<div align="right">ORIGINAL RESEARCH</div>

Hybrid human resources localization and tracking system

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ABSTRACT

Organizational success and productivity depend on the effective and efficient utilization of Human Resources (HR). In view of the importance of HR, organizations put high premium on their safety, wellbeing and adequate monitoring. Several researchers have come up with solutions for monitoring HR movements but the major challenge has been the inability of a single technique to adequately and comprehensively monitor and provide accurate positioning data due to the changing environments of the workplace. This paper presents the implementation of a hybrid HR monitoring system using Global Positioning System (GPS), Radio Frequency Identification (RFID), cameras and sensors. The model is implemented using Python programming language as frontend and MySQL database management system as backend. Case study of the monitoring of selected staff of Information and Communication Technology Application Centre (ICTAC) of Adekunle Ajasin University, Akungba-Akoko, Nigeria was used to test the adequacy and practical functions of the model. Obtained data on positioning accuracy, signal sensitivity, cost of deployment and coverage area formed the basis for evaluation and comparative analysis.

Key Words: Human Resources, Global Positioning System, Radio Frequency Identification, Positioning Techniques, Localization, Sensor

1. INTRODUCTION

The speed at which workplace technology has evolved over recent decades has been startling. Technology has changed the face of work across industry sectors by enabling relevant information to be shared with Human Resources (HRs) in real time irrespective of their locations. It is evident that HRs are vital asset of any establishment, there is the need to ensure they are preserved, cared for, monitored and made to perform the tasks they are employed for.[1] Employers in an attempt to reduce costs and cut off unnecessary bureaucratic bottlenecks have adopted technology in the management of their most valuable asset which is HR. The motivation for tracking HRs is linked to improving organization productiv-

ity. The author[2] defines people as one of the most important factors providing flexibility and adaptability to organizations. Several traditional means have been used to monitor and control the activities of HR, this includes the use of attendance register to monitor time of arrival and departure from work place. There is Movement Book in some organizations which HRs must sign whenever they are leaving their duty post. These methods are susceptible to human manipulations so they are unreliable as means of objective assessment and evaluation of the performance of HR.[3]

The need for an automated system which will adequately address the limitations and vulnerability of the traditional methods gave birth to the development of Real Time Lo-

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cating System (RTLS) which is a type of local positioning system that allows organizations to track and identify the location of objects in real time. It uses simple, inexpensive badges or tags attached to the objects, readers receive wireless signals from these tags to determine their locations. In recent years, important developments have emerged in the field of RTLS.[1, 20] This paper attempts to develop a hybrid system made of Global Positioning System (GPS), Radio Frequency Identification (RFID), Camera and Sensor for the monitoring of HRs movements irrespective of their location and environment.

2. RELATED WORK

In Ref.,[2] emerging issues in Human Resources Management (HRM) in Singapore were discussed. The research was motivated by the need to address the ad hoc nature of HRM policies and practices of organizations in Singapore which has contributed significantly to the job-hopping phenomenon. The objective of the study was to discuss critical issues in the management of HR in Singapore organizations. The author carried out extensive literature review using journals, text books and reports on the subject of HR and the impact on organizations. The researcher proposed important factors for managing HR as business strategy, organizational culture, competence level of HR managers, availability of HR strategy and outsourcing of HR activities. However, the research failed to give empirical data on the functions of the proposed factors. The researchers in Ref.[4] present a study on absenteeism of HRs in selected textile industries in Tirupur District of Tamilnadu, India. The research was motivated by poor utilization of textile machines, lower productivity and the attendant loss of revenue caused by absenteeism of HRs. The objectives of the study were to evaluate the factors that influence absenteeism, investigate how the private textile industries in India deal with absenteeism and study the working conditions prevailing in the market place. Descriptive research design was used in the study. Primary data were collected through structured questionnaire which was prepared to cover the objectives of the study and secondary data were collected from magazines, booklets, journals, conference proceedings and many other sources. The observation and conclusion which were presented in the report were based on data collected from the sample HRs of 10 private textile industries. An attempt was made at developing a mathematical model for the monitoring of junior staff in the manufacturing industry.[5] The research was motivated by the continuous decline in production, increase in demand for overtime pay, disharmony among members of staff, incessant cases of late coming, absenteeism among the junior staff and failure of the production department to meet up with customers order

as received by the marketing department. The objectives of the research were to design a model that quantifies the extra amount payable to a junior staff that is punctual to work and develop an innovative approach for the management of late arrivals at work in a processing industry. A late coming monitoring framework was developed using polynomial interpolation to generate a model that addressed the issue of late attendance. However, the research failed to accommodate problems associated with the transportation system which may cause delay for the HR and other factors such as environmental, social and domestic which affect movement of HRs are not captured in the model.

Integration of RFID, Global Navigation Satellite System (GNSS) and Dead Reckoning (DR) for ubiquitous positioning in pedestrian navigation was presented.[6] The research was motivated by the need to explore the possibilities of providing location information and navigation via ubiquitous environment to enhance route guidance in smart environments. The objective was to develop a hybrid system consisting of RFID, GNSS and DR for ubiquitous positioning in pedestrian navigation. The researchers used active RFID for positioning and Minimum Range Error Algorithm (MREA) for the integration of multi-sensors data. However, the use of active RFID increased the power consumption of the system and the experiments were conducted in sub-urban areas of about 12 meters range which makes the results uncertain for a larger environment.

Comprehensive review of various location services, localization systems, algorithms and techniques were carried out.[7–11] The aim of the research works was to provide very rich theoretical background on positioning techniques and systems. The research works carried out extensive review of literature using journals, conference proceedings, books and reports on location services. However, the research works failed to address the concept of hybridization of positioning techniques. The researchers[12, 13] presented a hybrid system made up of GPS and RFID technologies. The objectives were to harness the use of GPS in outdoor navigation and the potentials of RFID for indoor positioning. The developed systems were only applicable for monitoring of vehicles. In Ref.,[14] the authors presented a framework for HR monitoring system using RFID technology. The objective of the research was to develop a system to track the movements of the HRs and estimate the amount of time that HR spends in their workplace. Passive RFID tags, readers and JAVA programming language were used to implement the design. However, the research was limited by the inability of RFID to function in outdoor environment.

The application of RFID to HR monitoring motivated the de-

velopment.[15] The objective of the research was to develop an RFID system for monitoring of HR on duty post. An RFID real time system was developed using passive RFID tags and readers and it was implemented using PHP as the frontend and MySQL database management system as the backend. However, it was limited to indoor environment.

The use of smart objects and Internet of Things (IoT) in the tracking and monitoring of persons was carried out in Refs.[1, 16] The research works were motivated by the high rate of kidnapping and human trafficking which has attained global dimension and has defied several measures adopted by governments and organizations. The objectives of the research works were to design a framework of smart objects and IoT system for achieving cost effective and time saving measures to combat human trafficking and kidnapping and

to propose a model for heterogeneous positioning system that incorporate data from RFID, GPS, Sensors and IP camera. The researchers provided a framework for multi-sensors integration and heterogenous tracking of persons.

In Refs.,[15, 17–19] location of indoor HR was carried out using wireless LAN except[15] which used RFID. The level of accuracy of the first three research work was low and the equipment cost was high. In,[21, 22] location of outdoor HR was carried out using GPS and wireless Sensor network. The level of accuracy was low, the complexity was high and the equipment cost was high. There was no research carried out that addressed the location of HR indoor and outdoor at the same time.

The proposed research addresses the implementation of the multi-sensor framework as proposed by Ref.[1]
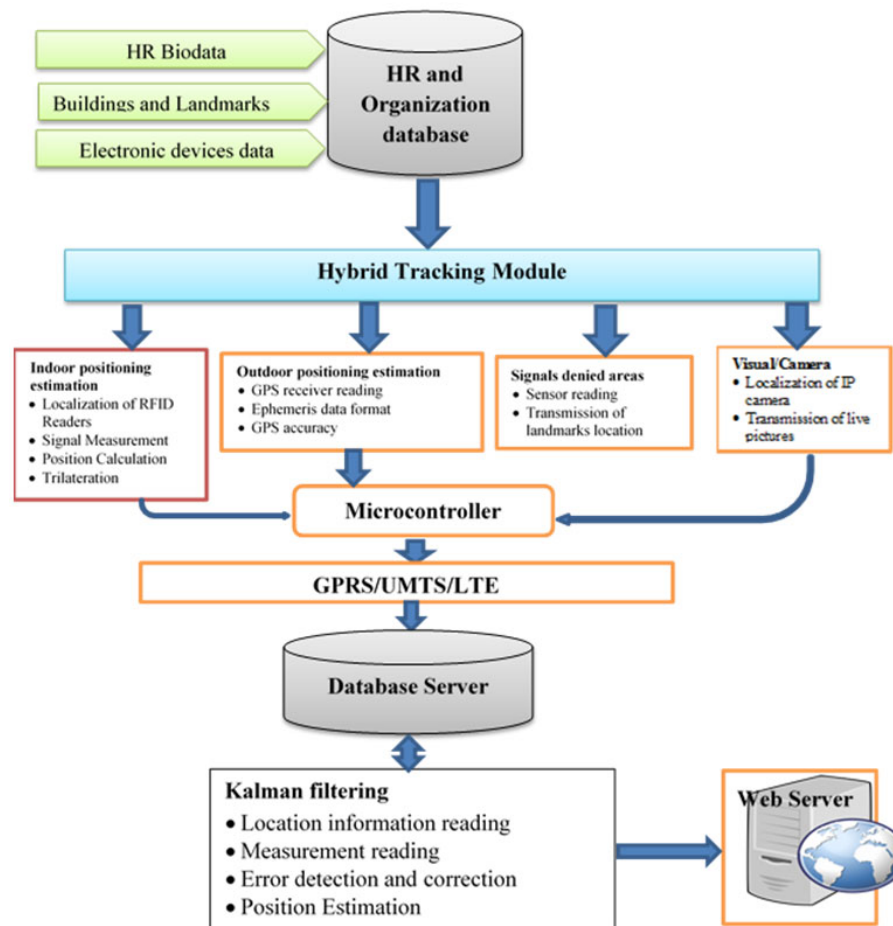
Figure 1. Architecture of a Hybrid HR Monitoring System

3. ARCHITECTURE OF THE PROPOSED SYSTEM

The conceptual diagram of the proposed system is presented in Figure 1 which comprises of the database, localization,

positioning data generation and hybrid location engine subsystems. The database is made up of HR biodata, building, landmarks and electronic devices data. The localization and positioning data generation consist of the hybrid tracking

module, GPS/Universal Mobile Telecommunication Service (UMTS)/Long Term Evolution (LTE) transmission media, microcontroller, indoor, outdoor, signal-denied areas and visual camera estimation subsystems. The hybrid location engine is made up of database server, Kalman filtering system and the web server.

4. EXPERIMENTAL SETUP

The technical details, specifications and functional requirements of the hardware and software used are stated as follows.

4.1 Hardware requirements

The hardware components used in the development of the proposed system are GPS modules, RFID readers, antennas and tags, proximity sensors, IP cameras, Arduino microcontrollers and HP Server. The research used SIM908 GPS module for the outdoor monitoring of HR. It is a Quad-Band GSM/GPRS module which combines GPS and GSM for satellite navigation. The feature includes an industry standard interface and GPS function which allows variable assets to be tracked seamlessly at any location and anytime within signal coverage. It features ultra-low power consumption in sleep mode and integrated with charging circuit for Li-Ion batteries for a super long standby time. It has high GPS signal reception sensitivity with 22 tracking receiver and 66 acquisition receiver channels. The components of the module are shown in Figure 2.

(a) SIM 908 Module   (b) GPS Antenna   (c) GSM Antenna

Figure 2. GPS/GSM Components

For the indoor environment, RFID tags, antennas and readers were used (shown in Figure 3). The RFID reader supports multi-detection and offers a high baud rate from 2,400 bps to 19,200 bps. It reads a variety of RFID tags and it is compliant with ISO 14443A Mifare MF, Ultralite and Desfire standards. The RFID reader communicates with a PC via RS232 interface and is powered by 5 V DC 150 mA adaptor for continuous operation. The reader can detect a tag up to a distance of 50 m. It is equipped with an antenna which extends the coverage. The hardware specifications are stated in Table 1 and Table 2.

(a) Long Range RFID Reader   (b) RFID Reader Antenna   (c) Passive RFID Tags

Figure 3. RFID Components

Table 1. Specifications of Long Range UHF Integrated RFID Reader

Specifications	Details
Supported RFID Tag Protocols	EPC Class 1 Gen 2, ISO – 18000-6c
Communications	RS232, LAN TCPI/IP(RJ-45)
Network Protocols	DHCP, TCP/IP, SNTP, DNS, SNMP
Frequency	865.6 MHz – 867.6 MHz
Channels	10
Channel Spacing	200 KHz
RF Power	2 watts ERP
Antennas	4 ports for 4 read points, multistatic topology, circular or linear polarization, reverse polarity TNC connectors
Software SDK	Java and .NET APIs
Compliance Safety	EN60950, EN 50364

Table 2. Technical specifications of Passive tag

Specifications	Details
Operating Frequency	860 – 960 MHz
Operating Mode	Passive, Beam Powered
Memory	240 bits NVM
Minimum Programming Cycles	10,000 write/read cycles
Operating Temperature	-25°C to + 65°C
Recommended Bending Radius	70 mm
Thickness	0.42 mm
Dimensions	76.2 mm × 76.2 mm

In areas where GPS and RFID signals are non-existent due to topography and environmental factors, Radio Frequency (RF) proximity sensor which communicates with passive RFID tags were used. Readings from these sensors are activated whenever the HR gets near the RF coverage of the sensor. It is a passive RFID proximity sensor using Ultra High Frequency (UHF) RFID technology. The equipment comprises of a customized double-antenna sensor tag and a commercial reader. The proximity sensor and its internal circuit is shown in Figure 4.

(a) RF sensor reader   (b) Internal board of RF sensor reader

Figure 4. Proximity Sensor

In order to fully authenticate the identity of the HR being monitored, visual images are captured by IP cameras installed in strategic locations in the campus. The images captured by these cameras are compared with the stored images of the HR in the database. Indoor and outdoor cameras are used in the research depending on the environment as shown in Figure 5. The indoor cameras are located at the entrance of the building to capture images of persons moving in and out of buildings while the outdoor cameras are located on top of communication masts in such a way to capture movement of people within the university premises. The technical specifications for the cameras are stated in Table 3 and Table 4.
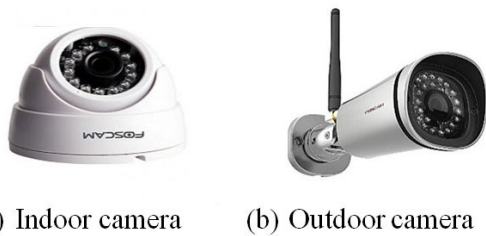

(a) Indoor camera   (b) Outdoor camera

Figure 5. IP Cameras

Table 3. Technical specifications of Foscam FI9821P Indoor Camera

Specifications	Details
Compliant standard	FCC
Low power voltage	DC 5V
Minimum Memory	256 MB
Infrared Lens	11
Features	brightness control, contrast control, e-mail alerts, motion sensor
Network interface	Ethernet 10Base-T/100Base-TX, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n
Network protocols supported	DDNS, DHCP, FTP, HTTP, PPPoE, SMTP, TCP/IP, UDP/IP, UPnP
Frame rate	720p at 15 frames per second

Table 4. Technical specifications of Foscam FI9928P Outdoor IP Camera

Specifications	Details
Compliant standard	FCC
Low power voltage	DC 5V
Minimum Memory	Uses SD Card up to 128 GB
Infrared Lens	355° horizontal and 85° vertical rotation range cover a much bigger vision range. True 4x optical zoom
Features	IP66 level weatherproof design, brightness control, contrast control, e-mail alerts, motion sensor
Network interface	Ethernet 10Base-T/100Base-TX, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n
Network protocols supported	DDNS, DHCP, FTP, HTTP, PPPoE, SMTP, TCP/IP, UDP/IP, UPnP
Video quality/frame rate	1080p at 25fps

The microcontroller used for the project is Arduino Uno R3. The R3 is the third and latest version of the Arduino Uno. The Arduino Uno is a microcontroller board based on the ATmega328 technology. It has 20 digital input/output pin, a USB connection, a power jack, an In-Circuit System Programming (ICSP) header and a reset button. The 5V pin outputs a regulated 5V from the regulator on the board. Figure 6 shows the Arduino Uno3 microcontroller.

Figure 6. Arduino Uno 3 Microcontroller

The integration of the GPS, GSM and RFID modules as done by the microcontroller gives the hybrid tracking module shown in Figure 7.
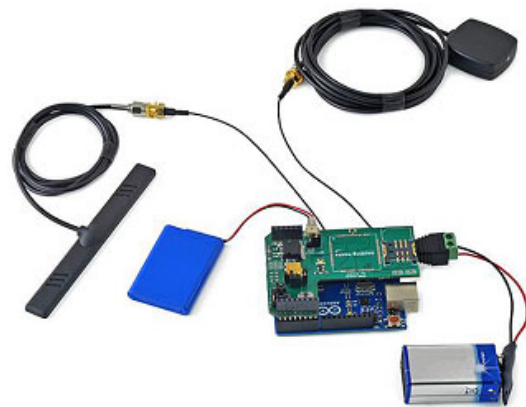

Figure 7. Hybrid tracking module

4.2 Software requirements

The system is developed in an environment characterized by Python programming language, MySQL, XAMPP and Google Map API. Python is a multi-paradigm programming language. Object-oriented programming and structured programming are fully supported. Python uses dynamic typing, and a combination of reference counting and a cycle-detecting garbage collector for memory management. The main advantage of Python relative to other languages, such as C, C++ and other higher-level languages, is that Python is relatively easy to learn, with the syntax looking more like human language and functions that users often struggle

with such as garbage collecting, automated. Nevertheless, Python, with its numerous libraries, is relatively powerful, despite its easy syntax and today it has enabled new types of applications, such as Global Information System (GIS) for mobile devices, integration of mapping features with web programs and other areas that require server and cloud based services for many new tools. Python allows access to well know libraries such as Google Maps and has libraries that are used for Internet-of-Things devices. Python was designed to be highly extensible. This compact modularity has made it particularly popular as a means of adding programmable interfaces to existing applications.

MySQL 5 is a free open source SQL database management system developed, distributed and supported by Oracle Corporation. It is used for the database of this research work. Arduino IDE software is open source software which is used by the microcontroller for receiving data from the satellite and sending data into the database. XAMPP stands for Cross Platform, Apache, MySQL PHP and Perl. It is a simple Apache distribution and it is easy for developers to create a local web server for testing purposes. Google Maps is a web mapping service developed by Google. It offers satellite imagery, street maps, 360° panoramic views of streets (Street View), real-time traffic conditions (Google Traffic) and route planning for traveling by foot, car, bicycle or public transportation.

4.3 Testbed setup

The research was conducted using the main campus of Adekunle Ajasin University, Akungba-Akoko, Nigeria as the testbed. Adekunle Ajasin University, Akungba-Akoko is a fast-growing university with a lot of infrastructure growing up daily. It is located in the northern part of Ondo State, Nigeria. It is located within the following satellite coordinates (7.482926N, 5.737127E) and (7.485909N, 5.766927E) to the north of the University and (7.477880N, 5.737084E) and (7.475679N, 5.766220E) to the south of the University. The monitoring of the activities of HRs in ICTAC of the University was used as the case study for the research due to the nature of their work schedule which involves both indoor and outdoor environments. There are specifically four divisions in the ICTAC namely: Administrative, System Development, Network and General Services divisions. The aerial view of the University landscape is shown in Figure 8.

Eighteen buildings were selected and used for the research and each building is equipped with RFID readers and IP cameras at their entrances to indicate the entry and exit of HR to the buildings as shown in Figure 9a. Outdoor IP cameras

are mounted on four (4) communication masts within the university premises to capture images of HR on-the-go (see Figure 9b). The University Farm is equipped with proximity sensor due the presence of tall trees in the area which will not guarantee direct access to satellite communication and absence of suitable building in the area makes it impossible to install RFID reader.

Figure 8. Aerial view of Adekunle Ajasin University, Akungba-Akoko

(a) RFID Reader and Indoor camera　　　(b) Outdoor camera on mast
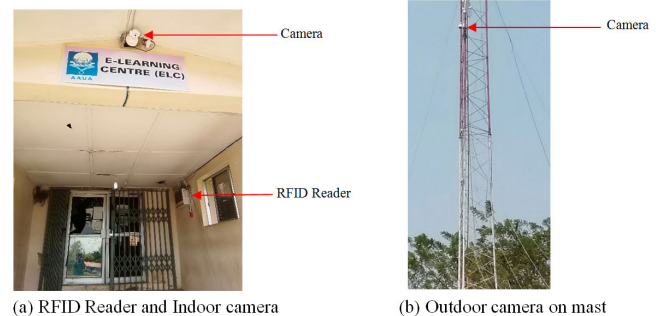
Figure 9. Installation of RFID reader, Indoor and Outdoor IP Camera

5. SYSTEM IMPLEMENTATION

The user activates the system by signing up. Once the registration is successful, the user is expected to login into the system as shown in Figure 10. If the login is successful, it takes the user to the setup page which contains HR, buildings and electronic devices setup pages. The user setups the HR database by entering the personal information of all HR involved in the research as shown in Figure 11.

(a) Sign-up Page   (b) Sign-in Page

Figure 10. Administrator Pages

Figure 11. HR Setup Page

Figure 12. HR wearing hybrid tracking device

Other databases including buildings, landmarks covered by the research and electronic devices are setup. When the setup is completed, the system is now ready to go live. The HOME button activates the process of localization and tracking of HR. Each of the HR is expected to wear the hybrid tracking device as a wristband whenever they are in the workplace as

shown in Figure 12.

Due to the worldwide coverage of GPS, it is possible for the system to monitor the activities of the HR even when they are at home or off-campus thereby infringing on their privacies. This is taken care of by restricting the map display of active HR to only areas covered by the GPS coordinates of the testbed. An example of the location of all the active HRs captured by the system is displayed on the dashboard as shown in Figure 13.
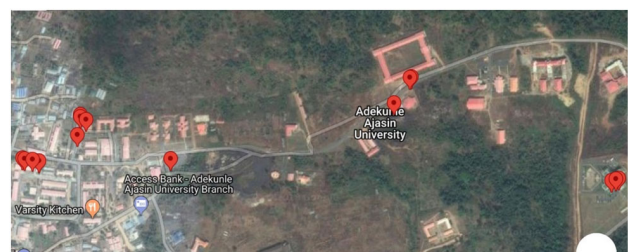

Figure 13. Live Tracking of HR

By hovering the mouse over the GPS marker, the identity of the HR is displayed by the system as shown in Figure 14. The identity, unit, location and GPS coordinates of all the active HRs depicted by GPS markers in Figure 13 is stated in Table 5. The authentication of the identity of a HR is done by comparing the captured image of the camera with the saved image in database as shown in Figure 15.
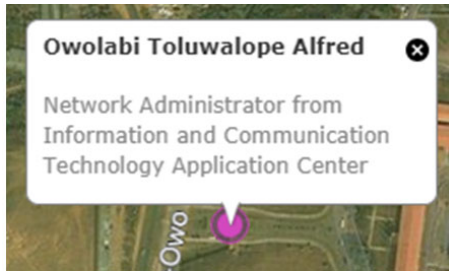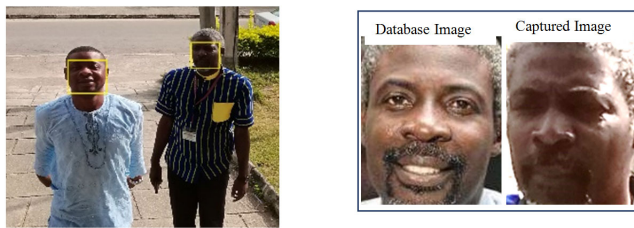

Figure 14. Identification of tracked HR

(a) Captured images of HRs entering the building   (b) Matching of HR Images

Figure 15. HR Image Authentication

Table 5. Active HRs List, Location and GPS Coordinates

HR ID	Unit	Location	GPS Coordinates
aauaict008	Network	AAUA CBT Centre	7.480986N, 5.739356E
aauaict009	Network	AAUA CBT Centre	7.480986N, 5.739356E
aauaict010	Network	AAUA CBT Centre	7.480986N, 5.739356E
aauaict002	Administration	ICTAC	7.482184N, 5.741238E
aauaict003	Administration	ICTAC	7.482184N, 5.741238E
aauaict013	Network	ICTAC	7.482184N, 5.741238E
aauaict015	Network	Access Bank	7.479479N, 5.742752E
aauaict012	Network	Library	7.483575N, 5.752748E
aauaict017	General Services	Faculty of Agriculture	7.483773N, 5.750815E
aauaict001	Administration	Senate	7.480462N, 5.756469E
aauaict025	Software	Senate	7.480462N, 5.756469E

6. PERFORMANCE EVALUATION

A case study of monitoring of the movements of twenty-five randomly selected HR of the ICTAC, Adekunle Ajasin University, Akungba-Akoko was carried out. The selected officers are from the Administration, Engineering, Software Development and General Services Units. The functionality and versatility of the developed system depends on its ability to meet user's specification and requirements. Major requirements of localization system are sensitivity, accuracy, cost and coverage. A number of experiments were conducted to evaluate the developed system using the above stated performance metrics. The research is designed to cover both indoor and outdoor environments, hence the evaluation of the system involved the two environments and the technology adopted for each of them.

6.1 Signal sensitivity

The level of sensitivity of the system to changes in location influences the effectiveness and efficiency of the system. In the indoor environment, the system uses RFID technology for localization since GPS does not function in locations where there is no line of sight to the satellites, hence the GPS module of the tracking device will be in standby mode for some time and if the HR stays for a long time within the building, the GPS module will go into sleep mode in order to conserve power and thereby prolong battery life. In that case, HR location readings were taken mainly by RFID readers and tags. The tag type and selection procedure, reader antenna strength, signal interference and path loss effects are parameters that determine the behaviour of RFID systems.

Tag type and selection procedure: Two types of passive RFID tags were used for the experiment. They are PVC RFID cards and RFID fob tags. The two types were used to find out the effect of tag's shape and size on the system. Three major factors were tested in the selection of tags for indoor localization subsystem. These major factors are the read-ranges, read count behavior and Received Signal Strength (RSS) measurements. Read Range is the longest distance a tag can be read from the reader. Passive RFID tags come in different shapes, sizes and frequencies. These features determine their suitability and functionality for different environments. A major challenge is the selection of the most suitable type of tags from a tag collection. This is addressed by measuring the longest distance a tag can be read from the RFID reader. Tags with the same frequency and technical specifications but different shapes may not have the same read ranges. It should be noted that in order to reduce the cost and complexity of the system, the number of deployed readers must be minimal and this is achieved by using tags with longer read-ranges. The experiments were conducted ten times using the same type

of RFID tags and different indoor scenarios. It was found that the PVC tags were readable at the maximum distance of 18 meters by the RFID reader, while the FOB tags could not be detected after 9 meters. The average distance covered by PVC tags was 14.1 meters with a standard deviation of 2.17 while FOB tags had an average distance of 7 meters with a standard deviation of 1.26. Figure 16 shows the read-range distribution for the two different types of EPC Gen2 passive tags.
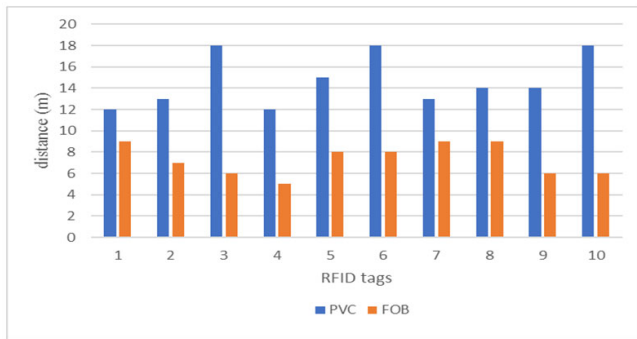

Figure 17. Read count distribution

Figure 16. RFID read range distribution

Read Count (RC) is the number of times a tag is read by the reader in a given time. This metric is used to measure the sensitivity and visibility of the tag to the reader. The selection of tags based on read-range ensures that the tags with longest read ranges are selected but tags with good read ranges may not be uniformly sensitive to different output power-levels of the reader over a period of time. It should be noted that the output power-level of the reader varies due to environmental factors and tag-reader distance. In RTLS, the precision and accuracy of the system depends largely on the sensitivity and visibility of the monitoring devices, hence the need for uniformly sensitive tags. In order to select uniformly sensitive tags, we conducted experiments that measured the cumulative tag read count for all the tags using the reader's output power-levels set of (19.6 dBm, 25.6 dBm, 31.6 dBm) and tag-reader distance set of (5 m, 10 m, 20 m), respectively. The PVC cards are tagged 1-3 while the FOB cards are 4-6. The RC distribution for different types of RFID tags is shown in Figure 17. The need to draw meaningful inferences for HR positioning and localization purposes and at the same time balance experimental efficiency and coverage area of the RFID subsystem necessitated the choice of output power-levels and tag-distance combinations for the measurement of RC behavior of tags.
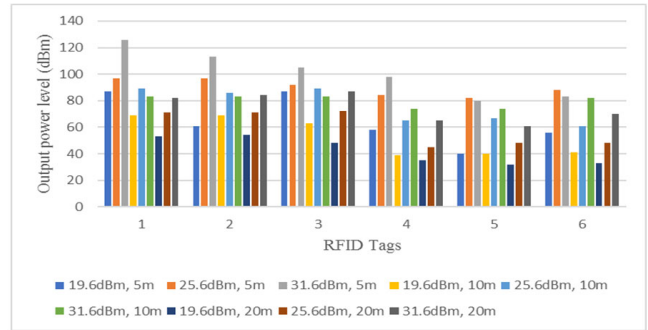
RSS is the amount of radio signal strength backscattered by the tag and received by the reader. In a RFID system, the reader identifies the presence of a tag by sending signals to it and the amount of such signal strength backscattered by the tag and received by the reader is used to estimate the distance between the reader and the tag. In the selection of tags, we must ensure that selected tags not only have the most uniform RC behaviors but uniformly backscatter reader-transmitted radio signals back to the reader. The measurement is called the tag's RSS. This type of tag selection approach enables selection of the uniformly sensitive tags using the RSS metric. We conducted experiments to select such uniformly sensitive tags by measuring the tag RSS for all the tags in the above tag collection over different combinations of reader output power-levels and tag-reader distance. The PVC cards are tagged 1-3 while the FOB cards are 4-6. In order to ensure consistency with the previous tag selection process, that is, RC, reader's output power-levels and tag-reader distance were iterated over the sets (19.6 dBm; 25.6 dBm; 31.6 dBm) and (5 m; 10 m; 20 m) respectively. The result is shown in Figure 18.
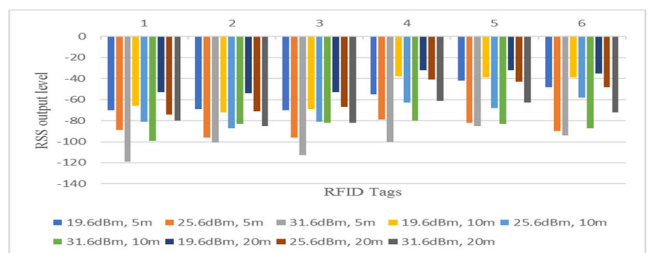

**Figure 18.** RSS measurements

Reader antenna location and strength: The location of the RFID reader and the positioning of the antenna determine the behaviour and the quality of signal that is been transmitted by the reader or received by the tags. It is the RSS transmission power of the reader as received by the tag that is used to estimate the distance between them and eventually used to

predict the location using the trilateration method. Figure 19 shows the relationship between the signal strength and the distance.
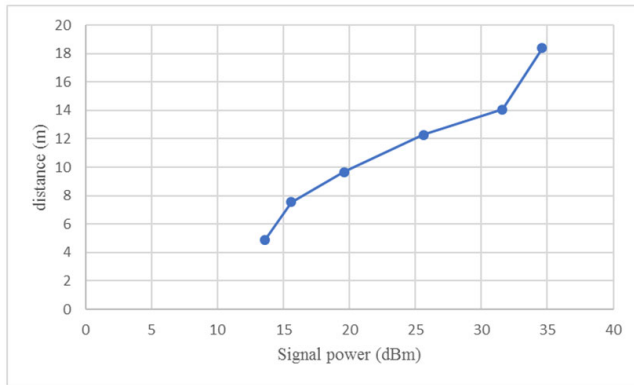
Figure 19. Relationship between the signal power and the distance from reader

From Figure 19, as the power signal is increasing the distance covered by the reader increases. This means that if we have readers with high power output, they will cover more areas and thereby reduce the complexity and overall cost of the solution. The positioning of the antenna affects the readings and sensitivity of the system. The effect of antenna placement is shown in Figure 20.
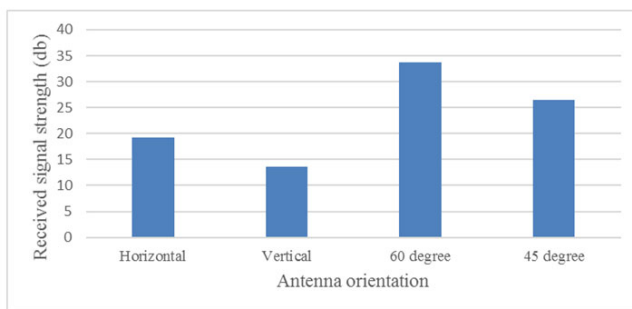
**Figure 20.** Effect of Antenna placement on received signal strength

6.2 Localization accuracy

Positioning accuracy is a major parameter for evaluating localization system. The ability of the system to accurately predict the exact location of an object is usually a major motivation for the development of such system. In this research, experiments were conducted to measure the level of accuracy obtained depending on the environment and dynamism of the workplace. In the indoor environment, the experiment was carried out to measure accuracy of the localization of

an object using the power- modulating algorithms of RFID readers. This is done by placing a uniformly sensitive tag at a fixed distance from the reader and using different power-modulating algorithms to locate it.

Figure 21 illustrates the localization accuracy of the RFID subsystem. The above results show that in most of the measurement points, the ground position (that is, the actual position) and the estimated position derived from RFID subsystem are very close. In a few locations where the difference between the ground position and estimated position is significant (for example, measurement point 7), it was due to target tag being present at a location where radio signals were either obstructed or non-available due to environmental factors, presence of metal or wooden materials in the indoor environment. For the outdoor environment, the accuracy of the GPS technology was tested by measuring the distance between the location coordinates of the HR as shown on the map and the actual ground distance from the reference coordinates. Distances between the two coordinates are calculated by using the Haversine formula which is calculated as

$$D = R \times C \tag{1}$$
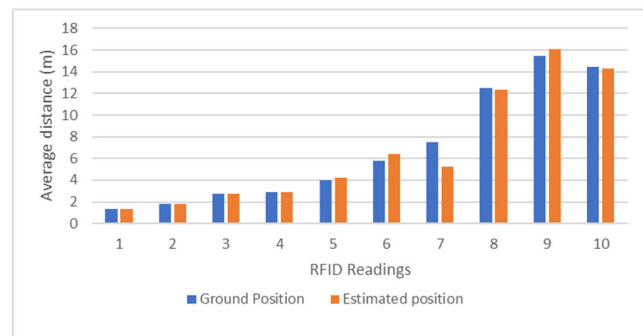
Figure 21. Indoor Location Measurements

where D is the distance between the two coordinates, R is the radius of the earth and C is calculated as

$$C = 2 \times a \tan\left(\sqrt{\frac{1}{1-a}}\right) \tag{2}$$

and

$$a = \left(\sin\left(\frac{dlat}{2}\right)\right)^2 + \cos(lat1) \times \cos(lat2) \times \sin\left(\frac{dlon}{2}\right)^2 \tag{3}$$

where dlan = lon2 – lon1; dlat = lat2 – lat1.

From Figure 22, it is observed that the difference between the actual location (ground) and the GPS prediction is too

small which means that the level of accuracy of the system is high. This is further verified by finding the Root Mean Square Error (RMSE) of all the observed values. The RMSE is calculated as

$$R = \sqrt{\frac{\sum_{i=1}^{n}(P_i - Q_i)^2}{n}} \qquad (4)$$

where R stands for the RMSE, P is the actual ground position, Q is the predicted GPS position and n is the number of readings taken. The value of the RMSE for the system is 0.980199 m.
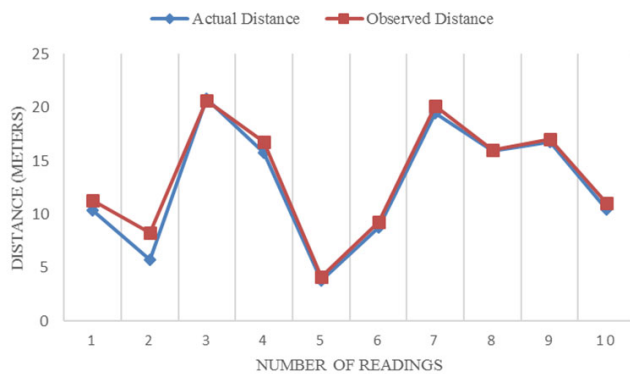

Figure 22. Outdoor location measurements

6.3 Cost of deployment

The estimated cost of deployment is calculated in order to find out the feasibility of deploying the system. Table 6 shows the cost estimate of the system.

Table 6. Analysis of system cost

	Components	Cost estimate
Hardware	GPS module	$10 that is Moderate in price
	RFID reader and antenna	$170 that is Moderate in price
	RFID passive tags	$0.10 - $0.50 that is Low in price
	Arduino Microcontroller	$10 that is Moderate in price
Software	Python	Free (open source)
	MySQL	Free (open source)
	Google Map API	Free up to 25,000 map loads per day
	XAMPP	Free (open source)
	Windows 10 IoT	Free with Windows 10 professional
Transmission network	UMTS, 4G LTE	$2/GB of data that is Low in price

6.4 Coverage area

The most effective positioning and localization systems are the ones that cover the widest range. This is measured by

three levels of coverage; local, scalable and global. Local coverage refers to a well-defined, limited area which is not extendible such as a single room or building, while scalable coverage refers to ability of a system to increase the area by adding hardware. On the other hand, global coverage refers to a system that has a worldwide area. Table 7 shows the evaluation of the developed system according to the levels of coverage.

Table 7. Coverage area evaluation

Local	Scalable	Global
The system is not local.	By adding more RFID readers in the indoor environment, the reach of the system can be extended. For the research, the use of one reader per building limits the coverage to about 20 metres.	The use of GPS technology gives the system a global coverage.

6.5 Record of availability

The amount of time each HR was available during a certain period would be a very useful data for the HR department in carrying out objective assessment of HR performance as it relates to availability at work. The system gives a record of availability of all the observed for the period of assessment as shown in Figure 23.
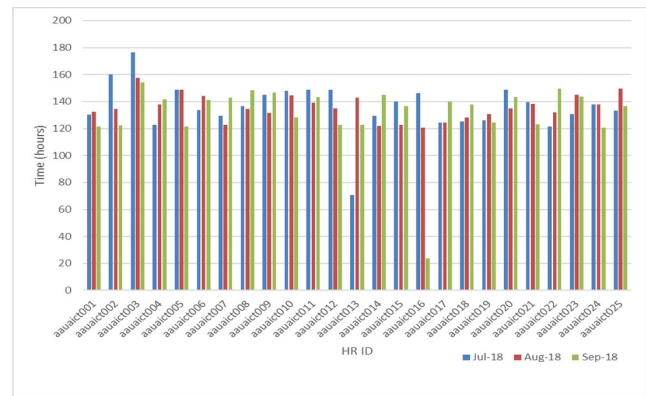

Figure 23. Record of availability

From Figure 21, it is evident that HR with ID 'aauaict003' put in the highest number of hours in the month of July while 'aauaict013' put in the least number of hours. The record of availability of the HR will help the Account Section of the organization in properly remunerating HRs for the actual number of hours put in at work.

6.6 Measurement of punctuality

The analysis of the number of times all the HRs were present at work by the resumption time of 8.00 am for the duration of the research is given in Figure 24.
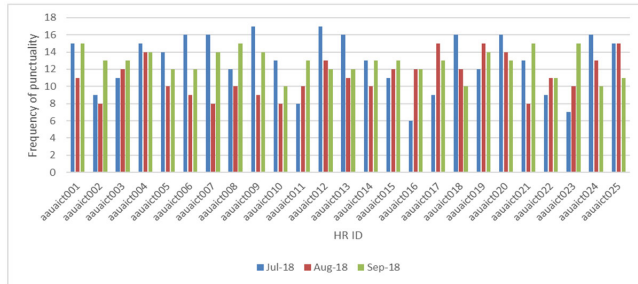
Figure 24. Measurement of punctuality at work

From Figure 24, two HRs, that is, 'aauaict009' and 'aauaict012' had the highest punctuality frequency of seven-

teen in the month of July 2018 while the HR 'aauaict016' had the least for the month of July 2018. Measurement of punctuality at work usually serves as motivation for HRs to put in their best and ensure they get to work on time.

6.7 Comparative analysis with similar systems

The results obtained in this research were compared with other similar and existing systems. The comparisons were based on the environment where they were deployed, that is, either indoor or outdoor and the metrics considered were technologies used, algorithm, accuracy, complexity, scalability, robustness and cost. Table 8 and Table 9 show the comparative analysis of the system with existing indoor and outdoor localization systems respectively.

Table 8. Comparative Analysis of Indoor Localization Systems

System	Technologies	Positioning Algorithm	Accuracy	Complexity	Scalability	Robustness	Cost
[17]	WLAN RSS	Probabilistic method	2 m	Moderate	Good 2D	Good	Low
[18]	Active RFID	kNN	2 m	Medium	Nodes placed densely	Poor	Medium
[19]	WLAN	TDOA	2.4 m	Moderate	2D	Good	Low
[15]	Passive RFID	ToA, RSSI, ANN	1 m – 2 m	Moderate	2D	Good	Low
Current research	Passive RFID	TOA, RSSI, Trilateration, Kalman Filter	<1 m	Moderate	Good, 3D	Good	Low

Table 9. Comparative Analysis of Outdoor Localization Systems

System	Technologies	Positioning Algorithm	Accuracy	Complexity	Scalability	Robustness	Cost
[20]	GPS, GSM	Kalman Filter	13.7 m – 21 m	Moderate	Global	Good	Medium
[21]	GPS, WSN	Cell of Origin (CoO)	12.5 m – 18 m	High	Global	Good	High
[22]	GPS, GPRS	TOA	10 m - 12.5 m	Moderate	Global	Good	Medium
[23]	RFID	RSSI Fingerprinting, LSM	6 m – 10 m	High	Limited by the RFID coverage	Poor	High due to the numbers of tags involved.
Current Research	GPS, Camera, Sensors	TOA, RSSI, Trilateration, Kalman Filter	< 5 m	Moderate	Global	Good	Low

7. CONCLUSION

This paper addresses the implementation and evaluation of heterogenous positioning and localization of HR in the workplace. The research developed a hybrid system for the tracking and monitoring of the movements of HRs irrespective of the environment in which they are working. The system provides heterogeneous platform for integration of different localization techniques and technologies and provide in real

time, instant locations of HR. Record of availability in the workplace and measurement of punctuality at work are important data of HR and payroll departments for objective and scientific assessment and equitable remuneration of HR. The extension of the coverage area, improvement of the accuracy of the system, integration of the system to existing Human Resource Information System (HRIS) and payroll system for performance evaluation and remuneration of HR shall be pursued in further research.

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