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Depth Camera

Design Methodology

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Abstract

This report presents the development and implementation of a depth measurement system using a USB webcam, focusing on the application of the Cambridge EDC Inclusive Design Methodology. The project aims to create a portable and cost-effective solution for accurate depth measurement by leveraging computer vision techniques, object detection, and feature matching.

Initially, photos were captured from a USB webcam using OpenCV. The camera was calibrated using custom functions with chessboard images, yielding essential parameters for accurate depth calculations. Object detection was implemented using the YOLOV8 model, custom-trained with a dataset from Roboflow, to output bounding boxes. Feature matching within these bounding boxes and triangulation based on the obtained matrices allowed the calculation of mean depths.

Additionally, a stepper motor mechanism controlled by an ATmega microcontroller enabled the camera to rotate and capture photos from two distinct positions. This setup ensured precise positional data for depth calculation.

The project documentation follows the Cambridge EDC Inclusive Design Methodology, detailing the progress review, stakeholder identification, user observations, needs list, idea stimulation, conceptual designs, evaluation, schematic design, PCB design, and SolidWorks design.

Contents

1 Review Progress

A thorough analysis of the work done in depth measurement by numerous companies and universities was done in order to evaluate the state of the available technology today. Understanding the current level of development in the area we are studying is important in innovating and developing project ideas for our project approach.

In recent years, significant progress has been made in the field of depth measurement, driven by advancements in technology, algorithms, and applications. Some key areas of progress include:

1. **Sensor Technology**: There has been a proliferation of depth sensing technologies,including structured light, time-of-flight (ToF), stereo vision, and LiDAR (Light Detection and Ranging). These sensors vary in their principles of operation, ranging from active methods (e.g., structured light and ToF) to passive methods (e.g., stereo vision). Advancements in sensor miniaturization, cost reduction, and performance optimization have facilitated their integration into a wide range of devices and applications

2. **High-Resolution Imaging**: Advances in imaging sensors and optics have led to the development of high-resolution depth cameras capable of capturing detailed depth information with enhanced accuracy and precision. These cameras offer improved spatial resolution and depth range, enabling a broader range of applications in fields such as 3D scanning, virtual reality, and medical imaging.

3. **Depth Sensing Algorithms**: Novel algorithms and computational techniques have been developed to process raw depth data and extract meaningful depth information. Machine learning approaches, such as deep neural networks, have shown promise in enhancing depth estimation accuracy and robustness, particularly in challenging environments with varying lighting conditions or occlusions

4. **Real-Time Processing**: The demand for real-time depth sensing applications has spurred research into efficient algorithms and hardware architectures capable of processing depth data at high speeds. Advances in parallel computing, GPU acceleration, and dedicated depth processing units have enabled the development of real-time depth sensing systems suitable for applications such as robotics, autonomous vehicles, and augmented reality

5. **Applications Across Industries**: Depth measurement technology has found widespread applications across various industries, including automotive, healthcare, gaming, manufacturing, and agriculture. From gesture recognition and facial authentication to object detection and 3D reconstruction, depth sensing enables a diverse range of innovative applications aimed at improving efficiency, safety, and user experience

In developing ideas for our project, we have mainly studied 3 research papers which has been published related to depth measuring using a single camera.

1. **Depth Measurement Based on Stereo Vision With Integrated Camera Rotation by Huei-Yung Lin (Senior Member, IEEE), Chun-Lung Tsai, and Van Luan Tran - IEEE Transactions on Instrumentation and Measurement, VOL. 70, 2021**

Article link - https://ieeexplore.ieee.org/abstract/document/9406044

This article presents a novel sensor system design aimed at depth recovery, with a focus on measuring distances. Unlike traditional stereo vision systems that utilize multiple cameras, this system is based on stereopsis with the integrated rotation of a single image sensor. By employing a circular constraint to direct the lateral motion of the sensor, the system generates visual parallax from multiple viewpoints.

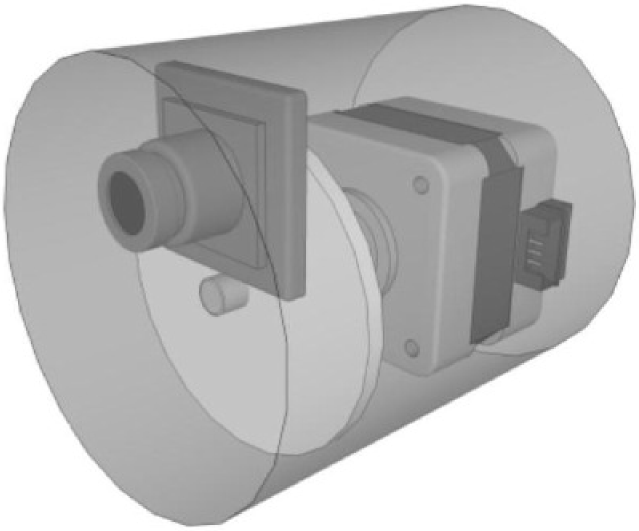


Figure 1: Schematic of the stereo from sensor rotation design. There is an offset r between the axis of rotation and the optical axis of the image sensor.

The theoretical construction of the imaging system with off-axis sensor rotation, detailing the geometry of the stereo configuration from coplanar circular motion is included in the article. Image rectification and feature extraction techniques for stereo matching and depth computation are also discussed, along with the development of a prototype device to demonstrate the feasibility of the proposed technique. Experimental results and performance evaluation has been provided to validate the effectiveness of the approach.

2. **Vision Measurement Scheme Using Single Camera Rotation by Shidu Dong (College of Computer Science and Engineering, Chongqing University of Technology,Chongqing)**

Article link - http://dx.doi.org/10.1155/2013/874084

This article has proposed a vision measurement scheme for estimating the distance or size of the object in static scene, using a single camera with 3-axis accelerometer sensor rotating around a fixed axis. As in the first article the camera does not rotate on a plane. Instead it rotates around a fixed axis which is not parallel to gravity.

Through the 3-axis accelerometer sensor, the slope angle of the camera relative to gravity direction has been obtained. The angle can uniquely determine the position of the camera if the camera is rotated around a fixed axis which is not parallel to gravity. Moreover, the relative position and orientation of the camera between two positions, one before and the other after camera rotation, has been determined by the rotation angle. Then, at the given two positions, assuming that the camera is calibrated, 3D coordinates of the points on objects has been extracted using the classical binocular view methods.

In their mathematical approach, first they have formulated the rotation matrix and translation vector from one coordinate system of the camera to another in terms of the rotation angle, using the readouts of the sensor. Then, with the camera calibration data and through coordinate system transformation, they have calculated the orientation and position of the rotation axis relative to camera coordinate system using the proposed method. It is also included how experimental results show the validity of proposed method.

3. **Depth perception in single rgb camera system using lens aperture and object size: a geometrical approach for depth estimation by P. J. A. Alphonse and K. V.Sriharsha**

Article link - https://link.springer.com/article/10.1007/s42452-021-04212-4

The approach proposed in this article leverages the focused portion of an object captured within a single image. Specifically, they have exploited the relationship between the object's distance from the camera lens center, the lens aperture radius, and the object's size in the image plane. By examining how the object distance varies with different aperture settings and maintaining a fixed focal length, they have proposed a method to establish a relationship that allows us to estimate depth solely from a single image.

The experimentation of the method has been done using a Nikon D5300 camera with a 50 mm prime lens set to infinite focus, enabling distance measurements for various aperture settings. The results shows an impressive accuracy of 98.1% at a 95% confidence level, underscoring its reliability and robustness in real-world applications. By offering accurate depth estimation using a single camera, this method presents a cost-effective and efficient solution for enhancing surveillance and security systems without the need for complex multi-camera setups.

Figure 2: Experimental Set-Up

2 Identification of Stake Holders

For our project focused on developing a depth camera system, stakeholders can span across various sectors, depending on the intended applications and the scale of the project. Here's the list of potential stakeholders that we studied.

1. Project Team Members: The undergraduate students who are directly involved in designing and building the depth camera system.

2. Academic Institutions: University and labs that may use the depth camera for research purposes, educational tools, or to support academic projects.

3. Investors and Funding Bodies: Organizations or individuals providing financial support for the project, interested in the potential return on investment or the project's success.

4. Technology Companies: Firms specializing in imaging technology, robotics, automation, or related fields that might use or integrate the depth camera into their products.

5. End Users: Depending on the application, this could include industries like manufacturing, automotive (for autonomous vehicles) or for applications like bin picking robots.

6. Regulatory Authorities: Government or industry bodies that regulate technology and safety standards, ensuring the product meets the required legal and compliance standards.

7. Suppliers and Partners: Entities supplying components or technology for the depth camera, as well as partners involved in the distribution or sale of the finished product.

8. Competitors: Other companies or research groups working on similar technology, as they may influence market dynamics and innovation strategies.

9. IT and Technical Support Teams: Responsible for maintaining the technologicalinfrastructure supporting the project, ensuring that the hardware and software components are operational and secure.

Understanding the needs and influences of these stakeholders, as mapped below, is crucial for the successful development and deployment of the depth camera system, as it can help in tailoring the product to meet diverse requirements and ensuring wide acceptance and adoption of the technology.

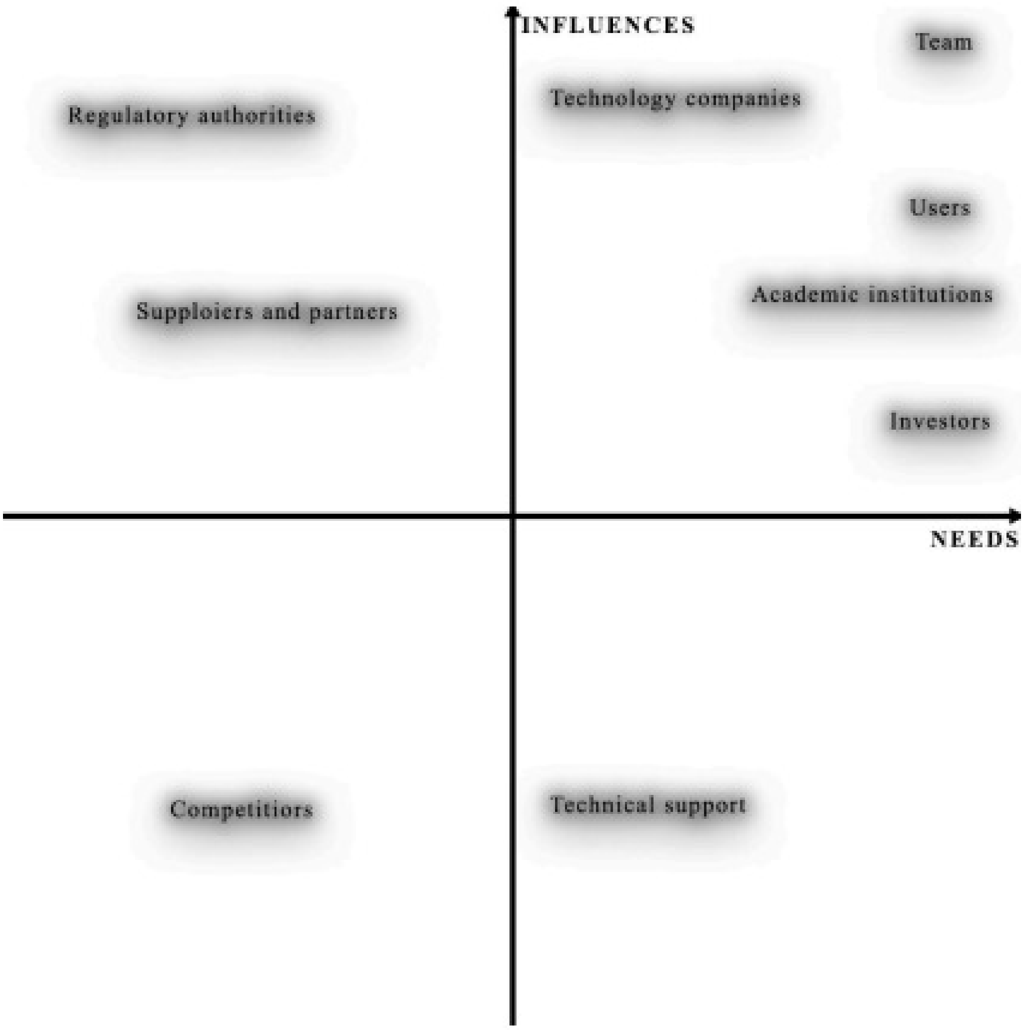


Figure 3: Stakeholder Map Diagram

3 Observe Users

In this section, use cases and user scenarios of Depth Camera is discussed.

- **Sony Depthsensing Solutions**:

Sony Depthsensing technology revolutionizes various industries by offering advanced depth sensing capabilities. Automotive applications leverage the technology for driver monitoring and intuitive gesture controls, enhancing safety and user experience. Additionally, Sony streamlines industrial processes with automated quality inspection and robotics perception, driving efficiency and innovation.

Youtube : DepthSense® CARlib for Automotive
Website : sony-depthsensing

- **PhotonicSens single lens 3D depth sensing**:

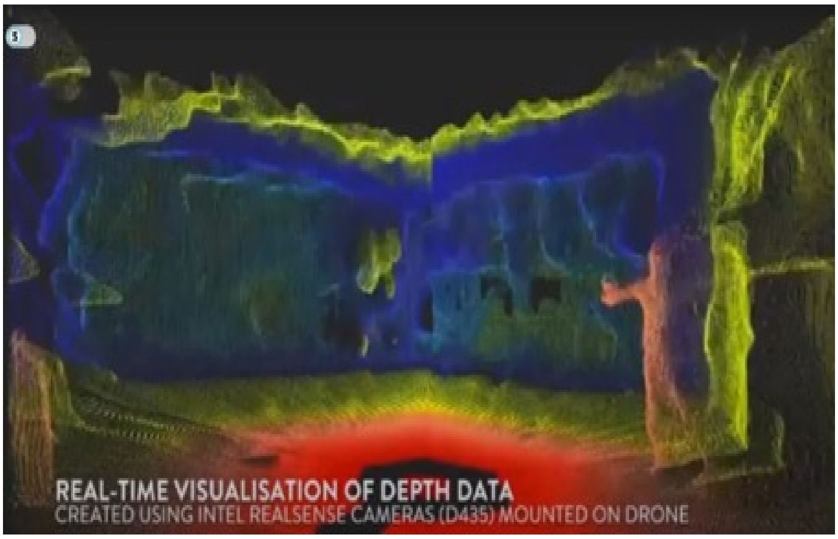
Built upon the innovative single lens apiCAM technology, their 3D depth camera reference designs deliver both RGB imagery and depth maps seamlessly in a single device, offering smartphone manufacturers unparalleled differentiation with advanced photographic capabilities, including a 1.4Mpx depth map. With the promise of the lowest component count, cost, and power consumption, coupled with superior performance in any environment, photonicSENS aims to set a new standard in 3D sensing technology.

Website: single lens 3D depth sensing solution
YouTube : photonicSENS

- **Depth data from Intel® RealSense ™ Depth Cameras**:

Depth data from Intel® RealSense ™ Depth Cameras enhances applications across industries, enabling precise 3D reconstruction, object tracking, gesture recognition, navigation in robotics. Below shows Depth data from RealSense ™ cameras mounted on drone.

YouTube: Depth Map for autonomous drones
Website: Depth Camera D400 Series



4 Need list

In a typical depth measuring system, requirements which are expected by users are as follows.

1. Accurate depth measurements across different ranges and environments for reliable performance.
2. Consistent and repeatable depth measurements to ensure precision in various applications.
3. Effective operation over a wide range of distances, from close-range object detection to long-range mapping.
4. Fast depth estimation to enable quick decision-making and response, especially in real-time applications like robotics and autonomous vehicles.
5. Robustness against environmental factors such as lighting conditions, surface reflectivity, and occlusions to maintain consistent performance.
6. Portability and compact size, allowing for lightweight and easy integration into devices or systems.
7. Cost-effectiveness, offering good value for money by balancing performance with affordability.
8. Ease of integration into existing hardware or software setups, with compatibility with common interfaces and programming languages.
9. Flexibility to adapt to different use cases and environments, with configurable options and customizable parameters to meet specific needs.

Apart from providing these requirements, our product is unique because it uses a single camera for depth measuring. Most of the commercially available depth measuring systems use multiple cameras. Even though there has been research conducted on depth measuring using a single camera, a practical implementation has not been done. Through our project, we provide the users with the uniqueness of a depth measuring system which uses a single camera.

4.1 Applications

1. Can be optimized for bin-picking robots to measure necessary distances
2. Can be used as an efficient solution for enhancing surveillance and security systems without the need for complex multi-camera setups.
3. Can be used to enable robots to perceive and interact with their surroundings, aiding in tasks such as navigation and object manipulation.
4. 3D scanning and modelling applications, including architectural design, industrial inspection, and cultural heritage preservation, rely on depth measuring systems for precise 3D reconstruction.
5. In applications such as environmental monitoring applications such as water level measurement, terrain mapping, and landslide detection.
6. In industrial automation applications utilize depth measuring systems for tasks such as object detection, quality control, and robotic assembly in manufacturing environments.
7. In gesture recognition technologies which leverage depth measuring systems to enable intuitive interaction with devices and interfaces by recognizing human gestures.

5 Stimulate Ideas

The process of stimulating ideas for our depth measurement system project was crucial to developing a robust and innovative solution. Our approach involved several targeted methods to generate and refine ideas, ensuring we addressed the project's specific needs and challenges effectively.

- **Brainstorming Sessions**

  We initiated the idea generation phase with intensive brainstorming sessions, involving all team members. These sessions focused on our core tasks: capturing photos, camera calibration, object detection, feature matching, and depth calculation. One significant idea was to use chessboard images (9x6) for accurate camera calibration, leveraging our custom **cameracalibrate** function. Additionally, we discussed integrating the YOLOV8 object detection model, trained with a custom dataset from Roboflow, to improve object detection accuracy.

- **Research and Benchmarking**

  Conducting thorough research on existing depth measurement systems and related technologies was a pivotal step. We analyzed current solutions, focusing on their application of computer vision techniques, object detection algorithms, and hardware integration. Benchmarking against industry standards allowed us to identify potential areas for innovation. For instance, we recognized the value of using a stepper motor mechanism controlled by an ATmega microcontroller for precise camera rotation, enhancing the accuracy of depth measurement.

- **User Feedback and Interviews**

  Engaging with potential users through feedback sessions and interviews provided invaluable insights. Users highlighted the need for a portable, cost-effective, and accurate depth measurement system. Their feedback guided our brainstorming sessions, emphasizing the importance of robust calibration and reliable feature matching functions. This user-centered approach ensured that our solutions were aligned with real-world needs and preferences.

- **Scenario Analysis**

  We developed detailed usage scenarios to envision how our depth measurement system would function in various real-world environments. Scenarios included diverse lighting conditions, different object types, and various user interactions. This analysis helped us anticipate potential challenges and refine our ideas. For example, we considered enhancing our image processing algorithms to maintain accuracy under varying lighting conditions, ensuring consistent performance.

  In conclusion, the "Stimulate Ideas" phase for our depth measurement system project was a dynamic and collaborative effort. By leveraging a variety of targeted techniques and fostering a culture of innovation, we generated a rich pool of ideas that are driving the success of our project. This comprehensive approach ensured that our solutions were not only innovative but also practical and user-centric.

6 Develop Concepts (Conceptual Designs)

6.1 Conceptual Design 1

Unlike traditional stereo vision systems that utilize multiple cameras, this system is based on stereopsis with the integrated rotation of a single image sensor. By employing a circular constraint to direct the lateral motion of the sensor, the system generates visual parallax from multiple viewpoints.

A rotating disk containing the camera sensor will be rotated around a fixed axis. Two positions of the camera which are 180 degrees apart will be used in the theoretical construction of the imaging system. Disk will be rotated using a servo motor at a certain velocity, automatically. An Nvidia Jetson Nano will be used for image processing and the functioning of the electronic circuit will be done using an Atmega328p microprocessor.

In the theoretical construction of the imaging system with off-axis sensor rotation, the geometry of the stereo configuration from coplanar circular motion, image rectification, feature extraction techniques for stereo matching and depth computation are used.

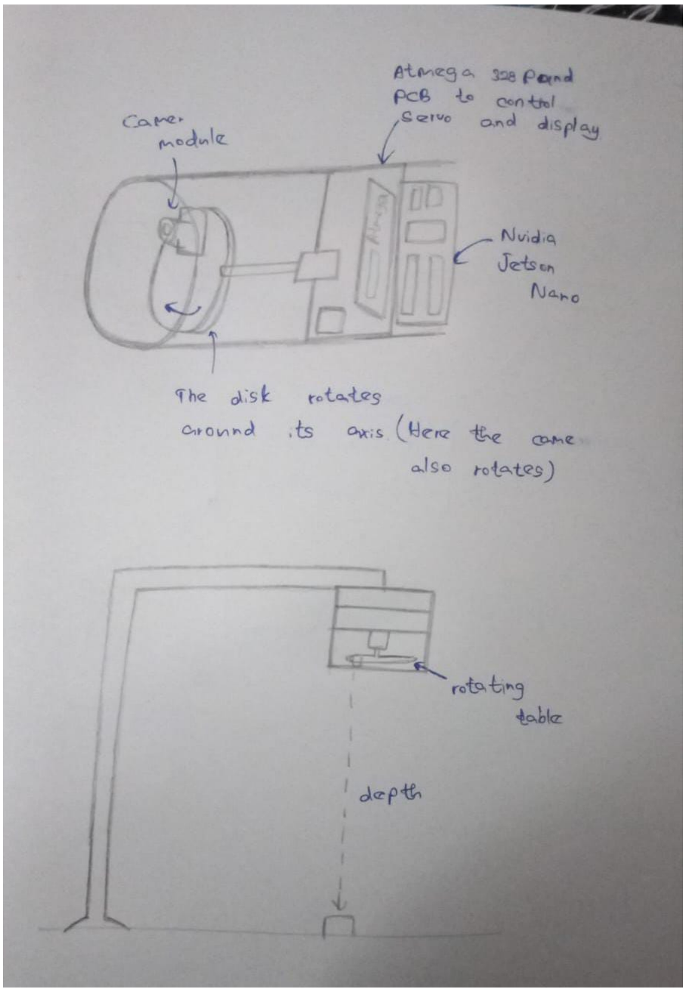


Figure 4: Conceptual design 1

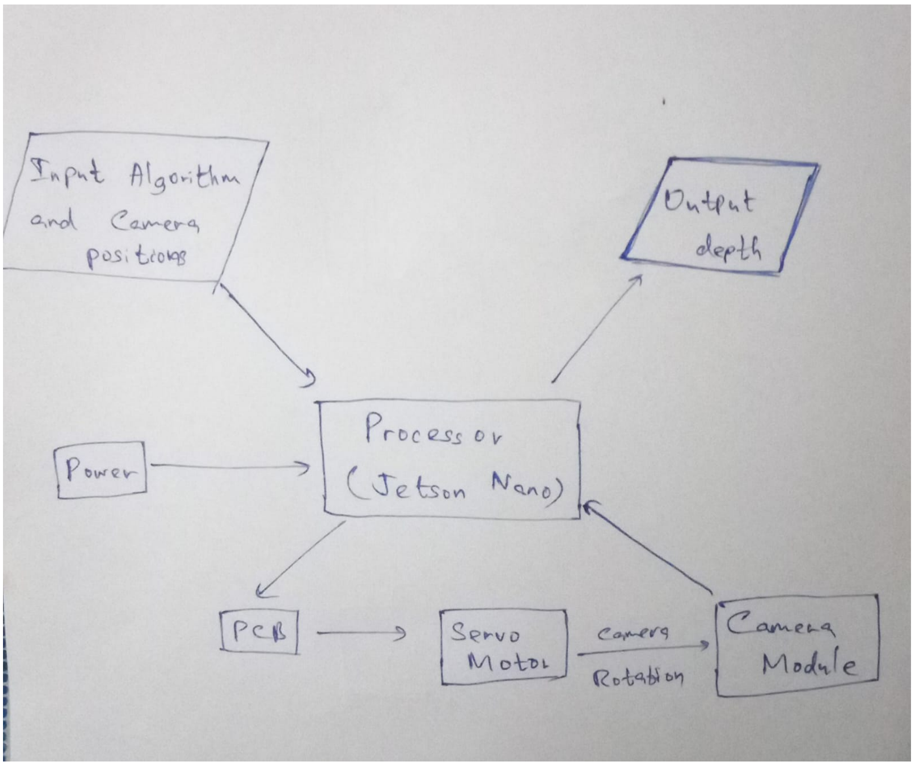


Figure 5: Functional block diagram for conceptual design

6.2 Conceptual Design 2

This is a vision measurement scheme for estimating the distance or size of the object in a static scene, using a single camera with a 3-axis accelerometer sensor or an encoder rotating around a fixed axis. As in the first conceptual design, the camera does not rotate on a plane. Instead, it rotates around a fixed axis which is not parallel to gravity.

Through the 3-axis accelerometer sensor, the slope angle of the camera relative to gravity direction has been obtained. The angle can uniquely determine the position of the camera if the camera is rotated around a fixed axis which is not parallel to gravity. Moreover, the relative position and orientation of the camera between two positions, one before and the other after camera rotation, has been determined by the rotation angle. Then, at the given two positions, assuming that the camera is calibrated, 3D coordinates of the points on objects have been extracted using the classical binocular view methods.

The rotation of the camera can be done using a servo motor. Since this method will demand a high image processing power a Raspberry Pi module will not be sufficient. We are proposing to use a Jetson Nano, which has graphical processing capabilities. Atmega328p microprocessor can be used to control the electronic circuits which facilitate the rotation of the camera.

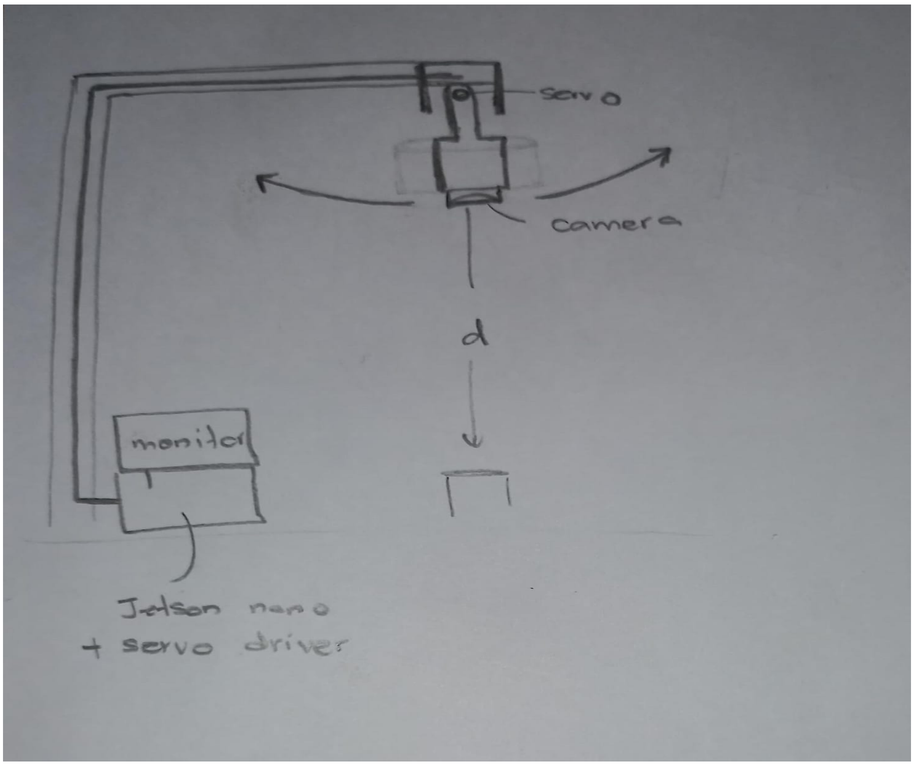


Figure 6: Conceptual design 2

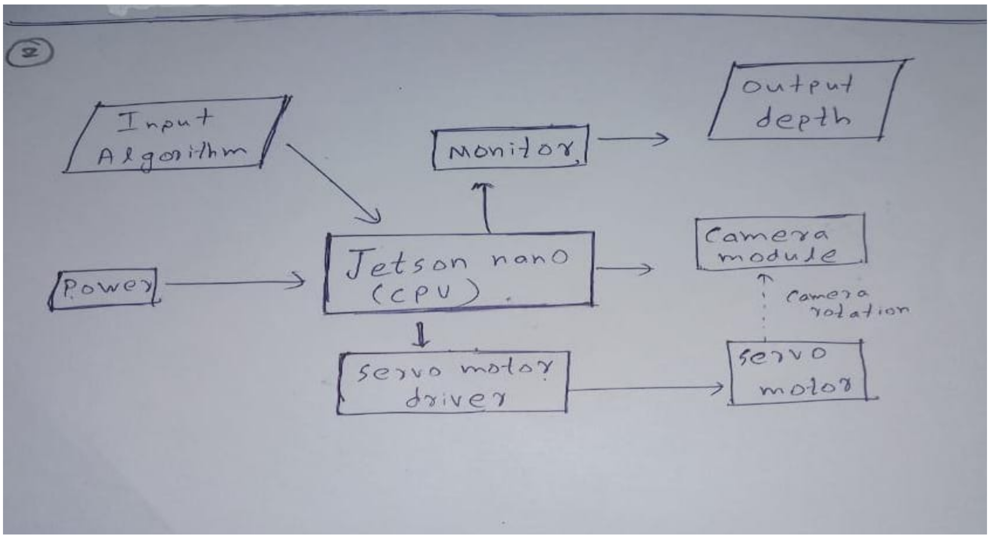


Figure 7: Functional block diagram for conceptual design 2

6.3 Conceptual Design 3

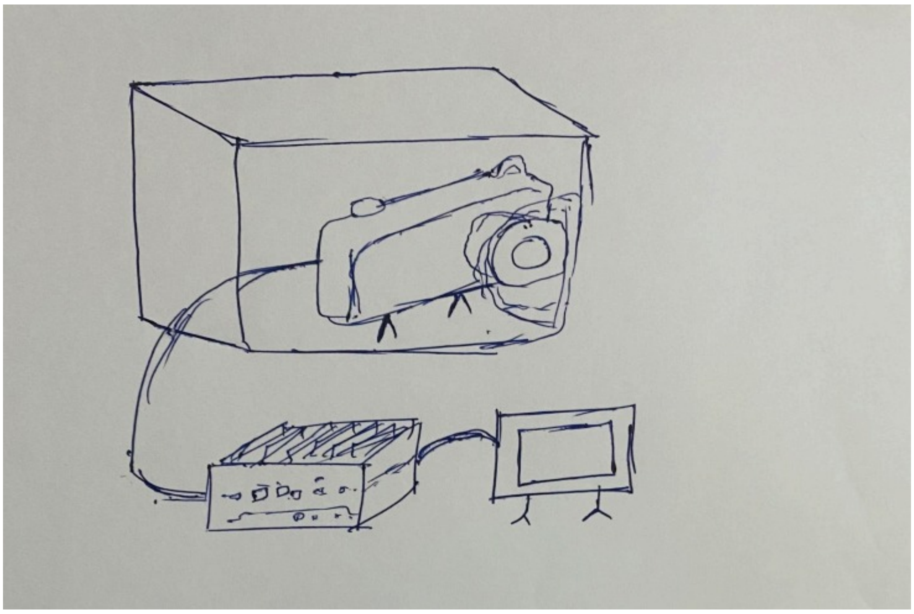


Figure 8: Conceptual design 3

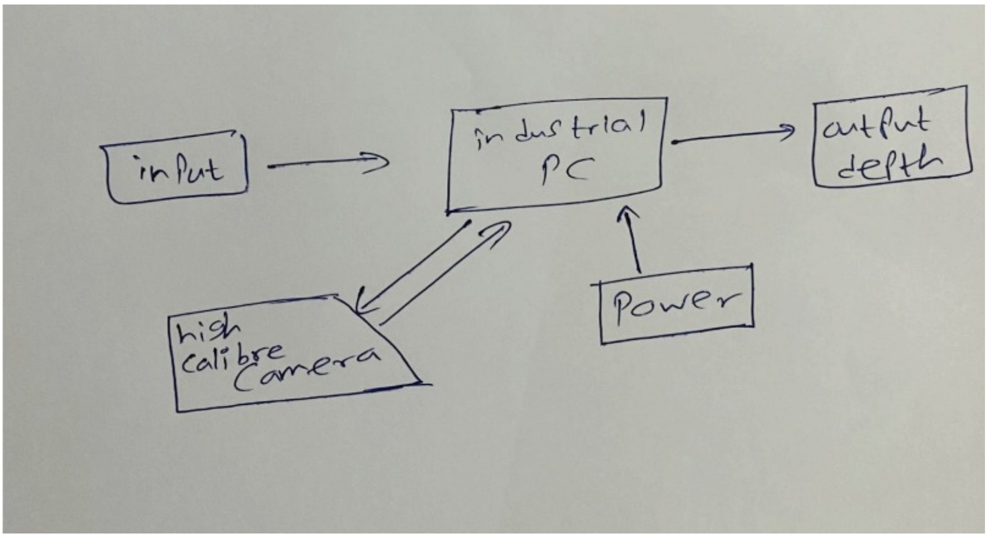


Figure 9: Functional block diagram for conceptual design 3

The approach proposed in this design leverages the focused portion of an object captured within a single image. Specifically, in this method the relationship between the object's distance from the camera lens centre, the lens aperture radius, and the object's size in the image plane is exploited. By examining how the object distance varies with different aperture settings and maintaining a fixed focal length, a method to establish a relationship that allows us to estimate depth solely from a single image can be proposed.

But the main drawback of this method is that we will need a high-end camera with different aperture settings like Nikon D5300 which we can't afford. Also, the complexity of the algorithms and image processing part is also high and we will need a more performance processor. Apart from that this is an efficient solution which does not use typical multi-camera setups and it can be used for many applications.

6.4 Conceptual Design 4

This design's main application will be measuring depth for bin-picking robots. The camera setup is integrated into the robot arm and the movement of the camera will be provided by the movement of the robot arm. The main drawback is this approach is only restricted to robot arms.

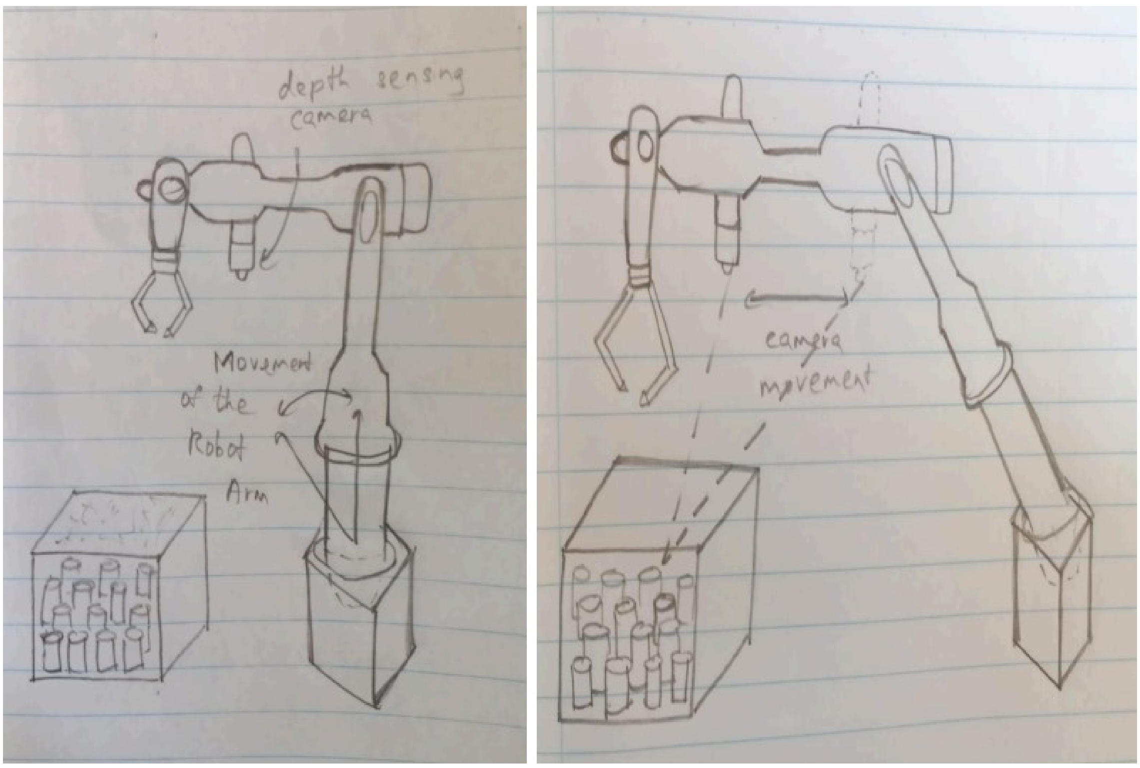


Figure 10: Conceptual design 4

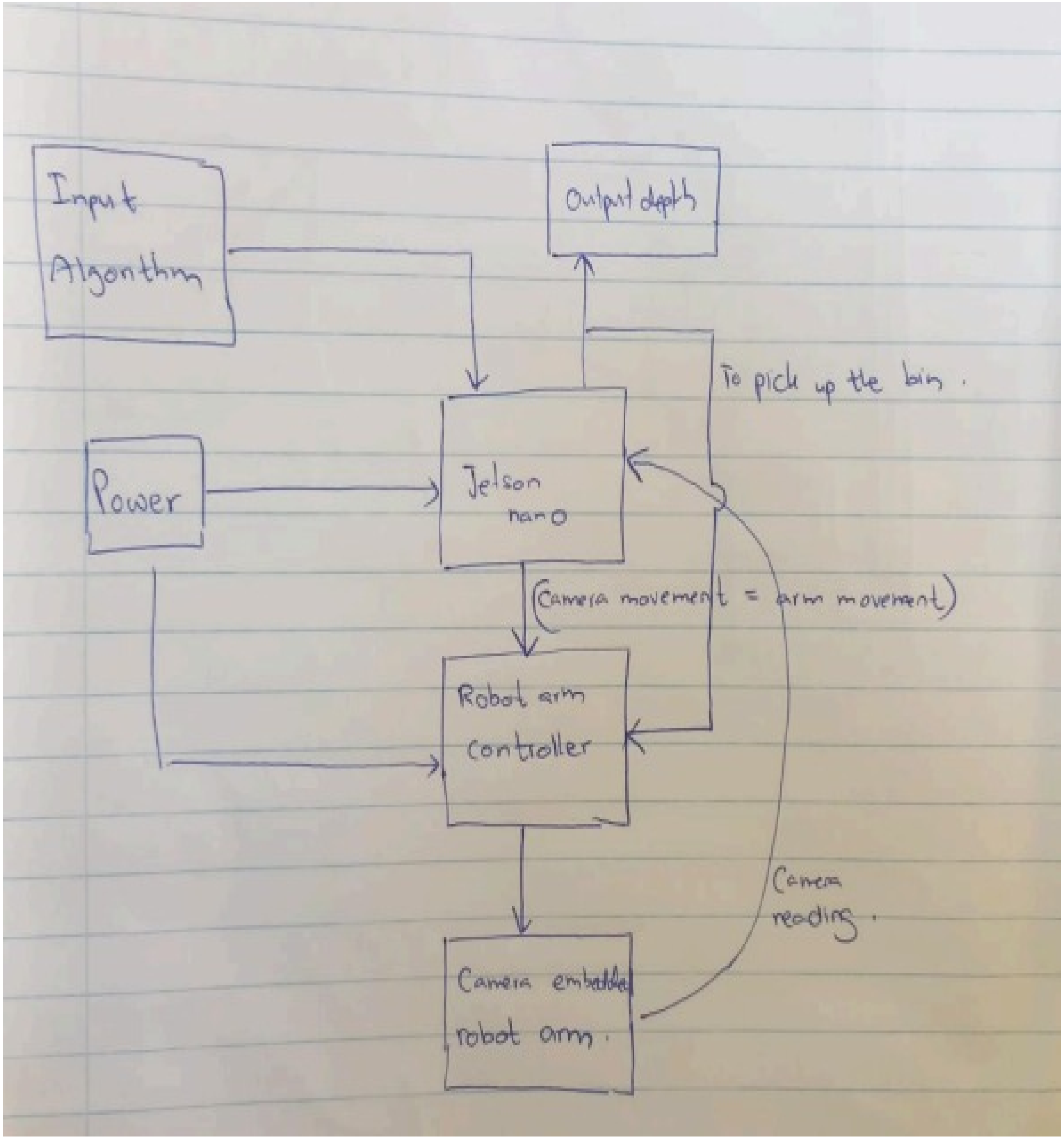


Figure 11: Functional block diagram for conceptual design 4

7 Evaluation of Conceptual Design

7.1 Evaluation Criteria

Enclosure Design Criteria:

1. Functionality: How well does the design support the main functionalities?
2. Aesthetics: How much eye-catching and overall appeal of the user?
3. Heat dissipation: How much heat is generated and how well it has been managed?
4. Assembly and serviceability: How easily is the assembly and disassembly is done?
5. Ergonomics: How well does the design 1t in the user's hand and allow easy interaction?
6. Durability: How well does the design withstand impacts and environmental conditions?
7. Simplicity

Functional block diagram criteria:

1. Functionality: How well does the circuit design meet functional requirements?
2. User experience: How intuitive and user-friendly is the interaction?
3. Manufacturing feasibility: Evaluate the feasibility of manufacturing the design
4. . Cost: Evaluate the overall cost-effectiveness of the provided functionality
5. Performance: Evaluate the signal quality, resolution and bandwidth range.
6. Future-proofing: To what extent does the design allow for easy replacement or upgrade of individual components?
7. Power Efficiency: How effectively does the device manage power consumption?

7.2 Complete Comparison

		Conceptual design 1	Conceptual design 2	Conceptual design 3	Conceptual design 4
Newly added features		Jetson Nano Portability Display to output the Depth	Jetson Nano Robustness High Computational Power	Accuracy Easy Design Less Hardware Portability	Directly integrated to the robot arm Complex High computational power
Removed features		Robustness Cost effectiveness	Portability Display	Controller Circuit Robustness	Not a separate unit Portability
Enclosure design criteria comparison	Functionality	9	9	8	7
	Aesthetics	8	7	5	7
	Heat dissipation	9	8	7	6
	Assembly and serviceability	8	6	5	6
	Ergonomics	8	9	9	8
	Simplicity	7	7	9	5
	Durability	9	8	9	9
Functiona l block design criteria comparis on	Functionality	8	7	8	7
	User experience	9	8	9	9
	Manufacturing feasibility	9	7	7	7
	Cost	7	8	5	5
	Performance	9	8	8	8
	Future proofing	9	8	8	7
	Power	8	8	6	5
Total		117	108	103	96

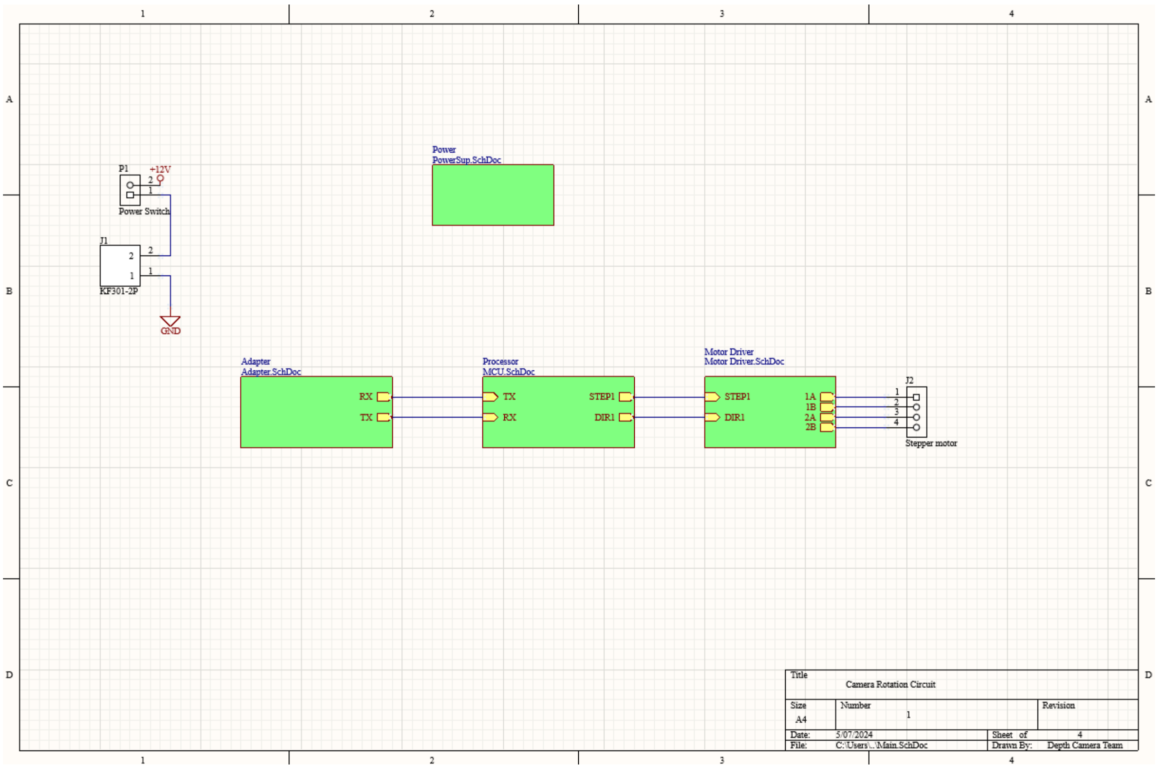
Based on the evaluation criteria, Conceptual Design One was selected for the project. Additionally, it was decided to use a laptop as the processor instead of the Jetson Nano due to budget constraints. Consequently, several adjustments were made to the conceptual design, which will be comprehensively described in the Comprehensive Design Report.

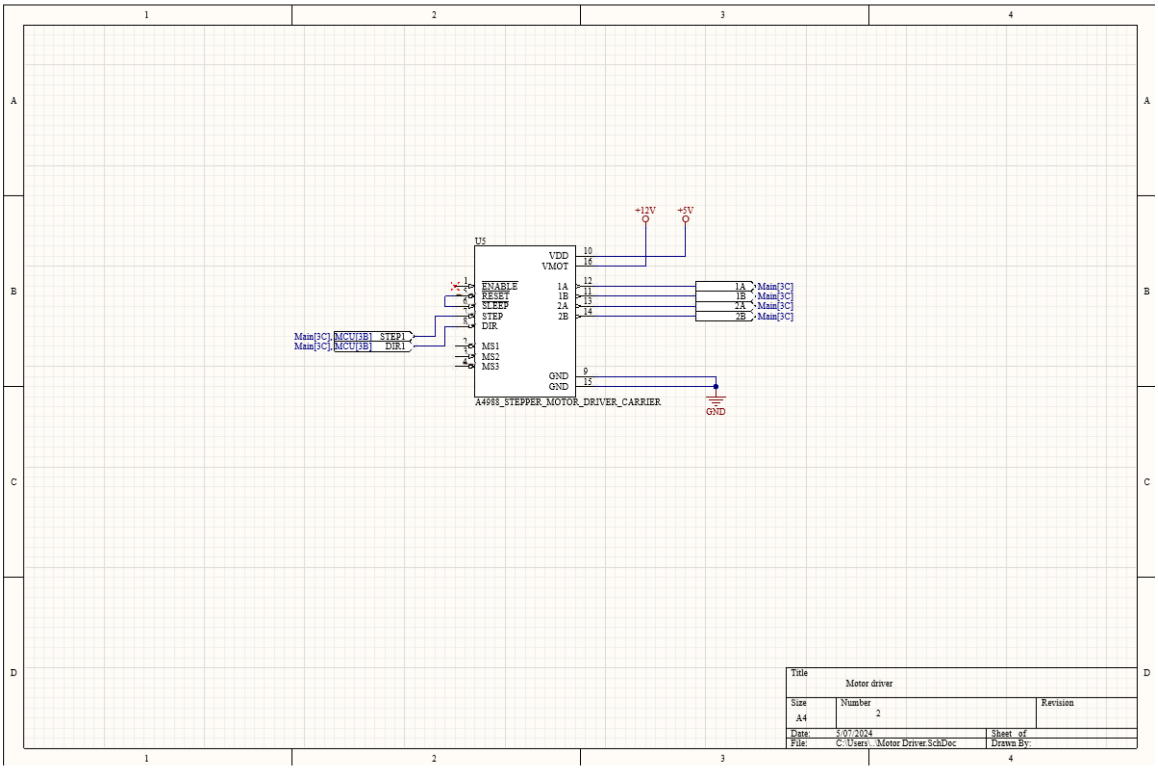
8 Schematic Design

According to our final chosen design, we needed a PCB that can rotate the servo motor based on commands from the computer. We decided to use a USB Type-C adapter to connect the PCB to the computer and an Atmega 328p chip for central processing, while using an A4988 stepper motor driver carrier to control the servo.

For simplicity, we divided the schematic into four main modules: the Motor Driver, Microcontroller Unit, Adapter Unit, and Power Supply. We carefully designed each module using our prior knowledge and what we learned during the Electronic Design Realization module.

To power the circuit, we decided to use a direct 12V DC power supply and employed a voltage regulator to obtain a 5V DC output for the pins requiring 5V. In the design, we also included a main switch to control when the device is powered.

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RESET
SLEEP
STEP
DIR
MS1
MS2
MS3
VDD
VMOT
1A
1B
2A
2B
GND
GND
+12V
+5V
GND
Main[3C]
Main[3C], MCU[3B] STEP1
Main[3C], MCU[3B] DIR1
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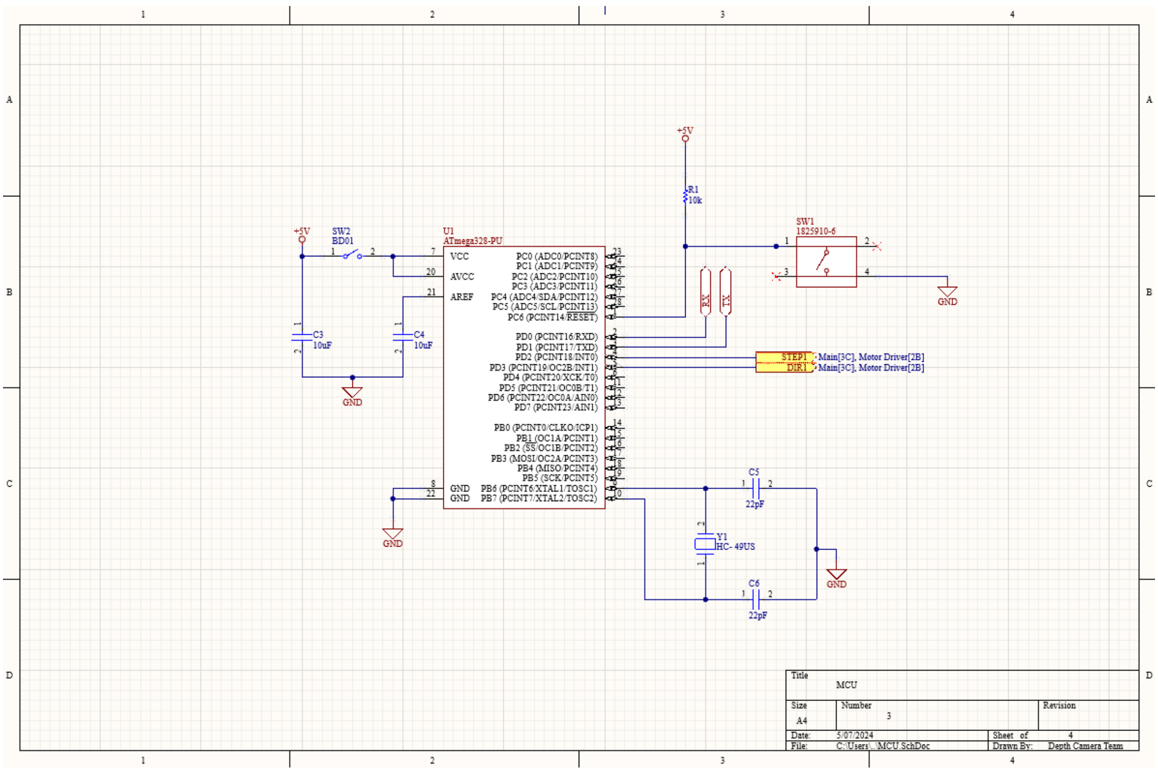
U1
ATmega328-PU
VCC
AVCC
AREF
GND
GND
PC0 (ADC0/PCINT8)
PC1 (ADC1/PCINT9)
PC2 (ADC2/PCINT10)
PC3 (ADC3/PCINT11)
PC4 (ADC4/SDA/PCINT12)
PC5 (ADC5/SCL/PCINT13)
PC6 (PCINT14/RESET)
PD0 (PCINT16/RXD)
PD1 (PCINT17/TXD)
PD2 (PCINT18/INT0)
PD3 (PCINT19/OC2B/INT1)
PD4 (PCINT20/XCK/T0)
PD5 (PCINT21/OC0B/T1)
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PD7 (PCINT23/AIN1)
PB0 (PCINT0/CLKO/ICP1)
PB1 (OC1A/PCINT1)
PB2 (SS/OC1B/PCINT2)
PB3 (MOSI/OC2A/PCINT3)
PB4 (MISO/PCINT4)
PB5 (SCK/PCINT5)
PB6 (PCINT6/XTAL1/TOSC1)
PB7 (PCINT7/XTAL2/TOSC2)
+5V
SW2
BD01
C3
10uF
C4
10uF
GND
R1
10k
SW1
1825910-6
RX
TX
STEP1 Main[3C], Motor Driver[2B]
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C6
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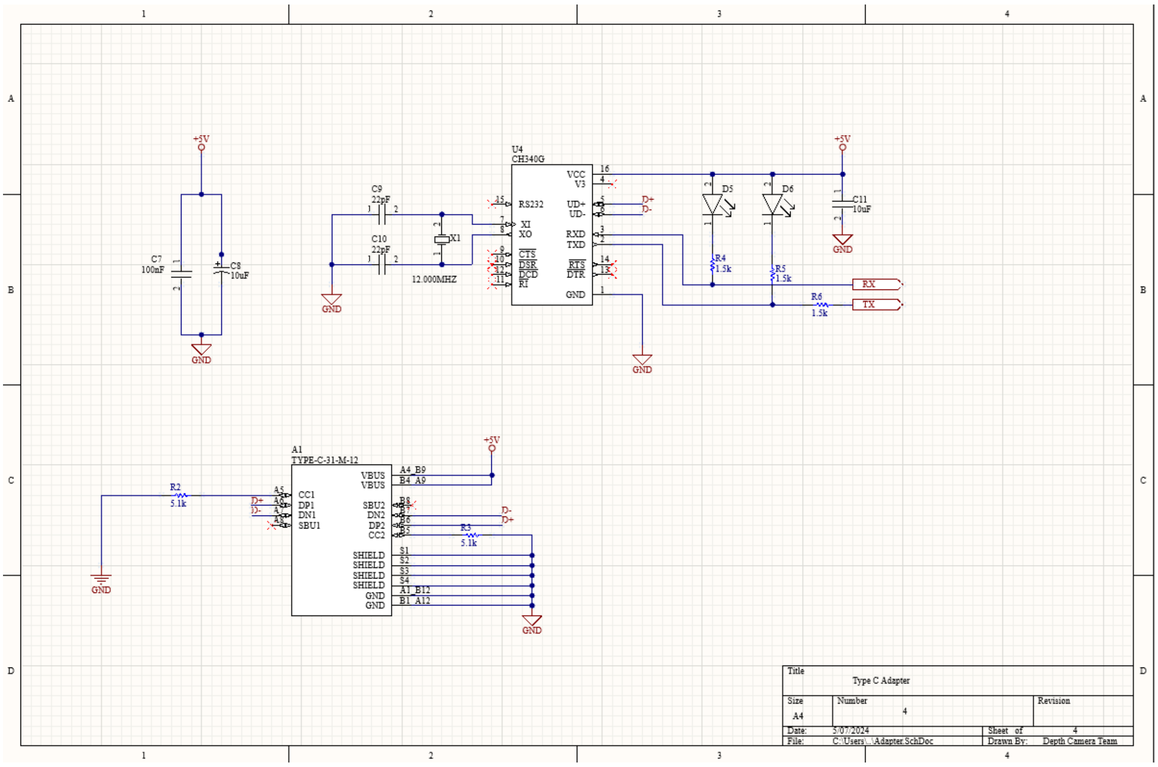
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V3
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UD-
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GND
C9
22pF
C10
22pF
X1
12.000MHZ
C7
100nF
C8
10uF
C11
10uF
D5
D6
R4
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R5
1.5k
R6
1.5k
RX
TX
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GND
D+
D-
A1
TYPE-C-31-M-12
VBUS
CC1
DP1
DN1
SBU1
SBU2
DN2
DP2
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SHIELD
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R3
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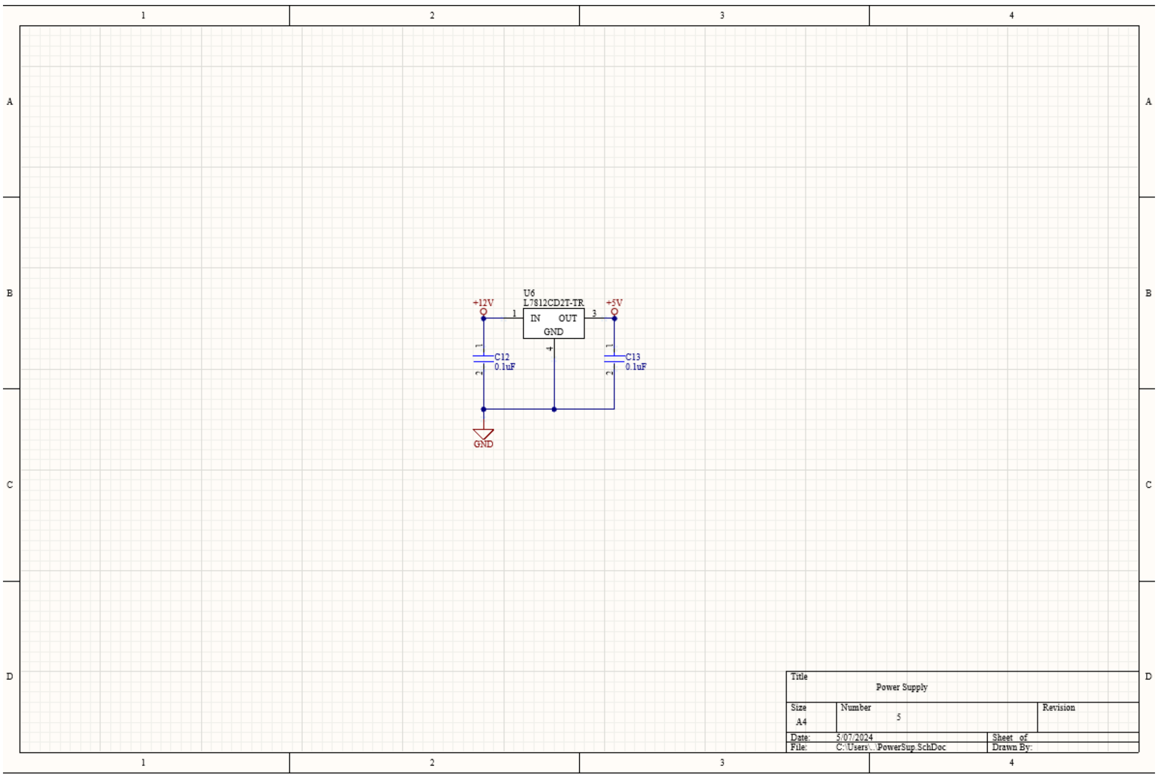
Drawn By:
Depth Camera Team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+5V
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Power Supply
Size
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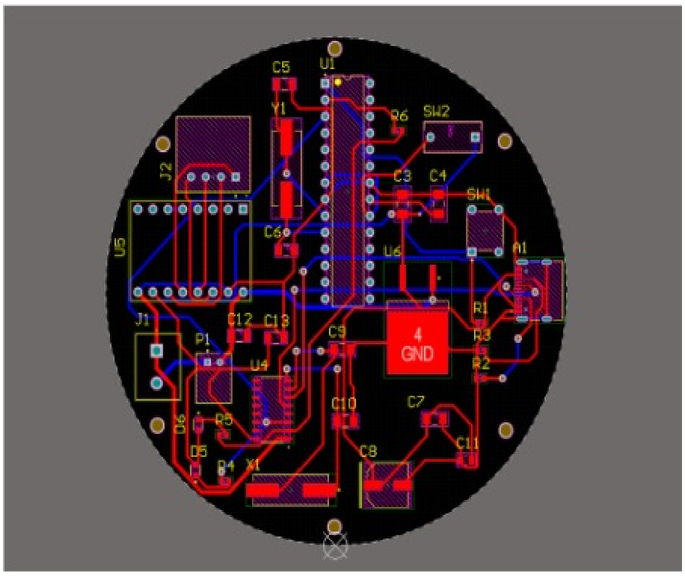
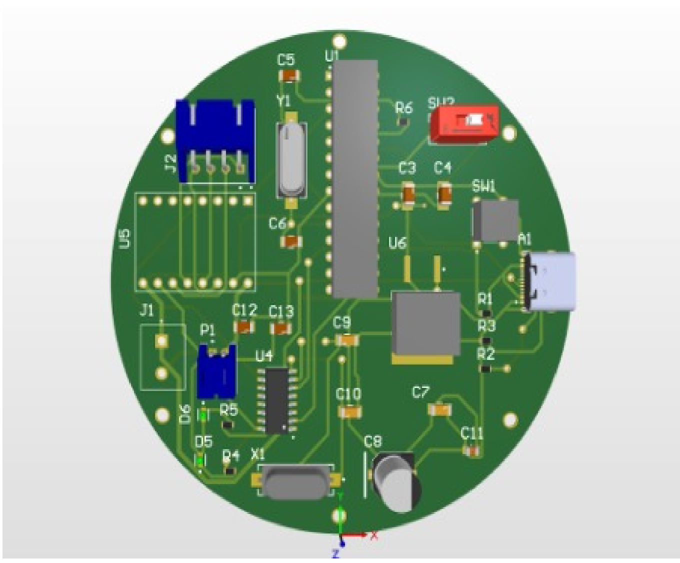
Drawn By:

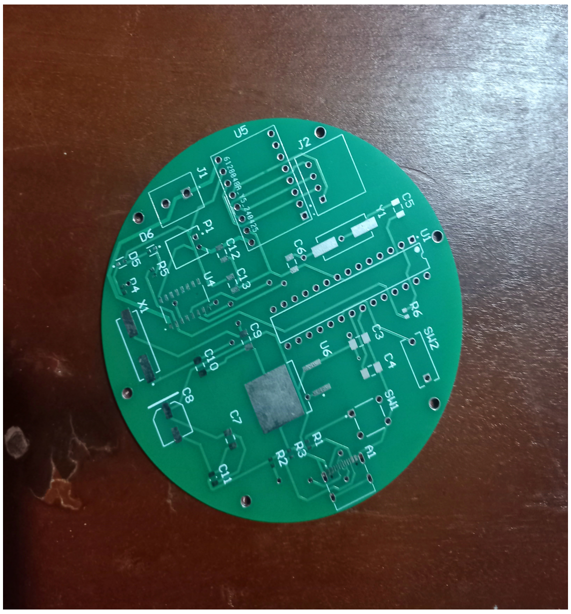
9 PCB Design

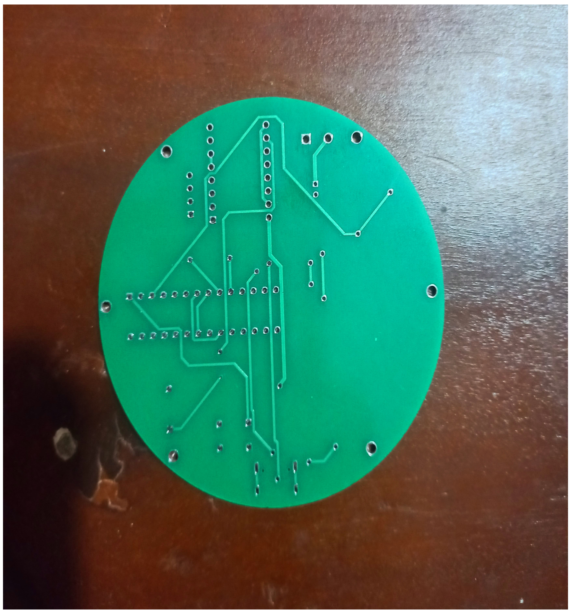
Using the above schematic, we designed a PCB that will fit to be implemented as a rotating sensor. We carefully chose the dimensions and shape for the PCB. We also carefully planned the power supply method for the PCB. Since the stepper motor driver needs a 12V power supply, we designed the power module and the paths to be suitable to carry the needed voltage. The enclosure will have a barrel jack, and from that, the power will be supplied to the designated headers on the PCB.

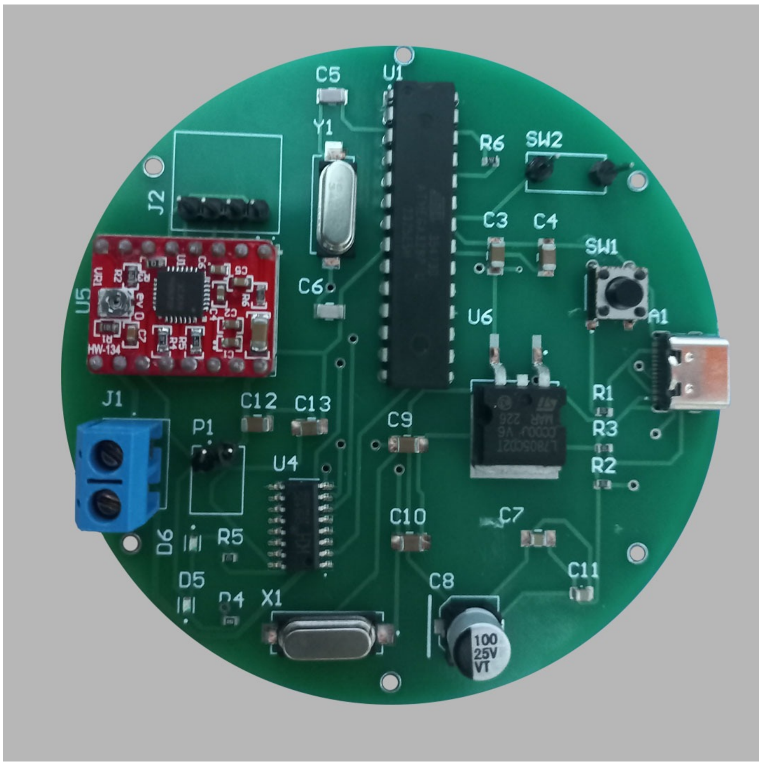
We also implemented the USB-C port and its connection such that we can control the rotation of the stepper motor from our PC. We placed mounting holes on the PCB to support the structure during movements.







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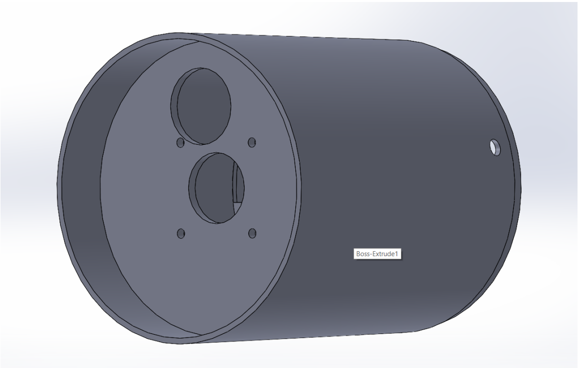
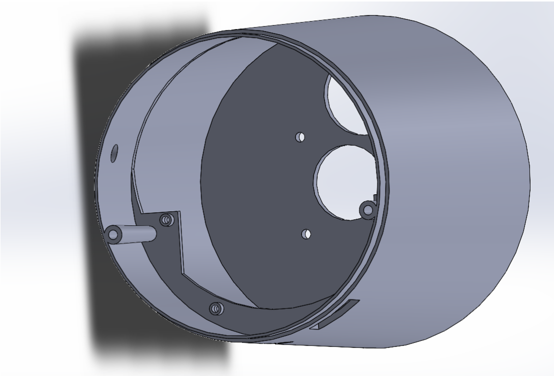
R1
R3
P1
U4
R2
C10
C7
D6
R5
C11
D5
D4
X1
C8
100
25V
VT

10 Solid Work Design

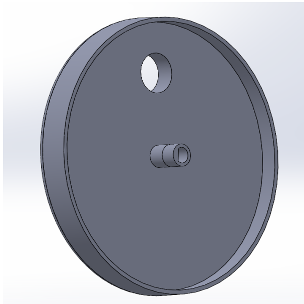
The enclosure was designed in SolidWorks utilizing fundamental engineering principles. We adhered to best practices, including maintaining an organized model tree, ensuring sketches were fully defined, incorporating appropriate draft angles for moldability, and adding fillets. A detailed analysis of how basic solid modeling principles were applied in the enclosure design is included in the appendix.



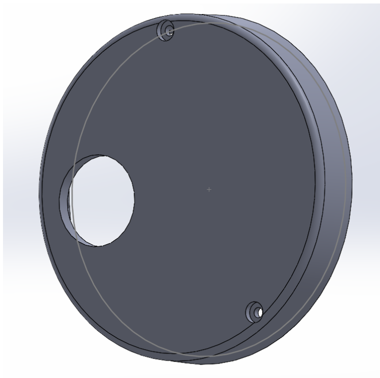
This is the SolidWorks model of the main body of the enclosure. A cylindrical shape was selected for its compatibility with the rotational mechanism of the camera, ensuring smooth and efficient movement. The cylindrical design also provides optimal space utilization, facilitating the integration of the PCB and other internal components. Additionally, this shape enhances the overall structural integrity and aesthetic appeal of the enclosure. The model also includes a visible compartment for the stepper motor holder, and an additional circular cutout has been made for effective wire management, further improving the design's functionality and ease of assembly.



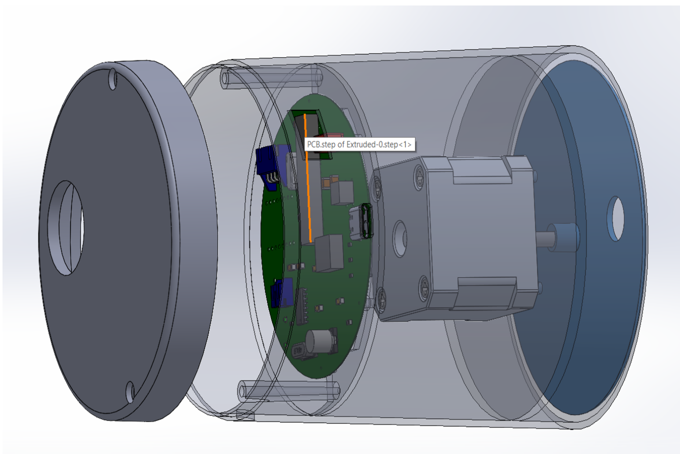
This is the view from the opposite side of the main body. On this side, the back lid will be attached, providing a secure closure for the enclosure. Additionally, the PCB holder is visible, demonstrating the well-designed placement and support structure for the internal electronics. This arrangement ensures the PCB remains securely in place, facilitating effective integration and protection of the electronic components.



This is the rotating component designed to interface with the stepper motor, to which the camera will be mounted. This part ensures precise rotational movement, critical for the accurate positioning and operation of the camera. The design includes secure attachment points for both the stepper motor and the camera, ensuring stability and reliability during operation.

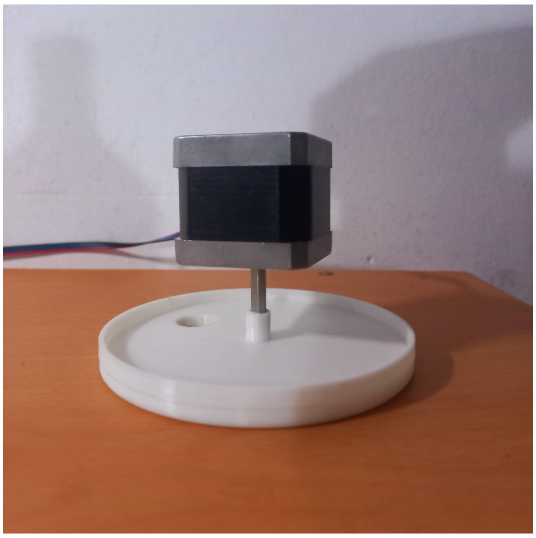


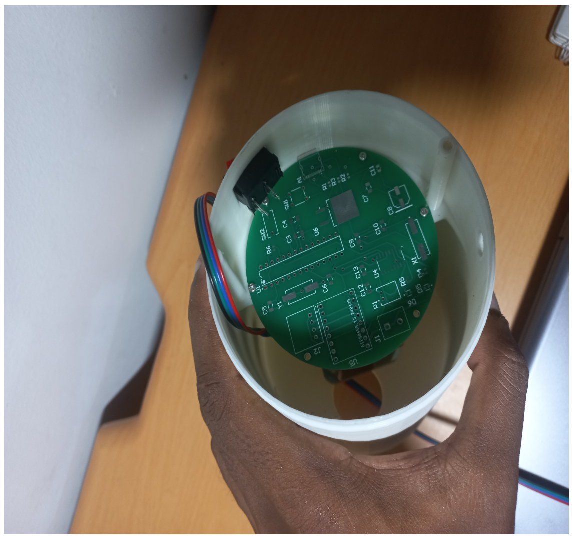
This is the back lid of the enclosure. It features a circular hole for wire management, allowing the camera wires to be routed externally and connected to the PC, which serves as the processor for this project. This design ensures organized cable routing and secure connections, contributing to the overall efficiency and functionality of the system.



This is the complete design with all three parts integrated. The assembly showcases the main body, the rotating component, and the back lid working together seamlessly. The PCB and the stepper motor are also clearly visible, highlighting their well-considered placement and integration within the enclosure. This comprehensive design ensures that all components function cohesively, providing a robust and efficient solution for the depth camera system.

The following images showcase the actual 3D printed parts, confirming the accuracy and effectiveness of the design. As evident in the images, the mentioned features, such as the cylindrical shape, the stepper motor holder compartment, the circular cutout for wire management, and the integration of the PCB, are clearly visible. These printed parts validate the design's functionality and adherence to the intended specifications, demonstrating the successful translation of the SolidWorks model into physical components.



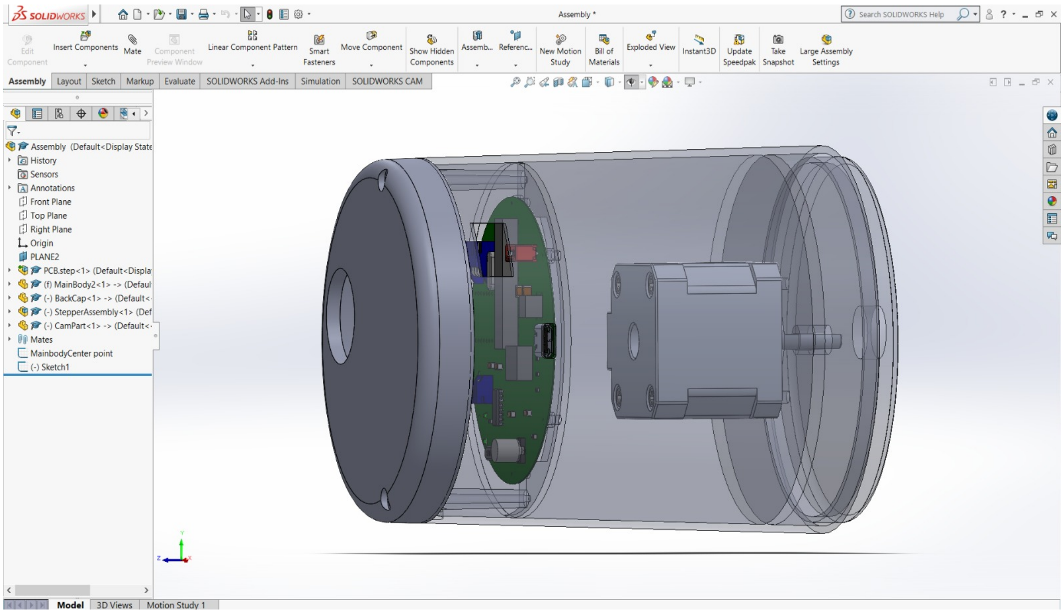


Progress So far...

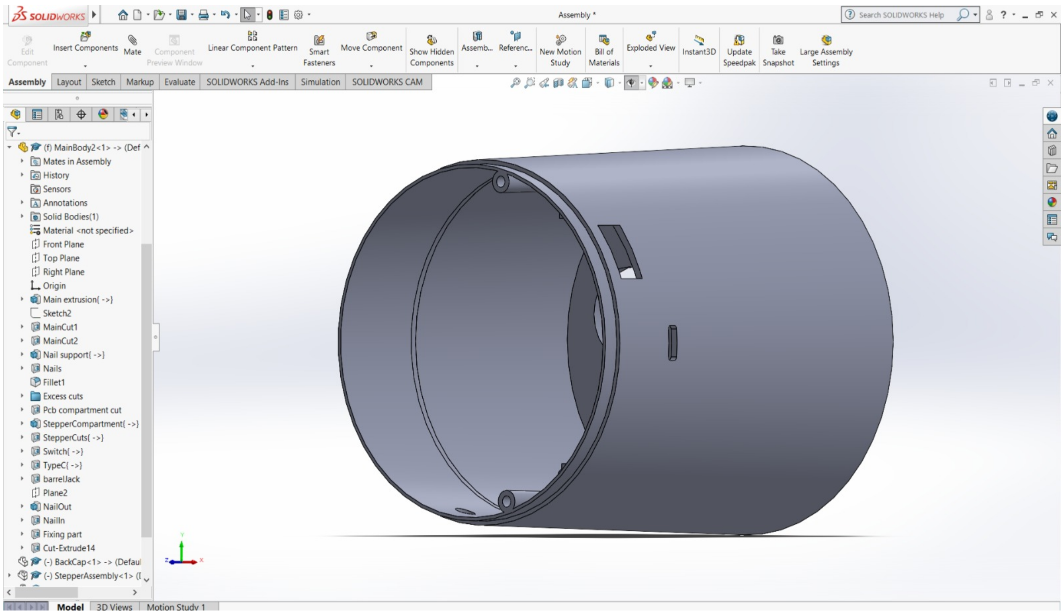
We have successfully deployed the complete model and obtained accurate results by taking pictures in two positions using a phone. All the codes have been finalized, and a detailed report on the models used will be discussed in the Comprehensive Design Report.

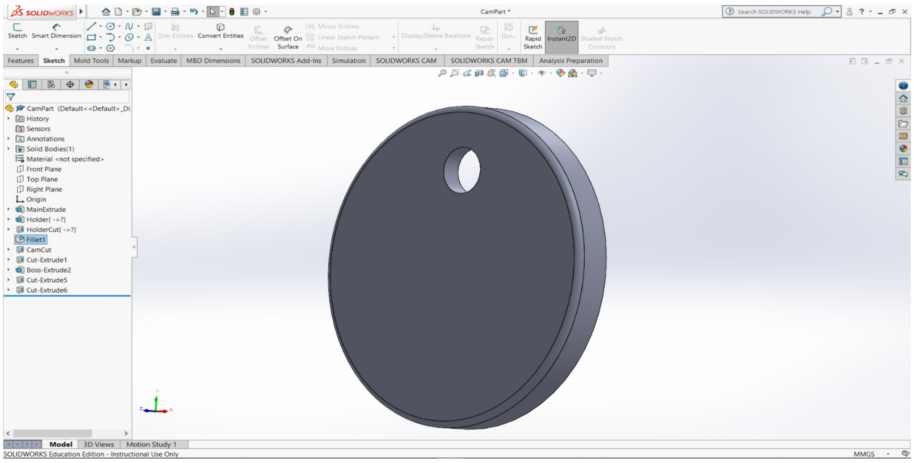
11 Appendix

1. **Final Design of Depth Camera enclosure**

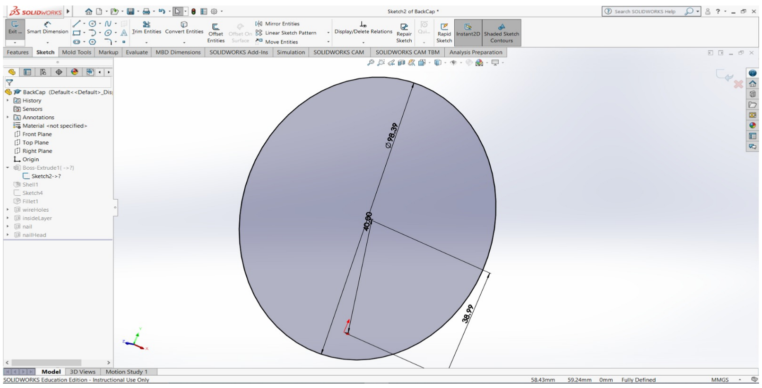


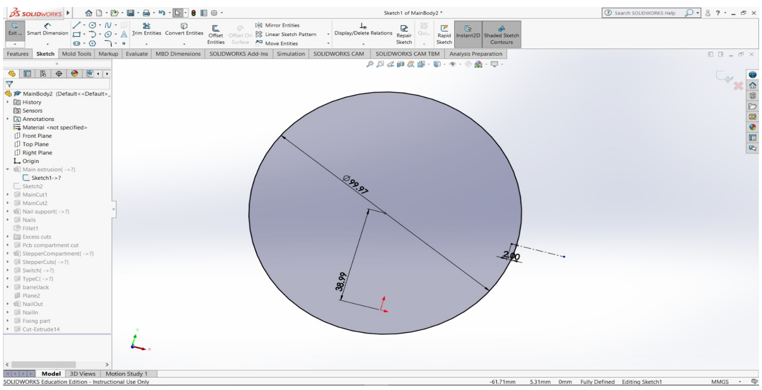
2. **Organised model Tree**



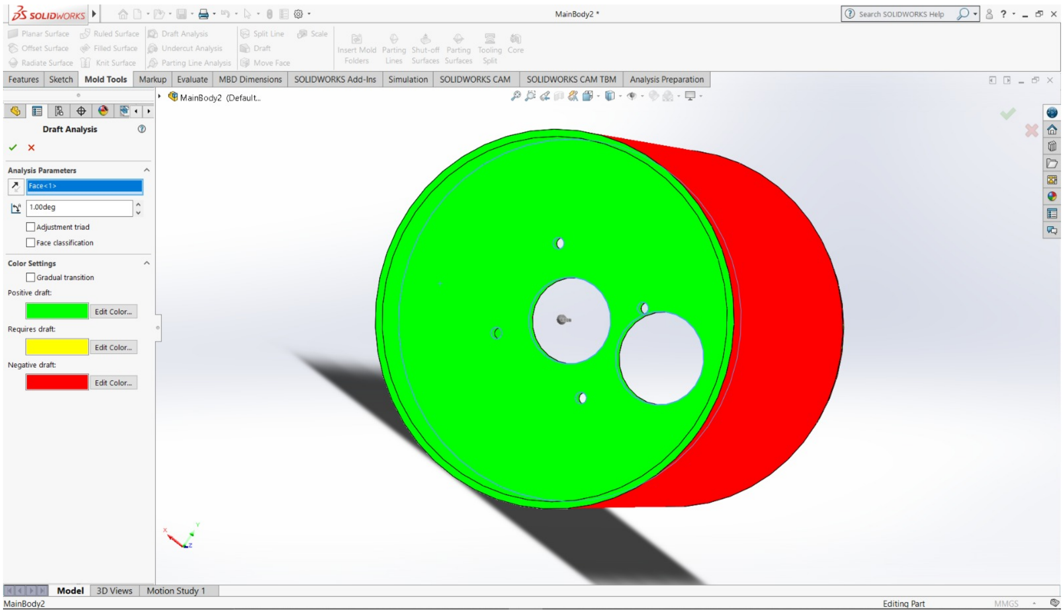


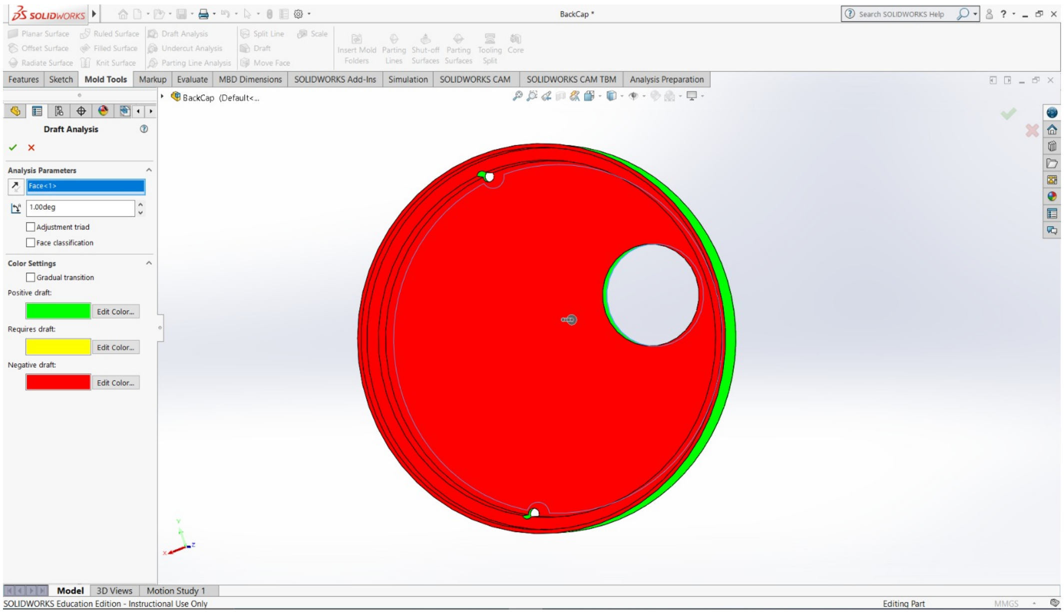
3. **Fully Defined Sketches**





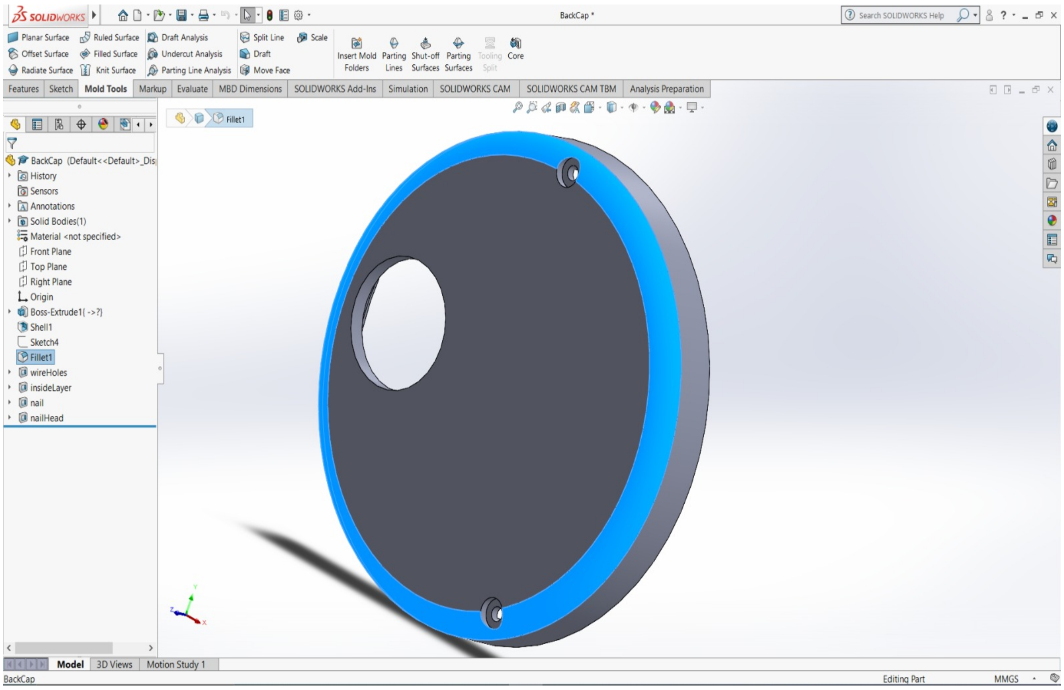
4. **Draft Angle**





All the faces have become red or green as required.

5. **Fillet**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BackCap *
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Ruled Surface
Draft Analysis
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Knit Surface
Parting Line Analysis
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Motion Study 1
BackCap
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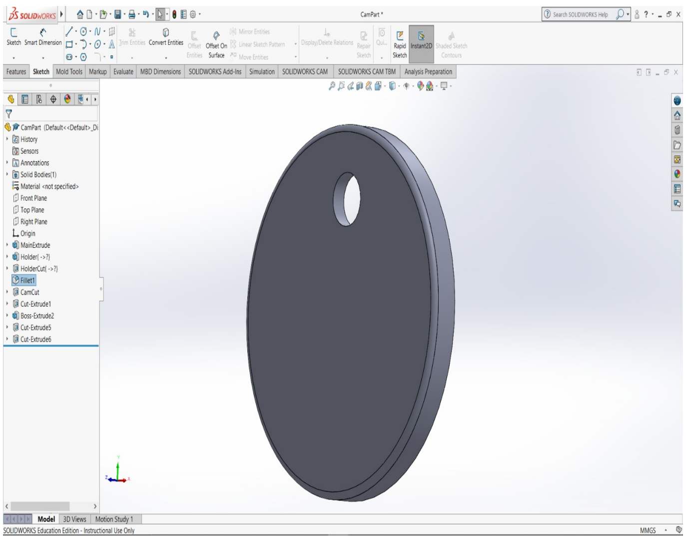
MMGS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Holder(->?)
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CamCut
Cut-Extrude1
Boss-Extrude2
Cut-Extrude5
Cut-Extrude6
Model
3D Views
Motion Study 1
SOLIDWORKS Education Edition - Instructional Use Only
MMGS