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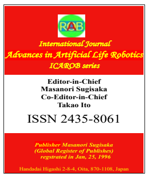

Research Article

Parking Space Recognition Method Based on Digital Image Technology

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ABSTRACT

In recent years, the urban landscape has witnessed a surge in vehicular population, exacerbating the challenge of finding adequate parking spaces. Consequently, the development of automatic methods to identify parking availability has gained significant attention. This study introduces a design and implementation framework aimed at discerning the status of urban parking spots utilizing digital image processing and allied technologies. Real-time images of multiple parking spaces are gathered to assess their occupancy, thereby facilitating efficient space utilization. Experimental findings affirm the practical viability and efficacy of the proposed approach, underscoring its relevance in tackling parking detection challenges through advanced digital image processing techniques.

1. Introduction

In recent years, the rise in family car ownership has exacerbated urban traffic congestion and highlighted challenges in managing urban parking spaces.

In recent advancements in intelligent parking management systems, the evolution of technology has refined methods for identifying parking space statuses. Initially, various sensor-based approaches were employed, each with its drawbacks: ultrasonic methods suffered from increased sensor errors due to multiple echoes, infrared methods were susceptible to ambient light and heat variations, leading to higher misjudgment rates, and geomagnetic detection was hindered by complex installation requirements.

Consequently, experts across relevant fields have sought innovative solutions, leading to a burgeoning research focus. Emerging findings highlight the advantages of employing digital image technology for real-time monitoring and analysis of parking lot utilization through advanced image algorithms. Thus, this paper investigates a parking space recognition method based on digital image technology.

This thesis consists of four main parts. The first part describes the background of the research. The second part gives a brief introduction to the development environment and covers the basic concepts of Python, OpenCV, and CNN. The third part describes the system process in detail, including data preprocessing, parking space division, CNN model construction and parking space detection; The fourth part summarizes and summarizes the main contents of the thesis.

2. Introduction to development environment

2.1. Introduction to Python

Python is a high-level programming language first published by Guido van Rossum in 1991. It is known for its clean and easy to read syntax, rich standard library, and strong community support. Python is widely used in a

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variety of fields, including data science, artificial intelligence, web development, automated scripting, and software development.

Application field:

- Data science: Python libraries such as NumPy, Pandas, and Matplotlib are widely used in data analysis and visualization.
- Artificial Intelligence: Libraries like TensorFlow, Keras, and PyTorch make Python stand out in the field of machine learning and deep learning.
- Web Development: Frameworks such as Django and Flask have made Python very popular for web development.
- Automation: Python is often used to write scripts to automate repetitive tasks and system administration.
- Software development: Python can be used to develop desktop applications, games, and other software solutions.

Overall, Python is a very popular programming language in many areas because of its simplicity and power.

2.2. *Introduction to OpenCV*

OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning library originally developed by Intel and later maintained by Willow Garage and Itseez (later OpenCV organization). OpenCV provides a wealth of tools and capabilities for computer vision and image processing that are widely used in industry, academic research, and business.

Main features:

- Rich features: OpenCV includes hundreds of image processing, computer vision, and machine learning capabilities, including image filtering, feature detection, target tracking, classification, object recognition, and more.
- Efficiency: OpenCV optimizes many compute-intensive operations, uses C++ implementation, supports multi-threading and GPU acceleration, and can run under efficient real-time processing requirements.
- Cross-platform support: OpenCV supports multiple operating systems such as Windows, macOS, Linux, and mobile platforms such as Android and iOS, making it suitable for a variety of development environments.
- Language bindings: Although OpenCV is mainly developed in C++, it also provides binding interfaces for Python, Java, C# and other languages, allowing developers to develop in languages they are familiar with.
- Open Source and Community support: As an open source project, OpenCV has an active development community and a large amount of documentation, tutorials, and sample code to support developers to customize and extend.

Overall, OpenCV is used for a wide variety of computer vision and image processing tasks due to its powerful features, cross-platform support, and active community, and is an important tool for developers and researchers [1], [2].

2.3. *Introduction to CNN*

Convolutional Neural networks (CNNS) are a class of deep learning models specifically designed to process data with a grid-like structure. It is most commonly used for image processing, but can also be applied to other types of grid data, such as video and audio signals. The design of CNN is inspired by the biological visual system, specifically the structure and function of the human visual cortex.

Advantages:

- Automatic feature extraction: CNN can automatically extract features from the original image without the need for manual feature engineering.
- Efficiency: With parameter sharing and local connections, CNNS are able to process high-dimensional data while maintaining low computational complexity.
- Scalability: CNNS can handle more complex tasks by stacking multiple convolutional and pooled layers.

Overall, convolutional neural networks have made significant progress in the field of computer vision and are a central tool for solving various image and video related problems.

3. Methodology

The system design process involves several stages: pre-processing, parking space segmentation, CNN model construction and training, and real-time parking space recognition. In the pre-processing stage, data is filtered to retain only relevant information. Parking spaces are segmented and stored as samples. The CNN model is then trained to classify whether a parking space is occupied. Finally, real-time monitoring identifies available spots and marks them accordingly.

3.1. pretreatment

Due to various natural factors, such as low contrast between the target object and the background scene, and the limited available information, direct recognition of parking spaces from images is challenging. Therefore, extensive preprocessing of the original image is necessary. This includes tasks like noise reduction and enhancing image details to differentiate the target object from the background image.

To enable post-processing, it is recommended to initially conduct background filtering to eliminate any irrelevant background details in the image and make subsequent recognition easier. This can be achieved by defining a mask, establishing maximum and minimum thresholds, and converting information outside the threshold range into zero value data.

The second step involves converting the image to grayscale. This transformation focuses solely on the brightness data, removing extraneous details and thus decreasing the computational effort needed for subsequent processing steps.

The third step involves using Canny edge detection, which consists of four main processes: applying Gaussian blur, computing the gradient magnitude and direction, performing non-maximum suppression, and applying a double threshold technique. This method effectively identifies both actual and potential edges, improving the precision in boundary detection [3].

Fig. 1 displays the original image, while Fig. 2 illustrates the image after preprocessing.

Fig.1 original image

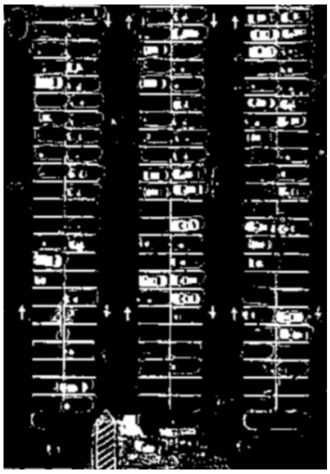

Fig.2 Pretreatment result

3.2. Parking space division

Upon observation, parking lots are structured with distinct straight lines, which can be effectively segmented using the Hough transform, a prominent feature detection algorithm in computer vision. This method enhances accuracy by specifying the types of shapes to identify, employing a voting mechanism in parameter space to determine object shapes while filtering out outliers with overly large or small intervals. It's crucial to note that some imperfections like cracks or other line segments in images might falsely resemble parking space lines; however, genuine parking space lines predominantly exhibit vertical or horizontal orientations. Calculating the slopes of these line segments can further refine accuracy by eliminating irregular segments.

3.3. CNN network training

Following the acquisition of parking space images, datasets were partitioned into training and test sets with a 70%-30% split. Further segmentation categorized images into occupied and non-occupied classes based on vehicle presence, facilitating subsequent model training.

Due to the limited size of the dataset, enhancing data becomes crucial for improving model performance. Data augmentation, whether conducted online or offline, helps expand the dataset effectively. Offline methods are particularly suitable for small datasets, increasing sample size by transforming images—for instance, by rotations—

thereby boosting dataset diversity. Supervised methods, commonly employed, analyze existing data completeness and apply rules to expand it, typically through single or multi-sample enhancements.

The training dataset is then fed into the model for training. Upon completion, the test set achieves an accuracy of 91.4%, consistent with expectations. Subsequently, consideration was given to switching from VGG16 to ResNet50 to enhance accuracy further. However, due to ResNet50's slower training speed compared to VGG16, efficiency considerations led to the decision to stick with VGG16.

Fig. 3 presents the outcomes of the parking space detection process.

Fig.3.Parking test results

4.Conclusion

The program will conduct real-time image processing to detect and display vacant parking spaces in green while leaving occupied spaces unmarked. There are occasional inaccuracies, such as incorrectly marking the guiding lines in the parking lot as empty spaces, which could be refined through adjustments to the CNN model. Despite these occasional errors, overall detection and statistical analysis of remaining areas generally meet anticipated standards, achieving effective processing and identification of parking space status.

Utilizing OpenCV and convolutional neural networks (CNNs), the study achieves real-time monitoring of parking space occupancy, offering practical urban parking management solutions. Future optimizations aim to enhance system speed and adaptability to diverse parking scenarios, ensuring timely and efficient data for effective parking lot management.

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