Design and Implementation of a Line Following and Obstacle Avoidance Robot

(Technical Report)

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***Abstract*—This paper presents the design, development, and implementation of an Arduino-based robot capable of following a black line and avoiding obstacles in its path. The system integrates IR sensors for line detection and an ultrasonic sensor mounted on a servo motor for environmental scanning. The robot's decision-making algorithm enables smooth path-following while dynamically reacting to obstacles. Both hardware and software components were prototyped virtually before real-world testing. Results show reliable performance in various test scenarios.**

***Index Terms*—Line follower robot, Obstacle avoidance, Arduino, Servo motor, Ultrasonic sensor**

I. Introduction

Line-following and obstacle-avoiding robots are fundamental projects in the field of robotics and embedded systems. These robots offer practical insights into sensor integration, motor control, decision-making algorithms, and real-time behavior. Such applications are widely used in industrial automation, delivery robots, and warehouse management systems.

This project focuses on the design and development of a mobile robot that can autonomously follow a predefined path while detecting and avoiding obstacles using infrared (IR) and ultrasonic sensors. The integration of hardware and software components was achieved through iterative prototyping, simulation (using Tinkercad), and formal verification using UPPAAL to ensure time-critical responsiveness.

The objective was to create a low-cost, Arduino-based robot capable of smart navigation in dynamic environments, with collaborative development managed via Git and GitHub.

II. System Modeling using SysML

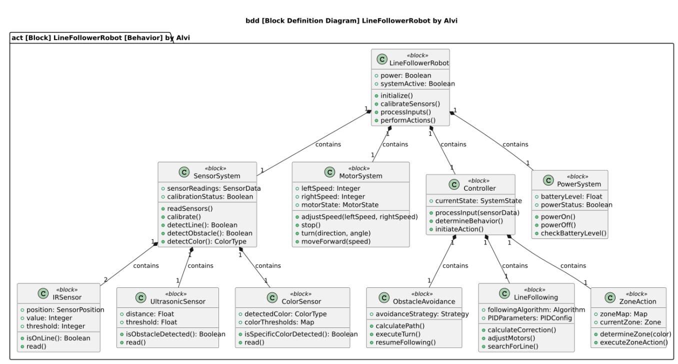

Fig. 1. SysML Block Definition Diagram (BDD)

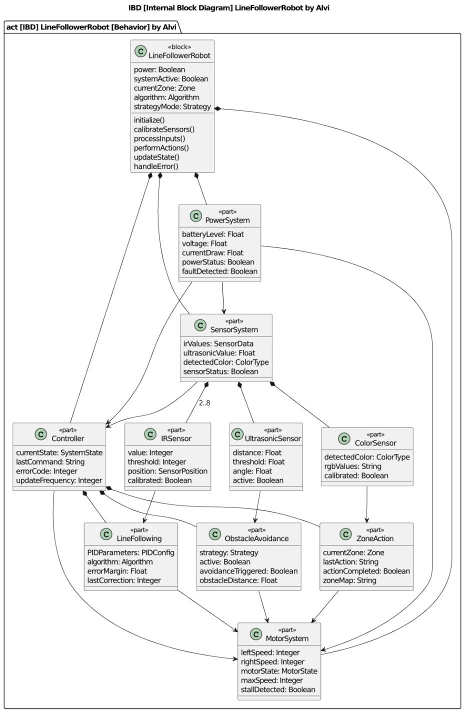

Fig. 2. SysML Internal Block Diagram (IBD)

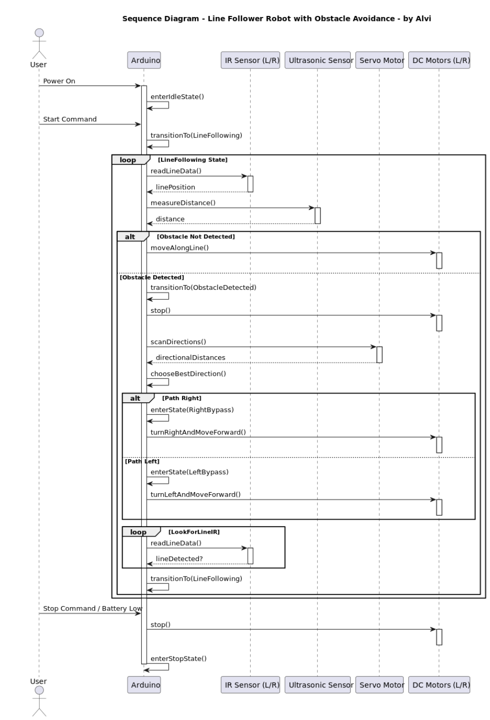

Fig. 3. SysML Sequence Diagram for Obstacle Avoidance

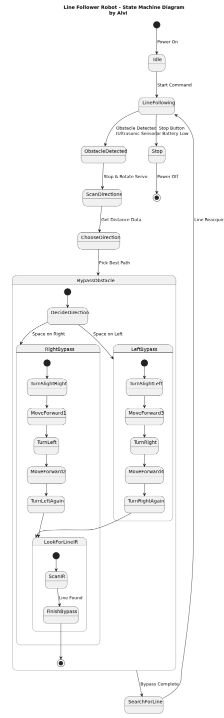

Fig. 4. SysML State Machine Diagram

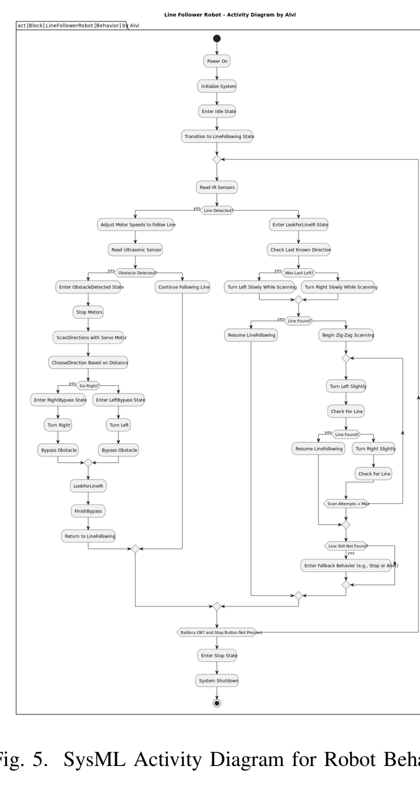

Fig. 5. SysML Activity Diagram for Robot Behavior

III. Prototyping and Design

A. Electronic Components

- Arduino Uno R3
- L298N Motor Driver

- 2 × IR Sensors
- 1 × Ultrasonic Sensor (HC-SR04)
- 1 × Servo Motor (SG90)
- 2 × DC Motors with Wheels
- Chassis, Wires, Breadboard

B. Virtual and Physical Prototypes

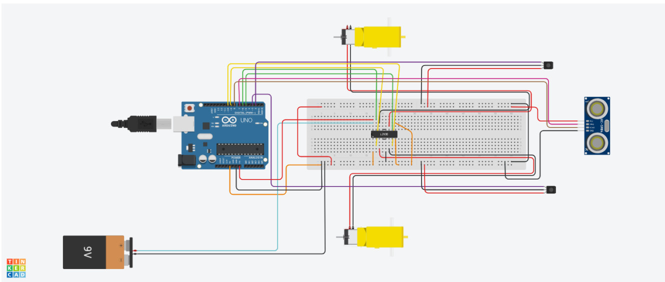

Fig. 6. Tinkercad Simulation: Full Circuit Layout

C. Assembled Car Design

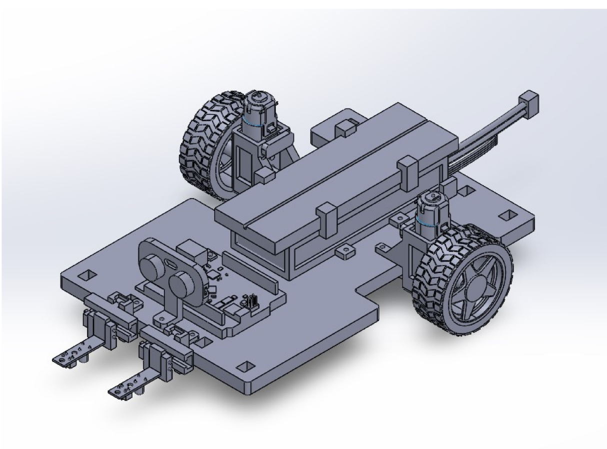

Fig. 7. Assembled Robot Car Design

The fully assembled robot car was modeled and visualized in SolidWorks 3D CAD software before physical construction. Each component—including the chassis, motor mounts, battery cover, sensor holders, and servo brackets—was individually designed to exact dimensions. These designs were then assembled virtually in SolidWorks to verify spatial alignment, mechanical fit, and wiring paths.

This digital mockup allowed us to detect and resolve potential mechanical interferences before 3D printing. The rendered model accurately represents the real-world robot structure and showcases the integration of all electronic and mechanical parts into a compact and modular design.

IV. Circuit Design

- IR sensors → pins 2 and 3
- Ultrasonic → TRIG (12), ECHO (13)
- Servo → pin 9
- Motor driver → IN1-IN4: pins 5–8; ENA/ENB: pins 10–11

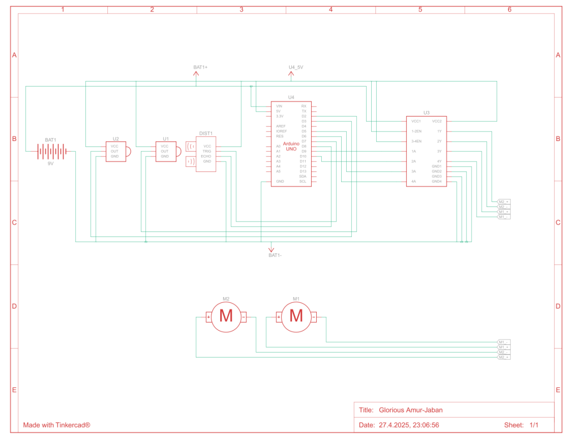

Fig. 8. Complete circuit layout of the robot

V. Software Implementation

A. A. UPPAAL Simulation

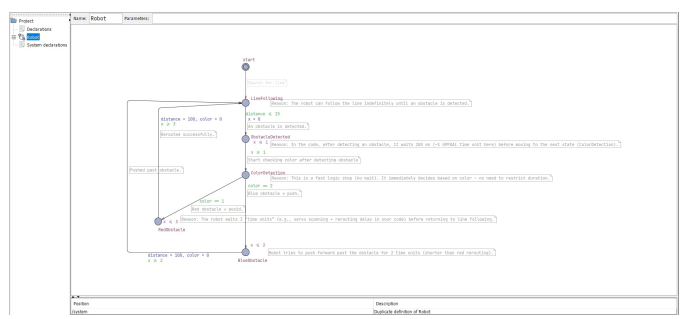

Fig. 9. UPPAAL Timed Automata Model for Robot Control

To formally verify the robot's behavior, a timed automata model was created in UPPAAL. The simulation captures key control states such as line following, obstacle detection, and turning logic with time constraints. By modeling transitions and clock conditions, we validated the robot's response timing to avoid delays or missed decisions during operation. This ensures reliability in real-world dynamic scenarios.

B. B. LTspice Simulation

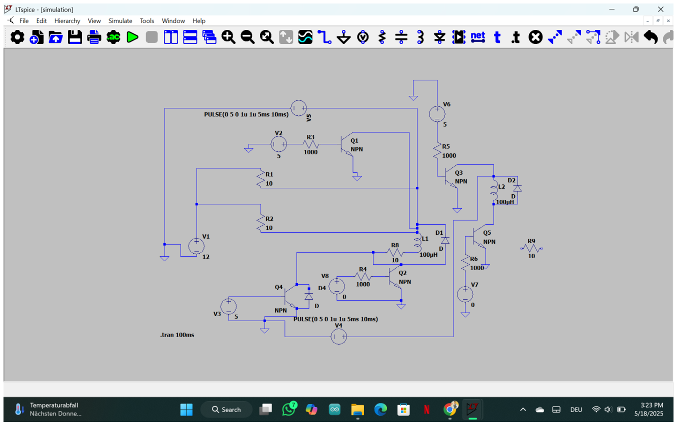

Fig. 10. LTspice Motor Driver Circuit Simulation

The motor driver circuit was simulated in LTspice to ensure proper voltage levels, current flow, and switching behavior before hardware implementation. This simulation helped verify the performance of the L298N driver in handling bidirectional DC motor control, confirming safe operation under load and validating protective components such as flyback diodes.

VI. Git Usage and Collaboration

Version control and collaborative development were managed using Git and GitHub.

- **Jubair Salehin Razin**: Simulation,validation testing, Wiring and Software Implementation,Physical hardware assembly, component placement, chassis design.
- **Md Ratul Ahmed Alvi**: Arduino logic, Program Development / Algorithm Development, wiring, testing, and diagramming
- **Faysal Ahammed Tonmoy**: Documentation, circuit design, integration and 3D Design, LTspice Simulation, Wiring, LaTex Documentation.
- **Soaib Mahin Ferdous**: Supporting diagrams, documentation, modeling, Wiring.

Team Member	**Commits**
Faysal Ahammed Tonmoy	82
Jubair Salehin Razin	122
Md Ratul Ahmed Alvi	162
Soaib Mahin Ferdous	30
Total	421

TABLE I
GitHub Commits by Team Members

VII. Key Achievements

- Built a reliable, intelligent robot system
- Designed and printed all mechanical parts in SolidWorks
- Simulated logic and hardware in Tinkercad, UPPAAL, LTspice
- Documented system architecture using SysML
- Worked collaboratively using GitHub

VIII. Conclusion and Future Work

The robot successfully integrates sensor data and motor control to follow a black line while avoiding obstacles. Future enhancements may include path memory, camera-based vision, Bluetooth control, and autonomous charging.

Acknowledgment

We would like to thank our professor and lab assistants for their guidance and support throughout the development of this project.

References

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[2] Tinkercad Simulation. https://www.tinkercad.com
[3] Uppaal Model Checker. http://www.uppaal.org/
[4] LTspice Simulator. https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html

Declaration of Originality

We hereby declare that this report is our own work and that we have acknowledged all sources used.

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