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Smart Parking System

This project is an embedded-based smart parking automation system developed to address the fundamental needs encountered in small and medium-sized parking lots with limited parking capacity, such as automating and simplifying parking space management, vehicle entry and exit management, and real-time monitoring of parking space occupancy. The primary design objective is to create a fully integrated microcontroller application capable of processing realtime sensor data, making decisions without human intervention, and clearly communicating system status to the user. The project is developed using the STM32F103C6T6 microcontroller with fully register-level GPIO control, with all pin configurations and peripheral settings configured directly through hardware registers.

The system uses three ultrasonic distance sensors to measure the occupancy rate of each parking space on a millisecond scale. When a vehicle approaches a certain distance, the space is classified as "occupied," "approaching" at a medium distance, and "empty" at a far distance. This status is instantly communicated to drivers via a triple LED indicator system (red, yellow, and green). Based on data obtained from these sensors, a status indicator system consisting of red, yellow, and green LEDs operates for each parking space. If the vehicle is very close to the parking space, the red LED is illuminated; if it is in the middle distance, the yellow LED is illuminated; and if the parking space is empty, the green LED is illuminated. The LED drivers are directly controlled using the BSRR and BRR registers via the microcontroller's GPIO output pins. This ensures reliable performance of fast bit set/reset operations and time-critical LED updates.

A detection mechanism consisting of IR barrier sensors is used at the vehicle entry and exit points. The IR LED is driven by a 38 kHz PWM signal via the TIM1 timer, while the IR photodiodes on the receiver side are monitored in pull-in mode on the GPIO input pins. When the vehicle passes the light barrier, the system automatically detects the entry/exit action, activates the corresponding servo motor, and opens the gate. Servo motor control is achieved through software-based PWM generation. This design eliminates the need for hardware timers for the servo drive, allowing precise control of gate movement using only the microcontroller's wait cycles and GPIO register writes.

The parking lot status, number of available parking spaces, and system messages (e.g., "SYSTEM READY," "WELCOME," "DOOR OPENING...", "PARKING FULL," etc.) are displayed on an LCD screen communicating via I2C. All settings of the I2C1 peripheral (clock configuration, CCR calculation, TRISE value, START/STOP bits, ACK mechanism) are programmed directly through the corresponding registers (CR1, CR2, CCR, DR, SR1, SR2). This approach offers lower memory usage and greater control and hardware-level communication monitoring compared to pre-built I2C libraries.

The system's software architecture features a modular design, with sensor drivers, servo control modules, an IR barrier unit, an LCD interface, and a decision-making mechanism separated into distinct functions. The main loop sequentially handles real-time data processing and status updates, ensuring uninterrupted and synchronized system operation with all peripherals.

This project presents an integrated approach encompassing the fundamental components of embedded system design: sensor integration, timing control, PWM generation, data processing, hardware interfaces, and low-level microcontroller programming. The developed smart parking prototype provides a functional model of a real parking automation system.