DESIGN AND DEVELOPMENT OF A MICRO-COMPUTER BASED VEHICLE DASHBOARD CAMERA USING SYNCTHING APPLICATION

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DOI: https://doi.org/10.5281/zenodo.8177283

Published Date: 24-July-2023

Abstract: **The automotive industry's growing population has raised concerns about road congestion and traffic accidents. To tackle these challenges, the Internet-of-Things (IoT) paradigm has regained attention in the tech market, accompanied by advancements in modern wireless telecommunications. However, companies like Thinkware and Blackvue rely on cloud storage for driving purposes, necessitating manual file downloading and fast internet access (Costa, 2019). In this research study, it aims to build and develop a microcomputer based vehicle dashboard camera system that incorporates GPS tracking and synchronized data transfer to a mobile application to address this issue without relying on cloud storage. The system's goals were to increase vehicle security, incident reporting capabilities, and overall safety. The study used functional suitability, performance efficiency, usability, functionality, and aesthetics as evaluation characteristics, assessing the system's effectiveness using ISO 25010 and the Mobile App Rating Scale (MARS). Purposive sampling was used to determine a sample size of fifty respondents. Participants expressed satisfaction with functionality, performance efficiency, usability, and aesthetics, according to survey replies. The system's features, such as video synchronization, accurate date-stamped information, GPS tracker location, and weather tracker location, garnered positive feedback. The study's findings show that the proposed dashboard camera system achieves its objectives and has the potential to improve vehicle security, monitoring, and incident reporting. The study provides important insights for future developments in dashboard camera systems, GPS integration, mobile application interfaces, and incident reporting capabilities which this system can benefit car owners/drivers, law enforcement authorities, and helps to enhance vehicle security technologies.**

Keywords: **Micro-computer, vehicle, dashboard, Global Positioning System (GPS).**

I. INTRODUCTION

Car ownership in the Philippines has become more accessible due to affordable options, leading to increased car sales based on Statista Research Development (2022) [1] findings. However, this has resulted in crowded roads and a higher risk of traffic accidents. To address this, dashboard cameras have become common in cars, aiding in dangerous driving detection and accident prevention. According to University of York (2020) [2], tracking devices have also become crucial for monitoring vehicle location, particularly in remembering precise parking spots. The rise of the Internet of Things (IoT) has influenced the automotive industry, with companies like Thinkware and Blackvue utilizing cloud storage for driving-related data. However, as Costa (2019) [3] stated, this reliance on the cloud requires manual file downloads and fast internet access.

The objective of the study titled "Design and Development of a Micro-computer Based Vehicle Dashboard camera using Syncthing application" is to create an enhanced dashboard camera system by utilizing a Micro SD card for storage and data transmission between devices. The system will synchronize video recording/dashboard camera footage and vehicle location to a mobile application, allowing users to access the content. Specifically, this study aimed to: (1) To design and develop a micro-computer-based vehicle dashboard camera interfacing a GPS module displaying the latitudinal and longitudinal data. (2) To develop a user interface for the mobile application of the vehicle through an Android Package Kit (APK) file format. (3) To test and evaluate the system using ISO 25010 with functional suitability, performance efficiency, and usability. (4) To test and evaluate the mobile application using MARS mobile application with functionality and aesthetics.

The findings of this research are beneficial to the users that can view and manage video logs through the app and report incidents via the E-Report feature, benefitting vehicle owners/drivers by enhancing security and safety, allowing them to track their vehicle, manage footage, and file reports conveniently. It also benefits LTO/PNP authorities by streamlining incident identification and resolution. Furthermore, future researchers can reference and build upon this study for technological advancements. The research focuses on synchronizing the vehicle dashboard camera with a mobile application using the Syncthing application. Prototype will be created using a Raspberry Pi 3B, GPS, RTC and a camera module with the camera as the central feature for monitoring the road. The study emphasizes the need for available storage hence the use of 32GB micro-SD card. The resolution of the camera will be set at 1290x730 to support the standard aspect ratio, which will record every 5 minutes and synchronized to the mobile application using Syncthing, and the oldest video file will be deleted if free storage capacity reaches less than 80% of 32GB. A mobile Android application will also be developed for easy management and navigation of video logs, GPS data, weather tracking feature, sharing video footage through a post-report feature and allows customization of network connectivity settings. The system will use Syncthing, that requires having same Wi-Fi network, to synchronize the captured footages, and users can manage the content and settings from the mobile application. Testing will be conducted on class 1 vehicles that have functioning cigarette lighter sockets in General Trias City, Cavite. It also restricts mobile application testing to Android versions 9 to 13.

II. METHODOLOGY

2.1 Research Design

The researchers would employ an applied research method for this study. As per Kothari (2008), applied research seeks to solve an immediate problem confronting a society or an industrial/business organization, whereas fundamental research is primarily concerned with generalizations and the formulation of a theory. According to Bajpai (2011), applied research is a non-systematic inquiry that is typically initiated by a company, agency, or individual in an attempt to address a particular problem.

The research study is quantitative research that will utilize a true-experimental research design to collect data needed in order to achieve a better understanding of the concept of the prototype of the dashboard camera and the solution for the problems that usually occur in the daily dilemma of the drivers. Thus, the researchers will use a post-test only for the reason that the research study is an experimental type that will have a controlled group during the testing, and the outcome for the control and experimental groups should be parallel

Research Locale

The researchers selected General Trias in Cavite City as their research location due to its proximity to a university with a significant number of individuals who own vehicles. This proximity enables them to conveniently study the chosen participants.

2.2 Project Construction Procedure

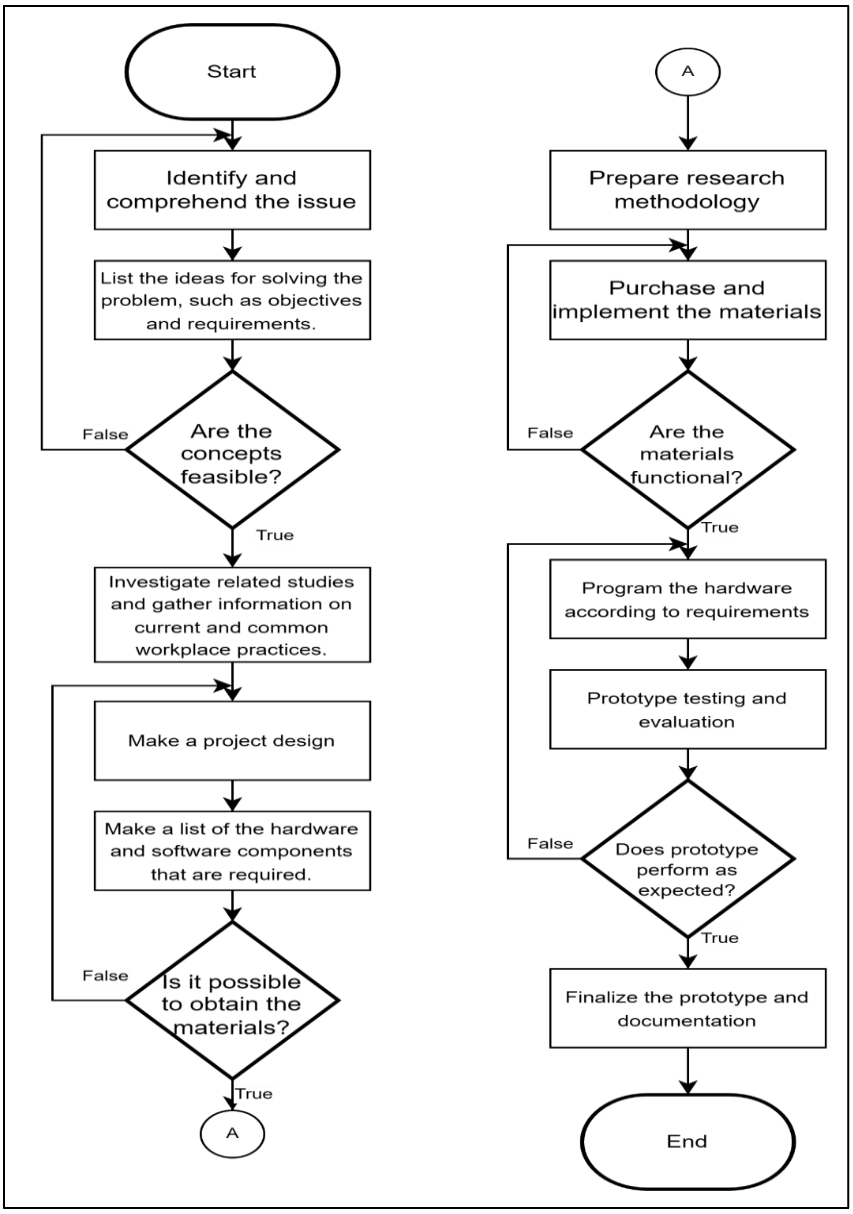

FIGURE 2.1: PROJECT CONSTRUCTION PROCEDURES

The study, titled "Design and Development of a Microcomputer Based Vehicle Dashboard Camera Using Syncthing Application," aims to create a dashboard camera that provides synchronizable data transmission of video files between the Raspberry Pi itself and the user phone, as well as having an option of sending these files to authorities in the event of an accident or crime. To make the project a reality, researchers examine previous research to determine the purpose of the study, while also gathering data and exploring practices to acquire knowledge and concepts from the Internet for the project's construction.

The first step in starting the project is to learn about and collect various components and devices by using reliable sources and consulting knowledgeable individuals to research the possible materials and right components to use. The choice was made carefully in order to avoid purchasing defective, unnecessary components or simply being unavailable inside the country.These materials will be put to good use by planning ahead of time before a proper setup is made by searching through Internet guides. The devices are also tested to see if they are functional for the hardware to function properly according to the specifications. To finalize the prototype, it will go through an unknown number of tests and evaluations until its performance meets the researchers' expectations. Following the completion of the prototype, the documents will be completed as well.

System Block Diagram

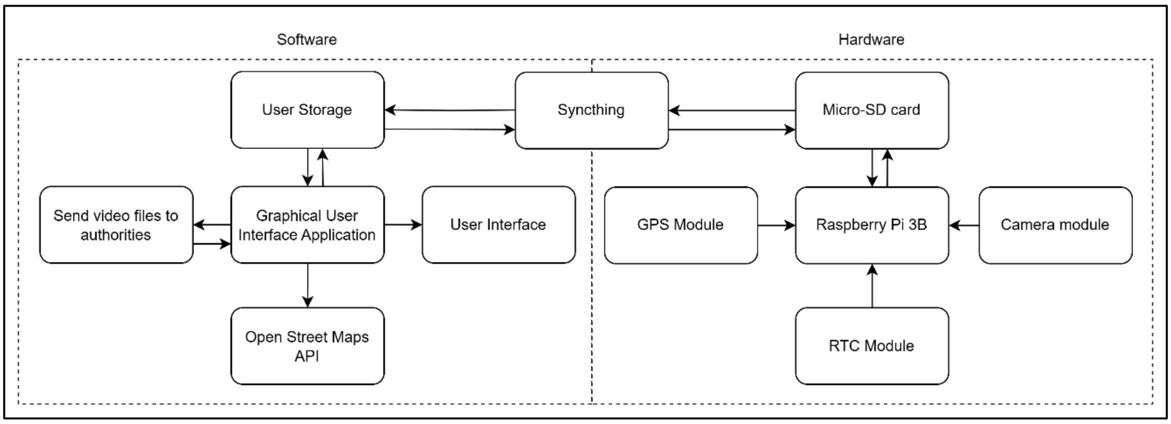

FIGURE 2.2: BLOCK DIAGRAM OF THE HARDWARE AND SOFTWARE

Figure 2.2 shows a simple explanation of this study, which employs both hardware and software. A GPS module, a micro-SD card, and a camera module comprise the Raspberry Pi's hardware. The software, on the other hand, is focused solely on the graphical user interface, where features such as post-reporting of videos to authorities are available. The videos will be captured using the camera module and saved to the micro-sd card, which is also required to load the Raspberry Pi operating system. Recording videos will always begin when the Raspberry Pi boots up. The GPS module, on the other hand, is used to generate longitudinal and latitudinal data, which is then converted and displayed on the user interface using GPS interface on mobile application.

The Syncthing program will handle these files in order to synchronize them with the file system of the user's phone, thereby establishing a software-hardware relationship. After synchronizing with the user phone's file system, the graphical user interface can also transfer video files to authorities from a form of shareable link.

Hardware Schematic Diagram

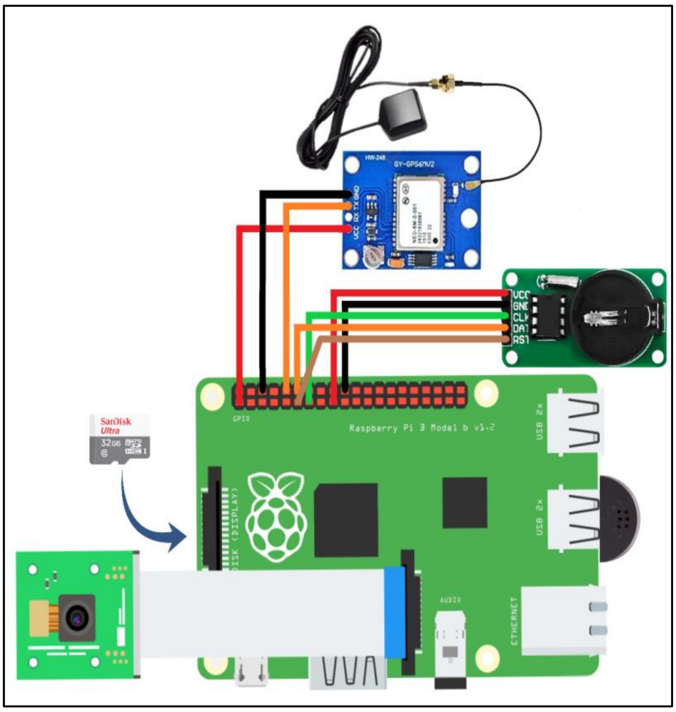

FIGURE 2.3: HARDWARE SCHEMATIC DIAGRAM

The prototype's schematic model is shown on Figure 2.3. This is where the Raspberry Pi and all other hardware modules provided from the research components are connected. Thus, having a schematic diagram of the hardware will help the researchers in organizing and managing the components in the prototype.

Prototype Casing

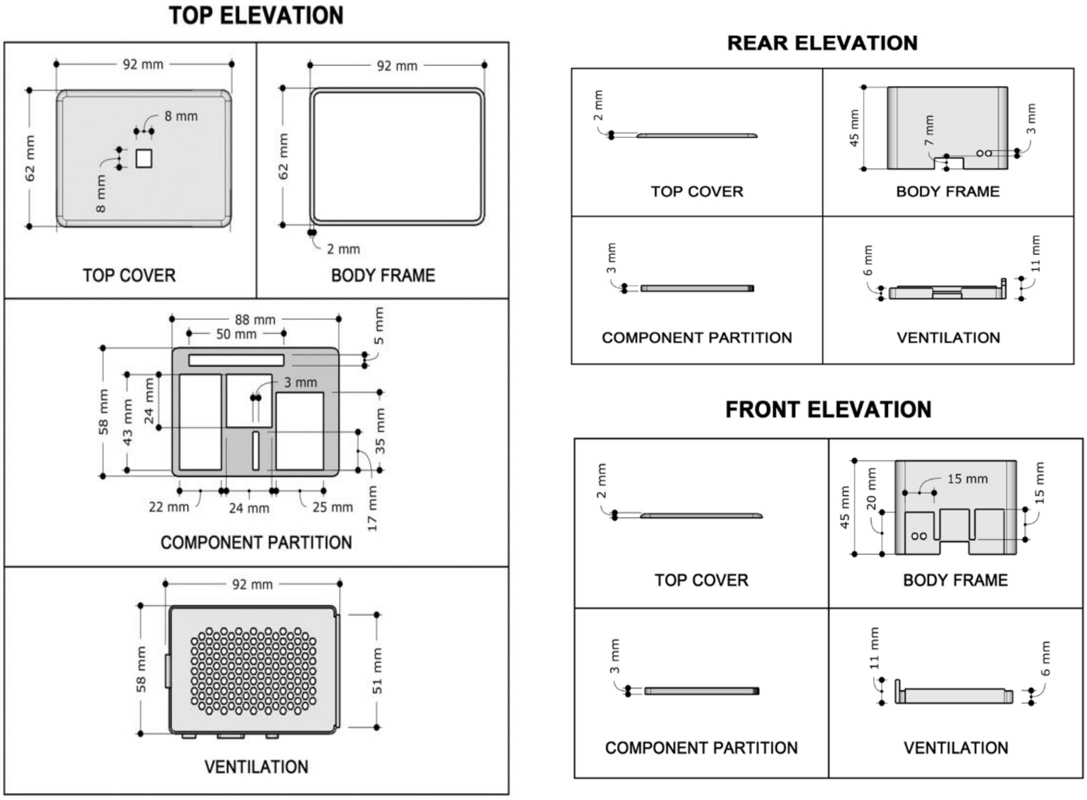

FIGURE 2.4: DASHBOARD CAMERA CASING

The prototype's camera casing design is shown on Figure 2.4. This is where the Raspberry Pi and all other hardware modules connected to it will be embedded. Thus, this design was carefully planned in order to be compact and to provide stabilized video footages.

Actual Model of the Dashboard Camera

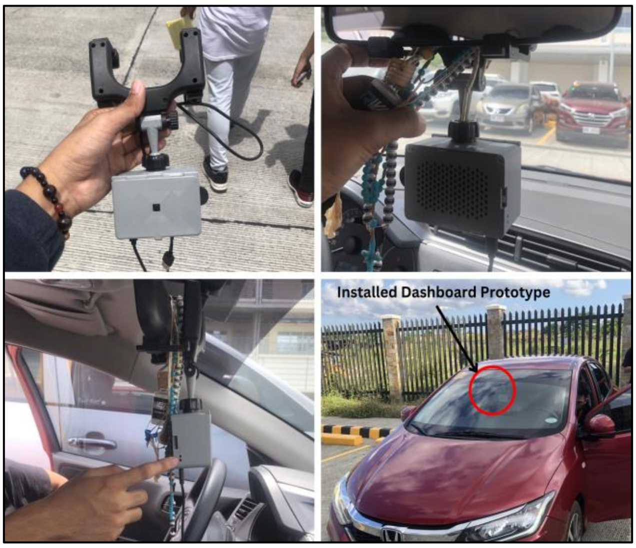

FIGURE 2.5: DASHBOARD CAMERA TESTING

Figure 2.5 presents the physical model of the prototype, which was successfully installed on a vehicle for rigorous testing purposes. The image showcases the actual implementation of the prototype, providing a tangible representation of its design and functionality during testing.

Mobile Application File Manager Wireframe

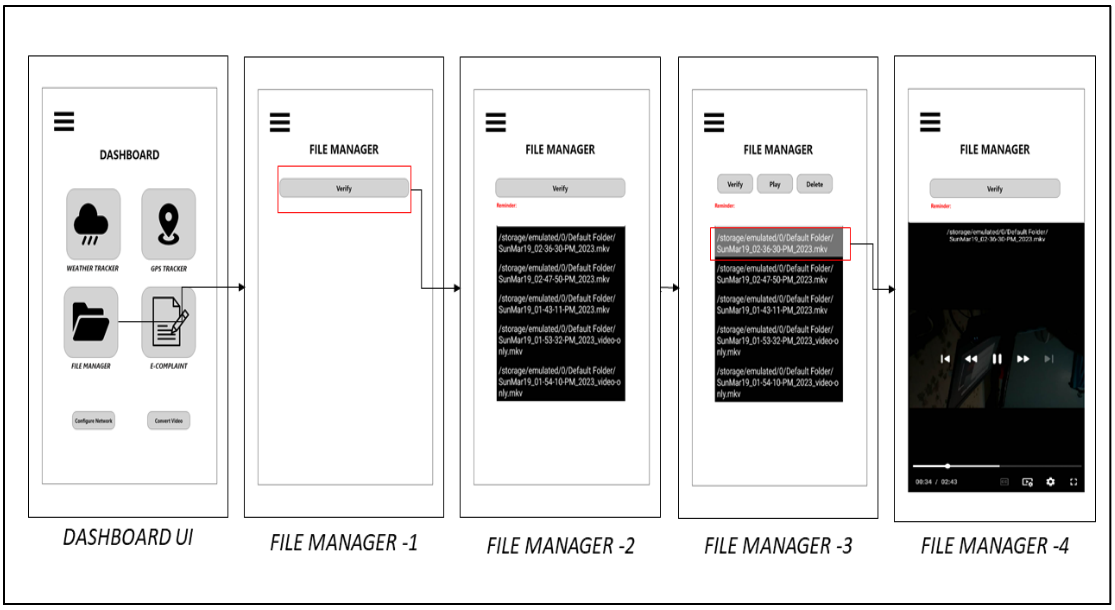

FIGURE 2.6: FILE MANAGER WIREFRAME

Figure 2.6 showcases the file manager button that serves as a gateway for synchronized files. It establishes a direct connection to the user's local storage, allowing easy access to the lists of all synchronized video. Users can watch and delete these videos, even without an internet connection. This feature ensures that files are always up to date, reflecting any changes made on the device. Thus, it provides convenient and quick access to files, enhancing the device's functionality.

III. RESULTS AND DISCUSSION

Hardware System Application Flowchart

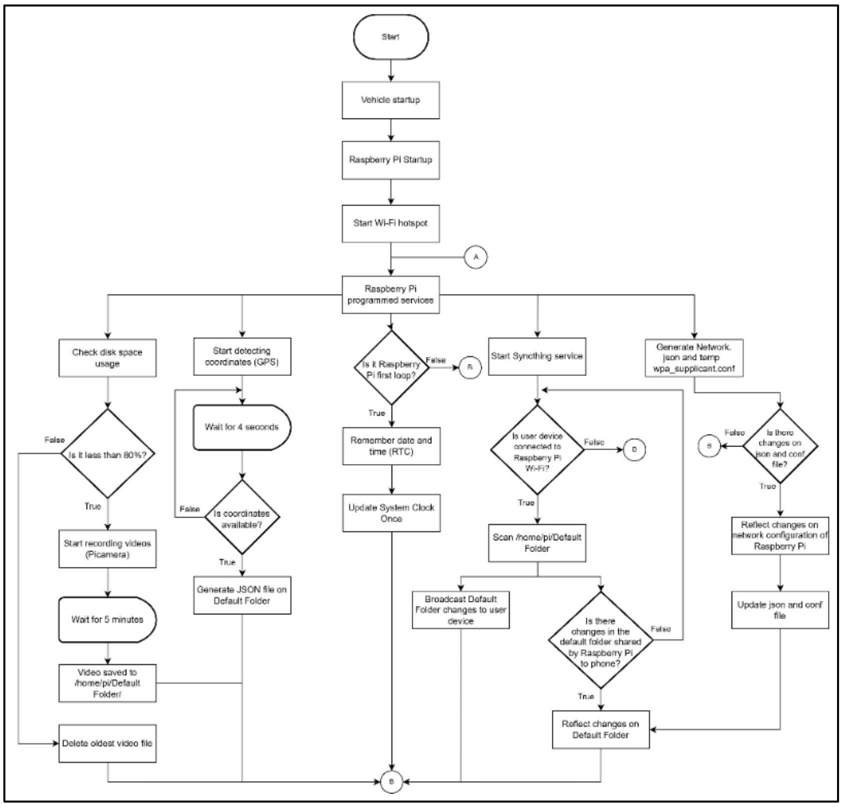

FIGURE 3.1 A: HARDWARE SYSTEM APPLICATION FLOWCHART

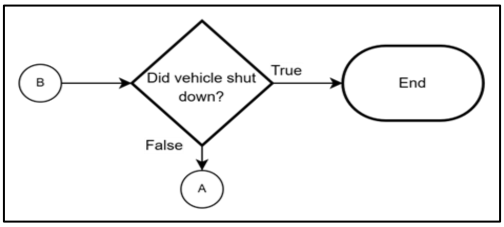

FIGURE 3.1 B: HARDWARE SYSTEM APPLICATION FLOWCHART

Figure 3.1 A&B illustrates the comprehensive application flowchart of the system, commencing with the Raspberry Pi's boot-up process when the vehicle itself is powered on. Upon startup, a set of pre-programmed services initiated by the developers come into operation. These services include the recording of videos and coordinates, as well as the Raspberry Pi's ability to remember the date and time at each startup. Additionally, the Syncthing service is activated to facilitate file synchronization.

At regular intervals of 5 minutes, video recording ensues, with the resulting files being saved on the micro-SD card of the Raspberry Pi. These videos are assigned filenames based on the date and time of recording. By default, these files are stored in a designated folder directory named "Default Folder" under home/pi on the Raspberry Pi, ready to be synchronized with the user's mobile device when connected to the Wi-Fi wireless access point generated by the Raspberry Pi. The synchronization process relies on the establishment of a connection between the two devices using Syncthing. It is essential for the user to configure this connection beforehand. Furthermore, if the available storage capacity on the hardware falls below 80%, with the remaining space reserved for the operating system, the system will automatically begin deleting the oldest video files to ensure uninterrupted recording.

The GPS functionality also plays a crucial role, with the software utilizing a file containing GPS data to display the current geographical location of the vehicle. OpenStreetMap is employed by the software application to provide accurate location representation. Over time, these GPS data files are overwritten to reflect the most up-to-date location information. The synchronization capability of Syncthing facilitates the seamless transfer of all these files between the Raspberry Pi and the user's connected devices. Any changes detected in these files will be reflected in both devices. However, it is important to note that before establishing a complete connection between the devices, the user must follow the initial setup steps outlined in the user manual. Once this initial setup is completed, further setup will not be required unless the application is uninstalled. Finally, it should be mentioned that unplugging the Raspberry Pi from the power source results in the device being powered off, rendering it unable to perform file synchronization or execute the programmed services described above.

Software System Application Flowchart

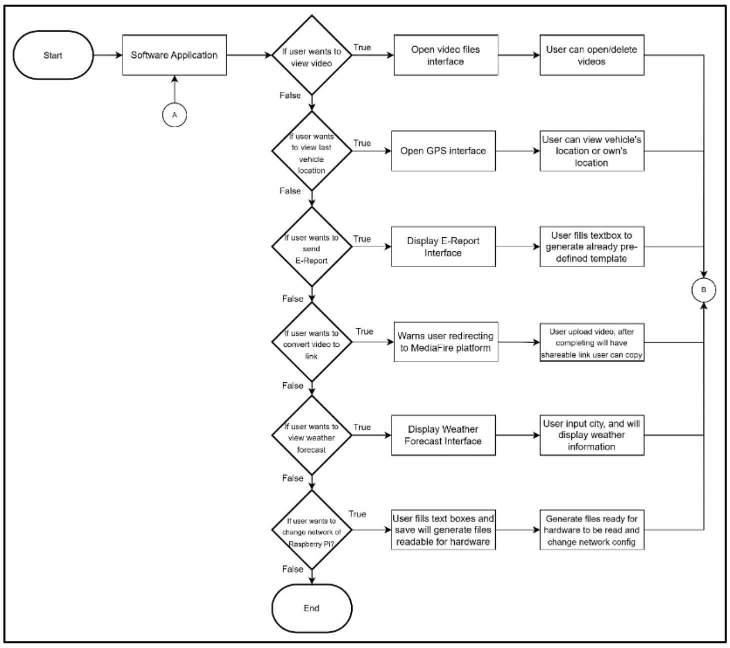

FIGURE 3.2 A: SOFTWARE SYSTEM APPLICATION FLOWCHART

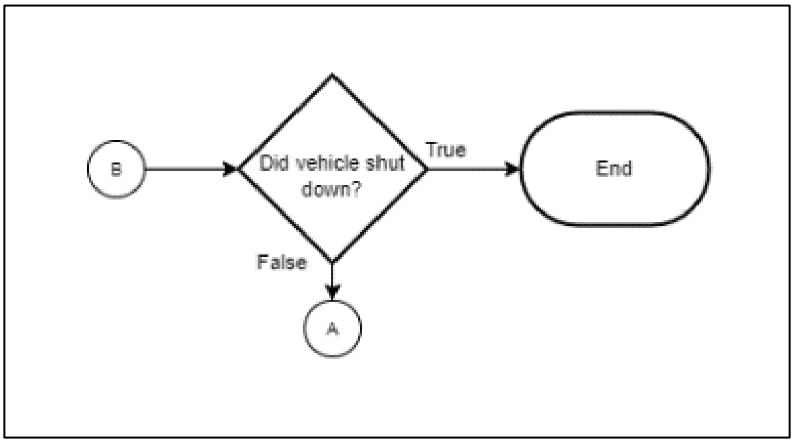

FIGURE 3.2 B: SOFTWARE SYSTEM APPLICATION FLOWCHART

In accordance with figure 3.2 A&B, the software application provides a comprehensive interface through which the data generated by the hardware can be effectively managed. Users are empowered with a range of functionalities, enabling them to manipulate the data according to their needs. This includes actions such as playing the recorded footage or deleting them if required. Additionally, users have the ability to access and view the precise location of the vehicle as recorded by the GPS. In addition, the user can get the weather prediction for the city they choose to enter.

One notable feature available to users is the option to share the recorded footage with relevant authorities. To achieve this, users can convert videos into links using the MediaFire platform. MediaFire offers 10GB of free storage space to registered users with a valid email address. The platform does not share personal information with the receiver, and it can track the number of downloads from a shared link. The software application can facilitate this process, automatically generating the necessary information to accompany the footage. Consequently, users can conveniently and efficiently send the footage, along with the associated details, to the respective authorities. This feature streamlines the reporting and sharing process, ensuring that the relevant information reaches the intended recipients promptly.

File Manager Initial Set-up Code

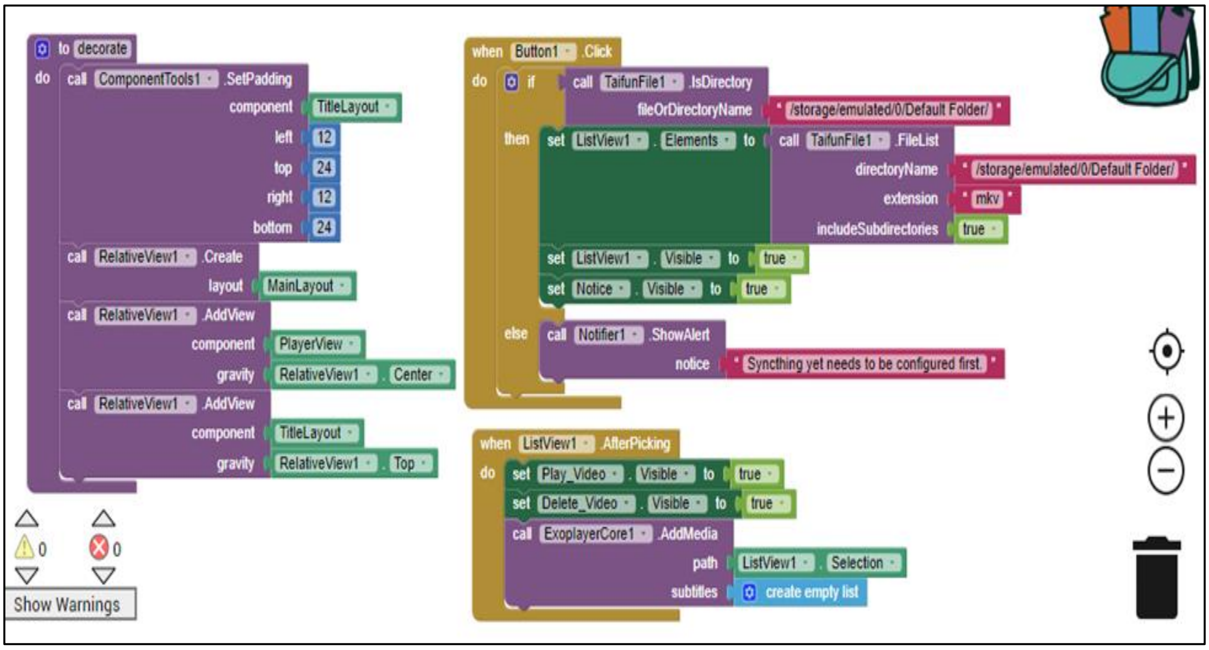

FIGURE 3.3: INITIAL SETUP FOR THE FILE MANAGER CODE USING MIT APP INVENTOR

The figure 3.3 depicts the primary user interface (UI) of the file manager, serving as the central hub for various functionalities, within this UI, there is a "Verify" button that triggers the execution of the button1 block. When pressed, the mobile application initiates a search for the default folder, enabling the displaying of list for all synchronized videos with the .mkv file extension.

Testing Validation using Paired Sample Statistics

TABLE I: PAIRED SAMPLE STATISTIC FOR COMPARING THE MODULE AND ALPHA TEST FOR VIDEO SYNCHRONIZATION TEST USING T-TEST

Paired Samples Statistics					
Testing/ Evaluation		**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Module Testing Number of Videos Synchronized	2.63	8	1.408	.498
	AlphaTesting Number of Videos Synchronized	1.88	8	.641	.227
Pair 2	Module Testing Number of Videos per minute	1.38	8	.518	.183
	AlphaTesting Number of Videos per minute	1.63	8	.518	.183
Pair 3	Module Testing - Storage Allocated	4.00	8	3.381	1.195
	AlphaTesting - Storage Allocated	5.00	8	3.295	1.165
Pair 4	Module Testing Synchronized	1.38	8	.518	.183
	AlphaTesting Synchronized	1.38	8	.518	.183

Table I shows module testing and alpha testing were conducted to evaluate the video synchronization capability of the system. The results of the paired samples t-test showed that there were no significant differences between module testing and alpha testing in terms of the number of videos synchronized, number of videos per minute, storage allocated, and synchronization success.

TABLE II: Paired Sample Statistic for Comparing the Module and Alpha Test for GPS and Weather Tracker Location Test using T-Test

Paired Samples Statistics					
Testing/ Evaluation		**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Module Testing - Date Stamped Accuracy	1.38	8	.518	.183
	Alpha Testing – Date Stamped Accuracy	1.25	8	.463	.164
Pair 2	Module Testing – GPS Tracker Location accuracy	1.63	8	.518	.183
	Alpha Testing -GPS Tracker Location Accuracy	1.38	8	.518	.183
Pair 3	Module Testing - Weather Tracker Location Accuracy	1.88	8	.354	.125
	Alpha Testing - Weather Tracker Location Accuracy	1.13	8	.354	.125

Table II aimed to assess the tests of date stamping, GPS tracker location, and weather tracker location. The findings indicate that there were no notable disparities. Until in terms of weather tracker location accuracy, that exhibited a significantly higher average value than alpha testing likely due to the specific weather conditions during the module tests.

Compatible Android Version for the Mobile Application

TABLE III: Android Version Compatibility Test

Android Version	Remarks
9	**Success**
10	**Success**
11	**Success**
12	**Success**
13	**Success**

The Table III shows the compatible android versions for the Drive Guard mobile application. It is compatible from android version 9 or Android Pie up to the recent version of android, Android 13 or Android Tiramisu.

Respondents of the Study

The researchers selected fifty (50) participants based on their relevance to evaluate the criteria for ISO 25010 and MARS or mobile app rating scale. Proponents also interviewed PNP Captain Sangria specifically for MARS, which is specifically focused on post-reporting and to be clarified with authorities' process of handling video footage from email.

Evaluation of the Study

The researchers evaluated the prototype using three criteria from the ISO 25010 standard: functional suitability, usability, and performance efficiency. These criteria were chosen due to the time constraint. The proponents then collected feedback from fifty (50) participants who were selected based on their relevance to the study, using a four-point Likert scale. This method was similar to another local study made by Mendeja et al. (2023) that used ISO 25010.

The researchers also used a Mobile App Rating Scale (MARS) questionnaire with the help of a statistician and a research adviser for assessing the mobile application created according to the objective of this study. The MARS questionnaire focused on two aspects: functionality and aesthetics. The researchers did not include information quality or engagement as they were not relevant to the software application.

Results for the ISO25010 Evaluation

TABLE IV: ISO25010 Evaluation Results

Criteria	Grand Mean	Verbal Equivalent
Functional Suitability	3.89	Strongly Agree
Usability	3.84	Strongly Agree
Performance Efficiency	3.66	Strongly Agree

Note: For interpretation, the following verbal equivalent was applied from rating scale of ISO 25010. 4.00 - 3.26 for Strongly Agree, 3.25 - 2.51 for Agree, 2.50 - 1.76 for Disagree, and 1.75 - 1.00 for Strongly Disagree

Table IV shows how the respondents rated the system based on ISO 25010 criteria: functional suitability, usability, and performance efficiency. The average scores for these criteria were 3.89, 3.84 and 3.66 respectively, which all correspond to a strongly agree verbal interpretation. The results imply that the respondents strongly agreed that the system worked well when used properly.

Results for the Mobile Application Rating Scale Evaluation

TABLE V: Mobile Application Rating Scale Evaluation Results

Criteria	Grand Mean	Verbal Equivalent
Functionality	3.86	Highly Acceptable
Usability	*3.65*	*Highly Acceptable*

Note: For interpretation, the following verbal equivalent was applied from rating scale of MARS. 4.00 - 3.26 for Highly Acceptable, 3.25 - 2.51 for Acceptable, 2.50 - 1.76 for Fairly Acceptable, and 1.75 - 1.00 for Unacceptable.

Table V shows how the respondents evaluated the software application using MARS or mobile app rating scale with two aspects: functionality and aesthetics. The mean scores for these aspects were 3.86 and 3.65 respectively, which both mean highly acceptable in verbal terms. The results suggest that the respondents highly accepted that the application functioned well and looked good when used correctly.

IV. CONCLUSION

In conclusion, the research study on the design and development of a micro-computer-based vehicle dashboard camera system using the Syncthing application has successfully achieved its objectives and addressed the identified research questions. The study aimed to develop a system that improves upon commercially available dashboard cameras by incorporating features such as GPS tracking, synchronized data transmission, and a user-friendly mobile application.

Through the implementation of the system, it was demonstrated that the use of a micro-computer, along with the integration of GPS and Syncthing application, allows for enhanced monitoring and general safety. The dashboard camera continuously records 5-minute video footage, providing valuable evidence for investigations related to road incidents. The GPS tracking feature enables real-time tracking of the vehicle's location, aiding in vehicle security and ensuring the safety of occupants.

The mobile application serves as a central hub for accessing and managing the synchronized data, including video logs and GPS information. It offers a user-friendly interface, allowing vehicle owners and drivers to easily navigate and control the system. Additionally, the application includes an incident reporting feature, enabling users to report road-related incidents directly to the email of Philippine National Police (PNP) and Land Transportation Office (LTO) authorities.

The evaluation of the system using ISO 25010 and the Mobile App Rating Scale (MARS) demonstrated satisfactory results in terms of functional suitability, performance efficiency, usability, functionality, and aesthetics. The system met the requirements set forth in the research study, and the data collected during the testing phases showed promising outcomes.

The developed micro-computer based vehicle dashboard camera system offers several benefits to different users. Vehicle owners and drivers can significantly benefit from improved vehicle security, safety, and protection. The system provides comprehensive coverage and monitoring capabilities, allowing users to have peace of mind on the road, and even remembering where the user parked the vehicle because of the GPS featured in this study.

Moreover, the integration of incident reporting features and direct communication with authorities streamlines the process of reporting accidents or crimes, enhancing the efficiency and convenience for both users and the PNP/LTO authorities.

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