ENVIRONMENT PERCEPTION SYSTEM FOR SMART VEHICLES

By

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TEAM NO.: 01 WINTER-2022 INTAKE

Project Advisor

DR. MUHAMMAD BILAL

CHECKED AND APPROVED (ADVISOR):

Project Co-advisor: **DR. MOHAMMED SHAHZAD HANIF**

Project Customer: **DR. MUHAMMAD BILAL**

SDP Evaluator: ______________________________

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
FACULTY OF ENGINEERING
KING ABDULAZIZ UNIVERSITY
JEDDAH – SAUDI ARABIA

OCTOBER 2023 G – RABI II 1445 H

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EXECUTIVE SUMMARY

ENVIRONMENT PERCEPTION SYSTEM FOR SMART VEHICLES

Introduction to the Project

The journey embarked upon in the development of the advanced "Environment Perception System for Smart Vehicles" has been both challenging and rewarding. This innovative system, designed to revolutionize safety in automotive technology, integrates cutting-edge solutions in camera calibration, image undistortion, bird's-eye view transformation, object detection, distance detection, and user interface design. The project's primary goal was to enhance vehicular safety by providing drivers with unparalleled situational awareness through sophisticated visual and detection systems.

In-Scope Specifications:

The project was meticulously designed to meet specific in-scope specifications essential for the system's effectiveness and reliability. These specifications were as follows:

The system was engineered to provide a distortion-free visual feed with an expansive 81° vertical field-of-view. This feature was crucial in covering the vehicle's blind spots, a pivotal factor in preventing on-road incidents.

A significant aspect of the project was the ability to depict the respective distances of surrounding objects within a 23-meter radius, correlating to the braking distance at 70 km/h. The system maintained an accuracy threshold of at least 90%, ensuring reliable and actionable information for the driver.

For enhanced navigational aid, especially in constrained environments, the system provided a comprehensive bird's eye view for 3 meters around the vehicle. This feature was invaluable for drivers while parking in tight spots and executing parallel parking, significantly reducing the risk of collision.

To ensure a seamless and responsive user experience, visual updates were engineered to be robust, maintaining a rate of at least 10 frames per second. This specification guarantees a flicker-free, smooth, and comfortable view, critical for real-time decision-making while driving.

Out-of-Scope Specifications:

While the project was ambitious and comprehensive, certain elements were designated as out-of-scope, primarily due to resource, time constraints, or the project's current focus. These were:

The capability to record all visual feeds from the previous hour was considered beneficial for accidental insurance claims. However, this feature was outside the project's current scope, representing a potential avenue for future development.

While the system successfully identified various elements in the vehicle's surroundings, providing a segmented view with distinct identification (people, cars, pavements, roads) using an appropriate coloring scheme was beyond this project's focus. This feature's complexity and the necessity for advanced integration made it suitable for a subsequent developmental phase.

The integration of audio notifications within the system was acknowledged as a valuable adjunct, contributing to a multi-sensory alert mechanism. However, this aspect was not within the current developmental framework, earmarked for exploration in future iterations of the system.

Innovative Approach to Camera Calibration

Our initial phase involved the meticulous calibration of a fisheye stereo camera setup, crucial for accurate 3D scene parameter estimation. We navigated through practical challenges, learning from each trial and error. The calibration process evolved from using a standard checkerboard method to adopting a larger pattern and eventually understanding the need for diverse image sets for calibration. These iterative refinements were instrumental in achieving consistent and reliable calibration results, setting a solid foundation for subsequent processes.

Challenges in Image Undistortion

Image undistortion was a critical phase, given its importance in applications like Advanced Driver-Assistance Systems (ADAS). We transitioned from MATLAB to OpenCV for compatibility and efficiency, only to encounter issues with image stretching due to the fisheye effect. Our team initiated a recalibration strategy, incorporating images with varied checkerboard orientations and distances. This approach significantly improved the undistortion results, preserving realistic scene dimensions while maintaining a comprehensive field of view.

Achieving the Bird's-Eye View

The bird's-eye view feature was a sophisticated multi-step process designed to provide a seamless overhead view of the vehicle's surroundings. The system meticulously adjusted the feeds from multiple cameras, undergoing an Inverse Perspective Mapping (IPM) transformation. The final stage involved a delicate alpha blending technique, ensuring a smooth transition between the camera feeds. This feature underwent rigorous testing, from still photographs to continuous video streams, ensuring its reliability and precision in real-time scenarios.

Object Detection and Enhancements

In the object detection phase, we combined traditional image processing with advanced deep learning techniques. The system identified various environmental elements, crucial for enhancing road safety. We strategically focused on detecting the most significant object in the camera's field of view, considering the dynamic nature of driving environments. This streamlined approach enhanced operational speed and focused on predominant risks, facilitating prompt driver reactions.

Distance Detection Refinements

The accuracy of disparity maps and distance calculations was paramount in our stereo vision system. We encountered challenges with noisy disparity maps and understood the sensitivity of stereo vision systems to camera placement. Through rigorous testing and refinement, especially in the 'DisparityRange,' we achieved reliable disparity maps, which were crucial for accurate distance calculations.

User Interface Development

The user interface (UI) development was pivotal, serving as the interaction point between the driver and the system. We undertook multiple trials, from basic layout formation using the GTK library to enhancing interface responsiveness and real-time data display. The UI was rigorously refined to ensure it was intuitive, user-friendly, and capable of presenting complex data efficiently.

Adherence to Engineering Standards

Throughout the project, we adhered to relevant engineering standards, ensuring our system's compatibility, safety, and reliability. These standards, including ANSI/SAE J563, UNECE R151, SAE J2400, and IEC 60445, guided various aspects of our design and implementation. They influenced decisions on system specifications, user interface characteristics, and safety features, ensuring our product met rigorous industry requirements.

Systematic Validation and Testing

Post-development, the product underwent a systematic validation process. Each subsystem was individually tested before final assembly, followed by comprehensive testing of the complete system. We designed detailed validation procedures, collected data systematically, and used modern software tools for analysis. This approach helped identify any deviations, uncertainties, and potential sources of error, ensuring each component functioned optimally within the integrated system.

Data-Driven Results and Discussion

Our validation process was extensive, with results indicating high performance and reliability. We encountered challenges, such as system latency and data interpretation complexities, which were meticulously documented and addressed. The data, organized in various visual representations, highlighted the system's performance under different conditions, validating its readiness for real-world application.

Evaluation of Solutions

Reflecting on our final product, we evaluated its performance from multiple technical and global aspects. The system excelled in providing accurate, real-time environmental perception, a testament to the robust design and implementation strategies employed. However, we acknowledged the necessity for continual improvement, particularly in adapting to diverse environmental conditions and ensuring universal applicability.

Impact on Safety and Navigation

The system's impact extends beyond standard safety measures, offering implications for broader traffic ecosystems. By providing detailed environmental perception, it significantly contributes to reducing road incidents, easing traffic flow, and enhancing overall driving experiences. Its integration into smart vehicles marks a step forward in intelligent transportation systems, potentially influencing future urban planning and traffic management strategies.

Sustainability and Environmental Considerations

In addition to safety, the project was grounded in principles of sustainability. The system's design considered environmental impacts, utilizing energy-efficient processes and prioritizing durable, eco-friendly materials. These considerations reflect our commitment to responsible engineering, contributing to a sustainable future while advancing technological innovation.

Future Directions

While the project achieved its objectives, it unveiled new avenues for exploration. Future directions include integrating more advanced AI for predictive analytics, expanding the system’s capabilities for harsh weather conditions, and tailoring the technology for different vehicle models. Additionally, exploring real-time data sharing between vehicles and infrastructure could usher in a new era of smart transportation networks.

Conclusion

The journey of developing the "Environment Perception System for Smart Vehicles" was marked by innovation, persistence, and in-depth technical exploration. Each challenge encountered was a learning opportunity, shaping the project into a robust, reliable system poised to transform automotive safety. As we look to the future, the potential for further advancement is vast, promising a horizon where technology and safety

TEAM ACTIVITY PORTFOLIO CONTENTS

TEAM MEMBERS

Table 1: Team Information

M#	NAME	ID	Cellphone numbers	Email
#1	KHALID MAMDOOH NASSER ALDAHASY	1935129	0539168939	kaldahasy@stu.kau.edu.sa
#2	SAAD ALI SADAGAH AL JEHANI	1935151	0536274271	sjehani0005@stu.kau.edu.sa
#3	BANDER SAEED ALSULAMI	1935181	0565153917	balsulami0162@stu.kau.edu.sa

MEMBER #1:

Figure 1:KHALID MAMDOOH NASSER ALDAHASY

Passionate and enthusiastic college student. Interested in both programming and electrical engineering. Hard-working and an excellent problem solver. Offering strong communication and team working skills.

WORK EXPERIENCE:

Aug 2021 – Present – Bravo Me Platform, Edu-tech Senior Engineer Head of instructors' technical affairs and senior engineer of Edu-tech usage on the bravome.net website. Responsible for setting up technical platforms to host education videos and courses on the website.

MEMBER #2:

Figure 2:SAAD ALI SADAGAH AL JEHANI

A hard-working Electrical & Computer Engineering student at King Abdelaziz University, interested in Computer Vision, Embedded Systems, Linux Kernel Development, Device Drivers, and Hardware Security. Skilled in C development, using CMake and Make tools for development, and GDB for debugging. Also skilled in MATLAB and Python programming for computer vision applications.

WORK EXPERIENCE

ELECTRICAL AND COMPUTER ENGINEERING ASSISTANT COACH

King Abdul-Aziz & his companions foundation for giftedness & creativity - July 2022.

ELECTRONICS AND POWER INTERN

Smart Methods Est. - June 2021.

MEMBER #3:

Figure 3:BANDER SAEED ALSULAMI

A student studying in the final year of the Bachelor of Science in Computer Engineering program. He is willing to develop his skills and gain experience and new skills. Keen on learning and personal and professional growth.

Certificates and Projects

Nano degree certificate in web development in 2020.

Nano Degree Certificate in Android Application Development in 2020.

Airplane Boarding Simulator project in 2021.

PROJECT TASKS AND TIMETABLE

Utilizing the versatile project management framework provided by Notion, our team innovatively designed a comprehensive timetable in the form of a Gantt chart for our Advanced Driver-Assistance Systems (ADAS) senior design project. This digital transformation of our workflow started with the creation of an intricate template in Notion that allowed us to visualize the entire timeline of our project, mapping out key milestones, deadlines, and individual tasks spanning the project's life cycle. By leveraging Notion's user-friendly interface, we assigned tasks ensuring clear delegation and maintaining team accountability.

We integrated individual and collaborative task lists, and progress tracking components, which were critical in maintaining an organized and cohesive approach. This system fostered real-time updates, enabling team members to mark stages or tasks as completed, and providing everyone with instantaneous progress visualization. Through this dynamic and collaborative use of Notion, we could strategically distribute workloads, set realistic timeframes, and establish a unified, transparent system for monitoring our project's advancement, ensuring that our ADAS design project was methodically planned and executed from inception to completion.

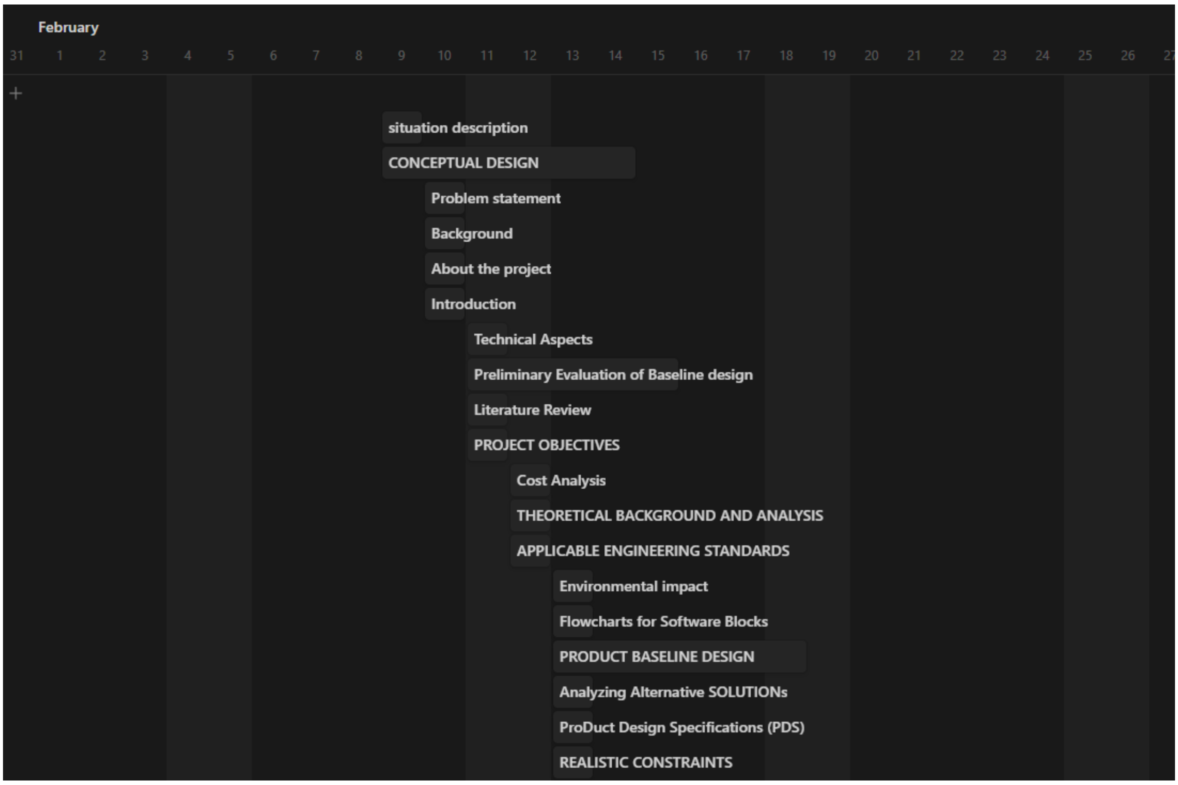


Figure 4 timetable for term 1

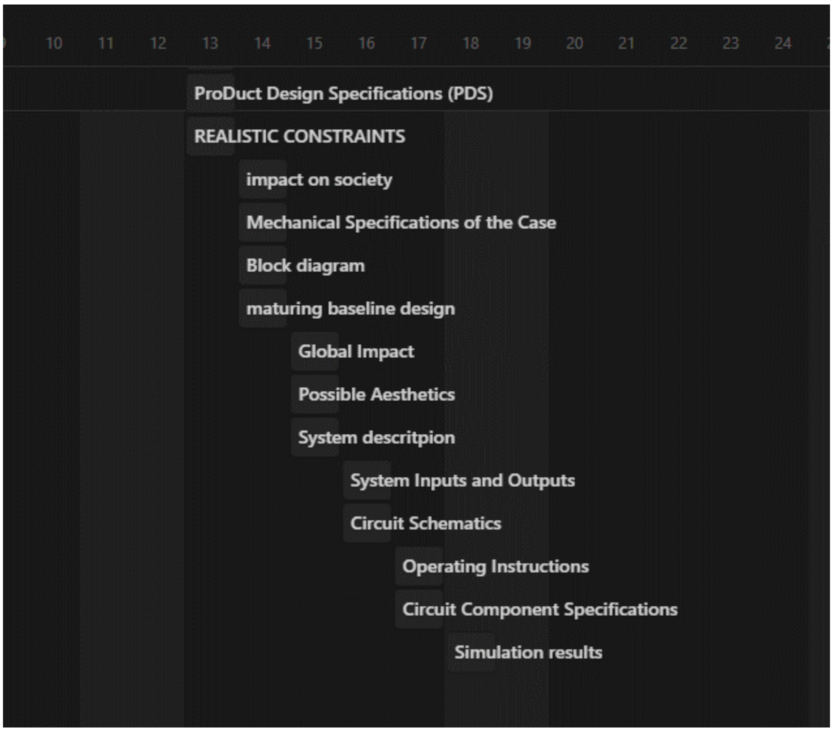


Figure 6 continuation of Term-1 timetable.

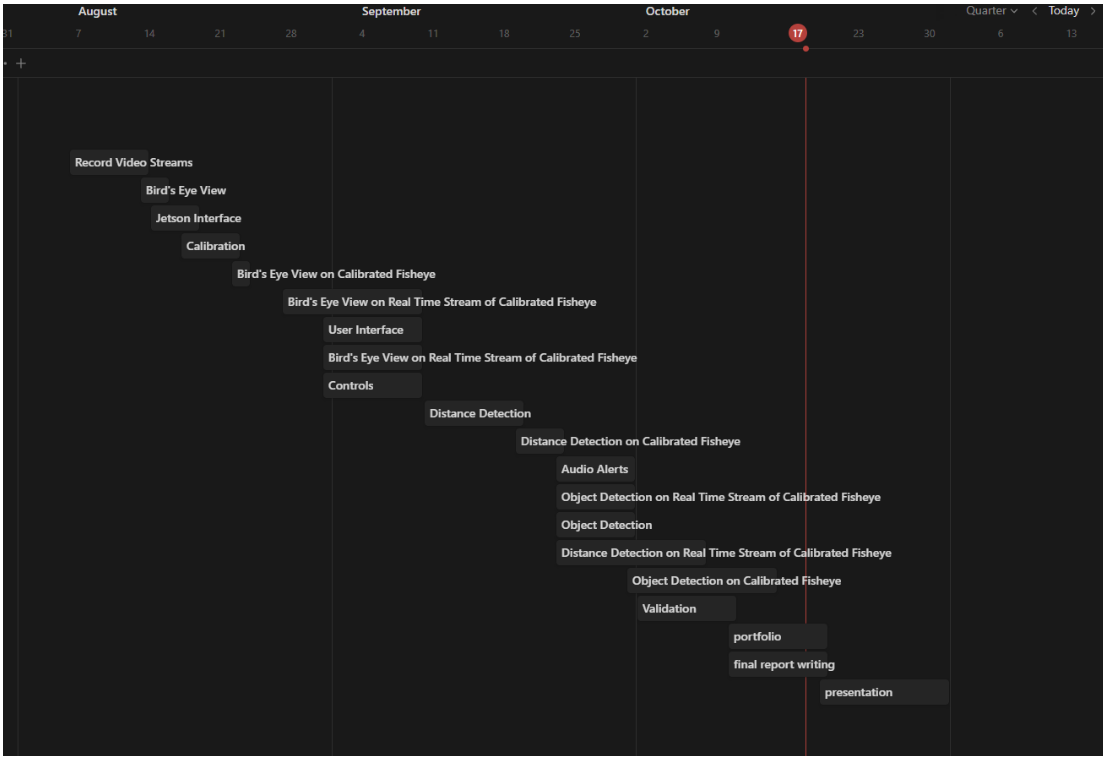


Figure 5 timetable of term 2

Table 2 Timetable of the project

TASK	*DATE*
CONCEPTUAL DESIGN	February 9, 2023 → February 14, 2023
situation description	February 9, 2023
Introduction	February 10, 2023
About the project	February 10, 2023
Background	February 10, 2023
Problem statement	February 10, 2023
PROJECT OBJECTIVES	February 11, 2023
Literature Review	February 11, 2023
Preliminary Evaluation of Baseline design	February 11, 2023 → February 15, 2023
Technical Aspects	February 11, 2023
APPLICABLE ENGINEERING STANDARDS	February 12, 2023
THEORETICAL BACKGROUND AND ANALYSIS	February 12, 2023
Cost Analysis	February 12, 2023
REALISTIC CONSTRAINTS	February 13, 2023
Product Design Specifications (PDS)	February 13, 2023
Analyzing Alternative SOLUTIONs	February 13, 2023
PRODUCT BASELINE DESIGN	February 13, 2023 → February 18, 2023
Flowcharts for Software Blocks	February 13, 2023
Environmental impact	February 13, 2023
maturing baseline design	February 14, 2023
Block diagram	February 14, 2023
Mechanical Specifications of the	February 14, 2023

Case	
impact on society	February 14, 2023
System description	February 15, 2023
Possible Aesthetics	February 15, 2023
Global Impact	February 15, 2023
Circuit Schematics	February 16, 2023
System Inputs and Outputs	February 16, 2023
Circuit Component	February 17, 2023
Specifications	February 17, 2023
Operating Instructions	February 18, 2023
Simulation results	August 6, 2023 → August 13, 2023
Record Video Streams	August 13, 2023 → August 15, 2023
Bird's Eye View	August 14, 2023 → August 18, 2023
Jetson Interface	August 17, 2023 → August 22, 2023
Calibration	August 22, 2023 → August 23, 2023
Bird's Eye View on Calibrated Fisheye	August 27, 2023 → September 9, 2023
Bird's Eye View on Real Time Stream of Calibrated Fisheye	August 31, 2023 → September 9, 2023
Controls	August 31, 2023 → September 9, 2023
Bird's Eye View on Real Time Stream of Calibrated Fisheye	August 31, 2023 → September 9, 2023
User Interface	September 10, 2023 → September 19, 2023
Distance Detection	September 19, 2023 → September 23, 2023
Distance Detection on Calibrated	September 23, 2023 → October 7, 2023

Fisheye	
Distance Detection on Real Time Stream of Calibrated Fisheye	September 23, 2023 → September 30, 2023
Object Detection	September 23, 2023 → September 30, 2023
Object Detection on Real Time Stream of Calibrated Fisheye	September 23, 2023 → September 30, 2023
Audio Alerts	September 30, 2023 → October 14, 2023
Object Detection on Calibrated Fisheye	October 1, 2023 → October 10, 2023
Validation	October 10, 2023 → October 19, 2023
final report writing	October 10, 2023 → October 19, 2023
portfolio	October 10, 2023 → October 19, 2023
Presentation	October 19, 2023 → October 31, 2023

TEAM ROLES AND CONTRIBUTIONS

The primary purpose of Team Rules is to create rules that the team strictly adheres to. Team rules must be created collectively, so there is no conflict between team members. We will mention the rules below.

Team Rules:

1. Mutual respect between team members.
2. Cooperation among team members and striving together to achieve common goals.
3. Attendance all meetings, inform the team in advance if you cannot attend.
4. Team members are open to suggestions and constructive criticism.
5. Willingness to learn from team members and share knowledge and experiences.

Table 3:Roles for the members

Member	Role
KHALID MAMDOOH NASSER ALDAHASY	Responsible for camera calibration and image undistortion and distance detection.
SAAD ALI SADAGAH AL JEHANI	Responsible for extrinsic parameters calculation, the bird's eye view processing, and object detection.
BANDER SAEED ALSULAMI	Responsible for the user interface and hardware implementation.

CURRICULAR RESOURCES

We learned a lot from the courses we took in college, including important ones that will help us implement the project. We will identify some courses that will help us in the SDP Program through the knowledge gained from these courses.

Table 4 Curricular Resources

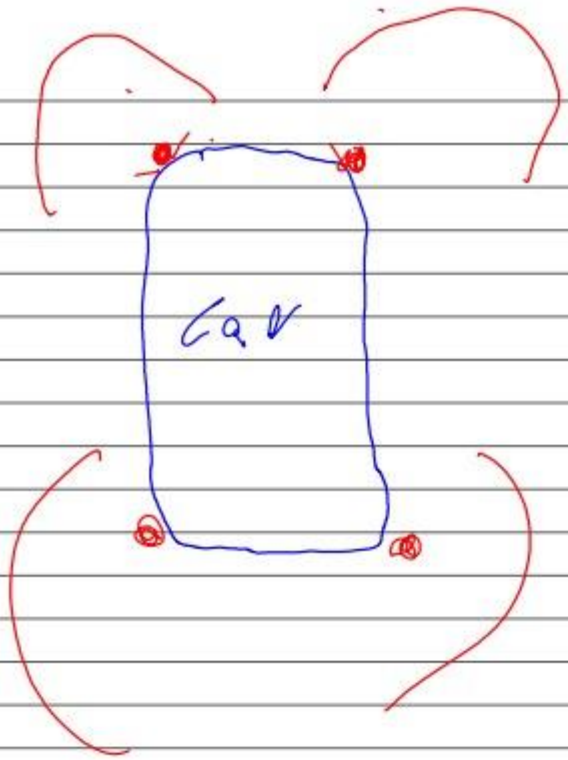
Tasks	courses
Image processing	EE490
MATLAB Programming	EE201
Numerical analysis	EE332
Embedded Systems	EE366
Operating System, Linux, Multithreading	EE463
Networking and protocols	EE462

DESIGN NOTES AND DRAFTS

Choosing alternatives

Table 1 Morphological chart of the project. all 3

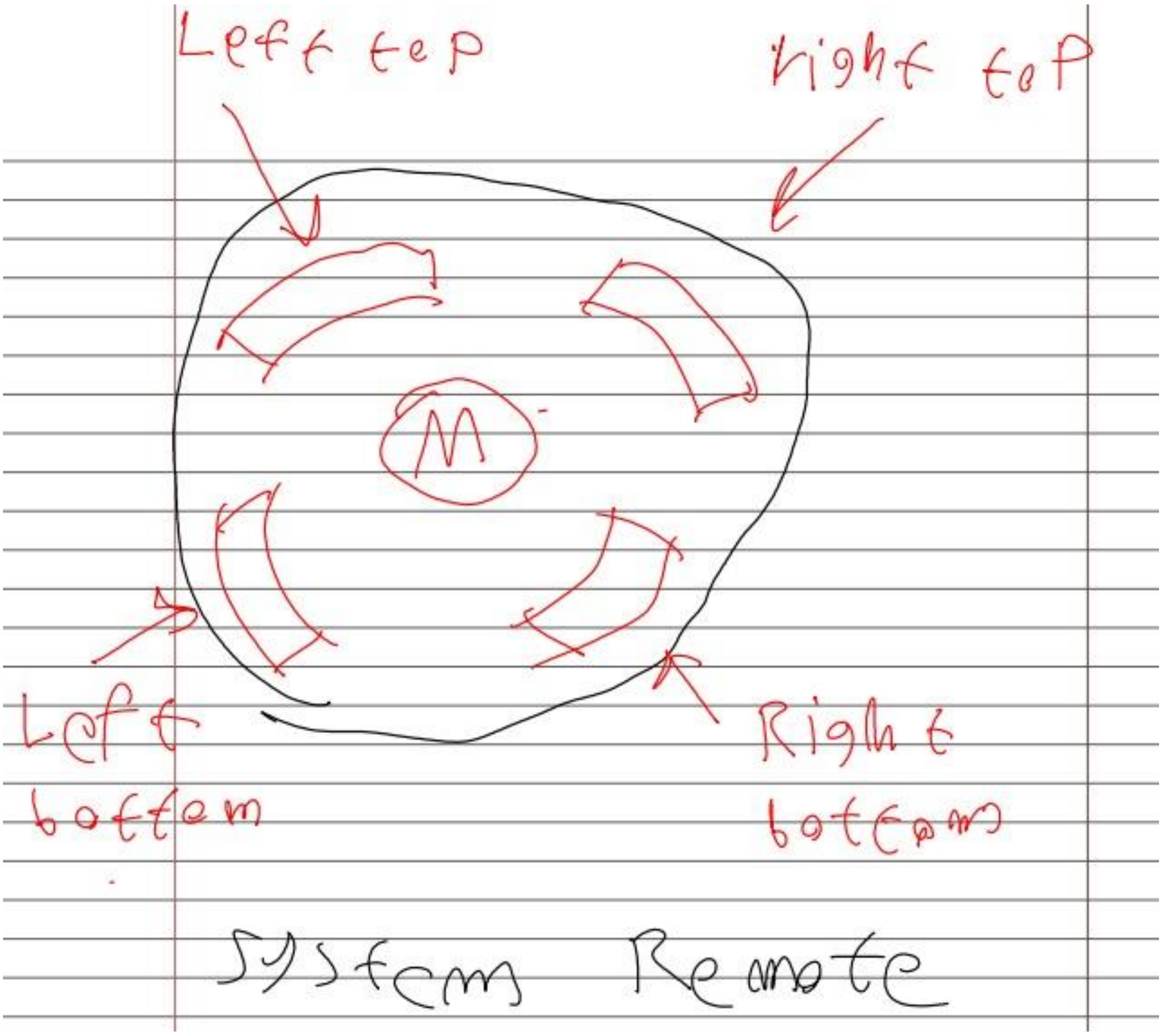
Functions	Options			
Provide a visual feed covering the blind spots.	Few fisheye (wide angle) cameras	Multiple narrow angle cameras	$\theta \geq 90^\circ$	
Detect distances of near objects.	Lidar	Radar	Stereo Camera	Ultra-sonic weak
Provide bird-eye view.	Inverse Perspective Mapping(IPM)	Pseudo-LIDAR	3D Dual-Fusions	
Processes input data to depict useful information.	FPGA Ai	Jetson	Raspberry pi GPU	
Display information.	Screen.	Connect to phone app.		
Store visual recording.	SD memory	Cloud memory	Connect to phone	
Object detection.	~~DIsp R-CNN~~	MMLAB LIGA-Stereo	Pseudo-LIDAR	3D Dual-Fusions
Provide information as audio.	Speaker.	Buzzer.	Connecting to phone app.	
Bus communication.	CAN	USB	Wi-fi.	Bluetooth.
Material for mounting sensors.	Drill hole on exterior of the car.	Magnetic mount.	Suction mount.	Bracket.

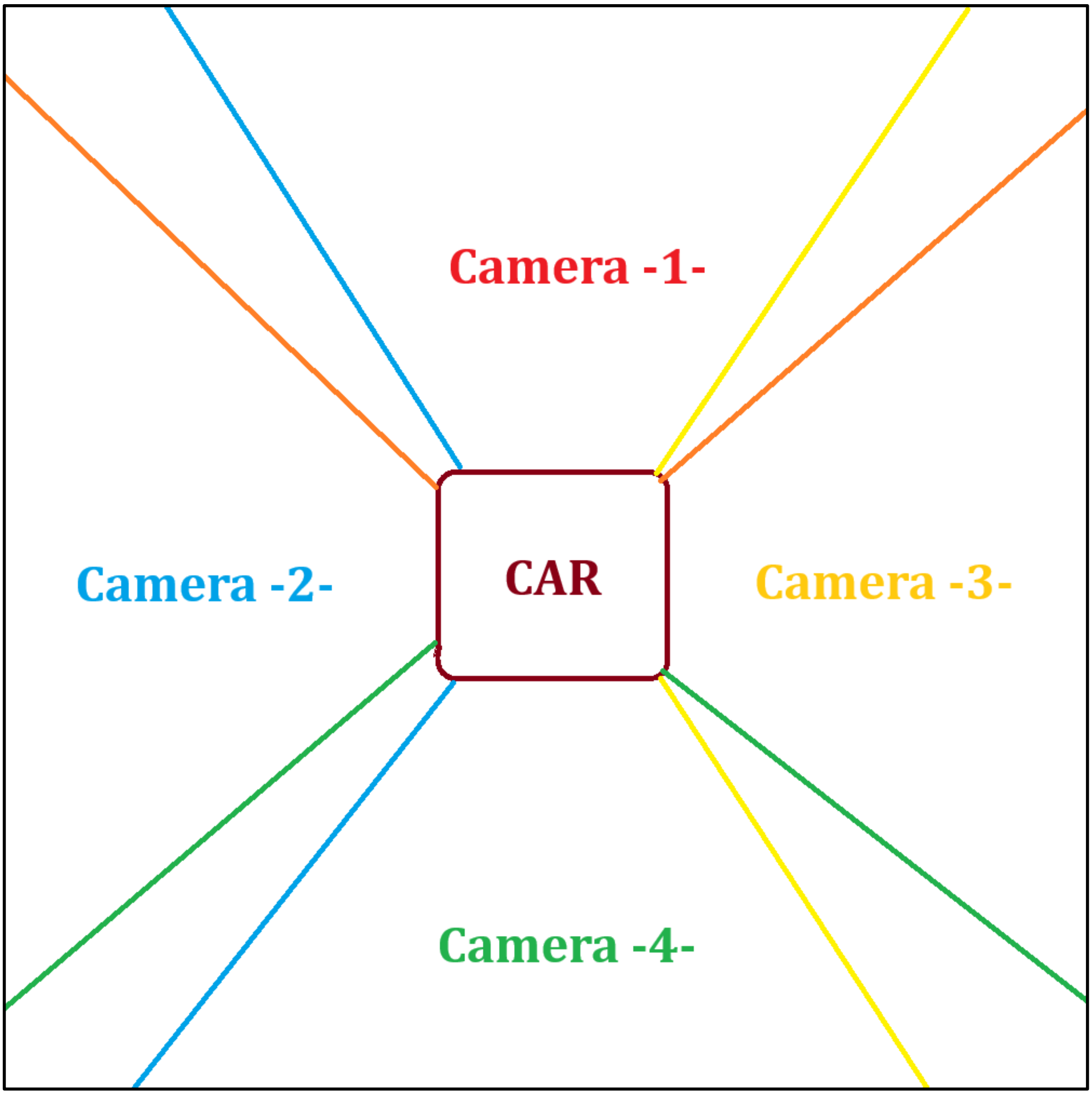


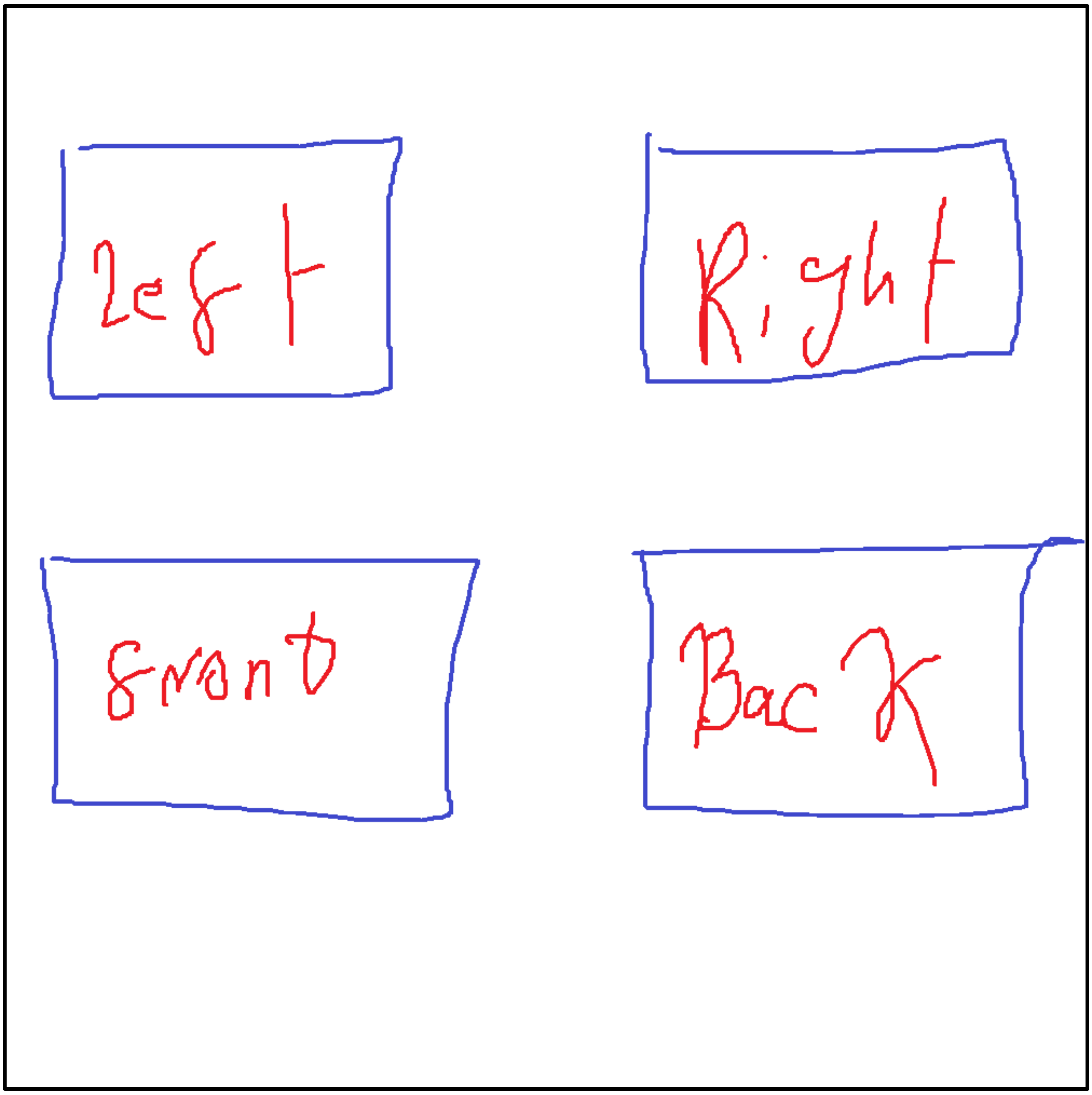
if 90°

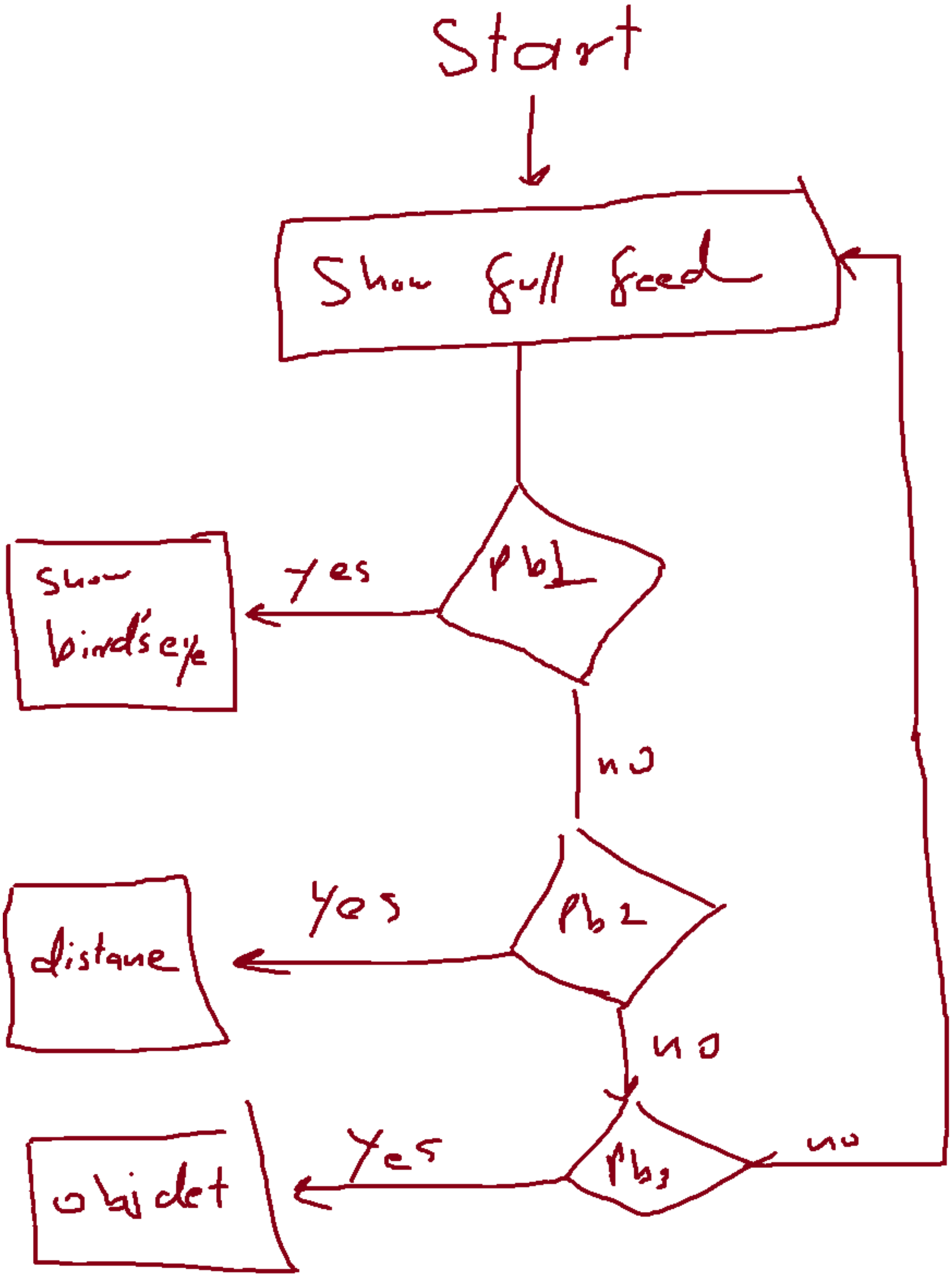
it can cover

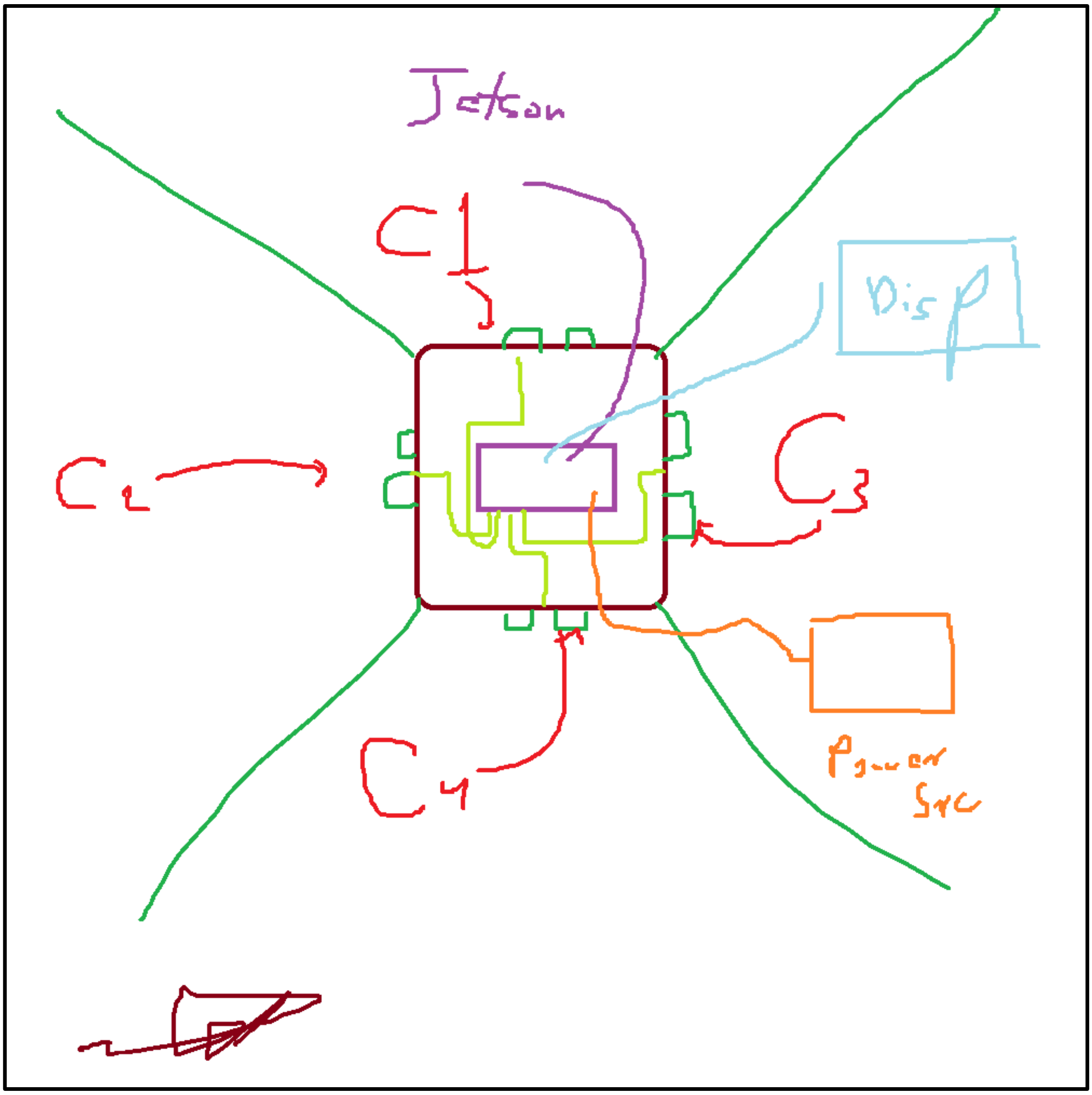
most of 360°


Left top
right top
M
Left bottom
Right bottom
System Remote


Camera -1-
Camera -2-
CAR
Camera -3-
Camera -4-


Left
Right
Front
Back


Start
Show full feed
pb1
yes
Show bird's eye
no
pb2
yes
distance
no
pb3
yes
objdet
no


Jetson
C1
C2
C3
C4
Disp
Power
Src

ETHICAL ISSUES

Integrating a code of ethics into the development of technological products, especially those that significantly impact safety and privacy like Advanced Driver-Assistance Systems (ADAS), is crucial. It ensures that the product not only meets regulatory standards but also aligns with moral guidelines safeguarding users' interests. In this context, we'll refer to the IEEE Code of Ethics, given the IEEE's authority in setting standards for technological advancements.

Incorporation of IEEE Code of Ethics

The Institute of Electrical and Electronics Engineers (IEEE) is a leading authority in setting standards for various technological fields. Their Code of Ethics outlines essential principles designed to guide professionals in responsible decision-making and conduct, particularly when creating technologies that could have profound societal impacts.

Key principles from the IEEE Code of Ethics that are especially pertinent to our ADAS project include:

1. Safety and Well-being: Prioritizing the safety, health, and welfare of the public in professional tasks and decisions.
2. Avoiding Conflicts of Interest: Rejecting any situation where a compromise on professional judgment or conflict of interest may occur.
3. Honest and Realistic Product Representation: Being honest in stating claims or estimates based on available data, avoiding any false or deceptive statements.

   *Improving Understanding of Technology: Working to improve the understanding of technology, its appropriate application, and potential consequences.

Ethical Dimension Analysis: User Privacy and Data Security

One of the prominent ethical dimensions related to our ADAS project is user privacy and data security. As our system processes and stores significant amounts of data, including visual feeds of the vehicle's surroundings, it potentially could be exploited for unauthorized surveillance or data breaches.

Analyzing this issue through the lens of the IEEE Code of Ethics involves several considerations:

1. Safety and Well-being: While the ADAS enhances physical safety, psychological comfort is equally crucial. Users must feel confident that their privacy is not being compromised. Any data collected or processed should strictly serve the system's safety functions, without exposing personal information to potential misuse.
2. Avoiding Conflicts of Interest: Transparency with stakeholders is key. If any third-party partnerships (e.g., software providers or data analysts) are necessary, we must ensure these entities share our ethical commitments and that collaborations don't compromise user data privacy.
3. Honest and Realistic Product Representation: We must be upfront about the system's data requirements, storage, and processing. This honesty extends to being clear about how the ADAS functions, what data it uses, and how that data is protected. Misrepresenting these aspects for market appeal would violate this ethical principle.
4. Improving Understanding of Technology: This principle involves two responsibilities. First, educating users on the technology, ensuring they understand what data is collected and why. Second, continuously researching to enhance data security measures, thereby safeguarding user privacy as technology advances.

Informed Decision

Considering the above ethical analysis, our informed decision is to implement stringent data encryption standards to protect stored and transmitted data. We will limit data access to essential personnel and use secure communication channels. Regarding data that doesn't contribute to the ADAS functionality, such as personal details, we opt for non-collection, thereby eliminating unnecessary privacy risks.

Furthermore, we commit to maintaining transparency with users, providing comprehensive privacy policies, and enabling user-controlled privacy settings, allowing them to decide on data sharing extents. Regular audits and updates will be scheduled to ensure that data security measures are up to date with emerging threats.

By adhering to these ethical guidelines, we uphold our commitment to user safety, both in physical and privacy terms, and align our project with the respected standards set forth by IEEE. This ethical grounding not only enhances our product's societal value but also ensures a basis of trust and integrity between us, the users, and our stakeholders.

MEETING MINUTES

MEETING MINUTES 1:

Date:	2022-12-28
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

This is the first meeting with the customer, our main objective is to understand the project and what the customer ask is.

Then we would be able to write a first version of the project charter.
Also see the lab we will work in with the advisor.

Discussion Points:

- Understand details about the project and the problem definition and the low-level objectives.
- Get an initial list of musts and wants and the constraints set by the customer.
- What are ADAS systems?

Follow-up of the Last Meeting:

Non. This is the first meeting.

Decisions Taken:

- Research ADAS systems. - Ready the lab for future work. - Write the project charter with the information we got from this meeting.

Actions to do before next meeting:

- Do the initial submission of the project charter. - Prepare any more questions about ADAS systems. - Prepare a presentation of the project charter.

MEETING MINUTES 2:

Date:	2023-01-11
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the comments we wrote down after the presentation of the project charter.

Discussion Points:

- Discuss the major criticisms we got which was:

1- specifications are not specific enough and should have background info

2- engineering standards

3- fps and field of view

4- sensors Discuss our next step in the project charter finalization and the lab work.

Follow-up of the Last Meeting:

- Updates on the lab work (preparing computers for the project work and testing environment).
- Discuss our questions that we had after the end of the first meeting that are about further details about ADAS and ADAS's sensors.

Decisions Taken:

- We define the standard for each Specification and get more Specifications from standards.
- Research more on ADAS and the Appropriate fps and field view for cameras that will be used in ADAS.
- Research more on ADS for Appropriate sensors are used nowadays.

Actions to do before next meeting:

- Update the project Charter and wait for the evaluator's comments to come and discuss them at thenext meeting.
- Using the lab to make a small demonstration for the project.

MEETING MINUTE 3:

Date:	2023-01-18
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature :	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature :	
Member 3:	BANDER SAEED ALSULAMI	Signature :	
Advisor:	Dr. Muhammad Bilal	Signature :	
Customer:	Dr. Muhammad Bilal	Signature :	

Agenda:

Discuss the comments received from the committee regarding the project charter.

Discussion Points:

- Revised the specifications of our project.
- Discussed the performance and safety standards that are applied to our project.
- Changed some of the musts & wants.
- Changed some of the assumptions.
- Discussed the Field of view required for the project and the fps of the screen.

Follow-up of the Last Meeting:

- Revised the project charter

Decisions Taken:

- We settled on the new specifications. - We settled on the standards applied in the project.

Actions to do before next meeting:

- See the recorded concept session #3 and read all the material with it. - read about other projects or products like ours.

MEETING MINUTE 4:

Date:	2023-01-25
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature :	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature :	
Member 3:	BANDER SAEED ALSULAMI	Signature :	
Advisor:	Dr. Muhammad Bilal	Signature :	
Customer:	Dr. Muhammad Bilal	Signature :	

Agenda:

Discuss the generation of alternative designs and the different components we could use.

Discussion Points:

- What are the different sensors that could be used.
- Could actuators and their power electronic circuits be used in our project?
- Could microelectronic receiving circuits be used in our projects?
- Different types of controllers that could be implemented in the project.

Follow-up of the Last Meeting:

- Finalized the charter and the specifications.
- Read the final report template and the concept session #3 material.
- Searched and found similar projects and scientific research.

Decisions Taken:

- We settled on how actuators can be used in our project.
- We settled on how microelectronic receiving circuits can be used in our project.
- We settled on how receiving circuits can be used in our project.
- More comprehensive literature review on the projects and the scientific research we foundshould be done to learn about the many sensors and controllers that could be used in our project.

Actions to do before next meeting:

- Do more literature review on the projects and the scientific research we found.
- Use the morphological chart on our finalized specification (musts , wants , constraints) togenerate designs.

MEETING MINUTE 5:

Date:	2023-02-02
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature :	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature :	
Member 3:	BANDER SAEED ALSULAMI	Signature :	
Advisor:	Dr. Muhammad Bilal	Signature :	
Customer:	Dr. Muhammad Bilal	Signature :	

Agenda:

Discuss the progress made for the literature review, and the generated morphological chart.

Discussion Points:

- Discussed the functions we listed in the morphological chart, and if it should be broad or not.
- Discussed the options for all functions in the morphological chart.
- Discussed the projects written in the literature review.
- Discussed the level of details for the literature review.
- Discussed the procedure used for choosing the alternative designs based on the morphological chart.

Follow-up of the Last Meeting:

- The literature review is practically finished.
- Made a morphological chart based on the literature review.

Decisions Taken:

- Change the options for the Bird's eye view and the object detection's functions into algorithms instead of sensors.
- Generate alternative designs using K-T analysis method.

Actions to do before next meeting:

- Finalize the morphological chart.
- Do K-T analysis to generate the alternative designs.

MEETING MINUTE 6:

Date:	2023-09-02
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the alternatives and decision analysis using K-T and other methods.

Discussion Points:

- Discussed the three alternative designs we choose in morphological chart.
- Discussed k-t decision analysis we had done to the alternative designs.
- Using other methods to choose a baseline design.

Follow-up of the Last Meeting:

- Finished the morphological chart by adding Bird eye view's algorithms and the object detection'salgorithms.
- Done the k-t decision analysis on the alternative designs.

Decisions Taken:

- Use Pugh method to Chooses the baseline design:
- Generate criteria list relevant to our project.
- Research on how the alternative meet the criteria.

Actions to do before next meeting:

- Finish the Pugh matrix.
- Choose the baseline design.
- Research about the baseline design to mature it.

MEETING MINUTE 7:

Date:	2023-22-02
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss Block Diagram and Baseline Design.

Discussion Points:

- Discussed The Block Diagram.
- Discussed The Baseline Design.

Follow-up of the Last Meeting:

- Finish the Pugh matrix.
- Choose the baseline design.

Decisions Taken:

- choosing a camera with FOV greater than 90 degrees to cover the 360-degree of the car.
- using buttons for user input.

Actions to do before next meeting:

- Finish the Flowchart.
- Finish the File.

MEETING MINUTE 8:

Date:	2023-23-02
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the Flowchart and review of the file.

Discussion Points:

- Discussed the Flowchart.
- Review of the file.

Follow-up of the Last Meeting:

- Finish the Flowchart.
- Finish the File.

Decisions Taken:

- Changing the detection meter to 23 to abide by braking distance calculation with 70 km/h speed and 1.5 reaction time according to studies.

Actions to do before next meeting:

- Submitted the file.
- Prepare for presentation.

MEETING MINUTE 9:

Date:	2023-02-24
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature :	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature :	
Member 3:	BANDER SAEED ALSULAMI	Signature :	
Advisor:	Dr. Muhammad Bilal	Signature :	
Customer:	Dr. Muhammad Bilal	Signature :	

Agenda:

Discussed how the vehicles would move and their effect on the system.

Discussion Points:

- Vehicle speed
- Braking time

Follow-up of the Last Meeting:

- The files are submitted.

Decisions Taken:

- Research how to reduce the affect of car movement on the system.

Actions to do before next meeting:

- Continue researching.

MEETING MINUTE 10:

Date:	2023-02-28
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature :	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature :	
Member 3:	BANDER SAEED ALSULAMI	Signature :	
Advisor:	Dr. Muhammad Bilal	Signature :	
Customer:	Dr. Muhammad Bilal	Signature :	

Agenda:

Discussed the math and physics in the algorithms.

Discussion Points:

- Image perspective mapping
- Camera calibration
- Stereo depth estimation

Follow-up of the Last Meeting:

- Researched about the math in these topics.

Decisions Taken:

- Will add the math to the report.

Actions to do before next meeting:

- Start working on the presentation.

MEETING MINUTE 11:

Date:	2023-03-01
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discussed the final term 1 presentation.

Discussion Points:

- Reviewing the presentation.

Follow-up of the Last Meeting:

- The presentation is getting finalized.

Decisions Taken:

- Modify the problem definition.

Actions to do before next meeting:

- Get ready for the presentation.

MEETING MINUTE 12:

Date:	2023-03-05
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discussed all requirements to start working on the prototype.

Discussion Points:

- Buying the cameras
- Setting up the jetson Nano
- Setting up the computer

Follow-up of the Last Meeting:

- The presentation was done, and the term-1 report was submitted.

Decisions Taken:

- Bought the cameras from Ali Express
- Started setting up the computer.

Actions to do before next meeting:

- Wait for the cameras to arrive and start working on them.

MEETING MINUTE 13:

Date:	2023-03-31
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discussing the cameras.

Discussion Points:

- Testing the cameras and do they fulfill our requirements.
- Getting ready for calibration.

Follow-up of the Last Meeting:

- The cameras have arrived.

Decisions Taken:

- Start working on the calibration and other algorithms.

Actions to do before next meeting:

- Start implementing the algorithms.

MEETING MINUTE 14:

Date:	2023-09-04
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature :	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature :	
Member 3:	BANDER SAEED ALSULAMI	Signature :	
Advisor:	Dr. Muhammad Bilal	Signature :	
Customer:	Dr. Muhammad Bilal	Signature :	

Agenda:

Discuss the progress after summer break.

Discussion Points:

- Show the progress done during summer.
- The steps of implementations of each task

Follow-up of the Last Meeting:

- The cameras have arrived and testing on them has started.

Decisions Taken:

- The code will be written in MATLAB and then deployed to the jetson Nano.

Actions to do before next meeting:

- Show some progress on the calibration and bird’s eye view and user interface.

MEETING MINUTE 15:

Date:	2023-09-11
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the progress made

Discussion Points:

- Birds eye view status
- Images calibration status
- Button and user interface status

Follow-up of the Last Meeting:

- The Birds eye view is working.
- The calibration works but is a bit distorted.
- Using a router on a private network to deploy the code using SSH.

Decisions Taken:

- Continue on this implementation.

Actions to do before next meeting:

- Make the programs more efficient.

MEETING MINUTE 16:

Date:	2023-09-18
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the progress.

Discussion Points:

- Discussing the difficulties faced with deploying the MATLAB code to the Jetson Nano.

Follow-up of the Last Meeting:

- The Bird’s eye is more efficient.
- The deployment is difficult to do.

Decisions Taken:

- Find different methods for deploying.

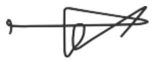
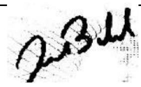
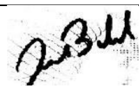
Actions to do before next meeting:

- Find different methods for deploying.

MEETING MINUTE 17:

Date:	2023-09-27
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the progress that is done.

Discussion Points:

- Discuss the placement of the cameras for the bird' eye.
- Discuss the camera calibration using OpenCV.

Follow-up of the Last Meeting:

- Deployment is made using SSH, but the code must be changed to be able to convert into CUDA.

Decisions Taken:

- Modify the code accordingly.

Actions to do before next meeting:

- Do the necessary modifications on the MATLAB code to be compatible for CUDA.

MEETING MINUTE 18:

Date:	2023-09-28
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discussed the validation.

Discussion Points:

- Discussed the validation experiment. - Numerical analysis methods

Follow-up of the Last Meeting:

- The modifications have started.

Decisions Taken:

- Change the numerical analysis method.

Actions to do before next meeting:

- Finish the validation and continue working on the project.

MEETING MINUTE 19:

Date:	2023-10-03
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the current progress of the project.

Discussion Points:

- The current status of the project.

Follow-up of the Last Meeting:

- The code still needs to be converted to be suitable on Jetson Nano.

Decisions Taken:

- Find ways to deploy MATLAB code on Jetson Nano.

Actions to do before next meeting:

- Make sure the bird’s eye and distance detection and camera feed and object detection and UI and all parts PDS work.

MEETING MINUTE 20:

Date:	2023-10-18
Team:	01
Project Title:	Environment Perception System for Smart Vehicles

Attendees:

Member 1:	KHALID MAMDOOH NASSER ALDAHASY	Signature:	
Member 2:	SAAD ALI SADAGAH AL JEHANI	Signature:	
Member 3:	BANDER SAEED ALSULAMI	Signature:	
Advisor:	Dr. Muhammad Bilal	Signature:	
Customer:	Dr. Muhammad Bilal	Signature:	

Agenda:

Discuss the final report.

Discussion Points:

- Discuss the document.
- Does it fulfill all the things in the evaluation sheet.
- Does the project fulfill all PDS requirements.

Follow-up of the Last Meeting:

- Tested all parts of the project on the development machines.

Decisions Taken:

- The project works as intended.

Actions to do before next meeting:

- N/A

KING ABDULAZIZ UNIVERSITY

THE COLLEGE OF ENGINEERING

Senior Design Project

EE499 – Winter 2023

Team 01 – Project Charter

Member	Name	ID
1	KHALID MAMDOOH NASSER ALDAHASY	1935129
2	SAAD ALI SADAGAH AL JEHANI	1935151
3	BANDER SAEED ALSULAMI	1935181

Submitted to: Dr. Muhammad Bilal

Thursday, January 19, 2023

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General Project Information	
Project Name	**Environment Perception System for Smart Vehicles**
Executive Sponsors	King Abdulaziz University, Department of Electrical and Computer Engineering
Project Timeline	December 2022 – November 2023

Project Stakeholders			
Role	Name	Department	Email
Project Sponsor	King Abdulaziz University	Electrical and Computer Engineering	ece@kau.edu.sa
Project Advisor and Customer Representative	Dr. Muhammad Bilal	Electrical and Computer Engineering	meftekar@kau.edu.sa
Project Co-Advisor	Dr. Mohammed Shahzad Hanif	Electrical and Computer Engineering	mshanif@kau.edu.sa
Team Members	Khalid Al-Dahasy	ECE, CoE	kaldahasy@stu.kau.edu.sa
	Saad Al-Jehani	ECE, CoE	sjehani0005@stu.kau.edu.sa
	Bandar Al-Sulami	ECE, CoE	balsulami0162@stu.kau.edu.sa

Executive Summary

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 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. [1]

The customer asks for a more conventional method to view the perspective of all the blind spots of a car and provides helpful information to the driver.

The increase in Saudi Arabia 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 [2]. 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.

Our project's objective is to make an Advanced Driver Assistance System (ADAS). That will provide more helpful information to the driver than the information received through the back and side mirrors. This system aims to make for a safer driving experience and display a more enhanced perspective than what the rear and side mirrors provide. By contributing to making an ADAS project, we also contribute to kickstarting the indigenous development of ADAS technology in KSA for the upcoming age of smart cars.

Project Purpose
Project Need / Justification
Some accidents happen due to drivers being unable to see from certain blind spots in the car. That can happen either on the road or during parking. That could endanger people and the driver. To see the perspective from the car's blind spot, the driver depends on the rear and side mirrors. Furthermore, during parallel and reverse parking, the driver also depends on the mirrors to see. Rear and side mirrors do not reflect the view, so accidents or parking difficulties still happen. Our project aims to provide a better solution than the classic mirrors installed on all cars. In which the project provides a clear and accurate view that displays all possible blind spots with information on the distances of objects near the car. All the while providing helpful information in different parking scenarios. That would be provided in a simple, straightforward, and comfortable experience. In achieving this, the project would also help reduce accidents, make the driver experience more comfortable and less stressful, and put light on ADAS projects and their uses to inspire more development work in Saudi Arabia in this field.
Objectives
Lower-level Objectives: 1. Provide the driver with a detailed distortion-free view of the vehicle surrounding 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 (Strategic) 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.

Project Description

The environment perception system is an ADAS system that provides several perspectives and information to the driver that would help avoid collisions and parking safely.

This includes a distortion-free visual feed with at least 81° field-of-view, covering the vehicle's blind spots, and a bird's eye view around the vehicle to assist while parking in tight spots and parallel parking. All the while providing this in a user-friendly interface and display. Additional services would be to display relative object detection information and the ability to record the events of an accident if it occurs, this is to be used for police reports and insurance company claims.

The prototype that will be presented by the end of this course would have to work on the available 12V power supply.

To develop this prototype, we assume that all the materials would be available within budgetary (6000 SAR) and time limits and that the testing would be concluded without the need to test the prototype on all types of cars nor the need to test it under harsh environmental conditions that would hinder the functionality of the sensors.

Project Scope	
Musts	Wants
Provide a distortion-free visual feed with at least 81° field-of-view, covering the vehicle's blind spots.	Record all visual feeds from the previous hour, to assist in accidental insurance claims
Provide a user-friendly visual to depict the respective distances of surrounding objects within a 15 meters radius with an accuracy of at least 90%	Provided a segmented view with people, cars, pavements, and roads using an appropriate coloring scheme.
Provide a bird's eye view for 3 meters around the vehicle to assist while parking in tight spots and parallel parking.	Provide audio notifications.
Visual updates should be at least at 10 fps for a flicker-free, smooth, and comfortable view.	
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.	
Constraints	
1. The budget does not exceed 6000 SAR. 2. The system operates on 12V DC.	

Project Deliverables

The project will be implemented as shown below. In the figure, there are primary and sub-tasks and their estimated dates.

Project Deliverables

Milestone / Deliverable	Estimated Date	Responsible individual
1. Project Initiation	25th Dec. – 3rd Feb.	Khaled, Saad, Bandar
1.1. Project Charter	Jan 19th	Khaled, Saad, Bandar
1.2. Business Model	Feb 3rd	Khaled, Saad
2. Planning	Jan 20th – Feb 23rd	Khaled, Saad, Bandar
2.1. Conceptual Design	Jan 27th	Bandar
2.2. Product Baseline Design	Feb 3rd	Khaled
2.3. Preliminary Evaluation of Baseline Design	Feb 17th	Saad
3. Execution	Mar 12th – Oct 1st	Khaled, Saad
3.1. The initial phase of designing the project	June 24th	Khaled, Saad
3.2. The final phase of designing the Prototype	Oct 1st	Khaled, Saad
4. Monitoring and controlling	Mar 12th – Oct 1st	Bandar

4.1. Track Effort and Cost	Mar 12th – Oct 1st	Bandar
4.2. Monitor Project Progress	Mar 12th – Oct 1st	Bandar
4.3. Ensure Adherence to plan	Mar 12th – Oct 1st	Bandar
5. closure	Oct 1st – Nov 31st	Khaled, Saad, Bandar
5.1. Submitting the Final Project	Oct 1st – Nov 31st	Khaled, Saad, Bandar
5.2. Submitting the Final Report	Oct 1st – Nov 31st	Khaled, Saad, Bandar

Major Known Risks	
Risk	**Remedy**
Equipment falling off.	Notify the driver in this case and connect all equipment with wires to prevent losing it or dropping it.
The device disconnects from the power supply.	Notify the driver that the device has turned off.
The chosen sensor isn't enough to provide the necessary perspective and distance calculation.	Use of a combination of sensors.
Difficulty in testing the prototype outdoors freely.	Test on robot cars available in the Lab.
Sensors or devices we order are defective from the factory.	Either order a spare if it's within the budget or order them as early as possible to test them.

Roles and Responsibilities		
Stakeholder	**Name**	**Roles and Responsibilities**
Advisor	Dr. Muhammad Bilal	supervising, frequent evaluation, and holding meetings.
Co-Advisor	Dr. Mohammed Shahzad Hanif	Offers help as a second opinion in evaluations and provides additional expert advice.
Project Team	Khalid Al-Dahasy	Responsible for hardware and input information processing such as being responsible for sensors and how they work and for processing the information that comes from them.
	Saad Al-Jehani	Responsible for Image processing and computer vision for the project.
	Bandar Al-Sulami	Responsible for the user interface and how it appears and is used by the user.
Customer/Client	Dr. Muhammad Bilal	Providing the main idea of the project and defining requirements.

Engineering Standards

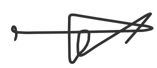
Engineering standards help in regulating the development of all kinds of technologies, such as that they do not conflict with each other and that it can be safe to use and implement them. In our project, we followed the **ANSI/SAE J563**, **UNECE R151**, **SAE J2400**, and **IEC 60445** standards on 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. [3]

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** of the standard. We use this as the remedy for the risk "The device disconnects from the power supply." [4]

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. [5]

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. [6]

Sign-Off			
	Name	**Signature**	**Date**
Project Advisor	Dr. Muhammad Bilal		19-Jan-23
Customer Representative	Dr. Muhammad Bilal		
Team Members			
Member #1	Khalid Al-Dahasy		19-Jan-23
Member #2	Saad Al-Jehani		19-Jan-23
Member #3	Bandar Al-Sulami		19-Jan-23

References

1. **Levine, L., 2013. In Formula One, it's already 2014. *The New York Times*, pp.6-L (Accessed: January 5, 2023).**
2. **Palmer Peterson, H. and Al Kassim, Z., 2020. A case study on perceptions of public transportation in the eastern province of saudi arabia. *Transport Problems*, *15*(2), pp.5-15 (Accessed: January 5, 2023).**
3. **SAE International (2009) J563_200902: Standard for 12 volt cigarette lighters, power outlets, and accessory plugs, SAE International. SAE International. Available at: https://www.sae.org/standards/content/j563_200902/ (Accessed: January 16, 2023).**
4. **UNECE (2021) UN Regulation No. 151 - blind spot information system for the detection of bicycles, UNECE. UNECE. Available at: https://unece.org/transport/documents/2021/08/standards/un-regulation-no-151-blind-spot-information-system-detection (Accessed: January 16, 2023).**
5. **SAE International (2014) J2400A human factors in forward collision warning systems: Operating characteristics and user interface requirements, SAE International. SAE International. Available at: https://www.sae.org/standards/content/j2400/ (Accessed: January 17, 2023).**
6. **IEC (2021) IEC 60445: Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors, IEC 60445:2021 | IEC Webstore. IEC . Available at: https://webstore.iec.ch/publication/66712 (Accessed: January 15, 2023).**

ENVIRONMENT PERCEPTION SYSTEM FOR SMART VEHICLES

by

KHALID MAMDOOH NASSER ALDAHASY 1935129

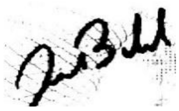
SAAD ALI SADAGAH AL JEHANI 1935151

BANDER SAEED ALSULAMI 1935181

TEAM NO.: 01 WINTER-2022 INTAKE

Project Advisor

DR. MUHAMMAD BILAL

CHECKED AND APPROVED (ADVISOR): 

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ABSTRACT

ENVIRONMENT PERCEPTION SYSTEM FOR SMART VEHICLES

Drivers can be put in danger due to blind spots in their cars, which cannot be seen through rear and side mirrors. Furthermore, these mirrors do not always provide a clear view, leading to accidents or parking difficulties. Thus, the problem we are trying to solve is to give drivers important information about the car's surroundings and blind spots.

By finishing this project, the higher-level objectives will be one step closer to being achieved. the first is to make cars safer, especially from accidents caused by collisions from blind spots. Secondly, enhance the surrounding view to make driving easier for people uncomfortable with a limited mirror view. Finally, kickstart indigenous development of ADAS technology in KSA for the upcoming age of smart cars.

We came up with three alternative solutions. First is a LIDAR-based design where LIDAR is used to detect distances of surrounding obstacles with high accuracy but high cost for the LIDAR. The second alternative is a Stereo-camera based design where a camera capable of measuring distance is used instead of adding a sensor, low cost but its accuracy is lower than that of LIDAR. The third alternative is a RADAR-based design where RADAR is used to detect distance at an accuracy lower than LIDAR and cost higher than a stereo camera but can withstand all weather conditions. For all alternatives, the visual feed is provided using wide-angle cameras surrounding the car, and the algorithms to produce a Birds eye's view and to detect objects are implemented on a Jetson nano.

The second alternative is the one we chose as it is the most optimal one of the three with a good balance between cost and accuracy.

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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 its 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 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 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

Some accidents happen due to drivers being unable to see from certain blind spots in the car. That can happen either on the road or during parking. That could endanger people and the driver. To see the perspective from the car's blind spot, the driver depends on the rear and side mirrors. Furthermore, during parallel and reverse parking, the driver also depends on the mirrors to see. Rear and side mirrors do not reflect the view, so accidents or parking difficulties still happen. Thus, the problem we are trying to solve is to give drivers important information about the car’s surroundings and blind spots.

2.3 PROJECT OBJECTIVES

Some specific goals and objectives must be met for all projects. And 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 surrounding 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.

2.4 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]

2.5 REALISTIC CONSTRAINTS

Realistic constraints are factors that limit projects, they could be external or internal, and the project must be able to achieve its objectives while those constraints exist. The following are our project constraints:

1. The budget is not more than 6000 SAR..
2. The system operates on 12V DC.

2.6 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° 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 meters (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

2.7 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.

Researched information related to the project:

Identifying the Blind spot zone:

In accordance with 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]

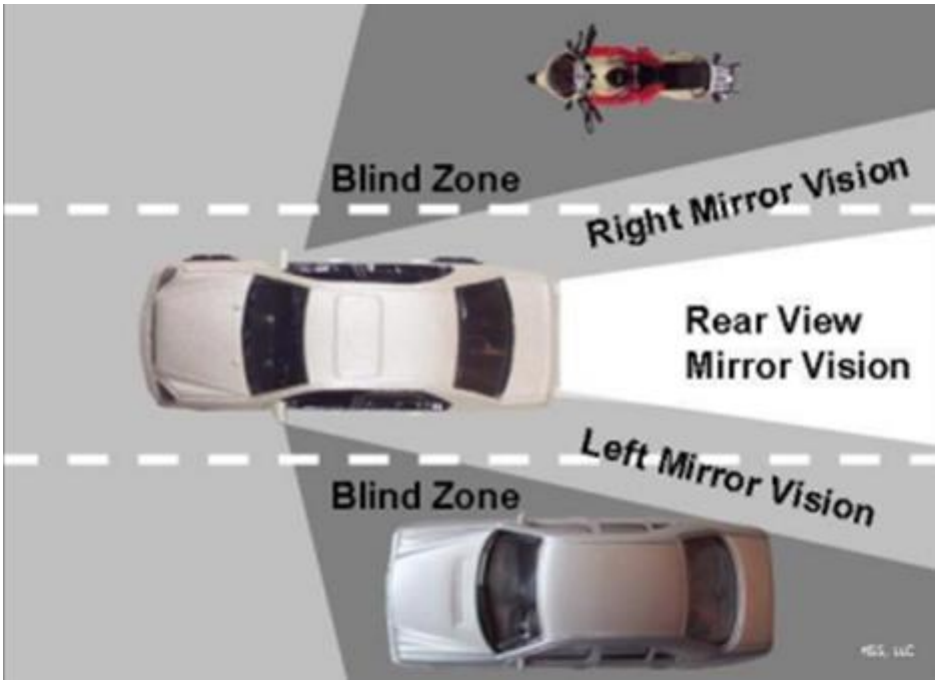

Figure 1 Blind zone of a car with traditional mirror settings.[7]

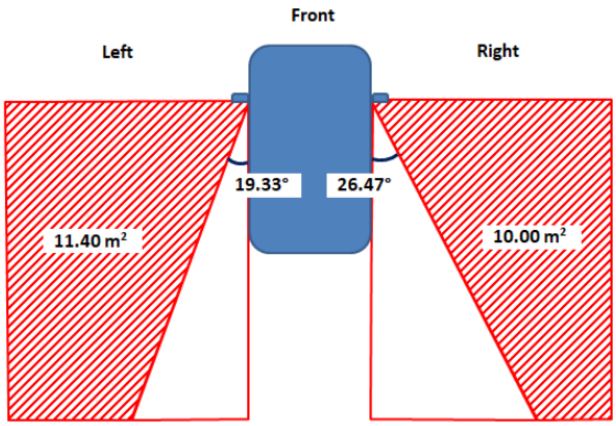

Figure 2 Blind spot based on research using the grid-based technique. [8]

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.

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. But 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]

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 using two of them which are installed on the left and right side of the car's rear. This particular module shown in Figure 2 was used due to its range being more suitable for short and middle-range zones. For example, between 0.5 to 75 meters. Which 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 prosses 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.

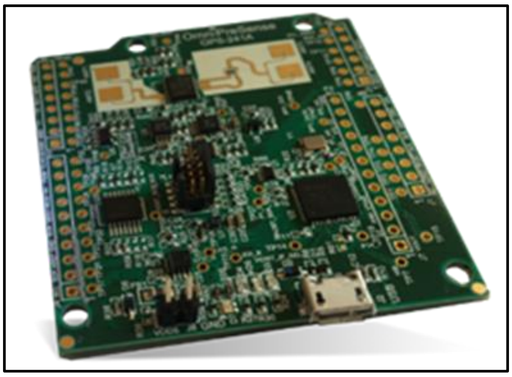

Figure 4 FMCW radar module.[14]

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 micro control 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 of 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 3. Buzzer is used to warn if the driver turned the turning signal to a side that has a car in its blind spot. [15]

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. And 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.

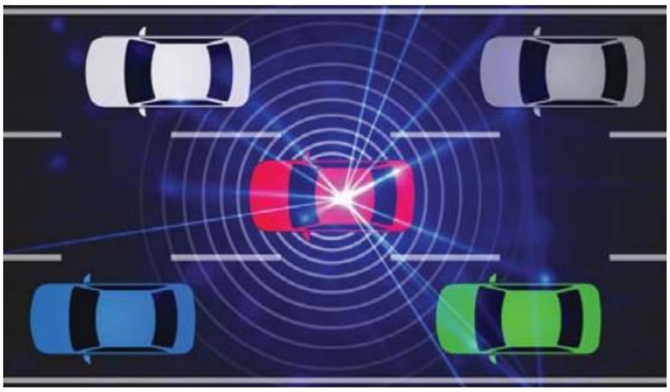

Figure 6 LIDAR Scanning Technique [16].

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

this project uses an RPLIDAR AIM8 2D 360 Degree Sensor connected via 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. And this algorithm outputs the warning type depending on the distance measured. [16]

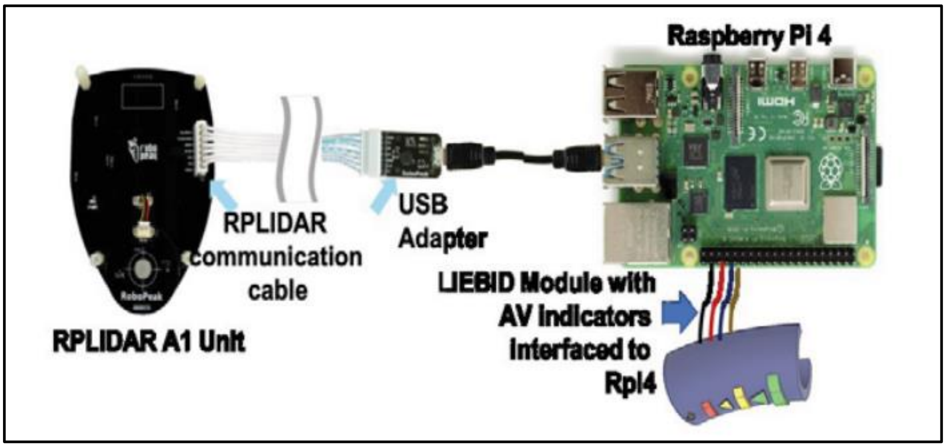

Figure 8 LIEBiD hardware components.

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

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 processes the image to track a car’s shadow on the road to then 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]

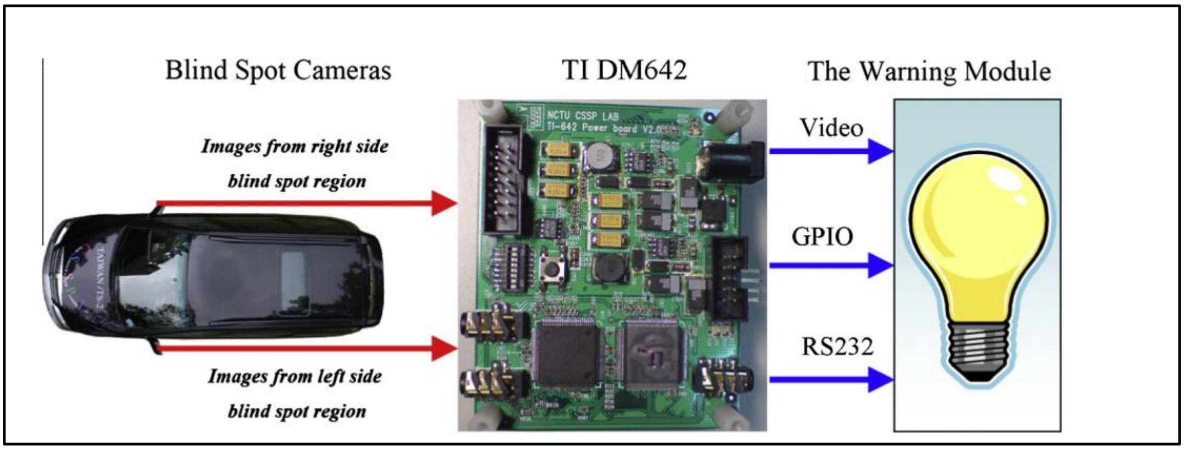

Figure 10 the system implemented on TI DM642 [17] .

2.8 THEORETICAL BACKGROUND AND ANALYSIS

Detecting Distances Approaches:

- *Stereo Camera:*

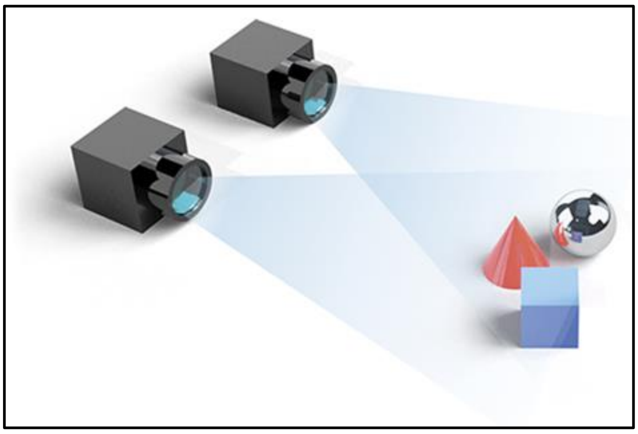

Figure 3 Artistic imagination of the proof of concept of stereo cameras measuring objects' distance and shape. [18]

Stereo Cameras could be used to find a 3D map representation of an original 2D image. The methodology of this lies in the use of two sets of lenses so that the depth could be calculated for objects captured by the cameras.

The algorithm mainly used to achieve this is called the stereo-matching algorithm. The algorithm works by taking a picture using the two lenses at the same time. Then the two images are processed to look for matching points in both. These matching points would be used to calculate the depth of each point with the following formula:

Equation 1 Triangulation formula for Stereo matching.

$$depth = \frac{focal\ length \times baseline}{disparity}$$

Where the focal length is the distance between the camera sensor and the camera lens. The baseline is the distance between the two lenses and the disparity is the difference in horizontal or X-coordinate distance of the same point on the two images. Getting the depth means we get the point coordinate on the 3D map. recent usage of deep learning has been implemented in this algorithm which has achieved greater performance results. [19]

- *Radar:*

Radio Detection and Ranging (RADAR) can be used to detect the distance by sending radio waves and receiving them after they reflect off the surface of obstacles. The time for the signal to return is used to calculate the distance.
One of the algorithms to do this is the “time-of-flight” algorithm. It uses the fact that the radio signals travel at the speed of light, so the speed is known and all that’s left to calculate the distance is the time it takes to reach the target. [20]
It works by sending the radio wave signal, then measuring the time it takes for the signal to return to the receiver. This time is divided by half (because it traverses the distance between the RADAR and the obstacle twice). Then using the speed of light and the measured time, the distance is calculated via the following formula:

Equation 2 Distance equation.

$$Distance = speed\ of\ light \times \frac{meusered\ time}{2}$$

- *Lidar*:

Light Detection and Ranging (LIDAR) is another sensor that can be used similarly to RADAR to measure distance. Also using a time-of-flight algorithm, the sensor sends a light signal and receives the signal if it reflects off an obstacle. Distance is calculated similarly as done in RADAR. But LIDAR could be used to get more accurate data as it can send many light signals in a short time and therefore it can sample information from the obstacle to create a 3D map. LIDAR has more accuracy than RADARs, but RADAR doesn’t get affected by weather conditions or the color of the obstacle. LIDAR is mainly used for robot navigation and autonomous car applications. [21]

Transformation algorithm:

- Inverse Perspective Mapping (IPM):

Inverse perspective mapping is a transformation algorithm where the input is the original image from the camera which is in the 2D plane where it would be transformed to points on the 3D plane. This is done by the assumption that the road Is flat and therefore the 3D coordinates' third dimension would equal 0 for a 3D representation of a flat 2D plane. Then using the relationship between the 2D coordinates and the 3D coordinates shown in Figure 11 the algorithm produces the 3D transformation of the original image. [22]

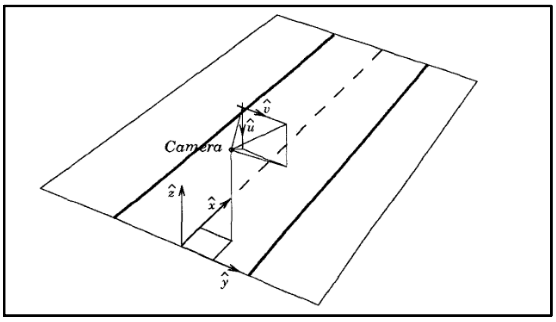

Figure 11 Relation between the 2D(u,v) coordinates and the 3D(x,y,z) coordinates.

After that, the algorithm does an inverse transform of the obtained 3D representation to a 2D representation for the top plane, which is the bird's eye view plane. The equations to transform from the original 2D to 3D are given:

Equation 3 3D coordinates (x,y,z) given the 2D original coordinates (u,v).

$$x(u,\ v) = h \times \cot\left[(\bar{\theta} - \alpha) + u\frac{2\alpha}{n-1}\right] \times \cos\left[(\bar{\gamma} - \alpha) + v\frac{2\alpha}{n-1}\right] + l$$

$$y(u,\ v) = h \times \cot\left[(\bar{\theta} - \alpha) + u\frac{2\alpha}{n-1}\right] \cdot \times \sin\left[(\bar{\gamma} - \alpha) + v\frac{2\alpha}{n-1}\right] + d$$

$$z(u,\ v) = 0$$

Where we need the camera position (length, depth, height) coordinates written as l, d, h in Equation 3. γ and θ are angles formed by the camera orientation to the height and depth respectively. α is the angular aperture of the camera and n is the camera resolution. [23]

Doing this for each pixel we have the 3D coordinates, then we retransform it back into top view 2D coordinates for bird's eye view. Similarly, the equations are:

Equation 4 2D coordinates (u, v) given the 3D coordinates (x,y,z).

$$u(x,\ y,\ 0) = \frac{\arctan\left\{\dfrac{h \sin\left[\arctan\left(\dfrac{y-d}{x-l}\right)\right]}{y-d}\right\} - (\bar{\theta} - \alpha)}{\dfrac{2\alpha}{n-1}}$$

$$\text{and } v(x,\ y,\ 0) = \frac{\arctan\left[\dfrac{y-d}{x-l}\right] - (\bar{\gamma} - \alpha)}{\dfrac{2\alpha}{n-1}}.$$

Object detection approaches:

- YOLO:

You only look once (YOLO) algorithm that uses a neural network in a grid representation method. The image is divided into grids and each grid is fed into the neural network where it predicts that an object is within a bounding box of multiple grid cells. This method makes the detection faster as the image is processed in one forward pass of the neural network with all grid cells being processed at once. [24]

- MMLAB LIGA-Stereo:

Developed by Multimedia Laboratory at Taiwan national university, the LIGA-stereo algorithm uses a stereo camera for left and right images to produce the depth map using the stereo camera approach with the addition of color and gray area comparison of each pixel to further find matching pixels more accurately. This algorithm increases the accuracy of depth maps produced by the stereo camera which can be used to detect objects by estimating the depth map points' clusters and feeding that information into a neural network trained on the depth map data. [25]

- Pseudo-LIDAR:

This algorithm uses neural networks to estimate the depth of each pixel in the obtained 2D image and using the depth map, the algorithm creates a 3D representation of all the points using the depth. Using the 3D representation, the algorithm could be further extended to produce a birds eye's view using the 3D coordinates transformation. And detect objects by estimating the 3D points clusters and what they represent as an object. This is done with neural networks as well. [26]

- 3D Dual-Fusions:

In this algorithm, the 2D image is fed through a neural network for feature extraction and then to another neural network for 3D representation and depth map. then the LIDAR estimation of the depth map I fused with the 3D one to make a more accurate 3D depth map. and the 2D feature map is used for object detection using neural networks. Combining the 3D depth map with the 2D object detection results, this algorithm then can make a 3D map with estimations for object detected depths and widths. [27]

2.9 ANALYZING ALTERNATIVE SOLUTIONS

In this section, we will form a morphological chart where the functions are based on the musts and want 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 function 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	Jetson	Jetson	Jetson

depict useful information.			
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.

Error! Reference source not found. shows the chosen alternatives via the m orphological 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):

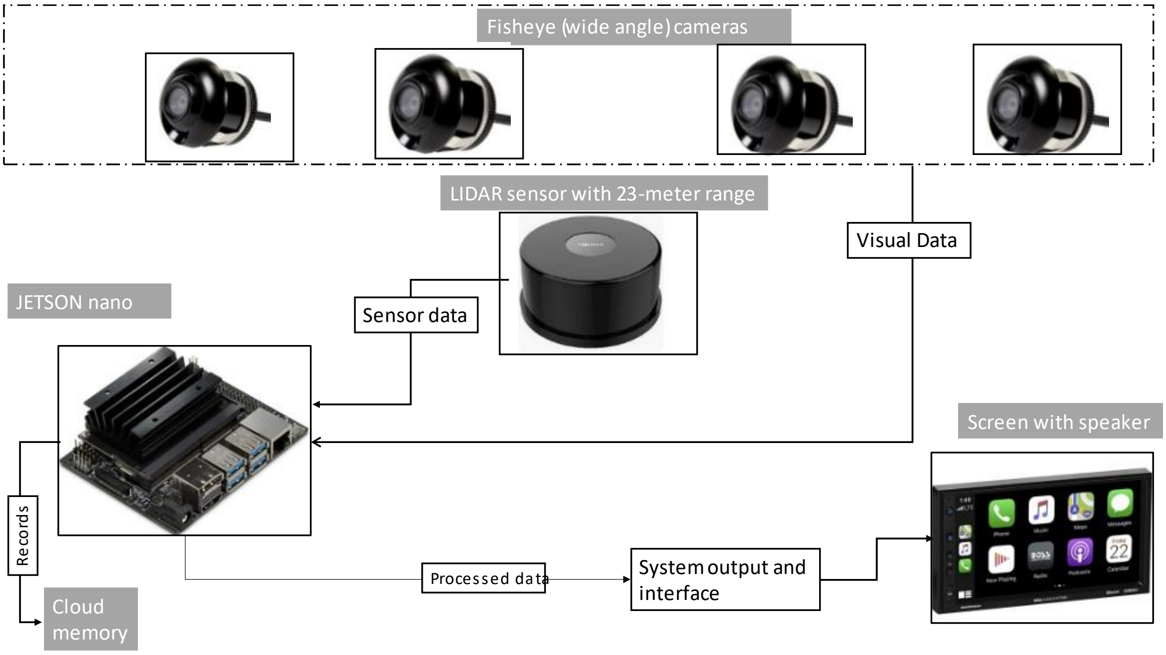

Figure 12 Block Diagram of Alternative 1.

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.

This alternative would use fisheye (wide angle) cameras to cover the blind spots and provide visual feed 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 then 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.

2 Alternative 2 (Stereo-Camera based):

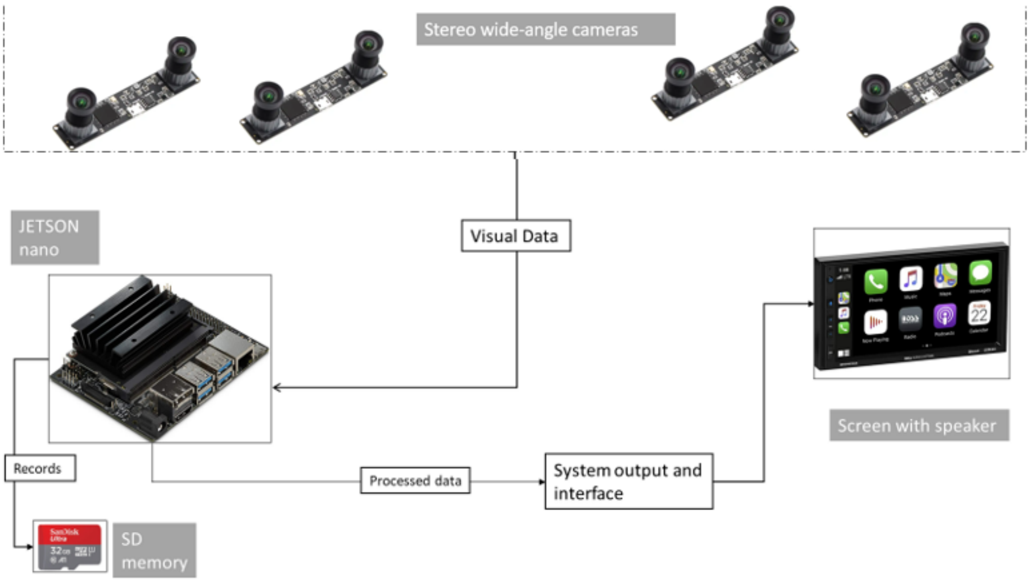

Figure 13 Alternative 2 block diagram.

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.

This alternative 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.

3 Alternative 3 (RADAR based):

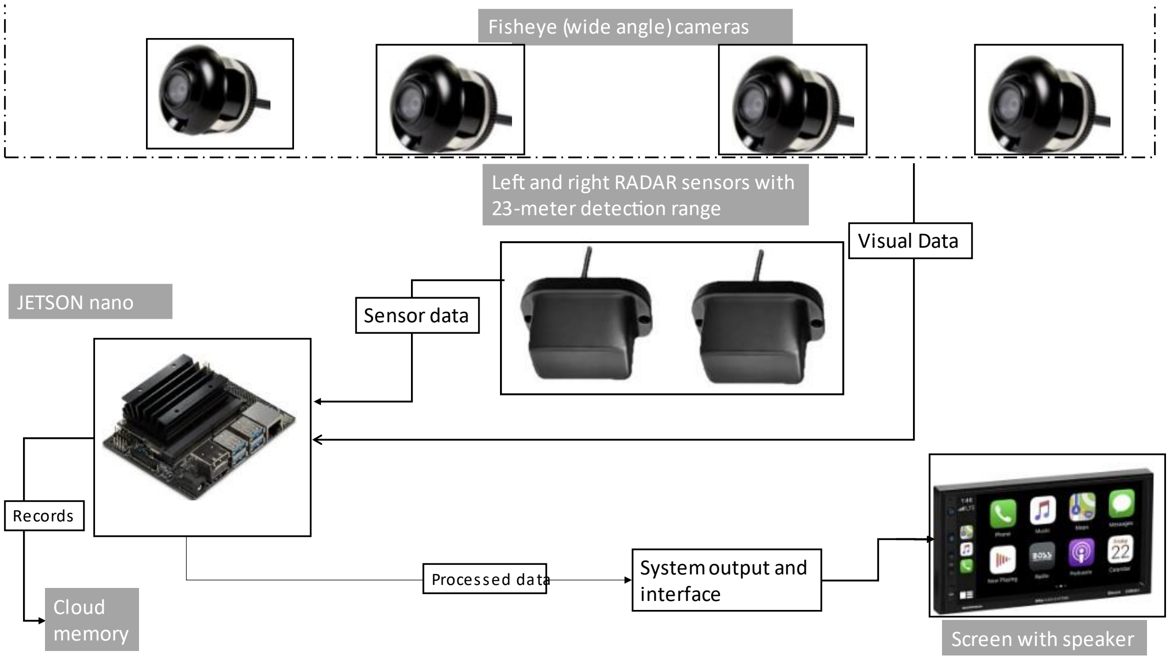

Figure 14 Alternative 3 Block Diagram.

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.

This alternative would use fisheye (wide angle) cameras to cover the blind spots and provide visual feed 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 then 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 will list the pros and cons of each alternative. This will help us put into perspective all the alternatives' weak and strong points. Second, we will do a KT analysis to compare the alternatives and see if they meet the musts and wants. Third, we do Pugh's method to further compare the alternatives against a DATUM and see how they differ. 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. 2- usage of fisheye cameras cut the cost due to using fewer than narrower angle cameras. 3- usage of cloud memory would save storage. 4- using JETSON nano will offer high capabilities in any algorithm based on AI.	1- high cost for the LIDAR. 2- Fisheye would have distortion that would be needed to be removed via processing. Which will add more work to the system. 3- an internet connection is needed for cloud saving. 4- can be affected by detected object's colors. 5- LIDAR needed may not be available easily locally.

	5- best for distance measurement.	6- difficult installation.
Stereo Camera based.	1- very low cost compared to other sensors. While still having good accuracy if suitable algorithms are used. 2- Fewer connections due to having fewer components (no sensor other than the camera) 3-usage of an SD card makes the system not depend on an internet connection or using the user's phone. 4- easier to install the system. 5- using JETSON nano will offer high capabilities in any algorithm based on AI.	1- Fisheye would have distortion that would be needed to be removed via processing. Which will add more work to the system. 2- adding more cost to the system by using SD storage. 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. 2- usage of fisheye cameras cut the cost due	1- more connections are needed, and multiplexing may need to be used. 2- Fisheye would have distortion that would be needed

	to using fewer than narrower angle cameras. 3- usage of cloud memory would save storage. 4- unaffected by weather conditions or nighttime or object colors. 5- using JETSON nano will offer high capabilities in any algorithm based on AI.	to be removed via processing. Which will add more work to the system. 3- an internet connection is needed for cloud saving. 4- having to drill holes for installation.

Alternatives:		1: Lidar based	2: Stereo-Camera	3: Radar-based
Musts	Provide a distortion-free visual feed with at least 81° 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 meters 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	8	3	2	1

coloring scheme.				
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 accidents 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 highest ranked algorithms on the KITTI database leaderboard. [28]

On the third item, it scored a 3 due to the speaker being a good method to provide 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 accidents 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 it being a very simple solution.

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

On the third item, it scored a 3 due to the speaker being a good method to provide 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 accidents 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]

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

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

Table 4 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

2.10 MATURING BASELINE DESIGN

Now that we have chosen our alternative which is alternative 2 (Stereo-camera based) we will further mature the design and 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 choose 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 PyTourch 1.11. And it can also build Torchvision 0.12 [29]. It can also run CUDA 10.2 and under. [30]

The power source is 12 Volt according to ANSI/SAE J563 standard, and the Jetson nano work 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’s 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 are 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.

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

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

CHAPTER – 3 PRODUCT BASELINE DESIGN

3.1 BLOCK DIAGRAM

Figure 15 is the detailed block diagram of the baseline design. Showcasing the blocks of components and the algorithm used.

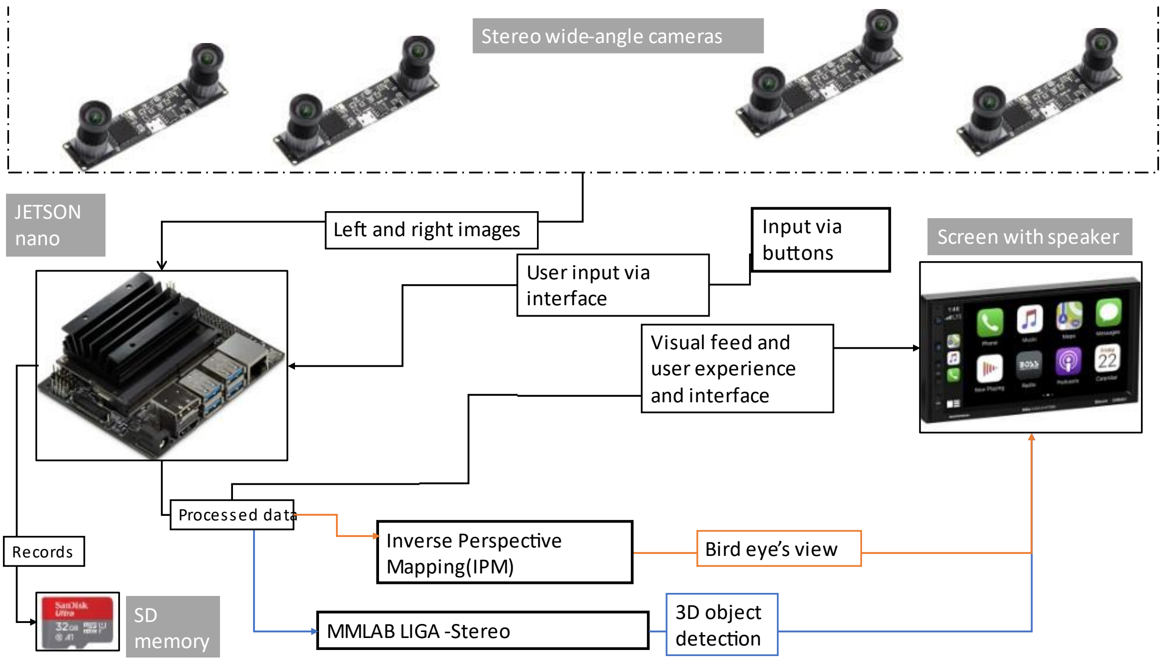

Figure 15 Matured block diagram.

3.2 SYSTEM DESCRIPTION

3.2.1 Circuit Schematics

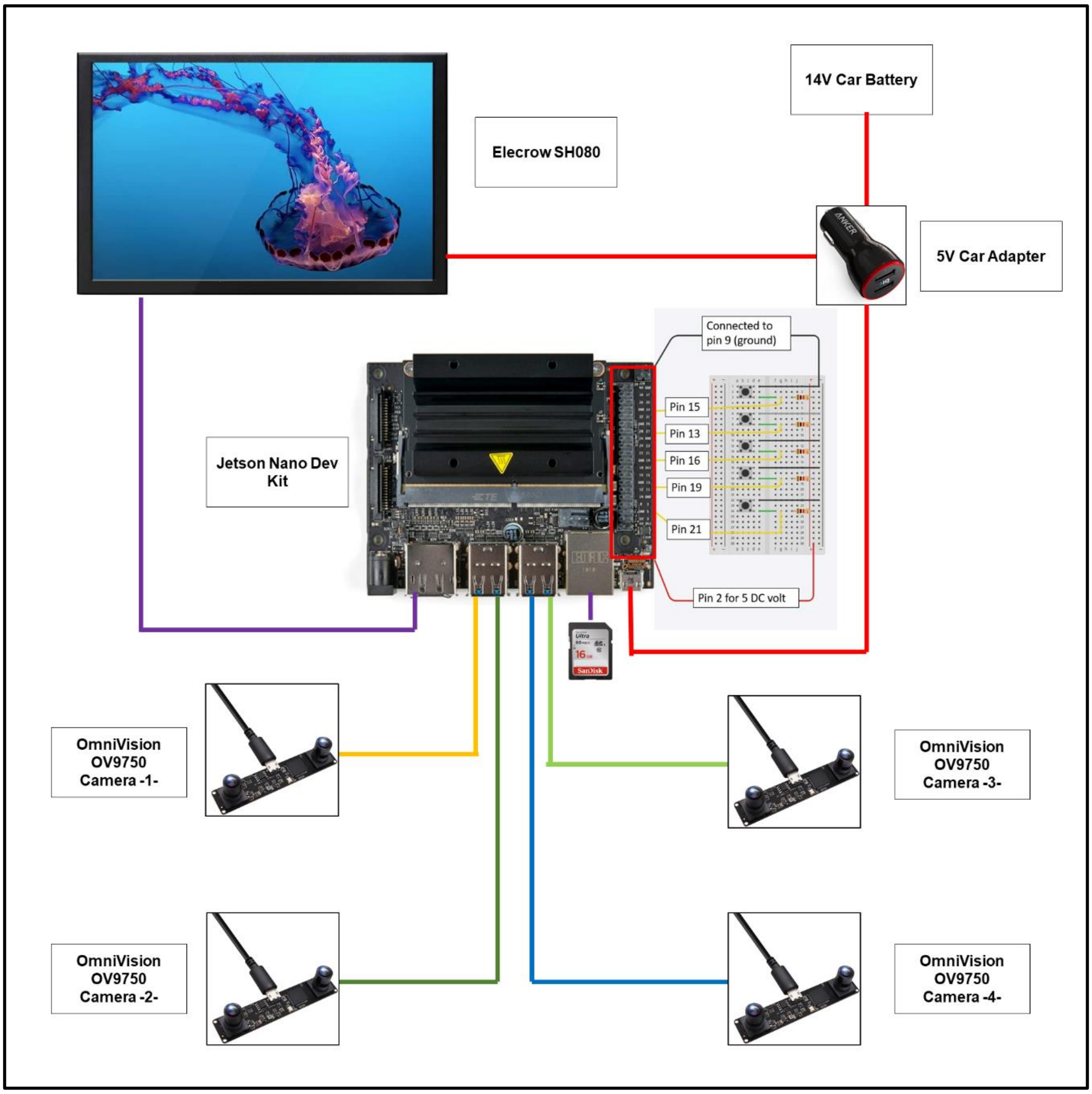

Figure 16 Circuit Schematic

3.2.2 Circuit Component Specifications

1. <u>Jetson nano</u>

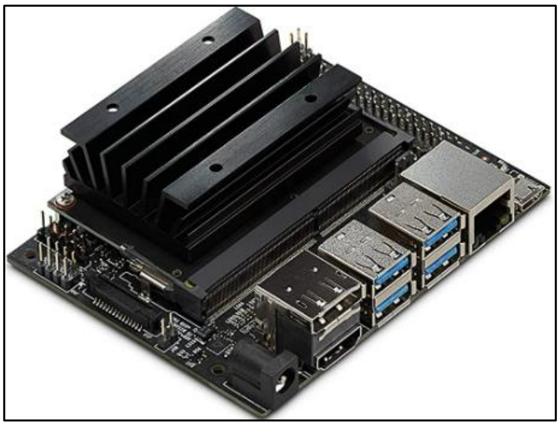

Figure 17 Jetson Nano

Jetson nano is a powerful tool computer used to run neural networks for image processing applications. Such as object detection and segmentation.

Table 5 Jetson Nano Developer Kit Specifications [31]

Jetson Nano Developer Kit	
GPU	128 core Maxwell GPU
CPU	Quad-core ARM A57 with 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 18 OmniVision OV9750

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 6 ELP-960P2CAM-V90 Specifications [32]

ELP-960P2CAM-V90	
Resolution & FPS	MJPEG:2560X960@ 60fps 2560X720@60fps 1280X480@60fps 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 19 Elecrow SH080

ELECROW is an In-Plane Switching monitor that uses liquid crystals aligned in parallel. It is also portable and has built-in speakers.

Table 7 ELECROW SH080 Specifications [33]

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

The flowchart we made in Figure 20 represents the processes used for our system to do its desired function. If the power is connected, the system starts by checking if all four cameras are connected and not mostly covered by the car's exterior or other objects. If at least one of them is not connected a warning to the user will show through the screen to connect the camera and follow the operating steps.

When all cameras are connected, the system starts to take the data which is the left and right images from all the cameras. The system will decide if its daylight or nighttime by measuring the brightness of the picture, if its low than the system works as if its nighttime. If its high, it works in the default algorithm. Because the image input is taken by the system, a parallel flow starts where the system continuously records the previous 60 minutes and depending on allocated memory it overwrites the oldest recording if it needs to. After the algorithms produce bird eye's view and visual feed segmented based on object detection and also produce information about distances of any detected object, the system provides by default a 2x2 object segmented view of all four perspective and wait for an input via the push buttons. The system reads the 5 buttons states and if any are pressed the system checks for exactly what button was pressed and change the displayed perspective accordingly. If one of the corner buttons are pressed (LT, RT, LB,RB) the system displays to that particular corner perspective and waits for another button press. If the Mod button is pressed the system displays the bird eye's view perspective and if the Mod was pressed and the displayed perspective was already the bird eye's view perspective, the system displays the default 2x2 perspective. And a parallel process that interrupts the main process is to this is to check the distance of detected objects surrounding the car, if the distance of one of the objects is less than 3 meters, the system shows the perspective that the system detected that distance from and warns the driver audibly. Then it returns to the previous perspective.

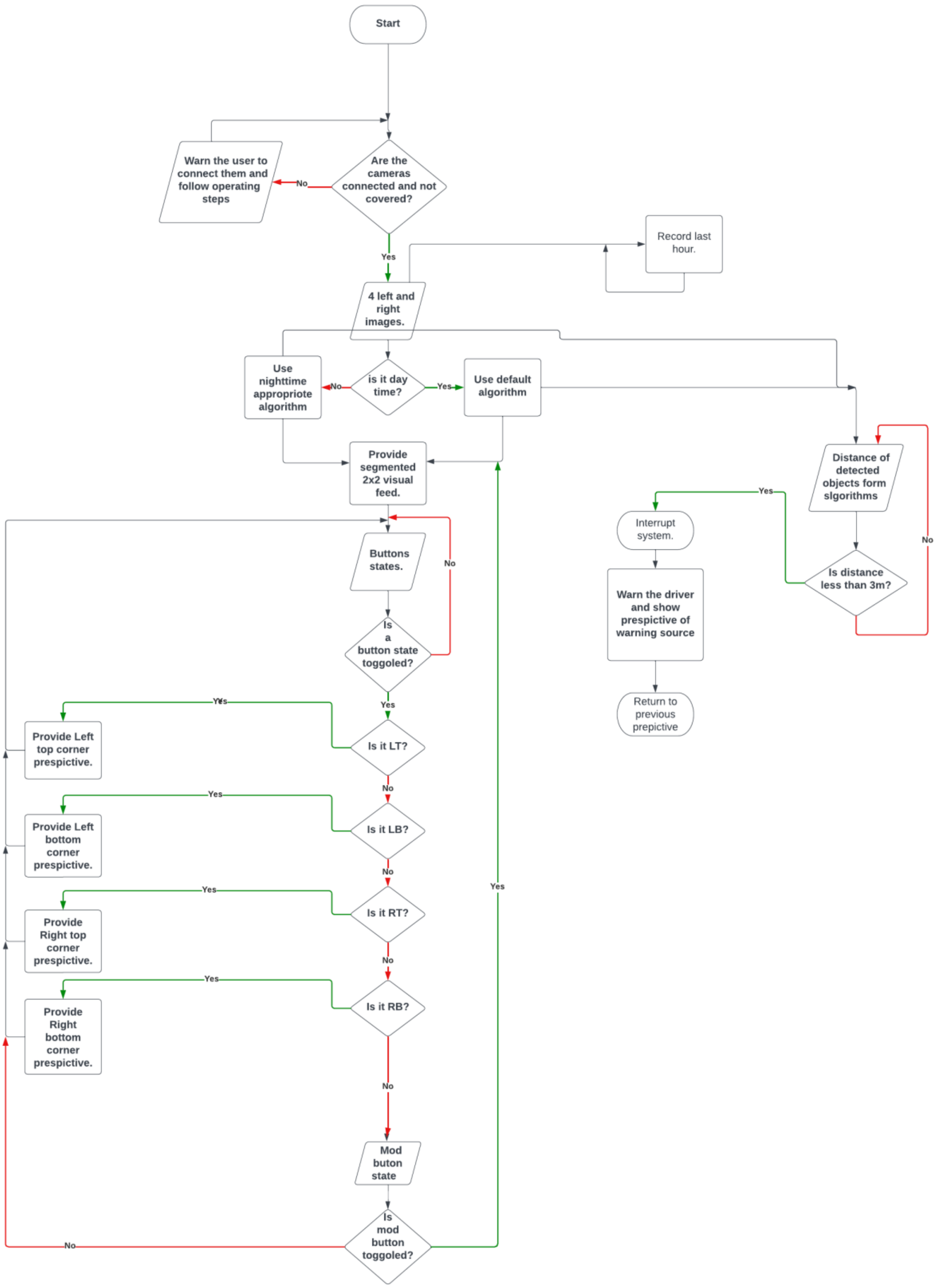

Figure 20 Software Flowchart.

3.2.4 Mechanical Specifications of the Case

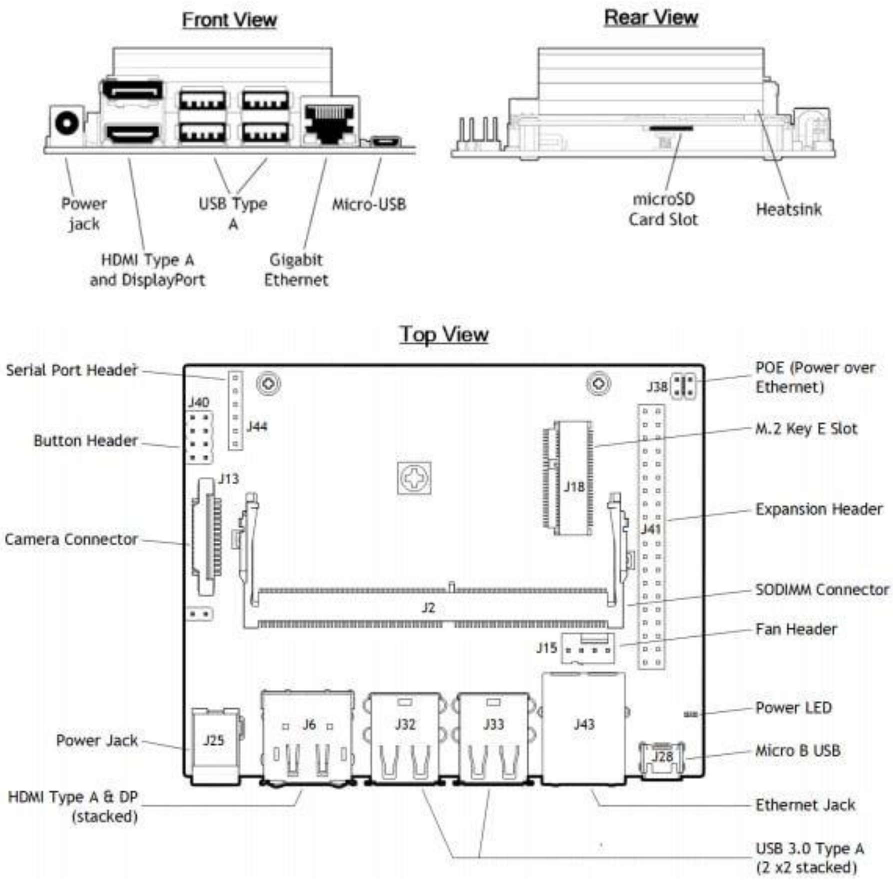

Figure 21 Jetson Nano I/O Ports [34]

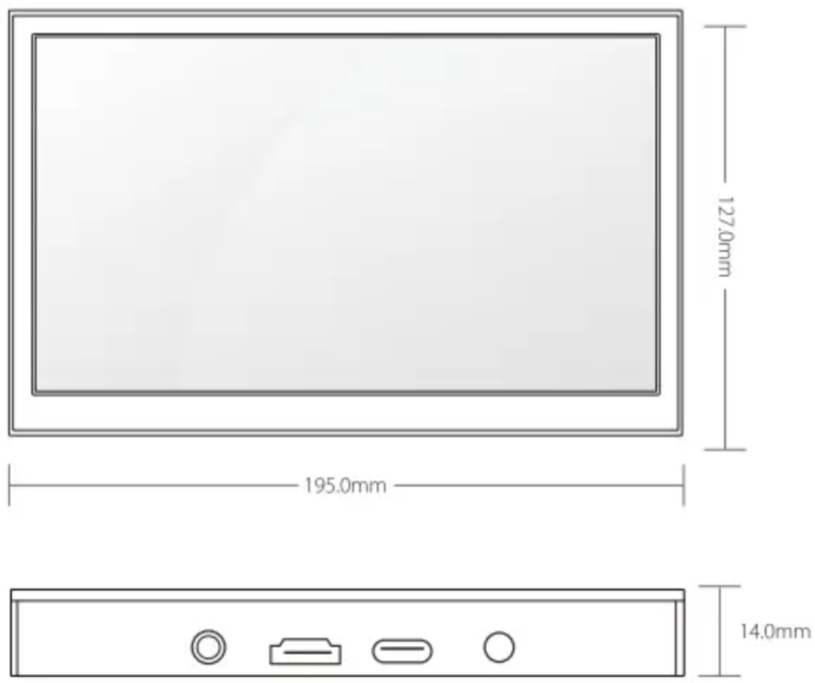

Figure 22 2D drawings of Elecrow SH080 monitor. [35]

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 23 Car Screen Mount [36]

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 sound 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 Bird eye’s view and if pressed again it changed back to the default 2x2 perspective.

CHAPTER – 4 PRELIMINARY EVALUATION OF BASELINE DESIGN

4.1 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.

4.2 COST ANALYSIS

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.

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 narrow-angle cameras	4	298	1192
Total (SR)			2387

As shown in the above table, 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, so it is clear that we are still under the budget that was set.

4.3 ENVIRONMENTAL IMPACT

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.

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 [37]. 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.

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.

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.

Screen

Screen significantly impacts the environment because it is 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. significantly impacts the environment because it is 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.

4.4 IMPACT ON SOCIETY

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.

4.5 GLOBAL IMPACT

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 [38].

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APPENDIX-A: INTERIM REPORTS

❖ Project Charter

KING ABDULAZIZ UNIVERSITY

THE COLLEGE OF ENGINEERING

Senior Design Project

EE499 – Winter 2023

Team 01 – Project Charter

Member	Name	ID
1	KHALID MAMDOOH NASSER ALDAHASY	1935129
2	SAAD ALI SADAGAH AL JEHANI	1935151
3	BANDER SAEED ALSULAMI	1935181

Submitted to: Dr. Muhammad Bilal

Thursday, January 19, 2023

1

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General Project Information	
Project Name	**Environment Perception System for Smart Vehicles**
Executive Sponsors	King Abdulaziz University, Department of Electrical and Computer Engineering
Project Timeline	December 2022 – November 2023

Project Stakeholders			
Role	Name	Department	Email
Project Sponsor	King Abdulaziz University	Electrical and Computer Engineering	ece@kau.edu.sa
Project Advisor and Customer Representative	Dr. Muhammad Bilal	Electrical and Computer Engineering	meftekar@kau.edu.sa
Project Co-Advisor	Dr. Mohammed Shahzad Hanif	Electrical and Computer Engineering	mshanif@kau.edu.sa
Team Members	Khalid Al-Dahasy	ECE, CoE	kaldahasy@stu.kau.edu.sa
	Saad Al-Jehani	ECE, CoE	sjehani0005@stu.kau.edu.sa
	Bandar Al-Sulami	ECE, CoE	balsulami0162@stu.kau.edu.sa

Executive Summary

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 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. [1]

The customer asks for a more conventional method to view the perspective of all the blind spots of a car and provides helpful information to the driver.

The increase in Saudi Arabia 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 [2]. 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.

Our project's objective is to make an Advanced Driver Assistance System (ADAS). That will provide more helpful information to the driver than the information received through the back and side mirrors. This system aims to make for a safer driving experience and display a more enhanced perspective than what the rear and side mirrors provide. By contributing to making an ADAS project, we also contribute to kickstarting the indigenous development of ADAS technology in KSA for the upcoming age of smart cars.

Project Purpose
Project Need / Justification
Some accidents happen due to drivers being unable to see from certain blind spots in the car. That can happen either on the road or during parking. That could endanger people and the driver. To see the perspective from the car's blind spot, the driver depends on the rear and side mirrors. Furthermore, during parallel and reverse parking, the driver also depends on the mirrors to see. Rear and side mirrors do not reflect the view, so accidents or parking difficulties still happen. Our project aims to provide a better solution than the classic mirrors installed on all cars. In which the project provides a clear and accurate view that displays all possible blind spots with information on the distances of objects near the car. All the while providing helpful information in different parking scenarios. That would be provided in a simple, straightforward, and comfortable experience. In achieving this, the project would also help reduce accidents, make the driver experience more comfortable and less stressful, and put light on ADAS projects and their uses to inspire more development work in Saudi Arabia in this field.
Objectives
Lower-level Objectives: 1. Provide the driver with a detailed distortion-free view of the vehicle surrounding 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 (Strategic) 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.

Project Description

The environment perception system is an ADAS system that provides several perspectives and information to the driver that would help avoid collisions and parking safely.

This includes a distortion-free visual feed with at least 81° field-of-view, covering the vehicle's blind spots, and a bird's eye view around the vehicle to assist while parking in tight spots and parallel parking. All the while providing this in a user-friendly interface and display. Additional services would be to display relative object detection information and the ability to record the events of an accident if it occurs, this is to be used for police reports and insurance company claims.

The prototype that will be presented by the end of this course would have to work on the available 12V power supply.

To develop this prototype, we assume that all the materials would be available within budgetary (6000 SAR) and time limits and that the testing would be concluded without the need to test the prototype on all types of cars nor the need to test it under harsh environmental conditions that would hinder the functionality of the sensors.

Project Scope	
Musts	Wants
Provide a distortion-free visual feed with at least 81° field-of-view, covering the vehicle's blind spots.	Record all visual feeds from the previous hour, to assist in accidental insurance claims
Provide a user-friendly visual to depict the respective distances of surrounding objects within a 15 meters radius with an accuracy of at least 90%	Provided a segmented view with people, cars, pavements, and roads using an appropriate coloring scheme.
Provide a bird's eye view for 3 meters around the vehicle to assist while parking in tight spots and parallel parking.	Provide audio notifications.
Visual updates should be at least at 10 fps for a flicker-free, smooth, and comfortable view.	

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.

Constraints

1. The budget does not exceed 6000 SAR.
2. The system operates on 12V DC.

Project Deliverables
The project will be implemented as shown below. In the figure, there are primary and sub-tasks and their estimated dates.
Project Deliverables

Milestone / Deliverable	Estimated Date	Responsible individual
1. Project Initiation	25th Dec. – 3rd Feb.	Khaled, Saad, Bandar
1.1. Project Charter	Jan 19th	Khaled, Saad, Bandar
1.2. Business Model	Feb 3rd	Khaled, Saad
2. Planning	Jan 20th – Feb 23rd	Khaled, Saad, Bandar
2.1. Conceptual Design	Jan 27th	Bandar
2.2. Product Baseline Design	Feb 3rd	Khaled
2.3. Preliminary Evaluation of Baseline Design	Feb 17th	Saad
3. Execution	Mar 12th – Oct 1st	Khaled, Saad
3.1. The initial phase of designing the project	June 24th	Khaled, Saad
3.2. The final phase of designing the Prototype	Oct 1st	Khaled, Saad
4. Monitoring and controlling	Mar 12th – Oct 1st	Bandar

4.1. Track Effort and Cost	Mar 12th – Oct 1st	Bandar
4.2. Monitor Project Progress	Mar 12th – Oct 1st	Bandar
4.3. Ensure Adherence to plan	Mar 12th – Oct 1st	Bandar
5. closure	Oct 1st – Nov 31st	Khaled, Saad, Bandar
5.1. Submitting the Final Project	Oct 1st – Nov 31st	Khaled, Saad, Bandar
5.2. Submitting the Final Report	Oct 1st – Nov 31st	Khaled, Saad, Bandar

Major Known Risks	
Risk	**Remedy**
Equipment falling off.	Notify the driver in this case and connect all equipment with wires to prevent losing it or dropping it.
The device disconnects from the power supply.	Notify the driver that the device has turned off.
The chosen sensor isn't enough to provide the necessary perspective and distance calculation.	Use of a combination of sensors.
Difficulty in testing the prototype outdoors freely.	Test on robot cars available in the Lab.
Sensors or devices we order are defective from the factory.	Either order a spare if it's within the budget or order them as early as possible to test them.

Roles and Responsibilities		
Stakeholder	**Name**	**Roles and Responsibilities**
Advisor	Dr. Muhammad Bilal	supervising, frequent evaluation, and holding meetings.
Co-Advisor	Dr. Mohammed Shahzad Hanif	Offers help as a second opinion in evaluations and provides additional expert advice.
Project Team	Khalid Al-Dahasy	Responsible for hardware and input information processing such as being responsible for sensors and how they work and for processing the information that comes from them.
	Saad Al-Jehani	Responsible for Image processing and computer vision for the project.
	Bandar Al-Sulami	Responsible for the user interface and how it appears and is used by the user.
Customer/Client	Dr. Muhammad Bilal	Providing the main idea of the project and defining requirements.

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. [3]

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** of the standard. We use this as the remedy for the risk "The device disconnects from the power supply." [4]

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. [5]

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. [6]

Sign-Off			
	Name	**Signature**	**Date**
Project Advisor	Dr. Muhammad Bilal		19-Jan-23
Customer Representative	Dr. Muhammad Bilal		
Team Members			
Member #1	Khalid Al-Dahasy		19-Jan-23
Member #2	Saad Al-Jehani		19-Jan-23
Member #3	Bandar Al-Sulami		19-Jan-23

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❖ **Ethical Case Studies**

M1

King Abdelaziz University

Faculty of Engineering

Department of Electrical and Computer Engineering

Senior Design Project EE-499 Term1

Ethical Case Study

Name: Khaled Dahhasi

ID: W22_T01_M1_1935129

Advisor and Customer: Dr. Muhammed Bilal

Co-Advisor: Dr. Shehzad Hanif

SCE, the Saudi Council of engineer's code of ethics:

Rule One: Every engineer should build her/his professional reputation based on efficiency and proficiency of her/his services, and away from unfair competition with others.

Rule Two: Every engineer should seek to develop her/his personal abilities and efficiency, and should also provide professional development opportunities for engineers and technicians working under his supervision.

Rule Three: Every engineer should be committed to promoting the fundamental values and principles of the ethics of the engineering profession and should plant them within society. Regarding her/his conduct, every engineer should be s in ways that support and enhance the prestige and dignity of the profession and the secretariat of the locally and globally.

Rule Four: Regarding professional issues, Every engineer shall act as a careful agent to the employer, and shall avoid any conflict of interests.

Rule Five: When submitting her/his ideas, views and decisions, every engineer should be keen to be objective and honest and confined to her/his field of expertise and professional experience.

Rule Six: When providing professional services, every engineer seeks to apply the highest standards of safety and environmental protection in order to achieve the public interest of individuals and society. [1]

The Ethical Dilemma

A construction engineer has to finish a project under specific budget but to abide by safety measures, the budget must be increased. The company doesn't know details about safety standards and refuses to increase budget.

Scenario 1

The engineer abides by the company's wishes and follow orders to do the project with the given budget. Although the project would be done, it would be against rule 6 of the code of ethics shown above.

Scenario 2

The engineer doesn't explain enough to convince the company with alternate plan to do the project under safety standards. And the engineer whistle-blows on the company choice to ignore safety standards to the public. Doing this, the engineer would go against rule 4 to act as a careful agent to the company. Doing this is not giving the company a good chance to understand why the budget must be increased.

Scenario 3

The engineer explains thoroughly the safety standards and why they would increase the budget in detail. And if the company doesn't abide by safety standards even after explanation, the engineer whistle-blows on the company only to the correct government branches in hopes of avoiding a project with no safety standards. Doing this the engineer flows rule 6 and also follows with the best of his capabilities rule 4. This is the correct ethical choice given the imaginary scenario.

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[1] IEEE code of Ethics (no date) IEEE. Available at: https://www.ieee.org/about/corporate/governance/p7-8.html (Accessed: February 22, 2023).

M2

King Abdulaziz University
Faculty of Engineering
Department of Electrical and Computer Engineering

Senior Design Project EE499
Winter 2023 – Term-1

Ethical Case Study

Name: Saad Ali Sadagah Al-Jehani
SDP ID: W22_T01_M2_1935151

Advisor and Customer: Dr. Muhammed Bilal

Co-Advisor: Dr. Shehzad Hanif

Introduction

Engineering is a crucial and specialized profession. Engineers are expected to uphold the greatest ethical and moral obligations as participants of this profession. Engineering does indeed have a straightforward and vital influence on everyone's quality of life. As a result, the service given by engineers must be honest, impartial, fair, and fair and equal, as well as dedicated to the protection of public health, safety, and welfare. Engineers must adhere to a professional standard of conduct that includes adhering to the highest ethical principles.

The following are the Fundamental cannons of the national society of professional engineers.

Fundamental canons

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Ethical dilemma

An engineer is tasked of making a sugar and oil factory at Jeddah's port and the company stated that he must abide by cannon 1 of the national society of professional engineers. Which states that engineers shall hold paramount the safety, health, and welfare of the public.

Scenario one:

The engineer starts making the factory while hiring cheap labor and buying cheap materials to reduce cost.

Scenario Two:

The engineer starts making the factory while hiring expensive labor and buying expensive materials to make the factory as safe as possible but the project is cancelled due to insufficient budget.

Scenario Three:

The engineer starts making the factory while hiring good labor and buys good materials while staying within the budget and the factory is completed. But the design of the factory makes the production time of sugar and oil longer.

Discussion

The engineer must determine wither he can abide by the cannons. For scenario one, he must make sure that buying the material and hiring the cheap labor the factory will abide by all safety standards. And for scenario two, he must determine whether his moral commitments cause him to make the company lose money and cancel projects. And finally, in scenario three, the engineer must determine whether the safety of the employees is important or how that company's making profit is important.

References

"Code of ethics," Code of Ethics | National Society of Professional Engineers. [Online]. Available: https://www.nspe.org/resources/ethics/code-ethics. [Accessed: 23-Feb-2023].

M3

King Abdelaziz University

Faculty of Engineering

Department of Electrical and Computer Engineering

Senior Design Project EE-499 Term1

Ethical Case Study

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The IEEE Code of Ethics is a set of principles and guidelines that guide ethical behavior and that all IEEE members must abide by. The IEEE Code of Ethics covers some important topics, such as respect for others and the professional conduct of an employee or member. IEEE members must read and follow the IEEE Code of Ethics to ensure that IEEE members do their work in a way that is beneficial to society and advances technology. I will mention some of the rules found in the IEEE Code of Ethics [1].

IEEE Code of Ethics:

- That the member adheres to the highest standards of integrity and professional behavior.
- To bear the responsibility in making the engineering decision in accordance with the safety of society.
- That the member assists in improving the awareness of individuals and communities of technology.
- To avoid illegal behavior in professional activities and to refuse bribes of all kinds.
- That the member accepts and accepts honest criticism and admits mistakes and corrects them.
- The member should avoid any kind of sexual harassment or bullying behavior.
- That the member avoids harming others or their property through false or malicious acts
- A member supports co-workers in following the IEEE Code of Ethics.

The Ethical Dilemma

An electrical engineer was assigned to design a new energy system to be used in a remote village the IEEE Ethics Code states that the engineer gives the utmost importance to the safety of society and avoiding conflicts.

Scenario 1

The engineer provides the option to use a cheap but less reliable system. The company will achieve more if they choose the cheap design, but the engineer is concerned about the safety of society.

Scenario 2

The engineer provides the system with more energy and cost, but the work is stopped due to the completion of the budget given.

Scenario 3

The engineer provides the option to use a new system that has not been used before but promises to offer more efficiency and reliability. The company is confident in the design, but there is a risk that the system may be unreliable.

Discussion

The engineer must determine whether he can morally comply with the IEEE Ethics Code in all three scenarios. In scenario 1, the engineer must decide what the cost would exceed the potential risks of using a cheaper system. And in scenario 2, the engineer must determine whether his moral commitment exceeds the gains. And in scenario 3, the engineer answers to consider whether the new system's potential benefits are superior to the potential risks of a system that has not been used before. The engineer must make a moral and useful decision for society in all three scenarios.

References:

[1] IEEE code of Ethics (no date) IEEE. Available at: https://www.ieee.org/about/corporate/governance/p7-8.html (Accessed: February 22, 2023).

❖ **Impact of engineering solutions:**

KING ABDULAZIZ UNIVERSITY

THE COLLEGE OF ENGINEERING

Senior Design Project

EE499 – Winter 2023

Team 01 – Impact of engineering solutions

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Introduction:
In this report we will review some published projects and research that would open our eyes to how the engineering fields is and how the published reasaerch in the field is written like. Also, how these projects or research changed the world and impacted the field. This would help us understand the impact of engineering solutions.

The Bionic-Hand Arms Race [1]
The author of this article talks about how prostheses were developed throughout history. This article discusses what is the current trend of designing prosthetic hands, how expensive it is, and the pros and cons of electronic hands. Reading this article made us excited about what the future holds for the development of prosthetics.

Building a Super Robust Robot Hand [2]
This article talks about how the German Aerospace Center (DLR) created Rollin' Justin, two humanoid hands that are designed to be extremely powerful. It can hold objects with a high degree of accuracy and can withstand tremendous forces without breaking or slipping. Each can be controlled individually, allowing the hand to adapt to different shapes and sizes of objects. As a team, we were affected by how human skill arrived at making a strong robotic hand in this way.

An image reorganization procedure for automotive road following systems[3]:
Inverse perspective mapping is a transformation algorithm where the input is the original image from the camera which is in the 2D plane where it would be transformed to points on the 3D plane. This is done by the assumption that the road Is flat and therefore the 3D coordinates' third dimension would equal 0 for a 3D representation of a flat 2D plane. Then using the relationship between the 2D coordinates and the 3D coordinates the algorithm produces the 3D transformation of the original image. This algorithm revolutionized the use of IPM for providing bird eye view. And this was commonly used for ADAS

systems in smart cars. Engineering solutions like these revolutionized smart cars and are one of the reasons this technology exist.

Obstacle detection using a 2D LIDAR system for an Autonomous Vehicle[4]:
Light Detection and Ranging (LIDAR) is sensor that can be used similarly to measure distance. Using time-of-flight algorithm, the sensor sends a light signal and receives the signal if it reflects off an obstacle. Distance is calculated by dividing speed over distance where speed is speed of light. LIDAR could be used to get more accurate data as it can send many light signals in a short time and therefore it can sample information from the obstacle to create a 3D map. LIDAR is mainly used for robot navigation and autonomous car applications.
This research uses LIDAR and its properties to calculate distances of any obstacle around the car and using this information to move the smart car away from these obstacles. This research was published in 2016. Research like these impacted the implementation of smart car ADAS system a lot. Now that smart cars are used in America and other countries. We can see the impact it had on people where it made driving safer. That is if the engineering design is prober and accuracy is good. Engineers must be careful not to develop solutions that would endanger people.

References:

[1] : B. H. Young, “The bionic-hand arms race,” IEEE Spectrum, 22-Nov-2022. [Online]. Available: https://spectrum.ieee.org/bionic-hand-design. [Accessed: 23-Feb-2023].

[2]: E. Guizzo, “Building a super robust robot hand,” IEEE Spectrum, 18-Aug-2022. [Online]. Available: https://spectrum.ieee.org/dlr-super-robust-robot-hand. [Accessed: 23-Feb-2023].

[3]: A. Broggi, "An image reorganization procedure for automotive road following systems," Proceedings., International Conference on Image Processing, Washington, DC, USA, 1995, pp. 532-535 vol.3, doi: 10.1109/ICIP.1995.537689.

[4]: “Obstacle detection using a 2D lidar system for an autonomous vehicle ...” [Online]. Available: https://ieeexplore.ieee.org/abstract/document/7893614. [Accessed: 23-Feb-2023]..