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Design and development of a black box for motorcycles

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Abstract

The increasing prevalence of motorcycle usage in Indonesia is directly linked to a surge in related accidents. Within the domain of traffic accident investigations, law enforcement often depends on witness testimonies, a method that is susceptible to substantial discrepancies. The variability in this context presents difficulties, resulting in inefficiencies when it comes to accurately determining the underlying causes of accidents. Hence, there is an urgent requirement for inventive measures to address these challenges and improve the efficiency of accident investigations. This study focuses on the creation of a Black Box, a vehicle data recording device that records information regarding speed, turn signal activation, and brake use. Its primary purpose is to identify the factors that contribute to motor vehicle accidents. The research includes the design, development, and testing phases of this customized Black Box for mechanized motorcycles. In addition, it provides a practical solution to the difficulties encountered by law enforcement and other parties in determining the cause of an accident. This study is structured as a development research project and entails the conception, production, and evaluation of a novel product. This research concludes with significant findings. First, it produces a reliable and effective vehicle data recording system that can identify accident causes. Secondly, experimental results confirm that the efficacy of the device is consistent with its intended design. In addition, the efficacy of the device is highlighted by the fact that it operates without interfering with other mechanical and electrical vehicle systems. This eliminates the need for manual activation and conserves battery power during vehicle inactivity.

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Keywords

Black box, Motorcycle, Battery power

Introduction

The escalation in the number of vehicles on the road has been concurrent with a significant surge in accidents involving terrestrial vehicles, encompassing motorcycles and cars. This assertion is substantiated by a marked upswing in accident frequencies documented annually between 2014 and 2018 [1]. Motor vehicle accidents rank among the top ten causes of mortality globally and also hinder economic prosperity and overall macroeconomic output [2]. Moreover, fatalities and casualties arising from road traffic collisions persist as a significant issue on a worldwide scale, and prevailing patterns indicate that this will persist in the foreseeable future. Expediting progress can be accomplished by implementing and enforcing comprehensive measures, such as safety regulations for roads and vehicles, in a coordinated manner [3].

There are three primary causes of traffic incidents. First, the human factor includes knowledge of traffic laws, driving abilities, and personal traits, such as disregarding speed limits or failing to comply with regulations. Second, infrastructure and environmental factors include road conditions, traffic signals, environmental conditions, and weather. Lastly, the third factor relates to vehicles, the majority of which are still in less-than-ideal roadworthy conditions, including inoperative turn signal lighting and inadequate braking systems, both of which significantly contribute to accidents. In traffic accident investigations, law enforcement frequently relies on witness testimonies, which often vary significantly, leading to inefficiencies in uncovering accident causes.

To address similar challenges in aviation, a technological solution known as the black box was developed. It functions as a data storage system for determining aircraft accident causes by capturing data from the Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) through data logger [4] [5] [6].

By applying a similar approach to motorcycles, equipped with Electronic Fuel Injection (EFI) systems and various sensors, we can create a tool for identifying accident causes. This research focuses on data recording as a supplemental means for understanding motorcycle accidents. It includes data on vehicle speed (from the Vehicle Speed Sensor), brake light usage, and turn signal activation [7][8]. All recorded data is stored for reference, containing information about speed, turn signals, and brake conditions at specific intervals. Furthermore, all the collected data will be stored using the data logger principle and stored into an SD card [7]. Therefore, whenever a motorcycle accident occurs, the stored data can be utilized to determine the accident's cause. This technology has the potential to enhance accident investigations for motorcycles, like how black boxes aid in aviation accident analysis.

To create this device, researchers studied several previous studies related to the development of additional equipment for vehicles [9][10][11][12]. The study incorporates additional devices such as the arduino Uno as a controller. A model for the recorder system is designed to be compatible with any vehicle. Various sensors, including temperature, touch, and vibration sensors, are employed to capture surrounding data. Additionally, IoT technology is utilized for the system's operations. Moreover, the majority of the supplementary devices utilized in vehicles are designed using Arduino microcontrollers. This is a result of their cost-effectiveness and straightforward implementation.

Methods

Product design

Proteus 8 Professional software was employed to create the initial hardware design of the device, while the Arduino Integrated Development Environment (IDE) was used to develop the hardware's program, illustrated in Figure 1 and Figure 2, respectively. The device operates based on three core principles: input circuitry, processing, and output circuitry.

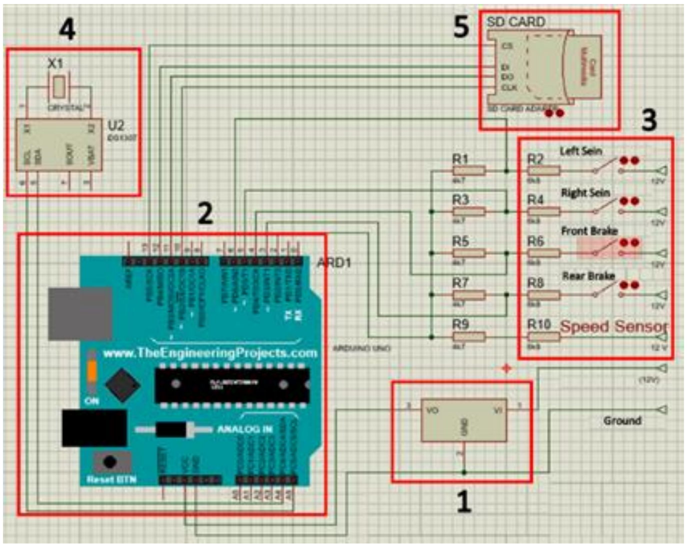


Figure 1. Schematic diagram of the Device, 1) Buck-Boost Converter is used to change the amount of DC voltage output, starting from lowering or increasing the voltage, 2) Arduino Uno Microcontroller, 3) Input data from the motorcycle sensor, 4) Real-time clock, 5) SD card

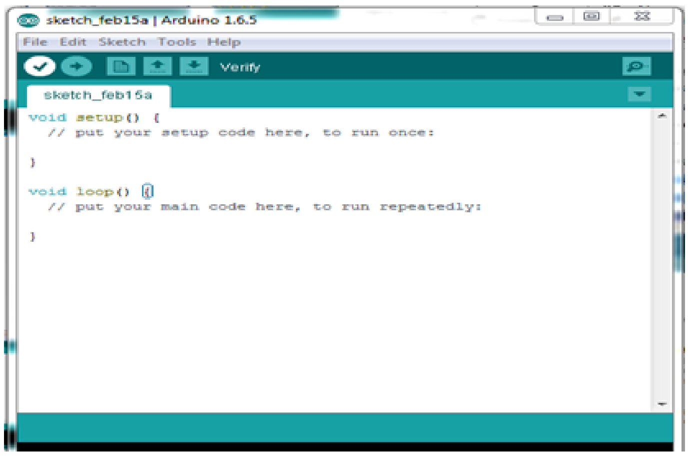


Figure 2. Arduino IDE GUI

The input circuitry consists of two main components. Firstly, it collects data from various motorcycle components, such as speed, braking, and turn signals, for logging purposes. Additionally, data is sourced from the Real-Time Clock (RTC), providing temporal references. The microcontroller within this device acts as the central processing unit, receiving, processing, and storing data on the SD Card memory. This data encompasses speed, braking, and turn signal status, which is recorded in real-time on the SD Card. In addition, the hardware will be compiled into a single package, as depicted in Figure 3.

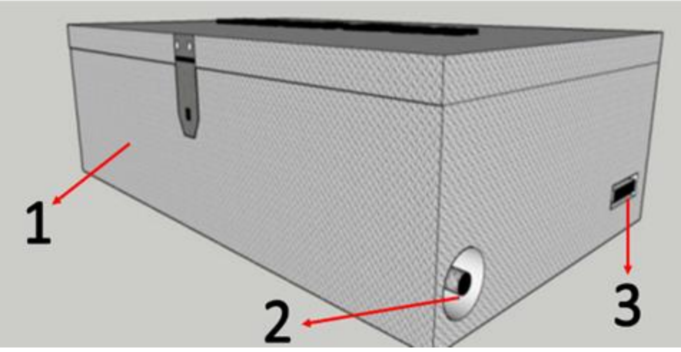


Figure 3. The black box design, 1) The main box, serves as the housing for the key components of the Black Box, which include the microcontroller, real-time clock, SD Card, and other supporting electronic circuitry, 2) Microcontroller power supply socket that connects to the battery through the vehicle's ignition key, 3) Socket that connects input data from the vehicle to the Arduino, including signals from speed sensors, left and right turn signal indicators, as well as front and rear brake signals.

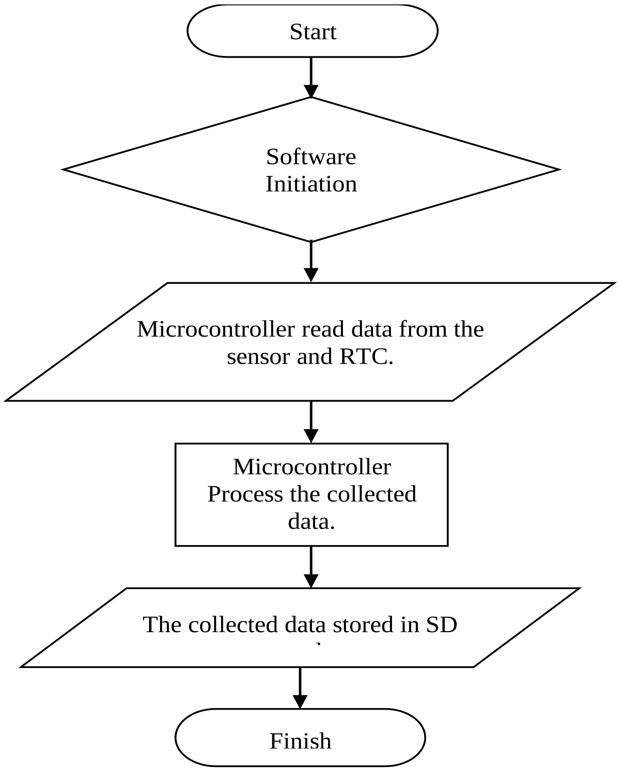


Figure 4. Black box working flow chart design

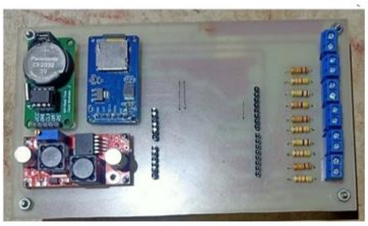
Device working flow

To enable the operation of the hardware, it is necessary to have a software program that has been appropriately configured based on known programming principles. The purpose of this configuration is to meet the specific research requirements and objectives. The software implemented on the microcontroller should possess the ability to effectively handle data obtained from diverse sensors and inputs, and afterwards save this data onto an SD Card. The programming language employed in the production of this product is the C program. The software block diagram is depicted in Figure 4.

Result and Discussion

Device manufacturing

The manufacturing and assembly of the device's components involves a series of preliminary steps. Initially, the Printed Circuit Board (PCB) is manufactured. In this instance, the PCB is manufactured by disintegrating a blank PCB onto which the circuit layout design has been screen-printed. Using Eagle Software, the circuit architecture design has previously been created. After the circuit pattern has been dissolved, holes are drilled into the PCB to accommodate the components according to the design. The produced and placement of the device in the motorcycle is depicted in the Figure 5 and Figure 6, respectively.



a)

b)

c)

Figure 5. Manufacturing processes, a) Top view circuit, b) Bottom view circuit, and c) Main box assembly

Figure 6. Placement of the device in the motorcycle

Product trials

In the automotive workshop of Universitas Negeri Padang, three iterations of a five-minute evaluation were conducted on the product's usability. The testing of the product involved actuating its components while simultaneously monitoring its performance status, which could be directly observed on the monitor display of the Arduino IDE software. The objective of the conducted experiments was to determine whether the designed black box operates within the expected parameters. The device periodically monitored several indicators, including time, turn signal and brake light conditions, and vehicle speed, as can be seen in Table 1.

Table 1. Instrument reading test of the device

No	Instrument	Status					
		Recorded			Unrecorded		
		1	2	3	1	2	3
1	Time	√	√	√	-	-	-
2	Right Sein (R)	√	√	√	-	-	-
3	Left Sein (L)	√	√	√	-	-	-
4	Front Brake	√	√	√	-	-	-
5	Rear Brake	√	√	√	-	-	-
6	Speed (m/s)	√	√	√	-	-	-

Table 2. Experiment results for the black box device

DD/MM/YYYY	Time	Sein R	Sein L	Brake F	Brake R	Speed
13/01/2023	15:20:57	OFF	OFF	OFF	OFF	10
13/01/2023	15:20:58	OFF	OFF	OFF	OFF	10
13/01/2023	15:20:59	OFF	OFF	OFF	OFF	12
13/01/2023	15:20:59	OFF	OFF	OFF	OFF	11
...	...	...	...	...	...	...
13/01/2023	15:23:22	ON	OFF	OFF	OFF	13
13/01/2023	15:23:13	ON	OFF	OFF	OFF	10
13/01/2023	15:23:14	ON	OFF	OFF	OFF	12
13/01/2023	15:23:15	ON	OFF	OFF	OFF	15
...	...	...	...	...	...	...
13/01/2023	15:25:25	OFF	ON	OFF	OFF	20
13/01/2023	15:25:26	OFF	ON	OFF	OFF	19
13/01/2023	15:25:27	OFF	ON	OFF	OFF	21
13/01/2023	15:25:28	OFF	ON	OFF	OFF	22
...	...	...	...	...	...	...
13/01/2023	15:26:16	ON	OFF	ON	ON	13
13/01/2023	15:26:17	ON	OFF	ON	ON	13
13/01/2023	15:26:18	ON	OFF	ON	ON	15
13/01/2023	15:26:19	ON	OFF	ON	ON	15
...	...	...	...	...	...	...
13/01/2023	15:28:39	OFF	OFF	ON	ON	30
13/01/2023	15:28:40	OFF	OFF	ON	ON	30
13/01/2023	15:28:41	OFF	OFF	ON	ON	35
13/01/2023	15:28:42	OFF	OFF	ON	ON	33

Based on the information presented in Table 1, the product is capable of detecting and recording the status of all logged motorcycle components, including the motorcycle's speed. In addition, field testing was conducted over the course of three days, with results indicating that the product remained in excellent condition and that its performance still met the standards established by the previous usage tests. The results of the operational field test analysis confirmed that the product was designed and manufactured as intended. As a result, mass production of the product could commence, whether by the researchers, the university, or companies. This was supported by the device's capacity to record all data, such as the left and right turn signal conditions and the front and rear brake conditions, as shown in Table 2.

Discussion

The experimental results provide validation for the system's functionality and effectiveness, confirming the researcher's original design of the motorcycle black box.

The device operates seamlessly without causing any negative impact on other mechanical or electrical vehicle systems. It diligently records crucial riding data, encompassing information such as speed, turn signals, and braking events, throughout the entire duration from motorcycle start up to shut down. Real-time date and time updates are logged every second, ensuring comprehensive and accurate data collection.

Modern aircraft typically employ Crash Survivable Memory Units (CSMU) in their black boxes, whereas our motorcycle black box employs SD Card memory, which is renowned for its widespread use, variable storage capacities, and user-friendly accessibility via standard devices such as PCs and smartphones. This option simplifies the retrieval of data and eliminates the need for specialized instruments.

The device records exhaustive vehicle data, including speed, turn signal activations, and braking events, from vehicle start-up to shut down, as well as real-time date and time updates every half second. To reduce file sizes, all data is stored in alphanumeric format within TXT files. In addition, the motorcycle black box has a robust steel plate casing, which increases its durability and reduces the risk of damage during accidents. Experiments validated the efficacy of the device in recording and storing vehicle data at half-second intervals. In the event of a catastrophe, the timestamped records of the stored information can aid in the determination of causative factors.

Conclusion

On the basis of the investigation findings, the following inferences can be made. First, this study effectively developed a valid and effective motorcycle data recording system (black box) by incorporating a microcontroller, RTC, and SD Card module with an SD Card as the data recorder. This system can be utilized to identify catastrophe causes. Second, the experimental results confirm the functionality and efficacy of this system, confirming the researcher's original design. The device operates without negatively influencing other mechanical or electrical vehicle systems. Its power source is linked to the ignition key, eradicating the need for manual activation and preventing battery discharge when the vehicle is off.

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