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Application of SCADA Technology for the Automatic Monitoring & Control of Road Traffic

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Abstract—*This research proposes to adopt Supervisory Control and Data Acquisition Technology in the improvement of the performance of an already-existing intelligent traffic control system which was based on the application of fuzzy logic and ANN with the use of inexpensive and opensource materials such as the CDS photoresistors. Object-oriented system analysis was adopted in the modelling of the relational database system used in securely storing data related to road traffic. This database system also provides real time access to data for the end-users such as vehicle drivers and road traffic officials. Results obtained indicate that the SCADA-improved system outperforms the former system by not only providing intuitive GUI interface to the end-users which enables them to make informed decisions concerning appropriate route to follow, the SCADA-improved system also further reduced the average waiting time of vehicles on traffic queues in that the flow rate of vehicles on queue were increased.*

Keywords— *SCADA Technology; Performance Improvement; Object-oriented Analysis; Road Traffic Data Security.*

I. INTRODUCTION

A. Background Information

Considering the rapid increase in the number of vehicles using roads in urban cities which as a matter of consequence often results to high traffic congestion [11][13][14], the need to implement traffic control systems that will not only efficiently schedule the flow of road traffic but also but also supervise vehicles that enter and leave traffic zones becomes important. This is in order to keep track of records of vehicles that enter and leave the traffic zones as to enhance the performance of road traffic lights and the decisions of drivers. However, this will generally improve the flow of traffic in congested regions of the city and also facilitate the monitoring of activities of vehicles that apply on the road with respect to traffic. Conversely, poorly implemented road traffic monitoring and control systems pose lots of threats to the society due to their dangerous impact on health, environment, and the economy [15]. This has also contributed immensely to the increase in percentage of road accidents due to the fact most drivers tend to spend longer time on traffic queues, thereby making them to become very exhausted and tired as they drive. This further leads to violation of traffic rules and regulations especially in under-developed and developing countries where effective and efficient measures are not put in place to checkmate defaulters. Still on the issue of under-developed and developing countries in which in most cases, human traffic controllers are situated at road intersections, similar issue of fatigue is also experienced by them which results to poor road traffic monitoring and control.

Nevertheless, for a road traffic to be effectively and efficiently monitored and controlled, it must exhibit a good level of intelligence by sensing its environment (the road lanes meeting at traffic intersection in this case), understanding it, and regulating the flow of traffic vehicles in all the lanes based on the processed results – just like the same way a human traffic controller with his/her right state of mind would do. By so doing, road traffic will be effectively controlled in the sense that the average waiting time of vehicles on the traffic zone of road traffic queues will be reduced – thereby leading to drastic reduction in the fuel consumption of vehicles and reduction in the emission of greenhouse gases such as CO_2 and chlorofluorocarbons which are hazardous to the environment [15]. All the same, drivers could access traffic conditions of different routes in real time in order to make informed decisions, vehicles that violate traffic rules and regulations could be truthfully identified with substantive evidence(s), and vehicles that are reported stolen could be reported if on traffic queues.

B. Research Contribution

This research attempts to apply Supervisory Control and Data Acquisition (SCADA) technique in effectively monitoring and controlling road traffic congestions. In this perspective, effectiveness in the monitoring and control mechanism simply implies the following;

i. Road traffic situation is observed – congested lanes and free lanes are detected and vehicles are made to flow according to the sensed environment.
ii. The average waiting time of vehicles on traffic queues are recorded by taking into account the time in which vehicles enter into the traffic zone.
iii. Defaulters of road traffic rules and regulations (by virtue of vehicles leaving the traffic zone when not permitted to) are captured and recorded in real time.
iv. Stolen vehicles are detected and reported in real time.

However, object-relational database engineering modelling was adopted in the analysis, design, and implementation of a SCADA system for automatic road traffic monitoring and control.

The remainder of this research is structured as thus; Section II reviews works in literature related to the application of SCADA technology in development of control systems in general, and road traffic control systems in particular, Section III presents the design framework/architecture of the system,

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Section IV showcases and discusses results obtained, and lastly, the research is drawn to Section V.

II. Review of Related Literatures

The survey conducted by [5] technically focused on discussing various research works related to intelligent transportation systems (ITS) and attention was given to the kind of technologies used and the application areas. In this case, literatures limited to six scopes of applications with respect to ITS were highlighted. These areas include – aerial and freeway management systems, freight management systems, transit management systems (TMS), incident management systems (FMS), emergency management systems, and regional multimodal & traveller information systems/ information management (IM). Although in-depth principles of applications of these scopes were not investigated as detailed in [6], the areas that captured the interest of road traffic control include; aerial and freeway management system, the emergency management information systems, and the regional multimodal and traveller information systems/ information management. In the case of the aerial and freeway management system, it was investigated that millions of raw data associated with road traffic such as average speed of vehicles, traffic flows, etc. are collected and stored for easy assessing. The arterial roads actually carry the major flows that run into the city which is fed by other smaller roads, that cut across sub-urban areas. The freeways are made up of many arterial roads that are found in each urban area. However,[5] further identifies major drawbacks associated with this method of traffic control which include high cost of implementation and maintenance, limited coverage, and ineffective responsiveness to change in traffic situations in real-time.

According to [7], weight sensors, programmable logic controllers (PLCs), counters, LEDs, and SCADA technology were applied in the development of a smart traffic controller. In this work, the approach adopted was centred on two major parts; diversion – which suggests a diversion route to a vehicle depending on its weight and the second being on congestion control – in which two counters (UP counter and DOWN counter) are set to a maximum value of 100. When a vehicle enters the traffic zone, the UP counter is set to 100 and DOWN counter to zero. Conversely, when a vehicle leaves the traffic zone, the DOWN counter is set to 100 and UP counter zero. According to this research, if UP counter == 100 && DOWN counter == 0; then red light will be displayed, if 100>UP counter>80 & 20>DOWN counter>0; then the amber light will be displayed, and finally, if UP counter<60 & DOWN counter>40; then green light will be shown. However, appropriate software engineering design patterns were not applied in the development of the software program that drives the SCADA system. This is prevalent in the flow charts developed for the operations of the route redirection and control mechanisms which do not conform to the design patterns of software engineering [1][2][3]. Furthermore, it could be argued that the intelligence of the system is not efficient in that the traffic signal controller does not have the capacity to learn its environment in order to be able to make changes to the congestion control process as road traffic situation changes in real time.

In [8], a strategy for controlling traffic congestion using vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies. In the proposed system, messages are transmitted to vehicle drivers to guide them take appropriate decisions required to control traffic congestion. Communication among vehicles and roadside units was achieved using VANET (Vehicular Ad-hoc Network) technology. In this case, vehicles affected by road traffic generate and broadcast data packets. These data packets contain decision messages. Vehicles in turn adapt appropriate driving behaviour which helps in controlling traffic congestion based on the decision. There are also roadside devices that monitor the traffic, if traffic is above a certain threshold value, it broadcasts the messages. The vehicles (referred to as nodes) which are involved in the V2V and V2I communication are assumed to be equipped with communicating device. Considering the real-time attributes of the system, the IEEE 802.11p Wireless Access in Vehicular Environment (W.A.V.E.) which supports Real-time Traffic Transportation System (RTTS) were adopted in the system development. It was also established in this research that Dedicated Short Range Communication (DSRC), a Wi-Fi standard used in VANETs for two-way short radio communication is less expensive, has low latency, high data rate, and high mobility communications relative to other wireless standard being the major reasons for using it. Based on the road condition, the traffic situation is geo-broadcasted to all vehicles which are coming in a specified range. For this reason, omni-directional antenna is used for broadcasting. Although this research presented a good approach to implementing an automatic road traffic monitoring and control system as it takes into account the real-time activities of the road, the technique adopted is quite expensive in terms of capital and prone to malicious attack from unauthorized users who could easily hack into the wireless communication network. However, software engineering principles and patterns were not applied in modelling the system thereby posing the difficulties of debugging the system when errors occur in the firmware programs.

[9] basically assessed different algorithms and tools used in the implementation of two major subtasks involved in traffic applications. These tasks include; Automatic Lane Finding (ALF), and vehicle detection (i.e., moving or stationary object/obstacle). The ALF is said to support the system to adapt to different environmental conditions and camera viewing positions. Lane detection in this case involved the use of fixed cameras to obtain a map of significant scene change. The map differentiates between active areas of the scene where motion occur (i.e., the road) and inactive areas where motion is insignificant (such as verges and central reservations). For that of moving cameras, the lane detection process is designed to estimate car position and orientation, and deduce a reference location for finding other vehicles or obstacles along the path of that vehicle. To speed up the processing and facilitate the lane detection task, it was suggested that, rather than processing entire images, a specific

region can be analysed and focused onto identify and extract the features of interest. A fixed lane width can also be assumed so that the system limits its search to virtually equivalent lane markings. Nevertheless, a system can besides abuse its knowledge of the camera and assume a precise 3D model to easily confine features and simplify the mapping between image pixels and their corresponding world coordinates. It was also established in this research that in the case of road traffic monitoring, video acquisition cameras are kept in a fixed position above the earth surface to obtain clear view of the road and moving vehicles. However, two major problems involved with recognising road environments identified in this research include the short execution time of real-time applications and the restricted amount of information from the environment. The ALF approaches explored are of three types which are; lane-region detection, feature-driven, and model-driven. In the lane-region detection approach, stationary camera is used to collect a map of major scene change. The map differentiates between active areas of the scene where motion is occurring (i.e., the road) from inactive areas of no significant motion (for instance, verges and central reservation). Generating the map includes a simple decomposition technique in which previously active areas gradually diminish from the map. The activity map then uses a lane finding algorithm to obtain the lane positions once formed. The feature-driven approach is technically based on detection of edges in the image and organising these edges into meaningful structures such as lanes or lane markings. Thus, this approach involves two levels of processing; feature detection and feature aggregation. Feature detection extracts intensity discontinuities while feature aggregation organises arranges edge segments into meaningful structures based on short-range or long-range attributes of the lane. In the model-driven approach, a deformable pattern that defines some scene characteristics is matched to an observed image to derive the parameter of the model that matches the observations. Despite that this research explored various image processing techniques that could be applied for finding lanes and detecting vehicles in traffic conditions to a certain degree, security mechanisms such as those in [11], for the entire system were ignored. However, one of the major drawbacks of the feature-driven approaches is that they suffer from noise effect and unrelated feature structure. In reality, the strongest edges are not the road edges so the detected edges do not actually fit a straight line or an even model. The model-driven approach is quite complicated in terms of implementation and inadequate in matching complex road structures. Finally, none of the proposed approach provides means of detecting defaulters of traffic rules and regulations, thus, monitoring of road traffic practically not sufficient.

The work proposed in [10] implemented a fuzzy intelligent traffic system (FITS). According to this research, the FITS is an adaptive traffic control approach which can be readily incorporated into already existing system with new functionalities and control mechanisms. FITS implements optimised algorithms and control mechanisms as software and can be embedded into a current traffic infrastructure so as to communicate with the already installed controller, receiving detection information and providing traffic light indication. the control system is programmed on a middleware that is capable of communicating with controller hardware as well as overriding traffic indications during real-time operations. The original idea behind FITS controller was to emulate the way policeman controls traffic at an intersection. In this case, the timing of the signal is based on the traffic situation using the detection information obtained. Here, vehicles must be detected and processed to detect the current state of the traffic. Fuzzy logic is then utilised to estimate human reasoning while modelling uncertainty of traffic conditions. The system is tested using an open source traffic simulator known as Simulation of Urban MObility (SUMO). FITS was compared with mainstream signal control strategies such as stage-based Vehicle Actuation (VA) control, dual-based VA control, and group-based VA control. It is stated in this research that both the real-time simulator used in simulating the system and the fuzzy controller are embedded as software components in the single board computing device. Nevertheless, software engineering principles and techniques were barely adopted in the project. Since the system simulation was achieved through distributed computing, appropriate communication paradigm such as Remote Method Invocation was not considered. For a system of this sort, more sophisticated sensors are required to achieve effective intelligence. Hence, the research was focused on short-term adaptive control strategies.

In another research carried out in [4], a cheap and inexpensive approach comprising of the use of CDS photoresistors, a composite AI technique consisting of ANN and Fuzzy Logic, and object-relational database design were adopted in the development of an intelligent road traffic signal control. Although the target location of this research was for under-developed and developing countries where the cost of implementation is a major factor affecting the effective implementation of such system, considering the status of the economy of such region. In this work, the CDS photoresistors where mounted along the road lanes that form the traffic intersection. The road traffic conditions are been monitored by these sensors and the processed results fed into an Arduino ATMega2560 microcontroller which runs a FALCON – based firmware [12]. The essence of the FALCON – based program is to enable the system adapt to changes in the traffic conditions of the road by learning its environment and controlling the flow of traffic based on the processed information. One major drawback in this research is its inability to implement object – relational database system, despite the adoption of the technique in the modelling of the system. However, end users such as drivers and road traffic officials does not have the privilege to supervise the activities of the road traffic in real time.

It is pertinent to state at this point that this research "*Application of SCADA Technology for the Automatic Monitoring and Control of Road Traffic*" is an improvement of the project implemented in [4]. Therefore, this research in general sense, tends to improve the performance of the latter work in terms of further reducing the wait time of vehicles on traffic queues, providing a database system for the storage of traffic related data and information, and also utilising SCADA

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technology in providing a GUI-based software of end users of the road which include drivers and road traffic officials.

C. Research Gaps

Having considered that this research was an improvement of an already-existing work which was focused on applying cheap approach to the implementation of intelligent road traffic signal control in developing countries[4], it was captured that none of the works reviewed in literature applied SCADA technology in combination with composite AI technique comprising of Fuzzy Logic and ANN for implementing a cost-effective implementation of intelligent traffic control systems. However, no object-relational database system has been implemented. Therefore, this research attempts to fill this gap.

D. Research Objectives

The aim of this research is to apply SCADA technology for the implementation of an automatic monitoring and control of road traffic. The objectives are as follows;

1. To adopt object-oriented analysis and design technique in implementing an object-relational database to keep track of traffic related data.
2. To develop a SCADA system which will provide a visual interface between the end-users and ATMega2560 microcontroller.
3. To further reduce the average waiting time of vehicles on traffic queues by providing real-time traffic information to road users in order to enable them make informed decisions on which route to apply.
4. To compare the performance of SCADA technology incorporated into the old system with that of the old system in terms reduction of average wait time of vehicles on traffic queues.

III. DESIGN FRAMEWORK/ARCHITECTURE

A. Object-Oriented System Analysis

A composite software engineering methodology comprising of 'Throwaway Prototype' and 'Rapid Unified Process (RUP)'[1][2][4] were applied in the software development process which led to the implementation of the first SCADA prototype – an improvement of the old system. Appropriate Unified Modelling Language (UML) designs [1] were also applied for the modelling of the system.

In order to understand the principles of operation of the SCADA – based road traffic controller system, an overview of the system was described and a block diagram developed to that effect, the requirements of the system were then captured, use cases developed for the requirements that are deemed complex, objects that make up the system are identified alongside their attributes and operations, object relationships modelled, and complex operations modelled in flowcharts.

System Overview:

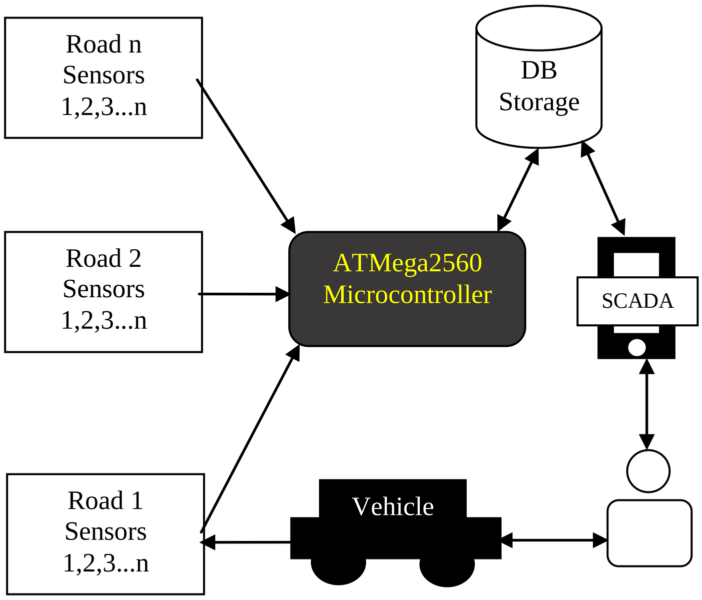

Fig. 1. Overview of the SCADA-enabled traffic control system

Following fig. 1 above, it could be seen that virtually all the components of the system depend on the ATMega2560 microcontroller which is being fed with input data from the sensors positioned at different road lanes that form the traffic intersections. The sensors get their input signals from the road condition in which they are mounted. Specifically, when a vehicle enters the traffic zone, the sensor senses it and forwards the read data to the microcontroller as detailed in [4]. However, it is a design decision for detaching the relational database from the microcontroller. This is in order to facilitate high cohesion and loosely coupling as the microcontroller will be solely focused with operations concerning processing of sensed road conditions and controlling the traffic lights according. On this same note, if the system presented in Fig. 1. is extended to accommodate other traffic intersections which have other road lanes attached to it, it could be noticed that information can be passed from one traffic region to another via the loosely coupled object-relational database. The SCADA system on the other hand does not have direct access to the microcontroller but rather draws data about the microcontroller for a particular traffic intersection from the database storage.

Requirements Gathering and Definition:

Following the overview of the system, the considered requirements specifications of the SCADA–based traffic controller - which is an extension of the requirements of the old system [4] are as follows;

1. The system must provide a GUI-enabled software which will facilitate the supervision of road traffic situations in real-time by the end-users without the users necessarily being present at the traffic location.
2. The system should store data related to traffic conditions in a secured database system.

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3. The system should provide quick access to stored data to the end users in real-time.
4. The system must process road traffic data and represent its information in a manner that could easily be understood by the end-users.
5. The network throughput across the communication channels of peripherals and the microcontroller must be good enough to enable effective communication without data loss.
6. The system must protect the stored data in the database storage from unauthorised access which could lead to malicious attack.

Although all the requirements of the system are very important to the optimal performance of the traffic controller, requirements numbers 2 and 6 are considered most complicated and are further interpreted in the use cases below;

Use Case Analysis

TABLE 1.0: Use case for storing traffic-related data in the in the database system.

Use case number:	#1
Use case name:	Store traffic-related data
Priority:	High
Primary actor:	Relational database, microcontroller
Brief Description:	This describes the interactions between the relational database and the microcontroller in order to achieve storage of traffic-related data.
Dependent on:	Traffic condition.
Precondition:	System is functioning properly, appropriate sensors are positioned at appropriate points, and there is no interference in communication between the subsystems.
Trigger:	Vehicles enter and leave the traffic zones in real-time.
Main Flow	
1.1. Road sensor captures the road situation of traffic zone of lane in real-time. 1.1.1. If the road lane is free, i. Sensor sends a null value to the microcontroller alongside the road lane ID which comprises of the location of the road, and the lane number. ii. Microcontroller requests to forward the null value with the road lane ID and time of event to the database. iii. Database verifies that the microcontroller is authorised to make storage request. 1.1.2. If the road lane is occupied, i. Sensor reads the level of congestion. ii. Sensor sends the level of congestion with the road lane ID to the microcontroller. iii. Microcontroller requests to forward the congestion level with the road lane ID and time of event to the database. iv. Database verifies that the microcontroller is authorised to make storage request.	
Post condition:	Traffic data related to a particular road lane at a specific point in time have successfully been stored in the database.
Special requirements:	Good network infrastructure at high bandwidth.

TABLE 2.0: Use case for protecting stored data in the database from unauthorised access.

Use case number:	#2
Use case name:	Protect stored data
Priority:	High
Primary actor:	Database system and peripherals that attempt to read, write, or read/write data.
Brief Description:	This use case describes how the database system is protected from unauthorised access.
Dependent on:	Read, write, or read/write permissions of peripherals on the database system
Precondition:	Connection to the database is made open for peripherals.
Trigger:	An attached peripheral attempt to access the database system.
Main Flow	
1.1. Sensor attempts to forward captured road data to microcontroller. 1.2. Microcontroller authenticates the sensor. 1.3. If sensor is authentic, i. Microcontroller accepts sensor data. ii. Microcontroller controls traffic signal based on processed data. iii. Microcontroller feeds the database with the sensor data. iv. Database authenticates microcontroller and stores the data. 1.4. Else if the sensor is not authentic, i. Microcontroller discards the data. ii. Microcontroller captures the details of the sensor and marks it as threat. iii. Microcontroller forwards the threat-related sensor data to the database system. iv. Database authenticates microcontroller and stores the information under blacklist data. 1.5. User attempts to access the database. 1.6. Database authenticates user. 1.7. If user is not authentic, i. Database blocks user access. ii. Database blacklists user details. 1.8. If user is authentic, i. Database further authenticates the type of user. ii. If the user is a road vehicle driver, - Database provides access to view traffic situation at that point in time, as well as previous traffic situations. iii. If the user is a road traffic official, - Database provides access to view traffic situation at that point in time, as well as previous traffic situations. - Database provides access to blacklist events such as suspected malicious users and sensors. - Database provides access to the list of details of road sensors and road lanes for a particular traffic location.	
Post condition:	Devices requesting access to the database system have been authenticated and unauthorised access prevented.
Special requirements:	Database system, mobile phones, microcontroller, and road sensors.

Taking a close observation at the flow of activities in the use cases, it is seen that security of data in the database management system is highly important to the system. This however is due to the fact that the SCADA application software which runs on the client device is solely depended on the database, so therefore malicious attack on stored data will affect will malign the performance of the system and the quality of service provided to the end-users.

Identification of Objects - Attributes, and Operations.

Following the principles adopted for capturing of objects that make up a system as described in [1][2][3], and from the

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analysis of the system thus far, the following are the captured objects, their attributes and operations;

Microcontroller
- id: string PK
- location: string
- no. of lanes: int
- road lanes: <lanes>

+getNoOfLanes():
+getRoadLane():
+getLocation():
+getID():
+readSensorData():
+controlTrafficLight():
+msgDB():
+authenticateSensor():

Road Lane
- lane id: string PK
- no. of sensors: int
- location of lane: string
- sensor: <sensor>
- traffic zone dist: float
- no. of vehicles: int
- vehicles: <vehicle>

Vehicle

+commSensor():

Sensor
- id: string PK
- position: int
- intensity: long
- sensor reading: long
- road lane id: string
- comm mic id: string

+getID():
+getPosition():
+getIntensity():
+getReading():
+sense():
+captureData():
+msgMicrocontroller():

User
- id: string PK
- type: string
- location: string
- name: string
- gender: string

+authenticateUser():
+getID():
+getType():
+getLocation():
+getName():
+getGender():
+commDB():

Driver/Road User

+viewPresentTraffic():
+viewPreviousTraffic():

Road Traffic Official

+viewPresentTraffic():
+viewPreviousTraffic():
+accessBlackList():
+accessRoadInfrast():

Thus far, seven objects have been captured alongside their attributes and operations. However, some objects appear to be more operational than some. For instance, the microcontroller object is of a very high priority as it has certain operations that are of huge impact to the system. These operations include; authenticateSensor(), readSensorData(), controlTrafficLight(), etc. In the same vein, some objects are considered container objects [1] as they not explicitly interact with the relational database, but serve as a means for activation of process(es) in the system. A typical instance of such object is the vehicle. Fig 2.0 below shows the relationship between the objects of the database.

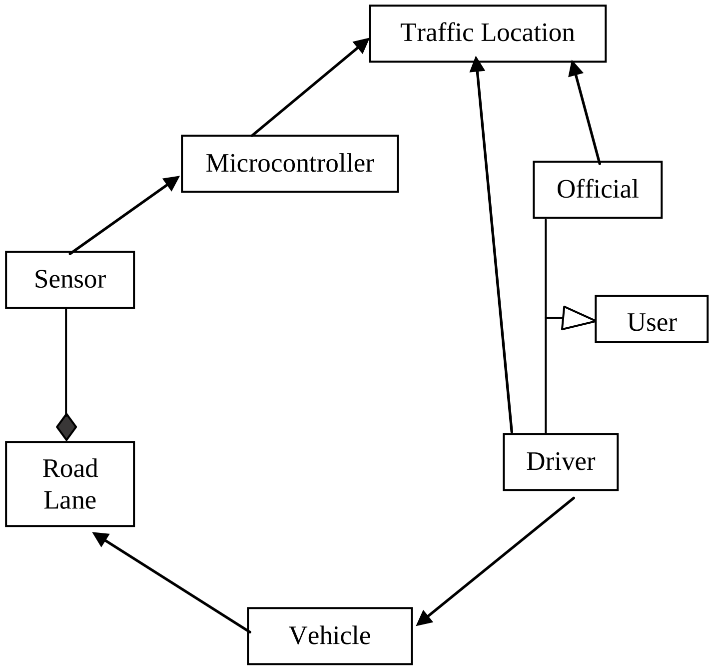

Fig. 2.0. Conceptual Class Diagram of the System

From the conceptual class diagram, one or many vehicles will use one road lane. A road lane comprises of many road sensors, and a sensor communicates with the one and only one microcontroller.

B. Prototype System Implementation

Considering that the SCADA runs on the client device in order to present traffic data to end-users in real-time, the system was implemented as an application software running on the client workstation. Moreover, the object-relational database system which stores the structured data and the access logic controlling the operations on the data, are all part of the SCADA system.

Having modelled the database, the software was developed in C# Asp.net using the the Microsoft Visual Studio IDE. The software was developed as a web app running on the http protocol. The essence of developing the SCADA system as a web app is to enable it to be platform-independent. Thus, the SCADA system runs on any platform that has a web browser and is compatible with the http web protocol.

Below are some of the screen shots of the web app.

Fig. 3.0. Homepage of the SCADA Web App

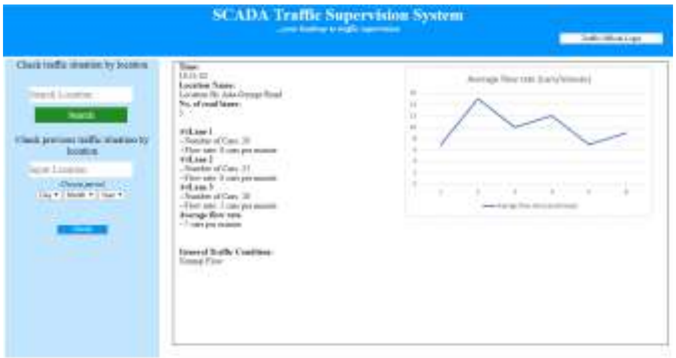

Fig. 4.0. User Traffic Search Supervision Page

Fig. 5.0 User Login Page

IV. Results and Discussions

Following that the SCADA traffic control system is an enhancement of the neuro-fuzzy system in which inexpensive photoresistors were applied in the implementation [4], the performance of the system was compared to that of the former system. With respect to this, ease of use and reduction in the average wait time of vehicles on traffic queues were the key factors considered. The ease of use was investigated for both systems, and it was ascertained that the SCADA system was much more user friendlier than the former system. This is attributed to the fact that the former system has no user interface that enables road traffic users to interact with it. On the contrary, it is obvious that the SCADA system provides a better interface to the end-users, while maintaining the intelligence and functionalities of the former.

As a result, the average waiting time (in an hour) of vehicles for the two systems were sampled and compared as represented in the table below.

TABLE 3. Average wait time flow rate of vehicles for the both systems

S/N	Time (minutes)	Average flow rate (cars/minute) S1	Average flow rate (cars/minute) S2
1	10	12	7
2	20	18	15
3	30	9	8
4	40	15	12
5	50	12	7
6	60	12	9

From table 3, it was observed that in general, the SCADA system (S2) has a better performance than the former system (S1) in that it has vehicle flow rate per minute when subjected to the same factor of time. This is shown in the graph in fig. 6.0 below;

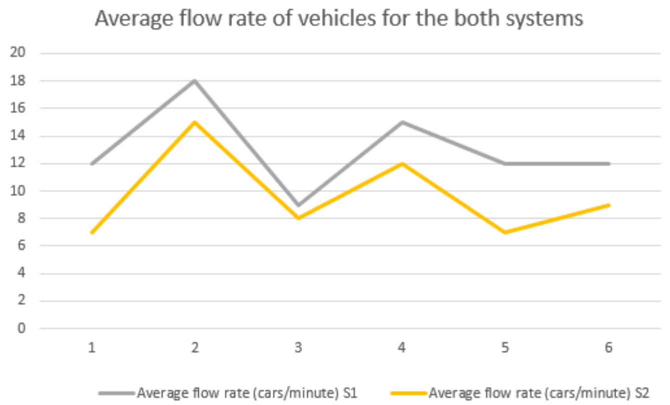

Fig. 6.0. Comparison of average flow rate of vehicles for the both systems

Looking at the diagram above, it could be seen that the SCADA system (S2) has a higher flow rate than that of the former, despite that there was a sharp decrease when the time was at 30 minutes. However, it was further investigated that this improved performance was as a result of the supervisory interface provided by system S2 which enables road users to observe the traffic situation of the road in real time.

V. Conclusion

In conclusion, the performance of an already-existing intelligent traffic control system [4] has been improved on using SCADA technology. The primary purpose of adopting the SCADA technique which is to facilitate the interactivity of the intelligent traffic controller with the end-users has been achieved. This was accomplished through the adoption of object-oriented system analysis in the development of an object-relational database where data concerning road traffic are stored and accessed. Data concerning the traffic situation of the road are accessed and retrieved in real-time, which enables road users to make informed decisions. However, this has contributed to the improved performance of the system by further increase the average flow rate of vehicles on traffic queues per minute and consequently, reduce vehicle wait time.

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