cases one may have to pay to park. Entry and exit access is often controlled at these type of lots to ensure that those parking pay the required fee. The technique used to enforce these kind payment are known as *access controls*. Automated payment, entry and exit systems will somehow reduce the need for employees' payment losses. Therefore in many congested areas where some business organizations lack their own parking areas,the driver is force to practically look for a nearby lot where he can pay a fee to park. In some parking lots, there are parking meters, into which payment are made. These payments are made in form of coins mostly and usually adjacent the parking space. Some spots could be tagged as *"reserved"*, mostly for either top government officials, paramount rulers of the community for certain people and the disabled. And these spaces may be slightly wider, close to the point of entry of the corresponding store or building.

Vehicles with handicapped tags may park there, but the non-handicapped are not allowed to. Provision of parking is a customer service which is aimed at providing good access around the town or neighbouring towns for residents, workers, and visitors as the case may be [8] . Proper management of parking will contribute positively in various ways to the community, including contributing positively to economic performance and visual amenity. Parking *"free for all"*, with no restrictions or controls on parking and a lack of enforcement, represents a failure to manage asset and a failure to provide good customer service. This may then adversely affect economic performance and it is therefore important to remember that different customers (residents, shoppers or workers for example) have very different parking needs and priorities and that the provision of parking systems also have some effects like congestion, accidents, pollution, obstruction to fire-fighting operations.

The car parking system is a machine-driven device that is capable of procreating parking capacity inside a parking lot. Parking systems are in general powered by electric motors or hydraulic pumps that move vehicles into a storage position. The *traditional type* of car parking system and *automated type* of car parking system are types of car parking system. The automated car parking systems have proven beyond doubt that they are likely to be more cost effective compared to the traditional parking garages. Automated multi-storey car park systems are less expensive per parking slot, since they tend to require less building volume and less ground area than a conventional facility with the same capacity. Both automated car parking systems and automated parking garage systems reduce pollution, cars are not running or circling around while drivers look for parking spaces.

Madhuri *et al* in their work stated types of parking as on-street parking, off-street parking, parallel parking, right-angled parking, 30°, 45°, and 60° parking [9]. They however went further to state that Multi-level Parking systems for some time have provided relief since they come with a number of advantages such as; optimal utilisation of space, lower maintenance and operational cost , lower construction cost , secure and environment-friendly nature, comfortable for the drivers , costs saving for builders by saving height or depth.

2.1.1 Difference between On-street parking and Off-street Parking.

On-street parking: That is parking at the side of the streets, and on the road side. On-street parking allows easy access to those kind of businesses on city streets and occupies less land per space. Regrettably, on-street parking creates an obstruction between already parked vehicles, moving traffic and individuals walking on the sidewalks. On-street parking is prohibited at rush hours in most countries and communities, however remorsefully, on street parking is a key factor in promoting businesses in cities, particularly within central business districts where there is either shortage of land use or parking garages, it utilizes less land per space [10]. Notwithstanding in [10] it was stated that depending upon how on-street parking is situated, it can also serve as a traffic calming device, thereby slowing vehicles and potentially reducing the number and severity of accidents. The question here is "**whether the on street parking will or will not increase safety hazards considerably?**

However considerations as to whether the capacity of the road-way left will be enough after on-street parking is done to cater for traffic on the road, should be accounted for.

Off-street parking: Is that place one can park one's car that isn't on a road side or curb side. It is any form of car storage that includes parking structures, surface parking lots, single-car garages and driveways. Hence Off-street parking boosts car ownership and car use, thereby encouraging increase in parking demand [11][12]. Off-street parking facilities are those built solely for the purpose of parking vehicles. It could be open-paved space type (i.e. surface parking garage), multi-storey parking, park and ride and so forth.

Partha and Animesh [13] in their book stated that off street parking must focus on providing spaces so as not to only allow easy and independent parking (i.e. every vehicle that parks can depart with ease without regard to any other parked vehicle) but to also allow easy vehicle circulation in the parking area.

2.1.2 Smart Parking

As technology advances, both the smart parking and intelligent parking are parking guidance systems which facilitates proper parking.

The question here is **What is "Smart Parking"?** Many and Different researchers and car manufacturers offer different definitions. However, there seem not to be an established definition on what smart parking is.

Smart Parking is a service-oriented intelligent parking system whereby drivers can view and reserve a parking spot on the fly. The parking process can then be above-board and a non-stop process. More importantly, Smart Parking is a secure and privacy-aware parking system.

At present, Navigant Research[1] defined Smart parking as the use of advanced technologies for the efficient operation, monitoring, and management of parking within an urban mobility strategy. A number of technologies provide the basis for smart parking solutions, including vehicle sensors, wireless communications, and data analysis. Smart parking is also made viable by innovation in areas such as smartphone apps for customer services, mobile payments, and in-car navigation systems.

Smart Parking can also be defined as when vehicles are manoeuvred resourcefully, calculatedly showing mental alertness into a location where its left temporarily.

[1] http://www.navigantresearch.com/

At the heart of the smart parking concept is the ability to access, collect, analyse, disseminate, and act on information on parking usage. Increasingly, this information is provided in real-time from intelligent devices that enable both parking managers and drivers to optimize the use of parking capacity. SPS is said to consist of 5 main modules. These modules include the image processing component, the status updater which will at intervals transmit status reports, I/O , timer function and the shortest cost path algorithm. All these components working effectively and efficiently will ensure a proper SPS.

Smart parking is applicable to both on-street and off-street parking, but in the course of this research we will be considering off-street parking. If parking resources are to be managed and used effectively, parking managers need a holistic view of parking availability. Intelligent Parking suggests to the motorist of avail-

Figure 2.1: Smart parking illustrated [14].

able parking in multiple parking zones, allowing the motorist to make an informed decision on where to park, long before they reach each critical decision making point; by the use of effective traffic and safety engineering techniques. Intelligent Parking then effectively guides the motorists to these open bays with minimum effort within a short possible time. Intelligent Parking makes the most of avail-

Figure 2.2: Senor nodes in parking spaces [15]

able parking spaces and increases the profitability of parking facilities. Intelligent parking also gives the client an effective tool to monitor, operate and maintain the entire parking facility effectively and efficiently. It also has the possibility of an online reservation system for users to book parking at the facility.

Benefits of Implementing Intelligent Parking include;

- Less congestion due to fewer vehicles driving around looking for parking.
- Reduction in time and fuel spent by road user searching for parking.
- Less queues as motorists will go to parking areas with the most available bays.
- Better flow of traffic through the area.

- Intelligent Parking results in higher revenues and profitability for parking facilities.

Intelligent Parking can operate using a variety of data sources for parking information, including:

- Integrated to an existing Parking Management System
- In/Out counter system using loops or other detector technologies.
- Individual bay counts using either indoor or outdoor bay count sensor.

Usage patterns and users need real-time information on both on-street and off-street parking. Misuse of parking premises in buildings is common in marketplaces. Parking spaces in public buildings and near retail outlets are being used for activities other than parking. This is a largely undocumented problem and no numbers are available, and the resultant spill over of vehicles outside the premises is not being assessed in commercial and office areas.

2.1.3 Difference between Robotic Parking, Intelligent Parking and Smart Parking.

To lots of people, there are really no differences between smart and intelligent, because the words seem to be synonymous or interchangeably used. However, there is a difference between the meanings and use of these words. Smart can be applied to learned inferences whereas according to the dictionary, "intelligence" means the act of understanding.

Hence, Intelligent Parking suggests to the motorist available parking in multiple parking zones, allowing the motorist to make an informed decision on where to park long before they reach each critical decision making point.

Robotic parking systems or garage as the case may be are arrangements which use a series of lifts and pallets, to automatically "park" or store cars in storage bays. In the robotic parking garage, one pull one's car over a pallet which is inside a lift, the pallet then rotates at an angle 180°, lifts and roll the car into the storage bay. The angle of rotation will be such that when it is retrieved, it is in a position for you to simply drive out. It is a great solution for dense urban areas where the cost of land is at a premium Whereas Smart Parking, is a service oriented intelligent parking system where by drivers can view and reserve a parking spot on the fly. Hence in smart parking, when the car enters into the parking facility, the system determines the availability of parking place to be used. Each parking place in the facility has an occupancy sensor connected it. The sensors provide information on how many parking lots are vacant and where those parking places are. The car pulls into the parking space and the occupancy sensor detects the car, transmits to the system and notifies the system of the occupancy. The system can provide real time management data on the number and location of parking spaces available. Drivers no longer search for a space or drive in circles, but instead drive directly to a space, reducing emissions and frustrations.

2.1.4 Difference Between Automated Parking and Smart Parking.

Parking facilities are really vital since people need to get to and from the buildings, people need to do business, go to the mall and the market. Therefore the need for parking is sceptical as to the fuel or power source of the vehicles; because regardless of how the vehicles are powered, we'll still end up with the same number of cars to park. Automated parking basically means an automated system that parks and retrieves cars without any human intervention. The driver of the incoming vehicle to an automated facility parks the car on a pallet or a conveyor belt, gets out of the car and an automated system moves the car to a storage space for parking. Upon the driver's return to the garage, the system retrieves the car from storage and brings it to the driver, a process that can be accomplished in about 90 seconds.

Shaheen et al, & Chinrungrueng, stated that, the SPS is considered beneficial for the car park operators, motorists as well as in environment conservation. Shaheen et al, went further to state that SPS can be divided in five major categories namely;

- Automated parking,
- E-Parking and Opti-parking,
- Smart Payment System,
- Parking Guidance and Information System (PGIS) and,
- Transit Based Information System.

2.1.5 Parking Guidance and Information System (PGIS).

The Parking Guidance and Information System (PGI) uses Variable Message Display (VMS) kind of system, and other methods including radios and phones to provide information to motorists. These systems can be implemented city wide or restricted within a specific car park and it provides the motorists with information about the parking lot or information about the traffic [16]. Having similar function like the PGI system, transit based information system provides motorists with information about the traffic as well. The main difference between these two systems is that the transit based information system directs motorists to car park nearest to a public transport ride lots. The main goal of such system is to encourage the public in using public transport by providing them a place to park their vehicle and switch to public transport.

PGI systems are designed and implemented with the goal of attaining a number of benefits which includes:

- Travel time savings;
- Cut down vehicle travel;
- Less congestion and driver frustration;
- Lower fuel and energy use;
- Reduced air pollution;
- Increased parking revenues; and,
- Improved enforcement of parking restrictions.

However a lot of the literature indicate that these types of city-based PGI systems tend to be used most frequently by city visitors rather than regular commuters and/or local travellers.

2.1.6 Automated Parking System (APS).

Research have shown that the world's population grows by approximately 80 million people and 25 million net new cars are added to the world's roadways each year. The percentage of people living in urban areas is also increasing while people living in rural area is decreasing. A quarter of the urban area is used for motorized traffic. The average car stands 95% of its time on a parking place - not on the roads. The growth in urbanization and motorization are on a collision course since they require the same thing; land or space [17]. This leads to the need for space efficiency and automated parking systems (APS). Automated parking may best be depicted as mechanical valet parking where the driver exits his or her car and the car is parked without a human attendant. Factors such as the need for parking spaces and a scarcity of available land affects the APS. The earliest use of an APS was in Paris, France, in 1905 at the Garage Rue de Ponthieu. APS comprises of a ground breaking multi-story concrete structure with an internal elevator to transport cars to upper levels where attendants parks the cars [17]. Automated parking systems eliminate the space wasted by conventional multi-story parking garages and parking lots. An APS with the same number of parking spaces can save more than 90% of land area than a parking lot and up to 75% less land area than a multi-story parking garage. Furthermore, automated parking systems enable parking in areas where parking garages are not just feasible such as between or inside existing buildings.

APS increases space efficiency by eliminating the challenges that make conventional parking space inefficient: driving lanes and ramps, large parking spaces to allow opening car doors, walkways, stairs, elevators, pedestrian, ceilings height, emergency exits and escape ways, ventilation and the massive building structures as pillars and beams. Interestingly, APS can be more environmentally friendly than mere parking garages since they eliminate the time spent searching for and driving to and from the parking space. Energy efficient since they do not require lighting, ventilation and other human amenities required in conventional parking garages is a major advantage of APS.

2.1.7 Transit Based Information System (TBIS).

The functionality of transit based information system implemented in countries such as France, Germany, Ireland, Japan, Switzerland, the United Kingdom and the U.S.A. is actually similar to PGIS. However the differences between PGIS and TBIS, is that TBIS concentrates on guiding a user to park-and-ride facilities. It provides real-time information on the status of each car park and condition to the public. The additional information provided enables the motorists plan for transit in advance without getting into any inconvenience.

2.2 Smart parking using Radio-frequency identification (RFID).

Radio-frequency identification (RFID) is an automatic identification method wherein the data stored on RFID tags or transponders is remotely retrieved. The RFID tag is a device that can be accompanied or incorporated into a product or person for identification and tracking purpose using radio waves. Some tags can be read from several meters away, beyond the line of sight of the reader, while some cannot [18].

There has been a considerable amount of reduction in transaction costs and decrease in stock shortage with the use of Radio Frequency Identification (RFID) technology in automation. Most of the RFID networks include a wide range of automation technologies. These technologies are RFID readers, RFID writers, RFID barcode scanners, RFID smart sensors and RFID controllers. In this study, a solution according to Pala et al in [19], has been provided for the problems encountered in parking-lot management systems via RFID technology. RFID readers, RFID labels, computers, barriers and software are used as for the main components of the RFID technology. A developed software to handle the management, controlling, transaction reporting and operation tasks for parking lots located on various parts of the city is in existence.

Check-ins and check-outs of the parking-lots will be under control with RFID readers, labels and barriers. Therefore personnel costs will be reduced considerably using this technology. It will be possible to see unmanned, secure, automized parking-lots functioning with RFID technology in the future. Check-ins and check-outs will be handled in a fast manner without having to stop the cars so that traffic jam problem will be avoided during these processes. Drivers will not have to stop at the circulation points and parking tickets will be out of usage during check-ins and check-outs. It will be avoiding ticket-jamming problems for the ticket processing machines as well. Vehicle owners will not have to make any payments at each check-out thus a faster traffic flow will be possible. Since there won't be any waiting during check-ins and check-outs the creation of emission gas as a result of such waiting will be avoided. An automized income tracking system, a car tracking system for charging and a central parking-car tracking system have been developed and utilized. Instead of cars parking on streets, a more modern and a fast operating parking-lot system have been developed [19].

At present, the RFID technology is contactless identification technology a suggestion was given to use this technology in parking systems. The RFID technology in comparison to other technologies have the following advantages.

- The necessity for physical contact between data carrier and the communication device is not needed.
- Robust tags can withstand extreme conditions and temperature.
- Tags can be used repeatedly.

- Low maintenance costs.
- RFID tags may be read by the RFID system at one time.
- Tags available in a range of types, sizes and materials.
- Non-line-of-sight communication makes it possible to read and write tags in dirty conditions.
- Extremely low error rate.

2.2.1 Research Work On RFID for Parking.

The RFID technology is not really a new technology as such, but it is being utilized in new ways, goaded by technological advances and decreased costs. However with the advancement in technology, RFID is now being used in all sort of public and private sector settings from hospitals to the highway and to parking [20, 21]. The effectivity of an RFID application in addressing desired functionality depends largely on factors, such as Contact-less, Absence of Line-of-Sight, Variety of Reading Ranges, Durable, Perform Smart Tasks and wireless communication technologies among others [22, 23].

Unlike Electro-Mechanical (EM) and Radio Frequency (RF) systems, which have existed and was in use for parking over the years, Radio Frequency Identification (RFID) is a technology used in parking theft detection systems as well as smart parking. RFID-based systems go beyond security to become tracking systems that combine security with more efficient tracking of materials throughout the parking, we also recall that RFID technology uses the radio frequency signals in data transmission. Tags that are attached to objects are automatically identified and detected. This method nowadays is used in determining the parking slots in a parking zone [24].

Having said all these about the RFID, RFID readers are connected to the vehicles and are also connected to the computers' USB port. The parking entrance serves as a barrier that controls the operation of a gate, the barrier is also connected to one of the USB ports on the computer. The gate is only opened when a vehicle is detected using RFID readers. All the information about the vehicles and available parking lot is thereby stored in a database that has been created. Included in the database are fields such as Vehicle ID, plate number, type and model. Also within the database, information about the parking lots availability, details of check-in and check-out time, parking fees payable are included. Hence when any registered vehicle enters the parking lot, the table is verified and updated. If it does not have any check-ins record, the details are entered in the respective fields. Having completed registration, the barrier is lifted for the vehicle to enter. This procedure is then repeated, when the vehicle leaves the parking lot. Interestingly a remote/ virtual database is conserved to continue the process when the internet is disconnected or unavailable. The use of RFID technology provides security to the parking management system. This makes the system less reliable when more than one tag responds at the same time [24].

2.3 Smart Parking Systems using Licence Plate Recognition (LPR).

Generally, Licence Plate Recognition system was developed to identify vehicles by the contents of their license plates. The LPR system consists of four major modules: image acquisition, licence plate extraction, segmentation and recognition of individual characters. Licence Plate Recognition (LPR) is a kind of intelligent system and is of considerable interest because of its potential applications to areas such as smart parking enhancement, highway electronic toll collection, traffic monitoring systems and so on. It can be considered as a logical complement for automatic radar and red-light running systems. Due to the rapid increase in number of vehicles across the world's big cities, one of which is Lagos , LPR system has become one of the most important digital image processing systems to be used. The field of LPR and its application has attracted many researchers to search and develop systems which can process images and get useful information from them. Most previous researches and applications have faced some kind of poor performance due to the diversity of plate formats, the non-uniform outdoor illumination conditions during image acquisition, noisy patterns connecting characters and poor edge enhancement.

Unique identification of every single vehicle can be made universally available by using licence plate recognition (LPR) systems. LPR plays an important role in numerous applications such as unattended autonomous parking lot surveillance, security control of restricted areas, traffic safety enforcement, statistical analysis. A typical system for LPR consists of four parts: vehicle image acquisition, license plate localization and segmentation, character segmentation and standardization, and licence plate characters identification [25]. The licence plates localization processing step is crucial for the entire system because it directly influences the accuracy and efficiency of all subsequent recognition steps. Researchers have proposed many methods for licence plates localization in order to extract the licence plate areas. Some of them are: edge detection methods, line sensitive filters, the window method and the mathematics morphology method. For licence characters identification a large number of techniques, such as Bayes' classifiers, artificial neural networks, support vector machines, and K-nearest neighbour classification are used. These algorithms can also process the licence plate segmentation part

and recognize licence plate characters. First LPR systems were problematic due to low resolution analog video signal, small available computational power and license plate configurations not suitable for computer based vision recognition. With technology advancement of computational power, usage of intelligent cameras that include built in basic image processing functions and adaptation of licence plate configuration these problem are now overcome. Current LPR systems are suitable for real -time application with vehicle speeds up to 250 km/h. Idris et al, in his work proposed the implementation of smart parking system using image processing technique, WSNs and shortest path algorithm to assist motorists in finding a vacant parking space with ease. In the course of his work, security surveillance (CCTVs) were used as sensing nodes, the image processing was through RabbitCore®, Microcontroller and transmitted via ZigBee.
Nigerian vehicle registration plates currently are issued in an autoreg format of “ABC-123-DE”. The state name and slogan is displayed at the top of the plate, and “Federal Republic of Nigeria” is displayed at the bottom and the Federal Coat of Arms in the middle. Private vehicles have their licence plated with blue lettering whereas the letterings for commercial vehicles are red. The vehicle class is differentiated based on the colour feature of the lettering on the number plates.

Figure 2.3: Nigeria Licence Plate Format for private vehicles [26]

In Ghana, for instance the series of vehicle registrations are white with black lettering for private car users where for commercial users it yellow with black

Figure 2.4: Licence Plate Format for Commercial vehicles users

lettering. It has the country flag on the right hand side. The format is “LL NNNN L”, with “L” standing for a letter and “N” for a number. The “L” codes are regional codes which the “N” are year codes which indicates the exact year in which the vehicle was registered. Diplomatic plates were also in a similar format with black or green number plates and white lettering. The vehicle class in this case is differentiated based on the colour feature on the number plate as the lettering remains the same on both.

Figure 2.5: Private Number Plate for Ghana [27].

Figure 2.6: Commerical number Plate for Ghana [27].

2.3.1 Research Work on Licence Plate Detection.

License Plates Recognition appears a solved problem considerably. Nevertheless, these existing algorithms, approaches or systems work well only under some controlled conditions. A lot of challenges for license plate recognition still exists in open environment. Such challenges are observation angles from cameras, background clutter, scale changes, multiple plates, uneven illumination, among others. Zhou in [28], proposed a novel scheme to automatically locate license plates by Principal Visual Word (PVW) as well as discovery and local feature matching. Having been motivated by the review of related works, he formulated in his License Plate Detection as a Visual Matching Problem (VMP). For every character, a Scale-Invariant Feature Transform (SIFT) features collected falling into the character region and generates PVW by unsupervised clustering. The amount of PVW for each plate character is determined automatically. The framework of their approach consists of key elements like PVW generation, visual word matching, and license plate location. However their proposed approach is in an open environment. Unfortunately the weakness of their approach is that it might fail when the license plate resolution is too low, and when there is distortion from the angle of observation. Reason being it's difficult to detect the SIFT features matching the PVW of related characters [28] .

Lalimi et al [29], in his paper, he proposed an efficient method for license plate localization in the images using complex backgrounds and other methods. In an attempt to reduce low quality and contraction problems, vehicle images contrasts and vertical edges are enhanced using different methods. Edge density method is the best of all the methods that was selected and was used as pre-processing for image enhancement.

However the proposed algorithm in [29] was performed only on the Iranian vehicle license plates under conditions such as different lighting conditions, varied distances and existence angle between the camera and the vehicle and varied weather conditions. Resulting that this algorithm might not be applicable to a different country's number plate. Further in [30] he proposed a different approach based on using the region and edge based methods for vehicle licence plate detection. This system was implemented and the image contrast at possible angle and location was improved.

2.4 Wireless Sensor Networks (WSNs).

WSNs is an acronym for wireless sensor networks, and can be defined as a network of devices, largely recognized as nodes which consists of sensor devices that are "small in size and able to sense, process data, and communicate with each other, typically over an RF (radio frequency) channel". WSNs is a domain that requires both hardware and system design.

However with the increase or proliferation in Micro-Electro-Mechanical system (MEMS) technology which facilitated the development of smart sensors, the WSNs have earned worldwide attention in recent years. These sensors are small, with limited processing and computing resources, and they are not expensive compared to traditional sensors [31]. Smart sensor nodes are low power devices equipped with one or more sensors, a processor,a memory, a power supply, a radio, and an actuator[2]. Varieties of mechanical, thermal, biological, chemical, optical, and magnetic sensors may be attached to the sensor node to measure properties of the environment. Since the sensor nodes have limited memory and are typically deployed in difficult-to-access locations, a radio is implemented for

[2] An actuator is an electro-mechanical device that can be used to control different components in a system. In a sensor node, actuators can actuate different sensing devices, adjust sensor parameters, move the sensor, or monitor power in the sensor node.

wireless communication to transfer the data to a base station (e.g., a laptop, a personal hand-held device, or an access point to a fixed infrastructure). The main power or energy source in a sensor node is the battery. Secondary power supply that harvests power from the environment such as solar panels may be added to the node depending on the appropriateness of the environment where the sensor will be deployed. Depending on the application and the type of sensors used, actuators may be incorporated in the sensors.

WSNs typically have little or no infrastructure. There are two types of WSNs: unstructured and structured. An unstructured WSN is one that contains a dense collection of sensor nodes. Sensor nodes may be deployed in an ad hoc manner[3] in the field. In an unstructured WSN, network maintenance such as managing connectivity and detecting failures is difficult since there are lots of nodes. Whereas in a structured WSN, most of the sensor nodes are deployed in a pre-planned pattern. Therefore the advantage of a structured network over the unstructured network is that fewer nodes can be deployed with lower network maintenance and management cost. Fewer nodes can be deployed since nodes are placed at specific locations to provide coverage while ad hoc deployment can have uncovered regions [31].

2.4.1 Research Issues in WSNs Application

WSNs applications are many and they vary depending on the areas where they are deployed or applied. However they are commonly used for both commercial and industrial applications, interestingly Wireless Sensor nodes could be deployed in wilderness areas, where they would remain for many years. vehicular monitoring, event detection and structural health monitoring are some examples of

[3]In ad hoc deployment, sensor nodes may be randomly placed into the field.

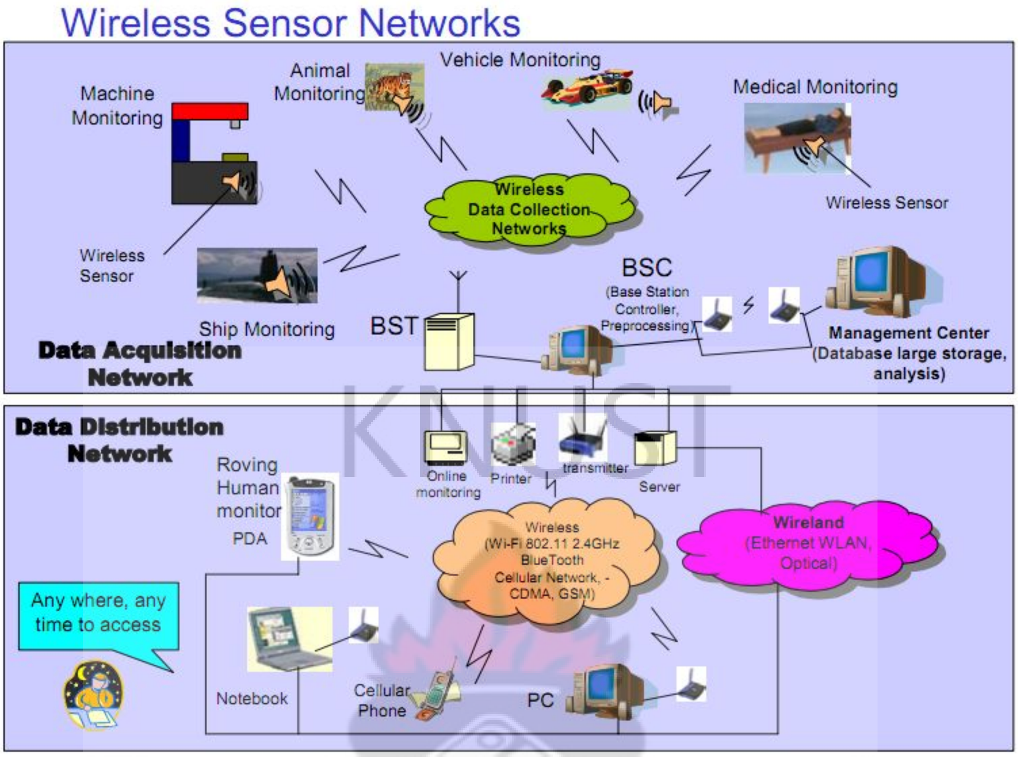

Figure 2.7: Overview of WSNs Applications [32].

commercial applications of WSNs.

Research Issues with Commercial Applications - The purpose or invention of any sort of intelligent or smart environment are of two different perspectives, i.e., human centered and technology centered [33]. Research works has been in WSNs, with sensor nodes having identical sensing units a lot of them. A typical characteristic of wireless sensor networks is tracking, most especially for instant tracking of objects and events [33].

In [34] a protocol Collaborative Event Detection and Tracking (Collect), fully distributed for event detection and tracking in wireless heterogeneous sensor networks (WHSN) was presented. Issues yet to be addressed however, are the results to sensor node deployment, data dissemination and routing in Wireless Heterogeneous Sensor Networks (WHSNs) [34][33]. Examples of commercial based applications using WSNs are material fatigue monitoring; constructing smart office spaces; building virtual key-boards/materials ; control in automatic manufacturing environments; interactive toys; interactive museums; factory process control and automation; monitoring disaster area.

Interactive Museums; In real time cause-and-effect experiments, where children participate and learn about science and environment. Since objects will be able to respond to their touch and speech, children will be able to interact with objects in museums to learn more about them. The wireless sensor network doesn't just allow all this in interactive museums but paging and localization in-side the museum. An example of such museums is the San Francisco Exploratorium.

Structural Health Monitoring (SHM); is referred to as the process of sensing of impairment or damage for civil, aerospace and other engineering systems. Any change of occurrence in the material or geometric properties of these systems due to factors as aging, natural calamities, and pollution is known as damage. The mode of operation of an SHM system basically includes low power, long-term monitoring of a structure to provide periodic updating of its health condition.

In [35], a WSN based application approach was presented for long-term, online SHM based information processing . Mascarenas *et al* & Mascarenas *et al* in [36][37] respectively proposed a novel WSN based application approach for SHM. Unfortunately, the WSN based application for SHM are faced with challenges and issues such as rigid bandwidth requirements, extended network lifetime and limiting multi-hop data exchange.

Research Issues with Home Applications- at present with the advancement in technology , smart sensor nodes and actuators can be buried in appliances, domestic devices such as light switches, vacuum cleaners, micro-wave ovens, refrigerators, and VCRs. The sensor nodes buried inside the domestic devices can interact with each other and with the external network via the Internet or Satellite. They however allow end users to manage home devices locally and remotely more easily.

Research Issues with Military Applications- Even in Military applications, the WSNs could be an integral part of military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting (C4ISRT) systems [6][34].

Some of the military applications of sensor networks are monitoring friendly and unfriendly forces, equipment and ammunition; battlefield surveillance; reconnaissance of opposing forces and terrain; targeting; assessment of battle damage; and nuclear, biological and chemical (NBC) attack detection and reconnaissance. In monitoring friendly forces, as well as the equipment and ammunitions; the commander or whoever is in charge would constantly monitor the status of friendly troops as they approach, the condition and the availability of the equipment and the ammunition in a battlefield by the use of sensor network. Tiny sensors can be attached to every troop, vehicle, equipment and critical ammunition to give situation or status report. The sink nodes gather these reports and transmit the data to the troop leaders.

In battlefield surveillance tiny sensor nodes can be deployed in critical terrains, approach routes, paths and straits to critically watched for the activities of the opposing forces. Hence as the operations evolve and new operational plans are prepared, new sensor networks can be deployed any time for battlefield surveillance.

For Targeting and Battle damage assessment, sensor networks can be integrated into guidance systems of the intelligent ammunition. They could also be deployed in the target area to gather the battle damage assessment data before or after attacks.

Research issues with Healthcare services using WSNs- WSNs can be embedded in several types of medical instrument for use at hospitals, clinics, and homes. Sensors provide patients and their healthcare providers' perceptivity into physiological and physical health states that are critical to the detection, diagnosis, treatment, and management of ailments [38].

In what follows, the reference [38] stated a list of healthcare applications enabled by WSNs technology ; Monitoring in Mass-Casualty disasters, Vital Sign Monitoring in hospitals, At-home and Mobile Aging, Large-scale in-field medical and behavioural studies among others. Furthermore, wireless networked sensing enables new types of assistive devices such as way finding, and walking navigation for the visually impaired [39, 40].

So far, research work involved with this method identifies some other fault of this scheme and is based to a very large extent on harnessing the disadvantages posed by the issue of information privacy, and its latent hostility with the quality and value of information. The level of trustworthiness and the need to ensure the privacy and security of medical data are challenges faced. These challenges are aggravated by resource scarcity that is inherent with wireless sensor network platforms. Looking critically into these directions in healthcare services using WSNs will determine the extent that wireless sensor networks will be successfully integrated in healthcare practice and research.

2.4.2 Standardization of WSNs.

IEEE 802.15.4

IEEE 802.15.4: The major standardization bodies in the WSN area are the Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering

Task Force (IETF) and the HART communication foundation. IEEE 802.15.4 is the proposed standard for Low Rate Wireless Personal Area Networks (LRW-PAN's).

IEEE 802.15.4 however focuses on low cost of deployment, low complexity, and most importantly low power consumption. IEEE 802.15.4 is designed for wireless sensor applications which necessitate short range communication to maximize the battery life. Wireless sensor applications using IEEE 802.15.4 include residential, industrial, and environment monitoring, control and automation. This standard allows the formation of the star and peer-to-peer topology for communication between network devices. Devices in the star topology intercommunicate with a central controller while in the peer-to-peer topology ad hoc and self-configuring networks can be formed.

IEEE 802.15.4 devices supports both the physical and data-link layer protocols. The physical layer supports 868/915 MHz low bands and 2.4 GHz high bands. The MAC layer controls access to the radio channel using the CSMA-CA (Carrier Sense Multiple Access with Collision Avoidance) mechanism.

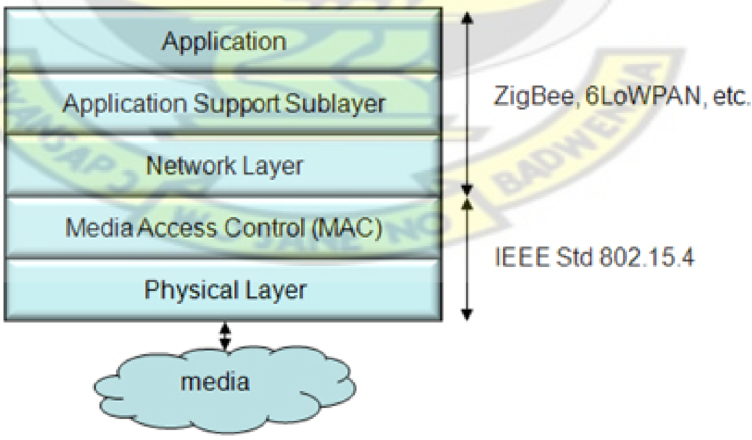

Figure 2.8: IEEE Protocol Stack [41].

2.5 Design Factors of the Sensor Network.

The design factors of an entire wireless sensor networks communications architecture as well as the design factors of protocols and algorithms for wireless sensor networks (WSNs) are described in this section. A couple of factors have been addressed by lots of researchers in this field. These design factors are however reviewed below;

1. **Fault Tolerance** : The reliability of any sensor node depends on its ability to maintain without any interruption the network functionalities due to any sort of sensor node failures [42]. As a result of lack of energy, damage either physically or technically, communications problem, inactivity (a node becomes suspended), or environmental interference sensor nodes could fail. Reliability is modelled in [43][44] using the Poisson distribution to capture the probability of not having a failure within the time interval (0, t):

$$R_k(t) = e^{-\lambda} K^t \tag{2.1}$$

Where$-\lambda$: is the failure rate of sensor node K and t is the time period.

2. **Scalability/Network Size:** The study of the phenomenon to interest of the user, determines whether hundreds, thousands or millions of sensor nodes should be deployed for the study. The density/ scalability of these nodes affects the degree of coverage area of interest. The network size is affected by reliability, accuracy and data processing algorithms [6]. The density can range from a fewer sensor nodes to a hundred in a region that

can be less than 10m in diameter.The density μ is calculated by:

$$\mu(R) = (N\pi R^2)/A \tag{2.2}$$

Where 'N' is the scattered sensor nodes in region A, and 'R' is the radio transmission range. Basically, μ(R) gives the number of nodes within the transmission radius of each node in region A.

3. **Energy Consumption:** The source of Power is a major component of the sensor nodes which the consumptions rate should be limited well enough. A sensor node is operates on battery, which means that the life time of a sensor node depends on the battery life time, most especially where/when no power source replacement is possible in some application scenarios. Since the principal objectives of sensor nodes are sensing/collecting events, data processing, and data transmission through routing; the power resource can be shared out among these three operations (sensing, computation, and communications). On the other hand, life time of a sensor node plays a key role on energy efficiency and robustness of sensor node. However many researches are focusing on designing power-aware protocols and algorithms for wireless sensor networks with the goal of minimization of energy expenditure [6][45, 46].

4. **Production Cost and Connectivity:** As sensor networks comprise of a multitude of sensor nodes, the cost of producing a single node is very significant to justify the overall cost of the network. If the cost of the network is more expensive than deploying traditional sensors, the sensor network is not cost-justified. As a result, the cost of each sensor node has to be kept low [47].

Connectivity is important. It is the only way interaction or transmission would take place between the sensor nodes, since it influences communications protocols' design and data dissemination techniques. Also, it is worth mentioning that connectivity of sensor network may not prevent the network topology from being variable. The network size from reduction as a result of the death or failure of some sensor nodes which would hinder proper connection and would not meet the purpose of production, thereby wasting the production cost.

2.6 Vehicle Detection Technologies.

A wide range of sensor technologies are available for vehicle detectors, the vehicle detection technology can be described as a three component device, comprising a transducer, a signal processing device, and a data processing device.

The transducer thus detects the presence of a vehicle or allow the passage of vehicle through or around its axles. The signal processing device on the other hand converts the transducer output into electrical signal. The data-processing device normally consists of the computer hardware and the firmware that converts the electrical signal into traffic parameters. These distinctive traffic parameters include vehicle presence, count, speed, class, gap, occupancy, link travel time and weight.

According to researchers such as Mimbela & Klein argued that, Vehicle Sensor and Detector systems can be categorized into two main categories: namely, Intrusive and Non-Intrusive sensors. The Intrusive sensors include inductive loops, magnetometers, active infrared sensors, magnetoresistive sensors, pneumatic road tubes, piezoelectric cables and other weigh-in-motion sensors. And are typically installed in holes on the road surface, by tunnelling, under the road surfaces or anchoring to the surface of the road which leads to invasive procedures of installation. The Non-Intrusive sensor can be easily installed by mounting the device on the ground or the ceiling of the car park. In the course of this work, only the magnetometers, active infrared sensors and the piezoelectric sensors will be reviewed [48, 49, 50]

2.6.1 Infrared Detectors

There are two types of infrared (IR) detectors, namely; active IR and passive IR. Active infrared sensors operates by transmitting energy from either a light emitting diode (LED) or a laser diode. Active IR detectors provide count, presence, speed, and occupancy data in both night and day operation. A passive infrared system detects energy emitted by objects in the field of view and may use signal-processing algorithms to extract the desired information. It does not emit any energy of its own for the purposes of detection. Passive infrared systems detect presence, occupancy, and count. Some of the advantages of infrared detectors are that they can be operated during both day and night, and they can be mounted in both side and overhead configurations, The disadvantages are that infrared detectors can be sensitive to inclement weather conditions and ambient light. The choice of detector materials and construction of the system, as well as sophisticated signal processing algorithms, can compensate for the disadvantages.

2.6.2 Magnetic Detectors

The magnetic detectors which are used to detect traffic are of two types. They both are in the form of probes, and operate on the principle of large metal object disturbing a magnetic field, just as inductive loop detectors work. They are both active and passive types. The active type called the magnetometer, acts in much the same way as an inductive loop detector, except that it consists of a coil of wire wrapped around a magnetic core. The magnetometer measures the change in the magnetic field caused by the passage of a vehicle. It can be used both for presence, and for vehicle passage detection. A magnetometer planted on the pavement on each parking slot would detect the presence of a vehicle parked over it.

2.7 Research Work on Vehicle Detection Technologies.

In [51], Cheng *et al*, stated that for driver assistance systems, vehicle detection methods play a vital role, therefore developing a high accuracy and efficiency vehicle detection system hence becomes essential. Lots of researches by researchers have shown a number of approaches to vehicle detection, but one of the popular approaches is the scanning method which is based on the sliding window search for locating the vehicles from the input images. This technique provides a high detection rate with a time consuming process that identifies the vehicle from each sliding window making search time unacceptable sometimes, as the searching space grows. However [51] in his paper, he presented a case study to accelerate a sliding-window based vehicle detection algorithm on a heterogeneous multicore systems using OpenCL designs, where he integrated width model into the vehicle detection method to reduce search space unlike transitional detection algorithm.
Sina et al, in his vehicle counting and speed measurement paper, proposed a new method of detecting the number of vehicles, and vehicle speed measurement in low light conditions [52].

Existing detection methods of identifying vehicles used headlight detection. Traffic information needed according to [52], extracted using CCTV. Extracting information from image sequences of CCTV can give real information about the number of passing vehicles and vehicles speed. The pin-hole and Euclidean distance methods are used to estimate the vehicle speed and count, Sina et al in his results also showed that the pin-hole model also is better in estimating vehicle speed compared to Euclidean distance.

In [53], traffic congestion is said to be a common scene that causes vehicle occlusion and is a challenge for current vehicle detection methods. To solve the occlusion problem in congested traffic conditions, an effective vehicle detection approach based on an And-Or graph (AOG) was proposed by Li et al in his paper. However, [54] recommended robust and reliable vehicle detection is a critical step detection system, Sun et al further presented in his paper a review of vision-based on-road vehicle detection systems concentrating mainly on systems where the camera is mounted on the vehicle rather than being fixed such as in traffic/-driveway monitoring systems.

Many vehicle detection techniques have been proposed in literature. Although vehicle detection techniques has been studied for many years, Rahul Singh in [55] implements a vehicle model identification through the use of Vehicle Logos and Emblem. Vehicle Model Identification can be categorized below the Image Segmentation domain. In his project he restrained himself to the Car Model Identification System. This system comprises both logo detection and logo recognise. They are both critical steps in the vehicle logo recognition system. He further stated that localization of Exact logo greatly improves the accuracy of logo recognition and classification. Wenju Li *et al.* [56] also in their paper proposed a new approach for vehicle logo location based on edge detection and morphological filter. Researchers have introduced a lot more techniques to locate vehicle logo, such as segmentation method for car logo based on texture homogeneity measure.

We believe however, that the WSN has a major advantage (of the ability) to bridge the gap between the physical and logical worlds, by collecting certain useful information from the physical world and communicating that information to more powerful logical devices that can process it. The WSNs makes thing easier by eliminating the need or involvement of humans in information gathering in most applications particularly in parking applications. In the nearest future, sensor devices will be produced in large quantities at a very low cost and densely deployed to improve validity and reliability [57].

2.8 Conclusion

So far, it's apparent that for parking, Smart Parking System (SPS), and Intelligent Parking appears to be the most suitable method to control traffic in and around market areas, as these methods provide a certain level of organization.

Consequently, in this study the vehicle detection technology is described, and its performance evaluated especially in reference to smart parking and how it will contribute in a useful way to the market environments.

Chapter 3

Methodology

This chapter presents a theoretical description of the entire studies, the research problem and a parking process analysis suffice to say, the role of markets in societies is vital for economic and social reasons. It is at the backdrop of the enormous importance of parking facilities to markets that this research is furthered.

3.1 Research Problem

The main problem this study seeks to curtail is the threat of traffic congestion in market areas. The WSN will be used to provide a solution. By considering a system model, the concept is applied as a means of correcting this menace using the vehicle detection technology. The performance of the MPS sensing unknown objects and non-vehicular objects are also determined. In addition, the effects of employing this system is ascertained.

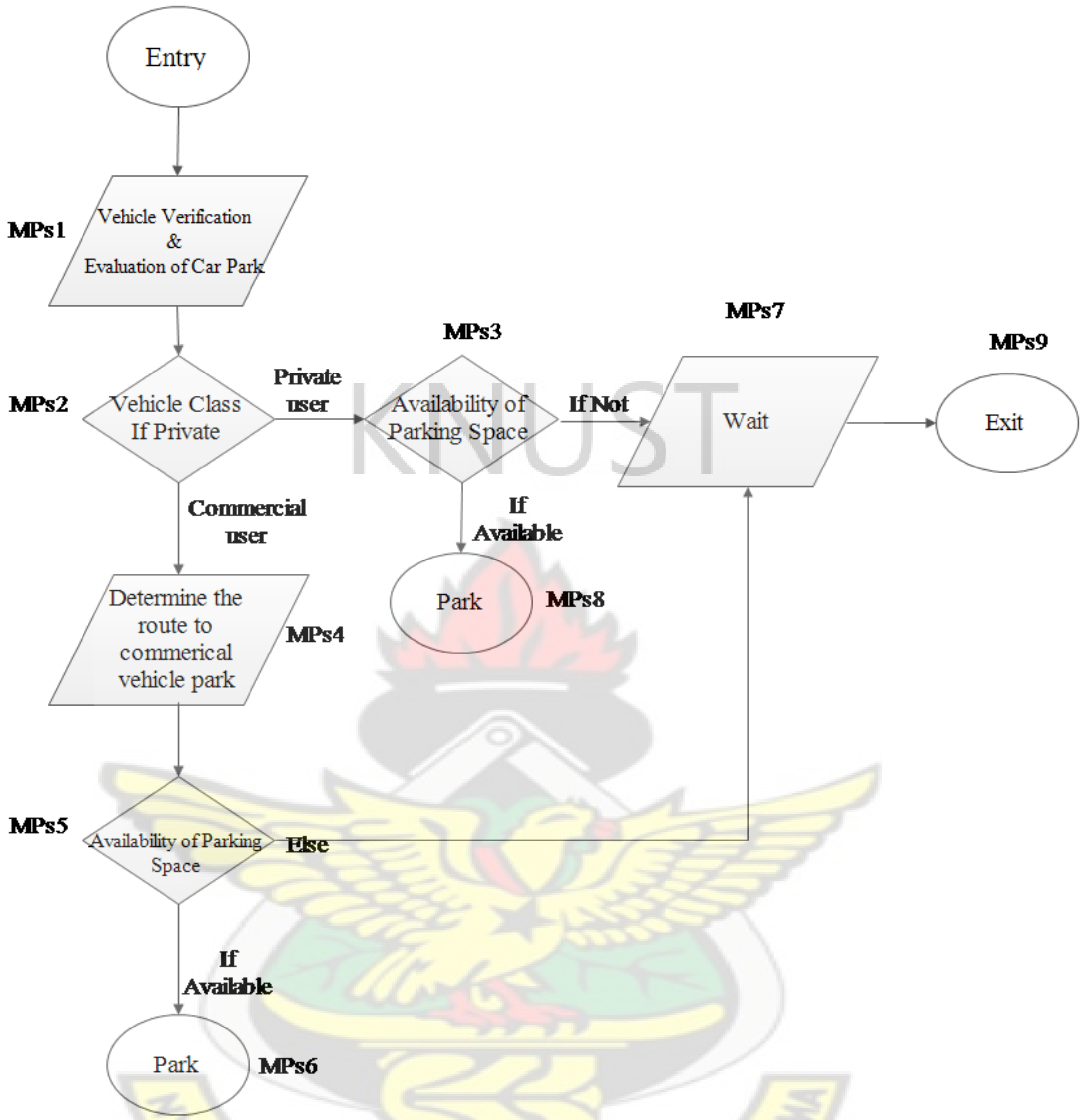

Figure 3.1: Flowchart for Parking Guidance.

3.2 Description of the Flowchart.

Figure 3.1 above gives a flowchart of parking guidance. This application as much as possible, detects, verifies authenticates, evaluates and classifies parking in market area. With reference to the flowchart, motorist/drivers enter the system and goes through MPs1 through to MPs9. At MPs1 the vehicle upon entry is verified and subsequently proceeds to MPs2 where the class of the vehicle is verified with the aid of the licence plate recognition..

After MPs1 & MPs2, the vehicle proceeds to MPs3 if only it is a private vehicle,check for availability of a lot and the parks thereby ending at MPs8. if no it goes to MPs4 to determine the route to the commercial vehicle park. Nonetheless if it is a commercial vehicle then it proceeds to MPs4 & MPs5 to check for availability and parks.

In a situation where there isn't an available lot, both scenarios goes into a waiting state at MPs7, and they all terminates at MPs9 which is the exit point.

3.3 System Model of the Vehicle Detection Technology.

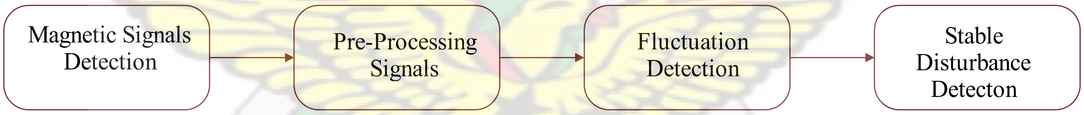

Figure 3.2: Block Diagram of a Vehicle Detection Characteristics.

3.3.1 Magnetic Signals Detection.

Most of the vehicles that ply the road have a substantial amount of ferrous metals in their chassis and engine, and these ferrous objects disturb the earth's field. The magnetometers available today can sense the earth's magnetic fields which is <1 μG (micro Gauss), and are used for detecting the vehicles. The earth's field is said to provide a uniform magnetic field over a wide area in the scale of kilometres, and ferrous objects, cars and like, create local disturbances in this field [58]. The mode of operation is such that, the magnetic sensing unit senses the alteration in a magnetic field attributable to the movement of a vehicle, and generates a magnetic signal. The Magnetic detector is used to detect the presence of a vehicle as it passes over or pulls over the sensor, which has been set into the ground. Oscillations are produced in the loop by the detector, the frequency of which depends upon the inductance of the loop. The detector senses this change, and gives an output.

3.3.2 Pre-Processing of Signal

The significant shift in the magnetic field is a fundamental factor in detection, unfortunately the amplitude and direction of the magnetic field are not so important. The pre-processing signal unit comprises a communication unit and a calibration information generation unit. The communication unit receives information about the movement of a reference vehicle from a central management centre; a magnetic sensing unit for sensing a change in a magnetic field attributable to movement of vehicles. The calibration unit calibrates information using the information about the movement of the reference vehicle and the change in the magnetic signal attributable to the movement of the reference vehicle. The Figure 3.3 how a ferrous object, like a car,can create a local distortion..

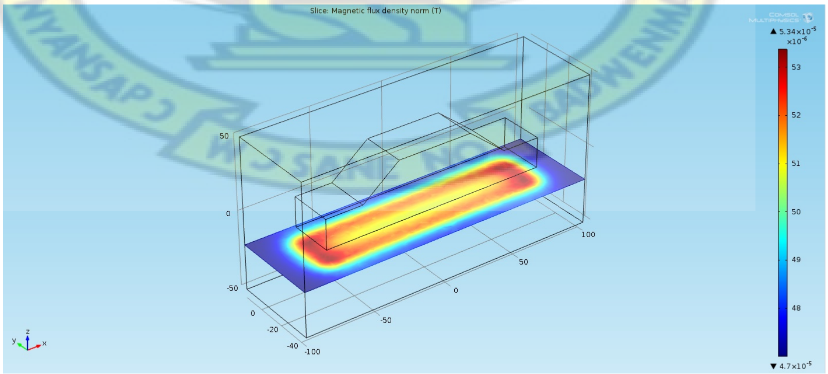

Figure 3.3: Magnetic field distortion caused by a vehicle.

Hence using digitized measurements of three-axis sensor outputs after amplification, the vector magnitude would be;

$$A(i) = \sqrt{{X_i}^2 + Y_i^2 + Z_i^2} \tag{3.1}$$

A smoothing filter is used to smoothen the signal thereby taking a running average of the signals which is given:

$$P(i) = \begin{cases} \frac{A(i)+A(i-1)+...+A(1)}{i} & i < L, \\ \frac{A(i)+A(i-1)+...+A(i-L+1)}{L} & i \geq L. \end{cases} \tag{3.2}$$

Where $A(i)$ is the vector magnitude and L is the running average of the buffer size.

3.3.3 Fluctuation Detection

The movement of vehicle(s) within and around the parking lot is a key attribute in the detection process using magnetic signals. Thorough detection of fluctuation signal signature is important for the vehicle detection. From each of every vehicle frame (t), the number of misses are therefore denoted by p_t and number of false positive denoted as f_{p_t};

$$F_{d(t)} = 1 - \frac{c_m(m_t) + c_f(f_{p_t})}{{N^t}_G} \tag{3.3}$$

Where c_m & c_f are the cost function of the missed detects as well as the false alarm penalties. N_G^t is be referred to as the number of ground true objects in the t^{th} vehicle frames [59].

3.4 Parking Process Analysis

The parking incline is not only high-priced but also limited in almost every major city in the world, not to make mention of market places - leading to traffic congestion, air pollution and frustrations on the part of the motorist [60].

However, considering a parking garage whereby the available parking slots are large enough for practical purpose, we assume it can be considered as infinite. Refer $X(t)$ to the number of slots in use at time,(t). In that case, our physical hunch is not violated by assuming that $\{X(t); t \geq 0\}$ is an *Entry* and *Exit* process. To this extent it appears reasonable to assume also, that for all $t > 0$, $h > 0$ and $i = 0, 1, ...$ where h is the period of time when only one more slot is in use, and the slot currently in use at λ, where λ is the rate of entry of the cars .

$$P\{X(t+h) = i+1 | X(t) = i\} = \lambda h + o(h)$$
$$P\{X(t+h) = i-1 | X(t) = i\} = \mu_i h + o(h) \qquad [60]$$

Therefore the probability that a vehicle would park in $(t, t+h)$ is however independent of the number of busy slots at time(t). It is same for the second equation as well.

Calculating $p_i(t)$under the assumption that

$\mu_i = i\mu$ where μ is the *Exit rate*(car leaving rate.)

Hence the system of difference-differential equations in this case becomes;

$$p'_0(t) = -\lambda p_0(t) + \mu p_1(t),$$
$$p'_j(t) = \lambda p_{j-1}(t) - (\lambda + j\mu)p_j(t) + \mu(j+1)p_{j+1}(t)$$

Resolving this, we use the generating functions, Set

$g\left(0,\mu\right) = u^{i_0}$

$g\left(t,u\right) = \sum\limits_{j=0}^{\infty} p_j\left(t\right)\mu^j$

Considering the two previous differential equations, we have;

$$\frac{dg\left(t,\mu\right)}{dt} = \sum_{j=0}^{\infty} p'_j\left(t\right)\mu^j$$

$$= -\lambda p_0\left(t\right)\left(1-\mu\right) + \mu p_1\left(t\right)\left(1-\mu\right) - \lambda p_1\left(t\right)\left(1-\mu\right)\mu + 2\mu p_2\left(t\right)\mu\left(1-\mu\right) - ...$$

$$= -\lambda\left(1-\mu\right)\sum_{j=0}^{\infty} p_j\left(t\right)\mu^j + \mu\left(1-\mu\right)\sum_{j=1}^{\infty} jp_j\left(t\right)\mu^{j-1}$$

$$= -\lambda\left(1-\mu\right)g\left(t,\mu\right) + \mu\left(1-\mu\right)\frac{dg\left(t,\mu\right)}{d\mu}$$

Thus, the function satisfies the linear partial differential equation.

$$\frac{dg\left(t,\mu\right)}{d\mu} - \mu\left(1-\mu\right)\frac{dg\left(t,\mu\right)}{d\mu} = -\lambda\left(1-\mu\right)g\left(t,\mu\right)$$

Assuming that $X\left(0\right) = i_0$, then we obtain,

$g\left(0,\mu\right) = u^{i_0}$

Going by the initial condition $g\left(0,\mu\right) = u^{i_0}$ and solving this equation using standard methods, we have

$$g\left(t,\mu\right) = \left[1-\left(1-\mu\right)e^{-\mu t}\right]^{io}\exp\left[-\frac{\lambda}{\mu}\left(1-\mu\right)\left(1-e^{-\mu t}\right)\right] \tag{3.4}$$

Case 1; expanding the above (3.4), to get $p_j\left(t\right)$

Hence, we can obtain $p_j\left(t\right)$ as,

$$p_j\left(t\right) = \exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\sum_{k=0}^{\min(i_0,j)}\begin{pmatrix} i_0 \\ k \end{pmatrix}\left(\frac{\lambda^{j-k}}{\mu}\right)X\frac{e^{-\mu tk}(1-e^{-\mu t})^{i_0+j-2k}}{(j-k)!}\ [60]. \tag{3.5}$$

$p_j\,(t)$, it signifies the probability that the number of parking cars is j at any time t, where j= 0,1,... It is important to note that in expanding the equations the probability generating function of the Binomial distribution with $p = \exp\{-\mu t\}$, and the probability generating function of the Poisson distribution with mean value $\wedge(t) = \frac{\lambda(1-e^{-\mu t})}{\mu}$ were used.

3.5 Parking Class.

The parking area is zoned into two types of service classes: the *Private Users* and the *Commercial Users or Business Users.* The private parking area generally has more parking spaces or spots as the case maybe, unlike the commercial users area with very few parking spots. The reason is that the commercial vehicles would drive in and out of the market more frequently than the private users who would come, park the vehicle and would not drive out until they are done with their shopping. However the statistical description of each of these two classes of parking lot involves the distribution of parking duration, parking lot occupancy over time and the preference of parking spots. The status of the parking lot is determined by the occupancy of the lot at the initial time and the preference as at the time of parking [61].

Similarly, the initial probability that a parking spot is to be occupied is denoted as $P_{0,i} = wp_i X\, occ_0$

Where wp_i is the term to weight the probability of the parking spot i to be occupied by its preference score.

The wp_i can be calculated as

$$wp_i = \frac{pref_i}{\frac{1}{N}\sum_{i=1}^{N} pref_i} \tag{3.6}$$

Where N is the total number of the parking spots;

$pref_i$ Is the preference score of the parking spot i.

occ_0 Is referred to as the initial occupancy of the parking lot;

3.6 Parking Maintenance.

The proper planning and design of a park facility, be it a community's park, school, church or market's park would provide a beautiful image for them, especially for people using the facility for the first time. The maintenance of a parking lot involves activities such as routine check on electronics, and clearance of mis-parked vehicles. The maintenance level of a park varies from park to park, though some parks are in need of greater attention while some aren't. It also appears that active parks tend to have a higher level of need and attention, most open spaces also require some type of annual maintenance.

However if the maintenance work is too seldom the parking service may stay in a malfunctioning state. Also if the maintenance work is too often it will interrupt the parking service. In the simulation, Figure 3.4 shows a typically illustration of what happens when the sensor detects arrival of a car, through the disturbance in the earth magnetic field resulting in fluctuation, it transmits to the base station. As the car parks in the lot, the sensor node being idle goes to sleep as there is no task to be carried out. Therefore it remains in the parking state unless the driver is leaving, the movement causes a change or fluctuation in the earth's magnetic field signal. The spot goes back to the vacant state and the sensor becomes idle,

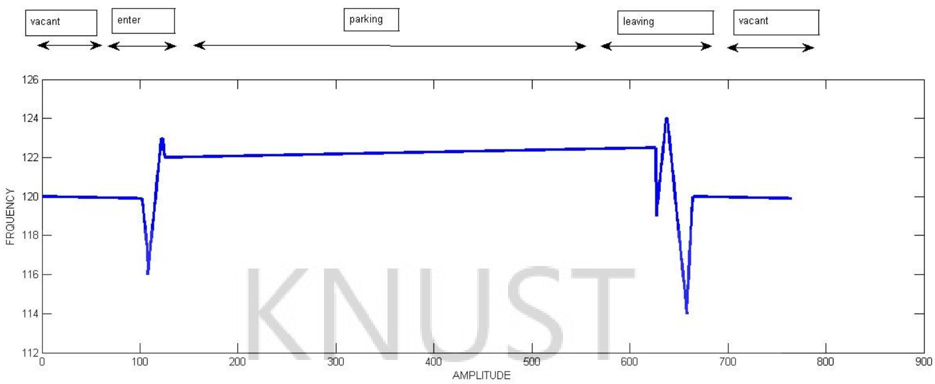

Figure 3.4: The Detection Results of a Parking Space.

as shown in Figure 3.4.

3.7 Algorithm for Sensor Networks.

Energy consumption by sensor nodes after being deployed in their useable area are strained, hard to replace or rejuvenate their batteries. Therefore, designing a routing protocol for WSNs to, enhance energy efficiency and prolong the lifespan of the WSN is an essential challenge for researchers. Many cluster-based routing protocols have been developed to increase WSN lifetime. Examples are low-energy adaptive clustering hierarchy (LEACH), threshold-sensitive energy efficient sensor network (TEEN), and power-efficient gathering in sensor information systems (PEGASIS) [62, 63, 64].

Low-energy adaptive clustering hierarchy (LEACH) which has been a standard, robust and widespread hierarchical routing algorithm for sensor networks is adapted for this work. The idea however has to do with formation of clusters in a sensor nodes network based on the received signal strength. The cluster heads are used as routers to the sink. Since its only the cluster heads that will do the transmissions, energy will be saved as compared to all the sensor nodes transmitting. The ideal number of cluster heads is estimated to be 5% of the total number of nodes used.

WSNs Topology Initialization.

In the course of our work, the deployment of wireless sensor nodes and random generation are in coverage area. 10% of the entire sensor nodes used is randomly deployed in a 100 $X100m^2$ area for our simulation work. The Figure 3.5 describes the topology initialization , with the initial settings and process. The structure of the routing protocol for the wireless sensor networks shown in the Figure 3.5, shows the sensor nodes clusters formation. The AP is selected as the cluster

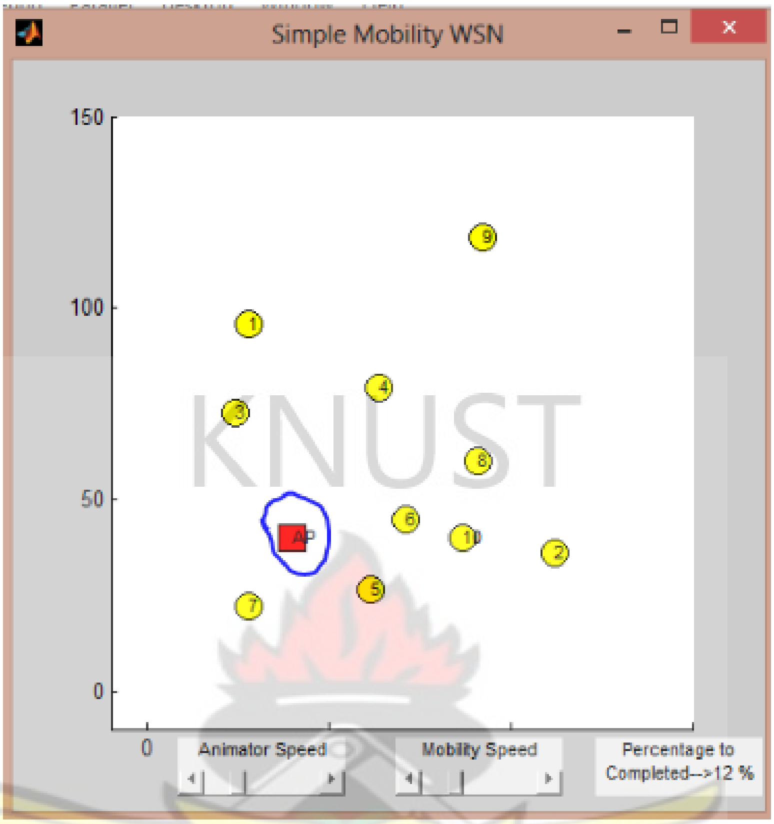

Figure 3.5: Wireless Sensor Network Topology Initialization

head, and this is done by the comparison of the residual energy of every node (individually) in each round. However it is through this cluster head (AP) that transmission to the base station is possible.

The LEACH used is to lower the consumption of energy needed by the nodes to create and sustain the clusters. It also improves the life time of the WSNs [65]. The LEACH presumes each node has a radio strong enough to directly transmit to the base station or the cluster head of its cluster, but using these radios owed by the sensor nodes at full power always would waste the energy. The details of the algorithm is as follows; Let 'r' be the beginning of every transmission round, and 'i' represent every node used. Recalling that the operation of the LEACH is divided into the set-up phase (i.e. cluster formation and organisation), steady phase (i.e. data transferred from nodes to clusters then to the base stations).

The Probability of one of the nodes becoming a cluster head (CH) is set as a function of nodes energy level relative to the aggregate energy remaining in the network. After the selection of the CH, it sends a broadcast in the form of an advertisement message (ADV) using CSMA MAC protocol (Carrier Sense Multiple Access with Collision Avoidance: is the MAC protocol of the 802.11) to achieve transmission indicating its state, which is based on the received signal strength of ADV message. After the set-up phase, after selecting its cluster and CH, each node transmits its data packet to its CH node, transmitting a join-request message (Join-REQ).
Consequently, after all that the CH broadcasts another message within its cluster indicating the termination of the cluster formation cycle. The CH sums the received data in one message packet and transmits it in a single hop to the base station.

In the next chapter, an analysis of the case scenarios is presented, which includes interpretation of results obtained from the analysis, which is based on the approach hitherto described.

Chapter 4

Results and Discussion

4.1 Introduction

In the previous chapter, the system model was introduced with mathematical deductions to present a theoretical description of vehicle detection systems, analysis of parking process, parking class and maintenance. In this section, simulations are performed alongside description of scenarios involved with the sensing of signals embedded in various forms of noise, applying the vehicle and distributed detection scheme.

This chapter will discuss the performance of every relevant component and identify areas of improvement. Results of the analysis performed are also presented here, where deductions and interpretations are also discussed.

4.1.1 Simulation Results and Discussions

All simulations in this work are executed using MATLAB[1] version R2012a. MATLAB is an application with tools for numerical computation and a fourth-generation

[1]MATLAB is a product of The Mathworks, Inc.

Simulation Parameters	Value
Total Number of nodes	1000
Number of Frames	10
Coverage area	20-200meters
Monitoring area	100m x 100m
Node Initial Energy	0.5j

Table 4.1: List Simulation Parameters Used.

programming language. MATLAB comprises tools for data visualization; functioning as a convenient "laboratory" for simulation, computations and analysis. The MPS contrives for real life and time applications to ensure effective parking and most importantly, saves the time the driver uses to search the parking spaces. Nevertheless the performance of MPS can be distinguished by likening various parameters related with various sensors used in parking system. Extensive simulations is performed to compare the outcome of the proposed algorithm with the existing techniques [66].
The Hilbert transform is a mathematical tool important in the field of signal processing and its used to derive analytic representation of a signal $\mu(t)$ forms the bases of this simulation. The Hilbert transform facilitates the formation of the analytic signal. The analytic signal is useful in the area of communications, particularly in bandpass signal processing.

4.2 Magnetometer Type.

Magnetic sensors detects alterations, or interference, in magnetic fields that occurs as a result of direction change, presence, rotation, angle, or electrical currents. These sensors output requires signal processing to convert the output signals into the wanted parameter. It is important to note that the magnetic detectors are slightly technical to use, they provide accurate and reliable data without physical contact.

Magnetic sensors are categorised according to sensing range capabilities. They could be low-, medium-, and high-field sense range. In this study, the low-field sensors devices are used because they detect magnetic fields <1 μG (micro Gauss). Magnetic field is approximately constant in a local field, i.e.,the horizontal position change is limited to 10km, and vertical position change is limited to 1km. The sensor errors are negligible [67].

4.2.1 Magnetometer Sources of Error.

The accuracy of readings taken by a magnetometer can be affected by factors such as;

- Variation of the earth's field
- Nearby ferrous materials

Present day magnetometers have resolvable Gauss fields less than 0.07 μG which is far less than the 0.39 μG required to achieve a resolution value of 0.01 μG . Magnetometer sensors can provide a total error of less than 0.1 μG.

Variation of the earth's field The final magnetometer error contributing factor is the variation, or declination, of the earths magnetic poles. It is well known that the earth's magnetic poles and its axis of rotation are separated by 11.5° in geographical location. This creates a difference between the true north, or grid north, and the magnetic north, or direction a magnetic magnetometer will point. This difference is defined as the variation angle and is dependent on the magnetometer location sometimes being as large as 25°. The Figure 4.1 below illustrates the relation between magnetic field strength and the orientation of the earths magnetic poles. The greater the variation angle the weaker the measured field [67].

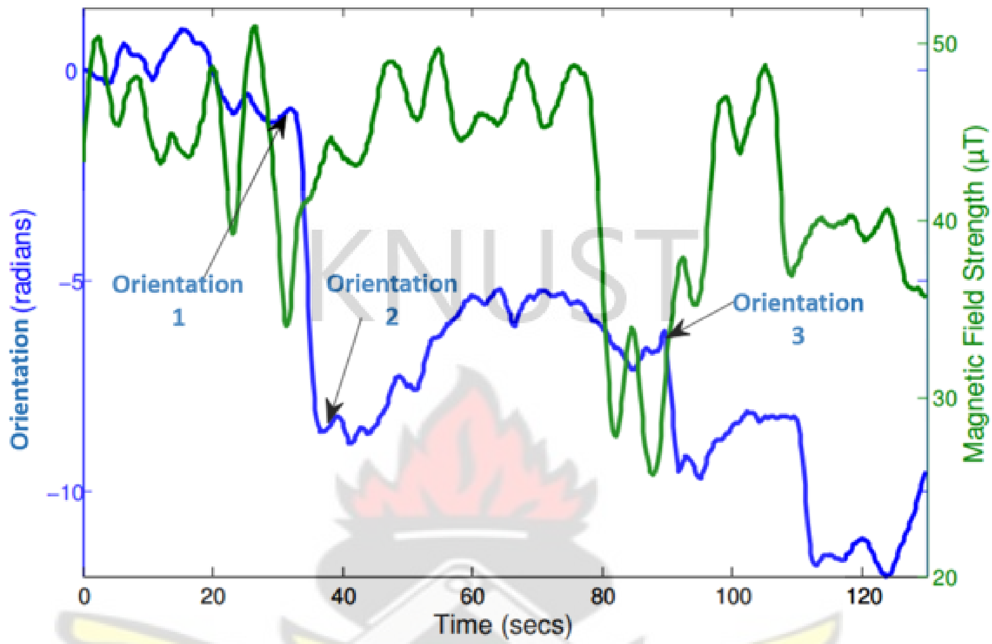

Figure 4.1: Variation angle in relation to field strength.

Nearby ferrous materials the effects of nearby ferrous materials on the earth's magnetic field can introduce errors in the operation of the device. Since the field strength is based on the direction of the earth's horizontal field, the magnetic sensor must be able to measure this field without influence from other nearby magnetic sources or disturbances. The degree of perturbation depends on the material content of the platform and connectors and ferrous objects near the magnetometer. When a ferrous object is placed in a uniform magnetic field it will create disturbances as shown in Figure 4.2. This object could be a steel bolt or bracket near the magnetometer or an iron door latch close to the magnetometer. The net result is a characteristic distortion, or anomaly, to the earths magnetic field that is unique to the shape of the object.

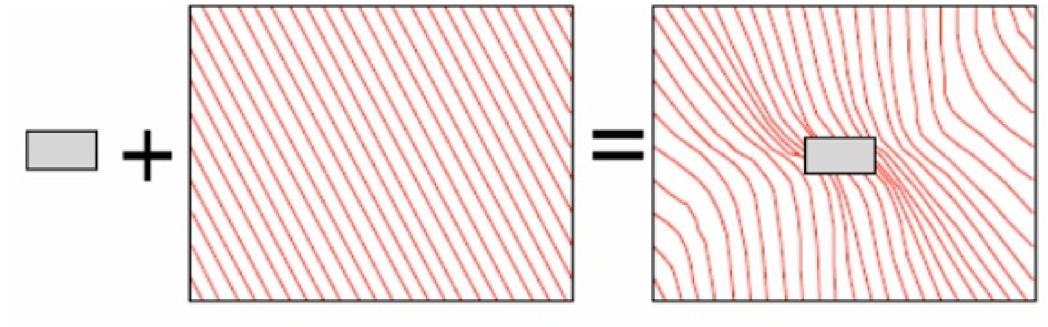

Figure 4.2: Interference of ferrous object in uniform field.

4.3 Market Interface.

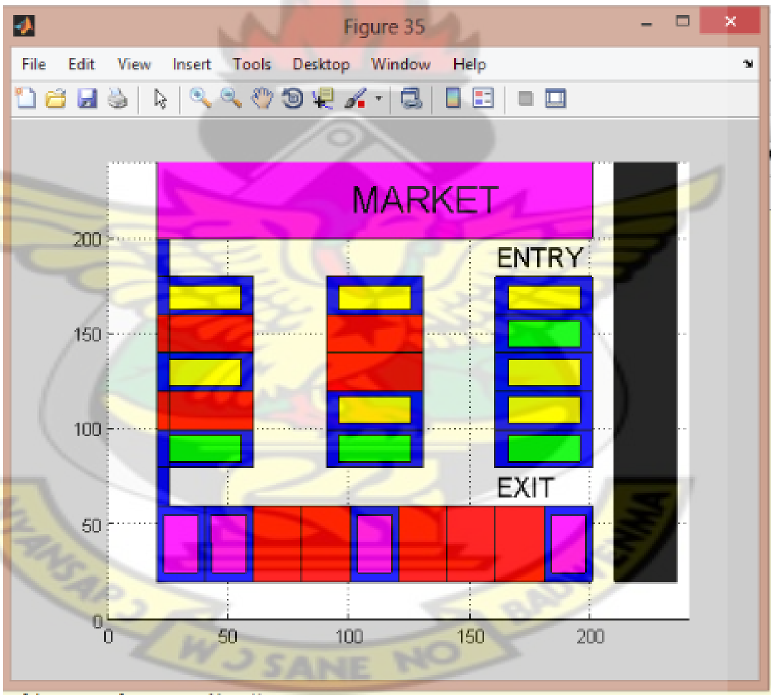

Figure 4.3: Market Parking Garage Interface.

The Figure 4.3 shows what happens after the head cluster transmits to the base station. Vacant spaces within the parking lot is ascertained. The vacant spaces in the Figure 4.3 are in red whereas the rest are said to be occupied.

4.4 Signals Detected from Vehicle and Non-Vehicular Metals.

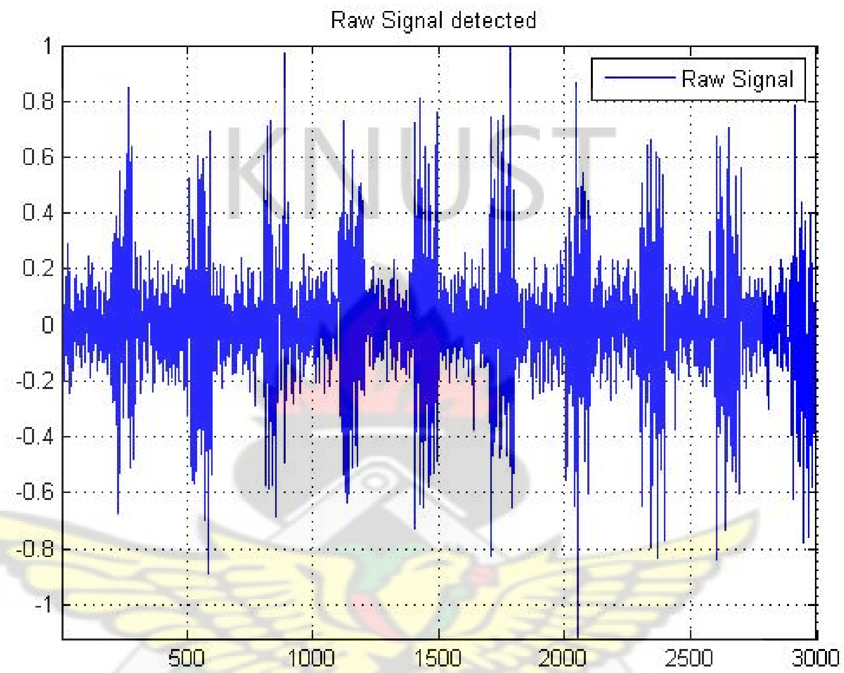

Figure 4.4: Raw Signal Detected from Vehicle.

Figure 4.4 illustrates raw signals sensed by the device as a vehicle approaches within a few meters. This indicates a distinctive vehicle raw signal waveform. On the contrary, some other non-vehicular objects such as metals could possess similar ferrous objects and would likely send signals as shown in Figure 4.5.

The size of the simulation area is 1000-units one dimensional array. One unit represents one parking slot. Vehicles arrive according to specified exponential distribution within the simulation area. Each simulation result is based on aggregated results from 10 independent simulations with the same parameter settings. As our interest is how long it takes a driver to locate an empty parking spot in a market parking area, we analyse and simulate the probability density function

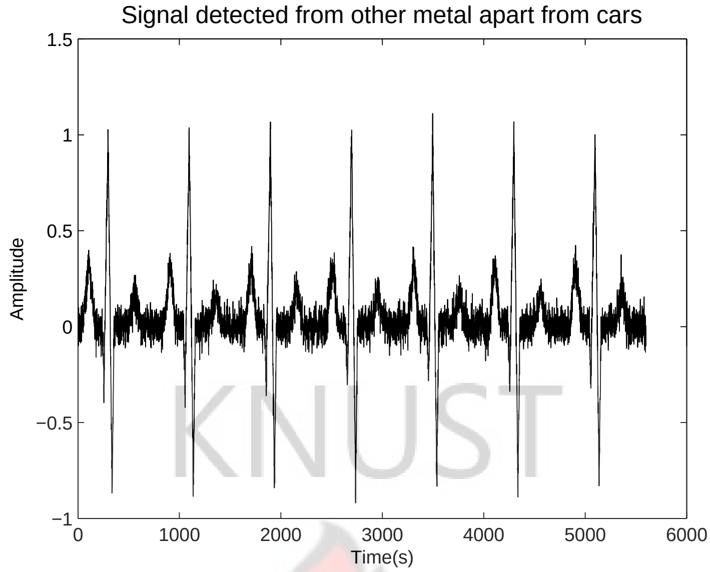

Figure 4.5: Raw signal Detected from Non-Vehicle

(pdf) with respect to the relationship between sensitivity (probability of detection) and specificity (false alarm rate), for a variety of thresholds.

4.5 Detection of Onset Activity.

The Figure 4.6 shows signals from vehicle along side signals detected from metals that are non-vehicles, adaptive threshold and the activity of the vehicle. Estimation of the noise level variance is important and must be first considered. If there is a change in the noise variance, the threshold should be adjusted to maintain a constant false-alarm rate. The adaptive thresholding used here, shows the threshold level for ascertaining whether or not to convert at a regional level. Apparently, if smoothing is insufficient, the signal-to-noise ratio of the derivative would be considerably poorer than the original signal. Smoothing, here is how important patterns in our data were detected, leaving out things that are unimportant. However, with adequate amounts of smoothing, the signal-to-noise ratio

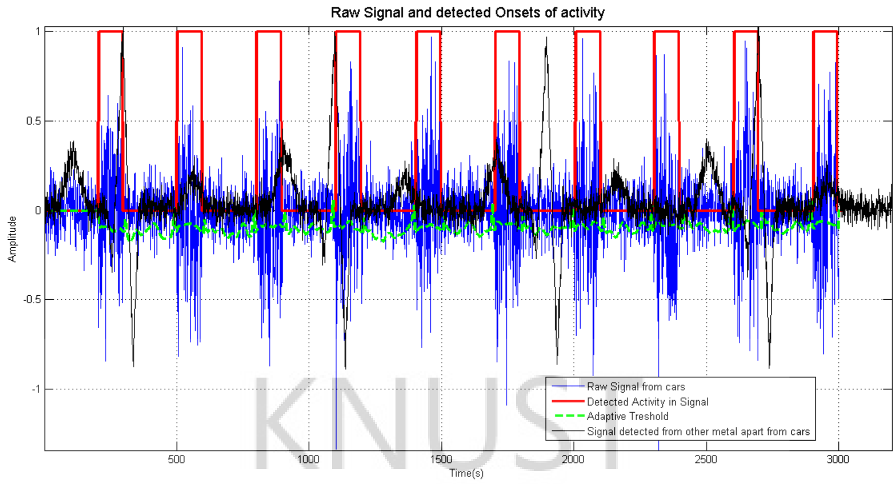

Figure 4.6: Detect of Onset Activity.

of the smoothed derivative can be better than that of the unsmoothed original [68].

The Hilbert transform is used to smoothen the signals detected, the adaptive threshold is used to identify the activity level of the signal. In doing this the Hilbert transform smoothens, while adaptive thresholding identifies the activations of the signal.

Furthermore it shows noise interference mixed with signals with amplitude as low interference generated by passing-by cars. Using of this detection technique, it is shown that there is no car parked in a particular lot. For 10 parking spaces out of the lot, we assume white noise as interferences. The sensing results are shown in Figure 4.6, the signals with white noise from the wireless sensor deployed. The activity level of the vehicle, the adaptive threshold and the smoothed envelope of the signal.

The detection results shown in the Figure 4.6, in which the value “1” on the graph output indicates that the parking space is occupied by a car and the value of the number “0” indicates that the parking space is empty.

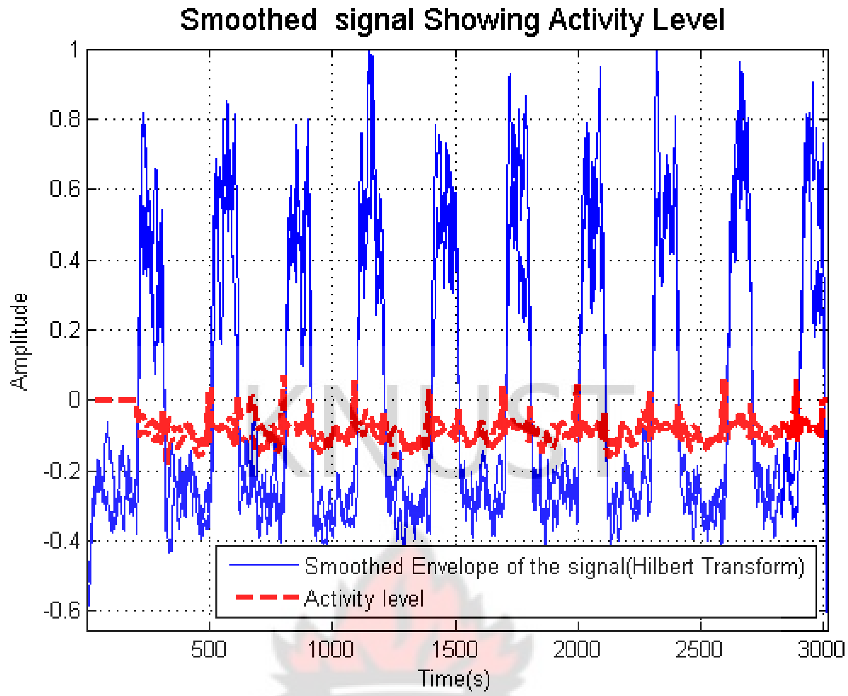

Figure 4.7: Detection result with low interference after smoothen.

The graphs only show the qualitative performance of the WSN based detection and parking system. When the signal graphs are plotted, both the frequency and amplitude parameters fixed while the sample index is varied, making it possible to generate various plots depending on the parameters of interest.

In the course of this work, we set the adaptive threshold value, in order to satisfy a minimum false-alarm probability [69][70]. From the preceding, it is apparent that the MPS senses approaching vehicle within few meters, and this occurs after cluster formation of the sensor nodes. A cluster head (CH) is selected and information is transmitted through the CH to the base station using the LEACH routing protocol of the WSNs.

The system goes further to verify the vehicle class using LPR feature and allocate a parking space based on availability.

It is also evident that the MPS using WSNs can be of use in providing motorist

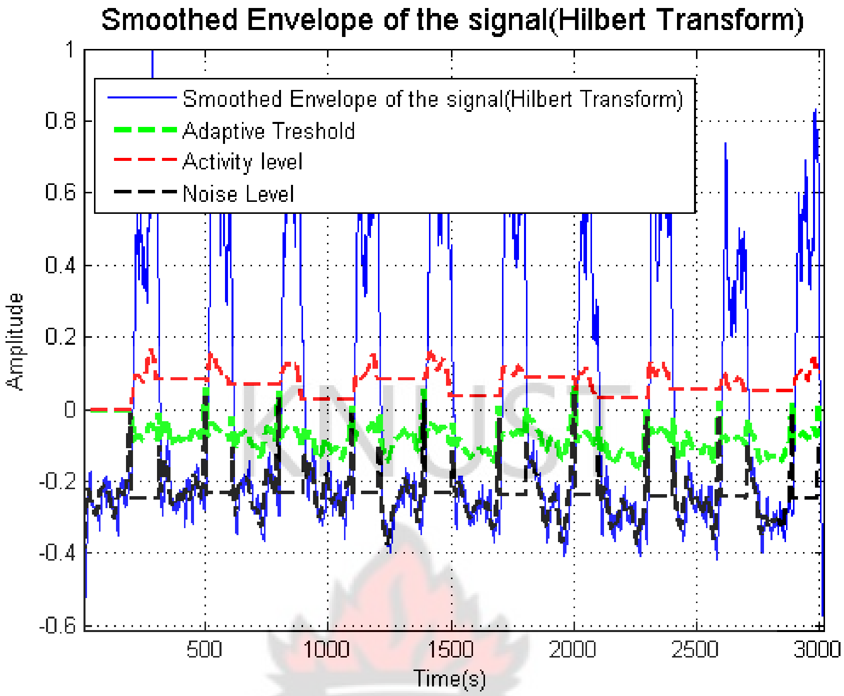

Figure 4.8: Detection result of smoothened signal.

with real time occupancy situation, and alert to vehicles which are approaching, and have exceeded the parking regulations, this method of sensing is a promising method of battling the inherent performance deterioration in existing parking techniques of a typical market environments.

Chapter 5

Conclusion and Recommendation

5.1 Conclusion

Conclusively, this study discussed the most efficient and effective way to optimize parking system in market places. This approach would reduce the level of traffic congestion in any typical environment in Africa.

In the quest to achieving this goal, the researcher sought to adopt and use a parking system with proven correctness and a good decisive parameters of the parking service, hence the Wireless Sensor Networks (WSNs) was adopted. This process can not only be efficient and effective but it's a non-stop type of service. This parking scheme is an intelligent service. A driver is able to locate a parking spot easily thereby saving the stress of time wasting, environmental pollution and frustration on the part of the driver.

Accordingly, different tests were also carried out in various models to assess the quality of this technique. The Hilbert transform was used in calculating the instantaneous attributes of the time series involved, especially with the amplitude and frequency.

The simulation results of the work agree with the proposed system results in management and utilization of parking space as well as finding parking spot on time.

5.2 Recommendation.

Even as a lot of research has gone into the area of WSNs, practical application is low and practical implementation has remained obscure. In the light of this, experiments (asides simulations) however small, need to be carried on to establish the reliability and steadfastness of this approach in real world scenarios.

The espousal of this parking scheme/technology across Africa, to optimize and control traffic congestion will go a long way to enhance both traffic and energy consciousness as well as obeying parking policies among the citizenry. This technology can also be useful in places other than a market area.

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Appendix A

Matlab Source codes

```
%sample code for graphs
function alarm = envelop_hilbert_v2(y,Smooth_window,threshold_style,DURATION,gr)
if nargin < 5
    gr = 1;
    if nargin < 4
        DURATION = 20; % default
        if nargin < 3
           threshold_style = 1; % default 1 ,
means it is done automatic
           if nargin < 2
            Smooth_window = 20; % default for smoothing length
             if  nargin < 1
               v = repmat([.1*ones(200,1);ones(100,1)],
[10 1]); % generate true variance profile
               y = sqrt(v).*randn(size(v));
             end

           end
```

```
        end
    end
end
%% calculate the analytical signal and get the envelope
test=y(:);
analytic = hilbert(test);
env = abs(analytic);

%% take the moving average of analytical signal
%env=movingav(env,70,0);
env = conv(env,ones(1,Smooth_window)/Smooth_window);%smooth
env = env(:) - mean(env); % get rid of offset
env = env/max(env); %normalize
%% threshold the signal
if threshold_style == 0
hg=figure;plot(env);title('Select a threshold on the graph')
[dummy THR_SIG] =ginput(1);
close(hg);
end
%DURATION = 20;
h=1;
alarm =zeros(1,length(env));
if threshold_style
THR_SIG = 4*mean(env);
end
nois = mean(env)*(1/3); % noise level
threshold = mean(env); % signal level

thres_buf  = [];

nois_buf = [];
```

```
THR_buf = zeros(1,length(env));

for i = 1:length(env)-DURATION
  if env(i:i+DURATION) > THR_SIG
      alarmx(h)=i;
      alarmy(h)=env(i);
      alarm(i) = max(env);
      threshold = 0.2*mean(env(i:i+DURATION));
% update threshold 10% of the maximum peaks found
      h=h+1;
  else
      if mean(env(i:i+DURATION)) < THR_SIG
      nois = mean(env(i:i+DURATION)); %update noise
      else
          if ~isempty(nois_buf)
              nois = mean(nois_buf);
          end
      end
  end

  thres_buf = [thres_buf threshold];
  nois_buf = [nois_buf nois];

  if h > 1
  THR_SIG = nois + 0.50*(abs(threshold - nois));
 %update threshold
  end
  THR_buf(i) = THR_SIG;
end
if gr
figure,ax(1)=subplot(211);plot(test/max(test)),
hold on,plot(alarm/(max(alarm)),'r','LineWidth',2.5),
```

```
hold on,plot(THR_buf,'--g','LineWidth',2.5);
% title('Raw Signal and detected Onsets of activity');
% legend('Raw Signal','Detected Activity in Signal','
Adaptive Treshold',...
%      'orientation','horizontal');
grid on;axis tight;
ax(2)=subplot(212);plot(env);
hold on,plot(THR_buf,'--g','LineWidth',2.5),
hold on,plot(thres_buf,'--r','LineWidth',2),
hold on,plot(nois_buf,'--k','LineWidth',2),
% title('Smoothed Envelope of the signal(Hilbert Transform)');
% legend('Smoothed Envelope of the signal(Hilbert Transform)',
'Adaptive Treshold',...
%'Activity level','Noise Level','orientation','horizontal');
linkaxes(ax,'x');
zoom on;
axis tight;
grid on;
end
```

A.1 mathematical equations the car uses in parking

$$PCC2x4 = 54$$

$$PCC2y4 = 70$$

$$WSeta = 45$$

(degree to radians)

$$WSeta = (\frac{WSeta}{180}) \times pi$$

$$S = 3$$

$$xi = PCC2x4 + S$$

$$yi = PCC2y4 - 9$$

$$f1e = 38$$

$$t = [0 : 0.01 : pi]$$

$$seta = 2t$$

$$Xc = xi - \frac{L}{tan(WSeta)}$$

$$Yc = yi + D$$

$$xi = x + A1 \times cos(seta(f1e))$$

$$yi = y - A1 \times sin(seta(f1e))$$

$$Xc = xi + Rbl \times cos(seta(f1e))$$

$$Yc = yi - Rbl \times sin(seta(f1e))$$

$$fori = f1e : -1 : 1$$

turning of red car

$$x = Xc + Rbl * cos(seta(i))$$

$$y = Yc - Rbl * sin(seta(i))$$

turning of yellow car

$$x = Xc * 2.2 * cos(seta(i) + 9)$$

$$y = Yc + 1 * sin(seta(i) - 9)$$

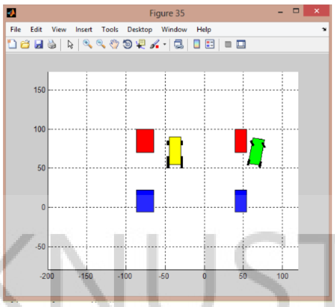

Figure A.1:

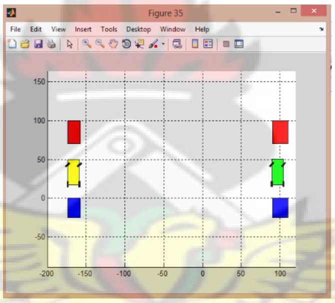

Figure A.2:

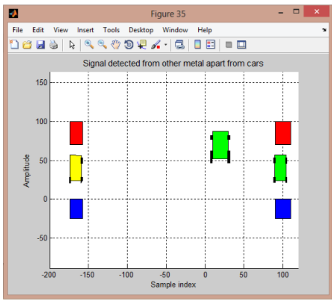

Figure A.3:

A.2 Parking Process Analysis.

$$\frac{dg\left(t,\mu\right)}{dt}=\sum_{j=0}^{\infty}p'_{j}\left(t\right)\mu^{j}$$

$$=-\lambda p_{0}\left(t\right)\left(1-\mu\right)+\mu p_{1}\left(t\right)\left(1-\mu\right)-\lambda p_{1}\left(t\right)\left(1-\mu\right)\mu+2\mu p_{2}\left(t\right)\mu\left(1-\mu\right)-...$$

$$=-\lambda\left(1-\mu\right)\sum_{j=0}^{\infty}p_{j}\left(t\right)\mu^{j}+\mu\left(1-\mu\right)\sum_{j=1}^{\infty}jp_{j}\left(t\right)\mu^{j-1}$$

$$=-\lambda\left(1-\mu\right)g\left(t,\mu\right)+\mu\left(1-\mu\right)\frac{dg\left(t,\mu\right)}{d\mu}$$

$$g\left(t,\mu\right)=\left[1-\left(1-\mu\right)e^{-\mu t}\right]^{io}$$

$$g\left(t,\mu\right)=\left[1-e^{-\mu t}-\mu e^{-\mu t}\right]^{io}$$

$$=\sum_{k=0}^{io}\begin{pmatrix}k\\ i_{0}\end{pmatrix}\left(1-e^{-\mu t}\right)^{i_{0}-k}\left(\mu e^{-\mu t}\right)^{k}$$

Then from $\exp\left[-\frac{\lambda}{\mu}\left(1-\mu\right)\left(1-e^{-\mu t}\right)\right]$ in equation (3.4) we have;

$$\begin{aligned}
&= \exp\left[-\frac{\lambda}{\mu}\left(1-\mu\right)\left(1-e^{-\mu t}\right)\right] \\
&= \exp\left[-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)+\frac{\lambda}{\mu}\mu\left(1-e^{-\mu t}\right)\right] \\
&= \exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\exp\left\{\frac{\lambda}{\mu}\mu\left(1-e^{-\mu t}\right)\right\} \\
&= \exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\sum_{j=0}^{\infty}\frac{\frac{\lambda^j}{\mu}\left(1-e^{-\mu t}\right)^j}{j!}\mu^j \\
&= \sum_{j=0}^{\infty}\exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\frac{\frac{\lambda^j}{\mu}\left(1-e^{-\mu t}\right)^j}{j!}\mu^j
\end{aligned}$$

Substituting in $g\left(t,\mu\right)$

$\therefore$ We have,

$$g\left(t,\mu\right)=\sum_{j=0}^{\infty}\exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\frac{\frac{\lambda^j}{\mu}\left(1-e^{-\mu t}\right)^j}{j!}\mu^j.\left[\sum_{k=0}^{i_0}\begin{matrix}k\\ i_0\end{matrix}\left(1-e^{-\mu t}\right)^{i_0-k}\left(e^{-\mu t}\right)^k\mu^k\right] \tag{A.1}$$

$$=\left[\sum_{j=k}^{\infty}\exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\frac{\frac{\lambda^{j-k}}{\mu}\left(1-e^{-\mu t}\right)^{j-k}}{j-k!}\mu^{j-k}\right].\left[\sum_{k=0}^{i_0}\begin{pmatrix}k\\ i_0\end{pmatrix}\left(1-e^{-\mu t}\right)^{i_0-k}\left(e^{-\mu t}\right)^k\mu^k\right] \tag{A.2}$$

Substituting and changing variables we have,

$$=\sum_{j=k}^{\infty}\exp\left\{-\frac{\lambda}{\mu}\left(1-e^{-\mu t}\right)\right\}\sum_{k=0}^{\min\{i_0,j\}}\begin{pmatrix}i_0\\ k\end{pmatrix}\left(\frac{\lambda^{j-k}}{\mu}\right)X\frac{e^{-\mu tk}\left(1-e^{-\mu t}\right)^{i_0+j-2k}}{(j-k)!}\mu^j \tag{A.3}$$

$$=\sum_{j=k}^{\infty}p_j\left(t\right)\mu^j \tag{A.4}$$