# Approach to Designing a Low-Cost 2D LiDAR System

## Objective:

Develop a low-cost, functional 2D LiDAR system capable of accurate environmental mapping and real-time visualization, with potential integration into ROS2 for visualization using Rviz2.

## 1. System Design Overview

### 1.1 Key Components:

• Microcontroller: ESP32 for processing due to its built-in Wi-Fi and Bluetooth, which facilitates real-time data transfer.  
• Sensor: A Time-of-Flight (ToF) sensor for distance measurement, selected for its affordability and accuracy in detecting surroundings.  
• Actuator: A stepper motor for precise rotation, enabling consistent scanning of the environment.  
• Support Electronics: USB breakout board for power supply and motor drivers for controlling the stepper motor.

### 1.2 Mechanical Design:

Construct a lightweight rotating platform using provided Styrofoam. Mount the ToF sensor on the platform, connected to the stepper motor for rotational scanning.

## 2. System Architecture

### 2.1 Data Acquisition:

The ToF sensor measures distances in real-time as the platform rotates. Angular data is obtained from the stepper motor's control signals to correlate distance with direction.

### 2.2 Data Processing:

Use the ESP32's processing power to map distance and angle into Cartesian coordinates. Implement filtering algorithms (e.g., Kalman filter) to reduce noise and improve accuracy.

### 2.3 Visualization:

Develop a user interface using Python with libraries such as Matplotlib or PyQt for real-time plotting of 2D data. For advanced users, integrate the data into ROS2 for visualization in Rviz2.

## 3. Algorithm Development

### 3.1 Pseudo Code:

initialize ToF sensor and stepper motor  
set rotation speed and scanning resolution  
  
while scanning:  
 for each angle in range(0, 360, resolution):  
 measure distance using ToF sensor  
 record (angle, distance)  
 filter data to remove noise  
 convert (angle, distance) to Cartesian coordinates  
 update real-time plot

### 3.2 Key Algorithms:

• Noise Filtering: Kalman or Median filtering for stable readings.  
• Coordinate Transformation: Use trigonometric functions to map polar coordinates to 2D Cartesian space.

## 4. Challenges and Solutions

### 4.1 Challenge: Limited accuracy of low-cost ToF sensors.

Solution: Implement software compensation algorithms to minimize error and calibrate the sensor under real-world conditions.

### 4.2 Challenge: Maintaining mechanical stability of the rotating platform.

Solution: Design a low-vibration setup using balanced Styrofoam components.

### 4.3 Challenge: Real-time visualization latency.

Solution: Optimize communication protocols (e.g., using ESP-NOW for low-latency data transfer).

## 5. Innovation and Additional Features

### 5.1 Dynamic Calibration:

Include a calibration routine that adjusts sensor parameters based on ambient lighting conditions.

### 5.2 Real-Time Visualization in Rviz2:

Provide ROS2 integration, enabling advanced users to visualize data in a 3D environment.

## 6. Evaluation Metrics

• Accuracy: Precision of distance measurement within a 2-5% margin of error.  
• Efficiency: Real-time processing without noticeable lag.  
• Durability: Robustness of the physical design.  
• User Interface: Intuitive and interactive plotting tool.

## Conclusion:

This approach balances affordability and functionality, leveraging widely available components and efficient algorithms. The final system aims to democratize LiDAR technology, making it accessible for educational and hobbyist applications.