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Intelligent GPS and Sensor Controlled Tracker and Locator for Human Trafficking, Kidnapping, Banditry and Theft Control in Nigeria

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ABSTRACT

Prevalent kidnappings for various nefarious purposes have resulted in an unprecedented rise in insecurity of lives and properties in Nigeria. Added to these are other vices such as cattle rustling and banditry, through which the lives and economy of many Nigerians 'are gradually being ruined. To control this trend, security operatives need location and operational information of perpetrators of these nefarious crimes in real time. This study developed a real-time tracking system using the Global Positioning System (GPS), a sensor-based module, a microcontroller, and a proximity sensor to determine the location of the lost item or person and to relay findings to the communication device (smartphone or tablet) of the designated rescue team. For the software development, C++ and PHP were used to code and configure the microcontroller (ATMEGA 8), the GSM message command, the NMEA Messaging 101 protocol command, and the Google Maps API. Findings showed that the tracker device was able to accurately detect a 'missing' (hidden) item or human, provided the locator device is not separated from the human or item. Location Detection Accuracy (LDA) success was 98% (49/50) for the 50 test cases with a 2% (1/50) error rate associated with low battery (below 20%). The average proximity detection distance (PDD) accuracy was approximately 1.6 m. Further studies should focus on improving proximity accuracy, further miniaturising the tracker device for effective concealment, and adopting more secure communication protocols.

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1.0 Introduction

Recently, news media are replete with news of lost valuables, missing or kidnapped individuals, and human trafficking. The alarming frequency of banditry, kidnapping, and human trafficking in Nigeria has caused people to become seriously worried about their safety. Neither adults nor their kids in school, nor properties at home and on the farm, including livestock, are safe anymore. These anxieties have led to an unbearably high cost of living, increased high blood pressure-related cases, helplessness, frustrations, and many deaths. Consequently, safety concerns have become a major issue these days as these inhumane acts continue to increase at an alarming rate day by day. According to Kleffman *et al.* (2024), "Although banditry in Northwest Nigeria has reached the level of a full-blown security crisis, it has only received limited attention … and its most common manifestations include 'kidnapping, armed robbery, murder, rape, cattle-rustling, and the exploitation of environmental resources.'" Ayegbusi (2024) specified that kidnapping had been reported in all parts of Nigeria as an ongoing crisis with lucrative returns. He added that countermeasures from both state and federal governments alone will not bring the desired relief, thereby calling for collaborative efforts among all stakeholders. Rosenje and Adeniyi (2021) elaborated on the prevalence of banditry and kidnapping in Nigeria, especially in the northwestern part of the country, citing unemployment, porous borders, and weak security systems as major drivers of these nefarious acts (see table 1). They singled out Northwest Nigeria as the most hit region, where the notoriety is most prevalent. Because of the delay in executing countermeasures to suppress and punish bandits and kidnappers for their heinous acts of terrorism on the part of the Nigerian government, this in turn has resulted in brewing more insurgencies and an influx of more bandit groups, such as Boko Haram and Lakurawas from neighbouring countries. The federal government has over the years preferred to toe the line of dialogue, disarmament, and lacklustre engagements. These had been misconstrued as tolerance, weakness, or both in many sectors and have resulted in devastating wanton economic woes and destruction of human lives on a regular basis. Consequently, these terrorists have been emboldened to even attack military personnel's convoy and barracks.

According to Aladeselu (2024), Boko Haram has caught the Nigerian Armed Forces off-guard twice in less than two weeks in November 2024. An unexpected attack was made on a Nigerian Army camp in Karreto, Borno State, on Saturday, November 16. As reported by the Defence Headquarters (DHQ), five soldiers lost their lives, and one military and fourteen other vehicles, including the camp itself, were destroyed.

By Monday, November 18, another attack linked to members of Boko Haram terrorists occurred in Farin-Kasa, Kaduna state, where a team of Nigerian Security and Civil Defence Corps (NSCDC) was attacked while on duty patrolling to check the National Grid from Shiroro, whose power lines were damaged, causing the recent and frequent blackout in the North. In the gun battle that ensued between the over 200 terrorists and the members of the NSCDC, over 50 of the attackers were eliminated, while 7 members of the NSCDC were missing, with some other officers wounded and receiving treatment at the hospital (Aladeselu, 2024).

The Lakurawas, a new terrorist group operating in Nigeria's Northwest region, killed 20 people in Kebbi state and destroyed livestock worth millions of naira. As if that is not enough, 4 persons from Gwosa, Benue State, were beheaded by members of the Boko Haram terrorist group in October 2024 as a retaliation for a military attack on their members. This was in addition to the killing of 40 Chadians in the same month by the same terrorist group in a surprise attack at a military base near the Chad-Nigerian border (Aladeselu, 2024).

Despite efforts such as the investment of up to 103 trillion naira between January and June 2024 by the federal government to curb this terrorists' menace, analysed data from the Armed Conflict

Location and Event Data (ACLED) Project (an organisation that collects data on protests and violence) revealed that not less than 2,336 Nigerians had died as a result of insecurity in the first quarter of 2024 alone (Aladeselu, 2024).

Speaking about why the efforts of the federal government had been less fruitful in managing the insecurity crisis, Oche & Robert (2024) recommend investing in technology-driven solutions, as they attribute the ineffectiveness of traditional approaches in solving the banditry and kidnapping problem in Nigeria to a lack of coordination, resource constraints, and injustices. Stemming from this, and by implication, the public interprets failure of the government to apprehend the terrorists and bring them to book in a timely fashion as injustice and tolerance of crime. However, to be productively engaged and functional, security agents need to know where, when, and how the terrorists operate in real time.

To that effect, it is apparent that the advent of smartphone technology has brought remarkable communication features. Combining these features with sensor technology can provide great real-time security applications such as tracker systems. However, the result of various tracking systems developed and deployed until now around the country is far from satisfactory. While some GSM-based tracking devices can and do send location information through text message to the phone of the binding user, such data is often not direct, sufficient, and clear enough for users to understand and safely work with, thereby leaving much to be done. With the prevailing smartphones, much more can further be done in facilitating the tracking of missing objects and people.

According to Sumil (2024) in PrioriData and as shown in Table 1, smartphone ownership and penetration are on the increase globally. With the Nigerian population standing at 218.54 million (2024 estimate figure), 83.34 million Nigerians own and use smartphones. This total represents 38.1% penetration.

Table 1 reveals the global trend in the use of smartphones. According to industry analysis, the number of smartphone users is currently 4.88 billion, and the number is expected to have reached 7.12 billion by the end of 2024 (Sumil, 2024).

Based on this trend, in this study, the researcher takes advantage of the growing utilisation, dependency, ubiquitous nature, and growing use and penetration, as well as the associated sensor network of smartphones, to design a sensor-based tracking system with alarm mechanisms that will support large-scale users and big data storage for the purpose of tracking kidnapped or lost individuals and items.

2.0 Review of Literature

The Global Positioning System (GPS) is a widely used technology that has many applications in various fields (Liu, Li, & Chen, 2016). GPS has been widely used for navigating air, sea, and land transportation for location information, route guidance, and traffic updates in real time to improve efficiency and safety (McDermott, Klimek, & Harrison, 2016) (Chen & Paulraj, 2004). In surveying and mapping, GPS has also been used for land and sea surveying and mapping to provide accurate location information for land-use planning, infrastructure development, and natural resource management (Chen & Paulraj, 2004; Javalgi, White, Ali, & Ali, 2009).

In precision agriculture, GPS has been used to map and monitor crop growth, soil quality, and weather conditions. It has also been used to guide vehicles and farm equipment, such as tractors and harvesters, for crop yield optimisation and waste reduction (Chen & Paulraj, 2004; Javalgi, White, Ali, & Ali, 2009).

Emergency services providers, such as ambulances and fire trucks, have found GPS quite useful for rapid response to emergencies and tracking locations of vehicles and personnel in real-time (Feintuch, 2010; McDermott, Klimek, & Harrison, 2016). In addition, GPS is being used to track and monitor the location of assets such as vehicles, goods in containers, equipment in logistics, fleet management, and other fields, with efficiency and at reduced costs (Chen & Paulraj, 2004; Javalgi, White, Ali, & Ali, 2009). In wildlife tracking, GPS has proved useful in tracking the movements of wild and migratory animals for research and conservation purposes. This has provided insights into the behavioural nature of different animal species (Visma, Reichborn-Kjennerud, Stormark, & Klungsoyr, 2016).

For timing and synchronisation, GPS signals have provided accurate time and synchronisation information for various applications such as power grids, telecommunications, and financial transactions (Kuo, Chen, & Chen, 2018; Visma, Reichborn-Kjennerud, Stormark, & Klungsoyr, 2016). For decades now, GPS has been widely used in transportation for obtaining route information in real time and for navigation and tracking of vehicles. This has improved service quality in tourism, as well as safety of lives and goods in transit (Chen & Paulraj, 2004; Javalgi, White, Ali, & Ali, 2009). The effective use of GPS precision farming has resulted in improved crop yields at reduced costs as farmers obtain real-time information about crop growth and soil conditions (Liu, Li, & Chen, 2016).

In sports and recreation, GPS has made tracking and analysing athletes' performances much easier as well as providingreal-time information to coaches and trainers (Kuo, Chen, & Chen, 2018).

In wildlife tracking, emergency services, and personal use, GPS tracking devices had proved to be of immense value. It has been used to track wildlife movements and behaviours to better understand their habitats and migration patterns and to locate emergency spots, ambulances, fire trucks, and police cars quickly. On personal devices, such as tablets, smartphones, and watches, GPS has been used for navigation and location-based services (Visma, Reichborn-Kjennerud, Stormark, & Klungsoyr, 2016).

Miniaturisation of GPS devices has made integrating the technology into smaller and more portable devices possible. This in turn has opened up new possibilities for its use. The advent of new technologies such as the Internet of Things (IoT), 5G, and edge computing has made using GPS in real-time tracking of assets, vehicles, and people possible.

2.1 Carer, Bluetooth Light Energies (BLEs), and GPS Technologies—Juxtaposing the Realities

It is undeniable that the vigilance, intelligence, and decision-making processes of a GPS-controlled tracker cannot be equated to that of a vigilant human carer. Neither can GPS-enabled intelligent trackers be compared to the much more preferred good human care and monitoring. Reality, however, shows that constant item or child monitoring and vigilance by another human is not always feasible due to other attention-demanding obligations, especially when the child-monitoring parent is secularly engaged and thus distracted. Incidentally, this is on the increase for both genders in both civilised and developing countries, as both parents have to be secularly engaged oftentimes. Therefore, deployment of an autonomous sensor-controlled human/item locator using GPS as an added carer security support system will greatly decrease parents' mental stress-related worries and give them more freedom during engagement with other activities away from their family. This is especially true for Nigerian communities often traumatised by bandits and terrorists. Besides, this can reduce government security expenses in the long run. This study was designed to address this objective.

GPS-based human and item locator devices have several strengths that make them effective and reliable tracking solutions. One strength is the high accuracy of GPS technology, which allows for precise location tracking within a few meters of the actual location (Yao, Wang, & Lu, 2016). The strength is the ability to provide real-time location information, allowing the user to track the location of the human or item in real time (Kim *et al.,* 2017). Also, the cost of GPS receivers and devices has decreased significantly over the years, making it an accessible technology for a wide range of users. This has made GPS useful for a wide range of applications, such as navigation, mapping, agriculture, and wildlife tracking (Schmitz & Doktor, 2019; Nawaz, Raza, & Alrajeh, 2020).

In addition, GPS-based human and item locator devices are widely available and relatively easy to use, requiring only a GPS receiver and a means of transmitting the location data to the user, such as a smartphone app (Li *et al.,* 2015). They can provide location information with high accuracy, which can be helpful for navigation, surveying, and mapping, as well as for various other applications (Schmitz & Doktor, 2019; Nawaz, Raza, & Alrajeh, 2020). This has allowed improved efficiency in various fields, such as transportation, logistics, and agriculture, by providing real-time location information and reducing the need for manual tracking and monitoring (Zhou, Wu, & Wang, 2020). GPS can improve safety in various fields, such as transportation and emergency services, by providing real-time location information and enabling faster response times (McDermott, Klimek, & Harrison, 2016; Kuo, Chen, & Chen, 2018). The GPS signals can be received by devices anywhere on the Earth's surface, making it a widely available technology (Schmitz & Doktor, 2019; Nawaz, Raza, & Alrajeh, 2020).

However, there are also some limitations to the use of GPS-based human and item locator devices. One limitation is the need for a clear view of the sky in order to receive satellite signals, which can be disrupted by tall buildings, trees, or other obstacles (Rao, Bapat, & Dandekar, 2012). This can decrease the accuracy of the location data, particularly in urban or densely populated areas.

Another limitation is the need for a reliable power source to operate the device, as well as a means of transmitting the GPS data to the user (Kim *et al.,* 2017). This can be a challenge, especially for devices that are designed to be carried or worn by a human. GPS-enabled devices and receivers can consume a lot of power, which can limit their battery life, especially in portable and mobile applications. The accuracy of GPS also depends on the availability and maintenance of the satellites and ground stations that make up the GPS infrastructure. It has also been seen that GPS signals can be jammed by electronic jamming devices, which can disrupt GPS-based applications and endanger the users (Schmitz & Doktor, 2019; Nawaz, Raza, & Alrajeh, 2020).

Alternative technologies, such as radio-frequency identification (RFID) and Bluetooth low energy (BLE), have also been used in human and item locator devices. These technologies have the advantage of not requiring a clear view of the sky and having a relatively low power consumption (Yang, Li, & Chen, 2018). However, they have a limited range, typically a few meters, and are not as accurate as GPS (Yang *et al.,* 2018). GPS may not be reliable or available in certain areas, such as in underground or indoor environments or in remote or rural areas (Nawaz, Raza, & Alrajeh, 2020). There are also issues with the use of GPS tracking devices, which raises privacy concerns, as they can be used to track and monitor individuals without their knowledge or consent (Schmitz & Doktor, 2019; Nawaz, Raza, & Alrajeh, 2020). It is important to note that GPS data can be vulnerable to cyberattacks and hacking, which can compromise the security and integrity of the data (Gao, Zhang, & Yang, 2020; Nawaz, Raza, & Alrajeh, 2020).

In addition, GPS-based human and item locator devices have the strengths of high accuracy and real-time location tracking but have the limitation of requiring a clear view of the sky and a reliable power source. Alternative technologies, such as RFID and BLE, have lower power consumption and a shorter range but are not as accurate as GPS. Which leaves us with some challenges to be addressed in terms of power management and ensuring the accuracy of the location data.

2.2 Working Principle of Global Positioning System

GPS (Global Positioning System) is a satellite-based navigation system that allows users to determine their precise location, velocity, and time on the earth's surface. It was initially developed by the U.S. military for use in military operations but has since become widely available for civilian use (Yao, Wang, & Lu, 2016). The Global Positioning System (GPS) is a navigation system using satellites, a receiver, and algorithms to synchronise location, velocity, and time data for air, sea, and land travel (Parkinson & Spilker, 1996). The working principle of GPS is based on the use of radio signals that are transmitted by the GPS satellites to the GPS receiver directly or to a device such as a smartphone that's embedded with a receiver (Rao, Bapat, & Dandekar, 2012).

GPS technology has been deployed in location tracking, on vehicle navigation systems, asset tracking, and human and item locator devices. It is gaining global acceptance due to its high accuracy and reliability, as well as its ability to provide real-time location information (Yao *et al.,* 2016).

GPS satellites continuously transmit signals that contain information about the satellite's location and the time the signal was transmitted (Maral & Bousquet, 2017). A GPS receiver on the device receives these signals and uses them to calculate the distance to the satellite by measuring the time it takes for the signal to travel from the satellite to the receiver (Kouba, 2001). By measuring the distance to at least four satellites, the GPS receiver can determine the device's location by a process called trilateration (Parkinson & Spilker, 1996; Kouba, 2001). Trilateration is the technique for determining an object's location, velocity, and elevation by collecting signals from at least four satellites to output location information. Satellites orbiting the earth send signals to be read and interpreted by a GPS device situated on or near the earth's surface. Each satellite in the network circles the earth twice a day, and each satellite sends a unique signal, orbital parameters, and time. At any given moment, a GPS device can read the signals from six or more satellites.

A single satellite broadcasts a microwave signal, which is picked up by a GPS device and used to calculate the distance from the GPS device to the satellite. Since a GPS device only gives information about the distance from a satellite, a single satellite cannot provide much location information. Satellites do not give off information about angles, so the location of a GPS device could be anywhere on a sphere's surface area.

When a satellite sends a signal, it creates a sphere with a radius measured from the GPS device to the satellite. When we add a second satellite, it creates a second sphere, and the location is narrowed down to one of two points where the spheres intersect. With a third satellite, the device's location can finally be determined, as the device is at the intersection of all three spheres. The intersection of the three spheres generates two points of intersection, and the point nearest Earth of the two is chosen. As a GPS device moves, the radius (distance to the satellite) changes. When the radius changes, new spheres are produced, giving us a new position. We can use that data, combined with the time from the satellite, to determine velocity and calculate the distance to our destination (Maral & Bousquet, 2017; Parkinson & Spilker, 1996).

2.3 Structure of a Global Positioning System

The structure of a Global Positioning System (GPS) includes three main segments: the space segment, the control segment, and the user segment (Nawaz, Raza, & Alrajeh, 2020).

The space segment (SS) of a GPS system is comprised of a network of satellites that are placed in orbit around the earth. These satellites continuously transmit signals that contain information about their location and the time the signal was transmitted (Nawaz, Raza, & Alrajeh, 2020). The number of satellites in the space segment varies, but the United States GPS system, for example, currently includes 31 operational satellites in six different orbital planes (GPS.gov, 2021).

The control segment (CS) is responsible for monitoring the satellites, updating their orbits and clock corrections, and transmitting these updates to the satellites. The control segment is composed of a network of ground stations located around the world (Nawaz, Raza, & Alrajeh, 2020).

The user segment (US) is composed of the GPS receivers that receive the signals from the satellites, process the signals, and calculate the user's location (Nawaz, Raza, & Alrajeh, 2020). The user segment is responsible for converting the raw GPS data into useful information, such as location, speed, and time. The user segment can include various types of receivers, from handheld devices to integrated systems in vehicles, smartphones, and other Internet of Things (IoT) devices (Zhou, Wu, & Wang, 2020).

2.4 Related Works

Lalit (2023) documented the procedure, tools, and techniques for developing and configuring a tracking device for vehicles using GPS satellites and GSM modules. He used the ATMega16 microcontroller and the SIM300 GSM module. His tracking device could be used to accurately track a vehicle's position on both land and water as an SMS message. However, the interface of the GSM modem used is not supported by all mobile devices for sending and receiving SMS messages, especially Blackberry, iPhone, and Windows. Besides, the tracker is designed for tracking automobiles specifically.

Kim *et al.* (2017) developed a GPS-based human locator device that used a wearable wristband and a smartphone app to track the location of a human in real-time. The device was found to be accurate and reliable in tracking the location of the human within a range of 3 meters. Li *et al.* (2015) developed a GPS-based item locator device that could be attached to a valuable item, such as a laptop or purse, and used to track its location in real-time using a smartphone app. The device was found to be effective in helping users locate their lost or misplaced items.

Moreover, the impact of GPS tracking technology on parent-child communication and parental perceptions of their ability to locate their child in an emergency was seen to be very helpful.

(McDermott, Klimek, & Harrison, 2016). A study used a sample of 78 parents and their adolescent children over a period of six months and found that parental use of GPS tracking improved parent-child communication and that it also increased parental perceptions of their ability to locate their child in an emergency. The study also found that the use of GPS tracking did not have any negative effects on the parent-human relationship or on the human's privacy concerns. This study revealed the potential benefits of GPS tracking technology in the context of parent-child relationships and human safety, providing some evidence of how this technology can be used to improve communication and safety in families. The study, however, did not include actual design and implementation of a tracker for the Nigerian context.

(Kuo, Chen, & Chen, 2018) aimed to investigate the effects of human-tracking technology on parental satisfaction, anxiety, and parenting behaviour. The study used a sample of 163 parents who used human-tracking technology and found that parental use of the technology was associated with increased parental satisfaction and reduced anxiety and parental overprotection. The study also found that parental use of the technology was associated with improved parenting behaviour, such as increased trust and autonomy-support in their children. This study provides insight into how technology can improve parents' well-being and be used to improve communication and safety in families.

Visma, Reichborn-Kjennerud, Stormark, & Klungsoyr (2016), in another study, aimed to examine the feasibility and parental acceptability of using GPS tracking for children with Autism Spectrum Disorder (ASD) or Attention-Deficit/Hyperactivity Disorder (ADHD) in order to evaluate the children's and parents' views on the use of GPS. The study was carried out with a sample of 46 children with ASD or ADHD and their parents and found that the GPS tracking system was considered feasible and acceptable by both children and parents. The study reported that the majority of parents found the GPS tracking system helpful in reducing their anxiety about their person's safety and managing the human's behaviour. Furthermore, the study found that most children with ASD or ADHD were not worried about wearing or carrying the GPS.

device on their person. The study provided evidence that GPS tracking technology could be a useful tool for monitoring the location of high-risk children, such as those with autism or ADHD, and is a useful resource for understanding the acceptability and feasibility of using GPS tracking for these populations. However, the study did not cover the challenges of design implementation of GPS-based tracking devices in real time.

3.0 Materials and Methods

3.1 Usability and Functional Design

The tracker device was designed to be quite portable, making it easy for individuals (young or old) to carry on their person. Besides, it has an easy-to-use interface and G-sensors with a high detection rate for reliable and accurate location determination. The device was activated by inserting a SIM card into the device and monitoring its activities via the installed application on a smartphone.

This device's terminals transmit the victim's location information gathered through the GPS module to the server cluster periodically. The SMS module helps the user to check the location of a lost item or person anytime he wants. Through the GPS receiver, the location data—latitude and longitude of a lost item or person—is received and sent to Google Maps in real time. The tracker device containing the map transfers the coordinates as it arrives to the smartphone making the tracking request. That means, in real time, we get to see the location of the lost item or person.

To conserve energy (battery life), the time gap between two messages is automatically adjusted based on the condition of the bearer through G-sensor preset parameters. If the movement speed of the device bearer increases up to a certain point, the frequency of transmitting location information of the bearer decreases and vice versa. Besides, the G-sensor consequently

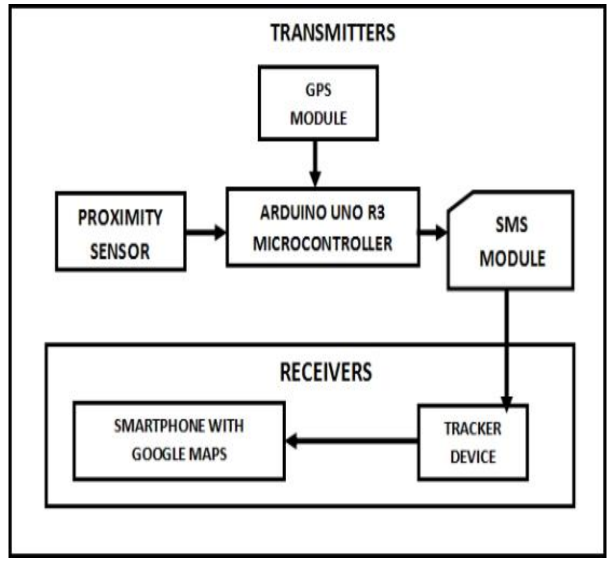
monitors the state of the carrier to ascertain the point of illegal cases and trigger off the alarm signals.

3.2 Device Hardware Components

The device consists of a GPS module, a microcontroller, and a proximity sensor. The GPS module is responsible for determining the device's location and sending this information to the microcontroller, which then sends the location data to the designated user's smartphone or tablet via a wireless connection. The proximity sensor is responsible for detecting when the device has been separated from its designated user. When the sensor detects separation, it sends a signal to the microcontroller, which then activates the GPS module and sends the device's location to the designated user's smartphones or tablets.

Figure 1

Proposed Architectural Framework for Item or Child Tracking System



The device is powered with a rechargeable battery that lasts up to five days when fully charged. The device is easy to use; parents can activate the device by inserting a SIM card into the device and monitoring its activities through an application on their smartphones or tablets. Once activated, the device will send the child's or item's location to the designated user's smartphone or tablet every few minutes, allowing the user to track the child's or item's location in real-time.

See figures 1 to 3 below for the components used, namely: a GPS module, a microcontroller for sending location data to the designated user's smartphone or tablet, a proximity sensor for detecting separation from the designated user, and a power source, a rechargeable battery.

3.3 Data Collection

Data collected from fifty test cases comprising 30 human volunteers and 20 items located in two different cities (Ijebu-Igbo and Ijebu Ode) and three villages (Mamu, Ago-Iwoye, and Apoje Farm Settlement) in the Ijebu North local government area of Ogun State, Nigeria, were used for the system's performance assessment and evaluation (table 1 and table 2). The tracker device (source) remained in Ijebu-Ode city for all searches, while search objects and supposed victims are located in 5 different cities and villages, namely, Ijebu-Ode, Ijebu Igbo, Apoje Farm Settlement, Ago-Iwoye, and Mamu.

An Android 13 Vivo Y02t smartphone with a 2.3 GHz Octa Core, 8 GB RAM, and 64 GB storage capacity was used for tracking from the source. The evaluation of the device performance required the help of a research assistant who moved from place to place with the tracker device. The tracker device was borne on the person in 10 different locations in Ijebu-Ode, another 10 different locations at Ijebu-Igbo, and another 10 spots at Apoje Farm Settlement (a village), totalling 30 (as shown in table 1). At other times, the same tracker device was kept inside a knapsack bag whose location was varied 10 times at Mamu town and 10 times at Ago-Iwoye town as well, totalling 20 locations (see table 2).

It took the pair (the researcher and the research assistant) 6 days to complete this exercise. Day 1 was used to train and intimate the research assistant on what the study was all about and what is expected of him in each situation. A car was made available for his conveyance to the location each day. A day was used to capture data from each of the 5 cities, towns, and villages used. The research assistant often needed to record the distance between the tracker-detected location and the actual item or human location using a tape rule.

Findings showed that the tracker device was able to accurately detect a 'missing' (hidden) item or human, provided the locator device is not separated from the human or item and the rechargeable battery of the device is not below 20%. Location detection accuracy of 98% success was recorded for the 50 test cases (49/50) with a 2% (1/50) module 'error rate (MER) associated with low battery. Results further showed average proximity detection distance (PDD) to be 1.5669 m (approx. 1.6 m), which is less than the estimated 2.5-meter perimeter radius. The detachment detection time (DDT) of 3.06667 (see table 1) and 2.89474 (see table 2), which on average is 2.9807 seconds, was recorded.

3.4 Data Analysis

The data collected during the testing (system assessment) of the device were analysed using statistical methods to determine the accuracy and reliability of the device (equations 1-3). While Location Accuracy Detection (LAD) is the difference between Total Detections (TD) and Detection Errors (DE). The difference between the total number of detections carried out (TD) and the total number of accurate (error-free) detections (LAD) is the Detection Error (DE). That is:

Figure 2
Proximity Sensor, GPS Module, and its Microcontroller

Detection Error (DE) = TD – LAD ------------------ i
For this study, DE = 50 – 49 = 1

This amounts to an error rate of 0.01 and an accuracy of 98%.

The GPS module's error rate (MER) was determined by obtaining and taking the percentage of the difference between the device's reported location (RL) and the actual location (AL). It is expressed in percentage. That is

$MER = (((RL - AL)^2)^{0.5} / AL \times 100)\%$ -------------- ii

For instance, from Ijebu – Ode to Ojowo in Ijebu – Igbo,
RL = 22,999m while AL = 23,001.1. Then,
RL = 22,999m from search source, and
AL = 23,001m, then
RL – AL = -2.1m
Then, $MER = ((-2.1^2)^{0.5}/23001) \times 100)\% = 0.008695\%$

and the sensor's Detachment Detection Time (DDT) was determined by measuring the time it took for the sensor to detect separation of the device from the designated user. Proximity detection accuracy (PDA) error rate is the ratio of the best (closest) and the worst (farthest) detection distances recorded for a particular tracked subject/ item. The average proximity detection distance (PDD) is the sum of D_1 ... Dn (that is Mean PDD 1…n for all groups of observations) for a particular tracked subject/ item divided by n. where n is the number of observation or detection groups. That is

Average Proximity Detection Distance (APDD) = $(D_1 + D_2 + \ldots + D_n) / n$ ------------------------------- iii

And for this study from tables 1 and 2,

APDD = (1.523333 + 1.610526) / 2 = 1.56693 m

Approximately = 1.6m.

From the observations in tables 1 and 2 above:

The best (closest) detection distance recorded for this particular tracking study was 0.5m and the worst (farthest) detection distances recorded for this particular tracking study was 2.6m. Since Proximity Detection Accuracy (PDA) Error Rate is the ratio of the best (closest) and the worst (farthest) detection distances recorded for a particular tracked subject/ item.

Therefore, PDA Error rate = 0.5 / 2.6 = 0.1923.

3.5 Implementation and Performance Assessment

Fifty test cases comprising 30 human volunteers and 20 items located in three different cites (Ijebu-Igbo, Ago-Iwoye and Ijebu Ode) and two towns (Mamu and Apoje Farm Settlement) in Ijebu North local government area of Ogun State, Nigeria, were used for system's performance assessment and evaluation.

Findings showed that, the tracker device was able to accurately detect 'missing' (hidden) item or human with a very high accuracy provided the locator device is not separated from the human or item and the rechargeable battery of the device is not below 20%. Location detection accuracy of 98% success was recorded for the 50 test cases (49/50) with a 2% (1/50) modules' error rate (MER) associated with low battery. Results further showed average proximity detection distance (PDD) of approximately 1.6m which is less than estimated 2.5 meters perimeter radius (See tables 1 and 2).

The detachment detection time (DDT) of less than three (3) seconds was recorded on average (table 1: 3.06667.; table 2: 2 8947).

Figure 3

Locating the Device Using a Mobile Application (Satellite view)

This device implementation that included its testing in different environments and situations, demonstrates that the prototype sensor-controlled child/item locator can effectively be implemented on a larger scale. The device's ability to function properly in varying situations and locations close to the tracker source or not, and its ability to function in extreme temperatures further demonstrate its effectiveness as a tool for keeping track of loved ones and personal belongings in any environment.

An equivalent map view of the satellite view is shown in figure 4.

Figure 4
A sample of Locating the Device Using a Mobile Application (Map view)

3.0 Results

The sensor-controlled child/item locator was tested in various environments, including urban and rural areas, and in different weather conditions. The device was found to be highly accurate in detecting the location of the hidden child or item, with an average error rate of less than 1.6 meters.

The device was also found to be very reliable, provided the battery has not discharged below 20% and the device is not subject to excessive humidity or hotness.

The device's Location Detection Accuracy (LDA) of 98%, Average Proximity Detection Distance (APDD) of 1.5669 m (approx. 1.6 m), which is less than the estimated 2.5-meter perimeter radius, and Detachment Detection Time (DDT) of 3.06667 s (see table 1) and 2.89474 s (see table 2), which on average is 2.9807 seconds, show that the device is reliable and highly accurate. The sensor was able to detect separation from the designated user within 3 seconds, allowing the device to quickly send the child's or item's location or detachment information to the designated user's smartphone or tablet in real time.

Overall, the sensor-controlled child/item locator is designed to provide peace of mind for parents and individuals by allowing them to easily track the location of their loved ones and personal belongings. With its compact size, easy-to-use interface, and reliable performance, it is a valuable tool for any parent or individual desiring to keep track of their loved ones and valuable properties.

4.0 Discussion

The sensor-controlled human/item locator was tested in a variety of environments, including urban and rural areas, and in different weather conditions. Its performance assessment revealed that the device is highly accurate in determining the location of the human or item, with an average error rate of 0.01 and an accuracy of 98%.

The device was also found to be reliable, with a battery life of up to 120 hours when fully charged and the ability to function properly in extreme temperatures.

The device's proximity sensor was also found to be highly accurate, with a detection rate of over 98% after undergoing 50 test cases. The sensor was able to detect separation from the designated user, giving a detachment detection time (DDT) of less than 3 seconds on average, allowing the device to quickly share this information with the designated user's smartphone or tablet of the search party. The tracker device has a very low PDD, averaging 1.6 m over 50 test cases. This tremendously brings the search party very close to the sought object or person and thus reduces the search workload remarkably.

Overall, the sensor-controlled human/item locator is designed to provide peace of mind for parents and individuals by allowing them to easily track the location of their loved ones and personal belongings in real time. With its multiple views (satellite and map), compact size, easy-to-use interface, and reliable performance, it is a valuable tool for any parent or individual looking to keep track of their loved ones and personal belongings.

5.0 Conclusion

This study confirms the feasibility of adopting a sensor-controlled human/item locator using GPS technology for the security of lives and properties in Nigeria. The tracking device can discreetly be deployed anywhere in the country where mobile devices and applications thrive, except underwater. The device was tested in various outdoor and indoor environments and found to be accurate and reliable in determining the location of the human or item and sending the information to the designated phone number or mobile application, as the case may be, in real time.

The study has several implications for the field of human and item tracking. The device developed in this research project can be used to ensure the safety of children and other valuable items. It can also be used by parents, carers, and other responsible parties to keep track of their loved ones and belongings. Furthermore, this research provides a proof of concept for the use of GPS and GSM technology in tracking and monitoring devices, which can be further developed and enhanced for various applications.

In conclusion, this study successfully confirms that making location and operational information of perpetrators of banditry, kidnapping, ritual killings, and other related nefarious crimes available in real time to security operatives to act upon in Nigeria is feasible.

6.0 Recommendations

The researcher hereby recommends that stakeholders such as local, state and federal governments adopt this study to realize a safer Nigeria.

For future studies, improving proximity accuracy, further miniaturizing tracker device for effective concealment, adopting more secure communication protocols, adaptation for underwater environments and provision of historical trail of places visited with the child or item of search until found by the tracker are suggested by the researcher.

7.0 Declaration of Conflicting Interests:

There is no conflict of interest to declare.

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