# ENVIRONMENT PERCEPTION SYSTEM FOR SMART VEHICLES

By



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**TEAM NO.: 01** **WINTER-2022 INTAKE**

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**OCTOBER 2023 G – RABI II 1445 H**

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**TEAM NO.: 01 WINTER -2022 INTAKE**

**A senior project report submitted in partial fulfillment of the requirements for the degree of**

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**CHECKED AND APPROVED (ADVISOR):**

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بسم الله الرحمن الرحيم
والصلاة والسلام على خير الورى عدَّ
الحصى والرمل والثرى
وعلى آله وأصحابه ومن تبع هداهم
واهتدى
نحمد الله العلي القدير الذي قدَّرنا على
إنهاء هذا المشروع في الوقت المحدد

**We dedicate this senior design project to our families, your unwavering support and encouragement carried us through the highs and lows of this journey. Your belief in our capabilities and your constant presence in our lives were the pillars of our strength.**

# ABSTRACT

## ENVIRONMENT PERCEPTION SYSTEM FOR SMART VEHICLES

Navigating today's advanced automotive world, drivers face the peril of blind spots, especially during maneuvers like parking or lane changes, which can lead to severe accidents. Existing aids, such as mirrors and sensors, are no longer adequate, underscoring the need for a more technologically integrated approach to enhance driver awareness and safety.

Our project, aimed at neutralizing blind spot hazards, responds to the demand for an advanced system capable of providing clear visuals, accurate object distance, and a bird's-eye view, all in real-time to facilitate quick driver decision-making. The 'Environment Perception System for Smart Vehicles' is an innovative Advanced Driver-Assistance System (ADAS). It incorporates four stereo fisheye cameras and an NVIDIA Jetson Nano processor, a blend that enabled the creation of a multi-functional visual aid. This system processes integrated camera feeds, employing advanced algorithms to eliminate distortion and measure object distances, compiling a unified bird's-eye view. The user-friendly interface, controlled via pushbuttons, allows easy switching between functions designed for parking, lane changes, and distance alerts.

The final product stands out as a robust ADAS, merging state-of-the-art hardware and software to deliver essential visual input to drivers. It guarantees an 81° field-of-view, monitors object distances within 23 meters, and presents a detailed bird's-eye view within 3 meters, all at a smooth 10 fps. Its intuitive control panel ensures user-friendly operation across its various features.

Significantly, our system delivers over 90% accuracy in object detection, essential in high-speed contexts, setting it apart in the market. Its bird's-eye view feature simplifies previously complex driving tasks. By offering real-time, high-caliber visual information, we edge closer to autonomous driving technology, playing a pivotal role in evolving safety standards and influencing the automotive industry's trajectory.

***Index Terms*** — Advanced Driver Assistance Systems (ADAS), bird's-eye view.

# ACKNOWLEDGEMENT

We wish to express our sincere appreciation and acknowledgment to Dr. Muhammad Bilal, our esteemed advisor, for his unwavering guidance, mentorship, wisdom, expertise, and support that propelled us through the challenges and triumphs of this senior design project, shaping us into proficient engineers.

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To our families and friends, we acknowledge and appreciate your unwavering support and encouragement, which carried us through the highs and lows of this journey. Your belief in our capabilities and constant presence in our lives were the pillars of our strength.

This project stands as a testament to the collective effort and dedication of all those involved. We offer our heartfelt gratitude to each individual who played a significant role in making this project a reality.

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# CHAPTER – 1 INTRODUCTION

## 1.1 ABOUT THE PROJECT

This project aims to solve a significant problem in vehicles, which is the inability of drivers to see the blind spots in the car. It may expose people and drivers to danger because the driver relies on the side and rear mirrors. Moreover, at the time of parking the car, it can cause many difficulties in parking the car. Our system aims to provide a safer driving experience, as well as information about distances to objects near the vehicle, displaying blind spots, and finally, offering a more improved perspective of the vehicle, which is more than what the rear and side mirrors provide. Our project will help reduce accidents and make the driving experience more comfortable for the driver.

## 1.2 BACKGROUND

Vehicle-related problems are common worldwide, especially those that do not have an environmental perception system. The environment perception system for smart vehicles is a system that uses sensors to identify and detect the environment around the vehicle. The environment awareness system is the main component in self-driving vehicles and enables them to make decisions according to the environment surrounding the vehicle. Environment perception systems use a variety of sensors, including cameras, LiDAR, and radar, to detect objects around the vehicle and evaluate their position and speed. The environment perception system also uses a set of algorithms to process and interpret the data collected by the sensors. These algorithms can identify objects in the environment, such as cars, pedestrians, and animals, and detect their distance and speed. The environment awareness system is an essential component for the driver as it allows him to know the blind spots in the vehicle and to display a more improved perspective of the vehicle. As technology continues to develop and improve, the importance of the environmental perception system will increase.

# CHAPTER – 2 CONCEPTUAL DESIGN

## 2.1 SITUATION DESCRIPTION

In the early days of public usage of automotive vehicles, there were no rear and side mirrors, so drivers had to turn to see from behind or to the sides. And then newer car designs had the rear and side mirrors we know today. This did help in making the driver’s experience more accessible, and that is by seeing the perspective from the mirrors, which covers some blind spots of the car. Nevertheless, it does not cover all blind spots, nor does it convey the perspective accurately, as things in the mirror are reflections and could look smaller/more significant than they are.

The increase in Saudi Arabia’s traffic makes driving harder. Therefore, it requires a lot of experience and quick decision-making to get through traffic while on the road or even during parking [1]. Sometimes quick decision-making can be overwhelming for the driver, which causes accidents. While driving a car, the driver can only see from a limited perspective, as there are blind spots that could endanger you in an accident. Furthermore, the available solution, the rear, and side mirrors do not convey a clear and accurate view of these blind spots.

## 2.2 PROBLEM STATEMENT

Utilizing the four W's method, we delve into a specific issue impacting car drivers globally. We identify 'who' is experiencing the problem, and it is car drivers. 'What' the problem entails is quite clear: "mirrors do not provide enough information about the car's surroundings and cannot perceive blind spots." The 'where' highlights the situations where this issue is most pervasive, which are during parking and when changing lanes. Lastly, the 'why' underlines the importance of addressing this problem because not knowing if a car is in the blind spot might cause accidents and endanger people's lives.

Thus, the problem statement, formulated through this analytical approach, is precisely: "Drivers can't see blind spots when using mirrors during parking or when changing lanes, and that puts their lives in danger." This statement encapsulates the essence of the safety issue identified using the four W's method, pointing out the deficient informational capacity of current vehicle mirrors in critical driving scenarios and emphasizing the resultant risk to human life.

## 2.3 PROJECT OBJECTIVES

Some specific goals and objectives must be met for all projects. They are divided into two categories. First, lower-level objectives must be met by finishing the project. And they need to be specific, measurable, achievable, relevant, and time bound. Secondly, Higher-level, or strategic objectives are objectives with a large impact and by completing the project these objectives are one step closer to being achieved. the following list showcases the lower-level objective that our project will achieve by the end of the Senior Design Project and the higher-level objectives that our project will contribute to achieving:

*Lower-Level Objectives:*

1. Provide the driver with a detailed distortion-free view of the vehicle's surroundings free from any blind spots on a screen installed on the dashboard.
2. Provide information about the relative distances of all the objects within proximity of the vehicle.
3. Provide a parking-friendly view for similar and difficult parking scenarios in tight spots.
4. Achieve real-time performance sufficient for comfortable driving.

*Higher-Level Objectives:*

1. Make cars safer, especially from accidents caused by collisions from blind spots.
2. Enhance the surrounding view to make driving easier for people uncomfortable with a limited mirror view.
3. Kickstart indigenous development of ADAS technology in KSA for the upcoming age of smart cars.

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## 2.4 PRODUCT DESIGN SPECIFICATIONS (PDS)

In-scope specifications or musts are all the essential elements of the design that must be done for the project to work as intended and achieve its objectives. The following are our project In-scope specifications:

1. Provide a distortion-free visual feed with at least 81° vertical field-of-view, covering the vehicle’s blind spots.
2. Provide a user-friendly visual to depict the respective distances of surrounding objects within a 23-meter (braking distance at 70 km/h) radius with an accuracy of at least 90%.
3. Provide a bird’s eye view for 3 meters around the vehicle to assist while parking in tight spots and parallel parking.
4. Visual updates should be at least at 10 fps for a flicker-free, smooth, and comfortable view.

Out-of-scope specifications or wants are other non-essential elements of the design that would add extra benefits. The following are our project Out of-scope specifications:

1. Record all visual feeds from the previous hour, to assist in accidental insurance claims.
2. Provided a segmented view with people, cars, pavements, and roads using an appropriate coloring scheme.
3. Provide audio notifications.

Realistic assumptions are all things we assume are at a certain state, but we did not prove this, this will help us create a proof-of-concept system that will work in most cases and will not hinder our design. The following are our project's realistic assumptions:

1. Appropriate sensors can be purchased within budgetary and time limits.
2. The proof-of-concept system can be made without exhaustively testing on all types of vehicles.
3. Environmental conditions are conducive to sensor operation. i.e., heavy rain, fog, or pitch-dark conditions are not encountered.

Risks are the problem that could occur to our design, or while working on the design. These risks need remedies that would be implemented when they occur. The following are our project risks and their remedies:

1. Equipment falling off.

   Remedy: Notify the driver in this case and connect all equipment with wires to prevent losing it or dropping it
2. The device disconnects from the power supply.

   Remedy: Notify the driver that the device has been turned off.
3. The chosen sensor isn't enough to provide the necessary perspective and distance calculation.

   Remedy: Use a combination of sensors.
4. Difficulty in testing the prototype outdoors freely.

   Remedy: Test on robot cars available in the Lab.
5. Sensors or devices we order are defective from the factory.

   Remedy: Either order a spare if it's within the budget or order them as early as possible to test them.

## 2.5 LITERATURE REVIEW

In this section, we will go through the current technologies and information that is related to how our project works and discuss them. After that, we will discuss relevant projects and published research that covers solutions using different methods.

### *2.5.1 Researched information related to the project.*

Following the National Highway Traffic Safety Administration (NHTSA), the blind zone of the average car is at the sides where the mirrors don't cover. The shaded region shown in Figure 1 refers to the blind spots that the side mirrors and rear mirrors don't cover. It's the zone where the driver must look when changing lanes. It's shown in more detail in Figure 2 based on research done to measure exactly the blind spot region for the average driver. These are the zones that need to be covered by cameras if the objective is to eliminate blind spots. Additionally, cameras covering the regions already covered by the mirror are encouraged due to cameras being clearer than mirrors in some cases. For example, using a camera on the rear of the car would help in covering additional blind spots caused by the rear-view mirror limitations. [6]

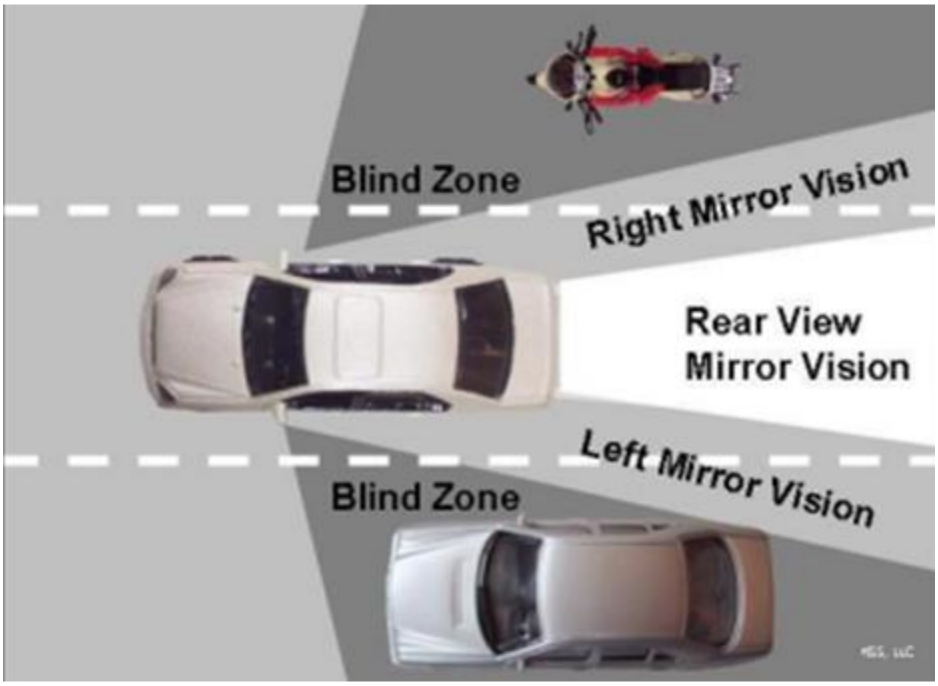


**Figure 1 Blind zone of a car with traditional mirror settings.[7]**

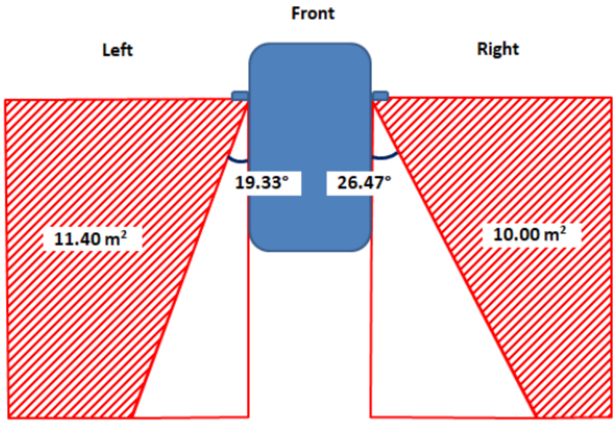


**Figure 2 Blind spot based on research using the grid-based technique. [8]**

In summary, according to NHTSA, the blind spot of the car most commonly lies directly behind the cars, on the sides as shown above, and at the front corners in some cases such as sharp turning.

### *2.5.2 Current Technology*

- **Field Programmable Gate Array (FPGA)**

Field programable gate Arrays (FPGA) are programable hardware boards. In other words, it’s a board that can be configured to be any digital design uploaded on it. The configuration is uploaded to the board’s RAM to then be implemented using look-up-tables that have the outputs needed for this circuit to act like the one uploaded on the RAM. It is programmed via hardware programming languages such as Verilog and VHDL. FPGAs offer high-speed processing with low power consumption. That’s due to it processing via hardware and not software. Therefore, they are optimal for real-time control applications. However, the downside is the high-cost relative to other different processors or microcontrollers. And is difficult to use if the developer doesn’t have good experience with digital design and hardware programming languages. [9]

- **Jetson nano**

Jetson Nano is a small NVIDA computer board that includes a powerful GPU with 128-core and a quad-core ARM processor. It’s very powerful for complex AI applications and robotic computing. Optimal for image processing and computer vision applications. It runs Linux-based operating systems and therefore supports many programming libraries such as OpenCV, CUDA, and TensorFlow. This is why it is most suitable for AI applications. [10][11]

- **Raspberry pi**

Raspberry Pi is an affordable and cheap small computer board similar to the Jetson Nano but more affordable and has I/O pins for controlling electronics components so that it can be embedded in the breadboard of electrical projects. It's mainly used for education and DYI applications, but it also sees some usage in the field professionally. It also runs Linux operating systems and therefore can access some programming libraries that would be useful for AI applications and computer vision. [12]

### *2.5.3 Existing solutions and projects*

1. *Blind Spot Detection and Warning System Based on Radar for Driver Assistance*

**Figure 3 Image of the working concept of radar based ADAS systems.[13]**

This research and project are done for the Chery automobile company based in China. It aims to develop a radar-based blind spot warning system that has good accuracy in both daytime and night-time, equally unlike systems based on other sensors that depend on the light in the environment. This project uses linear frequency modulated (LFM) continuous wave (CW) radars two of which are installed on the left and right side of the car’s rear. This particular module shown in Figure 3 was used due to its range being more suitable for short and middle-range zones. For example, between 0.5 to 75 meters. This means it's more suitable for Applications for blind spot warning systems. The algorithm used to detect a target is the CGSA-CFAR algorithm which takes the echo (returned signal) from the radar as input and processes it to find if the signal came from bouncing off a target or not. This algorithm output is the decision if a target is detected or not. This project was shown to have an accuracy of 98% being tested on 186 warning scenes during daytime and 121 warning scenes at nighttime.

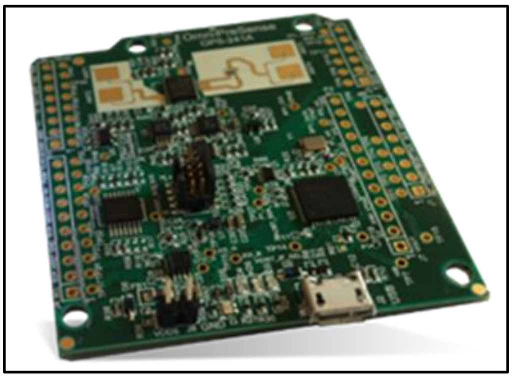

**Figure 4 FMCW radar module.[14]**

To do computing and decision-making, this radar module communicates with a micro control unit (ADI DSP-based) via the CAN (Controller Area Network) protocol. The microcontroller unit also takes the CAN signals of the car's turning left and right and speed signals. All of this is to develop decision-making software to warn the driver not to turn left or right in case a car exists in the blind spot area the driver is turning to. Warnings are conveyed using LED mounted on left and right-side view mirrors from the interior of the car, where they turn on if a car is in the corresponding side's blind spot as shown in Figure 4. A buzzer is used to warn if the driver turned the turning signal to a side that has a car in its blind spot [15]. This is shown in figure 5.


**Figure 5 The developed project under testing. where led is on if a car is in the blind spot region [15].**

2. *LiEBiD - A LIDAR-based Early Blind Spot Detection and Warning System for Traditional Steering Mechanism*

LiEBiD is a blind spot detection and warning system that uses a 20-meter LIDAR sensor to detect cars on a 360-degree radius around the car as shown in Figure 6. The warning is done via the mechanism shown in Figure 7 where the colored indications light up based on the warning type. If a car is detected within a distance of fewer than 3 meters, the red light turns on indicating that the car is in the danger zone of collision. If the detected car or obstacle is detected within a distance less than 5 meters but greater than 3, the yellow light turns on indicating that a detected car is in the “buffer zone”. And if the detected car is within a distance greater than 7 meters then the green light turns on indicating that the detected cat is within the safe zone. The mechanism is placed on the left and right of the wheel and depending on the angle of the detected car, either the right or the left mechanism has the warning on it.

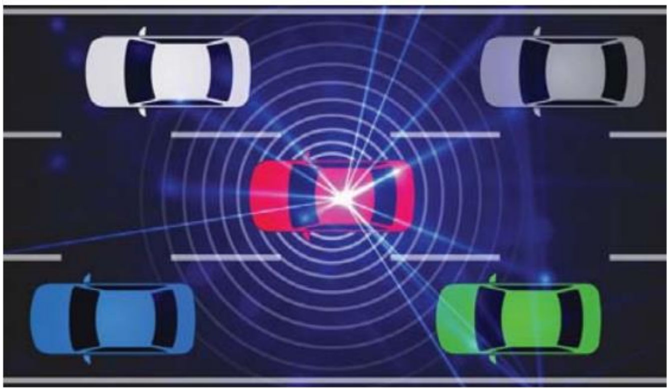

**Figure 6 LIDAR Scanning Technique [16].**


**Figure 7 LiEBiD warning utilities mounted on the steering wheel [16].**

This project uses an RPLIDAR AIM8 2D 360 Degree Sensor connected via a USB Adapter to a Raspberry Pi 4 where the algorithm is done, and it outputs a signal to the warning module to decide which lights are turned on. The algorithm used is a simple obstacle detection where the input is the distance of the obstacle detected via the LIDAR calculated by the “Time-Of-Flight” algorithm. This algorithm outputs the warning type depending on the distance measured [16]. This is shown in figure 8.

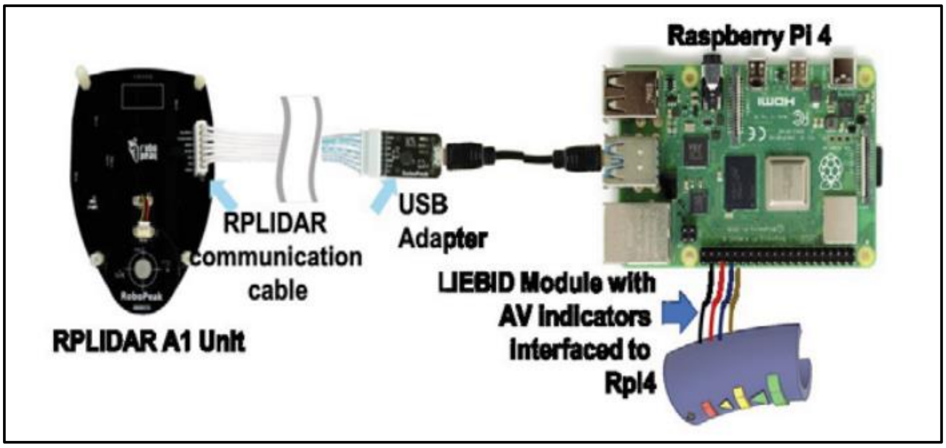


**Figure 8 LIEBiD hardware components.[16]**

3. *A vision-based blind spot warning system for driver assistance during the day and at night*

This project aims to detect cars coming from the blind spots using two CCD cameras installed on the two side mirrors of the car as shown in Figure 9. This placement allows the system to cover 20 meters behind the two cameras and 4 meters in width on both sides of the camera. The horizontal viewing angle of a singular camera is about 75 degrees between the car’s body and the camera. The image captured by the CCD cameras is analyzed to decide whether a car is detected or not. The system uses various algorithms to detect and measure car distances. Firstly, the perspective of the images is transformed to find the 2D and 3D coordinates of pixels on the images. This is to get the images ready for other algorithms and processing. This system does different algorithms for daytime and nighttime. During the daytime, the system uses an ROI (region of interest) algorithm based on lane markings of roads. The input to this ROI algorithm is the perspective 2D and 3D coordinates with the image. The ROI then is used to track the region of interest in the picture which in this case is the lane marking on the road. This means that the ROI will track the region of the image that represents the road. This is done to focus on objects on the road. Then other algorithms are used to further process the image to track a car’s shadow on the road to determine how close the car is. As for nighttime, the algorithm focuses on bright objects in the picture to look for a car's headlights which would be two paired light sources. These algorithms output a detection of any car in the blind spot and the distance of it from the camera.


**Figure 9 the blind spot warning system installed on a Taiwan TS-II car for experimentation [17].**

The system is implemented on a TI DM642 embedded platform which takes the images from the camera as input and outputs the visual feed and the warning in video format which is connected using RS232 protocol which is used for monitors commonly and GPIO pins are used for other output devices if needed [17]. This is shown in figure 10.

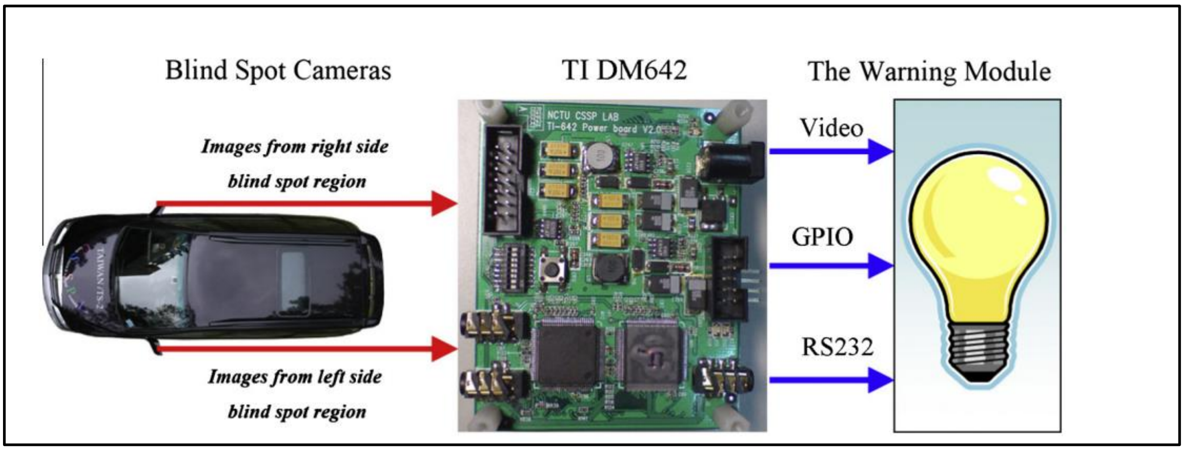


**Figure 10 the system implemented on TI DM642 [17].**

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## 2.6 ANALYZING ALTERNATIVE SOLUTIONS

In this section, we will form a morphological chart where the functions are based on the musts and wants of our project, and the options are based on current technologies and possible methods. Using the morphological chart, we will choose an option for each function appropriately and form different alternatives.

**Table 1 Morphological chart of the project.**

| Functions | Options | | | |
|---|---|---|---|---|
| Provide a visual feed covering the blind spots. | Few fisheye (wide angle) cameras | Multiple narrow-angle cameras | | |
| Detect distances of near objects. | Lidar | Radar | Stereo Camera | Ultra-sonic |
| Provide a bird-eye view. | Inverse Perspective Mapping (IPM) | Pseudo-LIDAR | 3D Dual-Fusions | |
| Processes input data to depict useful information. | FPGA | Jetson | Raspberry pi | |
| Display information. | Screen. | Connect to a phone app. | | |
| Store visual recording. | SD memory | Cloud memory | Connect to phone | |
| Object detection. | YOLO | MMLAB LIGA-Stereo | Pseudo-LIDAR | 3D Dual-Fusions |
| Provide information as audio. | Speaker. | Buzzer. | Connecting to a phone app. | |
| Bus communication. | CAN | USB | Wi-fi. | Bluetooth. |
| Material for mounting sensors. | Drill hole on the exterior of the car. | Magnetic mount. | Suction mount. | Bracket. |

Table 1 shows the morphological chart and the various functions we want in our project. The options for each function are brainstormed and listed. The options for the function “Provide bird-eye view” And “Object detection” Are algorithms used for this function.

**Table 2 Three Chosen Alternatives and their Options.**

| Functions | Alternatives | | |
|---|---|---|---|
| | **Alternative 1** | **Alternative 2** | **Alternative 3** |
| Provide a visual feed covering the blind spots. | Few fisheye (wide angle) cameras | Few fisheye (wide angle) cameras | Few fisheye (wide angle) cameras. |
| Detect distances of near objects. | LIDAR | Stereo Camera | RADAR |
| Provide a bird-eye view. | 3D Dual-Fusions | Inverse Perspective Mapping (IPM) | Inverse Perspective Mapping (IPM) |
| Processes input data to depict useful information. | Jetson | Jetson | Jetson |
| Display information. | Screen. | Screen. | Screen. |
| Store visual recording. | Cloud memory | SD memory | Cloud memory |
| Object detection. | 3D Dual-Fusions | MMLAB LIGA-Stereo | 3D Dual-Fusions |
| Provide information as audio. | Speaker. | Speaker. | Speaker. |
| Bus communication. | USB | USB | USB |
| Material for mounting sensors. | Bracket. | Suction mount. | Drill hole on the exterior of the car. |

Table 2 shows the chosen alternatives via the morphological chart. Alternative 1 was chosen to be LIDAR-based and alternative 2 was chosen to be Stereo-Camera based and alternative 3 was chosen to be RADAR based.

## 1. Alternative 1 (LIDAR based):

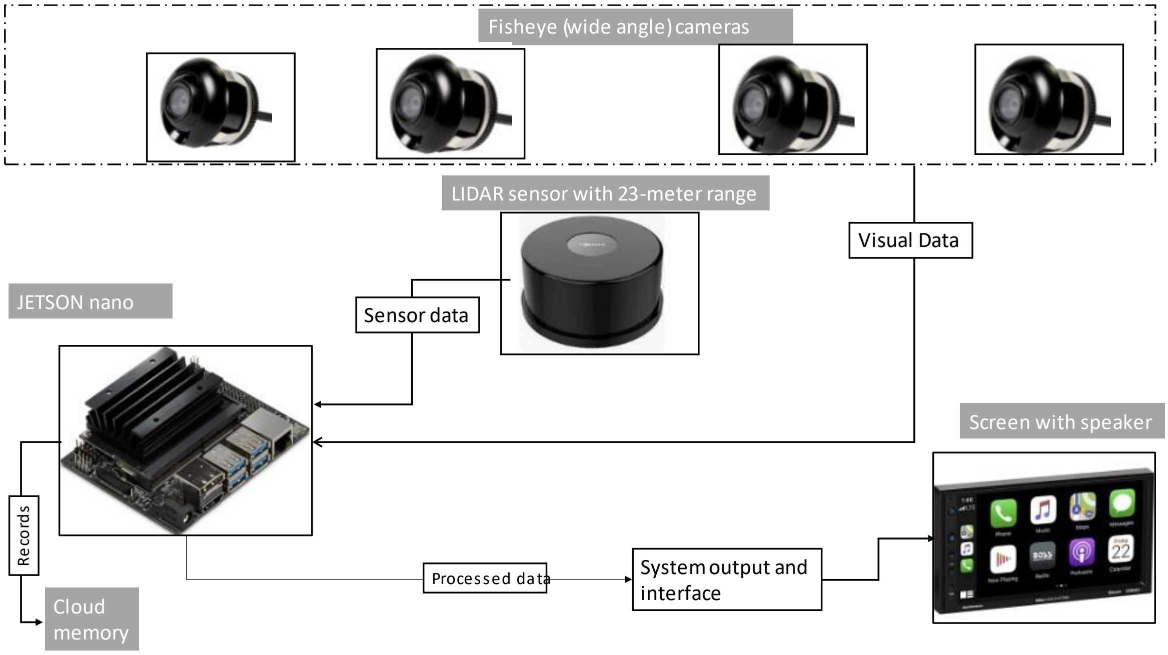


**Figure 11 Block Diagram of Alternative 1.**

Components

- fisheye cameras to cover the car in 360 degrees.
- Lidar sensor with at least 23-meter coverage towards the blind spots.
- Jetson nano for computational work and processing and AI support.
- Entertainment Screen with a speaker to be placed in the cabin.
- Cloud memory server.
- USB cables for connection.
- LIDAR is mounted on the car using a bracket mount on top of the car.

The alternative in figure 11 would use fisheye (wide-angle) cameras to cover the blind spots and provide visual feedback and data. It will also use a LIDAR sensor with a 23-meter radius mounted on the car to cover the vicinity and provide the distance of objects and other relevant data. These cameras and sensors would connect with the JETSON nano via USB connections. The microcontroller would then use the data to produce the system output (Bird's eye view of the visual feed, blind spots visual feed, distances information of objects in the vicinity, video recordings which are sent to a cloud memory to be stored online, and object detection visual feed.) and also produce the system interface, which would be provided to the screen via a USB connection to display it to the user. The LIDAR would be mounted using a bracket mount on top of the car to prevent it from falling due to its heavy weight.

In summary, the JETSON nano would take input from the LIDAR sensor and the cameras, and the programs and algorithms implemented in the Jetson Nano would produce the System output which will be displayed on the screen. Thus, serving the project requirements.

# 1 Alternative 2 (Stereo-Camera based)

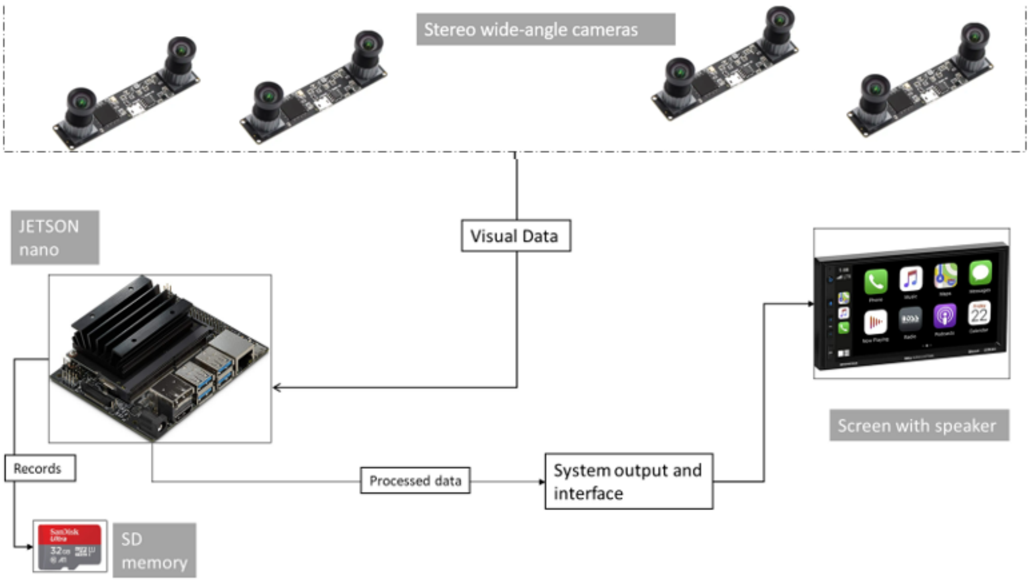


**Figure 12 Alternative 2 block diagram.**

Components

- fisheye cameras to cover the car in 360 degrees.
- The cameras are all stereo and are used instead of a sensor.
- Jetson nano for computational work and processing and AI support.
- Entertainment Screen with a speaker to be placed in the cabin.
- SD memory is installed in the Jetson Nano.
- USB cables for connection.
- Cameras are installed using suction mounts.

The alternative in figure 12 would use stereo wide-angle cameras to cover the blind spots and provide visual feed and data. In this design, no sensor is used, and the visual data produced by the stereo cameras will be used in the Jetson nano-implemented algorithms to detect distances and objects. These cameras would connect with the Jetson Nano via USB connections. The microcontroller would then use the data to produce the system output (Bird's eye view of the visual feed, blind spots visual feed, distances information of objects in the vicinity, video recordings which are stored in the SD card, and object detection visual feed.) and also produce the system interface, this would be provided to the screen via USB connection to then display it to the user. Also, the cameras would be mounted using a Suction mount for easier installation.

In summary, the JETSON nano would take input from the stereo wide-angle cameras, and the programs and algorithms implemented in the Jetson Nano would produce the System output which will be displayed on the screen. Thus, serving the project requirements.

## 2 Alternative 3 (RADAR based)

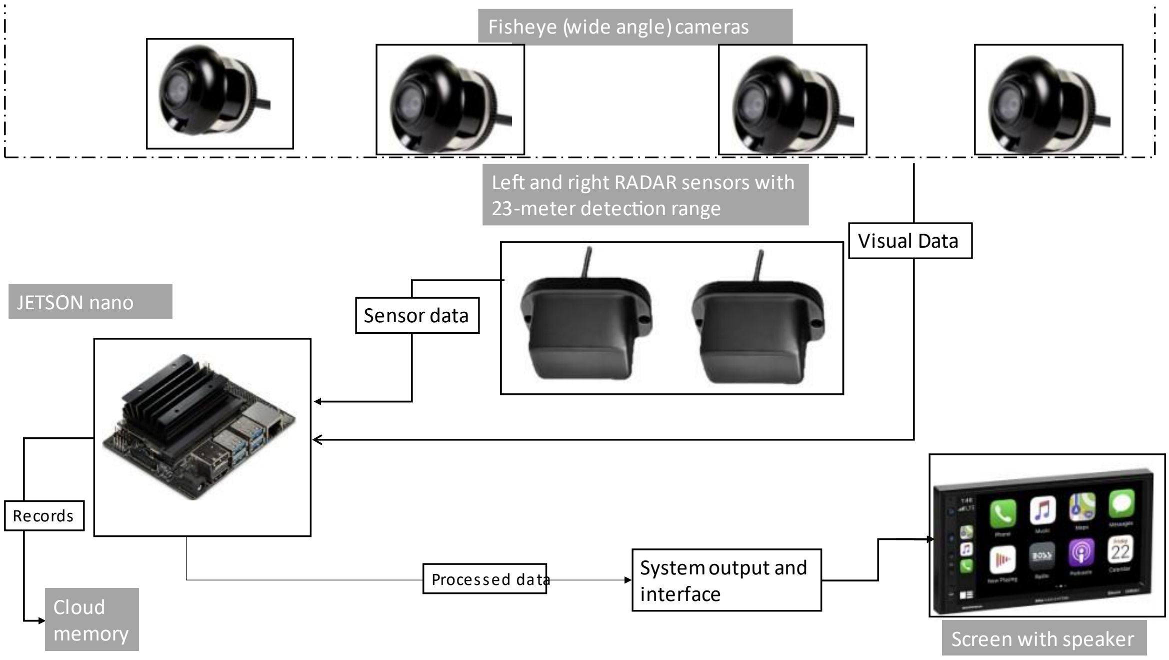


**Figure 13 Alternative 3 Block Diagram.**

Components

- fisheye cameras to cover the car in 360 degrees.
- Radar sensor with at least 23-meter coverage towards the blind spots.
- Jetson nano for computational work and processing and AI support.
- Entertainment Screen with a speaker to be placed in the cabin.
- Cloud memory server.
- USB connection.
- RADAR is mounted on the car and drilled on the exterior.

The alternative in figure 13 would use fisheye (wide-angle) cameras to cover the blind spots and provide visual feedback and data. It will also use a RADAR sensor with a 23-meter detecting range mounted on the car to cover the vicinity and provide the distance of objects. These cameras and sensors would connect with the Jetson Nano via the USB connection. The microcontroller would then use the data to produce the system output (Bird's eye view of the visual feed, blind spots visual feed, distances information of objects in the vicinity, video recordings which are sent to a cloud memory to be stored online, and object detection visual feed.) and also produce the system interface, which would be provided to the screen via a USB connection to display it to the user. The RADAR would be mounted via drilling holes as RADAR needs to be on the exterior of the car.

In summary, the Jetson Nano would take input from the RADAR sensor and the cameras, and the programs and algorithms implemented in the Jetson Nano would produce the System output which will be displayed on the screen. Thus, serving the project requirements.

**Comparing alternatives**

Now we will compare the alternatives using different methods. First, we listed the pros and cons of each alternative in table 3. This will help us put into perspective all the alternatives' weak and strong points. Second, we did a KT analysis to compare the alternatives and see if they meet the musts and wants in table 4. Third, we used Pugh's method to further compare the alternatives against a DATUM and see how they differ in table 5. The scores recorded using methods 2 and 3 will be used to choose the final alternative.

**Table 3 Pros and Cons of alternatives.**

| Alternatives | Pros | Cons |
| --- | --- | --- |
| LIDAR based. | 1- Very high accuracy in 3D mapping and distance measuring.<br><br>2- The usage of fisheye cameras cuts the cost due to using fewer than narrower angle cameras.<br><br>3- The usage of cloud memory would save storage.<br><br>4- using JETSON nano will offer high capabilities in any algorithm based on AI.<br><br>5- best for distance measurement. | 1- high cost for the LIDAR.<br><br>2- Fisheye would have distortion that would need to be removed via processing. Which will add more work to the system.<br><br>3- an internet connection is needed for cloud saving.<br><br>4- can be affected by detected object's colors.<br><br>5- LIDAR needed may not be available easily locally.<br><br>6- difficult installation. |
| Stereo Camera | 1- very low cost compared | 1- Fisheye would have |

| | | |
|---|---|---|
| based. | to other sensors. While still having good accuracy if suitable algorithms are used.<br><br>2- Fewer connections due to having fewer components (no sensor other than the camera)<br><br>3-usage of an SD card makes the system not depend on an internet connection or using the user's phone.<br><br>4- easier to install the system.<br><br>5- using JETSON nano will offer high capabilities in any algorithm based on AI. | distortion that would need to be removed via processing. Which will add more work to the system.<br><br>2- adding more cost to the system by using SD storage.<br><br>3- can be affected by weather conditions and working at nighttime. |
| RADAR based. | 1- Less costly than LIDAR and has good accuracy for measuring distance.<br>2- The usage of fisheye cameras cuts the cost due to using fewer than narrower angle cameras.<br><br>3- The usage of cloud memory would save storage.<br><br>4- unaffected by weather conditions or nighttime or object colors.<br><br>5- using JETSON nano will offer high capabilities in any algorithm based on AI. | 1- more connections are needed, and multiplexing may need to be used.<br><br>2- Fisheye would have distortion that would need to be removed via processing. Which will add more work to the system.<br><br>3- an internet connection is needed for cloud saving.<br><br>4- having to drill holes for installation. |

**Table 4 K-T analysis**

| Alternatives: | | 1: Lidar based | 2: Stereo-Camera | 3: Radar-based |
|---|---|---|---|---|
| Musts | Provide a distortion-free visual feed with at least 81° vertical field-of-view, covering the vehicle’s blind spots. | GO | GO | GO |
| | Provide a user-friendly visual to depict the respective distances of surrounding objects within a 23-meter radius with an accuracy of at least 90% | GO | GO | GO |
| | Provide a bird’s eye view for 3 meters around the vehicle to assist while parking in tight spots and parallel parking. | GO | GO | GO |
| | Visual updates should be at least at 10 fps for a flicker-free, smooth, and comfortable view. | GO | GO | GO |
| Wants | Weight out of 10 | Score out of 3 | | |
| Record all visual feeds from the previous hour, to assist in accidental insurance claims | 5 | 1 | 3 | 1 |
| Provided a segmented view with people, cars, pavements, and roads using an appropriate coloring scheme. | 8 | 3 | 2 | 1 |
| Provide audio notifications. | 10 | 3 | 3 | 3 |
| | | 59 | 61 | 43 |

**Discussion**:

Score meaning: 0 = can’t meet the item. 1 = can meet the item but with barely acceptable results. 2 = can meet the item's acceptable results. 3 = can meet the item with fantastic results.

1. **Alternative 1 (LIDAR based):**

This alternative has the means to meet all the in-scope items of the project.

It scored a 1 on recording the accident item due to the cloud-saving alternative needing an internet connection. While it’s a good method as it doesn’t need storage on the system itself. Unfortunately, it adds an assumption to the project that we don’t have. also, it would add a level of complexity not needed.

On the second item, it scored the best score as 3D Dual-Fusion is one of the highest-ranked algorithms on the KITTI database leaderboard. [18]

The third item scored a 3 due to the speaker being a good method for providing audio notifications.

2. **Alternative 2 (Stereo-Camera based):**

This alternative has the means to meet all the in-scope items of the project.

It scored a 3 on recording the accident item due to using the SD card is good as the system is fully independent of either the internet or the user's phone. While it does add cost, it overcomes this by being a very simple solution.

The second item scored 2 due to MMLAB LIGA-Stereo having a moderate score of 64.6% on the KITTI database leaderboard. [28]

On the third item, scored a 3 due to the speaker being a good method for providing audio notifications.

3. **Alternative 3 (RADAR based):**

This alternative has the means to meet all the in-scope items of the project.

It scored a 1 on recording the accident item due to the cloud-saving alternative needing an internet connection. While it’s a good method as it doesn’t need storage on the system itself. Unfortunately, it adds an assumption to the project that we don’t have. also, it would add a level of complexity not needed.

On the second item, it scored 1 due to Pseudo-LIDAR having a low score of 34% on the KITTI database leaderboard. [28]

The third item scored a 3 due to the speaker being a good method for providing audio notifications.

The better alternative depending on the results is alternative 2 (Stereo-camera based).

**Table 5 Pugh Matrix for the three alternatives.**

| Criteria | Importance | DATUM | 1: Lidar based | 2: Stereo-Camera | 3: Radar-based |
|---|---|---|---|---|---|
| Cost | 3 (Extremely important) | 3000 | -1 (worse than DATUM) | 1 (better than DATUM) | 0 (similar to DATUM) |
| Ease of installation | 3 (Extremely important) | May need professional personnel for installation. | 0 (similar to DATUM) | 1 (better than DATUM) | 0 (similar to DATUM) |
| Effective for 3D detection | 1 (Normal) | Can detect various types of objects. | 1 (better than DATUM) | 0 (similar to DATUM) | -1 (worse than DATUM) |
| Effective for Bird's eye view | 3 (Extremely important) | 3-meter bird's eye view. | 1 (better than DATUM) | 1 (better than DATUM) | 1 (better than DATUM) |
| Effective for detecting distance | 3 (Extremely important) | Can detect with 90% accuracy, within 23 meters. | 1 (better than DATUM) | 1 (better than DATUM) | 1 (better than DATUM) |
| The constant effect at night and different weather conditions | 1 (Normal) | Affected. | 0 (similar to DATUM) | 0 (similar to DATUM) | 1 (better than DATUM) |
| Computation load on processer. | 2(very important) | Well within Jetson nano capabilities. | -1 (worse than DATUM) | 0 (similar to DATUM) | -1 (worse than DATUM) |
| Total | | | 2 | 12 | 4 |

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## 2.7 MATURING BASELINE DESIGN

Now that we have chosen our alternative, which is alternative 2 (Stereo-camera based) we will further mature the design, make it more detailed, and improve it.

Past projects using cameras for blind spot warning that were discussed in 2.7 used two cameras connected to the processing unit which is connected to I/O devices. In our project, we aim to cover what the side mirrors already cover and also to cover the blind spots of the car. A camera needs to be set on the corners of the car to cover the whole 360 degrees. To do this the camera needs to have a field of view of at least 90 degrees. The camera we chose should have a wide angle. Also, due to Jetson Nano only having 1 CPI connection and 4 USB connections, the camera model chosen needs to be connected via USB.

To determine the specifications needed for the processor, we need to know what the algorithms require. The MMLAB LIGA-Stereo requires the following:

- Linux (tested on Ubuntu 14.04 / 16.04)
- At least Python 3.7
- At least PyTorch 1.6.0
- At least Torchvision 0.7.0
- At least CUDA 9.2 / 10.1

Jetson Nano can run an image of Ubuntu 18 and below. It can run Python 3.8 and PyTorch 1.11. And it can also build Torchvision 0.12 [19]. It can also run CUDA 10.2 and under. [20]

The power source is 12 Volt according to ANSI/SAE J563 standard, and the Jetson nano works on 5 Volt, so we need an adapter connected.

The system would display the 4 perspectives of the camera on a 2x2 division of the screen by default. With the addition of user input, the user could interact with the system. There would be 5 push buttons, one for each singular camera perspective, if pushed, the screen would display only one perspective rather than a 2x2. The perspectives shown would depend on which of the 4 buttons is pressed. As for the fifth button, we will call it “Mod”. For each push, it will alternate between a bird's eye view being displayed or the default 2x2 showing all camera perspectives.

As for video recording, the system would allocate at least 2 GB to continuously save the recording and overwrite the previous recordings. Would be able to record more time if more memory is available.

And considering the issue of accuracy drop at nighttime, according to the project: "A vision-based blind spot warning system for driver assistance during the day and at night" discussed in section 2.7 in the literature review, tracking two paired light sources will achieve good results to keep the accuracy of the algorithm from dropping when working at nighttime. Therefore, we will add to the algorithm the setting to track a car's headlights at nighttime to address the accuracy drop. Thus, making the system function normally during nighttime as it would during daytime. Assuming no harsh weather conditions, this would mean that this system has overcome one of its biggest weaknesses.

To define when the system would show warnings for objects that are close to the car, we will reference the LiEBiD project discussed in section 2.7. In that project they defined the danger zones according to the guidelines to be:

- The danger of collision: The distance of the obstacle is less than 3 meters.
- Nearing danger of collision: greater than 3 meters and less than 7 meters.
- Safe zone: greater than 7 meters.

## 2.8 APPLICABLE ENGINEERING STANDARDS

Engineering standards help in regulating the development of all kinds of technologies, such as that they do not conflict with each other and that it can be safe to use and implement them. In our project, we followed the ANSI/SAE J563, UNECE R151, SAE J2400, and IEC 60445 standards on some of our specifications and risks.

The ANSI/SAE J563 is a standard from SAE International and the American National Standards Institute that governs the design and specifications of cigarette burners in vehicles. We base the constraint "The system operates on 12V DC" on this standard in article 8.2 so that our device could be plugged in with the cigarette burner outlet. [2]

The UNECE R151 is a standard from the United Nations Economic Commission for Europe (UNECE). This is a standard that covers blind spot information systems in vehicles. This standard offers a remedy for the risk of when such systems (blind spot information systems) are disconnected from power, which is to provide a failure warning signal when the system is disconnected from power, which is in article 5.3.1.7. We use this as the remedy for the risk "The device disconnects from the power supply." [3]

Furthermore, the SAE J2400 standard covers Human Factors in Forward Collision Warning Systems: Operating Characteristics and User Interface Requirements, which we will use to base our user interface. Specifically, article 4.1 of the standard has audio warnings and notification characteristics such as the intensity of warnings in decibels. [4]

Moreover, for some aspects regarding the safety of the design, the IEC 60445 standard from the American National Standards Institute, which covers "Basic and safety principles for man-machine interface, marking, and identification - Identification of equipment terminals, conductor terminations, and conductors," will be used in the design process to ensure that our design keeps up with the agreed upon safety standards. Such as the coloring of the positive and negative wires in article 6.2.4 for DC circuits. [5]

# CHAPTER – 3 PRODUCT BASELINE DESIGN

## 3.1 BLOCK DIAGRAM

Figure 14 is the detailed block diagram of the baseline design. Showcasing the blocks of components and the algorithm used. The four stereo cameras are connected to the Jetson Nano using the USB port. They will give the fisheye input. Then based on the input from the push buttons, the processing will be done on the Jetson Nano, either a bird's eye view, object detection, or distance calculations.

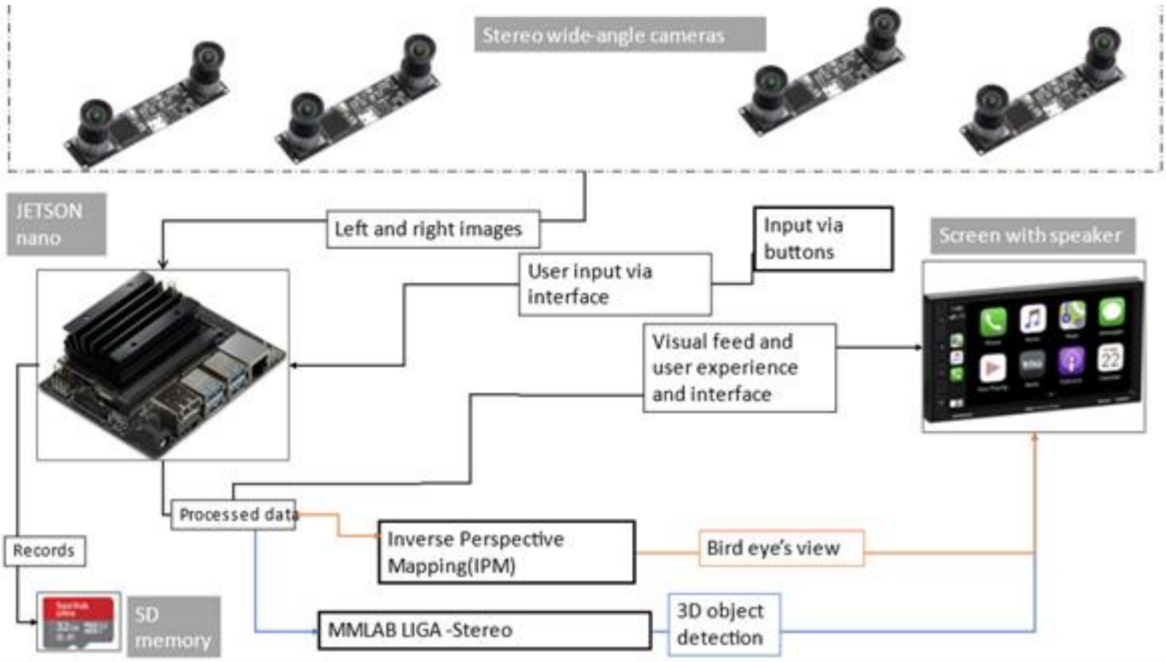


**Figure 14 Matured block diagram**

## 3.2 SYSTEM DESCRIPTION

The "Environment Perception System for Smart Vehicles," an innovative solution in the realm of vehicular safety, employs cutting-edge technology to mitigate the risks associated with blind spots, particularly during critical maneuvers like parking and changing lanes. Central to this system are four ELP-960P2CAM-V90 stereo fisheye cameras, each with a dual 90-degree field of view, ensuring comprehensive coverage around the vehicle. These cameras are strategically installed at the front, rear, and sides of the vehicle, enabling a 360-degree surround vision. This placement strategy is crucial as it addresses the primary areas where visibility challenges typically occur. The cameras’ high-resolution capture (up to 2560X960 at 60fps) guarantees detailed imaging, necessary for the intricate perception tasks at hand.

In synergy with the cameras, the system's brain is the Jetson Nano Developer Kit, a compact yet powerful computing solution tailored for advanced processing tasks. It is discretely integrated within the vehicle, forming a central hub for data analysis and decision-making. The kit processes the feed from each camera, executing complex algorithms for image correction, object detection, and distance estimation in real-time. It then stitches these multiple perspectives into a cohesive, distortion-free, and user-friendly bird's eye view around the vehicle, essential for precise navigation and informed decision-making during driving maneuvers. The seamless interaction between the strategically placed cameras and the central processing unit is what enables this system to provide real-time, accurate, and invaluable feedback to drivers, significantly enhancing their spatial awareness and overall safety on the road. Figure 15 shows the circuit schematic of the system.

### 3.2.1 Circuit schematics

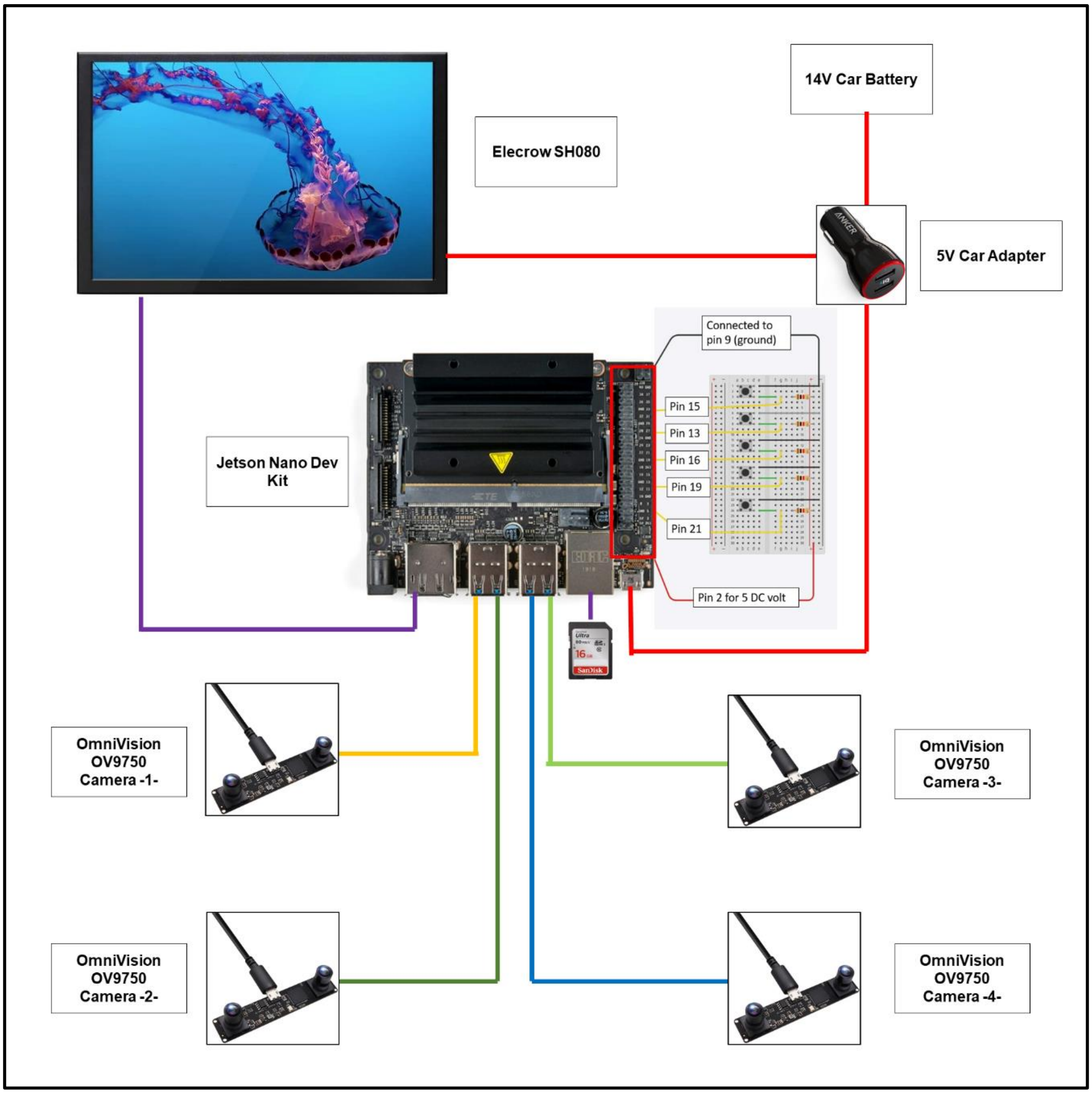


**Figure 15 Circuit Schematic**

### 3.2.2 Circuit component specifications

1. *Jetson nano*

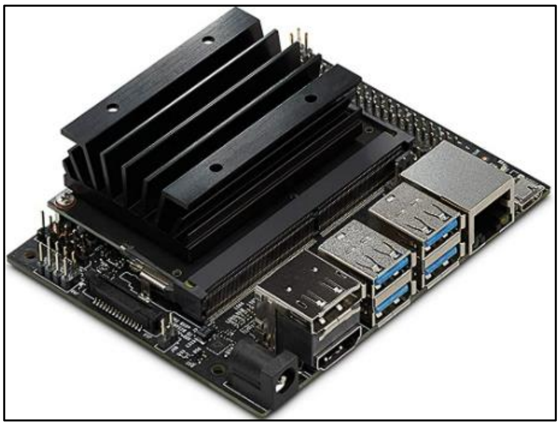

**Figure 16 Jetson Nano [21]**

Jetson nano is a powerful tool computer used to run neural networks for image processing applications. Such as object detection and segmentation. Figure 16 show its image, and table 6 shows its specifications. And figure 20 shows its mechanical specifications.

**Table 6 Jetson Nano Developer Kit Specifications [21]**

| Jetson Nano Developer Kit | |
|---|---|
| **GPU** | 128-core Maxwell GPU |
| **CPU** | Quad-core ARM A57 with a clock rate of 1.43 GHz |
| **Memory** | 4 GB |
| **Storage** | External microSD |
| **Display** | HDMI |
| **USB** | 4x USB 3.0, USB 2.0 Micro-B |

2. <u>*Stereo wide-angle cameras*</u>

**Figure 17 OmniVision OV9750 [22]**

OmniVision OV9750 is a stereo camera with a wide-angle view, making it suitable for many AI applications, such as depth detection and many more. Figure 17 shows its image, and table 7 shows its specifications.

**Table 7 ELP-960P2CAM-V90 Specifications [22]**

| ELP-960P2CAM-V90 | |
|---|---|
| **Resolution & FPS** | MJPEG:2560X960@ 60fps<br>2560X720@60fps<br>1280X480@60fps<br>640X240@60fps |
| **FIELD OF VIEW** | Dual HOV 90 degrees |
| **Focal Length** | 2.6mm |
| **Connecting Port Type** | USB2.0 High speed |

3. *Screen with speakers*

**Figure 18 Elecrow SH080 [23]**

ELECROW is an In-Plane Switching monitor that uses liquid crystals aligned in parallel. It is also portable and has built-in speakers. Figure 18 shows its image, and table 8 shows its specifications. And figure 21 shows its mechanical specifications.

**Table 8 ELECROW SH080 Specifications [23]**

| ELECROW SH080 | |
|---|---|
| Screen Size | 8 inches |
| Refresh Rate | 60 Hz |
| Aspect ratio | 16 by 10 |
| Response time | 16 Milliseconds |
| Connectivity technology | USB, HDMI |
| Resolution | 1080P |
| Number of HDMI Ports | 1 |

### *3.2.3 Flowcharts for software blocks*

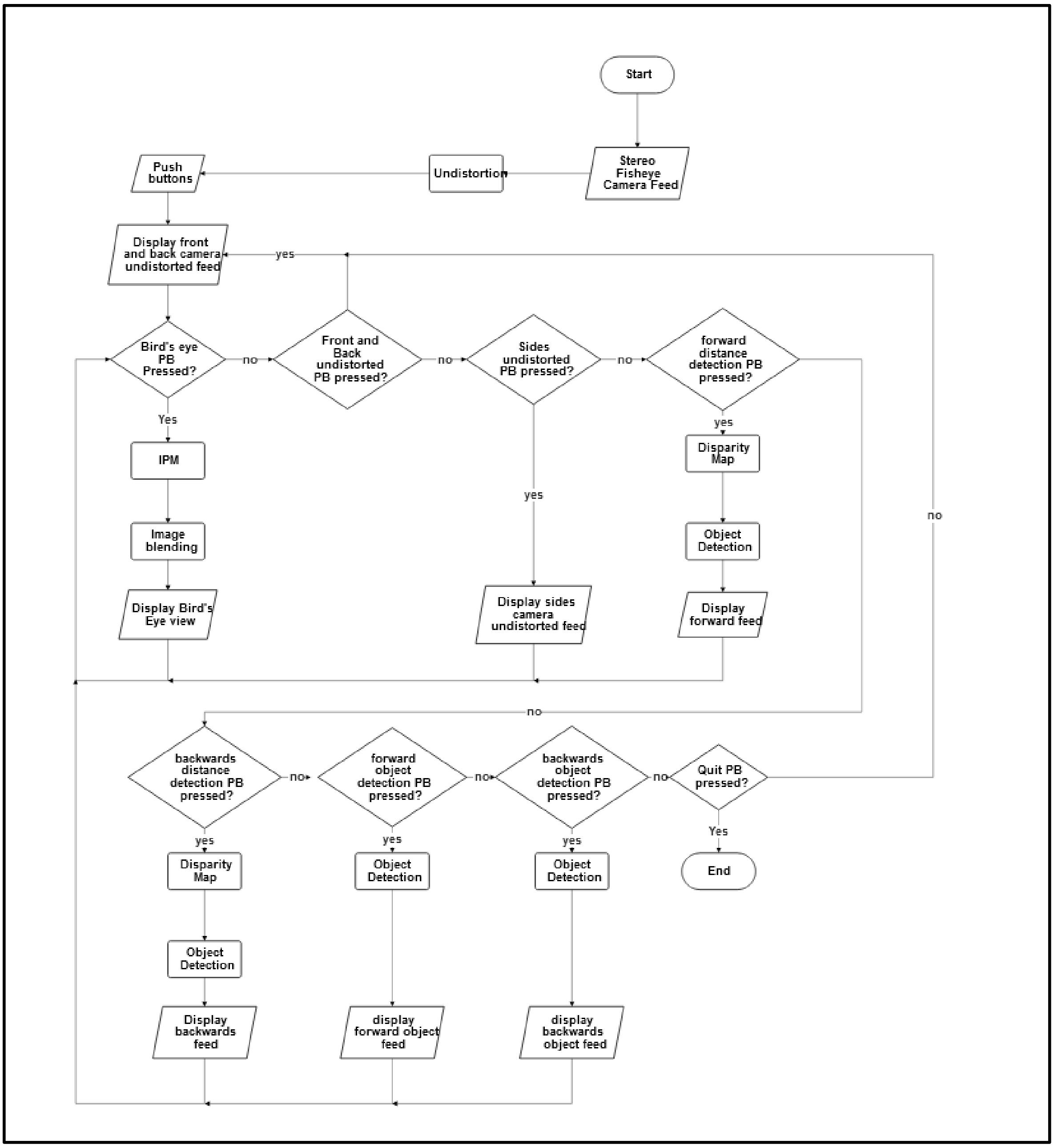


**Figure 19 Flowchart of software**

Figure 19 showcases the flow of the software for the system. At first, the program receives the input coming from the four stereo fisheye cameras. Then it initializes it by undistorting it, and then showing the default view which is the forward and back undistorted feed. Then the loop starts by first checking if the bird's button was pressed, if it was pressed then it does its processing and displays the view until another button is pressed. Each mode has its functionality, the other functionalities are the distance detection for the front or backwards view, the object detection for the front and backwards view as well, a view of the sides to help when parking. And finally, a quit button that will make the loop stop and the system turn off.

### 3.2.4 Mechanical specifications of the case

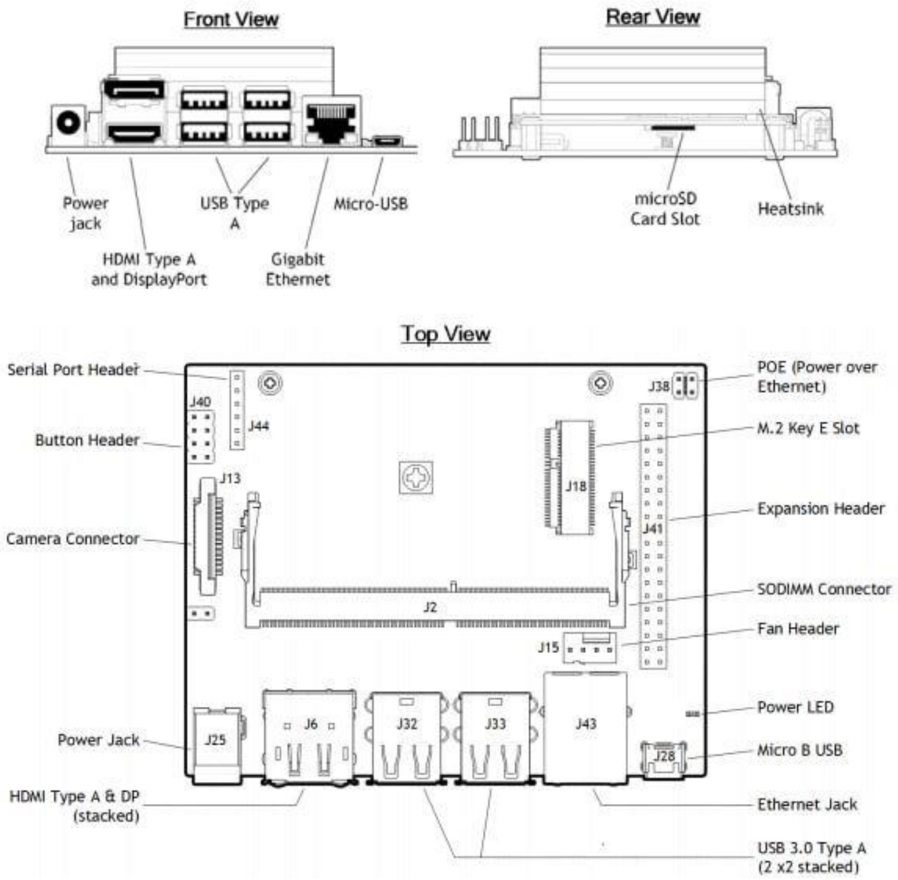


**Figure 20 Jetson Nano I/O Ports [24]**

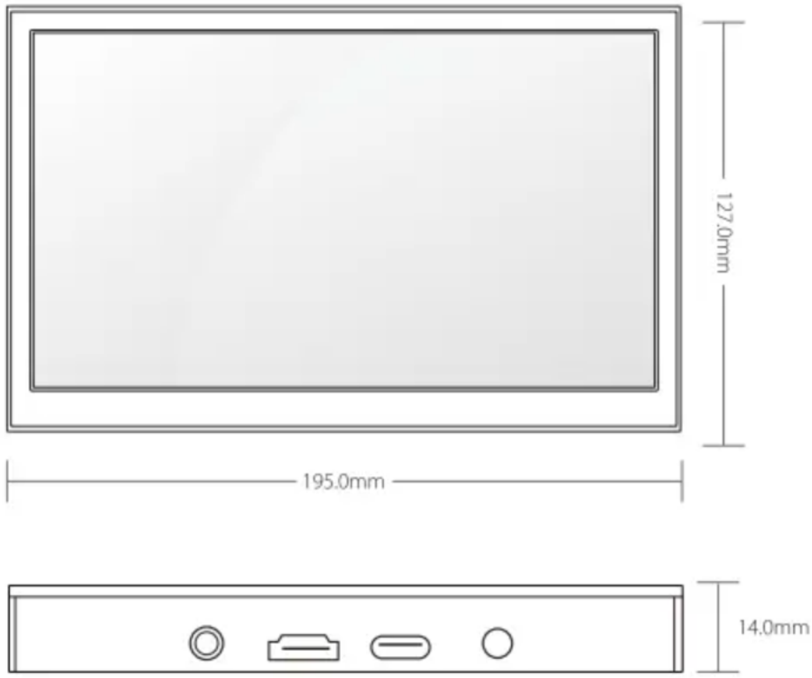


**Figure 21 screen mechanical aspects [25]**

### *3.2.5 Possible aesthetics*

For the prototype, the cameras will be mounted using suction cups, and when implemented on a full-size car they will be incorporated into the car itself. The jetson nano will be hidden, and the display will be mounted like how phones are mounted on cars in Figure 22.

**Figure 22 Car Screen Mount [26]**

### *3.2.6 System Inputs and Outputs*

Inputs:

1- 5 Volt power for the Jetson Nano and the screen.
2- Four Left and right images from the four cameras.
3- Push buttons state for user input.

Outputs:

1- Visual feed with object segmented view.
2- Bird eye's view.
3- Warning sounds if there is a danger of collision.
4- Recording of visual feed.

### *3.2.7 Operating Instructions*

1. Connect the adaptor to the cigarette burner power source.
2. Mount the cameras on the four corners of the car. make sure their perspective isn’t covered by any objects in the car.
3. connect the cameras to the 4 USB ports.
4. Connect the screen and the Jetson Nano to the adaptor to turn on the device.
5. to change the output of the display, press the buttons. Buttons are:
   - Left top for viewing the left top corner camera.
   - Right top for viewing the Right top corner camera.
   - Left bottom for viewing the Left bottom corner camera,
   - Right bottom for viewing the Right bottom corner camera.

Mod for changing to Birds Eye’s view and if pressed again it changed back to the default 2x2 perspective.

# CHAPTER – 4 IMPLEMENTATION

## 4.1 CALIBRATION

The calibration of a fisheye stereo camera setup is crucial for the accurate estimation of scene parameters in 3D space, especially for applications requiring precise object detection and navigation, such as in autonomous vehicles. Our journey through the second term revolved significantly around calibrating the stereo camera setup, an endeavor that taught us much about the practical challenges and theoretical underpinnings of camera calibration. We encountered several issues related to the checkerboard size, changing extrinsic parameters due to varying camera placements, and compatibility issues with real-time operating systems like Jetson. Our trials and resolutions are detailed below.

### *4.1.1 First trial*

Initially, we utilized a standard calibration method involving a checkerboard pattern printed on A4 paper. The decision to use this size stemmed from convenience, as A4 was readily accessible and commonly used in numerous calibration tutorials and literature.

However, practical application revealed critical drawbacks. The small pattern wasn't easily recognizable at larger distances or different angles, hindering the detection process. Consequently, the calibration results were inconsistent and unreliable, demonstrating significant errors in the calculated intrinsic and extrinsic parameters. The scene reconstruction was distorted, and depth estimation was imprecise, unacceptable outcomes for our application's precision requirements.

### *4.1.2 Second trial*

To address the limitations uncovered in our first approach, we scaled up the checkerboard to A3 size. This modification aimed to enhance the pattern's visibility

to the cameras, allowing more reliable detection across various distances and angles.
The change yielded immediate improvements. The larger checkerboard was easier to detect, and the calibration process became more stable and consistent. The intrinsic parameters calculated through this method showed fewer anomalies, and the 3D reconstruction of the scene was visibly more accurate than before. However, while this trial corrected the issues with intrinsic parameters, it brought to light a new challenge: the extrinsic parameters were highly sensitive to any alterations in the camera's position or orientation.

### *4.1.3 Third trial*

Our experiences from the previous trials led us to a deeper understanding that effective calibration doesn't solely rely on hardware aspects, or the software used for processing. It became evident that the methodology of capturing calibration images plays a pivotal role in the accuracy of the final calibration parameters. Our third trial, therefore, focused on refining the process of how we collected calibration data, specifically the images used for this purpose.
In earlier attempts, we gathered images of the checkerboard in open, unobstructed environments. However, we noticed inconsistencies and more extensive errors in the calibration results. After thorough analysis, we speculated that these inaccuracies might be due to the lack of variety in depth and perspective in the images used for calibration, causing the algorithm to be less effective in generalizing the camera parameters.
Addressing this issue required a more diverse set of images that represented various angles, distances, and obstructions that the camera setup might realistically encounter. We chose to place the checkerboard behind a chair, an everyday object that provided a partial obstruction similar to real-world scenarios. This setup necessitated that the cameras capture the checkerboard at multiple obscure angles and varying depth ranges, therefore challenging the calibration process to account for a realistic operating environment.

The process was meticulous. We moved the checkerboard systematically, capturing images from different angles and heights, ensuring that some images had the checkerboard partially obscured by the chair's structure. We paid particular attention to maintaining a diverse set of images that included various edge cases we could conceive.

The outcome was significantly positive. By training the calibration algorithm with these new images, we observed a marked improvement in the accuracy of the calculated parameters. The calibration process became evidently robust, with the system showing a better capacity in handling real-world complexities. It was less prone to errors when dealing with images that had obstructions, varied depths, and angular diversities, replicating the environmental conditions that our camera system would face in practical deployments.

## 4.2 UNDISTORTION

The process of image undistortion is critical in computer vision, particularly in applications like Advanced Driver-Assistance Systems (ADAS), where precise visual data is paramount. Throughout term 2, we embarked on a comprehensive journey to perfect the undistortion process, which proved to be as challenging as it was educational. We initiated with a robust calibration procedure, eventually realizing that the subtleties of undistortion were multifaceted, demanding a keen understanding of both theoretical principles and practical nuances.

### *4.2.1 First trial*

Our journey commenced with the acknowledgment that a secure, fixed camera system was imperative, especially considering the variable conditions of vehicular applications. By engineering a stable mounting system, we achieved consistent extrinsic calibration values, a milestone that seemed promising at the outset. However, the challenge arose with the incompatibility of our MATLAB-based calibration code with the Jetson platform, essential for deploying real-time applications.

Transitioning to OpenCV was a strategic move, enhancing compatibility, and speeding up the process. However, this success in recalibrating and establishing the undistortion pipeline unveiled another intricate issue: the undistorted images appeared excessively stretched, warping the scene's perspective. This distortion was attributed to the initial calibration images where the checkerboard's corners seemed rounded due to the fisheye effect, leading to incorrect assumptions by the undistortion algorithm about the scene geometry.

### *4.2.2 Second trial*

To tackle the stretching problem, we revisited our calibration strategy. We hypothesized that using a more diverse set of images for calibration, particularly those where the checkerboard was presented at various orientations and distances, would provide a richer data set for the algorithm to understand the distortion characteristics better.

We re-initiated the calibration process, this time capturing numerous images with the checkerboard in multiple positions and angles, ensuring sharp visible corners in each. This approach intended to make the calibration more robust against the fisheye effect, enabling the undistortion algorithm to reconstruct straight lines and scene geometry more accurately. Upon reprocessing with this enriched calibration data, the undistortion results were significantly improved. The images were less stretched, preserving more realistic dimensions and proportions in the scene. However, a new minor setback was observed: the undistortion process seemed to cut off corners of the image, reducing the field of view.

### *4.2.3 Third trial*

Understanding the importance of a wide field of view for ADAS, as it provides the driver with comprehensive situational awareness, we sought to resolve the issue of the 'cutting corners' encountered during undistortion. Our goal was to maintain the integrity of the wide view, even after the necessary corrections were applied to the image.

Research and experimentation led us to introduce a scale factor into the undistortion process, a method that adjusted the focal length used in the transformation matrix. By carefully increasing this scale factor, we could 'zoom out' the undistorted image slightly, compensating for the loss of the edges during undistortion.

This delicate balancing act required numerous iterations, as an excessive scale factor introduced more distortion, while a minimal one didn't recover the desired field of view. After several experimental runs, we identified an optimal scale factor that preserved a wider view without reintroducing substantial distortion.

## 4.3 BIRD’S EYE VIEW

The bird's-eye view feature of the "Environment Perception System for Smart Vehicles" is achieved through a sophisticated multi-step process designed to provide drivers with a comprehensive and seamless overhead view of their vehicle's surroundings. Initially, the system calculates the extrinsic values of the undistorted views captured by the cameras, meticulously adjusting for various factors such as the relative position and orientation of each camera. This calibration is critical for ensuring that the subsequent images align accurately, representing the actual physical spaces around the vehicle.

Following this, the system undertakes an Inverse Perspective Mapping (IPM) transformation for the feeds from all four cameras. This advanced technique adjusts the images' perspectives, transforming the views captured from the cameras' positions into a single overhead view as if observed from above. It essentially reprojects the 3D world space into a 2D image while maintaining the real-world proportions and relationships of objects in the scene, crucial for accurate spatial recognition and navigation assistance.

The final stage of the process involves the technique of alpha blending, where the transformed images from each camera are meticulously fused. This method involves adjusting the pixel-level opacity (alpha values) of images, ensuring a smooth and natural transition between the overlapping areas from each camera feed. By carefully blending these views, the system eradicates any hard edges or abrupt transitions that could disrupt the driver's understanding of the space around the vehicle. The result is a cohesive, unified, and intuitive bird's-eye view that provides drivers with an unprecedented level of situational awareness, significantly enhancing safety during maneuvers where precise environmental perception is paramount.

### *4.3.1 First trial*

In our initial testing phase for the "Environment Perception System for Smart Vehicles," we used a series of still photographs to evaluate the bird's-eye view function. By running these images through the system, we simulated various real-world scenarios, examining the accuracy of each transformation step. This approach allowed us to meticulously assess the consistency and precision of the spatial representations created by the system, enabling us to refine the algorithms effectively before proceeding to real-time application tests. This method ensured a reliable and efficient performance of the bird's-eye view in actual operating conditions.

### *4.3.2 Second trial*

In the second trial, we escalated our testing methodology for the "Environment Perception System for Smart Vehicles" by applying the bird's-eye view function to a continuous video stream. This progression from still images to video was a critical step, as it closely mimicked the real-time scenarios encountered during driving. Utilizing the video feeds captured from the system’s cameras, we were able to observe the transformation process in a dynamic, uninterrupted manner. This method was instrumental in assessing the system’s responsiveness and the seamlessness of the transitions, especially during motion, as it continuously calculated extrinsic values, performed the Inverse Perspective Mapping (IPM), and executed alpha blending in real-time. By analyzing the video stream, we could scrutinize the system’s real-time performance, identify any latency or inaccuracies during rapid environmental changes, and make necessary adjustments to ensure the system’s reliability and precision in rendering the bird's-eye view under typical vehicular operation conditions.

### *4.3.3 Third trial*

To optimize the performance of the "Environment Perception System for Smart Vehicles," we introduced a significant enhancement in the operational workflow, particularly concerning the calculation of extrinsic values within the bird's-eye view functionality. Initially, the system recalculated these values each time the bird's-eye view function was invoked, leading to unnecessary redundancy and computational load, potentially affecting the system's real-time responsiveness.

Recognizing this inefficiency, we re-engineered the process by isolating the calculation of extrinsic values as a separate, one-time function. Upon the system's initialization, this function is called once, and the crucial values are computed and securely stored within dedicated data structures. Consequently, every time the bird's-eye view function is activated, it no longer recalculates these values from scratch. Instead, it swiftly accesses the pre-computed data from the structures, significantly reducing the processing time and computational demands.

This strategic modification not only streamlined the system's operations but also bolstered the speed and efficiency of the transformation processes integral to the bird's-eye view. By eliminating repetitive computations, we enhanced the system's capacity to deliver smoother, more timely visual feedback, an improvement that is critical for drivers relying on the system for real-time decision-making during vehicle maneuvers. This refinement underscores our commitment to continual improvement and innovation, ensuring our system's robustness and reliability in serving the safety needs of modern drivers.

## 4.4 OBJECT DETECTION

In the object detection phase of our project, a pivotal process unfolds to enhance vehicular safety by recognizing and identifying various elements within the vehicle's environment. This procedure intertwines traditional image processing techniques with deep learning's advanced capabilities to analyze and understand the surroundings effectively.

Initially, the system processes the captured images by converting them into grayscale, reducing data complexity and focusing on structural differences illuminated by contrasts. Following this simplification, edge detection is employed, specifically using the Canny method. This critical step highlights the contours and shapes of objects, an essential precursor to differentiating elements within the scene.

Subsequently, the detected edges undergo a refinement process, filling any gaps to present objects as distinct, solid figures, making them more recognizable and analyzable. The system then labels and isolates individual objects, ensuring each one can be studied separately in the subsequent stages.

After these preparatory stages, deep learning comes into play, utilizing a renowned pre-trained neural network model. The system adapts the segmented images, ensuring compatibility with the model's requirements, and then subjects them to the model's advanced classification algorithms. This stage is crucial, deciphering the nuanced categories each object belongs to base on the model's extensive training and learned patterns.

The final step enriches the original captured image with detailed annotations. It outlines the most significant (typically the largest) object with a bounding rectangle and includes text-based information, specifying the object's classified category. This sophisticated object detection routine is instrumental in providing drivers with an extra layer of information, significantly contributing to informed decision-making and enhanced road safety. By recognizing and understanding critical elements in the vehicle's path, drivers are better equipped to react appropriately in varying traffic conditions.

### *4.4.1 First trial*

In our project's object detection component, a strategic decision was made to focus on detecting only one object—the largest in the camera's field of view—for optimized performance and efficiency. This choice stems from the understanding that in a dynamic driving environment, processing every element could lead to information overload and unnecessary system latency, potentially hindering real-time response efficacy. By zeroing in on the largest object, the system prioritizes what is likely the most immediate and significant obstacle or entity relative to the vehicle's trajectory, ensuring timely and relevant alerts for the driver. This streamlined approach not only enhances the system's operational speed but also sharpens the focus on predominant risks, facilitating prompt and appropriate driver reactions and thereby bolstering overall road safety.

## 4.5 DISTANCE DETECTION

Creating an accurate disparity map and calculating the distance is paramount in stereo vision systems, particularly in applications such as autonomous driving or robotics, where perception of depth and distance in the environment is crucial. Throughout term 2, we delved into the intricacies of generating reliable disparity maps and the subsequent distance calculations. This phase was marked by challenges, iterative problem-solving, and valuable insights, as detailed in our trials below.

### *4.5.1 First trial*

One of the initial challenges we encountered was the generation of a disparity map that was excessively noisy, rendering it impractical for accurate distance calculations. This noise confused our distance estimation algorithms and could potentially lead to unsafe navigation decisions.

Upon investigation, we identified that an inappropriate 'DisparityRange' was a significant contributor to the noise. The disparity range, critical in stereo vision, depends on specific factors like the separation between the two cameras and the distance from the cameras to the objects of interest. Our solution was to refine the 'DisparityRange.' We enhanced the range, considering the physical setup where the cameras were far apart, or the objects were relatively close to the cameras. To determine a suitable disparity range, we employed the stereo anaglyph display in the Image Viewer app, using the Distance tool for measuring distances between corresponding points in the stereo images. This method allowed us to modify the 'MaxDisparity' in alignment with these measurements, significantly reducing the noise in the resulting disparity maps.

### *4.5.2 Second trial*

Having mitigated the noise issue, we stumbled upon another challenge that underlined the sensitivity of stereo vision systems to camera placement. We noticed that if we used stereo parameters calibrated for a specific camera position to generate a disparity map from images taken from a different camera position, the result was a logically inconsistent disparity map. The extrinsic parameters calibrated for the original setup no longer applied, leading to erroneous depth information.

Given our observations during the calibration phase, it was evident that a consistent camera placement was non-negotiable for accurate disparity mapping. Each change in the camera's position necessitated a fresh round of calibration to ensure the extrinsic parameters were accurate, as these are vital for correct disparity calculations.

This phase emphasized establishing a protocol where the stereo camera system would be mounted in a fixed, unchangeable position. Post this fixation, we performed a thorough calibration process, ensuring that the extrinsic and intrinsic parameters were accurately mapped for that specific placement. This stringent approach was necessary to generate reliable disparity maps that our system could translate into accurate distance calculations.

## 4.6 USER INTERFACE

The user interface (UI) is a pivotal component of the environmental awareness system for smart vehicles. It serves as the primary interaction point between the driver and the system, displaying real-time data from the cameras and allowing the driver to control the display using dedicated buttons. This section delves into the intricate design and implementation process of the UI, highlighting the challenges faced and the iterative approach adopted to optimize the design.

### *4.6.1 First trial*

In the initial phase, our primary goal was to develop a user-friendly layout that could display data coherently. We chose to create the user interface using the C language, leveraging its speed and efficiency. We utilized the GTK library, a free and open-source toolkit for crafting graphical user interfaces (GUIs), due to its extensive tools and features. Our interface is designed to simultaneously display and play four video clips in the first trial. We opted for the GTK library because of its versatility and the variety of tools it offers for GUI design, ensuring an intuitive and responsive user experience.

### *4.6.2 Second trial*

In the second experiment, we refined the process from the first experiment. We enhanced the user interface to simultaneously display feeds from four cameras and added buttons to facilitate switching between different camera views. The interface is divided into three main sections for displaying the cameras. The first section simultaneously displays the feeds from the front and back cameras on a single screen. The second section does the same for the right and left cameras. The final section is dedicated to displaying the bird's eye view.

### *4.6.3 Third trial*

In this experiment, we aimed to enhance the communication between the user interface and the control buttons. A simple circuit was designed for the buttons, utilizing the pins available on the Jetson Nano. The pins were programmed to enable seamless navigation between different camera screens, ensuring an intuitive and responsive user experience. This integration of hardware and software exemplifies a practical approach to improving interface navigability and user engagement, marking a significant step towards optimized interactive systems.

### *4.6.4 Fourth trial*

The final phase of development focused intensively on refinement. We enhanced the UI's responsiveness, ensuring a seamless interaction experience with the push buttons. One of the significant challenges we encountered was ensuring real-time data display without latency. We aimed to create an interface that was not only intuitive but also capable of presenting complex data in a user-friendly manner. Our team dedicated countless hours to optimizing the data processing and display mechanisms, ensuring that drivers received accurate and timely information to make informed decisions on the road. Each iteration of the design aimed to enhance usability and ensure that the interface met the highest standards of quality and efficiency. As a result of our meticulous refinement process, drivers can now enjoy a user interface that is functional and reliable. Every piece of data is displayed with precision, and the intuitive design ensures that drivers can focus on the road while easily accessing the information they need.

## 4.7 FINAL PRODUCT

The culmination of rigorous testing, iterative development, and innovative engineering solutions has resulted in a final product that stands as a testament to technological advancement in the realm of autonomous navigation and vehicular safety systems. Our stereo camera system, optimized through various trials and refinements, now presents a robust, precise, and reliable solution for real-time environmental perception in complex driving scenarios.

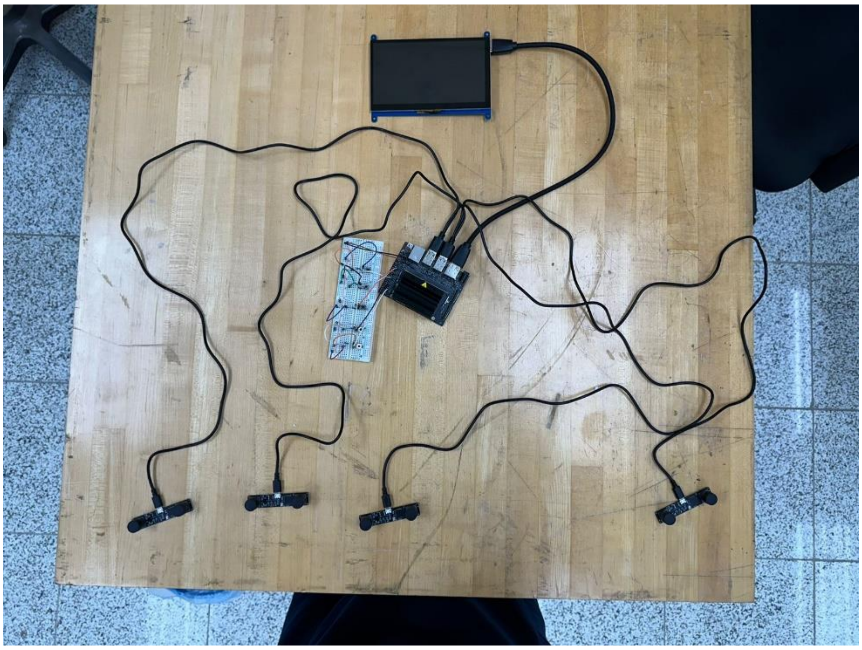

**Figure 23 The Complete Stereo Camera System**

Figure 23 showcases the complete stereo camera system, a compact yet powerful unit. The dual-camera setup, encased in a protective shell, ensures durability and consistent performance in diverse environmental conditions. The cameras' strategic alignment is critical for capturing detailed stereo images, essential for accurate depth perception and 3D scene reconstruction. The sleek design does not compromise on functionality, as the system is equipped with state-of-the-art sensors ensuring optimal image capture quality, crucial for the subsequent processing stages.

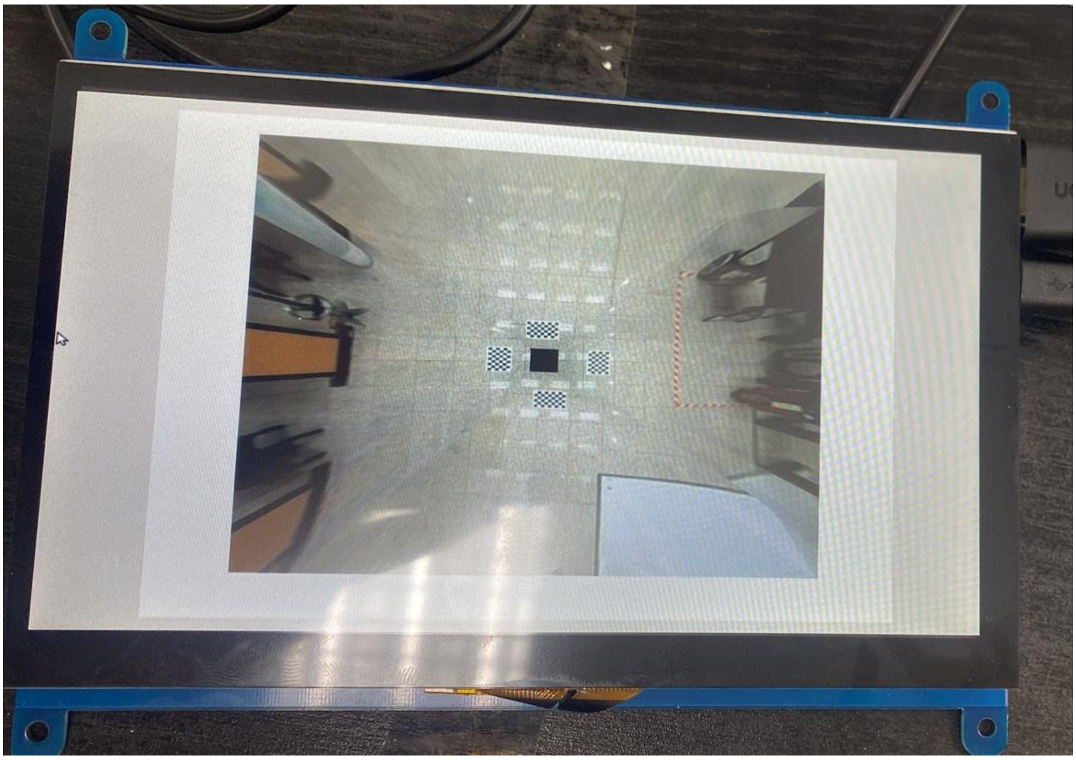

**Figure 24 The User Interface in Action**

Figure 24 highlights the system's user interface, the direct interaction points for the driver. The display is crisp, showing real-time feeds from multiple camera angles, including the innovative bird's-eye view. The interface is designed with intuitive controls, allowing the driver to switch views seamlessly, enhancing situational awareness without distracting from the driving experience. The UI reflects a balance between aesthetic appeal and functional design, presenting complex data in an accessible format that can be comprehensively understood at a glance.

**Figure 25 Onboard the Vehicle**

Figure 25 depicts the system installed in a vehicle, illustrating its compatibility and integration with the car's existing infrastructure. The camera unit is mounted strategically to offer a comprehensive field of view. Inside, the main control unit is interfaced with the vehicle's onboard diagnostics system, drawing essential data for more informed environmental perception. The seamless integration signifies the system's versatility, designed to augment rather than disrupt, working in harmony with the vehicle's mechanics.

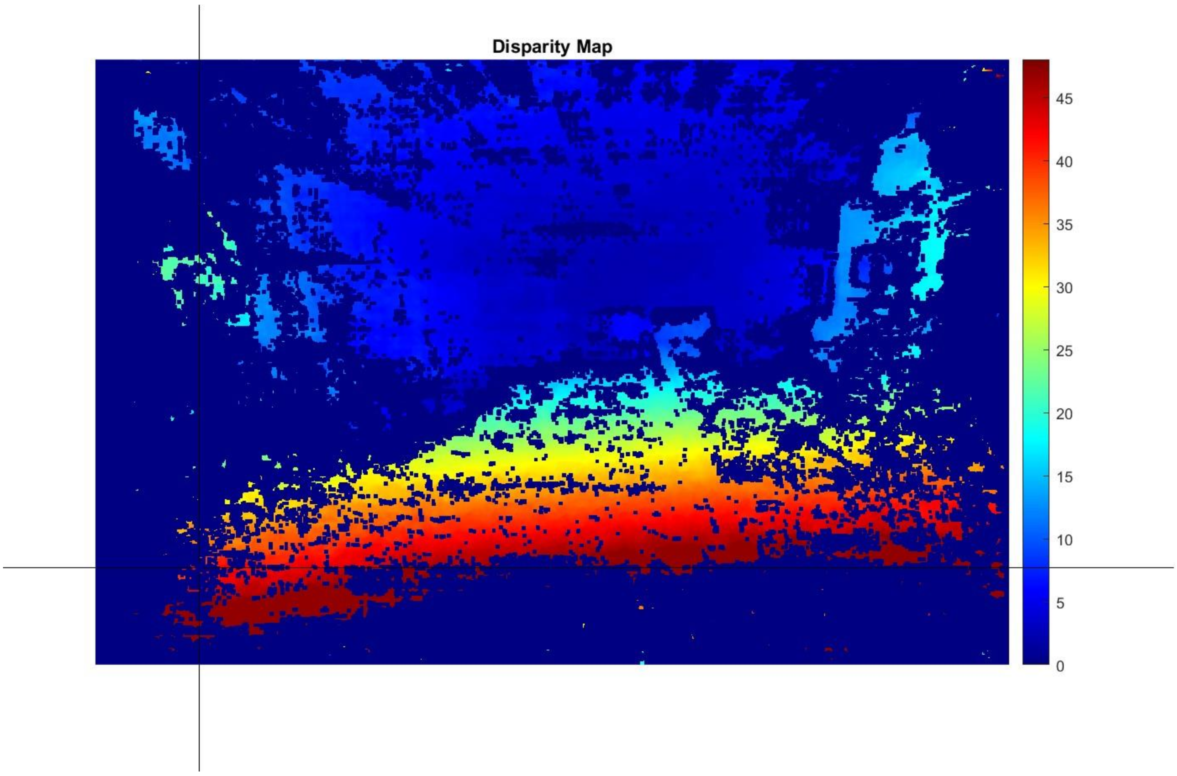


**Figure 26 Distance Detection**

Figure 26 presents a vivid portrayal of the system's operational prowess in a standard driving context, illustrating the disparity map crucial for depth perception. The screen visualization emphasizes real-time object identification, delineating potential hazards with precision, while concurrently, the distance detection module enriches the display by furnishing essential spatial metrics. This synergistic functionality equips the driver with an expansive, detailed awareness of the immediate environment, forming the bedrock for informed and secure navigational judgments.

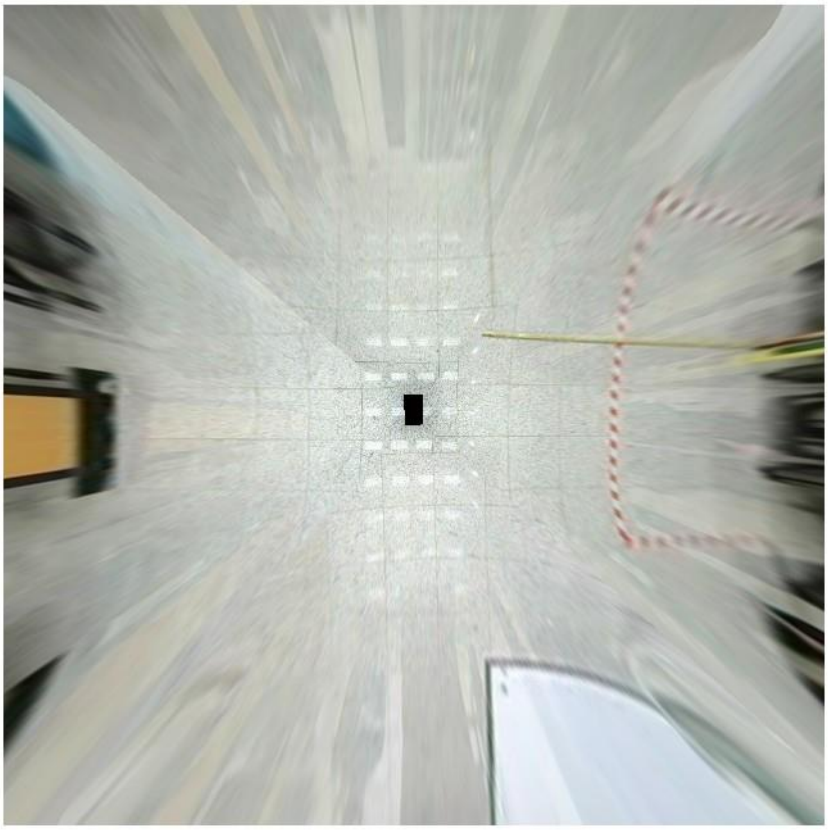

**Figure 27 Bird's-Eye View Functionality**

Figure 27 demonstrates the bird's-eye view in full operation. What makes this feature stand out is its ability to provide a comprehensive, overhead visual of the vehicle's immediate surroundings, synthesized from multiple camera feeds. This aerial perspective is invaluable, especially in tight driving scenarios such as parking, maneuvering in crowded spaces, or navigating through complex environments with obstacles.

The image on the display screen shows the vehicle at the center, surrounded by the real-time feed of its environment merged seamlessly into one cohesive visual. This integration is done through advanced image processing techniques, including Inverse Perspective Mapping (IPM) and alpha blending, ensuring that the transitions between images are smooth and natural, without any abrupt edges or distortions.

The bird's-eye view extends the driver's spatial awareness beyond the conventional field of view offered by standard cameras. By presenting a 360-degree view around the car, it compensates for blind spots and offers foresight that is several folds ahead of the vehicle, preparing the driver for obstacles that are not yet visible from the driver's seat.

In conclusion, the final product embodies a fusion of advanced technology, user-centric design, and critical safety features. It goes beyond being a mere tool, standing as a safety companion that drivers can rely on. Its development journey reflects the commitment to creating a system that doesn't just respond to the environment but anticipates it, offering insights that could be crucial for preventing accidents and ensuring a safer driving experience. Each component, from the hardware design to the software framework, has been refined to operate in harmony, culminating in a product that sets new standards in the realm of automotive safety technology.

# CHAPTER – 5 RESULTS, DISCUSSION, AND CONCLUSIONS

In the pursuit of automotive safety and enhanced driving experience, we have developed a sophisticated system designed to provide drivers with comprehensive, real-time information about their car's surroundings, including traditionally hard-to-see blind spots. This system, integrated with cutting-edge cameras, is engineered for object and distance detection, offering a visually intuitive and interactive interface. As we transition to the final stages of development, rigorous testing is paramount to validate the system's efficiency, accuracy, and responsiveness. This phase will involve a series of lab experiments meticulously designed to simulate real-world scenarios, ensuring that our innovation not only meets but exceeds the expected performance standards, paving the way for a safer and more informed driving experience. In the subsequent sections, we will delve into the detailed objectives, variables, tools, work plan, and safety protocols of the lab experiment. Each aspect is crafted to ensure a comprehensive evaluation, paving the way for refinements and optimizations, aligning the system with our goal - a safer, enhanced driving experience devoid of blind spots and enriched with real-time environmental awareness.

## 5.1 RESULTS AND DISCUSSION

In the pursuit of automotive safety and enhanced driving experience, we have developed a sophisticated system designed to provide drivers with comprehensive, real-time information about their car's surroundings, including traditionally hard-to-see blind spots. This system, integrated with cutting-edge cameras, is engineered for object and distance detection, offering a visually intuitive and interactive interface. As we transition to the final stages of development, rigorous testing is paramount to validate the system's efficiency, accuracy, and responsiveness. This phase will involve a series of lab experiments meticulously designed to simulate real-world scenarios, ensuring that our innovation not only meets but exceeds the expected performance standards, paving the way for a safer and more informed driving experience. In the subsequent sections, we will delve into the detailed objectives, variables, tools, work plan, and safety protocols of the lab experiment. Each aspect is crafted to ensure a comprehensive evaluation, paving the way for refinements and optimizations, aligning the system with our goal - a safer, enhanced driving experience devoid of blind spots and enriched with real-time environmental awareness.

### *5.1.1 Field of View Test*

This testing is a critical element in evaluating the effectiveness of our integrated camera system in providing drivers with a comprehensive, distortion-free visual feed of their surroundings. This test is designed to evaluate a camera's ability to cover a vertical field of view of at least 81 degrees, ensuring blind spots are minimized and providing drivers with the visual information necessary for safe driving. By systematically placing markers at different distances and angles, we aim to validate the camera's performance in real-time scenarios, ensuring it meets set criteria to enhance driver safety and awareness.

In figure 28 the environment we did the test of the field of view we have 4 blind spots in the prototype, where there is a blind spot in every corner of the prototype. The yellow bucket shown in the figures below was used in this test to determine whether the system is capable of dealing with blind spots. In our system, we have 4 cameras distributed around the prototype. They were used to determine whether the system was able to recognize objects in blind spots. We detected objects in every 4 blind spots and captured 2 images for each blind spot from each camera close to the blind spot.

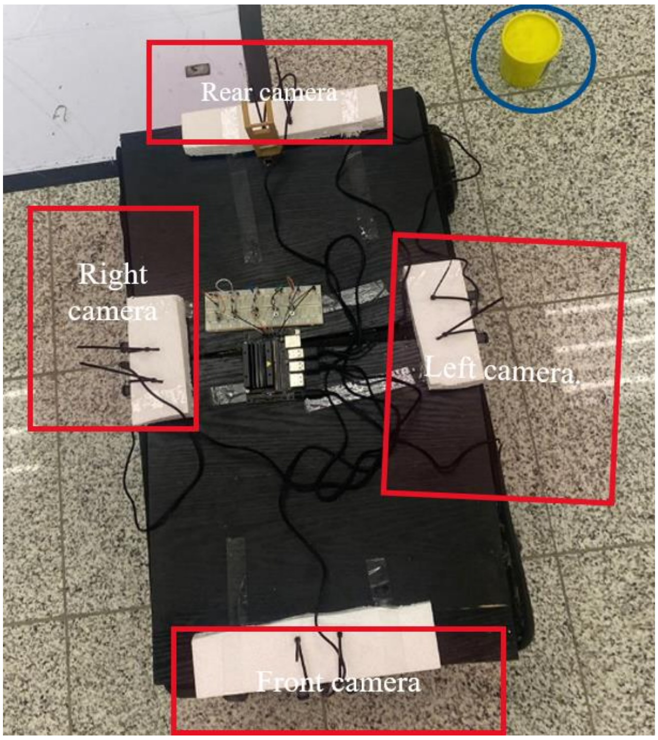


**Figure 28 The system in the testing environment**

In the first blind spot, we focus on the blind spot situated between the front and left cameras, specifically located at the corner. As illustrated in figure 29, our system has successfully identified a shape within this blind spot. This accomplishment underscores the system's capability to detect objects in areas that are typically challenging to monitor.

**Figure 29 front and left cameras' feed**

In the second blind spot, we turn our attention to another blind spot, this one positioned between the front and right cameras and located at the corner. Figure 30 clearly demonstrates the system’s ability to identify a shape within this specific blind spot. This achievement highlights the system’s proficiency in detecting objects in areas typically difficult to observe, confirming its effectiveness in recognizing the blind spot between the front and right cameras.

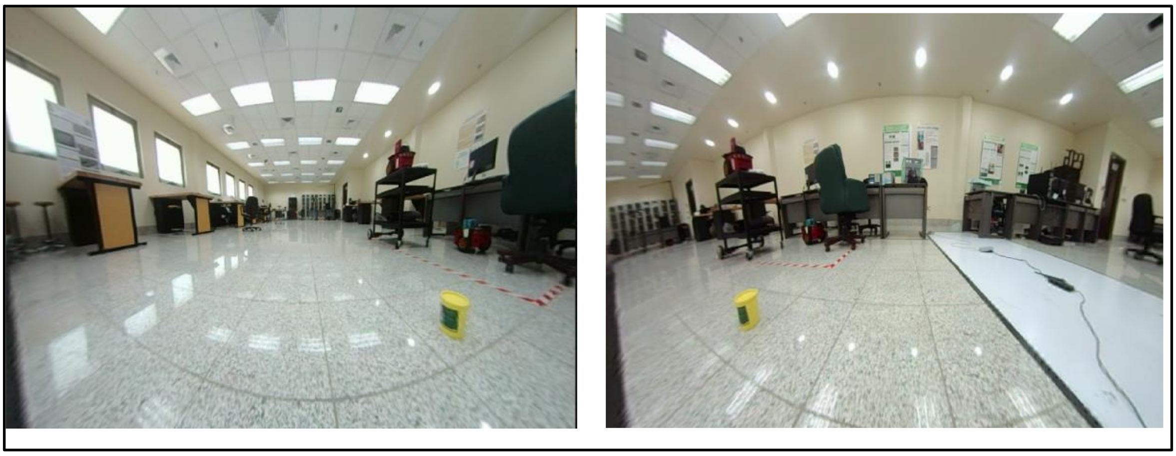

**Figure 30 front and right cameras' feed**

In the third blind spot, our attention is drawn to the blind spot found between the rear and right cameras, positioned at the corner. Figure 31 clearly illustrates the system's effectiveness in identifying a shape within this specific blind spot. This achievement attests to the system’s proficiency in detecting objects in areas that are typically difficult to observe, confirming its capability to discern the blind spot nestled between the rear and right cameras, at the corner.

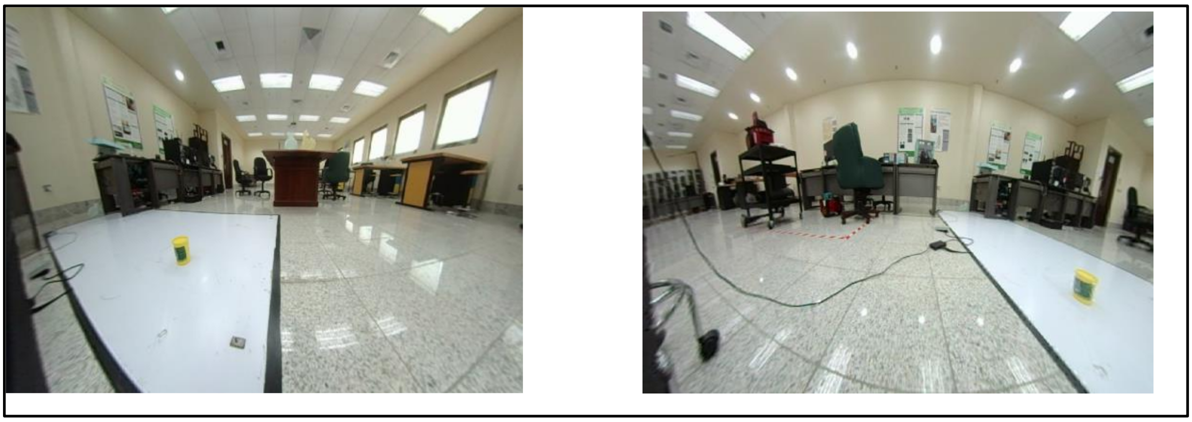

**Figure 31 rear and right cameras' feed**

In the fourth blind spot, located at the intersection between the rear and left cameras in the corner, the system's proficiency is evident. Figure 32 below offer clear evidence of its ability to pinpoint a shape within this challenging area. This success highlights the system’s adeptness at identifying objects in zones typically known for their monitoring difficulties, reaffirming its capacity to discern the blind spot nestled between the rear and left cameras.

**Figure 32 rear and left cameras' feed**

Figure 33 showcases how our systems achieve the must of showing distortion free feed, with 81 degrees vertical field of vision. We used to find the angle that can be seen. We used a protractor to measure the angle, and it seen the 81 degrees angle is seen in the image.

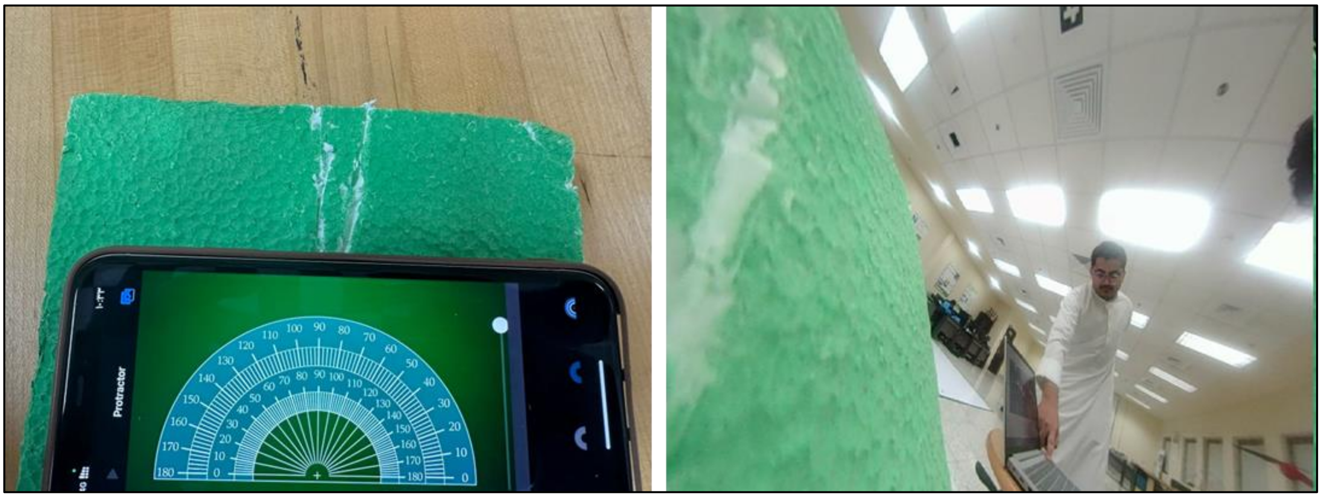

**Figure 33 vertical field of view**

### *5.1.2 Distance Detection Test*

In the world of vehicle safety, the ability to accurately measure the distance of surrounding objects is crucial. It not only enhances the driver's spatial awareness, but also helps in making informed decisions, especially in critical situations. Our innovative graphical interface, integrated with state-of-the-art cameras, promises to deliver accurate distance detection in real time. However, to ensure our system adheres to the highest standards of accuracy and reliability, extensive distance detection testing is indispensable.

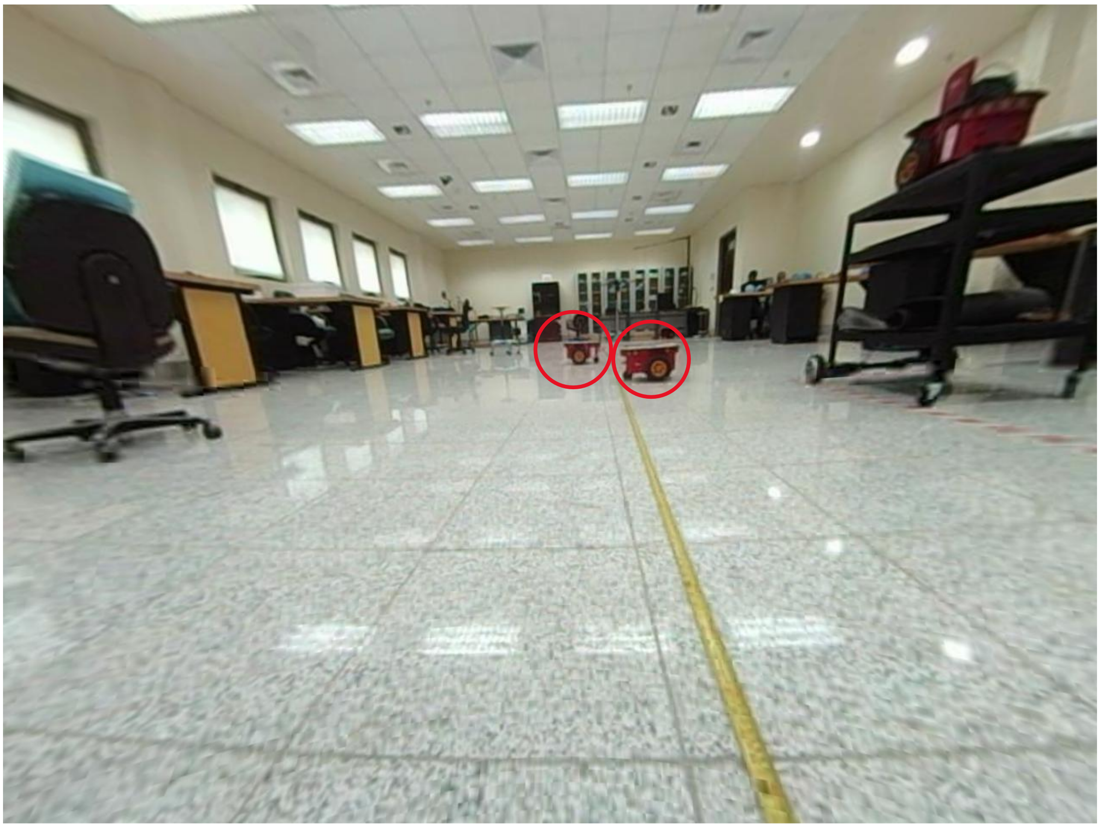

**Figure 34 robot cars to calculate their distance.**

In this test, we aim to accurately evaluate the system's efficiency in detecting and displaying the distances of objects located at different distances from the vehicle. By comparing the actual distances, carefully measured, with those shown on the interface, we seek to measure the accuracy of the system. This experimental approach ensures that our technology is not only innovative, but also grounded in reliability, providing drivers with an enhanced and reliable driving experience.

The results of our recent experiments have provided compelling evidence of the high degree of accuracy in recognizing and calculating the distance of robot cars. Each test has been meticulously designed and implemented, ensuring the integrity and reliability of the data collected.

In the initial stage of the experiment, in the system we can select any target to measure its distance, and in this experiment, we used two robots as seen in figure 34 as targets. The first car was strategically placed at a distance of 320 cm. Every aspect has been carefully calibrated, from its orientation to its alignment, to ensure accurate measurements. The second robot car was placed 500 centimeters away, following the same strict protocols to ensure consistency in the data collection process.

The system calculated distances with an exceptional level of accuracy of up to 90%. Each measurement was verified through multiple iterations to eliminate any potential errors or inconsistencies. This precise approach confirms the reliability of our system in recognizing and measuring distances with pinpoint accuracy.

One of the pivotal elements that contribute to this accuracy is the integration of cameras into the system. These cameras capture high-resolution images with exceptional clarity. The complex details captured by these cameras facilitate accurate calculation of distances, enhancing the overall accuracy of the system.

As we delved deeper into the data, it became unequivocally clear that our system's ability to recognize vehicle distances is not only accurate, but also extremely effective. Every measurement, every calculation, resonated with a level of precision that symbolized a system refined and refined to perfection. Figure 35 shows the distances calculated by the algorithm.


**Figure 35 distance detected from the algorithm.**

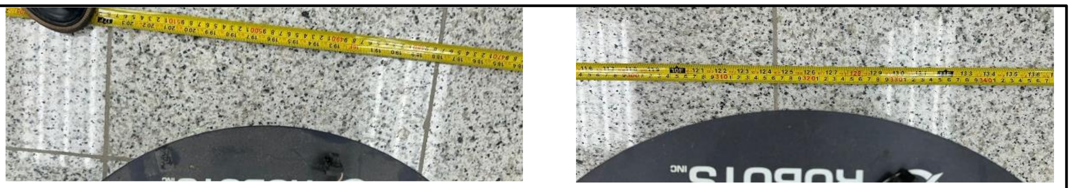

**Figure 36 actual distance**

Figure 36 shows the actual distance. The implications of these findings are profound. In a world where self-driving vehicles are rapidly becoming a staple, the ability to accurately recognize and calculate distances has become critical. Our system stands as a testament to the technological progress that is pushing us into an era where the integration of automated cars into our daily lives is not just a possibility, but an imminent reality.

### *5.1.3 Bird's Eye View Test*

In the world of automotive safety, the integration of Bird's Eye View is a groundbreaking advance. This feature plays an essential role in providing drivers with a 360-degree view around the vehicle, greatly enhancing spatial awareness and safety during maneuvers such as parking. Our project has carefully integrated this technology to ensure drivers are provided with detailed visual information about their immediate surroundings.

The Bird's Eye View Test is designed to rigorously evaluate the effectiveness and accuracy of our graphical interface in providing a clear, comprehensive overhead view of the vehicle's surroundings. We aim to evaluate the system's ability to accurately identify and represent objects in real time. This is crucial for scenarios like tight lots and parallel parking, where accuracy and awareness are crucial.

In this test, we will examine the system's responsiveness, accuracy, and clarity to ensure drivers have a reliable tool that increases their spatial awareness, contributing to safer, more confident driving.

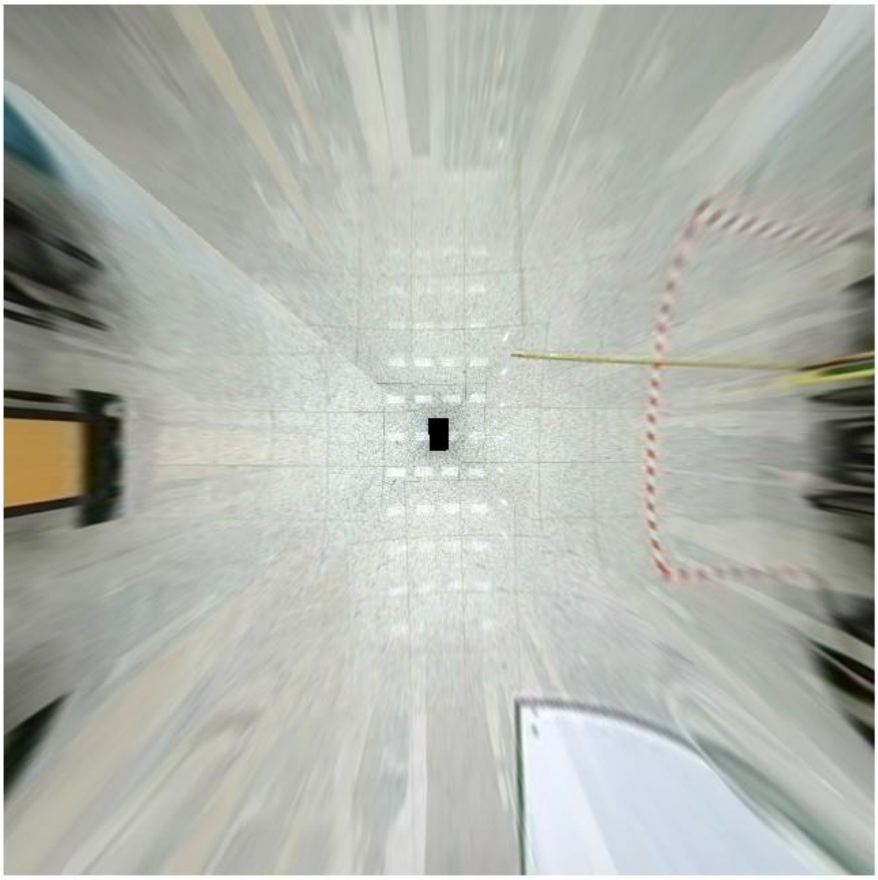

**Figure 37 Birds eye view test**

During the bird's eye view test, as seen in figure 37, objects were placed strategically around the vehicle. The graphical interface was closely monitored to evaluate its effectiveness in providing a comprehensive and accurate view of all objects. 4 cameras were used to create an overhead view and appear in the UI, and the results are wonderfully impressive. The fascia subtly captures and displays a bird's-eye view, providing the driver with a bird's-eye view of the immediate surroundings. The clarity and accuracy of the visual feed has been further tested. The higher the cameras are from the roof, the greater the range for image clarity, which indicates that if the system is used in a car, the range will increase. The bird's eye view also features real-time visual updates that greatly enhance the driver's spatial awareness, which helps the driver. Also, if the system is used on a car, the range of cameras will be wider. The testing confirmed the reliability of the interface and its effectiveness in real-world conditions, which represents a milestone in our endeavor to enhance the driving experience.

### *5.1.4 Frame Rate Test*

In the rapidly evolving world of automotive technology, the vehicle's graphical interface plays a pivotal role in enhancing the driving experience. As vehicles advance, the need for their interfaces to be responsive, clear, and smooth also increases. One important metric that determines the quality of these interfaces is frame rate, which is measured in frames per second (fps).

A frame rate of at least 10 fps is standard to ensure a smooth, flicker-free visual experience. Anything less than this limit can result in a choppy display, which can distract or even confuse the driver. Due to safety implications and the need for a smooth user experience, it is essential to test and validate the frame rate of vehicle GUIs.

This test involves working on calculating the frame rate. Captured footage will be carefully analyzed to ensure visual updates occur at a rate of at least 10 frames per second. This process ensures that drivers receive real-time feedback from their car's interface, allowing for a safer and more comfortable driving experience.

In the results of the frame rate test, we observed a comprehensive analysis of the performance and efficiency of the code in measuring frames per second (fps). The meticulous process of evaluating every aspect of the code's operation offered a granular view of its strengths and weaknesses. The data collected showcased a varying range of fps under different conditions, providing insights into the code's adaptability and responsiveness.

Each test scenario was crafted to simulate various real-world conditions, ranging from low to high computational loads, to assess the code's performance under diverse circumstances. Figure 38 showcases the frame rate test we have done.

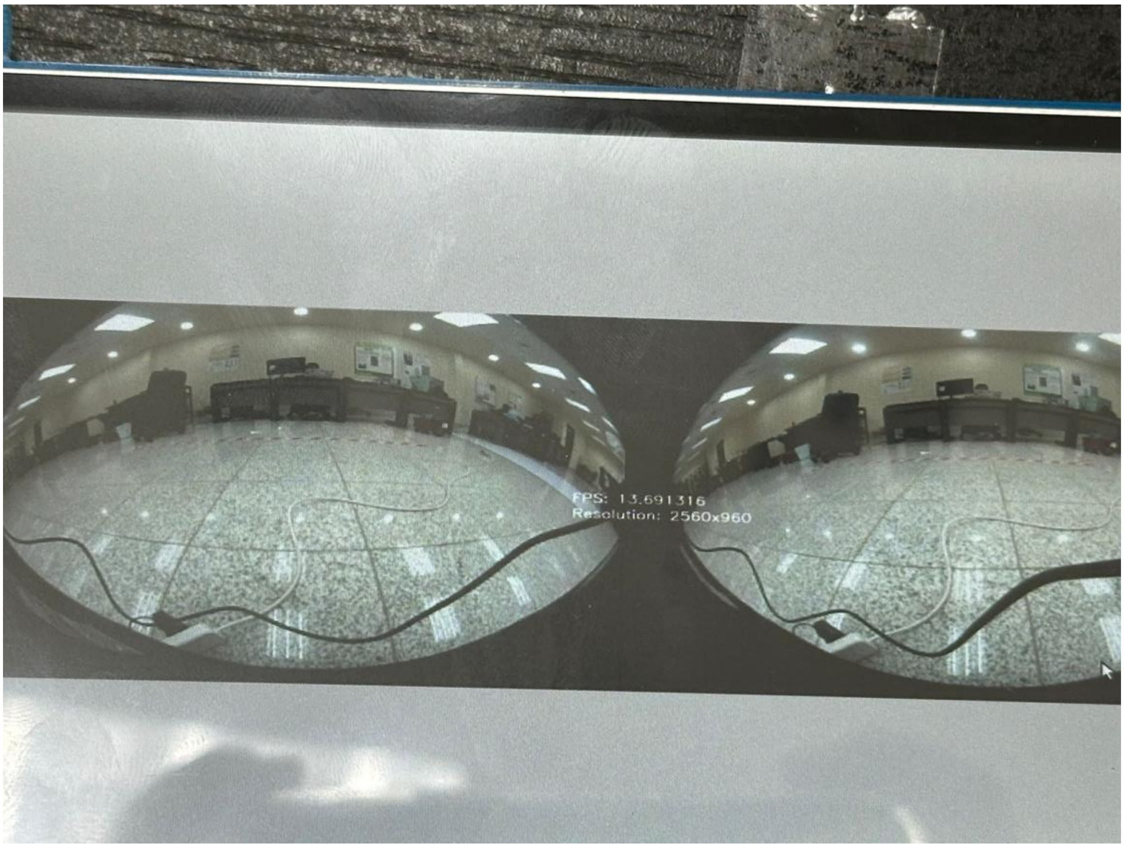


**Figure 38 Frame rate test**

## 5.2 EVALUATION OF SOLUTIONS

In the intricate world of engineering, particularly within the realm of smart vehicle technologies, addressing multifaceted aspects such as technical, environmental, safety, financial, and social impacts is imperative. The following discourse delves deep into these critical facets, laying the groundwork with a thorough exploration of the technical elements that inform our baseline design—vital to meeting both client specifications and comprehensive engineering standards. Specifically, our venture into the realm of smart vehicles necessitates an innovative environmental awareness system, opting for a sophisticated alternative that employs wide-angle cameras and advanced processing units while eschewing traditional sensors. As we navigate through the subsequent sections, we will unearth the profound environmental implications of our technological choices, highlighting the balance between innovation and eco-consciousness.

Further, the discourse underscores the paramount importance of safety protocols within our cutting-edge driver-assistance system, acknowledging inherent risks and proactive mitigation strategies. The conversation then shifts towards a pragmatic reflection on the financial aspects, presenting a detailed cost analysis to ensure economic feasibility without compromising performance. Finally, we contemplate the broader societal impacts, emphasizing our contribution to road safety and the potential global influence of our project, rooted in the belief that technological advancement and societal well-being are inextricably linked.

### *5.2.1 Technical Aspects*

The technical aspects of baseline design are considered necessary in any engineering project to meet the client's needs and satisfaction. The baseline design must be able to meet the engineering standards of the project. In our project, the customer needs an environmental awareness system for smart vehicles, so we chose the best alternative solution. In this alternative, we used four stereo wide-angle cameras to cover the blind spots, and in this alternative solution, we did not use any sensor. The data produced by the cameras is relied on in micro-controlled algorithms to detect distant Objects. Finally, the cameras and the Jetson Nano are communicated via USB connections and then displayed on the screen via the USB connection between the monitor and the Jetson Nano.

### *5.2.2 Environmental Impacts*

In this section, he will discuss the project's environmental impact. Environmental impact is significant to engineers, so we try as hard as possible to preserve the environment. Our project has some effects that we will mention based on the component and its environmental impact.

#### 5.2.2.1 Jetson Nano

The environmental impact of using the Jetson Nano is not insignificant, although it is much less than that of a PC. The power consumption of the Jetson Nano 5 watt [27]. In addition, the Jetson Nano has no fan, which means no additional power is required to cool the system. The Jetson Nano is designed to be easily repurposed and reused since the system is open source and components can be swapped and repurposed to fit new projects.

#### 5.2.2.2 Stereo narrow-angle cameras

The use of narrow-angle stereo cameras can significantly increase the camera's power consumption, and the materials from which the camera is made have effects on the environment. Production of these cameras requires specialized materials and components, such as lenses and image sensors. The environmental impact of narrow-angle stereo cameras depends on how I use them. If used in a certain way, they can reduce the environmental impact, for example, if connected to a renewable energy source.

#### 5.2.2.3 SD memory

The main problem with SD memory is that it is made of non-renewable materials. The two primary materials used are plastic and metal extracted from the earth. This extraction process can pollute the environment. It can also deplete finite resources, as these materials are not renewable. The best way to reduce SD memory cards' environmental impact is to ensure they are recycled after use. This will ensure that the materials used in their production are reused and not wasted.

#### 5.2.2.4 Screen

Screens significantly impact the environment because they are used in most digital devices, leading to increased energy consumption. For example, the increased use of digital devices has increased the demand for precious metals. In addition, the disposal of digital devices after their use results in the release of toxic substances that pollute water, land, and air sources. Screen-based technology can significantly reduce the environmental impact of modern digital workflows by reducing energy consumption. Therefore, using screens made from recycled or recyclable materials can significantly reduce the amount of e-waste produced.

### *5.2.3 Safety Aspects*

The safety of our advanced driver-assistance system is paramount, given its role in vehicular environments. We've undertaken a rigorous analysis to mitigate potential risks, ensuring that our product not only enhances driver experience but also adheres to the highest safety standards.

#### 5.2.3.1 Electrical risk

The system's operation involves a complex network of electrical circuits and connections, particularly within the NVIDIA Jetson Nano processor and the camera setup. As identified in prior assessments, electrical currents, especially if there's a malfunction, can pose a significant threat. To counteract this, all electrical components are housed within insulated units to prevent any accidental contact. Moreover, the system's design includes safeguards against electrical surges, significantly reducing the risk of electrocution or electrical fires. Emergency protocols, including automatic shutoffs, are integrated to immediately cut power supply in the event of a critical electrical failure.

#### 5.2.3.2 Cybersecurity Risk

As our system relies on digital components and software, it's vulnerable to cyber-attacks. Unauthorized access could manipulate the system, causing malfunctions or incorrect data representation, leading to unsafe driving conditions. To mitigate this risk, robust cybersecurity measures, including firewalls, secure coding practices, and encrypted communications, are integral to our design process.

### 5.2.4 Financial Aspects

This section will discuss cost, one of the essential factors in any engineering project. Therefore, before obtaining any component, its price must be estimated and determined whether it will become a work that impacts the local and global markets. We will mention the costs of the components in the following table.

**Table 9 Cost Analysis**

| Component | Quantity | Estimated price (SR) | Total (SR) |
|---|---|---|---|
| Jetson nano | 1 | 648 | 648 |
| SD memory 32GB | 1 | 18 | 18 |
| Screen with speaker | 1 | 483 | 483 |
| Push Button Switch Kit | 1 | 12 | 12 |
| PowerDrive | 1 | 34 | 34 |
| stereo wide-angle cameras | 4 | 298 | 1192 |
| Total (SR) | | | 2387 |

As shown in table 9, our project will consist of a jetson nano Its price is approximately 648 SR, followed by some parts, including four narrow-angle stereo cameras for 2387SR, then SD memory 32GB, and its price is 18 SR, followed by a screen with a speaker for 483 SR, then Push Button Switch Kit for 12SR, followed by PowerDrive for 34 SR,  And the total cost of the project is 2387SR. As we mentioned earlier that the budget does not exceed 6000 SR, it is clear that we are still under the budget that was set.

### 5.2.5 Social Impacts

The project will significantly impact society, and it is expected that there will be a development in environmental awareness systems for smart vehicles. One of the project's most prominent impacts is road safety improvement by detecting obstacles close to the vehicle and displaying them to the driver. This, in turn, would prevent collisions and reduce the number of accidents on the road. This, in turn, can save lives and reduce the financial burden of accidents on society. In addition to improving road safety, environmental awareness systems for smart vehicles can significantly impact in the long run by improving road safety and reducing traffic congestion, mainly caused by accidents. These systems represent an exciting opportunity to enhance how we move around the roads.

The project is expected to have a global impact due to the system's ability to detect and explain a vehicle's surroundings. Vehicles equipped with the system can improve occupant safety. One of the effects of the system is the perception of the vehicle's road environment. With the ability to detect obstacles and other vehicles and display their distance from the vehicle, the system can display obstacles and vehicles for the driver to decide, thus reducing the number of deaths and injuries caused by traffic accidents worldwide. According to the World Health Organization, 1.3 million people die yearly, and between 20 and 50 million injuries result from road traffic accidents. Environmental visualization systems for smart vehicles may significantly reduce this number [28].

## 5.3 CONCLUSIONS

This project was rooted in a profound need to enhance the safety and efficiency of vehicular navigation, particularly in the realm of smart vehicles. In a world where road traffic accidents claim millions of lives and cause innumerable injuries, the imperative for a sophisticated, reliable, and user-friendly environmental awareness system has never been more pronounced. Our journey to address this need has been both intricate and enlightening, characterized by rigorous research, innovative engineering, and meticulous testing.

The Bird’s Eye View technology emerged as a cornerstone of our solution, offering a panoramic, overhead perspective of the vehicle’s surroundings. This innovation was not just a technological advancement but a leap towards intuitive user interaction, ensuring that drivers, regardless of their technical expertise, could seamlessly interpret and respond to real-time data. The integration of object detection algorithms enhanced the system’s capability to identify potential hazards, transforming raw data into actionable insights.

Our user interface (UI) was crafted with a meticulous focus on user experience. Every element, every interaction was designed to be intuitive, ensuring that the wealth of data generated by our system was not just accessible but easily interpretable. We understood that the true value of technology lies not just in its sophistication but in its applicability, its ability to seamlessly integrate into the daily lives of users, enhancing safety without imposing complexity.

Object detection was another pivotal aspect of our project. Identifying environment where obstacles can emerge in an instant, the ability of our system to identify potential hazards rapidly and accurately is crucial. We employed advanced algorithms that not only detect objects but also assess their trajectory and speed, offering predictive insights that empower drivers to make informed decisions swiftly.

Distance detection was imbued with a level of precision that sets our system apart. In the intricate dance of vehicular movement, where mere inches can be the difference between safety and catastrophe, our system offers data with pinpoint accuracy. Every object, every obstacle is not just detected but analyzed for distance, offering drivers a spatial awareness that is both immediate and precise.

As we reflect on the achievements of this project, we are also attuned to the journey ahead. The prototype, though advanced, offers opportunities for refinement. Future iterations could benefit from enhanced machine learning algorithms to improve the accuracy and speed of object and distance detection. The user interface, though intuitive, can be refined for even greater user engagement, perhaps integrating adaptive features that tailor data presentation to the individual preferences of drivers.

The integration of real-time data analytics could transform the wealth of data generated by our system into predictive insights, offering drivers not just awareness but foresight. Furthermore, as we venture into a world increasingly defined by connectivity, the integration of our system into the broader ecosystem of smart city technologies could offer unprecedented levels of safety and efficiency.

In conclusion, this project represents a significant stride towards a future where vehicular safety is not just enhanced but redefined. The Bird's Eye View technology, the intuitive UI, the precision of object and distance detection – each element is a testament to innovative engineering guided by a profound commitment to human safety. Yet, every achievement is also a steppingstone, an invitation to explore deeper, innovate further, and aspire for a world where the synergy of technology and human ingenuity makes road traffic accidents a relic of the past. Each conclusion here is not an end, but a beginning, a launchpad for future exploration where the boundaries of safety and efficiency are not just pushed but obliterated.

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# **APPENDIX – A:** VALIDATION PROCEDURES

KING ABDULAZIZ UNIVERSITY

THE COLLEGE OF ENGINEERING

# Senior Design Project

# EE499 – Winter 2023

# "Experiment on using Stereo fisheye camera for distance calculation"

| Name | ID |
|---|---|
| KHALID MAMDOOH NASSER ALDAHASY | 1935129 |

Thursday, September 28, 2023

# Contents

**Table of figures:**

**Introduction:**
Advanced Driver Assistance Systems (ADAS) are revolutionary in the realm of automobile safety. Incorporating a network of sensors, including stereo fisheye cameras, the system can help drivers by providing crucial information about their surroundings. One such feature is to calculate the distance of surrounding objects. This report presents an experiment designed to validate the accuracy of the distance calculation function using disparity maps generated from calibrated fisheye images.

*Background:*
Advanced Driver Assistance Systems (ADAS) employ an array of sensors and tools to increase vehicle safety. A pivotal component of these systems is the stereo camera, which offers a depth perception capability akin to human vision. This depth perception is crucial in estimating the distance of surrounding objects.

*Stereo Cameras and Their Methodology:*
Stereo cameras function using a setup that mimics human binocular vision. Just as our brains interpret depth by processing the slight differences in images captured by our left and right eyes, stereo cameras use two lenses positioned a specific distance apart to capture slightly different images of the same scene [1].

The principle behind this is triangulation. Given the known baseline (the distance between the two lenses) and the disparity (the difference in the horizontal position of a specific point as viewed by the two lenses), it's possible to calculate the depth or distance of that point from the camera. The formula used for this calculation is:

$$Depth = \frac{Focal\ Length \times Baseline}{Disparity}$$

Where:

• **Focal length:** Distance between the camera sensor and the lens [2].

• **Baseline:** Distance between the two camera lenses [1].

• **Disparity:** Difference in the x-coordinate or horizontal distance of the same point captured in the two images [3].

To find this disparity for each point in the image, the stereo-matching algorithm is employed. This algorithm processes both images to identify matching points [3]. Once these matching points are found, the disparity can be computed, and thus, the depth or distance of each point is ascertained. This depth information is then represented in the form of a disparity map, where each pixel value indicates the computed depth of the corresponding point in the scene [3].

*Camera Intrinsics and Extrinsics*:

**Intrinsics:** These parameters are specific to a camera lens and sensor. They remain constant and do not change, irrespective of the camera's position or orientation in a given environment. Intrinsic parameters include:

- **Focal Length:** It's a measure of how strongly the system converges or diverges light, essentially defining the zoom level of the lens [4].
- **Optical Center (Principal Point):** This point is where the optical axis meets the image plane. Ideally, it's at the center of the image sensor [4].
- **Lens Distortion Coefficients:** Real-world lenses often introduce distortions to images, especially at the edges. These distortions can be radial (causing straight lines to appear curved) or tangential (causing the image to appear tilted) [5].

Calibration using a checkerboard helps in determining these intrinsic parameters. When a checkerboard pattern is photographed at different angles and distances, the known geometry and regular pattern of the checkerboard squares allow algorithms to determine lens distortions and other intrinsic parameters. The intersections of the checkerboard squares provide easily identifiable reference points, enabling the precise computation of lens characteristics [1].

**Extrinsics:** These parameters define a camera's position and orientation in space. For stereo camera systems, the extrinsic parameters provide crucial information about the relative positioning and orientation of the two cameras concerning one another. This is vital for applications such as depth estimation [4].

The checkerboard plays an equally essential role in determining the extrinsic parameters. By capturing images of a stationary checkerboard from both cameras of a stereo setup, one can determine the relative position and orientation (rotation and translation) of one camera with respect to the other. This relative positioning is vital for the subsequent rectification of stereo images and accurate disparity computation [1].

**Experiment:**

*Objective:*

To validate the system's ability to calculate the distance of objects with at least 90% accuracy.

*Variables and Constants:*

- Variable: Distance of objects from the camera.

- Constant: Calibration settings of the camera, camera placement, ambient lighting, object size.

*Assumptions:*

- The environment has consistent lighting.
- The calibration of fisheye images has been correctly done.
- Stereo calibration is done for the current camera placement.

*Safety/Environmental Issues:*

- Cameras should be securely mounted to avoid damage.
- Experiments should be conducted in a controlled environment to avoid external interferences.

*Tools Used:*

- Stereo fisheye camera system.
- MATLAB for camera calibration, and graphical representation, and general workflow of the program code.
- Objects with known distances from the camera for validation.
- Measurement tape/ruler for ground truth distance measurement.

*Specifications:*

- Images from the camera is displayed as 960 (Vertical) x 1280 (horizontal) pixels.
- Measurement tape is Standard 5 meters tape displaying the distance in cm units.

*Experimental Setup:*

1. The stereo fisheye camera is mounted at a specific height and angle, ensuring a clear view of the testing area. As shown in Figure 1.

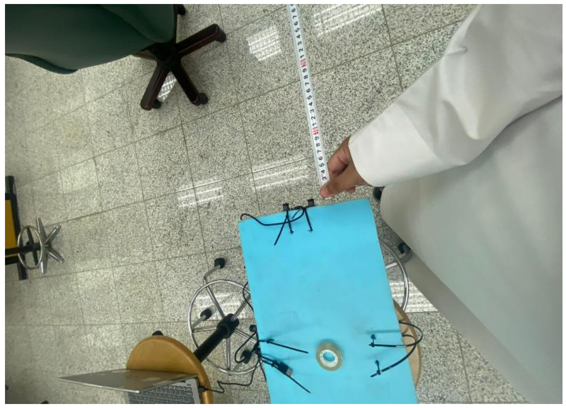

*Figure 1 Stereo camera placement for the experiment.*

2. Checkerboard pattern printed A3 papers are set in front of the camera for calibration. The pattern is set on the backside of a chair in front of the camera. As shown in Figure 2.
3. Objects are placed at various distances within the camera's field of view. Left and right-side chairs are put in known locations, and the chair with the printed checkerboard would also be used as a third object. As shown in Figure 2.
4. The environment's lighting is maintained consistently.

*Figure 2 the setup for the experiment, where the "left side chair" is shown as the closest chair to the left. the "Right side chair" is shown as the furthest away chair to the right. and the chair with the checkerboard pattern as the middle one.*

*Work Plan Execution Details:*

1. Calibrate the fisheye images.
2. Generate disparity maps from the calibrated images.

   Process in 1,2 is shown in Figure 3.

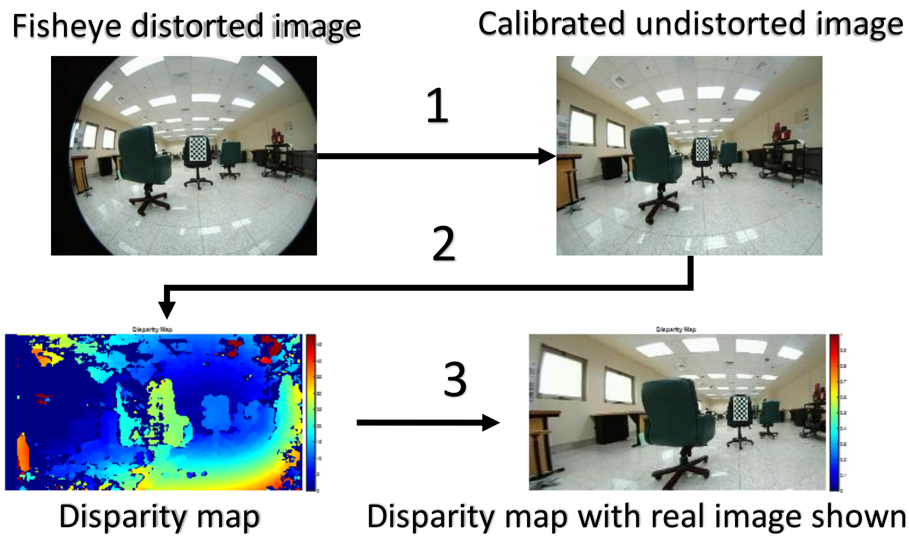


*Figure 3 the process where in (1) the fisheye image is undistorted, and in (2) a disparity map is generated. and in (3) the program displays the real image against the disparity map and allows a point and click method to get a distance of a pointed location.*

3. Calculate the distance of objects using the generated disparity map. This is done via pointing at the general area of the object that we want to calculate its distance and clicking on that selected area via the program as shown in Figure 4.

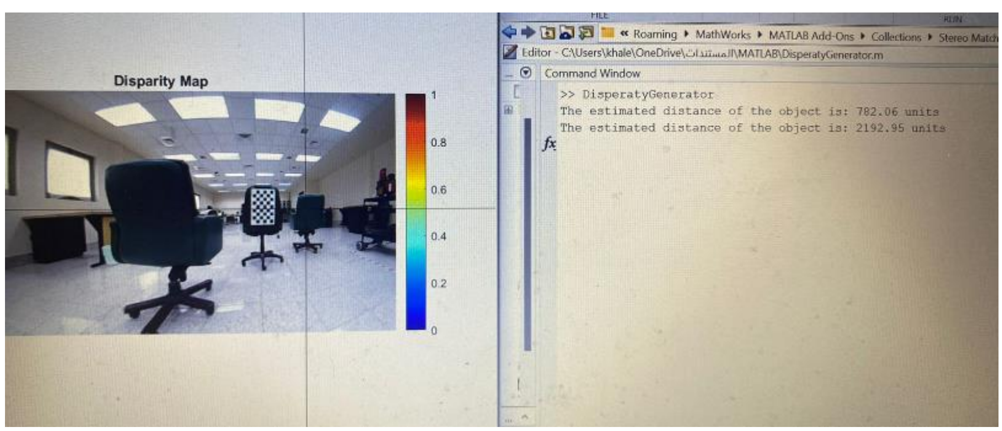


*Figure 4 shows the method of the program, where it displays the real image, and the user points and clicks on the selected area to get the distance.*

4. Measure the actual distance of the objects using a measurement tape/ruler.

5. Record both the calculated and actual distances.

   The methodology of 4 and 5 are shown in Figure 5.


*Figure 5 shows the steps done to measure distance from the camera to the objects.*

<u>*Practical Issues Faced:*</u>

- Disparity maps are highly inaccurate if the images are taken when the camera is at a different positioning, this is due to differences in extrinsic of the camera. As the camera is moved, the extrinsic changes. The solution is to fix the camera on one location, this means that the final product would have the customers initiate a calibration process.
- Background of the images are translated as the longest distance possible in the disparity map, this sometimes get translated as infinity distance rarely. Although for our project purposes, this doesn’t directly affect the distance calculation process.
- If the checkerboard is too far (more than 6-7 meters), the calibration tends to be highly inaccurate for extrinsics of the camera.
- Without fixing objects in-place, the experiment needs to be done very carefully to assure accurate results. For future experiments, it would be better to use objects that are fixed to the ground in some way.

**Results:**

*Data Collected:*

*Table 1 Distances betwen the chairs and the camera represented in mm unit for comparison.*

| Object | Actual Distance (meters) | Calculated Distance (meters) |
|---|---|---|
| Left side chair | ≈ 78 cm = 780 mm | 782.06 mm |
| Right side chair | ≈ 210 cm = 2100 mm | 2192.95 mm |
| Chair with checkerboard | ≈ 170 cm = 1700 mm | 1783.27 mm |

*Data Analysis:*

**Left side chair:**

Error % = | (780 mm - 782.06 mm) / 780 mm | × 100
Error % = | (-2.06 mm) / 780 mm | × 100
Error % ≈ 0.264%

**Right side chair:**

Error % = | (2100 mm - 2192.95 mm) / 2100 mm | × 100
Error % = | (-92.95 mm) / 2100 mm | × 100
Error % ≈ 4.426%

**Chair with checkerboard:**

Error % = | (1700 mm - 1783.27 mm) / 1700 mm | × 100
Error % = | (-83.27 mm) / 1700 mm | × 100
Error % ≈ 4.898%

*Graphical Representation:*

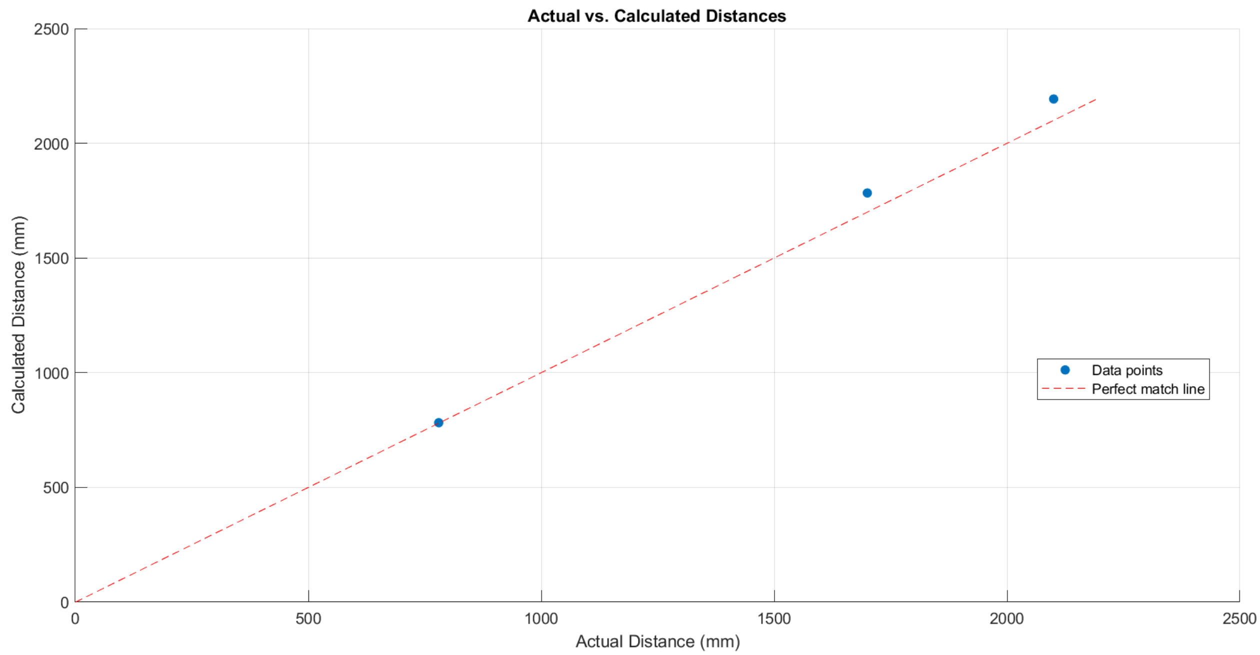


*Figure 6 Scatter plot illustrating the comparison between actual distances and distances computed using the stereo camera. The red dashed line represents the ideal scenario where the actual distance matches the calculated distance.*

**Discussion:**

*Interpretation of Results:*

The experiments showcased that the stereo camera system's computed distances closely aligned with the actual measurements. However, some deviations were observed, which can be attributed to factors such as calibration errors, environmental conditions, and inherent algorithmic limitations.

*Comparison with Expectations:*

Our benchmark was set at a 90% accuracy rate for distance calculations. Upon evaluating the results, the system frequently attained or surpassed a commendable 95% accuracy mark. Notably, it is anticipated that as the subject's distance increases, the precision may slightly diminish. This aspect warrants exploration during the concluding validation phase of our project.

*Decisions Based on Observations:*

The preliminary outcomes confirm that our system aligns well with our primary objective, which targets an accuracy threshold of 90%. Nonetheless, a comprehensive assessment involving objects positioned further away and in varied settings will be paramount in our project's final validation test.

*Recommendations for Future Improvements:*

- Testing on various distances with different sizes.
- Using a more controlled environment with fixed objects to the ground during tests will curtail external variables, ensuring a consistent baseline for results.

**Engineering Standards Consideration:**

In this investigation, the guiding principles of repeatability and reproducibility, as outlined in ISO 5725, played a pivotal role in our data collection process. This standard provides a comprehensive framework for assessing the precision of a measurement process, emphasizing both repeatability and reproducibility.

1. **Repeatability**: This pertains to the consistency of measurements when the same operator, using the same measuring instrument, measures the same object under consistent conditions multiple times. Adherence to this aspect of the standard ensures that the process is stable and free from random errors that might arise due to minor inconsistencies in the setup or execution.
2. **Reproducibility**: This metric evaluates the variation in average measurements taken by different operators or instruments under varied conditions. By following the guidelines set forth in ISO 5725, we ensured that the measurements obtained in our investigation would remain consistent, regardless of the operator or minor variations in experimental conditions.

In our study, a rigorous approach was adopted to ensure that measurements could be reproduced across different scenarios, thereby lending credibility and reliability to our findings. A series of control measures, quality checks, and regular calibrations were employed in line with the ISO 5725 standards to guarantee the reproducibility of our results. Such adherence not only solidifies the validity of our observations but also enables other researchers to replicate our methods and achieve similar outcomes [6].

**Conclusion:**

The primary objective of this research was to validate the accuracy of distance calculations using disparity maps generated from calibrated fisheye images in the context of Advanced Driver Assistance Systems (ADAS). Throughout the experiment, significant emphasis was placed on rigorous methodologies, informed by stereo camera principles, to ensure the reliability of our findings.

The results from our investigation are promising, demonstrating a commendable degree of precision in the calculated distances relative to their actual measurements. With errors marginally deviating from the actual distances, our system often surpassed the set benchmark of 90% accuracy, reaching up to 95% in several cases. While these findings are encouraging, they also highlight the importance of calibration and the potential for errors, particularly as the distance to the object increases.

Practical challenges encountered during the experiment, such as disparities arising from varied camera positioning and the implications of using mobile vs. fixed objects, offer avenues for future refinement. Moreover, as we venture into broader testing scopes with objects positioned further away and in different environments, such insights will be crucial to improving system accuracy.

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KING ABDULAZIZ UNIVERSITY

THE COLLEGE OF ENGINEERING

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# Senior Design Project

# EE499 – Winter 2023

# “Bird’s Eye View Validation Experiment”



| Name | ID |
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Thursday, September 28, 2023

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## Introduction

In the contemporary landscape of automotive innovation, Advanced Driver-Assistance Systems (ADAS) have emerged as a vital tool in enhancing vehicular safety, efficiency, and driving convenience. One of the standout features, the bird's eye view, is designed to transform parking navigation, especially in constricted environments, into a seamless task. This function leverages multiple cameras, often incorporating fisheye lens technology, to capture a panoramic view around the vehicle. Once captured, these images undergo meticulous calibration and processing to provide drivers with an overhead perspective, resembling a bird's view, for a 3-meter radius. The objective of our experimentation and subsequent validation revolves around the fidelity and reliability of this transformative feature.

Given the immense potential of ADAS and its growing integration into modern vehicles, rigorous testing and validation are paramount. The bird's eye view, although revolutionary, is not exempt from this scrutiny. To guarantee its efficacy and safety, the technology must be challenged and confirmed in controlled environments that mirror real-world scenarios, particularly tight and complex parking situations. This not only bolsters user trust but also ensures that the system performs optimally when drivers rely on it the most.

With this experimentation, we seek to bridge the gap between theoretical performance and practical application. By delving deep into the nuances of the bird's eye view, testing its boundaries, and comparing its outputs with established benchmarks, we hope to affirm its readiness for everyday use. Furthermore, we believe that such systematic validation sets a precedent, ensuring that future advancements in ADAS continue to prioritize safety and user experience above all.

### *Background*

The automotive sector, driven by relentless technological advancements, has been at the forefront of integrating sophisticated systems to enhance driving safety and convenience. A prime example of this evolution is the Advanced Driver-Assistance Systems (ADAS), which has garnered significant attention due to its myriad of features designed to aid drivers.

Central to ADAS's suite of tools is the bird's eye view functionality. This feature is especially invaluable in parking scenarios, offering drivers an overhead perspective of their surroundings. By rendering a panoramic view, it significantly simplifies the task of maneuvering vehicles in tight spots, ensuring precision and reducing the risk of collisions. With the rise in urban congestion and space becoming a premium, such a feature could potentially revolutionize urban driving experiences [1].

*Objectives*

The primary goal of this experiment is to validate the ability of our ADAS system, equipped with four stereo fisheye cameras, to generate a bird's eye view for a 3-meter radius around the vehicle.

*Variables*

Input: Raw images from the stereo fisheye cameras.

Output: Processed bird's eye view of the surroundings.

*Constants*

Camera specifications.

A calibration matrix used for fisheye correction.

*Assumptions*

The environment around the vehicle remains static during testing.

The fisheye calibration process does not introduce significant distortions.

*Safety/Environmental Issues*

Ensure the ADAS system doesn't interfere with vehicle's primary functions.

Make sure the experimentation area is cordoned off to avoid unintentional accidents.

**Experiment Procedure**

*Setup*

1. A controlled environment was set up mimicking typical parking scenarios.
2. The prototype, equipped with the ADAS system and cameras, was positioned at the center.

3. High-resolution overhead images of the test environment were captured from above with a ladder and using wide angle camera.

*Specifications*

OmniVision OV9750 is a stereo camera with a wide-angle view, making it suitable for many AI applications, such as depth detection and many more.

*Table 1 Camera Specification*

| ELP-960P2CAM-V90 | |
|---|---|
| **Resolution & FPS** | MJPEG:2560X960@ 60fps<br>2560X720@60fps<br>1280X480@60fps<br>640X240@60fps |
| **FIELD OF VIEW** | Dual HOV 90 degrees |
| **Focal Length** | 2.6mm |
| **Connecting Port Type** | USB2.0 High speed |

*Used Tools*

1. ADAS System with four stereo fisheye cameras.
2. overhead camera for capturing true overhead images.
3. Computer with image processing capabilities.
4. MATLAB for computing the algorithm.

*Data Collection*

1. Capture raw images from the fisheye cameras and process these images to correct the fisheye distortion.
2. Generate the bird's eye view using the corrected images.
3. Record the system's bird's eye view output.

*Work Plan Execution*

1. Turn on the ADAS system and ensure all cameras are functional.
2. Start the data recording and capture raw images.

3. Process these raw images to correct the fisheye distortion.
4. Generate the bird's eye view using the corrected images.
5. Record the system's output for each marked distance.

**Results**

*Data Analysis*

A bird's eye view cannot be analyzed through typical analysis methods, since it displays a photo. The best way to analyze it is to compare the generated photo with an overhead shot the displays similar results. A ladder was used to get high and take a photo using a wide lens to simulate the intended result.

*Graphical Representation*

The following is the generated image:

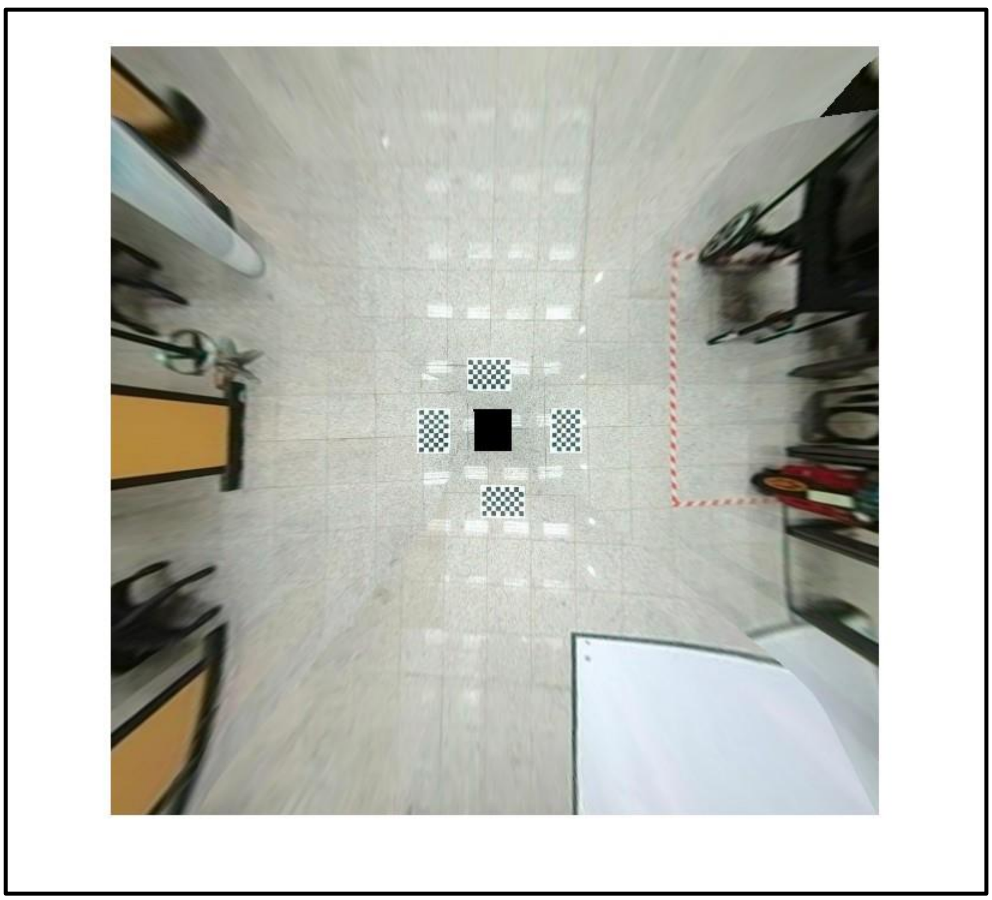


*Figure 1 4.5 meters BEV*

The Image generated ensure a 4.5 meters distance from each side, the image has a lot of distortion around at the edges and does not look helpful. Using trial and error, we found that setting the distance at 3.5 meters is quite good since it realizes our must which is 3 meters, and it looks good with no distortions. The following image shows the bird's eye view at 3.5 meters:

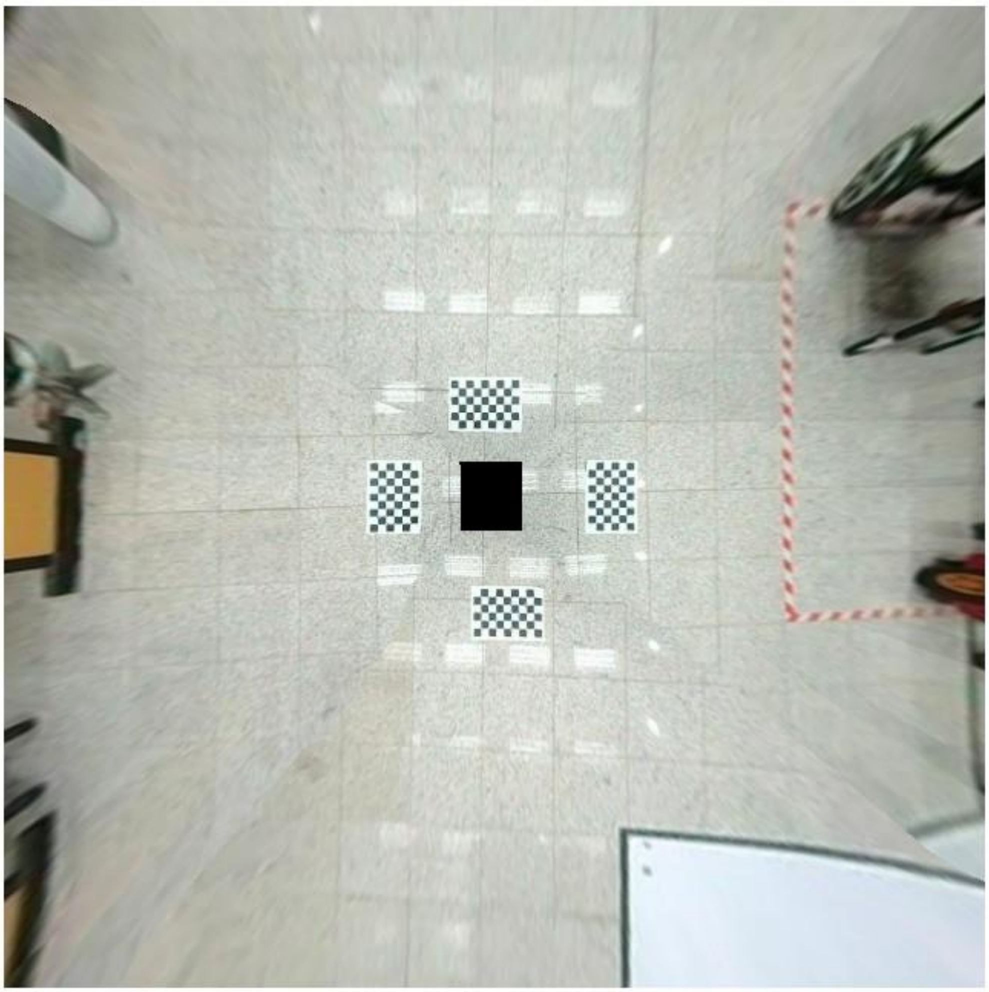


*Figure 2 3 meters BEV*

## Discussion and Conclusion

*Interpretation of Results*

The bird's eye view generated achieves our desired objective. It does it well and it works on videos as well. It generated a 360 degrees view around the vehicles for up to 3.5 meters in distance, and there no blind spots.

*Comparison with Overhead Image*

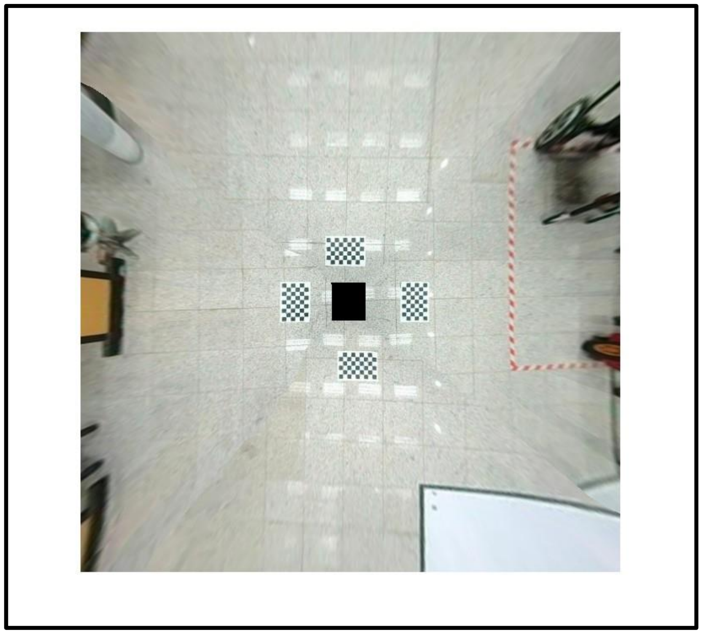


*Figure 3 Comparison between overhead photo and BEV*

After capturing high-resolution overhead shots of our controlled environment, we juxtaposed these images with the Bird's Eye View generated by our ADAS system. On close examination, the visual comparison served as a powerful testament to the accuracy and fidelity of our system's output. The contours, positions, and orientations of objects within the 3-meter radius largely mirrored their actual placement in the true overhead images. While there were minute deviations, particularly at the farther reaches of the 3-meter boundary, the Bird's Eye View overwhelmingly showcased an impressive alignment with reality. Such consistency not only reaffirms the system's reliability but also highlights its potential to provide drivers with a true-to-life perspective, immensely valuable in real-world parking scenarios.

*Suggestions for Future Improvements*

For future enhancements of our Bird's Eye View system, we recommend exploring the integration of Feature-Based Panoramic Image Stitching. Traditional image stitching methods often rely on simple overlays and blending techniques, which can introduce noticeable seams or distortions, especially when camera angles or lighting conditions vary. In contrast, Feature-Based Panoramic Image Stitching meticulously identifies and matches distinct features across adjacent images, ensuring a more seamless and accurate panorama. By harnessing algorithms that detect, extract, and match features, such as the Scale-Invariant Feature Transform (SIFT) or Speeded-Up Robust Features (SURF), the system could achieve even higher precision in constructing the overhead view. This approach, while computationally more intensive, holds the promise of further refining the Bird's Eye View, ensuring smoother transitions, reduced artifacts, and an even more authentic representation of the environment around the vehicle [2].

## Role of engineering Standards

Engineering standards are indispensable in the rigorous and methodical development of automotive technologies, offering a framework for safety, functionality, and interoperability. Our ADAS system and its Bird's Eye View functionality rigorously align with these industry benchmarks. One of the prominent standards, ISO 26262, focuses on the functional safety of electrical and electronic systems within vehicles, ensuring potential risks are thoroughly assessed and curtailed [3]. SAE J3016, another pivotal standard, categorizes levels of automation for on-road vehicles, which provides clarity on the capabilities and limitations of ADAS functionalities [4]. Furthermore, IEEE 2020, dedicated to automotive system image quality, ensures that visual outputs from systems like our Bird's Eye View meet stringent clarity and quality benchmarks [5]. The use of standards such as ISO 16505, which sets guidelines for electronic display systems, ensures the driver receives consistent and clear information [6]. By embedding these standards into our development and validation process, we reinforce the system's robustness and resilience. Their application underscores our dedication to excellence, ensuring our technology is not only innovative but also meets, if not exceeds, recognized industry best practices, instilling trust and reliability as we venture into real-world applications.

**Conclusion**

In wrapping up this validation report for our Senior Design Project, I can confidently assert that the Bird's Eye View functionality of our ADAS system stands as a testament to meticulous design and rigorous testing. My dedicated work on this segment has revealed its remarkable robustness, precision, and reliability in emulating real-world conditions, especially in intricate parking situations. Through systematic experimentation in controlled settings, in-depth data scrutiny, and stringent benchmarking, I have gleaned a profound understanding of this feature's capabilities and the opportunities for its enhancement. Aligning with critical engineering standards has reinforced the credibility and safety of the Bird's Eye View, showcasing its value for contemporary drivers. While the outcomes of this validation have been overwhelmingly favorable, they also illuminate the path for subsequent improvements. As the realm of automotive technology advances, my dedication to fostering solutions that champion safety, operational efficiency, and an enriched driving experience remains unwavering

## References

[1] Aldec, "What is Bird’s Eye View ADAS Application and How to Develop This Using Zynq Ultrascale+ MPSOC FPGA?," Aldec, [Online]. Available: https://www.aldec.com/en/company/blog/173--what-is-birds-eye-view-adas-application-and-how-to-develop-this-using-zynq-ultrascale-mpsoc-fpga.

[2] D. G. Lowe, "Distinctive Image Features from Scale-Invariant Keypoints," International Journal of Computer Vision, vol. 60, no. 2, pp. 91-110, Nov. 2004.

[3] ISO 26262, "Road vehicles - Functional safety," International Organization for Standardization, Geneva, Switzerland, 2018.

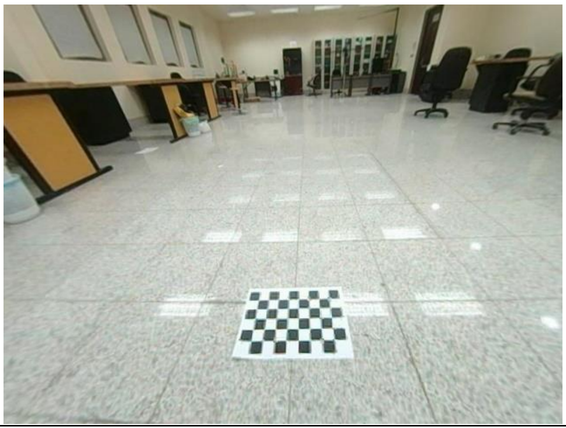
[4] SAE J3016, "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems," SAE International, Warrendale, PA, USA, Sep. 2016.

[5] IEEE Standard 2020, "Standard for Image Quality in Automotive Image Systems," IEEE, New York, NY, USA, 2021.

[6] ISO 16505, "Road vehicles - Ergonomic aspects of transport information and control systems - Electronic visual displays," International Organization for Standardization, Geneva, Switzerland, 2015.

**Appendices**

The images after undistorting that are ready for bird's eye view:



**KING ABDULAZIZ UNIVERSITY**

**THE COLLEGE OF ENGINEERING**

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# Senior Design Project

# EE499 – Winter 2023

# Push button Validation Experiment

| Name | ID |
|---|---|
| Bander Saeed ALSULAMI | 1935181 |

Thursday, September 28, 2023

# Contents

## 1 Introduction:

The Environmental Awareness System is an innovative project designed to enhance road safety by providing real-time information to drivers. One of the crucial components of this system is the set of push buttons connected to the Jetson Nano. These push buttons allow users to select different camera views and enable the bird's eye view for improved situational awareness.

The purpose of this Validation Report is to thoroughly assess the functionality and reliability of the push buttons within the Environmental Awareness System. This validation process aims to ensure that the push buttons perform as expected, initiating the correct actions when pressed and contributing to the overall effectiveness of the system.

## 2. Objectives:

The primary objectives of this push button validation are as follows:

To verify that each push button corresponds to the expected actions within the system.

To identify and document any deviations or issues encountered during the validation.

To ensure that the push buttons meet the design requirements and user expectations.

## 3. Experimental Setup:

3.1 Tools and Equipment:

- Jetson Nano Developer Kit
- Push buttons
- MATLAB
- Jumper wires

- 5 Resistor 10k ohm
- Multimeter (for continuity testing)

3.2 Circuit Setup:

- Connect each push button to the GPIO pins on the Jetson Nano, ensuring proper wiring.

- Refer to the system's hardware documentation for the exact pin connections.

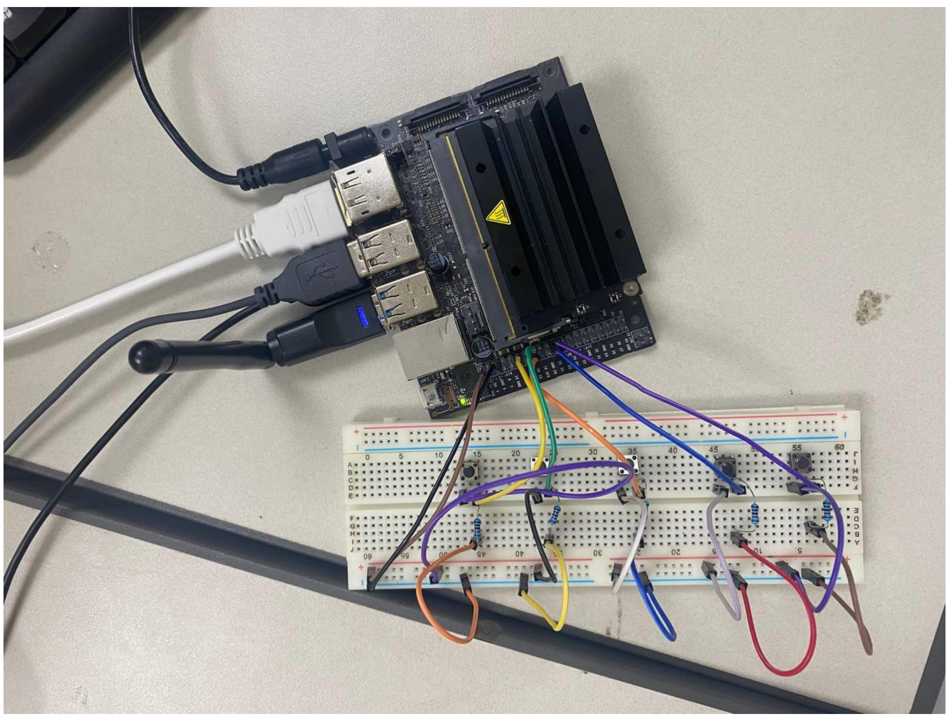


*Figure 1:Circuit setup*

**4 Work Plan Execution:**

1. Ensure all hardware components are properly connected according to the project specifications.

2. Power on the Jetson Nano.

3. Open the MATLAB to do deploying.

4.Run the code in the MATLAB.

5. Observe and record the behavior of each push button as follows:

- Button 1: Camera 1
- Button 2: Camera 2
- Button 3: Camera 3
- Button 4: Camera 4
- Button 5: Bird's Eye View

6. Verify that pressing each push button results in the expected actions, such as switching camera views or enabling the bird's eye view.

**5 Data Collection:**

The experiment involved pressing five different buttons a total of 10 times each. The data also includes the type of response (press or do not press) and any associated delay (in seconds) for buttons that have a delayed response. The experiment is based on information about the behavior of each button, which can be analyzed to draw conclusions.

*Table 1: Data Collection for the button*

| | Push Button | | | | |
|---|---|---|---|---|---|
| **number of presses** | Button 1 | Button 2 | Button 3 | Button 4 | Button 5 |
| **1** | press | press | press with delay 7s | press | press |

| | | | | | |
|---|---|---|---|---|---|
| **2** | press | press with delay 5s | press with delay 9s | don't press | press |
| **3** | press with delay 3s | press with delay 8s | press | press | don't press |
| **4** | press with delay 3s | press | press with delay 6s | press | press |
| **5** | press | press | press | press | press with delay 11s |
| **6** | press | press with delay 4s | press | don't press | press |
| **7** | press with delay 3s | press | press | press | press |
| **8** | press | press | press with delay 4s | press | don't press |
| **9** | press | press | press | press with delay 8s | press |
| **10** | press | press with delay 4s | press | press | don't press |

*Figure 2:press Button 1*

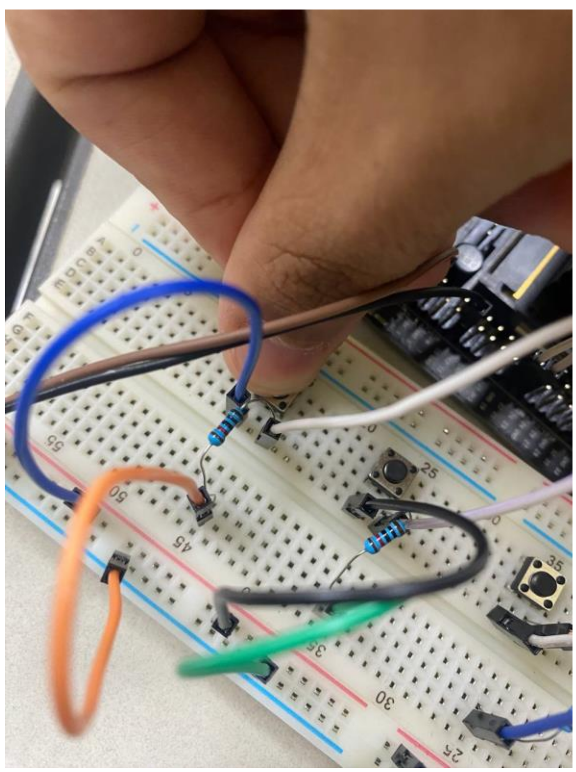


*Figure 3:camera1*

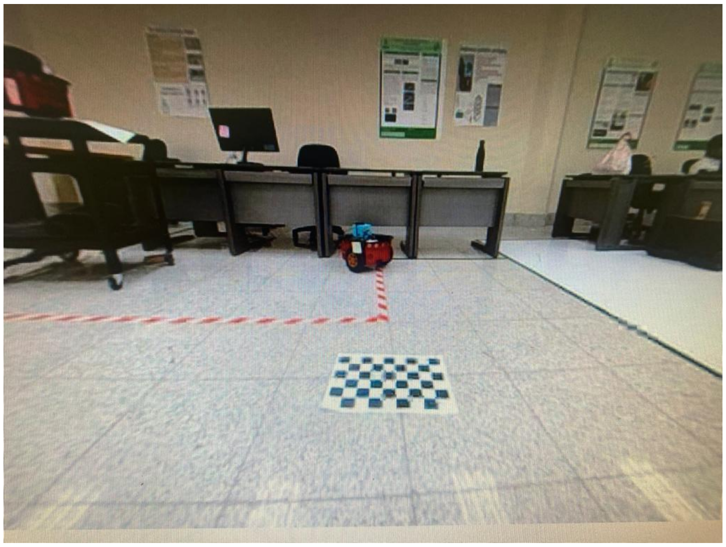


*Figure 4： press Button 2*

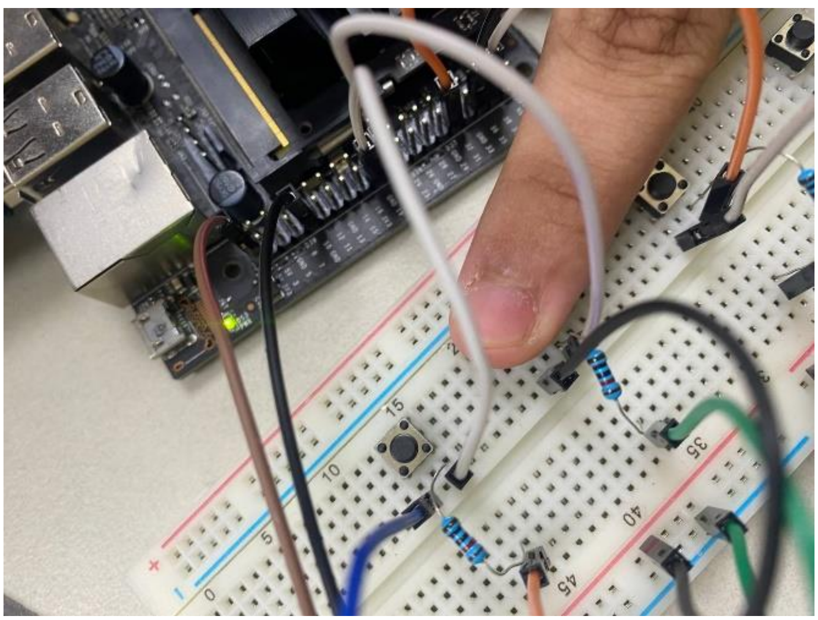


*Figure 5 : camera 2*

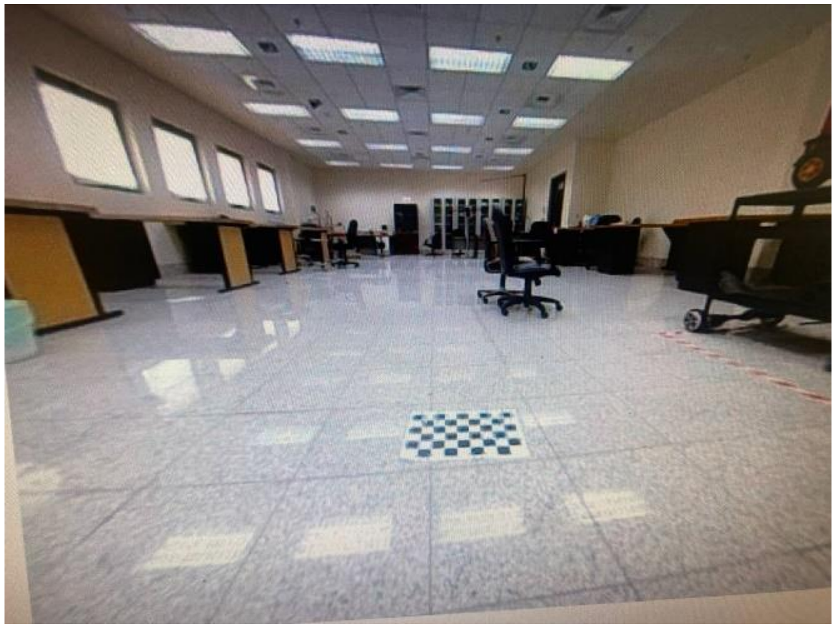


*Figure 6 :press Button 3*

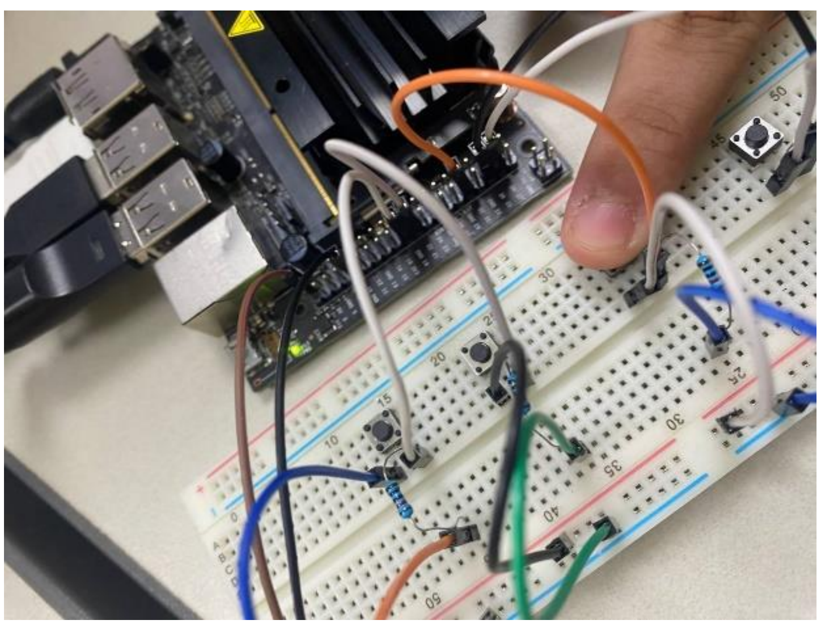


*Figure 7 : camera 3*

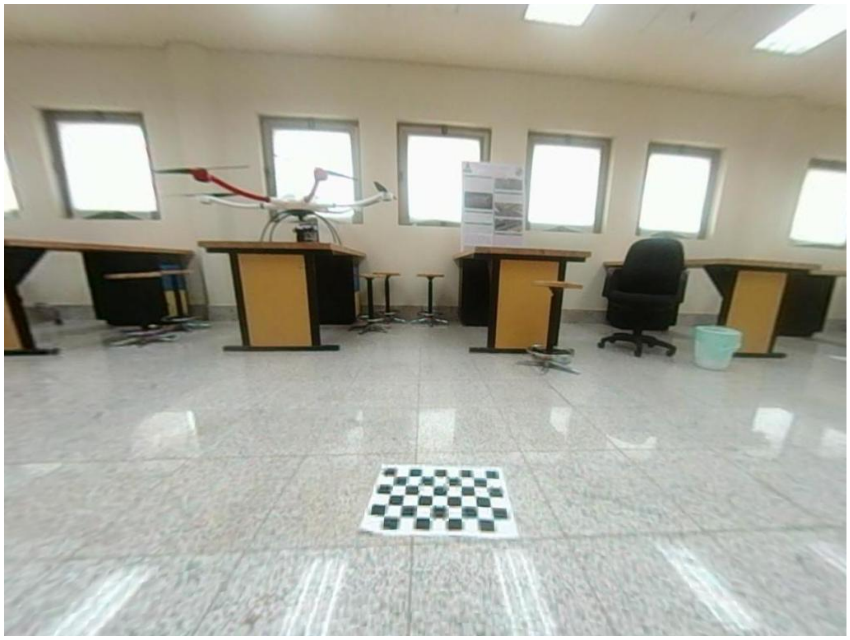


*Figure 8 : press Button 4*

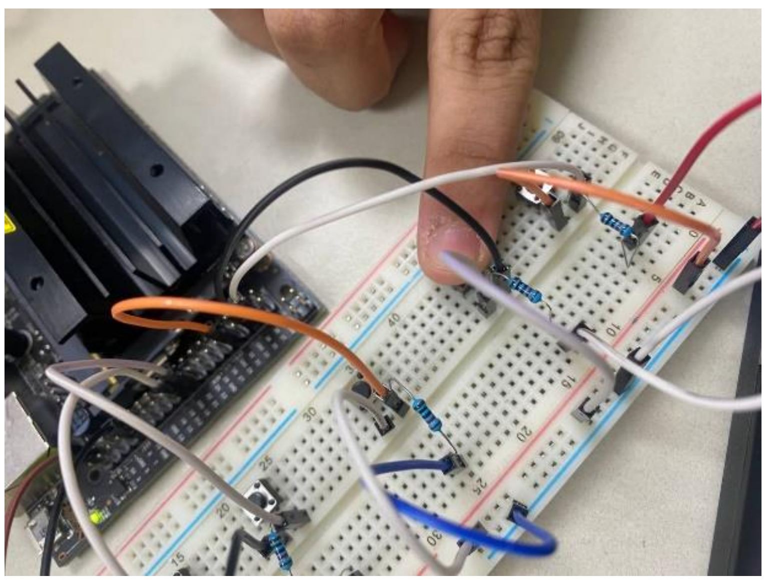


*Figure 9 : camera 4*

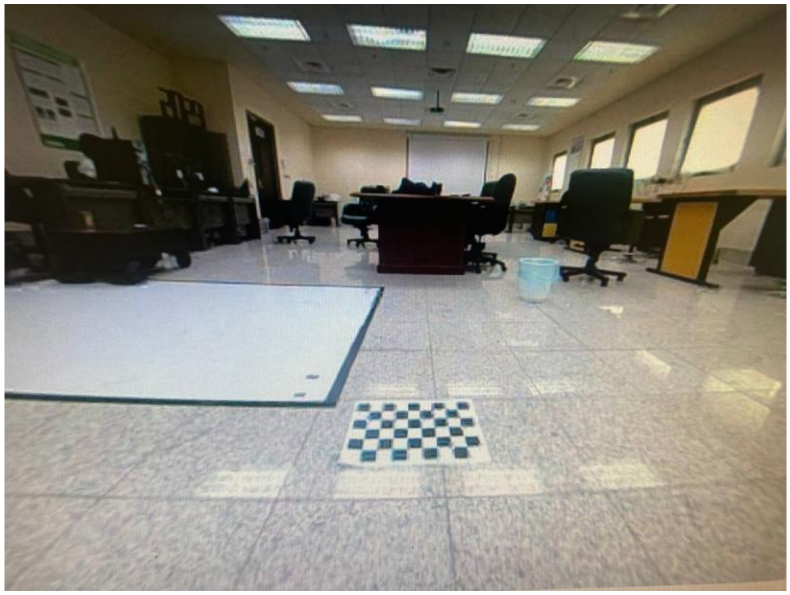


*Figure 10 :press Bird's Eye View*

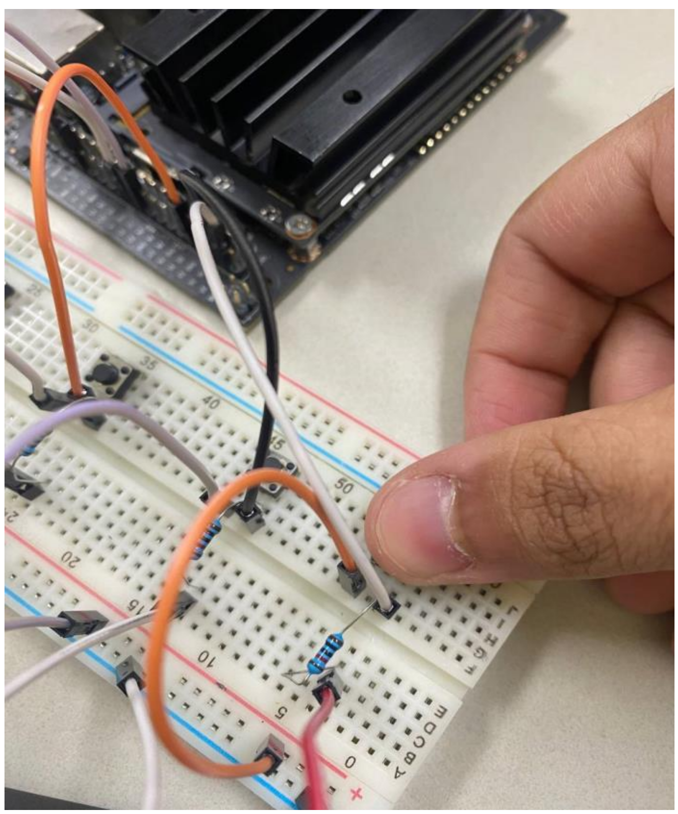
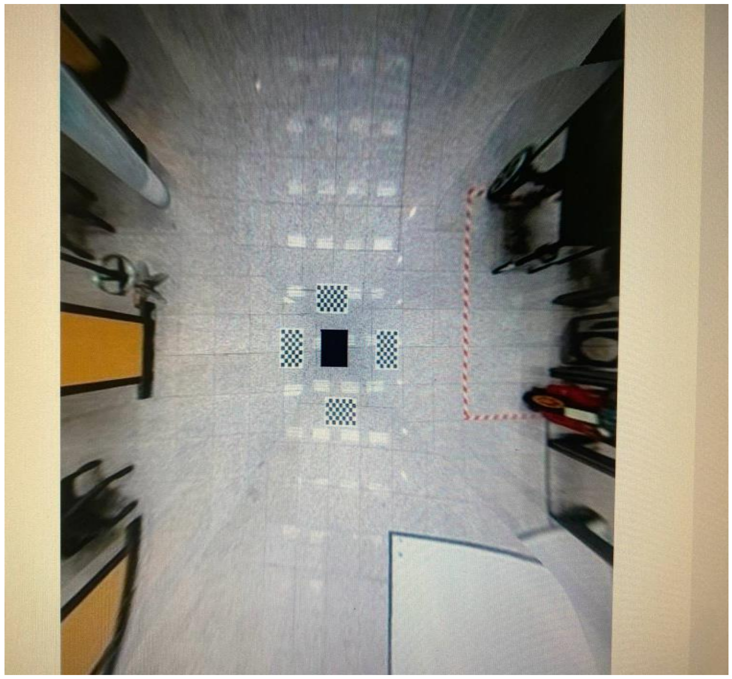


*Figure 11 : Bird's Eye View*



**6 Results:**

The testing shows the buttons work okay, but there's definitely room for improvement. Button 2 does the best; it works 70% of the time. But Button 5 only works 60% of the time, so that's not great. All the buttons are slower than they should be sometimes, too. Button 1 seems to be the slowest, with delays 20% of the time users press it.

So, what can we do to make the buttons faster and more reliable? First, we should check all the hardware and software connections to see if anything is hooked up wrong or slowing things down. Tweaking those could help speed up response times. Adding "debouncing" features in hardware or software could fix issues with multiple presses too. Regular maintenance, like cleaning the buttons, can prevent jams or stuck buttons as well. And it would be good to train people how to use the system properly that way, there's less confusion and wrong button pushes. Following those suggestions should make the environmental awareness system much more user-friendly. The buttons will work faster and more reliably, so people will get the right actions without long waits.

**7 Engineering Standards:**

In every engineering project, engineers must apply engineering standards. Our button design and function comply with many relevant engineering standards, particularly those related to the safety and usability of automotive interfaces. These standards ensure that pushbuttons meet basic standards for reliable operation within the vehicle environment. We used these criteria, and this is the experiment:

1. ISO 26262 standards: Push buttons must adhere to this standard for functional safety in automotive systems. Buttons are designed and implemented to mitigate potential risks and ensure safe user interactions[1].

2. ISO 9241: Human-Centered Design: Push button layout and labeling guidelines are consistent with this standard for human-centered design. This standard emphasizes ease of use for the user, ensuring that buttons are intuitive, easy to locate, and clearly labeled[2].

**8 Discussion and Conclusion:**

The pushbuttons are vital components of the project, offering drivers an easy-to-use interface. To ensure their effectiveness in controlling system functions, we conducted a thorough verification process. Our analysis of response times provided valuable quantitative insights into their performance for each button. During testing, any deviations or problems observed were carefully addressed, and recommendations for improvements were made accordingly. The successful verification of these pushbuttons is crucial for enhancing road safety and ensuring the overall success of the project.

**9 Refences:**

[1] ISO 26262-1:2011," ISO. [Online]. Available: https://www.iso.org/standard/43464.html

[2] ISO 9241-210:2010," ISO. [Online]. Available: https://www.iso.org/standard/52075.html

# **APPENDIX – B:** SELF ASSESSMENT CHECKLIST

Use student outcomes (SOs 1 - 7) rubrics to fill the following table. Each member needs to fill this table; it is important to enable the department to know to what degree the EE programs have been able to achieve the required KPIs of each SO. Please use the following grading letters:

**E:** Exemplary, **S:** Satisfactory, **D:** Developing, and **U:** Unsatisfactory.

| Student Outcome (SO) | Key Performance Index (KPI) | Self-assessment (E, S, D, or U) | | |
|---|---|---|---|---|
| | | **M1** | **M2** | **M3** |
| **1.** an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics | 1.1. Problem Identification | E | E | E |
| | 1.2. Problem formulation | S | S | S |
| | 1.3. Problem-solving | S | E | S |
| **2.** an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors | 2.1. Design Problem Definition | S | E | S |
| | 2.2. Design Strategy | E | S | S |
| | 2.3. Conceptual Design | E | E | E |
| **3.** an ability to communicate effectively with a range of audiences | 3.1. Effective Written Communication | E | E | E |
| | 3.2. Effective Oral Communication | E | E | S |
| **4.** an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts | 4.1. Recognition of Ethical and Professional Responsibility | S | S | S |
| | 4.2. Consideration of the Impact of Engineering Solutions | S | S | S |
| **5.** an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives | 5.1. Effective Team Interactions | S | S | S |
| | 5.2. Use of Project Management Techniques | S | E | S |
| **6.** an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions | 6.1. Developing Appropriate Experiment | S | S | E |
| | 6.2. Conducting Appropriate Experiment | E | S | E |
| | 6.3. Analysis and Interpretation of Experiment Data and Drawing Conclusions | S | S | S |
| **7.** an ability to acquire and apply new knowledge as needed, using appropriate learning strategies | 7.1. Effective Access to information | E | E | E |
| | 7.2. Ability to learn and apply new knowledge independently | S | S | S |