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Research Paper

Development of Safe Road Management System in Nigeria using Data Fusion (DF) and Internet of Things (IoT).

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ABSTRACT: *The worries over the numerous road accidents in Nigeria and the inability of Road safety officials to manage these occurrence as a result of poorly equipped road safety officials for real time responses is what led to this research. The study was limited to the development of interconnected system useful for prompt monitoring and reportage of road accidents to road traffic officials. The developed system were configured to use a modified version of data fusion in IoT. The methodologies applied are predictive and monitoring method. IoT incorporate a large number of sensors that establish communication with the cloud environment, other devices and the vehicles. The data from sensors is fused to get an enhance information for an improved road safety system. The connected cars allows for the constant monitoring of basic aspects of the vehicle to ensure its safety. In this research work, data fusion of multi-sensory system uses the integration of imager/camera, accelerometer and carbon monoxide sensors for situation awareness to monitor and detect real condition of the road network.This system would enable safe road officials better understand true road condition using real time road monitoring of some physical parameters (the road condition, Speed of the vehicle and CO emission from the vehicle). This system shall predict and monitor road accidents in the road networks in Nigeria. The number of deaths recorded in our roads in most developing countries like Nigeria will greatly be reduced with this new technological development*

KEYWORDS: *Internet; Data; Fusion; Sensor; Monitor,*

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I. INTRODUCTION

The delay in information sharing in our roads has increased the chances of death of victims in accident situations. Certainly, more losses is going to be recorded in the nearest future if some control measures are not put in place to forestall this occurrences. This research will go a long way in curtailing the losses of life and its attendant consequences in Nigeria. The study will be limited to the development of interconnected system useful for prompt monitoring and reportage of road accidents to road traffic officials. The developed system will be configured to use a modified version of data fusion in IoT. This system with sensors and GSM module sends messages about road situations to the respective safety officials in real time

Following the advances in sensor technology, data mining techniques and the internet, information and communication technology further motivates the development of smart systems such as intelligent transportation systems, smart utilities and smart grid. With the availability of low cost sensors, there is a growing focus on Multi-Sensor Data Fusion (MSDF). Internet of things can connect as large as possible number of devices. Internet of things refers to the interconnected set of sensors via internet that targets to improve management and analytics [1]. The internet of things technologies enable information exchange between drivers, vehicles and roads leading towards intelligent transportation system [2].The theory of data fusion comprises of systems and devices. These are used in joining together feeder data to a single one. And it is used for making of inference [3]. Data fusion deals with the combination and permutation of data. It also deals with information taken from one or many bases. These are used to obtain advanced and unique points. These points can be used for the estimation of the complete and real time evaluation of circumstances [4]. This work will bring about improvement in the action and response of the management of the safe road system using model based approach. The result of this work will serve as a benchmark for Artificial Intelligence (AI) researchers

Data fusion mechanism plays a great role in IoT based safe road smart emergency response system. Data fusion creates room for maximum data accuracy in handling issues relating to safe road network. It also increases efficiency, reliability and accuracy of measurements/prediction thus minimizing false prediction in the system design. In this research work, data fusion of multi-sensory system uses the integration of imager/camera, accelerometer and carbon monoxide sensors for situation awareness to monitor and detect real condition of road network. This system would enable safe road officials better understand true road condition using real time road monitoring with some physical parameters.

II. DATA FUSION ALGORITHM BASED ON DEMPSTER-SHAFER EVIDENCE THEORY

Dempster-Shafer evidence theory is use for the development of a data fusion algorithm. The algorithm can be used to measure the data of a multi-sensor system. However, the manner in which uncertainty gap is reduced is slow. The Dempster Shafer Theory is a conservation of the Bayesian theory and it is proficient way for handling uncertainty problem. Application of Dempster-Shafer evidence theory to unsupervised classification in multisource remote sensing- the aim is to show that Dempster-Shafer evidence theory may be successfully applied to unsupervised classification in multisource remote sensing. Dempster-Shafer formulation allows for consideration of unions of classes and to represent both imprecision and uncertainty through the definition of belief and plausibility functions. These two functions, derived from mass function are generally chosen in a supervised way. Data fusion is then performed discarding invalid clusters (e.g. corresponding to conflicting information) thank to iterative process. Unsupervised multisource classification algorithm is applied to MAC-Europe'91 multisensory airborne campaign data collected over the Orgeval French site.

Classification results using different combinations of sensors (TMS and AirSAR) or wavelengths (L- and C-bands) are compared. Performance of data fusion is evaluated in terms of identification of land cover types.

2.1 Bayes' Theorem

In probability theory and statistics, this theorem describes the probability of an event based on prior knowledge of conditions that might be related to the event. Taking for instance, if the risk of developing health problems is known to increase with age, Bayes' theorem allows the risk to an individual of a known age to be assessed more accurately by conditioning it on his age than simply assuming that the individual is typical of the population as a whole[5]. Bayesian Interpretation in probability measures a "degree of belief". Bayes' theorem links the degree of belief in a proposition before and after accounting for evidence. Suppose it is believed with 50% certainty that a coin is twice as likely to land heads as tails.

If the coin is flipped a number of times and the outcomes observed, that degree of belief will probably rise or fall, but might even remain the same, depending on the results.

Mathematically, Bayes' theorem states that:

$$P(A/B) = \frac{P(B/A)PA}{P(B)} \tag{1}$$

If B_1, B_2, $B_3 \ldots B_n$ are mutually exclusive events with P (Bi) given as (I – 1, 2 …n) of a random experiment then for any arbitrary even a of the sample space of the above experiment with P (A), we have:

$$P(B_2/A) = \frac{P(B_2)P(A/B_2)}{P(B_1)\ P(A/B_1)\ +\ P(B_2)\ P(A/B_2) + P(B_3)\ P(A/B_3)} \tag{2}$$

Let S be the sample space of the random experiment. The events B_1, $B_2 \ldots B_n$ being exclusive.

$$S = B_1 \cup B_2 \cup \ldots \cup B_3 \tag{3}$$

$$A = A \cap S \tag{4}$$

$$= A \cap (B_1 \cup B_2 \cup \ldots \cup B_n) \tag{5}$$

$$= (A \cap B_1) \cup (A \cap B_2) \cup \ldots \cup (A \cap B_n) \ldots. \tag{6}$$

$$P(A) = P(A \cap B_1) + P(A \cap B_2) + ... + P(A \cap B_n)$$

$$= P(B_1) + P(A/B_1) + (B_2)(PA/B_2) + ...+ P(B_n)P(A/B_n) \quad (7)$$

$$\sum_{i-1}^{n} P(B_i)P(A/B_i)$$

Now $P(A \cap B_i = P(A)\ P(Bi/A)$

$$= \frac{P(B_i)P(A/B_i)}{\sum_{i-1}^{n} P(B_i)P(A/B_i)} \quad (8)$$

One of the many applications of Bayes' theorem is a Bayesian inference, a particular approach to statistical inference. When applied, the probabilities involved in the theorem may have different probability interpretations. The theorem expresses how a degree of belief, expressed as a probability should rationally change to account for the availability of related evidence. This system was proposed with the use of dynamic detective and error or fault detection mechanism to search inconsistencies in the vehicle data.

The most common methods for performing risk of internet of things are: Preliminary Hazard Analysis (PHA), Fault Tree Analysis (FTA) and Hazard and Operability Analysis (HazOp).

- PHA is used in the design stage of a system in order to discover possible threats, early in the development process.
- FTA does not identify the possible attacks of a system, but analyses the causes that may lead to them.
- Finally, HazOp (Braba, 2006) is a bottom-up hazard identification technique. It uses HazOp tables to determine the likelihood of an attack to occur and estimate the impact that the attack has on the system.

The determination of likelihood is based on the vulnerabilities of the system and the motivation of potential attackers. The estimation of impact considers the related system's asset.The likelihood and impact values can be quantitative, semi-qualitative or qualitative. In the following, a qualitative risk analysis is performed that uses descriptive scales (i.e., very small, small, medium, high, very high) to classify likelihood of an attack to occur as well as the magnitude its consequences. Both values (i.e., likelihood & impact) are combined in a matrix in order to determine \he values of risk. The determined risk values are categorized as acceptable and non acceptable. The risk values that fall outside the acceptable range require treatment in order to achieve an appropriate risk level.

III. MATERIALS AND METHOD

3.1 Materials

This section gives insight on the materials required to achieve the objectives of the research. The materials employed in the study included:

- Data Source: Interview method, Questionnaire method, Observation method
- Software: Microsoft word, Microsoft excel, and Minitab 17, Matlab
- Engineering Models: Bayes' Theorem, Basic Probability Function of Events
- Simulation: The Monte Carlo

3.1.1 Data Source

We have primary and secondary data collection; the primary data collection methods are:

- Interview method
- Questionnaire method
- Observation method

Secondary data consists of data that is available already and also analyzed by another person. Data collected by someone other than the user is a secondary data. Among sources of secondary data are published or unpublished data, trade journals, magazines and books.

3.2 Method

The method employed in the study included:

- Impact estimation, probabilities of identified threats, risk analysis methods,
- Qualitative Methods: Brainstorming, structured interviews, judgment of specialists and experts

- Semi-Qualitative Methods:
- Quantitative Methods: Analysis of likelihood, analysis of consequences
- Computer Simulation: Monte Carlo simulation

3.2.1 Impact estimation.

The participatory action research (PAR) was used in this research. This approach seeks to understand the world by trying to change it collaboratively, following reflection. PAR emphasizes collective enquiry and experimentation grounded in experience and social history. Within a PAR process, communities of inquiry and action evolve and address questions and issues that are significant for those who participate as co-researchers (Bradbury and Reason, 2010). In this work, an iterative software procedure, the Rational Unified Process (RUP) method was used. Rational unified process is a software engineering process that utilizes disciplined approach in allocating responsibilities within a developmental team. According to [6], RUP expansion activities create, and semantically characterize and maintain software. It also serves as a guide for the effective usage of Unified Modeling Language (UML). UML, is an industry-standard general-purpose, developmental modelling language in which software systems requirements, architectures and designs can be clearly visualized.

UML is not just a programming language; it is rather a visual language. We use UML diagrams to portray the behavior and structure of a system. UML helps software engineers, businessmen and system architects with modelling, design and analysis. The Object Management Group (OMG) adopted Unified Modelling Language as a standard in 1997.The Rational Unified Process (RUP) suggests that complex applications need collaboration and planning from multiple teams and hence require a clear and a concise to communicate
amongst them. A lot of time is saved down the line when teams are able to visualize processes, user interactions and static structure of the system.

The system architecture of the proposed multisensory IoT-enabled safe road system for predictive and smart decision making is shown in Figure 1 below. This technology enhances system reliability and also decreases likelihood of false alarm to the officials.

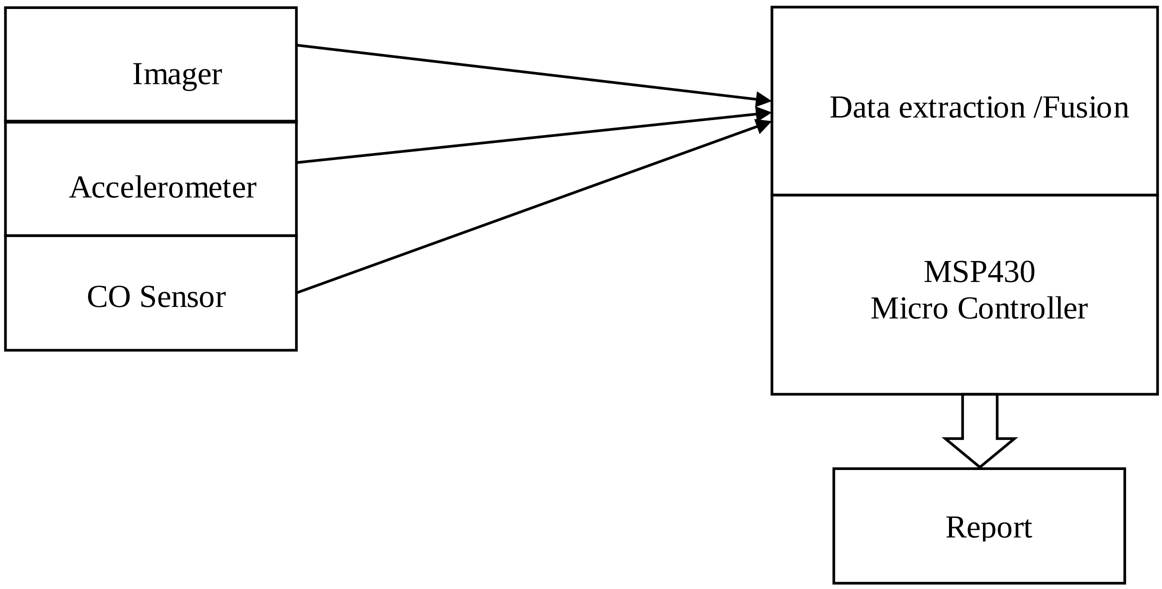

Figure 1: Architecture of the proposed system

The network will perform different parameter measurements for safe road monitoring. The Wireless Sensor Network will sense the surrounding for any change in input parameters. It will collect sensory data, analyze it and accurately trigger alarm for easy remedy operation of the situation at hand. This response is readily made available on real time bases following the Artificial Intelligent (AI) fuzzy logic technique as embedded in the Micro Controller MSP430 for smart decision making. The block diagram explaning each unit of the IoT/Data Fusion in Safe Road System is shown in Figure 2 . The sensor: Imager, Accelerometer and CO Sensors making inputs to the MSP 430 Micr Controller for a logical inference.

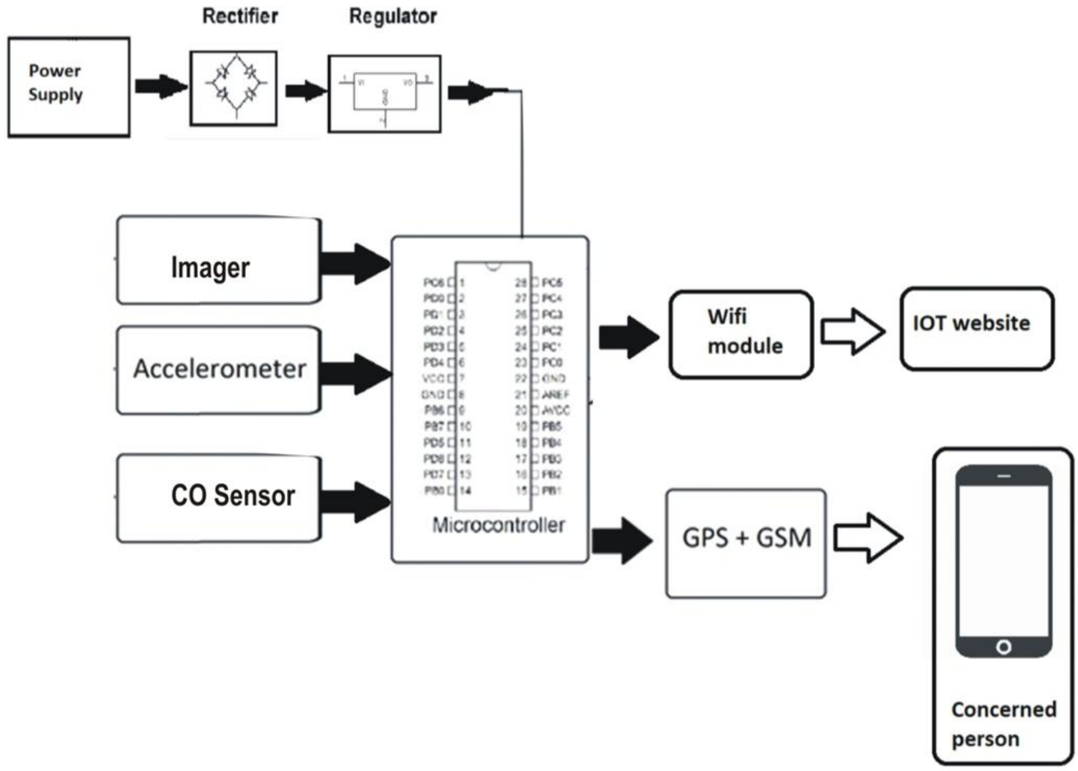

Figure 2: Block Diagram of IOT/Data Fusion on Safe Road System

3.3 Project Implementation Requirement

This shows how sensors network should be built on the physical system design. It depicts all activities to be carried out to put the multi sensor fusion in IoT based safe road system into practice. Simulation is an imitation of the operation of a real-world process or system. Before live implementation, testing of the developed technique is required. Most of the time, testing and evaluating the protocols or theories proposed is not practically feasible through real experiments as it would be more complex, time consuming and even costly. So, to overcome this problem, "SIMULATORS and TESTBEDS are effective tools to test and analyze the performance of protocols and algorithms proposed[7].

3.3.1 Design Software and Hardware Requirements

- Windows operating system (WOS)
- Application packages required; MATLAB
- Google chrome or Mozilla Firefox.
- Processor: Core i3
- Processor speed is: 4.3 GHz
- The system type is: 64 and 32-bit Operating System
- Hard Disk capacity: 2GByte

3.3.2 Project Implementation using MATLAB

MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces and interfacing with programs written in other languages. MATLAB is intended primarily for numerical computing; an optional toolbox uses the MuPAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi domain simulation and model-based design for dynamic and embedded systems. It is very easy to use and highly dependable. Moreso, MATLAB is an open source programming language and can be installed on various different web-servers. Also, it can be installed on majority of operating systems. The software runs as a server which gives multi-user access to a number of databases. It can be run on most platform such as Linux, Windows including others. It is often used in free software projects which make use of a full-featured database management system. The efficient and economical way to deploy live implementation is to perform adequate testing of the developed technique. But the environment to carry out the required test for wired/wireless network is not readily available especially for live experimental study which could be very challenging, costly and time wasting. Hence, the solution is to use "SIMULATORS, EMULATORS and MODELERS which is a helpful tool to adequately analyze and test the performance of algorithms and protocols[8].

This section demonstrates the carrying out of IoT/data fusion technique for predicting road accidents as designed in the previous chapter. The programming language used in the implementation of the system (MATLAB) was also analyzed. Both hardware and software requirements of the system were highlighted.

3.4 Safe Road System Design Algorithm

Sensory elements are:

- Imager (image sensors)
- Accelerometer (speed/vibration sensor)
- Carbon monoxide sensor

3.4.1 Ranges of measurement

Imager scale (1-3) (4-6) (7-10)
Accelerometer (km/h)
Carbon monoxide sensor (%)

3.5 Qualitative Road Safety Data

The result after series of test was carried out on the design for safe road system is shown in table 1,table 2 and table 3. Three parameters namely; grading of the road, speed (km/h), and carbon monoxide level (%) were used. Different values were entered into the system. Whenever the output value is above the threshold value, the system triggers alarm and alert is sent to officials for immediate response

Table 1:Prediction Table for the Sensors (Imager)

S/N	Input (Imager)	Notation	Output
1	1 – 3	Very good	Pass
2	4 - 6	Good	Pass
3	7 – 10	Bad	Danger

Table 2 Prediction Table for the Sensors (Accelerometer)

S/N	Accelerometer (km/h)	Notation	Output
1	10-120	Very good	Pass
2	120 and above	Bad	Danger

Table 3 Prediction Table for the Sensors (CO Sensor)

S/N	Carbon monoxide Sensor (%)	Notation	Output
1	0-30	Good	Pass
2	30 and above	Bad	Danger

IV RESULTS AND DISCUSSION

In the developed system, three parameters were used namely; Image (Imager); Speed (Accelerometer) and Carbon monoxide (CO) sensors. A range of value is set for each of the parameter. The system was tested in a confined environment with three sensor nodes, which are arranged in 2 meters apart to each other in order to avoid unnecessary interference. The sensors respectively detects image to ascertain road condition, speed and vibration of the vehicle and carbon monoxide level of the vehicle. Sensors detect and sense environment for parametric level which is compared to the range of values pre-set before sending a signal to the control room for analysis. Here the actual condition of the road can only be predicted when the sensor values of different elements: road conditions, speed and carbon monoxide levels are fused/mixed together.Table 4. presents the deployment of the system to the problem domain

Table 4.: Data Fusion: IoT/Data Fusion sensor results

S/N	Input (Imager) Safe road	Safe driver Accelerometer	Safe vehicle (CO) Sensor	Output
1	1 – 3	10-20 km/h	5%	Pass
2	1 – 3	20-30km/h	30%	Pass
3	1 – 3	30-40km/h	15%	Pass
4	7-10	40-50km/h	20%	Danger
5	7-10	50-60km/h	25%	Danger
6	4-6	60-70km/h	40%	Danger
7	4-6	70-80km/h	15%	Pass
8	1-3	80-90km/h	35%	Danger
9	4-6	90-100km/h	10%	Pass
10	4-6	100-110km/h	25%	Pass
11	1-3	110-120km/h	30%	Pass
12	4-6	120km/h-Above	5%	Danger

Fusion of these data in an artificial intelligent (AI) through the use of fuzzy logic technique will give the real time condition of road at any instant to give a report to officials on every condition of road users. A detective and monitoring system was designed using data fusion technique through the application of Dempster Shafer Theory (DST) which is a probabilistic tool for logical occurrence of events to give a real time condition of road network. The Data fusion of three different physical parameters will give a better definition of a safe road situation with the incorporation of fuzzy technique in order to reduce the error to (0.05%) as can be obtainable in the system design. The result from this fusion following the range of values from different parameters is PASS when all the input data are satisfying according to a preset standard of the sensors, else it will read DANGER which through the cloud system is reported to officials for appropriate action to be taken to forestall the breakdown or the occurrence of road mishap/accident at that particular instant. The result is reliable as it entails the output from various physical parameters with little or no error as a result of smart fuzzy logic technique.

4.1 Simulation Results using MATLAB Program

When Imager value is ranging from 1 – 3.
Accelerometer value is ranging from 10-20km.
CO sensor value is 5%.
This shows a good road, vehicle and drivers conditions and hence the result is **PASS** as shown in figure 3

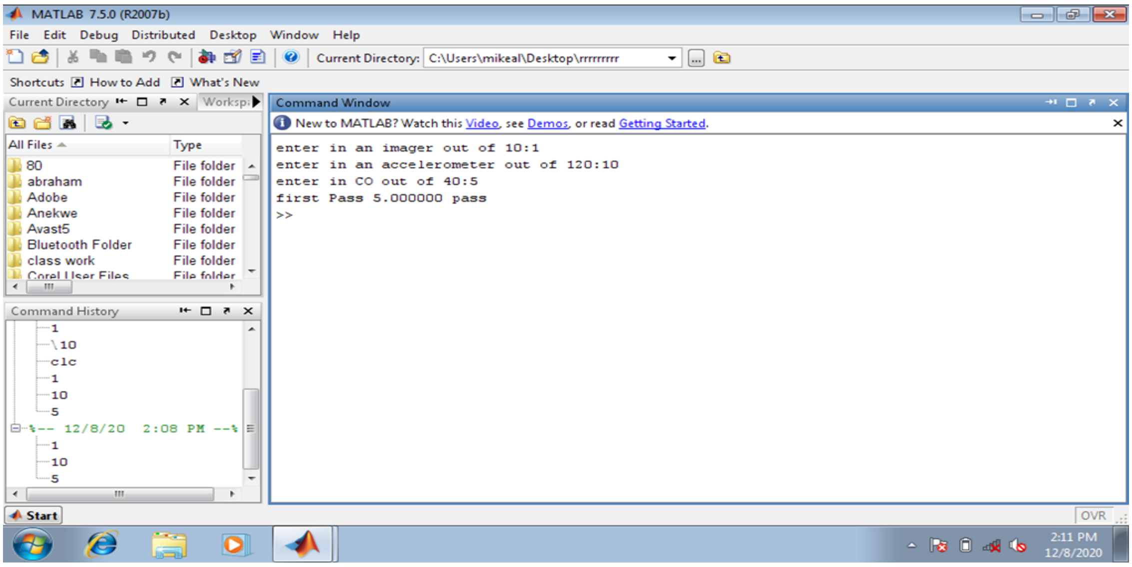

Figure 3: A good road, vehicle and drivers conditions and hence the result is **PASS**

When Imager value is 3.
Accelerometer value is ranging from 30-40km.
CO sensor value is 30%.
This shows a good road, vehicle and drivers conditions and hence the result is **PASS** as shown in figure 4.

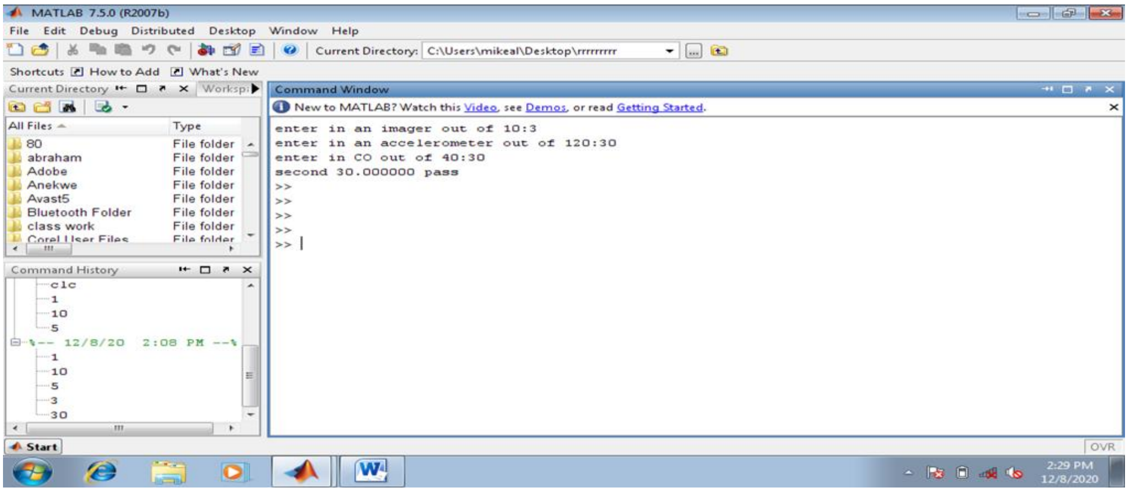

Figure 4: A good road, vehicle and drivers conditions and hence the result is PASS

When Imager value is ranging from 7 – 10.
Accelerometer value is ranging from 50-60km.
CO sensor value is 2%.
This shows a bad road, vehicle and drivers conditions and hence the result is **DANGER** as shown in figure 5

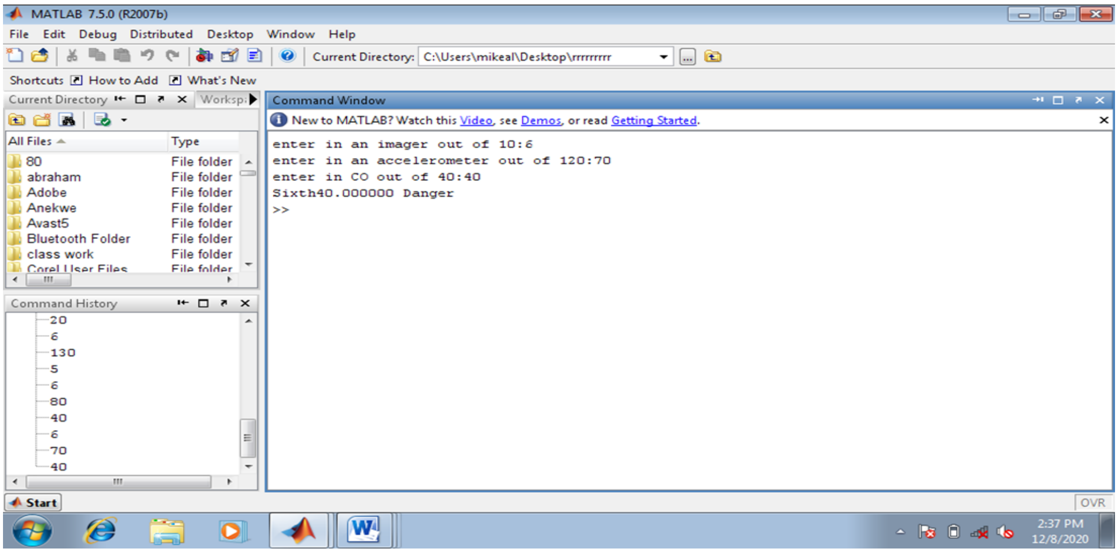

Figure 5: A bad road, vehicle and drivers conditions and hence the result is **DANGER**

When Imager value is ranging from 4 – 6.
Accelerometer value is ranging from 70-80km.
CO sensor value is 40%.
This shows a high carbon monoxide (CO) level and hence the result is **DANGER** as shown in figure 6

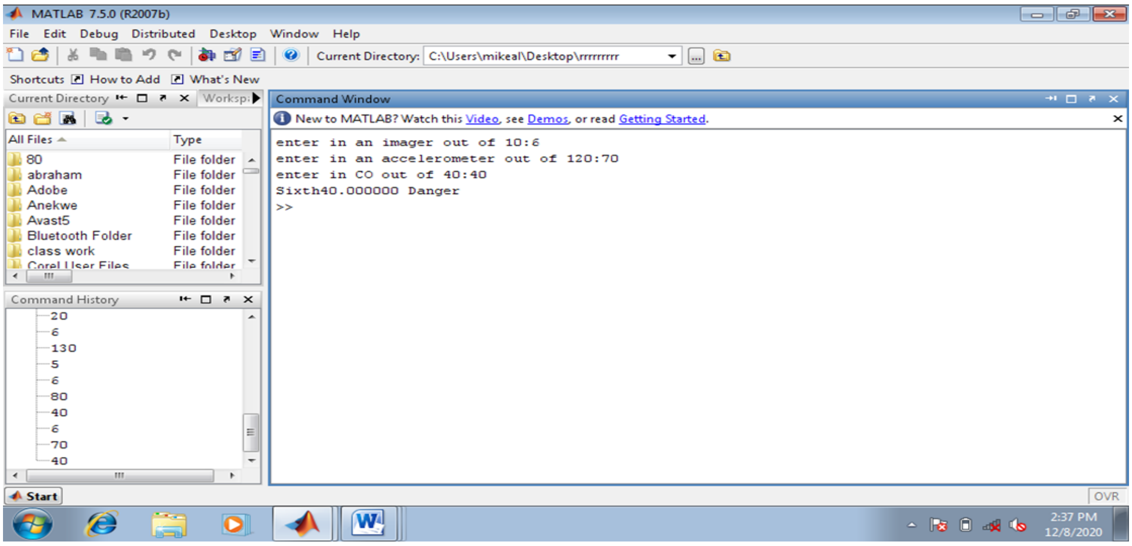

Figure 6: A high carbon monoxide (CO) level and hence the result is **DANGER**

V CONCLUSION

Analytical studies were performed to examine the data fusion/internet of things in safe road system. From the investigations undertaken, the following conclusions can be drawn in line with the achieved objectives:

Data fusion mechanism plays a great role in IoT based safe road smart emergency response system. Data fusion creates room for maximum data accuracy in handling issues relating to safe road network. It also increases efficiency, reliability and accuracy of measurements/prediction thus minimizing false prediction in the system design. In this research work, data fusion of multi-sensory system uses the integration of imager/camera, accelerometer and carbon monoxide sensors for situation awareness to monitor and detect real condition of road network. This system would enable safe road officials better understand true road condition using real time road monitoring using some physical parameters.The number of deaths recorded in our roads in most developing countries like Nigeria will greatly be reduced with this great technological development. We can therefore advise Federal Road Safety Corps (FRSC) to adopt the use of this new system as its gives good and reliable prediction of true road condition

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