Distance Measurement Using Laser Sensor

For

Sensor Lab mini Project

Third Year (Semester-VI) Bachelors in Information Technology, Autonomous Program

By

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Certificate

This is to certify that **Komal Deolekar (14), Shreyash Dhekane (16), Tejas Gunjal (18)** have completed the project report on the topic **Distance Measurement Using Laser Sensor** satisfactorily in partial fulfilment of the requirements for the award of Mini Project in sensor lab of third Year, (Semester-VI) in Information Technology under the guidance of Mr. Abhishek Chaudhari during the year 2024-2025 as prescribed by An Autonomous Institute Affiliated to University of Mumbai

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Table of Contents

Abstract

In this project, we explore the implementation of a laser-based distance measurement system using the VL53L0X Time-of-Flight (ToF) sensor. The system is designed to measure distances up to 2 meters with high precision and stability, making it suitable for a wide range of industrial, robotic, and consumer-level applications. The VL53L0X sensor uses laser-based ranging technology and operates on the principle of measuring the time taken by a light pulse to travel to an object and back. Unlike traditional infrared sensors, the VL53L0X offers better accuracy, faster response time, and superior performance under varying lighting conditions.

The sensor communicates using the I2C protocol and is interfaced with an Arduino Uno R3 microcontroller, which is responsible for initializing the sensor, reading the measured values, and processing the data. The distance data is displayed in real-time on a 16x2 LCD using an I2C module, providing a compact and user-friendly interface. The entire system is powered using a standard 5V supply from the Arduino, making the setup simple, portable, and energy-efficient.

This report discusses the theoretical background of Time-of-Flight sensing, a detailed overview of the hardware and software components used, interfacing techniques, circuit design, step-by-step implementation, and analysis of the results. The project demonstrates a practical, low-cost solution for accurate distance measurement, with potential applications in automation, smart devices, object detection, and educational tools.

List of Figures **PageNo.**

Chapter 1

Introduction

1. Introduction

Accurate distance measurement is critical in numerous fields including robotics, industrial automation, and smart devices. Traditional methods of distance measurement often struggle in low-light or reflective environments. Laser sensors provide a reliable and precise alternative. In this project, we use the VL53L0X Time-of-Flight sensor to measure distances by calculating the time taken by the laser to reflect back from an object. This data is processed by an Arduino Uno and can be visualized using an LCD.

1.1 Objective

- To design a cost-effective and efficient distance measurement system using laser technology.
- To provide real-time distance display using a microcontroller and an LCD.

1.2 Scope

- Can be used in proximity sensors, obstacle detection systems, robotics, and automation.
- Works reliably in low-light conditions due to laser sensing technology.

Chapter 2

Review of Literature

2.1 Survey

1] Application of low-cost VL53L0X ToF sensor for robot environment detection

The paper focuses on the use of the VL53L0X Time-of-Flight sensor for robot environment detection. It evaluates the accuracy and reliability of the sensor in various real-world conditions.
Testing includes surfaces with different materials and colors to analyze sensor consistency.The sensor's performance was also assessed under different lighting conditions, including low light.Results show the VL53L0X offers precise distance measurement up to 2 meters.The paper concludes that the sensor is suitable for proximity sensing, object detection, and robot odometry due to its stable performance and low cost.

2] Real-time simulation of time-of-flight sensors

The paper presents a real-time simulation model for Time-of-Flight (ToF) sensors, specifically the Photonic Mixing Device (PMD) type.ToF sensors are compact, low-cost, and suitable for applications in robotics, automotive, and 3D imaging.The simulation includes real-world effects like motion blur, flying pixels, and deviation errors.A physics-based approach is used to ensure realistic sensor behavior.The system uses GPU acceleration to enable interactive, real-time feedback and control during simulation.

3] Study of arduino microcontroller board

Explains the working principle of Arduino microcontrollers.Highlights Arduino's use in education and research, especially sensor-based projects. Arduino is easy to learn and program using the free Arduino IDE. IDE includes built-in libraries to simplify coding. Discusses different types of Arduino boards and their applications. Arduino offers a low-cost, fast solution for small-scale electronics projects.

2.2 Research Gap

1. **Limited Real-world Application Demonstrations**:
   While the papers discuss the **technical performance and simulation** of Time-of-Flight sensors like the VL53L0X, they **lack practical implementation examples** in simple, low-cost projects such as basic **distance measurement systems** for students or hobbyists.

2. **Complex Environments Not Deeply Explored**:
   The simulations and tests mostly focused on **controlled lab environments**. There is a gap in evaluating the **sensor's accuracy in real-world conditions** (e.g., outdoor light, moving objects, unstable surfaces).

3. **Integration Simplicity for Beginners**:
   Although Arduino is discussed, there is **little emphasis on beginner-friendly implementation**, such as combining VL53L0X with Arduino and LCD/OLED displays in a structured and cost-effective way.

4. **Educational Usage**:
   Existing research lacks focus on **how these sensors can be used in educational tools or student projects** for learning electronics and embedded systems.

Chapter 3

Project Description

3.1 Problem Definition

Accurate distance measurement is essential in fields like robotics, automation, and industrial monitoring. Traditional sensors such as ultrasonic or infrared often face issues with precision and performance in varying lighting or surface conditions.

This project aims to develop a **compact, cost-effective, and accurate laser-based distance measurement system** using the **VL53L0X Time-of-Flight sensor** and **Arduino Uno R3**. The system will measure distances up to 2 meters and display the output in real-time on an LCD. Using I2C communication, the design remains simple and efficient.

The objective is to create a reliable and easy-to-build prototype that can be used in practical applications or extended for more advanced systems like robotics or wireless monitoring.

3.2 Steps involved

1. **Study of Sensor and I2C Communication**
   Understood the working of the VL53L0X Time-of-Flight sensor and how it communicates using the I2C protocol.

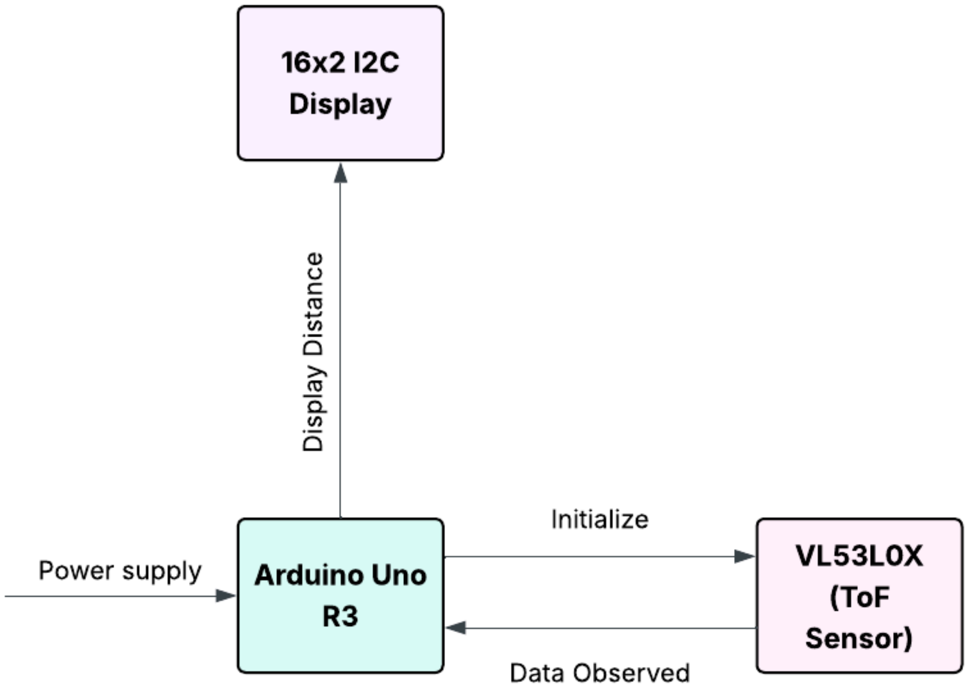
2. **Interfacing with Arduino UnoVL53L0X**
   Connected the sensor to the Arduino Uno R3 using SDA and SCL pins and installed necessary libraries.

3. **Displaying Values on LCD**
   Used a 16x2 LCD with an I2C module to display the distance values in real-time.

4. **Circuit Design and Wiring**
   Built the complete circuit on a breadboard using jumper wires and ensured proper connections.

5. **Code Development and Testing**
   Wrote and uploaded the Arduino code for sensor reading and LCD display, then tested the setup for accuracy and reliability.

3.3 Block Diagram of proposed Project



3.4 Component Description

3.4.1 VL53L0X Time-of-Flight Sensor

- Measures distance by calculating the time taken by laser light to travel to the object and back.
- Range up to 2 meters.
- Communicates using I2C protocol.
- High accuracy even in low-light or dark conditions.
- Operates at 3.3V–5V DC.

3.4.2 Arduino Uno R3

- Based on the ATmega328P microcontroller.
- Reads sensor data through I2C protocol.
- Processes the distance information.
- Sends output to the display or serial monitor.
- Provides power to the sensor module.

3.4.3 LCD Display (16x2 or OLED)

- Displays real-time distance values.
- Uses I2C module to reduce wiring (SDA to A4, SCL to A5 on Arduino).
- Optional component for visual feedback.

3.4.4 Jumper Wires & Breadboard

- Used for prototyping.
- Connects Arduino, sensor, and display in a clean, modular manner.

3.4.5 Power Supply

- Arduino supplies 5V DC to the sensor and display modules.
- Ensures portability and simplicity in wiring.

3.5 Working of proposed project

3.5.1 Working

The core functionality of the project revolves around the operation of the **VL53L0X Time-of-Flight (ToF) distance sensor**, which is capable of measuring distances using laser light. The complete working process of the proposed system can be broken down into the following detailed steps:

1. **Laser Emission by VL53L0X Sensor**
   The VL53L0X sensor uses an internal Vertical Cavity Surface Emitting Laser (VCSEL) to emit an invisible, low-power laser beam in the infrared spectrum. This laser beam is directed towards the target object in front of the sensor.

2. **Reflection from the Object**
   When the laser beam hits the surface of the object, it reflects back toward the sensor. The sensor contains a Single Photon Avalanche Diode (SPAD) array that is highly sensitive to the returning photons. It detects the reflected light and records the time it took to return.

3. **Time-of-Flight Calculation**
   The sensor calculates the distance by measuring the **round-trip time** taken by the laser pulse to travel from the sensor to the object and back. Since the speed of light is a known constant, this time measurement is used to determine the exact distance between the sensor and the object with high accuracy.

4. **Communication with Arduino Uno**
   The sensor communicates with the Arduino Uno via the **I2C communication protocol**. The Arduino acts as the central processing unit that requests distance measurements from the sensor at regular intervals and receives the raw data in millimeters.

5. **Display of Distance**
   The processed distance value is then sent to a **16x2 LCD display (or OLED display)** that is connected to the Arduino through an I2C module. This minimizes the number of wiring connections and allows easy integration. The display continuously updates in real-time, showing the current distance measurement to the user.

6. **Power Supply and Portability**
   The entire setup is powered via the Arduino Uno, which can be powered by a USB cable from a computer or a battery adapter. This makes the system lightweight and portable for field use or integration into larger systems such as robots or automation setups.

7. **Accuracy and Performance in Varying Conditions**
   One of the key strengths of the VL53L0X sensor is its ability to function accurately in **low-light environments** due to its laser-based measurement method. Unlike ultrasonic or IR sensors, it is less affected by the color or reflectivity of the target surface.

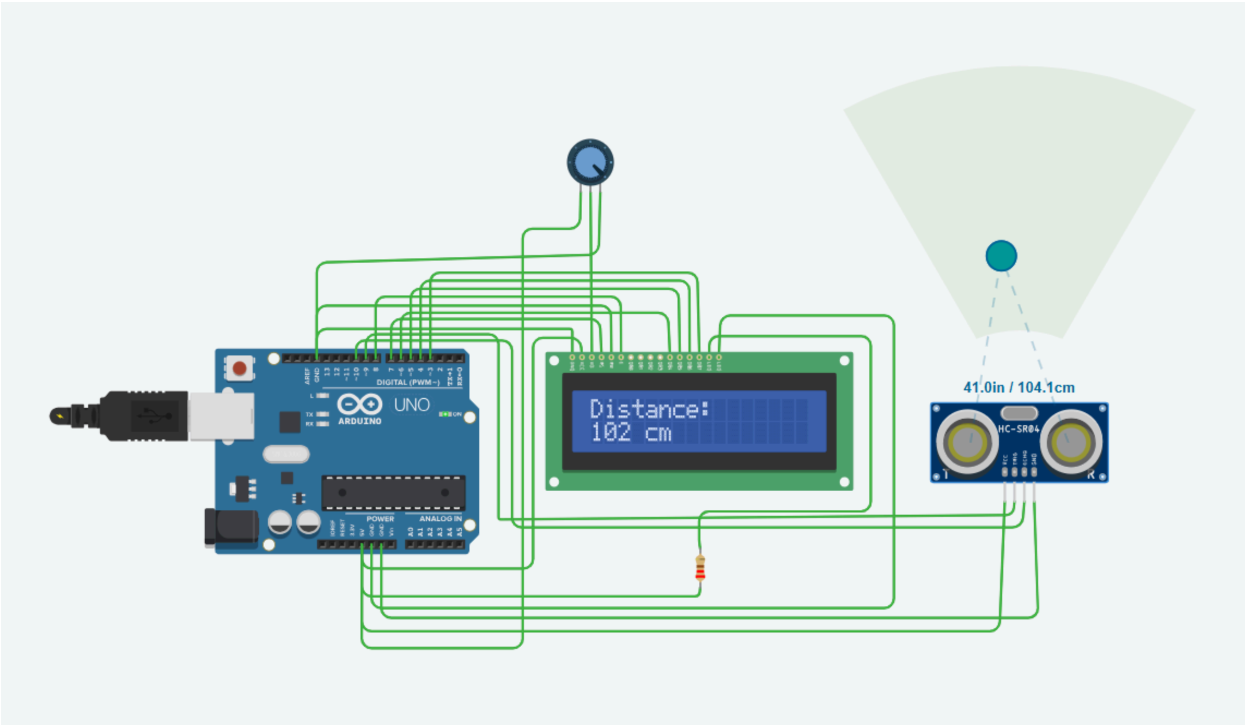
3.5.1 System Workflow

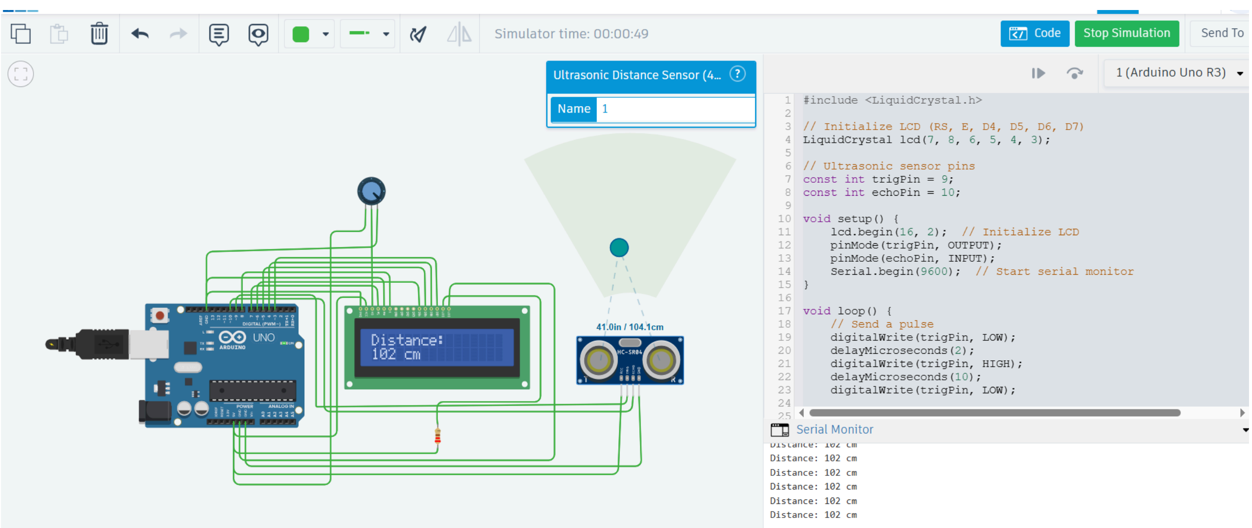
The system workflow begins with the initialization of the VL53L0X sensor and the LCD display within the Arduino setup code. Once powered on, the Arduino configures the I2C communication protocol and ensures that both the sensor and the display are ready for operation. In the main loop of the program, the Arduino continuously reads distance values from the sensor in real time. These values are then processed and immediately sent to the LCD display for output. The display is updated in each cycle to reflect the latest distance measurement. Additionally, the Arduino code includes logic to handle potential measurement errors, such as out-of-range readings or temporary signal drop-offs, by displaying error messages or retrying the measurement to maintain system reliability and consistent performance.

Chapter 4

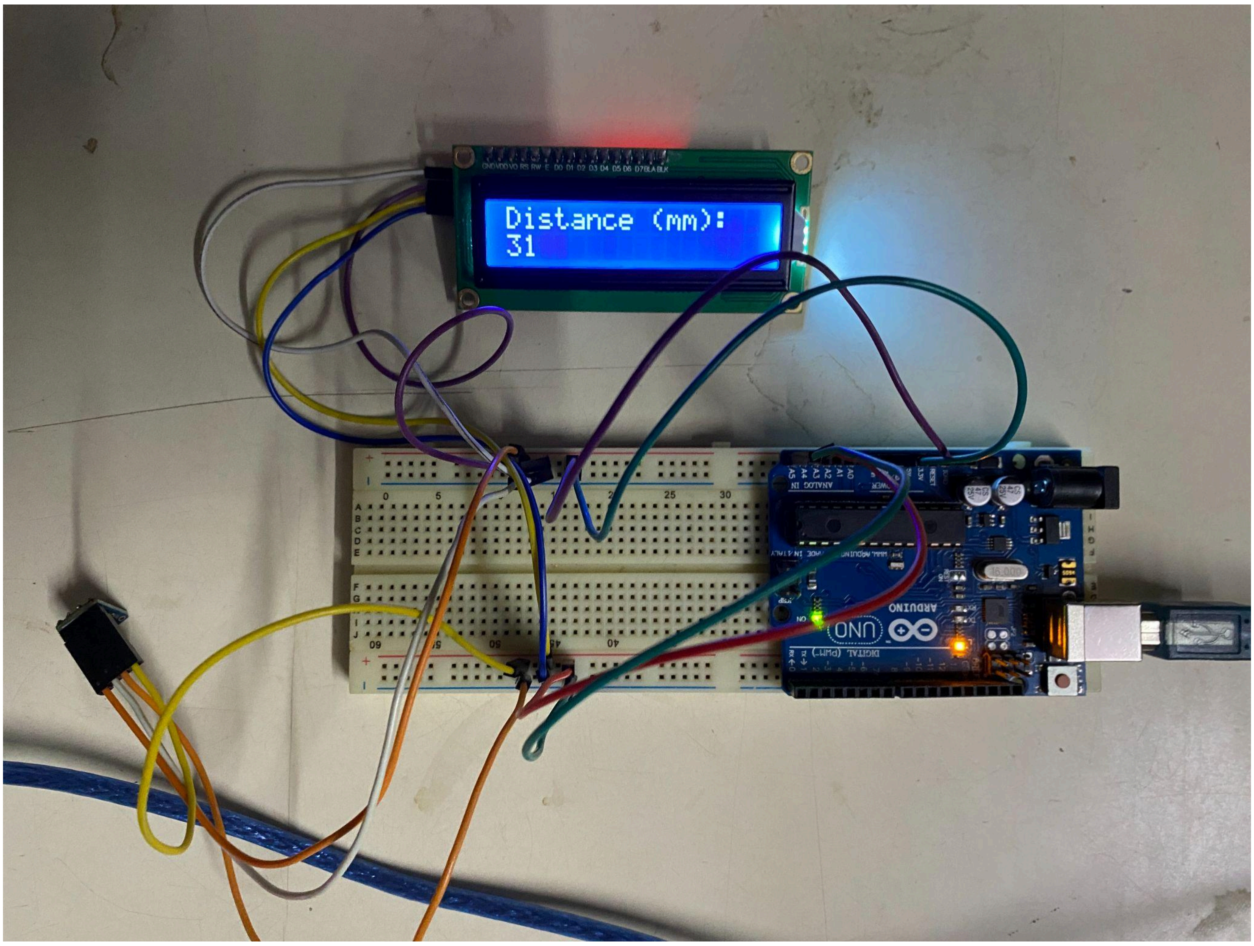
Implementation

4.1 Simulation





4.2 Actual Implementation



4.3 Hardware

4.3.1 Circuit Connection

- VL53L0X
  - VCC → 5V on Arduino
  - GND → GND on Arduino
  - SDA → A4 on Arduino
  - SCL → A5 on Arduino
- LCD (I2C)
  - VCC → 5V on Arduino

- **GND → GND on Arduino**
- **SDA → A4 on Arduino**
- **SCL → A5 on Arduino**

4.3.2 Code:

```
#include <Wire.h>
#include <Adafruit_VL53L0X.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 2); // Use 0x3F if your LCD address is different
Adafruit_VL53L0X sensor = Adafruit_VL53L0X();

void setup() {
  Serial.begin(9600);

  // Initialize LCD
  lcd.init();
  lcd.backlight();
  lcd.print("Initializing...");

  // Initialize VL53L0X sensor
  if (!sensor.begin()) {
    lcd.clear();
    lcd.print("Sensor Error!");
    while (1);
  }

  lcd.clear();
  lcd.print("Distance (mm):");
  delay(1000);
}

void loop() {
  VL53L0X_RangingMeasurementData_t measure;

  sensor.rangingTest(&measure, false); // Get distance in mm

  if (measure.RangeStatus != 4) { // Check if measurement is valid
    lcd.setCursor(0, 1);
```

```
  lcd.print("                "); // Clear previous value
  lcd.setCursor(0, 1);
  lcd.print(measure.RangeMilliMeter);
} else {
  lcd.setCursor(0, 1);
  lcd.print("Out of Range");
}

delay(500); // Update every 0.5 seconds
```

4.4 Software (Flowchart/ Algorithms)

The software is the core part of the distance measurement system and is developed using the **Arduino Integrated Development Environment (IDE)**. Arduino IDE is an open-source platform that supports programming in C/C++ and is widely used for microcontroller-based applications. In this project, Arduino IDE is used to write, compile, and upload the code to the **Arduino Uno R3**.

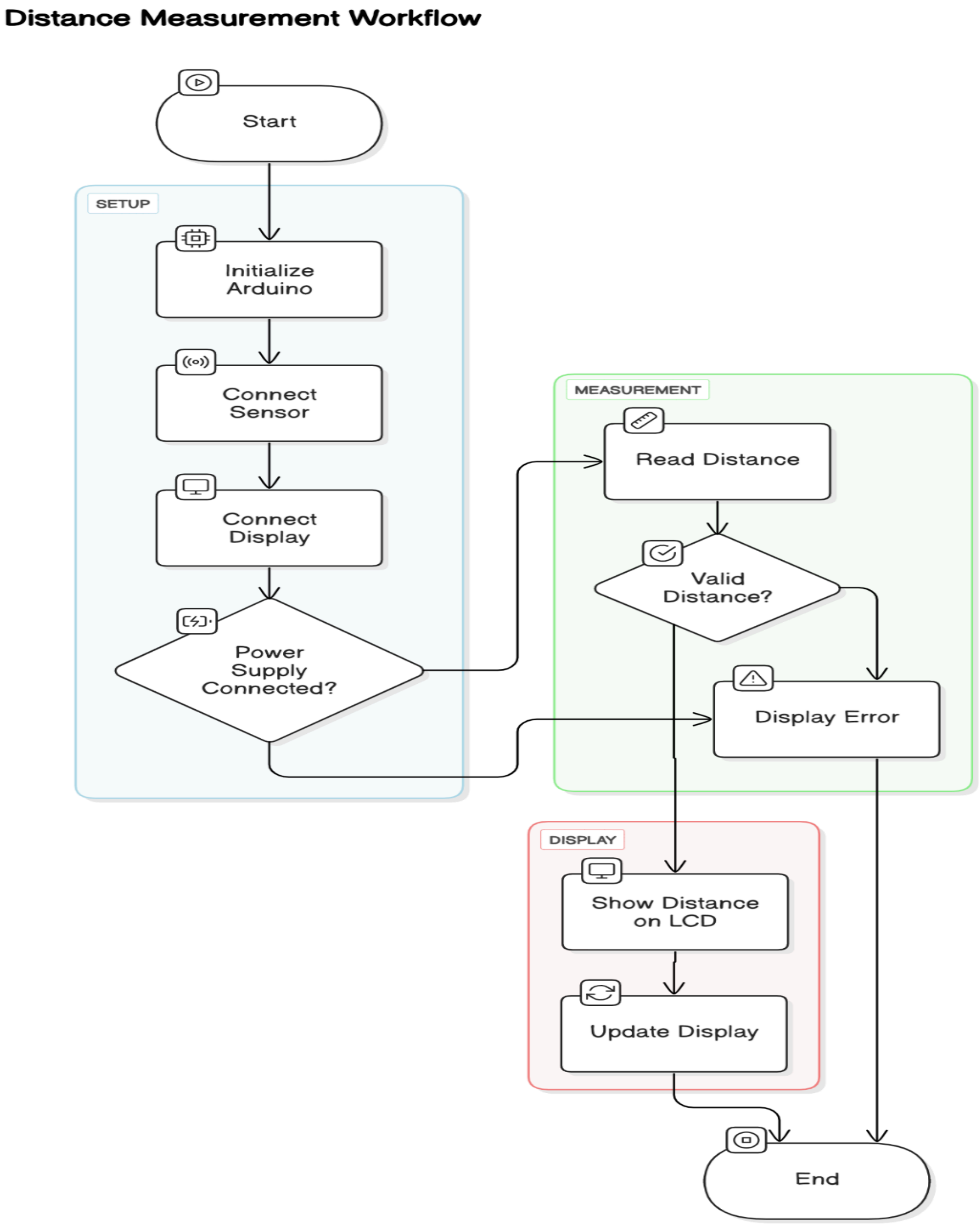
4.4.1 Software Implementation Process:

1. **Installing the Required Libraries:**
   - We installed the `Adafruit_VL53L0X` library to interface with the VL53L0X sensor.
   - For the LCD display (16x2 with I2C), we use the `LiquidCrystal_I2C` library.
2. **Writing the Code:**
   - The Arduino sketch begins with including necessary libraries and defining sensor and LCD objects.
   - In the `setup()` function, the sensor and LCD are initialized.
   - In the `loop()` function, the sensor continuously reads the distance, and the result is printed on the LCD screen.
3. **Uploading to Arduino Uno:**
   - The code is compiled and uploaded to the Arduino board via a USB connection using the Upload button in the Arduino IDE.
   - The **Serial Monitor** can be used for debugging and checking values during development.

4.4.2 Algorithm:

1. Start the program.
2. Include necessary sensor and LCD libraries.
3. Initialize the sensor and LCD in the `setup()` function.
4. Begin continuous distance measurement in the `loop()`.
5. Read distance from VL53L0X sensor.
6. Convert and format the result for display.
7. Print the distance on the LCD.
8. Delay slightly before next reading for stability.
9. Repeat indefinitely.

4.4.3 Flowchart



Chapter 5

Results and Conclusion

The **distance measurement system** using the **VL53L0X Time-of-Flight (ToF) sensor** was successfully designed and implemented. The system demonstrated reliable and consistent performance in real-world testing conditions.

The VL53L0X sensor provided **accurate distance readings up to 2 meters**, with precision measured within a few millimeters. The readings remained stable across different surfaces and lighting environments, validating the sensor's robustness and reliability. The **use of I2C communication** allowed seamless integration with the **Arduino Uno R3**, ensuring fast and efficient data transmission.

The measured distance values were displayed in **real time on a 16x2 LCD**, which updated dynamically with each reading cycle. This allowed users to observe immediate feedback during testing, making the system user-friendly and interactive.

Key observations from testing include:

- **High accuracy** in distance measurement with minimal fluctuation.
- **Real-time display** on LCD worked efficiently without noticeable lag.
- **Stable performance** even under low-light or varied ambient conditions.
- The overall system was **compact, lightweight, and cost-effective**, making it ideal for small-scale and educational projects.

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