Sonar Technology Assisted Vehicle Sensor

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***Abstract**: In the Philippines, more than half of its vehicular accidents are caused by motorcycles, and most of the reasons why these accidents are happening is because of distracted driving, lowered road awareness, delayed response to emergency such as accidents, and over speeding to name a few as confirmed by World Health Organization's reports. Premised on this idea, the researchers decided to design, develop, and test a device that would provide a solution to this. Thus, the title "Sonar Technology Assisted Vehicle Sensor" was created. The device was completed after three months of research and development in Eastern Samar State University Salcedo Campus. Results of the four-stage test: the Benchmark; Alpha; Beta; and Usability tests indicated that the Sonar Technology Assisted Vehicle Sensor is fully functional and can detect vehicles approaching and can produce corresponding alarms, and can now be implemented. As an additional feature, the device has been imbedded with a Global Positioning System (GPS) Tracker that activates whenever an accident happens to the user/rider. The GPS Tracker would extract the device's location and the system would automatically send the data to appropriate authorities using its Global System for Mobile Communications (GSM) shield through text messaging. The researchers recommend that the device should be marketed directly to motorcycle companies; its GPS system should be submitted for further testing, while the image processing should be trained in computers with RAM size of 8 GB and should be tested paired with an infrared lamp to maximize its use in night time traveling conditions.*

***Keywords**: Sonar-Assisted Device, Image Processing, Multi-Processor.*

Manuscript published on November 30, 2019.
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I. INTRODUCTION

Due to the increase in the number of motor vehicles in the streets more and more traffic related accidents are happening. To combat these incidents, a number of automotive navigation systems and anti-collision devices have sprung-up in the market. Some major automotive companies in order to improve their product's safety and marketability have also made it a point to include or to imbed navigational and anti-collision systems and devices in their latest automobile models. This technology is not only limited to automotive vehicles but are also a crucial component of naval vessels, submarines, and robotics for the development of unmanned exploration and reconnaissance robots. These systems have also proven its usefulness in law enforcement

In Florida USA, there is a law requiring cars to give bikes at least a three-foot gap of space, which was fairly impossible to impose until a gadget was developed that allowed bike-cops to measure the distance between them and the cars. It works by using sonar pulses side scans that sends a ping whenever the car is inside the three-foot space [1].

In the Philippines there are 8.08 million vehicles that are registered with the LTO or Land Transportation Office and more than half of the vehicles are motorcycles. Furthermore, more than half of the total vehicular related accidents that happen in the Philippines are caused by motorcycles [2].

Premised on the information mentioned above, this study was conducted in order to develop, design, and test a Sonar Technology Assisted Vehicle Sensor exclusively for motorcycles that will provide additional safety functions gravitating around sonar technology including the device's many add-ons such as: an image processing system; a balance sensor; a global positioning system module; and an automatic distress text system that will activate in case the motorcycle falls or tips over on its side that will be imbedded in an existing motorcycle system; and has investigated its performance in terms of measuring distance to other vehicles, obstacle detection, and early detection of in-coming vehicles from behind or front of the vehicle. This has also investigated the effectiveness of the technology in low visibility situations such as rainy, foggy, and night traveling conditions.

II. OBJECTIVES OF THE STUDY

This study had the following objectives:

1. To design Sonar Technology Assisted Vehicle Sensor compatible with motorcycle vehicles.

2. To develop the Sonar Technology Assisted Vehicle Sensor that will be able to provide the motorcycle driver the capability to react faster in emergency situation while driving by utilizing its early warning features with an imbedded system that allows simultaneous recording while detection is on-going.
3. To test the Sonar Technology Assisted Vehicle Sensor.

III. SCOPE AND LIMITATION OF THE STUDY

The scope of the study involved the development, designing, programming, and testing of a Sonar Technology Assisted Vehicle Sensor.

This is limited for motorcycle only. In addition, limitations of testing include accuracy in terms of distance, speed, and size of objects; effectiveness during sunny, rainy, and night traveling conditions; exploring whether the technology will improve the driver's reaction time while driving in terms of detecting in-coming traffic; and if the technology is Bluetooth compatible. Although this study aimed to provide more options for the driver to improve safety while driving, the study does not claim that it would prevent accidents permanently.

IV. RELATED LITERATURE

As the growing need for exploration and reconnaissance mission increases, more automotive navigation techniques are being considered. In the field of robotics which boasts which boasts great potential in many fields such as unmanned explorations for example, Martian mission and underwater scientific observation and sample collection, automated mine detection in war stricken areas, military reconnaissance missions, and even in the development of artificial intelligence sonar technology has been the most common sensing method used for development. Early work with sonar-based mapping initially motivated the development of occupancy grids and led to the implementation of a mobile robot, range-based mapping and navigation system called Dolphin. A variety of experiments were used to test this system. For indoor runs, a mobile robot called Neptune was used; outdoor runs were performed with a larger robot vehicle called the Terregator. A newer version came after Neptune and Terregator; the Dolphin system was installed on the Locomotion Emulator, a mobile platform designed for navigation in mining environments [3].

A report from the World Health Organization (WHO) which was updated this 2017 indicated that nearly half of those dying in the world's roads every year are "vulnerable road users": pedestrians, cyclists, and motorcyclists. That is out of 1.25 million traffic accidents in a year. The most disturbing fact is that 90% of the total numbers of traffic fatalities occur in low- and middle-income countries, even though these countries have approximately 54% of the world's vehicles, and even within high-income countries, people from lower socioeconomic backgrounds are more likely to be involved in road traffic crashes (World Health Organization, 2017). This directly points out that the Philippines is one of the countries that are smack dab at the center of the road traffic danger zone of the world. In addition, using a mobile phone whether it is hand-held or hand-free sets greatly reduces the driver's reaction time while increasing the risk of a crash [4].

V. METHODOLOGY

A. Device Design, Development, and Testing Schedule

The process of device design, development, and testing included the following activities: analysis and definition; software, program, and device design; acceptance testing; usability testing; documentation of the study, and device delivery. Requirement analysis and definition contains naming of the device, conceptualization, data gathering, analysis of the data gathered, review of related literature and planning, design and specification of the device, which were completed for 50 days from the month of September 2017 to the first week of December 2017. Software and device design contains the following: designing the software and hardware interfaces; programing the microprocessor; installing the Bluetooth modules and devices; choosing and connecting to an appropriate power source; and connecting and reconfiguring the device sensors such as: GPS Tracker; ultrasonic range finder; 3d-axis accelerometer; and cameras, and is estimated to be completed within a eighty-two-day timeframe, from the month of January to the end of March. The acceptance test included the benchmark, alpha and beta test. The benchmark test was conducted for one (1) day on the first week of March 2018; the Alpha test was done for one (1) day on the second week of March 2018 and the Beta test was done for one (1) day on the third week of March 2018. The usability test was also done for one (1) day on the last week of March 2018.

B. Data Flow

The Sonar Technology Assisted Vehicle Sensor has the entities: the rider; the motorcycle; the sensors; the microprocessor; the smartphone; the Bluetooth audio device; and other vehicles.

The sensors will start generating pulses and begin gathering data needed for processing. If the rider will be approached at the back by a vehicle, the sensors located at the back of the motorcycle would be stimulated. These would then send pulses to the Bluetooth enabled microprocessor. The microprocessor will then determine what kind of vehicle is approaching and would calculate its distance in real-time while warning the driver of the incoming traffic, at the same time sending beeps to the driver's speakerphones indicating the speed of approach of the detected vehicle. One important function of the device is its automatic distress text function that only activates if the balance sensor detects an anomaly in the orientation of the motorcycle. This is true in any crash event. The feature would automatically generate information such as: the location of the crash event that would be sent as a computer generated text message to a designated recipient number listed in the mobile phone of the rider.

C. Device Flow

In order to initialize the device, all the driver has to do is to switch on the motorcycle's ignition switch which in turn will power up the device connected to the motorcycle's battery through a DC to AC inverter. After the device initialization, the driver must turn on the Bluetooth audio device so that it can connect to the device.

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Once the device initialization is completed, the system will initialize the individual function of the system such as: the camera; ultrasonic sensor; GPS module; GSM shield; 3DLXXX, a three-dimensional orientation sensor; and an image recognition system that focuses on detecting motorcycles and four wheeled vehicles.

Now, every time the system detects a vehicle behind the motorcycle, it will warn the driver of the approaching vehicles. But if the system detects a vehicle or any object within a five-meter range of the motorcycle, it will produce beeps with durations equal to the distance of the detected object in centimeters expressed in milliseconds. A video of the travel is recorded and saved every time the system is turned off. And every time the device is turned on the system overwrites the recorded video with the current recording.

In the case that the system detects an anomaly in the orientation of the vehicle, the system will stop all other sensor function and will produce beeping sounds that will last up to ten seconds. If the driver does not press the alarm off button within ten seconds, the device shall move on to determine its location by initializing the GPS module of the device. Once the system receives a valid location in the form of longitude and latitude GPS values, the system shall send to the saved mobile number a system generated distress text message containing the device's current location. The system will repeat this process twice. At the same time the system shall move the current recorded video to a different directory named "Accident_Recordings" in order to prevent the overwriting of the recorded video that can be used as evidence when the need arises.

The device will only shut down (1) if the ignition switch is turned off or (2) if the motorcycle's battery runs out of charge or (3) if the inverter backs down or (4) if the device is destroyed or (5) if the device malfunctions. For cases (1) to (3), the video will be saved upon shutdown. For case (4), the video will be saved if the device's SD card is still intact. And for case (5), the video will be saved if the device's image processing system does not get corrupted.

D. Hardware Specification

The system requires that the rider makes as little attention to his/her phone for safety purposes, that is why a wireless **headphone** was required to receive all the communication from the phone and the microprocessors. Since the communication between devices is wireless, a Bluetooth dongle was required to facilitate communication, because the Raspberry Pi 3 Model B microprocessor even having a built-in Bluetooth receiver is unable to stream audio to external devices such as hands-free/wireless headsets/earphones.

The **laptop** and the processor were used in coding and editing the device's software.

The **microprocessors** runs using 5 volts of power and would require a minimum of 2.5 amperes of current to run smoothly, since it could not be directly connected to the on-board battery of the motorcycle. It would require a power inverter with a minimum of 220 volts alternating current (AC) output and an input of 12 volts direct current (the standard output of any motorcycle battery in the market).

The **microprocessors**: Raspberry Pi 3 Model B; Arduino Uno would be used to demonstrate the device concept, including the different sensors that would be incorporated: the Ultrasonic sensor that can measure distance using Ultrasonic waves; GPS module which can directly access the GPS data from orbiting GPS satellites; ADXL335 (Balance Sensor) that can detect acceleration in the x, y, and z axis; and the Pi NoIR camera that can take images and make video streams and if coupled with an infrared lamp can have night-vision capabilities.

When it comes to training the device, a minimum **Random Access Memory (RAM)** is 4 gigabytes and up, since the image training will require 2 gigabytes of RAM leaving another 2 gigabytes of RAM for the host operating system.

The **smartphone** was used to control the device, requiring it at least to be a smartphone since most application used in the system runs on android platforms; SD card to store the recorded video and to act as a hard drive that housed the operating system of the Raspberry Pi 3 model B microprocessor, which required at least 4 gigabytes of space for Raspbean Stretch Operating System alone; and the motorcycle with a working battery to test the device on.

E. Software Specification

The software requirements that were used in designing, developing, and testing the Sonar Assisted Vehicle Sensor.

Arduino Integrated Design Environment (IDE) was used to program the microprocessor of the device.

The **Paint application in Windows 10** was used to edit the sizes and view the dimensions of the each image in order to annotate all the images. It was also used to convert to greyscale each image. Each image was labelled and the annotations were saved in a text file.

The **Massachusetts Institute of technology App Inventor (MIT AI)** was used to create a mobile app that will allow the rider to communicate with the device and receive and read incoming texts.

The **notepad app**, whether in the Ubuntu OS or in the Windows 10 OS was used to record all processed images and their corresponding dimensions and the number of vehicles needed to be detected during the image training process.

Python 3 + OpenCV 3.4 was used to program the image processing capabilities of the device.

The mobile app **Mobile SSH** was used to connect to the Raspberry Pi 3 microcontroller. The **VNC Viewer** was also used to control the device remotely using a mobile phone.

Since some software used in the development have compatibility issues with the Windows based operating systems, the **Oracle Virtual Box was** used in order to create OS within an OS form of system with **Ubuntu 16** as the systems development operating system hosted in a **Windows 10** operating system.

VI. RESULT AND DISCUSSION

The Sonar Technology Assisted Vehicle Sensor was designed after gathering all the necessary information needed to complete it. It made up the device hardware, software requirements, a database, dataflow diagram, and system flowchart. The device was designed with the following software: **Arduino IDE** for the hardware programming of the Arduino Uno board; Python 3 + OpenCV libraries,

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which were used to design the image processing functions of the device; the VNC viewer that was used to control the Raspberry Pi 3 Model B using an android phone; and the Mobile SSH which established the connection between the Raspberry Pi 3 Model B and the Android Phone.

The development of the device started on the month January 2018 and was completed on the month of March 2018.

After the device and system development, testing took place to further device evaluation, assessment, and calibration. The device was evaluated using four methods: The Benchmark test; Alpha Test; Beta Test; and Usability Testing.

The scores retrieved from the respondents of the study through the scorecards were computed, tallied, and analyzed and treated using appropriate statistical measures.
Frequency counts, average and grand mean were computed from the scores and obtained using MS Excel Application.

A. Benchmark Test Result

Table I presents the summary result of Product Revision, Product Transition, and Product Operation during the Benchmark test of the Sonar Technology Assisted Vehicle Sensor. In the criteria “Product Revision” the system obtained a weighted mean value of 3.5 and was interpreted as Very Good. In the criteria “Product Transition” the system obtained a weighted mean value of 2.8 and was interpreted as Good. In the criteria “Product Operation” the system obtained a weighted mean of 3.1 and was interpreted as Good. The grand mean obtained of the Benchmark Test of the system was 3.1 and was interpreted as Good. Based on the result of the Benchmark Test done by the researchers and adviser, the developed device is functional and is ready for implementation.

Table I. Benchmark Test for Sonar Technology Assisted Vehicles Sensor

Criteria	Mean	Interpretation
1. Product Revision	3.50	Very Good
2. Product Transition	2.80	Good
3. Product Operation	3.10	Good
Overall Mean	**3.10**	**Good**

B. Alpha Test Result

Table II presents the summary result of Product Revision, Product Transition, and Product Operation during the Alpha Test of the Sonar Technology Assisted Vehicle Sensor. In the criteria “Product Revision” the system obtained a weighted mean value of 4.84 and was interpreted as Excellent. In the criteria “Product Transition” the system obtained a weighted mean value of 4.78 and was interpreted as Excellent. In the criteria “Product Operation” the system obtained a weighted mean of 4.79 and was interpreted as Excellent. The grand mean obtained of the Alpha Test of the system was 4.80 and was interpreted as Excellent. Based on the result of the Alpha Test done by the researchers and adviser, the developed device is functional and is ready for implementation.

Table II. Alpha Test for Sonar Technology Assisted Vehicles Sensor

Criteria	Mean	Interpretation
1. Product Revision	4.84	Excellent
2. Product Transition	4.78	Excellent
3. Product Operation	4.79	Excellent
Overall Mean	**4.80**	**Excellent**

C. Beta Test Result

Table III presents the summary result of Product Revision, Product Transition, and Product Operation during the Benchmark test of the Sonar Technology Assisted Vehicle Sensor. In the criteria “Product Revision” the system obtained a weighted mean value of 5.0 and was interpreted as Excellent. In the criteria “Product Transition” the system obtained a weighted mean value of 5.0 and was interpreted as Excellent. In the criteria “Product Operation” the system obtained a weighted mean of 5.0 and was interpreted as Excellent. The grand mean obtained of the Benchmark Test of the system was 5.0 and was interpreted as Excellent. Based on the result of the Benchmark Test done by the motorcycle drivers, the developed device is functional and is ready for implementation.

Table III. Beta Test for Sonar Technology Assisted Vehicles Sensor

Criteria	Mean	Interpretation
1. Product Revision	5.00	Excellent
2. Product Transition	5.00	Excellent
3. Product Operation	5.00	Excellent
Overall Mean	**5.00**	Excellent

D. System Usability Test Result

Table IV displays the summary for system usability [5] on the quality of the Sonar Assisted Vehicle Sensor device. It represents the overall score of the 10 item statements. It obtained an overall SU score of 69.5. This implies that the developed device has a score above average, is usable, and now ready for implementation.

Table IV. System Usability Results on the Quality Attributes of the Sonar Technology Assisted Vehicle Sensor Device.

Criteria	Mean	SUS Score
1. I think that I would like to use the device frequently	**3.8**	**2.8**
2. I found the device unnecessarily complex	**2.2**	**2.8**
3. I thought the device was easy to use	**3.2**	**2.2**
4. I think that I would need the support of a technical person to be able to use the device	**2.0**	**3.0**
5. I found the various functions in this device were all integrated	**3.8**	**2.8**

Retrieval Number: D7032118419/2019©BEIESP
DOI:10.35940/ijrte.D7032.118419
Journal Website: www.ijrte.org

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6. I thought there was too much inconsistency in this device	**1.5**	**3.5**
7. I would imagine that most people would learn to use this device very quickly	**3.8**	**2.8**
8. I found the device very cumbersome to use	**2.5**	**2.5**
9. I felt very confident using the device	**3.3**	**2.3**
10. I needed to learn a lot of things before I could get going with this device.	**2.0**	**3.0**
SUS SCORE x 2.5		**27.8**
Overall SUS Score		**69.5**

VII. CONCLUSION

Based on the findings and evaluation of the study, the researchers had come up with the following conclusions:

1. The Sonar Technology Assisted Vehicle Sensor device had been successfully developed and tested.
2. The Sonar Technology Assisted Vehicle Sensor device was widely supported by the experts (the third year CICT ESSU Salcedo Campus students).
3. The Sonar Technology Assisted Vehicle Sensor device was effective and usable since it has met the requirements that had been specified during the proposal defense.
4. The Sonar Technology Assisted Vehicle Sensor device is compatible with any motorcycle that has a 12 volt battery.
5. The Sonar Technology Assisted Vehicle Sensor device's GPS module is functional even without internet connection and is only mobile network signal dependent whenever sending destress messages.
6. The Sonar Technology Assisted Vehicle Sensor device's image processor can never reach a hundred percent detection. Training can only reach an acceptance ratio of 0.01, or 99.9% accuracy. Regardless, anything resembling a vehicle, the sensor detects it.
7. The Sonar Technology Assisted Vehicle Sensor device's balance sensor or the 3d axes accelerometer is effective in detecting the motorcycle's inclination and triggers the alarm when tilted too far based on the specified max values of the developers.
8. The image processor is only effective during day time. At night, all sensors are functional, except for the camera.

VIII. RECOMMENDATION

Based on the findings of the study, the researchers had drawn the following recommendations:

1. Instead of making the Sonar Technology Assisted Vehicle Sensor device readily available for the users, it should be marketed to the designers and developers of motorcycles as an additional feature of their product bearing in mind the mechanical and aesthetic design of their vehicles.
2. The device should be tested with an infrared lamp in order for the image processor to detect vehicles in the dark without blinding the drivers of the approaching vehicles.
3. The device's image processing should be trained using a computer that has at least eight (8) gigabytes of RAM to accommodate a larger number of training images and training stages.
4. When using Python 3 together with OpenCV for programming the image processor, it is advisable to use a Linux-based operating system such as Ubuntu and OSX because some features of Python and OpenCV work well with these.

ACKNOWLEDGMENT

The researchers would like to express their deepest gratitude to God almighty for providing the opportunities for them to grow in the course of the conduct of this study, Raven Von-Gray Rama for providing valuable resources and learning materials for free that was used in the development of the device and the system, and the University for providing the environment wherein the researchers' polish their skills that allowed them to grow and learn the necessary traits to complete this study.

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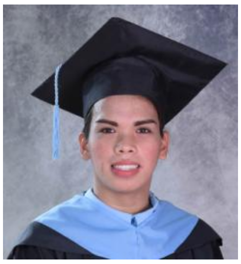

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