Embedded Systems Project

STM32 Mobile Robot Control

Autonomous robot behavior:
Forward motion – Obstacle detection – Rotation – Forward motion

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Author

Sami BENNANE

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Introduction

This document describes the embedded software developed for a mobile robot based on an STM32 microcontroller. The program controls the robot motion, handles obstacle detection using infrared sensors, and manages autonomous behaviors using timers and interrupts.

The objective is to implement a reactive system capable of:

- moving forward autonomously,
- detecting obstacles in real time,
- performing avoidance maneuvers,
- stopping safely when required.

Hardware and Peripherals

Microcontroller

The system is based on an STM32 microcontroller using the HAL library.

Motors and PWM

Two DC motors are controlled using PWM signals generated by **TIM2**:

- Channel 1: left motor
- Channel 4: right motor

Motor direction is controlled through GPIO pins.

Sensors

Three analog signals are acquired using **ADC1** in scan mode:

- Battery voltage measurement
- Infrared sensor IR3
- Infrared sensor IR4

Timers

- **TIM6**: periodic interrupt used as the main control loop
- **TIM3** / **TIM4**: encoder interfaces (position and speed measurement)
- **TIM7**: reserved for future extensions

User Interface

A push button configured with an external interrupt (EXTI) allows the user to enable or disable the robot.

Software Architecture

The software is interrupt-driven and relies on:

- external interrupts for user interaction,
- timer interrupts for periodic control,
- ADC interrupts for sensor acquisition.

The main loop remains lightweight, while most of the logic is executed inside interrupt callbacks.

Robot Behavior and Control States

The robot behavior is governed by an internal state variable `T`.

State (T)	Behavior
1	Forward motion at constant speed
2	Rotation to avoid obstacle
3	Forward motion after rotation
4	Stop (motors disabled)

State transitions are triggered either by timers or by obstacle detection events.

Obstacle Detection

Obstacle detection is performed after each ADC conversion sequence. If one of the infrared sensors exceeds a predefined threshold, the robot immediately switches to the rotation state.

$$(IR3 > \text{threshold}) \quad \text{or} \quad (IR4 > \text{threshold})$$

This ensures a fast and reactive obstacle avoidance behavior.

Motor Control

Motor speed is controlled through PWM duty cycles. Different PWM values are applied depending on the robot state (forward motion, rotation, stop).

Direction pins are adjusted to achieve either straight motion or in-place rotation.

Battery Monitoring

The battery voltage is periodically measured. If the voltage falls below a predefined threshold, a warning LED is activated to indicate low battery conditions.

Conclusion

This project demonstrates the implementation of a real-time embedded control system using STM32 peripherals. The robot combines sensor acquisition, motor control, and interrupt-driven logic to achieve autonomous navigation with obstacle avoidance.

The architecture is modular and can be extended with additional sensors, control algorithms, or communication interfaces.