

Drone (UAV) for Monitoring Traffic Light Violation

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Abstract Numerous Nigerian cities have begun to experience expansion and modern development, this has resulted to rapid increase in population density which gives rise to the urgent requirement for smart solutions to cope with the demands applied to the infrastructure of cities especially in the area of traffic regulation and safety of road users. This study proposes an intelligent, autonomous Unmanned Ariel Vehicle (UAV) traffic monitoring and policing system to combat traffic violations. In this paper, the shortcomings of traffic policing and emergency response handling systems was investigate. An intelligent, autonomous UAV-enabled solution was proposed and developed. Several scenarios of traffic monitoring and policing system were considered in the simulation: traffic light violations and accident detection, mobile speeding traps and automated notification, congestion detection and traffic rerouting, flagged stolen vehicles, pending arrest warrants and vehicle tracking using UAVs, and autonomous emergency response handling systems. The results of the simulated system were presented and discussed.

Keywords: Smart city · Traffic monitoring · Traffic policing · UAV · Emergency response · Accident detection

I. Introduction

Unmanned aerial vehicles (UAVs), commonly known as drones, are gaining considerable interest in applications such as surveillance, mapping, and remote sensing [1]. UAVs are gaining considerable interest in transportation engineering in order to monitor and analyze traffic [2]. UAV use is still in its infancy and that progress in advanced image processing techniques and technologies used in the construction of UAV systems will lead to an explosion in the number of applications, which will result in increased benefits for society, reducing unpleasant situations, such as congestion and collisions in major urban centers of the world [2]. The growing interest in the use of UAVs is based on many factors, including reduced cost of acquiring these systems, the availability of trained operators, low risk to

human life, and ease of use. Due to these advantages, as well as offering a good resolution and tracking capabilities, they are starting to be used increasingly in more fields [2].

UAVs became commonly used tools for data acquisition after they were first used in geomatics applications, providing alternatives to classical photogrammetry and 3D mapping to present data in a suitable format for architects and engineers [3][4]. Through photogrammetry techniques and remote sensing, structure from motion (SFM) applications allow for the creation of 3D models of different objects, buildings, or areas [5]. In the last few years, UAVs have found their applicability in the field of civil engineering, especially in transportation engineering, in order to supervise and monitor traffic [6]. The main benefit of traffic monitoring with UAVs is that they can be deployed to many different places, for example, a local council may want to gather information on the use of infrastructure, such as roads, bridges, train tracks, and so on [2].

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The growth in traffic volume and the growth of global travel makes traffic monitoring a problem of interest and a major challenge in many countries around the world. In this context, it is expected that UAVs will be an emerging solution to this challenge [7]. The bird's eye-view of the camera provided by UAVs improves the traditional methodologies used in traffic monitoring but the recognition and tracking of moving vehicles still remains a challenging problem, depending on the accuracy of image registration methods [8] [9]. UAVs represent a potential solution to support many aspects of the existing traffic monitoring systems such as surveillance and collision avoidance [10]. UAVs have been applied for the monitoring of environmental parameters, e.g., air pollution, land surface temperature, flood risk, forest fire, road surface distress and land terrain monitoring [11] [12], and also pedestrian traffic monitoring and disaster evacuation [13][14].

A comprehensive guide on the potential benefits and applications of UAVs in wireless communications and investigation of the important challenges and the fundamental tradeoffs in UAV-enabled wireless networks (providing key guidelines on how to analyze, optimize, and design UAV-based wireless communication systems) were presented by [15]. Key UAV challenges such as three-dimensional (3D) deployment, performance analysis, air-to-ground channel modeling, and energy efficiency were explored along with representative results. They introduced fundamental open problems and potential research directions pertaining to wireless communications and networking with UAVs.

A systematic review of multiple regional and national articles to reflect the best practices utilized in these countries for crime prevention

was carried out by [16]. Drones are futuristic machinery complimenting the existing workforce in law-and-order scenario [16]. UAVs provide scientific contributions in the applications for civil engineering, especially those related to traffic monitoring [2]. Emerging technology of UAV in transportation was analysed by [7], to determine performance measures, network and communications, software architecture, privacy, and security concerns.

Research on using UAVs for vehicle detection by means of deep learning techniques was investigated by [17]. Accuracy improvements and computation overhead reduction, similarities and differences of various techniques was the focus[17]. A comprehensive review of UAVs, types, swarms, classifications, charging methods and regulations was provided by [18]. They examined application scenarios, potential challenges and security issues and finally identified future research directions to further hone the research work.

Developing cities (including Nigeria) have begun to experience expansion and modern development, resulting to the rapid increase in population density, which gives rise to the urgent requirement for smart solutions to cope with the demands applied to infrastructures such as traffic regulation and safety of road users. Through investigating the shortcomings of traffic policing and emergency response handling systems, this study proposes an intelligent, autonomous Unmanned Ariel Vehicle (UAV) traffic monitoring and policing system to combat traffic light violations.

II. Materials and Method

UAV using Arduino is an IOT based project. Arduino was used for code execution, motion

sensor for detecting movement, ESP32 cam for motion capturing and system alert of a prototype vehicle violating traffic light. The project required some software as well as hardware.

Software Components used are:- Arduino IDE and Telegram BOT. The Hardware Components used are:- Wifi Module, Relay , Arduino, Motion sensor, Resistor, Breadboard, Jumper wire, ESP32 CAM, Battery, LED and Drone.

A. Hardware Components

i. Wifi module

As presented in Figure 1 (a), Wi-Fi modules was used to send and receive data over Wi-Fi. The module was used as a link between the ESP module on the drone and the Arduino microcontroller. The module was connected to a Wi-Fi network enabling signal connection between the Arduino and ESP CAM.

ii. Arduino

The entirety setup was constructed around an Arduino Microcontroller (Figure 1c). This microcontroller, featuring 54 Digital I/O pins and 16 Analog I/O pins, facilitated the interfacing of sensors and actuators essential for achieving the intended functionalities. The microcontroller's 8-bit resolution ADC pins were employed to read and process signals from the motion sensor, Wi-Fi module and ESP CAM. Output pins for the LEDs were configured on the Arduino Microcontroller.

iii. Motion sensor

As presented in Figure 1(d), a motion sensor capable of covering an area of over 15 feet was connected to pin 12 of the Arduino. The motion sensor is active only when the stop signal is activated.

iv. Resistor

An ON/OFF switch was utilized to activate and de-activate the sensor and camera whenever require as per situation. A pull-up resistor of 10K was connected in series with the switch in order to solve the de-bouncing problem.

v. Breadboard and jumper wire

Breadboard and jumper wires were used for the circuit connection (Figure 1f and 1g). Bread board was utilized for easy connection of the modules and components of the set up without soldering. Jumper wires were used to interconnect the components of the circuit without soldering. Individual jump wires were fitted by inserting their “end connectors” into the slots in the breadboard and the header connector of modules or controllers.

vi. ESP 32 cam

The ESP32-CAM (Figure k) was configured to interface with the telegram bot and Arduino through the Wi-Fi modem. The ESP32-CAM was fastened to the drone so that it can capture images when it receives signals from the Arduino.

vii. Lithium Battery

lithium-ion batteries were employed as power sources in the drone and also for the Arduino (Figure 1i). Batteries were utilized to ensure uninterrupted power supply. A 12v battery was used for the Arduino set up while a 7.5 volt was used for the drone and camera set up.

viii. Led light

A light-emitting diodes (LEDs) were used in the set up to simulate traffic lights (Figure 1j).

LEDs representing the different colours of a traffic light were connected to the output pins of

the Arduino which was programed to simulate the required traffic scenario.

ix. Drone

A drone aircraft (Figure 1k), using autonomous

software-controlled flight plan in its embedded systems, was utilized for the set up. The drone with the ESP camera attached to it captures movement from above.

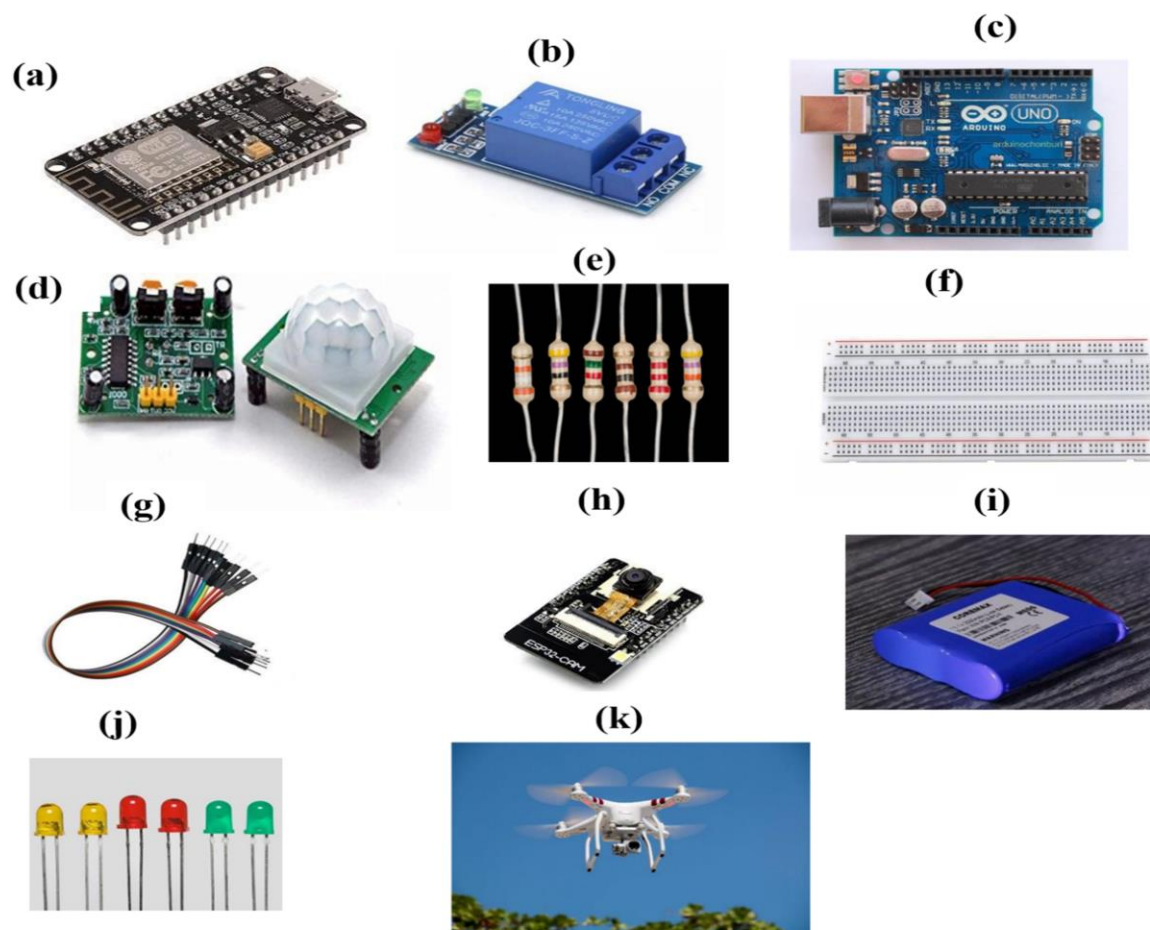


Figure 1: Hardware Components

B. UAV Set-up

i. Traffic light setup

The Arduino Uno was programed through Arduino IDE to regulate the traffic light (LED) in sequence. The sequence was STOP, READY and MOVE (Red, Yellow and Green).

ii. Motion Sensor Setup

The motion sensor is connected to the red light of the traffic light control in the circuit. This ensures the motion sensor is switched on when the light turns red. The motion sensor is looped

with a Wi-Fi modem. For this mechanism to operate in sequence a programmed microprocessor is used to control the whole circuit (Arduino Uno).

iii. The Esp32 cam setup

The Arduino Uno is used to regulate the set-up components to sense and transmit detected signal to the Esp32 cam through the Wi-Fi modem. Immediately this signal is received the programmed Esp32 cam takes picture image of the vehicle detected violating traffic signal (on red light). The Esp32 cam is attached to the drone. After this image as been captured the Esp32 cam sends it to telegram through a telegram bot as programmed. The Esp 32 cam also uses Wi-Fi, this is used to receive signal from the sensor and send captured image through the telegram bot linked with the camera.

iv. Telegram bot setup

A Telegram Bot is a program that behaves like a normal chat partner with additional functions. It performs predefined tasks independently and without the user's involvement. A programmed Arduino Uno is used to create a link between the BOT and the ESP32 CAM through the following process:- Firstly, a Telegram bot is created for the ESP32 CAM; To start a conversation with the bot; A message is sent (led on to the bot, the ESP board receives the message and turns GPIO 2 on); Similarly, a message can be sent (led off, it turns GPIO 2 off) . When the ESP receives the message "State", the bot responds with the current GPIO state. Similarly, "Start message" is used to receive a welcome message with the commands to control the board. Figure 2 presents the telegram bot setup.

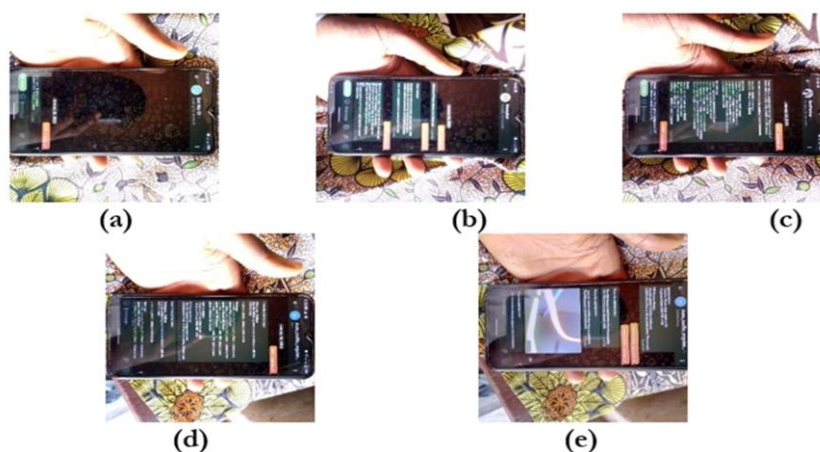


Figure 2: The telegram bot setup. (a) obtaining id for telegram link to esp32 cam using (Get My ID). (b) creation of telegram bot using (Manybot). (c) telegram bot creation guide using (BotFather). (d) telegram bot created with full link to esp 32 cam using a register name from BotFather (Auto_Trafficlight_Regulation). (e) successful captured image from esp 32 cam

C. Circuit Diagram and Wiring up the Components

Figure 3 is the circuit connection of all the components i.e. LED Light, Motion sensor,

relay and Wi-Fi module. The Wi-Fi module is further connected to the Arduino to control the lights and send detected signals to the Esp32 wirelessly. This finishes up the build process.

The motion sensor echo pin and trigger pin are connected to pin digital pin D7 and D8. The +Vcc pin is connected to +5V supply and GND pin is connected to ground pin of Arduino Uno board. The control (PWM) pin of motion sensor is connected to digital pin D9 of Arduino. Hence, motion sensor is used to detect motion of an upcoming obstacle (vehicle). For this project and components used, the preset level of distance between the sensor and prototype vehicle is fixed to 40 cm.

ESP32 Cam includes two power pins; 5V & 3.3V, the module is powered through the 3.3V/5V pins. The VCC pin of this module usually outputs 3.3Volts from the on-board voltage regulator but it can be configured to 5V output with the Zero ohm link close to the VCC pin. As soon as motion is detected, the wifi module sends signal 1 to the ESP32 camera which captures the Image of the obstacle (prototype vehicle) moving along the path of the motion sensor which is turned on when the red (traffic regulation) is on. An ON/OFF switch is utilized in order to activate and de-activate the sensor and camera whenever require as per situation. A pull-up resistor of 10K is connected in series with the switch in order to solve the de-bouncing problem. The simplest part of the UAV system using Arduino is the software part because it is simple and easy to understand. Note the ESP32 cam is attached to the drone which is stable at flights when turned ON and the camera is positioned directly towards the zebra crossing lane, in order to take image of the vehicle violating traffic regulation. Figure 4 presents, the testing of traffic light violation system

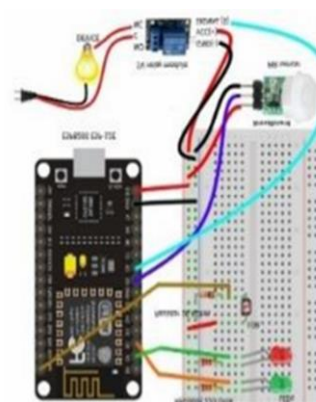


Figure 3: The Traffic Light detection Unit Circuit Diagram and Simultaneous Wireless Connection for Violation Detection

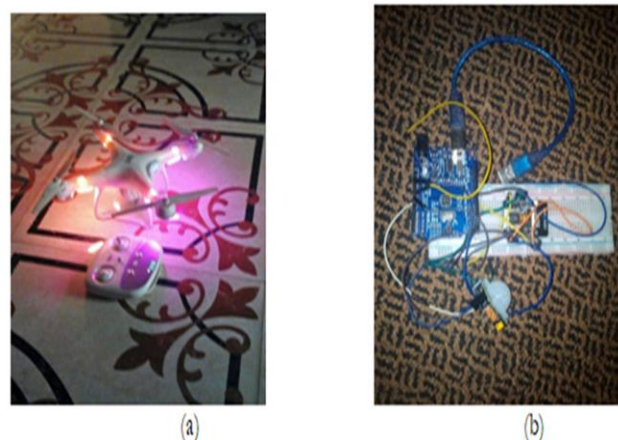


Figure 4: Testing of Traffic Light Violation System (UAV) (a) Drone Aviation System With Attached Esp32 Cam for Image Capturing (b) Violation Detection Unit Consisting of Motion Sensor, Wi-Fi module and Arduino.

III. Results and Discussion

A simulation was carried out to provide a proof-of-concept for the UAV surveillance system to detect traffic violations. Figure 5 below shows the ESP32 cam and telegram bot in action. The

camera captures and sends violation image. The detection rate for motion was high and image quality obtained was moderate in day light. The real time communication through telegram was effective with notification speed ranging between 2 and 5 seconds

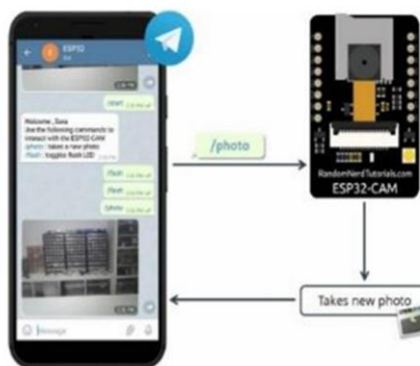


Figure 5: ESP32 Cam Connection with Telegram Bot, Capturing and Sending of Violating Image

IV. Conclusion

A Drone (UAV) for monitoring traffic light violation' was developed. The device was capable of detecting traffic violation and alerting the appropriate authorities when traffic was violated by a vehicle. A further improvement of the device for monitoring traffic light violation can integrate routine traffic policing tasks for issuing traffic violations and notifications to registered owners of vehicles crossing an intersection during a red light or crossing the speed limit of a designated zone, the latter being a dynamic solution using mobile UAV patrol units as opposed to statically placed detector nodes. The system can be expanded to consider more traffic policing scenarios. For example, the detection of driving while intoxicated (DWI) drivers by

monitoring the behavior of the vehicle with UAV patrol units.

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