

Implementation of A Smart System for Combating Human Kidnapping

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Abstract

The paper presents the implementation of a system for combating human kidnapping using smart objects and Internet of things. The implementation contains the technical details of the hardware and software requirements, the mapping of the experimental testbed, implementation procedure and user interface of the application. The case study of kidnapped victims between Ibadan, Oyo State and Ilishan Remo, Ogun State in Nigeria was carried out to test the adequacy and practical functions of the application. The evaluation and comparative analysis of the system on the basis of coverage area, cost incurred in deployment, positioning accuracy and signal sensitivity is carried out and the result obtained presented.

1. Introduction

The literature review of existing studies carried out on combating human kidnapping using smart objects and Internet of things has been presented in Akinyokun et al, 2022 and Omoruyi, 2023. The architecture of the Smart system for combating human kidnapping has been presented in Akinyokun and Omoruyi, 2023. The implementation of Smart system contains the technical details of the hardware and software requirements, the mapping of the experimental testbed, implementation procedures and user interfaces of the application. A case study of the application for monitoring a presumed kidnapped victim between Ibadan, Oyo State and Ilishan Remo, Ogun State, in Nigeria was carried out to test the adequacy and practical functions of the system. The evaluation and comparative analysis of the system is based on coverage area, cost incurred in deployment, positioning accuracy and signal sensitivity.

2. Implementation Procedure

The implementation procedure is comprised of:

- System hardware and software requirements.
- Experimental test-bed setup.
- Case study of simulated victim.
- Object recognition and identification module.

2.1. System Hardware and Software Requirements

The technical details, specification and functional requirements of the hardware and software used stated as follows:

• Hardware Requirements

The hardware requirements are GPS modules, GSM modules,

RFID tags, antennas and readers, IP cameras, Arduino-based microcontrollers, Raspberry Pi and cloud servers. The research utilised ESP32 SIM800L T-call GPRS Microcontroller and NEO 6M GPS modules for the GPS tracking. The components are shown in Figure A combination of these two modules allows for a seamless tracking of an object at any location and at any time if it is within the signal coverage of the underlying GSM network. The ESP32 SIM800L T-Call GPRS features very low power consumption when in sleep mode especially when integrated with batteries having a long standby time. The NEO 6m GPS has reliable signal reception sensitivity. The module is controlled by AT commands via UART and supports both 3.3V and 5V logic level. The ESP32 SIM800L offers the advantage of portability. These are depicted in Figures 2.1(a), 2.1(b) and 2.1(c).



Figure: 2.1(a): ESP32 SIM800L Module (front-side) **Figure 2.1(b):** ESP32 SIM800L Module (back side)



Figure: 2.1(c): ESP 32 SIM800L GPRS Module and NEO6m GPS Module

A critical block shown in Figure 2.2 is the Network Switcher which consists of two GSM module, one serving as the primary medium for Internet connection and the other serving as backup. The Network Switcher ensures that on occasions where there is no network on the primary GSM module, signal reception is switched

to the secondary GSM module with a different SIM carrier provider. This arrangement is aimed at reducing blind spots as much as possible and improves the chances of always knowing the whereabouts of the victim.

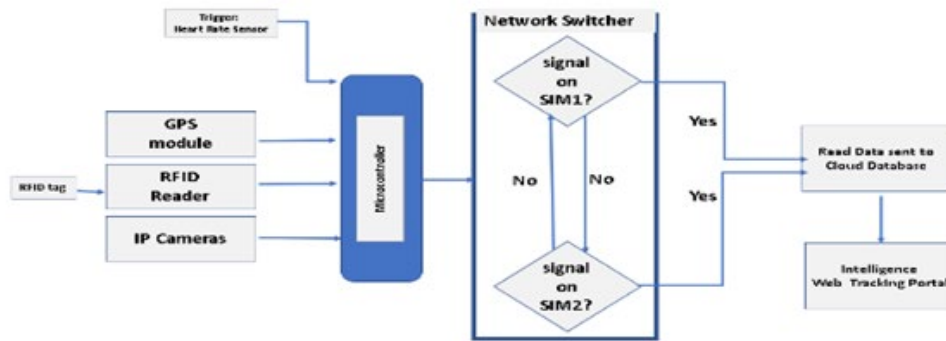


Figure: 2.2: Flowchart of System Implementation

The complementary RFID tracking subsystem made use of wearable RFID tags, antennas and readers strategically stationed in designated landmarks. The RFID sub-system also supports multi-detection of tags and offers a high baud rate that ranges

from 2400 bps to 19200 bps. The chosen RFID reader used in the implementation has a tag read range of 10 Metres. It is equipped with an antenna to extend the signal coverage. These are depicted in Figures 2.3(a), 2.3(b) and 2.3(c).



Figure: 2.3 (a): RFID Reader



Figure: 2.3(b): RFID Tag (Adhesive Version)



Figure: 2.3(c): RFID Tag (Wearable Wristband)

Table 2.1 and Figure 2.4 shows the RFID reading distance with the tag no barrier and obstructed by various barriers.

| BARRIER | RFID READNG DISTANCE (meters) |
|-----------|-------------------------------|
| None | 10 |
| Pocket | 10 |
| Shoe sole | 9.4 |
| Book | 9.1 |
| Bags | 9.5 |
| Metal | 8.8 |
| Plastic | 10 |

Table 2.1: RFID Reading Distance (meters) vs Barrier Type



Figure: 2.4: Graph of RFID Reading Distance vs Barrier Type

• Software Requirements

The system is developed using Python (version 3.11.4), PHP (version 8.2) and JavaScript (ECMAScript ES6) programming languages, MySQL (version 8.0) database management system, XAMPP as the local server and Google Map API as the mapping and geo-coding platform. Recognition AWS Cloud services and YOLOv8 (You-Only-Look-Once) algorithm are also utilised in the development of the Facial recognition and identification module of the system.

2.2. Experimental Test-Bed Setup

The research was conducted on the Housing Estate at NorthGate, Sasa, Ojoo, Federal School of Statistics zone, Ibadan, Oyo State, Nigeria. It is in the Southern part of Oyo State. The aerial view of the housing estate landscape is shown in Figure 2.5. It is located within the following satellite coordinates (7.477847) and (3.907565) to the north of the estate and (7.478070) and (3.908681) to the south of the estate. The position tracking of an assumed kid-napped victim was used as a case study for the research.

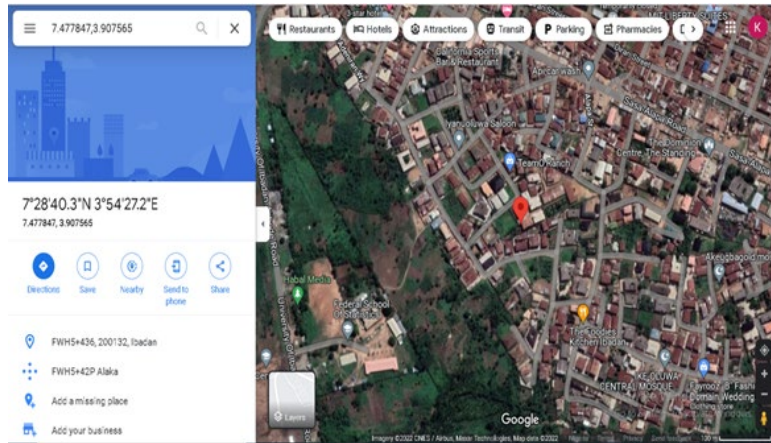


Figure: 2.5: Area View of Experimental Test-bed Location: Housing Estate, North Gate, Federal School of Statistics Zone, Ibadan, Oyo State, Nigeria

Figure 2.5 was captured using Google Maps platform. The coordinate of the area was utilized in the geolocating. The red marker on the centre of the map indicates the current position of the simulated assumed victim. The application is activated by

clicking on a web browser and entering the web address of the application in the address bar, which will take the user to the home page as depicted in Figure 2.6.

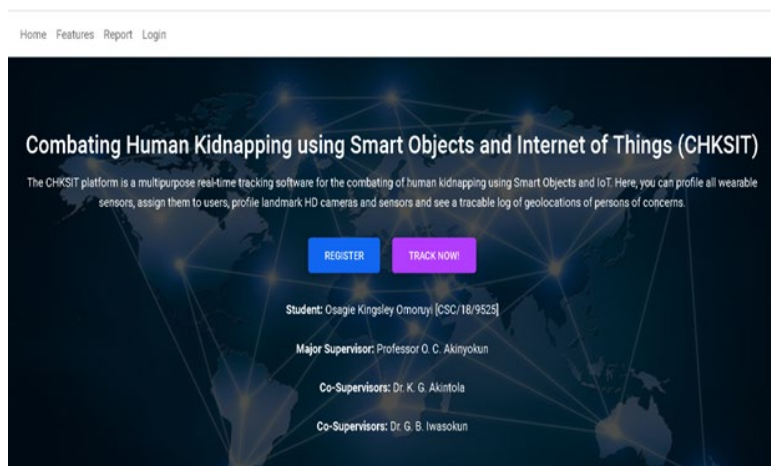


Figure: 2.6: The Landing Page of Web Application

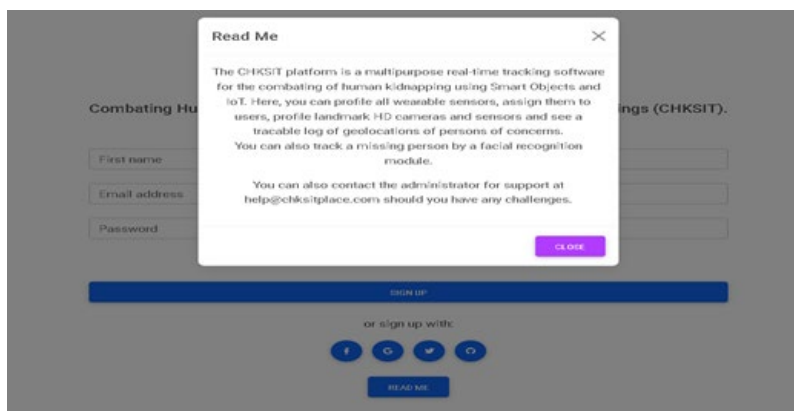


Figure: 2.7: Read Me Pop-Up Modal Showing Brief Description of Software

When the “Read Me” button is clicked, it opens the page showing a brief description of the system as shown in Figure 2.7. The user is taken to the login page when he or she clicks on the “Login”

button. On this page, the user registers as the System Administrator to use the system for the first time as shown in Figure 2.8.

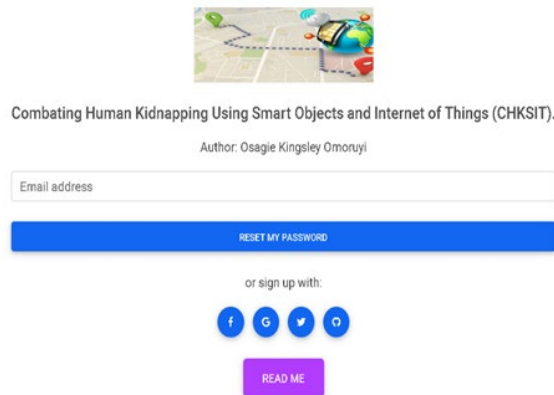


Figure: 2.8: Password Reset Screen to Help Users Recover their Forgotten Password

On successful registration, the user is expected to sign into the system through the view shown in Figure 2.8. There is a “Password Reminder” module to assist the users in cases where they cannot recall their correct username or password. On successful login, the user is taken to the configuration page, where the following entities can be set up:

- Profile
- Mobile Electronic Devices
- Immobile Electronic Devices
- Landmarks
- Geo-locations

After a successful configuration of the system, an enrolled user can be tracked anywhere in the world if he or she is putting on the wearable device. Due to the unpredictability of location in kidnapping cases, no perimeter restriction is set up on the system. This is to enable the possibility of a missing victim to be tracked

from any location.

2.3 Case Study of Simulated Victim

An RFID reader and IP camera were installed at strategic locations and landmarks. The RFID reader scans and monitors the environment to read tags within its range that have been registered on the database. Similarly, the IP camera, which is linked with a pre-trained facial recognition and identification model monitors the environment to compare the faces within its field coverage to faces on the database that has been flagged for surveillance search. The RFID reader serves as a fail-safe alternative to the GPS receiver which is battery operated and renowned for making it impossible to track when the battery drains out. When this is the case, any closest long-range RFID reader can pick up a signal from the wearable RFID tag on the victim’s dress accessories and trigger a notification message to the server room or web portal.

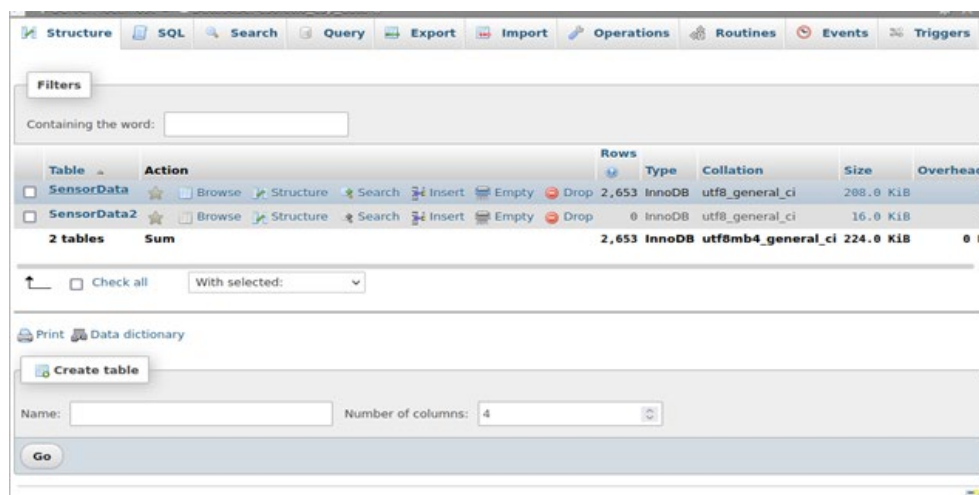
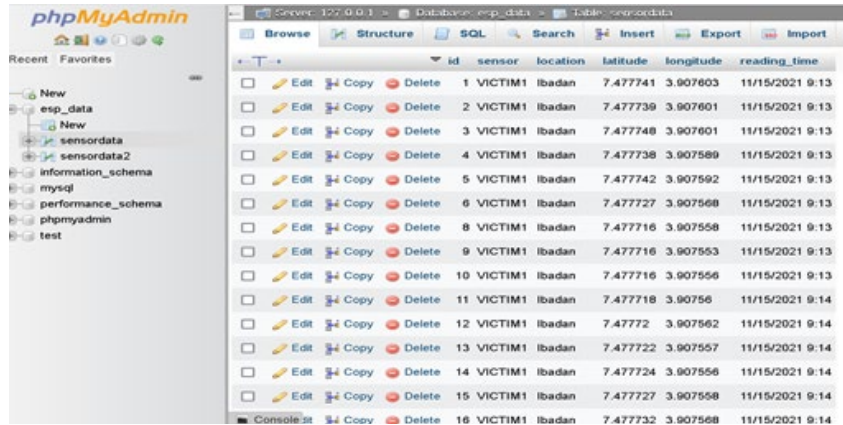


Figure: 2.9: PhpMyAdmin View of Database

Figure 2.9 shows the GPS recording sent to the remote database server during the period of the simulated kidnapping scenario. A total of 2,653 records consisting of the longitude and latitude

coordinates was captured during the tracking period from Ibadan, Oyo State to Ilisan Remo, Ogun State.

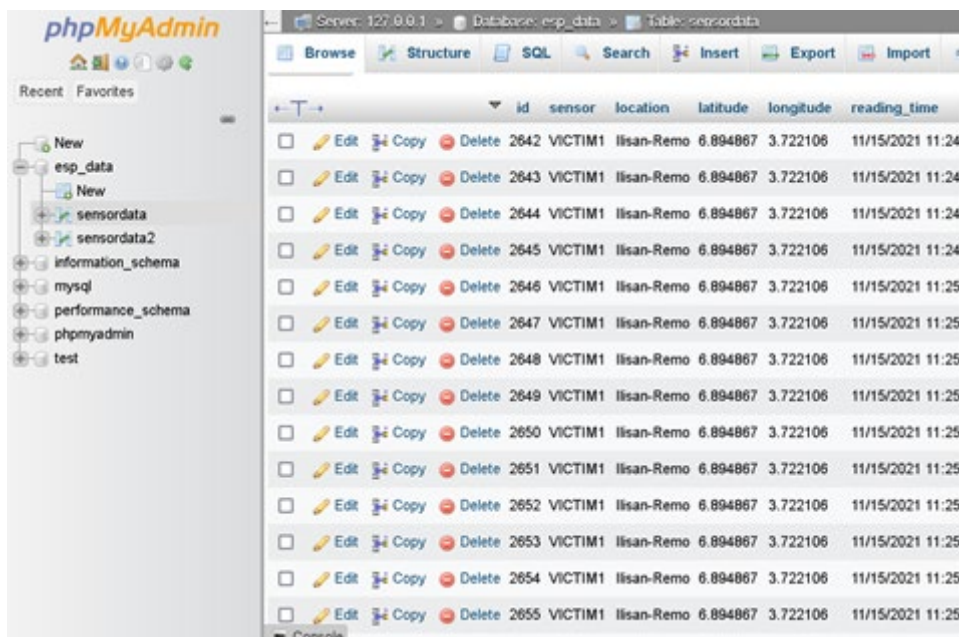


The screenshot shows the phpMyAdmin interface with a table named 'sensordata' in the 'esp_data' database. The table contains 16 records of GPS coordinates for Ibadan, Oyo State. Each record includes an ID, sensor name, location, latitude, longitude, and reading time.

| id | sensor | location | latitude | longitude | reading_time |
|----|---------|----------|----------|-----------|-----------------|
| 1 | VICTIM1 | Ibadan | 7.477741 | 3.907603 | 11/15/2021 9:13 |
| 2 | VICTIM1 | Ibadan | 7.477739 | 3.907601 | 11/15/2021 9:13 |
| 3 | VICTIM1 | Ibadan | 7.477748 | 3.907601 | 11/15/2021 9:13 |
| 4 | VICTIM1 | Ibadan | 7.477738 | 3.907589 | 11/15/2021 9:13 |
| 5 | VICTIM1 | Ibadan | 7.477742 | 3.907592 | 11/15/2021 9:13 |
| 6 | VICTIM1 | Ibadan | 7.477727 | 3.907568 | 11/15/2021 9:13 |
| 8 | VICTIM1 | Ibadan | 7.477716 | 3.907558 | 11/15/2021 9:13 |
| 9 | VICTIM1 | Ibadan | 7.477716 | 3.907553 | 11/15/2021 9:13 |
| 10 | VICTIM1 | Ibadan | 7.477716 | 3.907556 | 11/15/2021 9:13 |
| 11 | VICTIM1 | Ibadan | 7.477718 | 3.90756 | 11/15/2021 9:14 |
| 12 | VICTIM1 | Ibadan | 7.47772 | 3.907562 | 11/15/2021 9:14 |
| 13 | VICTIM1 | Ibadan | 7.477722 | 3.907557 | 11/15/2021 9:14 |
| 14 | VICTIM1 | Ibadan | 7.477724 | 3.907556 | 11/15/2021 9:14 |
| 15 | VICTIM1 | Ibadan | 7.477727 | 3.907558 | 11/15/2021 9:14 |
| 16 | VICTIM1 | Ibadan | 7.477732 | 3.907568 | 11/15/2021 9:14 |

Figure: 2.10: PhpMyAdmin View of Database – GPS Coordinates Ibadan Area

Figure 2.10 shows a subset of the GPS coordinate recording covering the Ibadan, Oyo State axis of the simulated route for this experiment.



The screenshot shows the phpMyAdmin interface with a table named 'sensordata' in the 'esp_data' database. The table contains 14 records of GPS coordinates for Ilisan Remo, Ogun State. Each record includes an ID, sensor name, location, latitude, longitude, and reading time.

| id | sensor | location | latitude | longitude | reading_time |
|------|---------|-------------|----------|-----------|------------------|
| 2642 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:24 |
| 2643 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:24 |
| 2644 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:24 |
| 2645 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:24 |
| 2646 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2647 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2648 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2649 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2650 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2651 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2652 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2653 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2654 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |
| 2655 | VICTIM1 | Ilisan-Remo | 6.894867 | 3.722106 | 11/15/2021 11:25 |

Figure: 2.11: PhpMyAdmin View of Database – GPS Coordinate of Ilisan Remo Area.

Figure 2.11 shows a subset of the GPS coordinate recording covering the Ilisan Remo, Ogun State axis of the simulated route for this experiment.

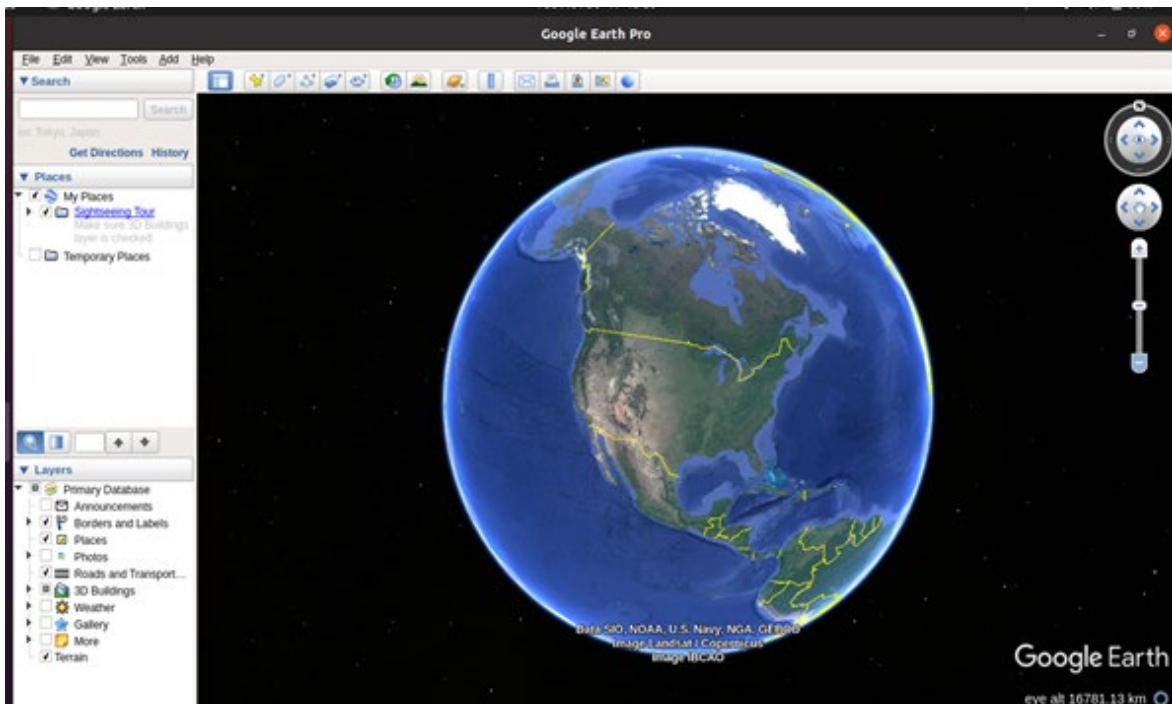


Figure: 2.12: Google Earth Pro Software used for GPS Coordinates Mapping and Tracking

The captured data stream was connected to the latest edition of Google Earth Pro, version 7.3 to view and monitor the progression of the movement of the kidnapped victim.

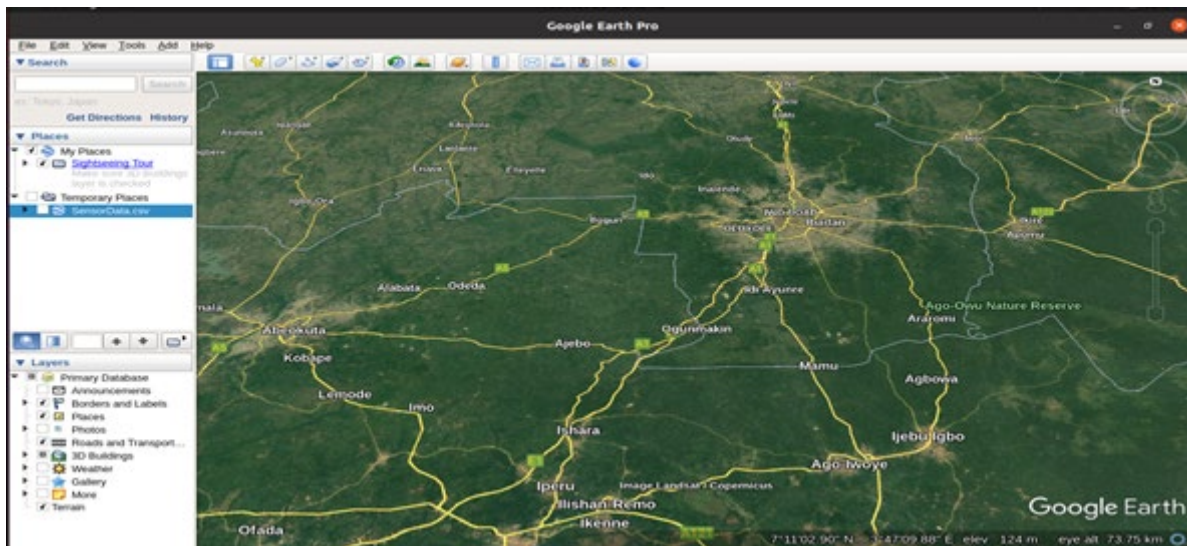


Figure: 2.13: Testbed Area used for Simulated Route between Ibadan and Ilishan-Remo.

Figure 2.13 shows the test bed area where the simulated kidnapping tracking was carried out. The land area spans from Ibadan through Ibadan-Lagos expressway and terminating the tracking at Babcock University, Ilishan Remo, Ogun State.

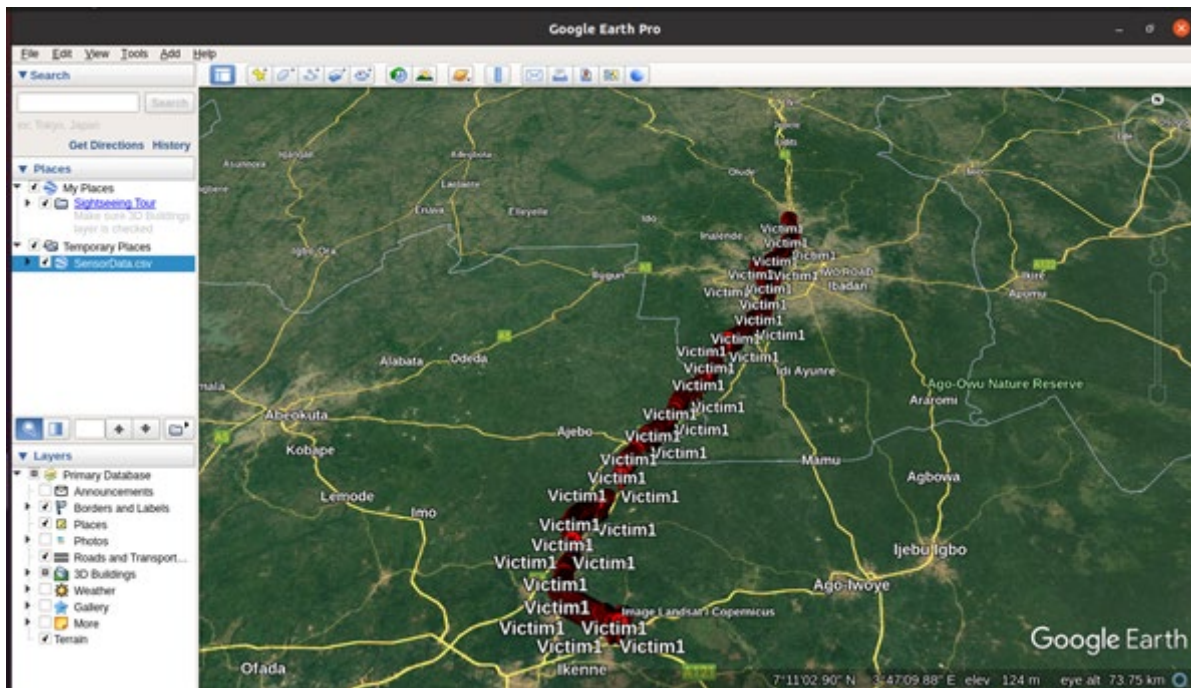


Figure: 2.14: Google Earth Pro Software Showing the Kidnap Victim on Lagos-Ibadan Express Road between Ibadan, Oyo State and Ikenne, Ogun State.

Figure 2.14 shows the timeline of the victim's movement. It is depicted with a dynamic red marker on the map. The plot was generated at a rate of one record per second, hence the crowded

marker of the victim's location on the map. This was done to make sure we can track the location of the victim in near real time as much as possible, specifically per seconds in this instance.

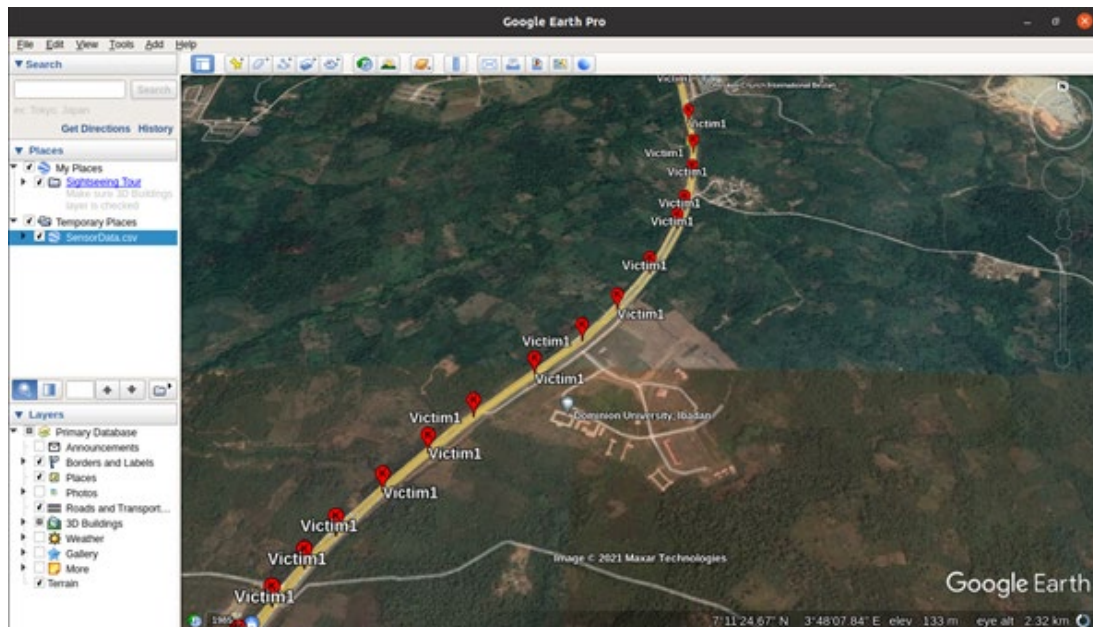


Figure 2.15: Google Earth Pro Software Showing the Kidnap Victim along Dominican University, Ibadan, Along Lagos-Ibadan Express Way

On Figure 1.15, the map plot rate was set at a record per minute, hence an enhanced timeline was achieved.

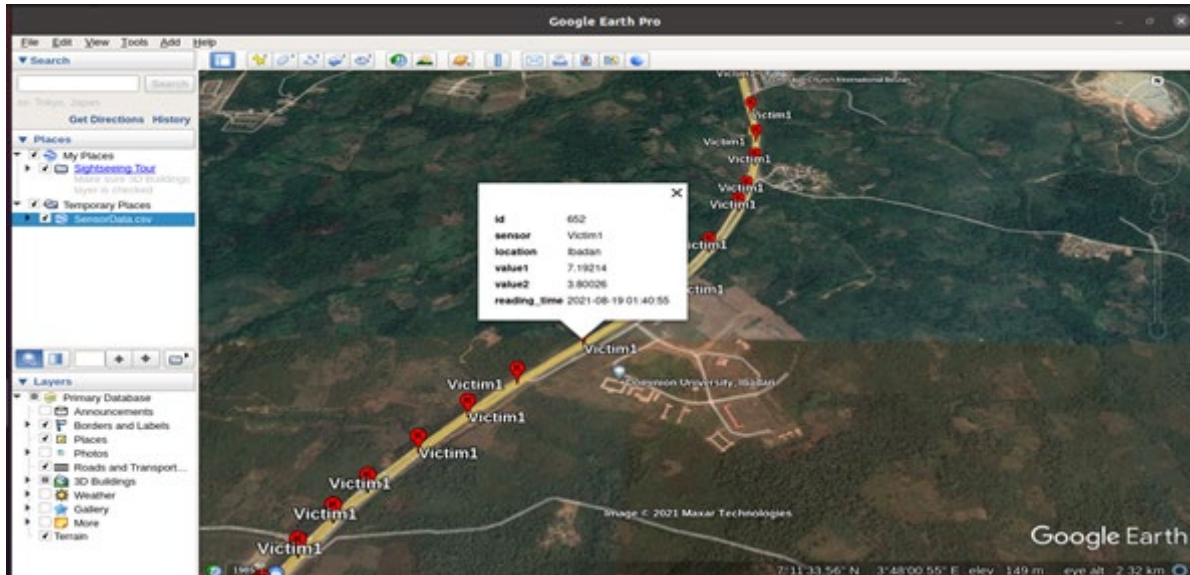


Figure: 2.15: Google Earth Pro Software Showing the Coordinates and Timestamp of Signal Capture

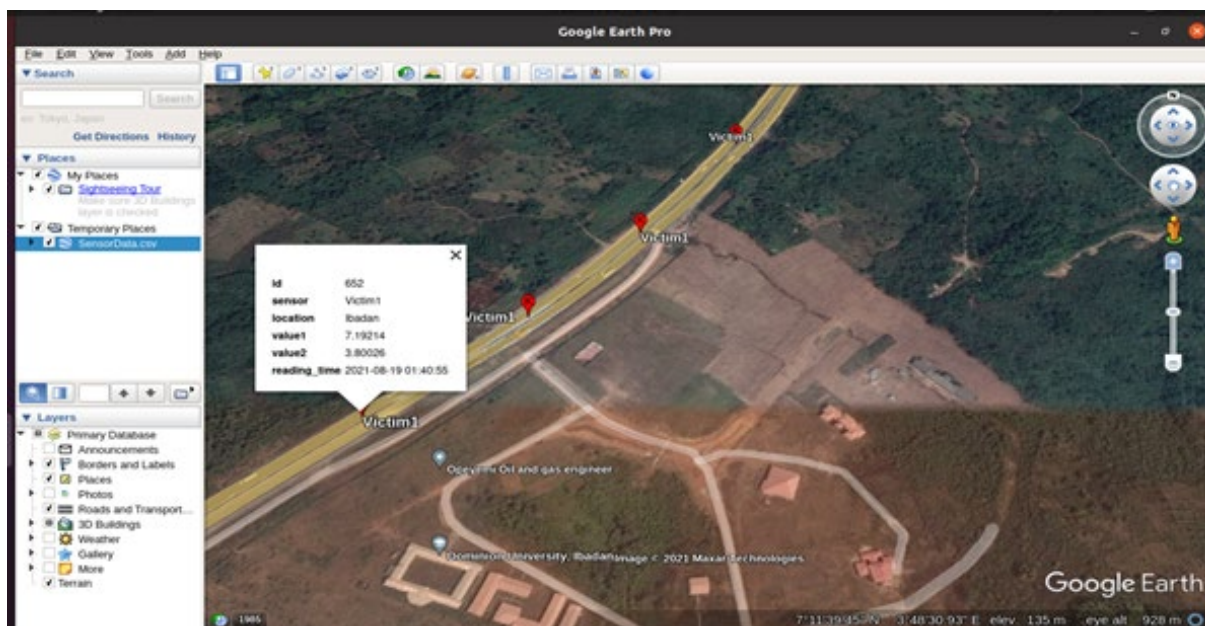


Figure: 2.16: Google Earth Pro Software Showing Victim is Trackable Along Lagos-Ibadan Express

On Figures 2.16 and 2.17, an info tip marker was generated for each point. This is useful in a worst-case scenario when the wearable GPS receiver has run out of power supply due to a drained battery.

The platform provides in addition to historical coordinates, the timestamp of any point of interest.

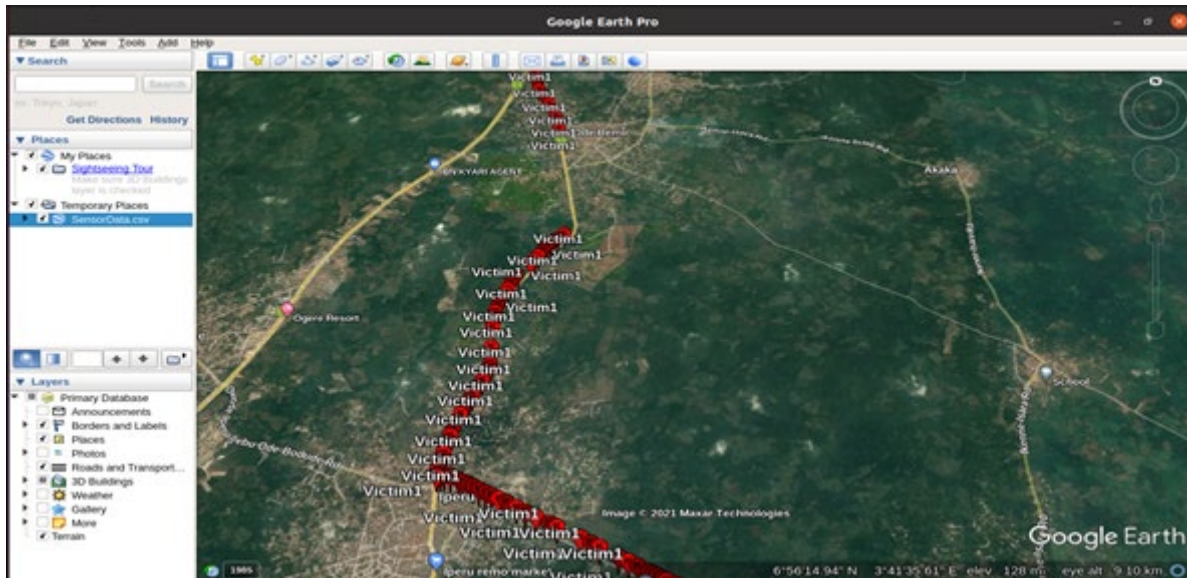


Figure 2.17: Google Earth Pro Software Showing Victim Branching off Lagos Ibadan Express.

2.18 shows a no-signal zone between two close cities, Ode Remo and Ilishan Remo in Ogun State. This is a potential landmark for RFID Reader installation to serve as a fail-safe alternative.

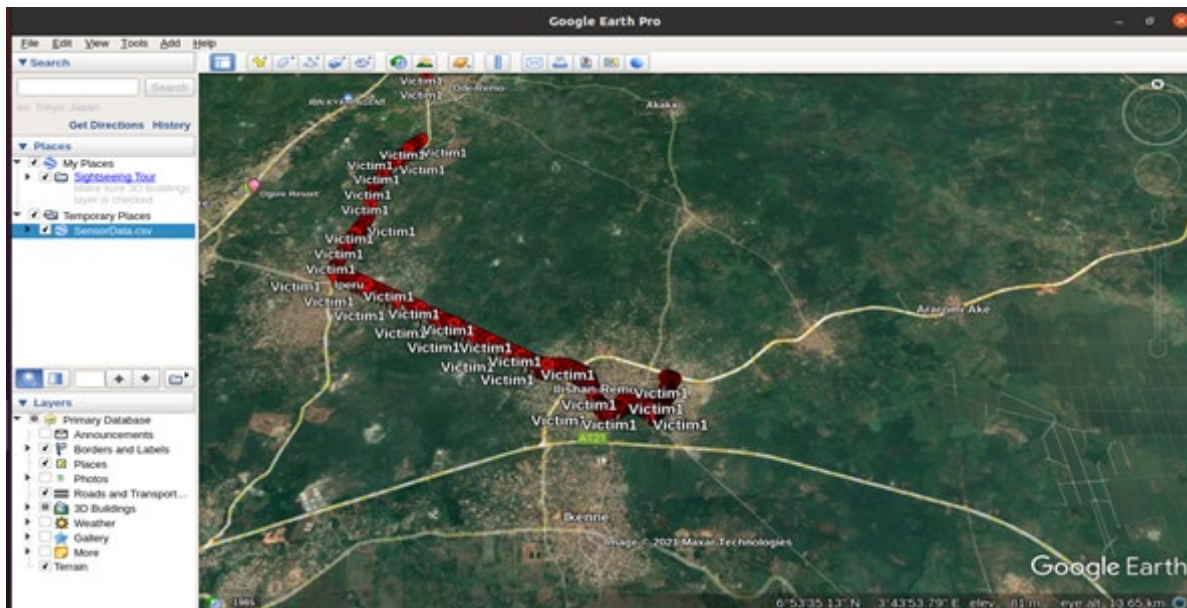


Figure 2.18: Google Earth Pro Software Showing Victim Branching off Lagos Ibadan Expressway and Approaching to Ilishan Remo, Ogun State

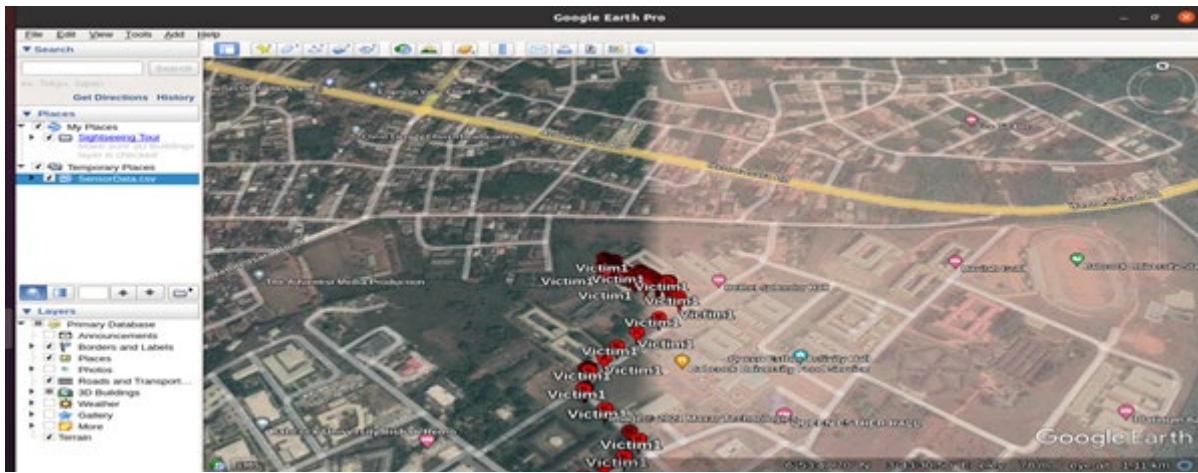


Figure: 2.19: Google Earth Pro Software Showing Victim Arriving Babcock University, Ilisan Remo

Figures 2.18 and 2.19 show the crowded position markers depicting the slow movement of the victim as the course has moved off the expressway to an intra-city road. The end of the tracking terminates at Bethel Splendor Male Hall at Babcock University, Ilisan Remo, Ogun State.

2.3. Object Recognition and Identification Module

Two datasets were utilised in training the facial recognition and identification model. First, the Flickr-Faces-HD Dataset (FFHQ) public facial image dataset, which consists of human faces which were crawled from Flickr, was utilised. The dataset consists of

70,000 high quality PNG images at 1024 by 1024 resolution. A bespoke facial dataset was generated by taking pictures of 10 volunteers. An image recognition module was developed by training a model using 300 facial images inclusive of augmented images. The augmentation was done by skewing the images, varying the brightness, and flipping the images on its horizontal axis. This enabled us to increase the quantity of the training and testing image set. An instance of the data set is shown in Figure 2.20. Figure 2.21 shows the resultant ability of the trained model to be able to predict the age range, gender and other important features that can match a reported kidnapped victim’s features.



Figure: 2.20: Subset of Images of Facial Recognition and Identification Dataset

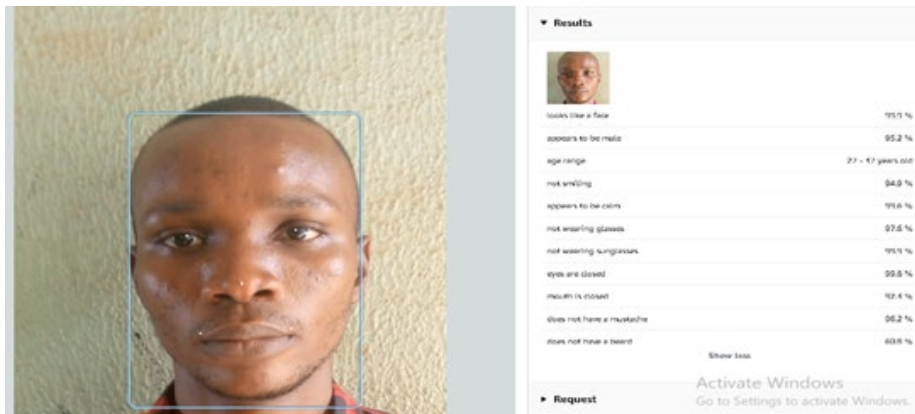


Figure: 2.21: Subset of Images of Facial Recognition and Identification Dataset

Figure: 2.22 shows the ability of the model to identify a person with a similarity score of 99.9% irrespective of the difference in facial expression.

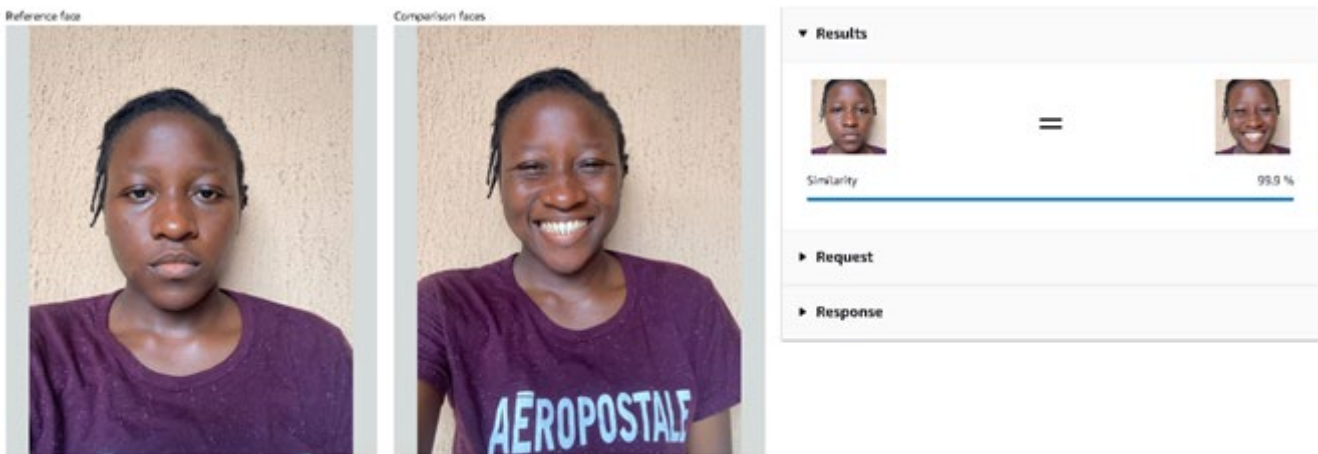


Figure 2.22: A subset of images of the Facial recognition and identification dataset

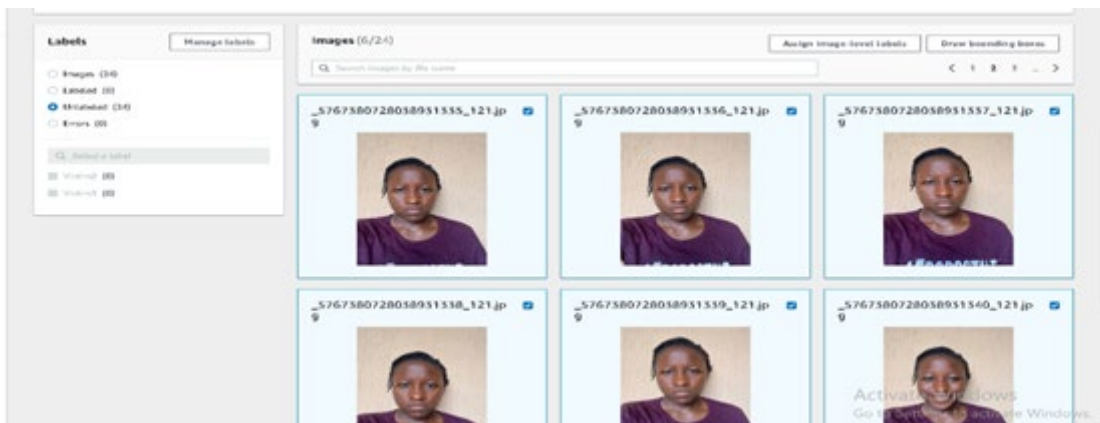


Figure: 2.23: A subset of images of the Facial recognition and identification dataset

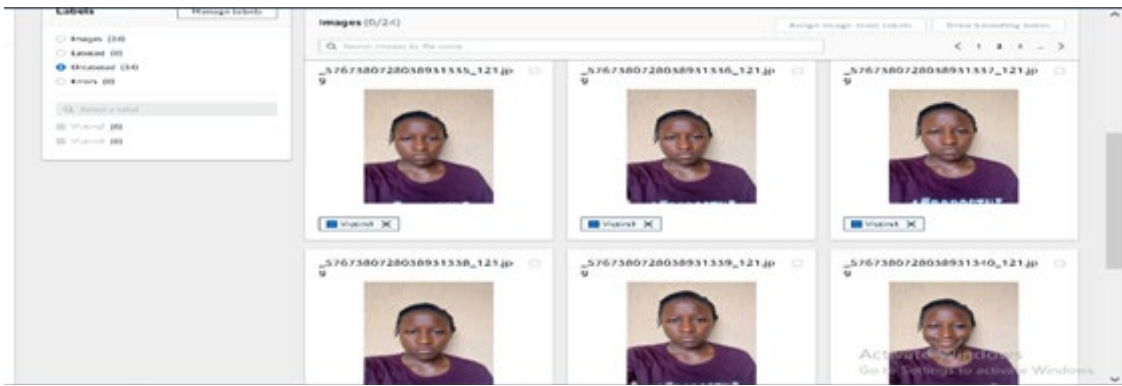


Figure: 2.24: A subset of images of the Facial recognition and identification dataset

Figures 2,23 and 2.24 show the buildup of the dataset from unlabeled data to a label dataset (Victim1) respectively. The AWS Rekognition engine was used in the training. The dataset was divided into a training set and test set on an 80:20 ratio. The final model produced a recognition accuracy of above 91%.

3. Comparative Analysis with Existing Systems

The results obtained in this research work were compared with other

existing systems. The comparisons were based on the availability to a fail-safe alternative to GPS signal, victim identification, 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 3.1 shows the comparative analysis of the system with other works.

| System | Technology | Facial Recognition | Fail-safe alternative | Scalability | Cost | Network Switching |
|-----------------------------|------------------------------------|--------------------|-----------------------|-------------|----------|-------------------|
| Matthews et al., (2013) | GSM, GPS | No | No | Low | Low | No |
| Pankaj & Bhatia (2013) | GSM, GPS | No | No | Low | Moderate | No |
| Hadi et al., (2015) | Galileo Board, Webcam, OpenCV, WSN | Yes | No | Low | Moderate | No |
| Adewole (2019). | GPS, RFID, Camera | Yes | No | High | Moderate | No |
| Poonkodi et al., (2019) | GSM, RFID | No | No | Medium | Low | No |
| Idashaba et al. (2020) | GSM, GPS | No | No | Low | Low | No |
| Tiwakar S. A. et al. (2020) | NodeMCU, RFID, ESP8266, Android | No | No | Medium | Low | No |
| Kjutar D. Z. et al. (2021) | GSM, GPS | No | No | Low | Low | No |
| Kamalrag et al. (2021) | GSM, GPS, RFID | No | No | Medium | Low | No |
| Shyelesh et al. (2022) | GSM, GPS | No | No | Low | Low | No |

Table 3.1: Comparative Analysis with Existing Systems

4. Conclusion of Research Work

The primary focus of this paper is on the following:
 Implementation of a smart system for combating human kidnapping using Smart Objects and Internet of Things. Carry out the case study of tracking kidnapped victim and evaluate the system and carry out the comparative analysis with other existing works. The research carried out an extensive and comprehensive review of Smart Objects and Internet of Things (IoT) and their application to solving the menace of kidnapping. Smart Objects and Internet of Things (IoT), RFID, GPS, Microcontrollers, GSM module, Smart cameras were used in the research. A web application portal was developed for easy profiling of devices, victims, landmarks

and real-time tracking of object and object recognition with a view to improving the security awareness of a community and providing data for informative investigation and efficient tracking of kidnapped victims. The study successfully tracks, in real-time victims wearing a covert GPS device and recognizes simulated victims at landmarks using object recognition technology at 90% accuracy. RFID has been used to implement fail-safe alternatives in areas where there is no signal or weak GPS signal or there is loss of power on the GPS device. The research established a system for combating human kidnapping harnessing the features of Smart Objects and Internet of Things. Development of a hybrid Smart Objects and IoT-based system with fail-safe alternative that

increases the availability and accuracy of the localization data sent to the cloud service and foster facial identification of kidnappers and victims.

The testbed area spans between Ibadan and Ogun State, hence more landscape or inter-state road network needs to be covered. Due to the nature of the express road networks, the effects of signal diffraction usually associated with high rise buildings and skyscrapers could not be investigated. The application developed in this research is a Web Application. The development of a mobile version of the system will ensure its mobility and seamless real-time monitoring of persons. For budgetary constraints, only two volunteers could be accommodated. Experiment on larger number of volunteers is recommended. Integration of the system with existing National database like the National Identity Management Commission (NIMC) portal is suggested for further study. A further look into nanotechnology can be carried out to improve the miniaturization of devices.

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