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Yeditepe University

Mechanical Engineering Department

ME 456

Mechatronics

Competition Vehicle

"GEBEŞ KAPLUMBAĞA"

FINAL REPORT

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INTRODUCTION

In this report, the sumo robot project named "GEBEŞ KAPLUMBAĞA", developed for the "ME456 - Mechatronics" course, is presented. During the vehicle development process, the knowledge and skills gained from the workshops conducted throughout the semester were utilized. In addition to this, the characteristic features and predator-prey behaviors of living creatures in nature were examined. Based on the insights gained from these observations, control infrastructures were developed by translating the concepts into code using computer-aided environments.

ALGORITHM

The control algorithm of our mini sumo robot is built around a finite state machine (FSM) approach, enabling autonomous behavior under changing environmental conditions. The robot transitions between several distinct behavioral states based on input from ultrasonic and infrared (IR) sensors. These states are designed to manage both offensive (attacking) and defensive (line avoidance) strategies during the match.

Behavioral States

Our algorithm defines five main states:

- **Seeking:** In this state, the robot actively scans its environment using two ultrasonic distance sensors (HC-SR04) positioned on the left and right sides. These sensors provide distance measurements to detect the presence of the opponent. The robot uses a simple proportional controller (P-controller) to align itself toward the target based on the difference between left and right sensor readings. If the opponent is detected within a defined threshold distance (`DETECT_DIST`), the robot transitions to the `ATTACKING` state. If no opponent is found (`dAvg > MAX_LOST_DIST`), it switches to the `SEARCHING` state.

- **Attacking:** Once an opponent is detected within range, the robot increases its speed (using `FAST_ATTACK_SPEED`) to aggressively push the opponent. The robot continues using the P-controller to maintain direction. If the opponent moves out of range, it transitions back to the `SEARCHING` state.

- **Searching:** In the searching state, the robot rotates in place to locate the opponent again. If an object is detected by either ultrasonic sensor within `MAX_LOST_DIST`, it re-enters the `SEEKING` state.

- **Backing:** This state is triggered when one of the IR line sensors (TCRT5000) detects the white border of the ring (value drops below `THRESHOLD`). The robot briefly moves forward to kick away from the line, then backs up with a speed ramping pattern. After backing up, it transitions to `TURNING`.

- **Turning:** Following a backup maneuver, the robot pivots in place for a short time (`TURN_TIME`) to change direction before continuing in the `SEEKING` state.

Sensor Fusion and Override

The robot prioritizes safety over aggression by using the line sensors to override any current behavior. Whenever a line is detected, regardless of the current state, the robot immediately executes an escape sequence consisting of:

- Short forward kick (`KICK_TIME`)
- Backward motion (`BACKUP_TIME`)
- Pivot turn (`TURN_TIME`)

This ensures the robot does not leave the ring and maintains its position inside the dohyo.

Control Logic

A proportional steering control is applied during `SEEKING` and `ATTACKING` using the following logic:

error = distanceRight - distanceLeft

steer = Kp * error

leftMotor = baseSpeed - steer

rightMotor = baseSpeed + steer

This allows the robot to smoothly adjust its heading without overshooting, and continuously follow the opponent if within range.

This hierarchical and interruptible control structure allows the robot to aggressively engage opponents when found, recover from lost targets, and avoid falling off the dohyo at all times. The robot operates fully autonomously after a 5-second startup delay, in compliance with the competition rules.

Flowchart

The flowchart below illustrates the behavior-based decision-making structure implemented in our mini sumo robot. This hierarchical flow ensures that the robot can dynamically adapt its actions based on its surroundings, prioritize safety, and maintain continuous engagement during the match.

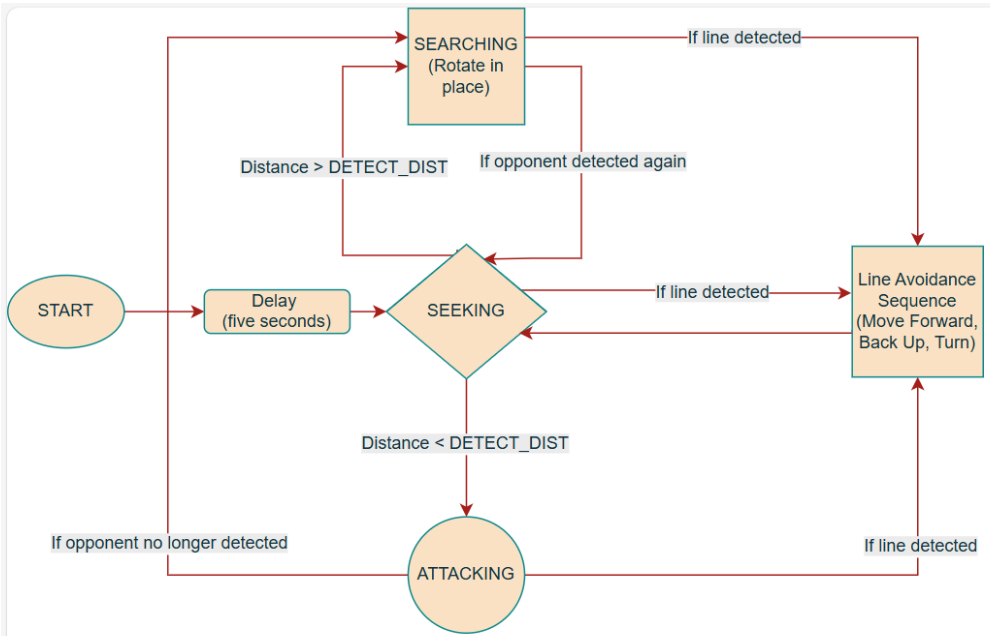

Figure 1: The control algorithm of the mini sumo robot

MECHANICAL DESIGN

Our sumo robot was designed using the Makeblock mBot kit. The main body of the robot consists of an aluminum chassis, which is lightweight yet durable. The center of gravity of the robot was positioned close to the ground to ensure stability.

The robot is equipped with two DC motors connected to wheels. The wheels are covered with rubber to provide sufficient traction. The motors were directly mounted onto the chassis to achieve high pushing force. For sensor placement, two ultrasonic sensors were mounted on the front and side to detect the opponent. Additionally, two IR sensors were placed at the front bottom side of the robot to detect the boundary lines of the ring (dohyo). The sensors were mounted in appropriate positions to allow easy angle adjustment.
A sloped blade was added to the front of the robot. This component helps push the opponent out by sliding underneath them. To comply with the competition rules, all sharp edges were smoothed and no harmful mechanisms were used. All robot components were firmly secured with screws to withstand impacts. Electronic parts were also insulated to prevent damage from vibrations.

Overall, the mechanical design was optimized to meet the competition requirements in terms of both durability and functionality. Thanks to well-considered component placement, traction control, and balance, the robot performed at a high level.

ELECTRICAL DESIGN

The electrical system of our sumo robot is based on the components provided by the Arduino Mega, along with additional sensors used for autonomous operation during the sumo competition.

Main Control Board: At the core of the system lies the arduino mega control board. It is Arduino-compatible and provides built-in motor drivers, sensor ports, and communication interfaces. This board is responsible for processing sensor data and controlling the motors based on our algorithm.

Power Supply: The robot is powered by a 11.1V Li-Po battery rechargeable battery pack, which provides enough current for both the control board and the DC motors. A built-in voltage regulator on the mCore ensures safe voltage levels for all components. Power is distributed through the PCB traces to connected modules.

Motors and Drivers: Two DC geared motors are connected to the mCore motor ports (M1 and M2). These are driven by an integrated dual motor driver module (L298N), allowing bidirectional motion and speed control through PWM signals. Each motor is controlled independently to enable turning and forward/backward motion.

Ultrasonic Sensors: We used two ultrasonic sensors (HC-SR04). These sensors are positioned to detect the opponent robot in front and at slight side angles. The sensors operate by sending sound waves and measuring the reflection time to calculate distance, which is used to trigger movement decisions.

Infrared (IR) Line Sensors: Two IR (TCRT5000) line-following sensors are connected to detect the black boundary lines of the dohyo ring. These sensors emit infrared light and measure the reflection from the surface. A sharp drop in reflection (detected as black line) signals the robot to stop or reverse to stay inside the ring.

Wiring and Connections: All modules are connected using jumper wires, which provide both power and signal lines in a color-coded manner. This simplifies connections and reduces wiring errors. Additional wires were secured to the chassis using clips to prevent disconnection during movement.

RESULTS

Our robot, Gebeş Kaplumbağa, worked pretty well in both the testing phase and during the competition. Most of the time, it did what we expected — like detecting opponents, attacking effectively, and avoiding the ring border using its sensors and control system. We used a P-controller for smoother turning, and it helped a lot while chasing the target.

The IR sensors were very useful. When the robot got close to the white edge, it reacted fast and did the escape move. It first moved forward a bit, then went back, and turned. This helped the robot stay in the ring almost every time.Ultrasonic sensors also worked okay, but sometimes they didn't see the opponent if it came from an angle. That caused small delays. But in general, it could find the other robot again by rotating.

In one match, we had a problem. The other robot was scanning fast and came from the side. Our sensors didn't see it early, so it pushed us out. We realized that our sensor range wasn't wide enough from the sides. This is something we can fix next time.Mechanically, nothing broke or fell off. The screws stayed tight and the motors worked fine. The robot moved smoothly and didn't shake. Battery power was also enough; we had no power cuts.

In conclusion, our robot's second-place result proves that the mechanical, electrical, and software systems were well integrated. The project was a success, and the single loss showed us areas to improve — like making the attack more aggressive or improving the line detection response.

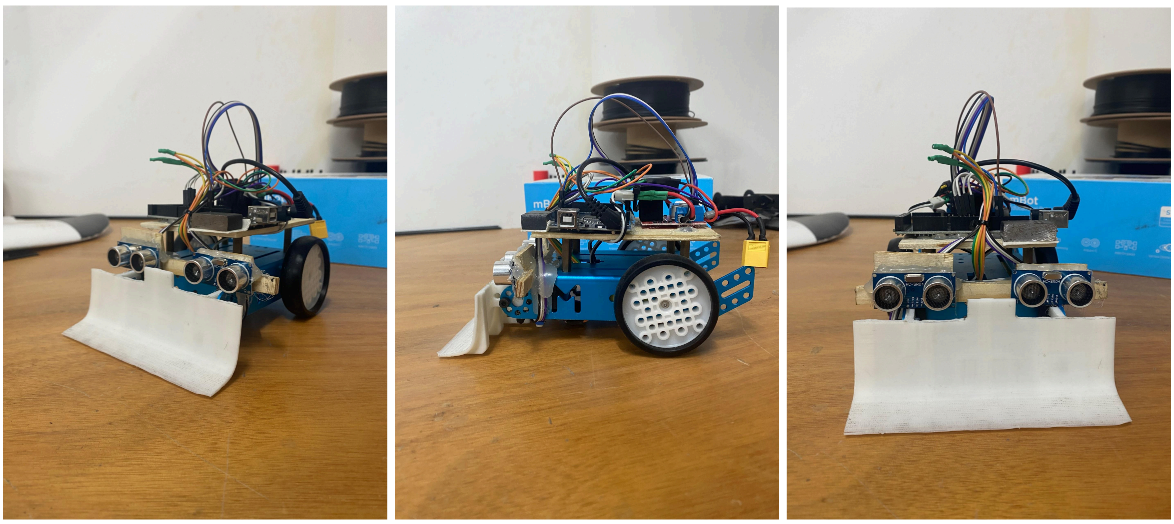

Figure 2: Photographs of the GEBEŞ KAPLUMBAĞA robot used in the competition