路邊自動停車收費柱系統及其車牌辨識在嵌入式平台上的實作

Members: 陳冠瑋、袁鈺彬
Dept. of Electrical Engineering, National Chung Hsing University

Abstract

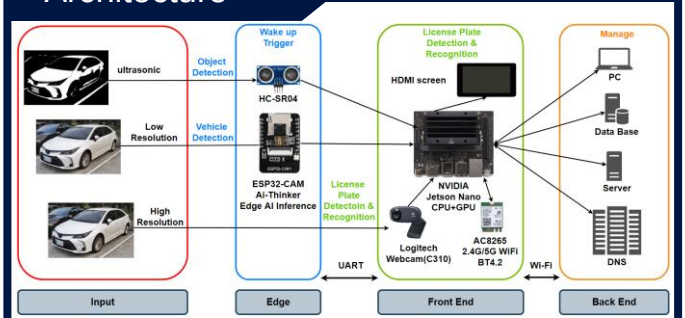
Traditional license plate recognition systems usually recognize scenes with fixed angles, small tilt angles, and abundant light sources.

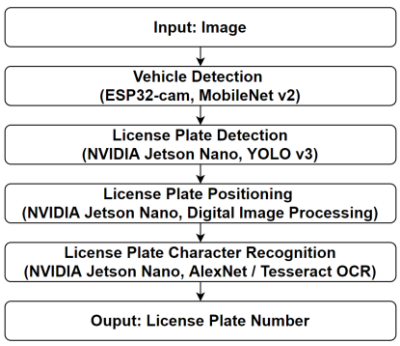
This work proposes a series of image processing algorithms to handle sharp camera angles, poor lighting, and license plate defect. In addition, to reduce system power consumption, a low-power embedded AI inference vehicle detection device (ESP32-CAM) is added at the edge of the system as a wake-up sensor.

Introduction

This project uses NVIDIA Jetson Nano as the primary computing platform and ESP32-CAM as the edge inference device for vehicle detection. Mainly through MobileNet v2 for vehicle detection, YOLO v3 for license plate detection, and image processing for extracting and correcting the license plate features. Finally, we use AlexNet and Optical Character Recognition (OCR) for the license plate character recognition.

Architecture



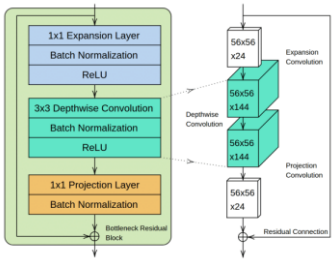


Edge Inference

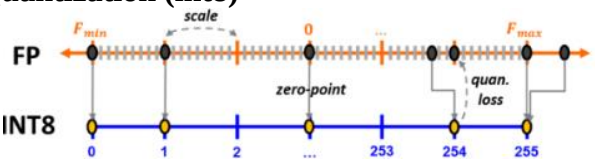
Vehicle Detection (MobileNet v2)

Advantages:

- Real-Time
- Low Power
- Low Price
- Reliability
- Security



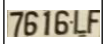
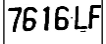
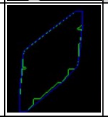
Quantization (int8)



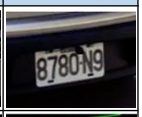
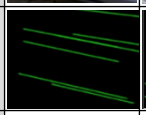
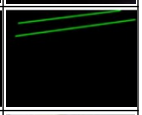
Pre-processing

LP Positioning

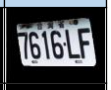
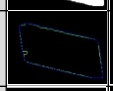
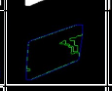
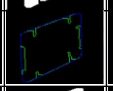
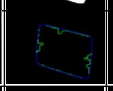
- Basic image pre-processing (denoise)
- Image segmentation: GrabCut
- LP tilt correction: Hough line transformation
- Morphology
- Defect repairing: Convex hull
- Restore LP: Perspective transformation

Step	Procedure	Result	Step	Procedure	Result
1	LP detection (YOLO v3)		6	LP mask	
2	Region of Interest (ROI)		7	LP positioning	
3	GrabCut		8	Perspective Transformation	
4	Morphology		9	After Pre-processing	
5	Convex Hull				

▲ Oblique LP Recognition

Step	LP1	LP2	LP3	LP4
Original				
Hough Line				
Tilt Correction				

▲ Tilt angle correction based on Hough line transform

Step	LP1	LP2	LP3	LP4	LP5
Image Segmentation					
Morphology					
Convex Hull					
LP mask					
Canny					
LP positioning					

Repair license plate defect ▶

Result & Conclusion

cars: 0.92
unknown: 0.08
inference time: 745ms

▲ Vehicle detection (MobileNet v2)

▲ LP detection (YOLO v3)

▲ Character recognition (AlexNet)

Step	Procedure	Result	Step	Procedure	Result
1	Original		9	Binarization	
2	Grayscale		10	Canny	
3	Hough Line		11	Convex Hull	
4	Tilt Correction		12	LP mask	
5	Canny		13	Canny	
6	Rectangle Fitting		14	LP positioning	
7	Bounding Box		15	Perspective Transformation	
8	GrabCut (Segmentation)		16	Character Recognition (AlexNet)	

▲ LP recognition algorithm

The above figures and tables show the algorithm and results of our design. Based on the results, we observe that the helps of image processing can simplify the complexity of the problem. The problem of license plate recognition can turn be turned into the license plate positioning problem and character recognition problem. At the same time, it can reduce the difficulty of training the model. For the edge inference detection of vehicle, the accuracy is about 70%~90%, and the inference time is about 750 ms (1.33 fps). Compaing with NVIDIA Jetson Nano (5~10w), the low-power ESP32-CAM (30mW~1.5W) is more efficient in power consumption. It is suitable for always-on scenarios.