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3D Mapping Device for Object Tracking
Conceptual Design Report - Group B

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EN 2160 : Electronic Design Realization

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Contents

1 Conceptual Designs and Functional Block Diagrams

1.1 Design 1

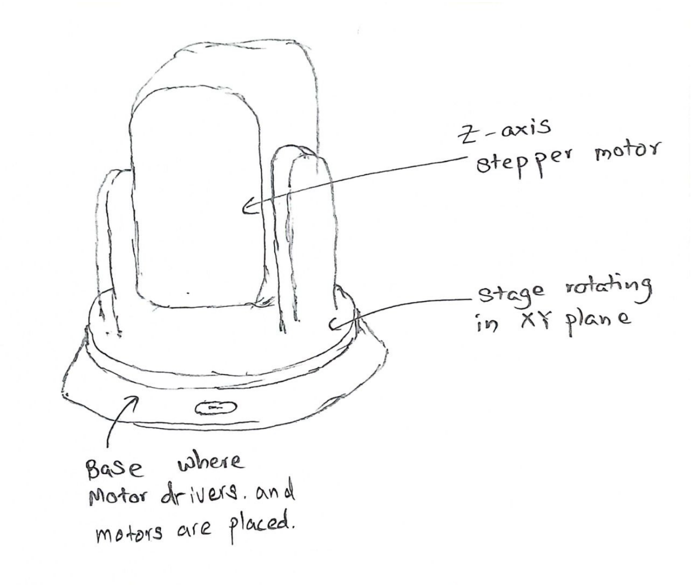

Figure 1: Design 1: Stage and 2 Steppers

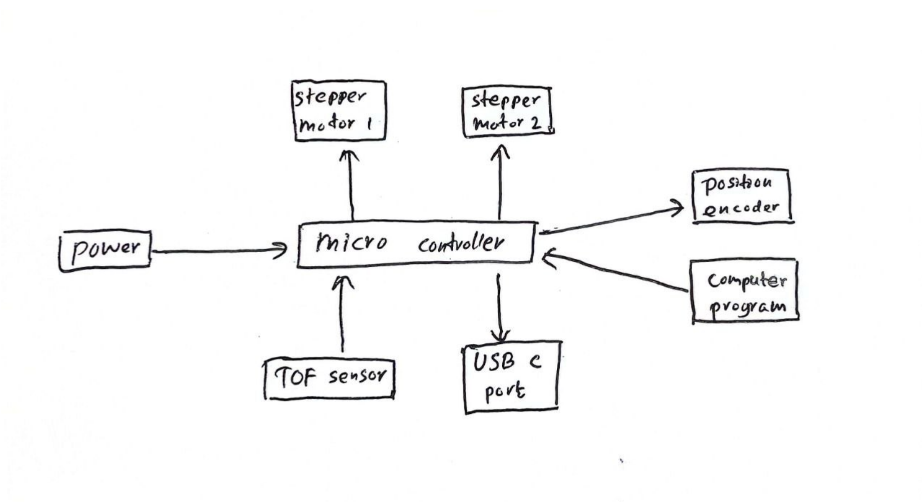

Figure 2: Block Diagram 1

1.1.1 Overview

This innovative design merges the Time of Flight (ToF) sensor concept with the precision control of stepper motors to create a dynamic two Degrees of Freedom (2-DoF) rotational system. It incorporates two stepper motors, with one strategically positioned to govern movement along the xy plane within the base, while the other orchestrates stage rotation using z-axis angles obtained from the ToF sensor. This arrangement ensures meticulous measurement of r, θ, and α values for each reading, thereby enhancing system accuracy.

1.1.2 Operation

- Integration of ToF sensor technology with stepper motors for precise control.
- Two stepper motors utilized: one for xy plane movement and another for stage rotation.
- ToF sensor provides z-axis angles for enhanced control and accuracy.
- Enables meticulous measurement of r, θ, and α values for each reading.
- Data transmission facilitated through USB Type-C port, ensuring seamless connectivity and efficient data transfer.
- Advanced processing techniques applied on the computer to convert data into a comprehensive point cloud representation.
- Sophisticated image detection algorithms employed for in-depth analysis and interpretation.

1.1.3 Advantages

- This design offers precise control over rotational movements.
- Streamlines data processing and analysis, making it a versatile solution for diverse applications requiring precise spatial measurements and analysis.

1.1.4 Challenges

However, there are some challenges associated with this design:

- Mechanical Complexity: Incorporating two stepper motors and a ToF sensor system adds mechanical complexity, requiring careful calibration and maintenance to ensure reliable operation.
- Computational Requirements: Advanced processing techniques and image detection algorithms may demand significant computational power, posing challenges in terms of hardware requirements and computational efficiency.

1.2 Design 2

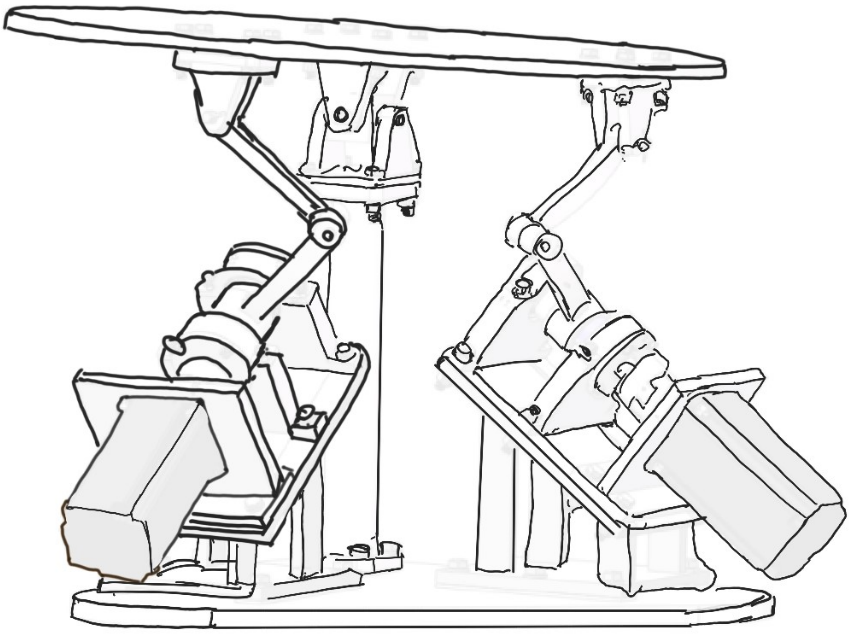

Figure 3: Design 2: Servo Motors and Liver System

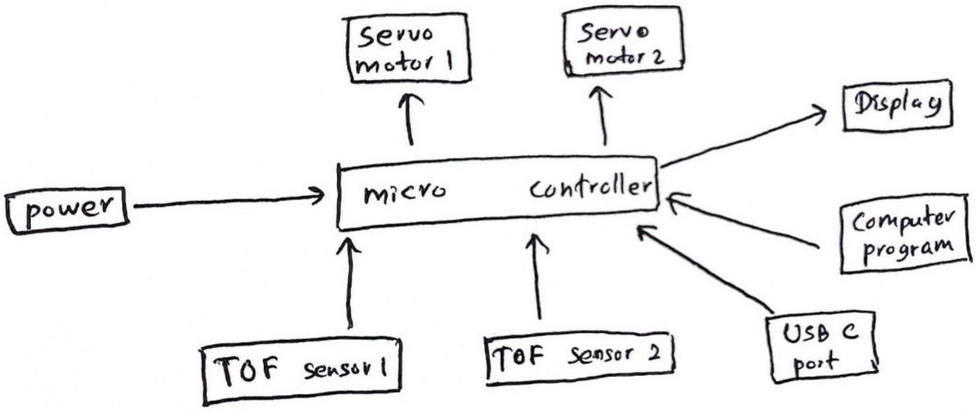

Figure 4: Block Diagram 2

1.2.1 Overview:

Design 1 utilizes a basement housing two time-of-flight (ToF) sensors, each equipped with servo motors for precise adjustment. The servo motors enable the rotation and tilting of the basement to capture surrounding data from various angles.

Components:

1. **Basement Housing:** The basement serves as the platform for mounting the ToF sensors and servo motors. It is designed to be adjustable in both rotation and tilt angles.

2. **ToF Sensors:** Two ToF sensors are mounted on the basement to capture depth information. These sensors emit infrared light pulses and measure the time taken for the pulses to reflect back, allowing for accurate distance calculations.

3. **Servo Motors:** The servo motors are responsible for adjusting the orientation of the basement. They provide precise control over the rotation and tilt angles, allowing for comprehensive coverage of the surrounding environment.

1.2.2 Operation:

- **Rotation Control:** One servo motor is dedicated to controlling the rotation of the basement. By rotating the basement, the sensors can scan the surroundings horizontally, providing a panoramic view of the scene.

- **Tilt Control:** The second servo motor adjusts the tilt angle of the basement. This enables the sensors to capture data from different elevations, facilitating a more detailed representation of the environment.

1.2.3 Advantages:

- **Precise Control:** The servo motors offer precise adjustment capabilities, allowing for fine-tuning of the sensor positions to capture accurate data.

- **Comprehensive Coverage:** By rotating and tilting the basement, the design ensures thorough coverage of the surrounding environment, resulting in more comprehensive 3D scans.

1.2.4 Challenges:

- **Mechanical Complexity:** The incorporation of servo motors adds mechanical complexity to the design, requiring careful calibration and maintenance to ensure reliable operation.

- **Power Consumption:** Servo motors may consume significant power, which could impact the overall energy efficiency of the system.

1.3 Design 3

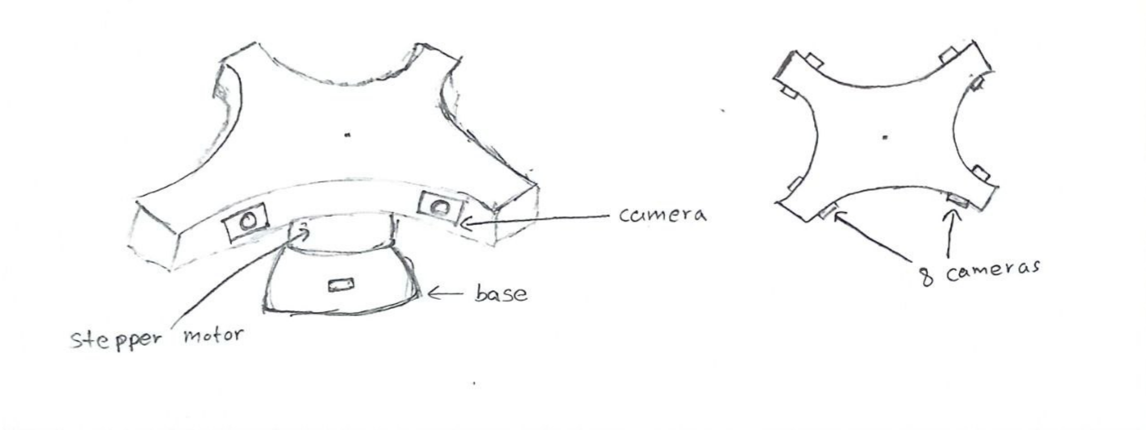

Figure 5: Design 3

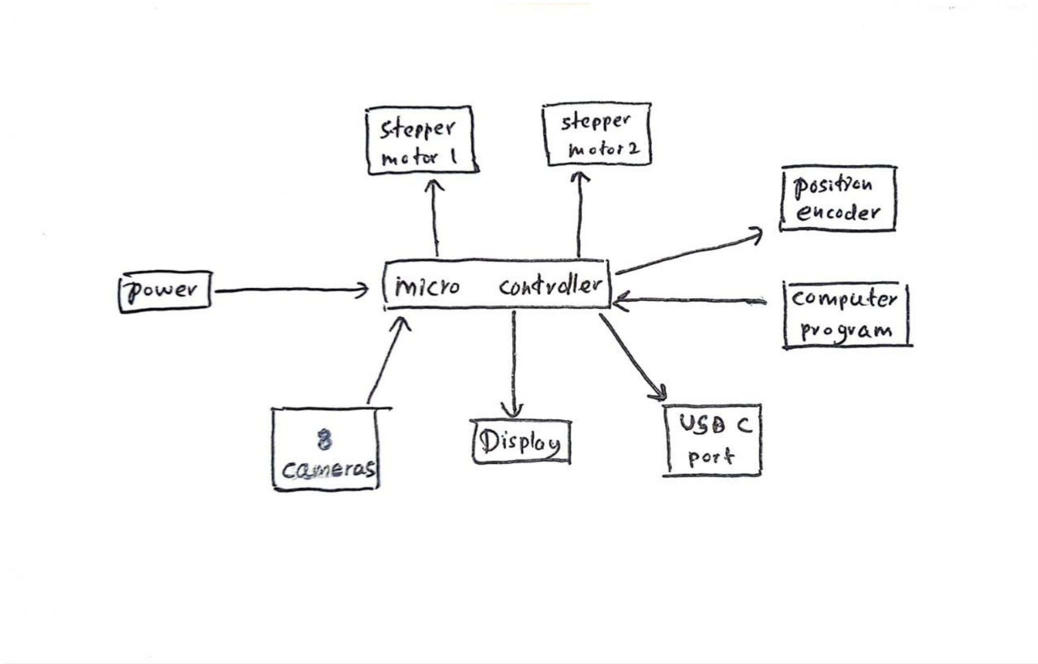

Figure 6: Block Diagram 3

1.3.1 Overview

This cutting-edge design leverages image processing technology, employing a sophisticated array of eight cameras strategically positioned to capture comprehensive visual data. Among these cameras, a subset is dedicated to recording videos from one side, utilizing precise angles and calibration to facilitate the generation of detailed 3D objects through advanced image processing concepts. The collective data captured by the eight cameras is then meticulously processed through Convolutional Neural Networks (CNNs), enabling the generation of accurate 3D mappings and point clouds.

- Utilization of eight cameras for comprehensive visual data capture.
- Subset of cameras dedicated to video recording from one side.
- Angled and calibrated cameras facilitate detailed 3D object generation.
- Data from the camera array processed through Convolutional Neural Networks (CNNs).
- CNNs enable accurate generation of 3D mappings and point clouds.

1.3.2 Challenges

However, a notable challenge lies in the associated costs and computational requirements. The complexity of processing data from multiple cameras in real-time demands significant computational power, which may pose challenges in terms of both hardware affordability and computational efficiency.

1.3.3 Advantages

The advantages of this design include:

- High-Quality Data: The use of eight cameras allows for comprehensive visual data capture, resulting in high-quality 3D reconstructions.
- Detailed 3D Objects: The subset of cameras dedicated to video recording from one side, along with precise angles and calibration, facilitates the generation of detailed 3D objects.
- Accurate Processing: The utilization of Convolutional Neural Networks (CNNs) ensures accurate processing of the captured data, leading to precise 3D mappings and point clouds.

1.3.4 Significance

This design represents a powerful fusion of cutting-edge imaging technology and advanced computational algorithms, promising high-fidelity 3D reconstructions and data analysis. Despite the challenges posed by cost and computational demands, the potential applications of such a system in various fields such as robotics, augmented reality, and medical imaging underscore its significance and potential impact.

2 Comparison of Designs

Table 1: Comparison of Designs

Criteria	**Design 1**	**Design 2**	**Design 3**
Features			
TOF sensor	✓	✓	
cameras			✓
servo motors		✓	
stepper motors	✓		✓
display		✓	✓
position encoder	✓		✓
Enclosure Design Criteria Comparison			
Functionality	8	7	8
Aesthetics	9	8	6
Heat Dissipation	9	8	9
Assembly and Serviceability	8	7	6
Ergonomics	9	9	7
Simplicity	9	5	7
Durability	9	7	6
Functional Block Design Criteria Comparison			
Functionality	8	7	8
User Experience	9	8	7
Manufacturing Feasibility	9	6	9
Cost Efficiency	8	6	9
Performance	8	7	8
Future Proofing	9	8	9
Power	8	7	6
Total	120	100	105

3 Evaluation Criteria

3.1 Enclosure Design Criteria:

1. **Functionality:** How well the design supports the main functionalities?
2. **Aesthetics:** How eye-catching is the design and what is the overall appeal to the user?
3. **Heat Dissipation:** How much heat is generated and how well has it been managed?
4. **Assembly and Serviceability:** How easily can the assembly and disassembly be done?
5. **Ergonomics:** How well does the design fit in the user's hand and allow easy interaction?
6. **Durability:** How well does the design withstand impacts and environmental conditions?
7. **Simplicity:** How simple is the design?

3.2 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 for the provided functionality.
5. **Performance:** Evaluate 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?