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Design And Implementation of a Smart Parking System

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Abstract:
Nowadays, along with the rapid development of science and technology and the increasing demand for travel, the number of vehicles is constantly rising, especially in large urban areas in Vietnam. This poses many challenges for traffic control and management, including the issue of parking management. This study presents the design and implementation of a smart parking system based on image processing technology for License Plate Recognition (LPR) and uses an Arduino microcontroller to control peripheral devices. The system aims to automate the vehicle entry and exit management process, minimize human effort, enhance security, and improve parking management efficiency. The system includes the following main components: a webcam to capture images, a computer for image processing to recognize license plates using the OpenCV library and Python language, and an Arduino Nano microcontroller to control an infrared sensor for vehicle detection and a servo motor for operating the barrier gate. The experimental results show that the model operates stably, is capable of recognizing license plates with relative accuracy under certain conditions, and controls the barrier automatically. This system offers a potential solution for efficient parking management, while also opening up future development possibilities for integrating AI technology and modern payment methods.
Keywords: *Smart parking, license plate recognition, image processing, Arduino, OpenCV, automatic parking management.*

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I. INTRODUCTION

I The rapid increase of personal vehicles in major cities in Vietnam has put great pressure on the infrastructure, especially parking lots. Traditional parking management methods, which rely heavily on manual labor and paper tickets, often face many limitations such as high labor costs, susceptibility to errors and losses, and inadequate security (e.g., vehicle theft, damaged tickets). To address these shortcomings, the application of automated systems is an urgent need.

The automatic License Plate Recognition (LPR) system is an advanced technological solution that allows for the "reading" and "understanding" of information on vehicle license plates from camera images. This technology has many practical applications, such as automatic toll collection, vehicle control at border gates and security checkpoints, anti-theft measures, and especially in automatic parking management systems.

Based on this situation, this research focuses on the "Design and Implementation of a Smart Parking System." The main objective is to build an automated parking management model that applies image processing technology for license plate recognition and uses microcontrollers for access control. The system aims to mitigate the existing problems of traditional parking lots, enhancing convenience, safety, and management efficiency.

II. SYSTEM DESIGN

2.1 Necessary requirements

Automatic License Plate Recognition (ALPR): Real-time detection and recognition of vehicle license plates using computer vision techniques.
Automated Barrier Control: Servo motors manage entry and exit barriers based on license plate verification.
Real-Time Monitoring Interface: Graphical User Interface (GUI) developed with PyQt5 provides live system status and control.
Manual Override Functionality: Redundancy mode enables manual control in case of system failures or special circumstances.

2.2 System Architecture

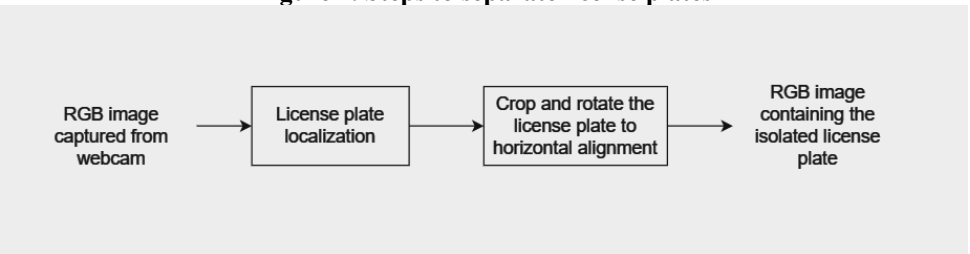
Hardware:
Arduino Nano: Main microcontroller, processing signals from sensors and controlling servo motors.
IR infrared sensor: Detecting the presence of vehicles at the barrier location.
SG90 servo motor: Controlling the opening/closing of the barrier.

720p HD camera: Recording images of vehicle license plates.
Power IC LM2596, 7805: Stabilizing electrical applications for devices in the system.
Software:
OpenCV: Image processing library for number recognition, character separation and information extraction.
PyQt5: Developing real-time monitoring and control user interface.
Tesseract OCR or CNN network: Character recognition after analysis.

III. LICENSE PLATE RECOGNITION ALGORITHM

3.1. Opportunities

Figure 1. Steps to separate license plates



After the license plate has been detected and cropped from the original image, the next step is character segmentation, which involves separating individual characters for recognition. Accurate segmentation is critical to the overall success of the license plate recognition system.

The character separation process includes:
License plate image pre-processing:
- The cropped plate image is converted to grayscale to simplify processing.
- Smoothing filters such as Gaussian Blur are applied to reduce noise.
- Binary thresholding is used to create a high-contrast image where characters are clearly distinguished from the background.

Edge and contour detection:
- Canny edge detection is used to highlight edges in the image.
- Contours are extracted to identify regions that may contain characters.

False character filtering:
- Contours are filtered based on criteria such as aspect ratio, size, and position to eliminate noise or irrelevant objects (e.g., screws, plate frame).
- Only regions matching expected character features are retained.

Character sorting:
- Detected character regions are sorted from left to right based on their X-coordinates to preserve the correct order.
- In some cases, if the plate has multiple rows, each row is processed separately.

Output normalization:
- Each isolated character is resized to a uniform dimension for the recognition stage.
- Care is taken to preserve shape and clarity to avoid distortion or information loss.

Output:
The result is a set of individual character images extracted from the license plate. These segmented characters are then passed to an OCR engine or a neural network for final recognition and conversion into a complete license plate string.

Figure 2. License plate separation

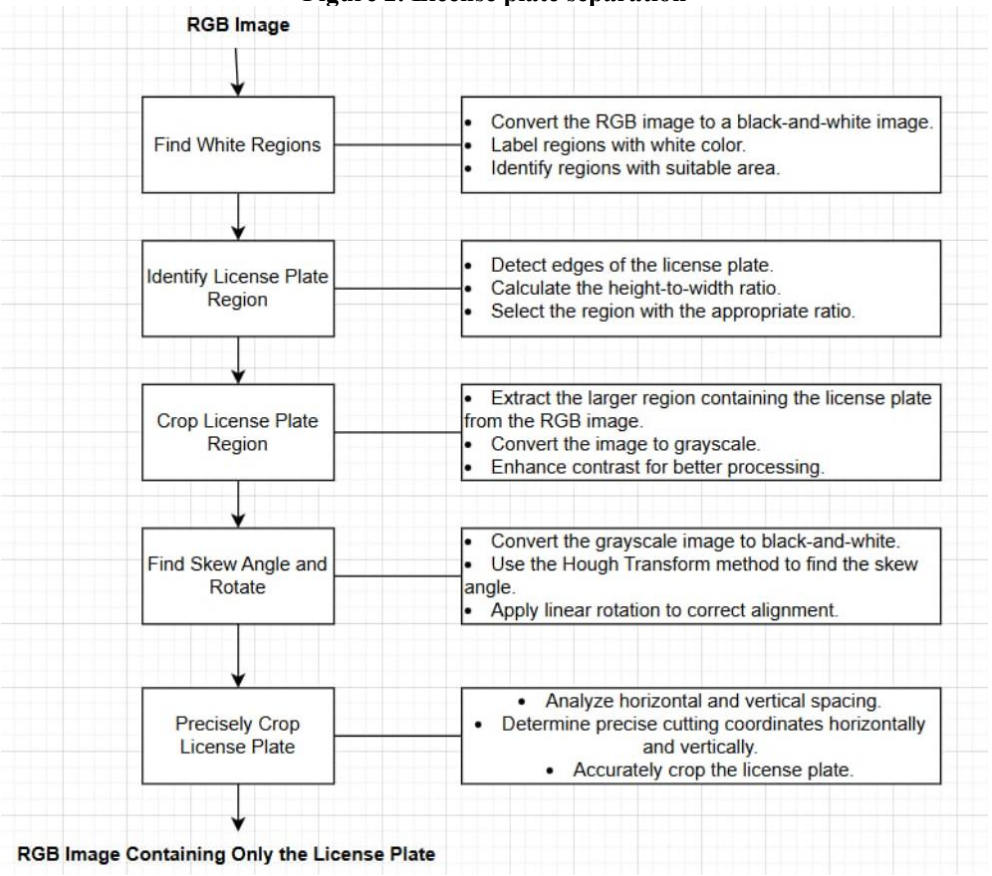
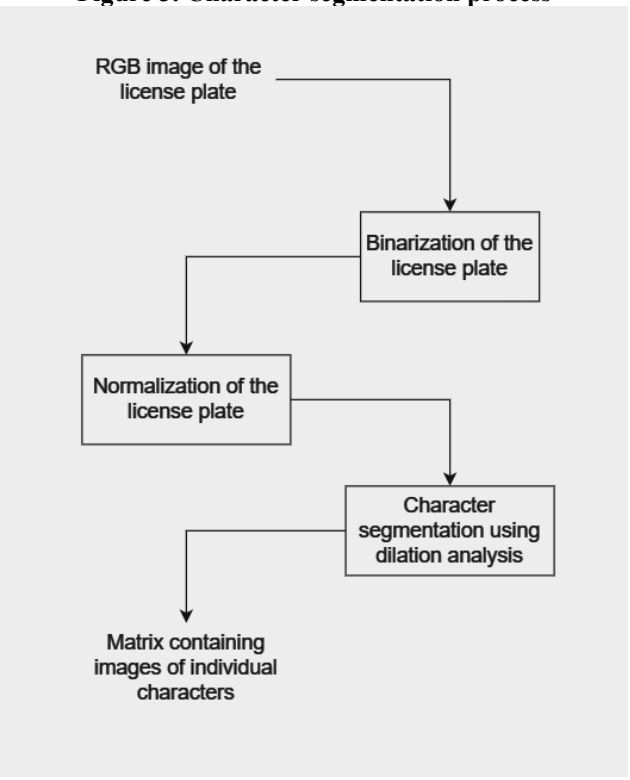
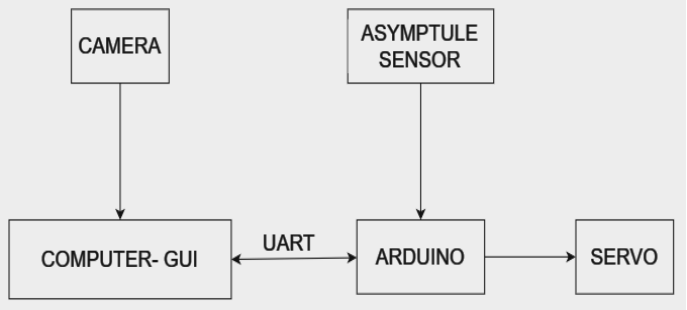


Figure 3. Character segmentation process



3.2 Software design

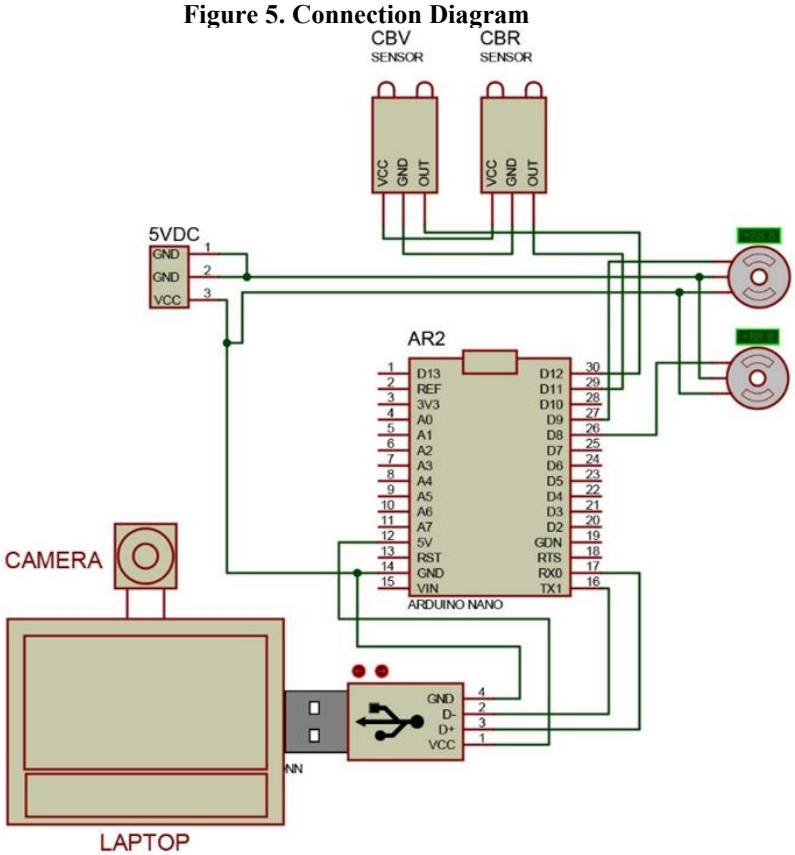
Figure 4. Block Diagram



The computer acts as the image processor. It is responsible for receiving image data from the camera and processing the algorithms related to license plate recognition as well as the GUI (Graphical User Interface) control
The camera helps to capture images of the license plate and send them to the computer for processing
Input sensors, including two infrared sensors, play the role of detecting obstacles and stopping the vehicle at the barrier gate
Arduino serves as the controller for peripheral devices. It receives signals from the proximity sensors and, through control algorithms, generates control signals for the actuators
The actuators in this case are two servo motors, which provide the driving force for opening and closing the barrier gate

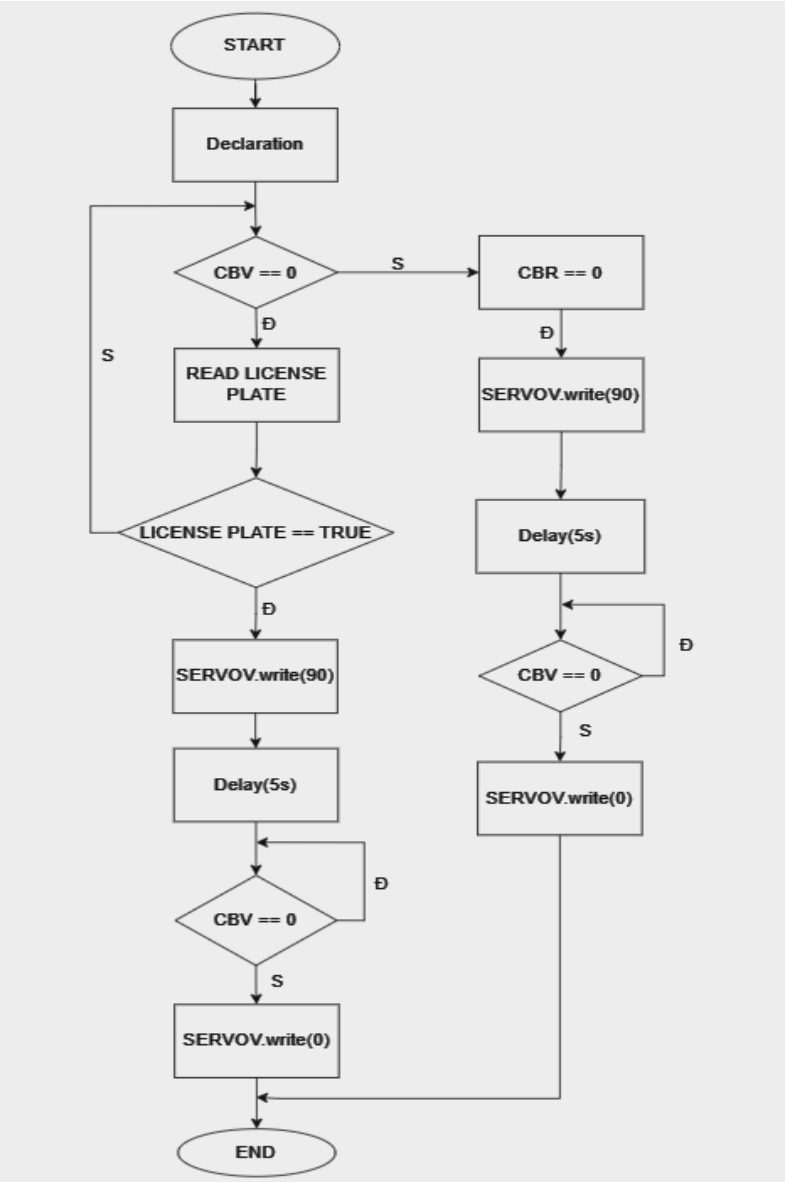
3.3 Connection Diagram

Figure 5. Connection Diagram



3.4 Algorithm Flowchart

Figure 6. Diagram of central control algorithm



3.5 System Operation

The system supports both **automatic** and **manual** modes:

- In **automatic mode**, the camera captures images as a vehicle approaches, processes the license plate, and opens the barrier if the plate is in the whitelist.
- In **manual mode**, the operator can trigger gate operation via GUI buttons, suitable for fallback scenarios.

A real-time vehicle counter is implemented to control entry based on parking lot capacity.

IV. SYSTEM IMPLEMENTATION

4.1 Hardware Implementation

Components used
Arduino Nano
HD Webcam (720p)
IR sensor
SG90 servo motor

LM2596 step-down IC

4.2 Circuit Design

Figure 7. Processing Unit

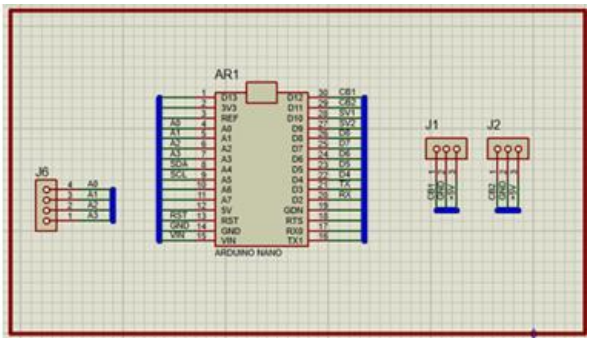


Figure 8. Power Control Unit

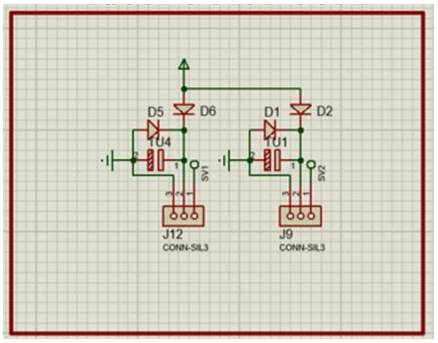
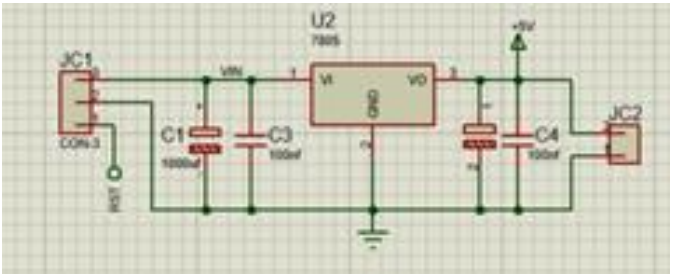


Figure 9. Circuit diagram



4.3 Kết quả và đánh giá

Figure 10. Circuit installation

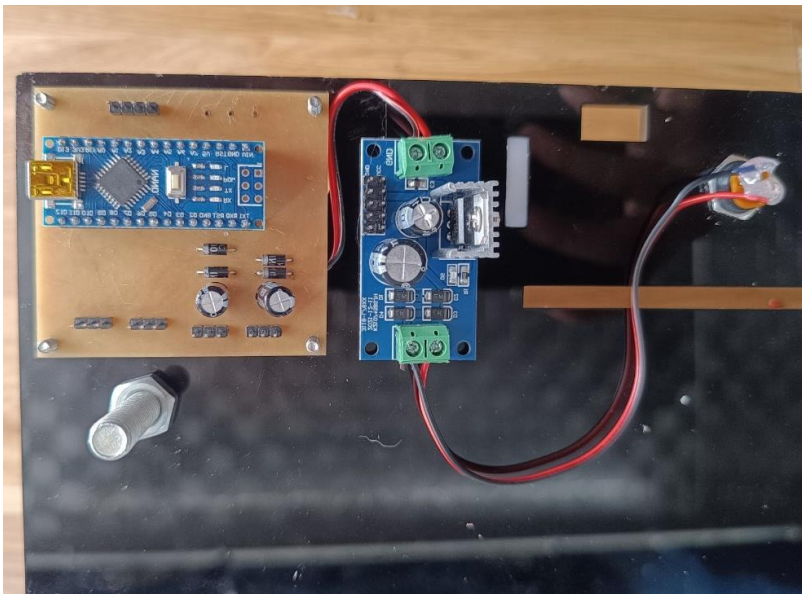
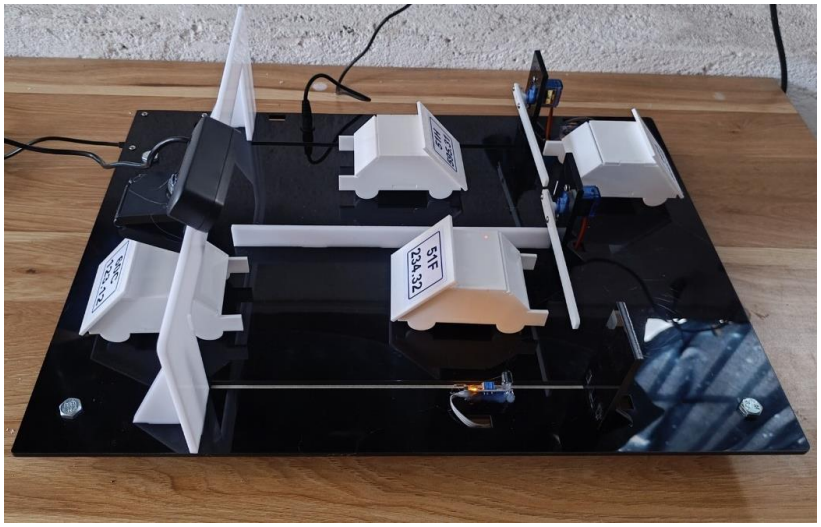


Figure 11. Model completion



Recognition Accuracy: The system accurately recognizes clearly visible license plates with a tilt angle of less than 45°.

Mechanical Performance: Motors and sensors operate smoothly without conflicts.

User Interface: Intuitive and easy to use, with license plate display.

Scalability: Modular design allows for integration of AI and new payment methods in the future.

V. CONCLUSIONS

The project successfully met its core objectives. A clear and straightforward hardware architecture was introduced, and the sensor system was programmed to operate reliably without signal interference. The data collected from the system demonstrated relatively high accuracy under typical environmental conditions. While the system achieved its intended functionality, there are still limitations to be addressed. The data transmission

rate and signal responsiveness could be further optimized. Moreover, the current model remains relatively basic and would benefit from enhancements in both functionality and user experience. Future development will focus on expanding the system's capabilities. Plans include integrating additional sensors and applying artificial intelligence (AI) and machine learning techniques to address more complex challenges, such as detecting fraudulent license plates. Additionally, new algorithms for calculating parking fees via bank transfer or other convenient payment methods will be explored. Finally, a dedicated Windows-based management interface and a mobile application will be developed to provide users with a more seamless parking experience.

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