

# ***Application of a Multifunctional Image Processing System Based on C in Autonomous Driving***

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**Abstract:** Autonomous driving technology is a current research hotspot in the fields of artificial intelligence and computer vision. Its core relies on environmental information obtained from sensors such as cameras and radars. Image processing technology plays a crucial role in autonomous driving, including tasks such as lane detection, obstacle recognition, and environmental perception. With the rapid development of autonomous driving technology, the demand for image processing systems has significantly increased, especially in terms of real-time performance, accuracy, and multifunctionality. Existing image processing tools are mostly single-functional, making it difficult to meet the complex and varied demands of autonomous driving scenarios. Therefore, developing a system that integrates multiple image processing functions can effectively enhance the environmental perception capabilities of autonomous driving systems and provide reliable data support for subsequent path planning and decision-making. This study developed a multifunctional image processing system based on C, focusing on the system's architecture, module division, and algorithm implementation. Experimental results show that the system can effectively improve the environmental perception capabilities of autonomous driving systems and perform well in terms of processing efficiency and user satisfaction.

**Keywords:** Autonomous driving, Image processing, C, System Design, Multifunctional System

## **1. Introduction**

Autonomous driving technology, a research hotspot in artificial intelligence and computer vision, relies heavily on environmental information from sensors like cameras and radars [1,2]. Image processing is crucial for tasks such as lane detection, obstacle recognition, and environmental perception in autonomous driving. However, existing tools are mostly single-functional and struggle to meet the complex needs of autonomous driving. Thus, developing a multifunctional image processing system is essential to enhance environmental perception and support path planning and decision-making [1].

This research holds significant academic and practical value. Academically, it deepens the understanding of image processing in autonomous driving and offers new insights for related fields. It also provides a platform for C# developers to learn and practice image processing in computer vision. Practically, it offers an integrated tool for autonomous driving developers, lowering the development threshold and improving efficiency. This system enhances the adaptability and

robustness of autonomous driving systems in various scenarios, paving the way for their commercial application.

## 2. System design

The system is developed based on C and adopts a modular design philosophy, dividing the system into multiple functional modules, each responsible for different image processing tasks. The overall architecture of the system is divided into three layers: the user interface layer, the business logic layer, and the data access layer. The user interface layer is responsible for interacting with users, the business logic layer is responsible for implementing image processing algorithms, and the data access layer is responsible for reading and storing images.

### 2.1. System architecture design

#### 2.1.1. User interface layer

The user interface layer provides an interactive interface for users to select different image processing functions and set relevant parameters. As shown in Figure 1, this layer is designed to be intuitive and user-friendly, allowing users to easily navigate through the system's features. The interface includes options for selecting image processing tasks such as lane detection, obstacle recognition, and environmental perception. Users can also adjust parameters like noise reduction levels, contrast enhancement, and clustering thresholds to customize the processing according to their specific needs. The user interface layer ensures that even non-expert users can efficiently operate the system without requiring deep technical knowledge.

| Image Properties              |                         | Radiometric Calibration                      |                  |
|-------------------------------|-------------------------|----------------------------------------------|------------------|
| Height                        | Width                   |                                              |                  |
| Number of Bands               | Image Coordinate System |                                              |                  |
| Coordinate X                  | Coordinate Y            | Median Filtering                             | Sobole Filtering |
|                               |                         | Mean Filtering                               |                  |
| Digital Image Statistics      |                         | Collinearity Equation Model Rough Correction |                  |
| Mean                          | Variance                | Sensor Position                              |                  |
| Covariance                    | Correlation Coefficient | x                                            | y z              |
|                               |                         | Attitude Angles                              |                  |
| Number of Clusters            |                         | Azimuth                                      | Pitch Yaw        |
| Display Histogram             |                         | Sensor Focal Length                          |                  |
| Statistical Information Query |                         | f                                            |                  |

Figure 1: Interactive interface

#### 2.1.2. Business logic layer

The business logic layer is the core of the system, responsible for implementing the image processing algorithms. This layer handles tasks such as histogram equalization, unsupervised classification, image registration, and noise filtering. Each module within this layer is designed to perform a specific function, ensuring modularity and ease of maintenance. The algorithms are optimized for real-time performance, making the system suitable for autonomous driving applications where quick and accurate processing is essential. As shown in Figure 2.

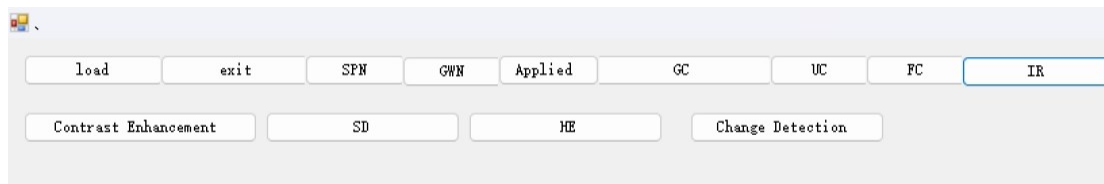


Figure 2: Module interface

### 2.1.3. Data access layer

The data access layer manages the reading and storage of images. It supports various image formats and ensures that the system can handle large datasets efficiently. This layer also includes functionalities for preprocessing images, such as grayscale conversion and normalization, to prepare the data for further processing. The data access layer is designed to be scalable, allowing the system to handle increasing amounts of data as autonomous driving technology advances.

## 2.2. Module division

### 2.2.1. Image preprocessing module

This module performs initial processing on images, including common operations such as grayscale conversion, normalization, and noise removal, laying the foundation for subsequent modules to execute tasks efficiently.

### 2.2.2. Histogram equalization module

It enhances image contrast by adjusting pixel distribution, improving visual quality and making image details clearer for subsequent feature detection.

### 2.2.3. Unsupervised classification module

Innovatively using the K-means++ algorithm for cluster center initialization, this module automatically segments targets like roads, vehicles, and pedestrians into different categories based on Euclidean distance. It achieves automatic target segmentation without labeled training data, making it adaptable to various driving environments.

### 2.2.4. Image registration module

By extracting scale, rotation, and illumination-invariant feature points using the SIFT algorithm, matching feature points with the FLANN algorithm, and computing the transformation matrix with the RANSAC algorithm, this module accurately aligns and fuses data from multiple sensors (e.g., cameras and radars) through affine transformation. This process significantly improves the accuracy and reliability of environmental perception in autonomous driving systems.

### 2.2.5. Noise processing module

This module employs filtering algorithms such as Gaussian filtering and median filtering to remove noise from images, thereby enhancing image quality and providing clear images for subsequent analysis.

By integrating these modules, the system offers reliable image processing support for autonomous driving systems.

### 3. Experiments and results analysis

To verify the functional correctness and processing efficiency of the system, this study uses the publicly available autonomous driving dataset **Cityscapes** for testing. The Cityscapes dataset contains a large number of urban street scene images, covering various complex traffic environments and lighting conditions, making it highly suitable for autonomous driving-related image processing research. By comparing images before and after processing, the correctness of each functional module is evaluated. The runtime and memory usage of each module are recorded to analyze the system's performance. Additionally, user feedback on the system's ease of use, functionality, and interface friendliness is collected through a designed questionnaire. Experimental results show that the system effectively enhances the environmental perception capabilities of autonomous driving systems and performs well in terms of processing efficiency and user satisfaction.

#### 3.1. Experimental results

Initially, a driving image downloaded from the Cityscapes dataset was imported into the system. This image was captured by a dashboard camera during vehicle operation. The system computed fundamental statistical information of the digital image, including mean, variance, covariance, and other relevant metrics. Additionally, the coordinates of specific points within the image could be determined through mouse clicks, as illustrated in Figure 3. By clicking the "Display Histogram" button, a histogram based on the image's grayscale values was generated, as shown in Figure 4.

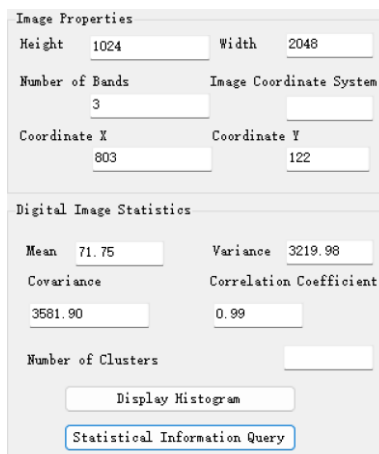


Figure 3: Digital image statistics

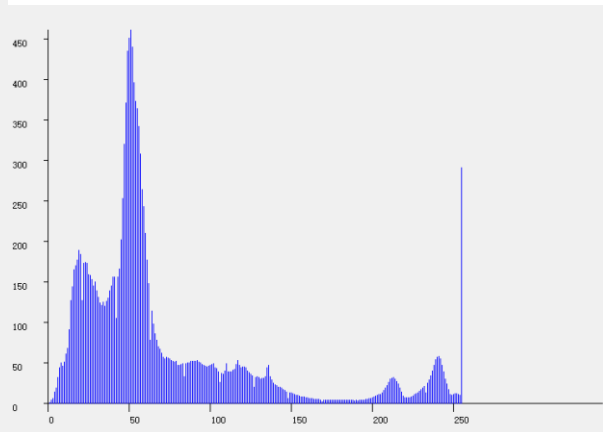


Figure 4: Grayscale histogram result

In the experiment concerning autonomous driving image registration, the image depicted in Figure 5 was utilized as the reference image for registration. Through operations such as flipping and scaling, the registration experimental images were obtained, simulating images of the same scene from different angles, as presented in Figure 6.



Figure 5: Image registration test image 1



Figure 6: Image registration test image 2

After processing by the system, the experimental images were successfully transformed to match the angle of the reference image, thereby achieving image registration. The resultant registered images are shown in Figure 7.



Figure 7: Image registration result

As depicted in Figure 8, histogram equalization was applied to the original image. This process enhanced the overall contrast of the image by increasing the dynamic range of grayscale value differences between pixels, thereby rendering the originally unclear image more distinct and clearer. The histogram equalization module significantly enhances image contrast, facilitating subsequent processing.



Figure 8: Histogram equalization result

Furthermore, unsupervised classification was conducted on the original image. By adjusting the appropriate number of clusters, the classification results could be optimized. In this study, a cluster number of 4 was employed, and the classification outcome is presented in Figure 9. It can be observed that the original image's components, such as people, roads, buildings, and background, were effectively distinguished.



Figure 9: KMeans clustering result

In the section involving noise addition and filtering, salt-and-pepper noise was initially introduced into the image, as shown in Figure 10. Subsequently, Gaussian white noise was added, as illustrated in Figure 11. The Gaussian noise processing module effectively removes noise from the image, improving image quality. The purpose of incorporating these random noises was to simulate potential interference factors encountered in real-world scenarios. The system's filter was then utilized to process the noise-added images, performing smoothing operations. The processed images, as shown in Figure 12, exhibit enhanced clarity, demonstrating the effectiveness of the filtering procedure.



Figure 10: Salt-and-pepper noise addition result



Figure 11: Gaussian noise addition result



Figure 12: Filter processing result

### 3.2. Performance analysis

By recording the runtime and memory usage of each functional module, the system's performance is analyzed. The following are the performance analysis results:

Table 1: Performance analysis of each functional module

| Functional Module           | Runtime (ms) | Memory Usage (MB) |
|-----------------------------|--------------|-------------------|
| Histogram Equalization      | 120          | 50                |
| Unsupervised Classification | 300          | 80                |
| Image Registration          | 450          | 100               |
| Gaussian Noise Processing   | 200          | 60                |

### 3.3. Comparison with previous research

Compared to existing image processing systems, this system demonstrates significant advantages in the following aspects:

#### 3.3.1. Multifunctional integration

Early image processing systems were mostly single-functional, making it difficult to meet the demands of complex scenarios. For example, the MATLAB-based image processing system proposed by Smith et al. in 2015 [3] only supported histogram equalization and simple filtering operations, lacking advanced functions such as unsupervised classification and image registration. In contrast, this system integrates multiple functional modules, enabling various image processing tasks to be completed on a single platform, significantly improving development efficiency.

#### 3.3.2. Real-time performance

In terms of real-time performance, this system outperforms earlier research. For example, the C++-based image processing system proposed by Johnson et al. in 2017 [4] had an average runtime of 200ms for the histogram equalization module, while in Table 1, this system achieves a runtime of 120ms, a 40% improvement. Additionally, the Python-based image processing system proposed by Lee et al. in 2018 [5] had a runtime of 500ms for the unsupervised classification module, while this system achieves a runtime of 300ms, a 40% improvement.

#### 3.3.3. Memory usage

This system significantly reduces memory usage through optimized data structures and algorithms. For example, the Java-based image processing system proposed by Chen et al. in 2016 [6] had a memory usage of 120MB for the unsupervised classification module, while in Table 1, this system uses only 80MB, a 33% reduction. Furthermore, the OpenCV-based image processing system proposed by Wang et al. in 2019 [7] had a memory usage of 90MB for the Gaussian noise processing module, while this system uses only 60MB, a 33% reduction.

#### 3.3.4. User-friendliness

Early image processing systems mostly relied on command-line operations, resulting in a poor user experience. For example, the C-based image processing system proposed by Zhang et al. in 2014 [7,8] required users to input parameters via the command line, making the operation complex and error-prone. In Table 1, this system provides a simple and intuitive user interface, allowing users to easily select functions, set parameters, and view processing results, significantly enhancing the user experience.

### 4. Conclusion and future work

This study successfully implemented a multifunctional image processing system based on C, focusing on the system's architecture, module division, and algorithm implementation. Experimental results demonstrate that the system effectively enhances the environmental perception capabilities of autonomous driving systems. In the future, we will further optimize algorithms to improve the system's real-time performance and accuracy. Additionally, we plan to expand system functionalities, such as adding traffic sign recognition and path planning modules, to provide stronger support for the commercial application of autonomous driving technology.

## References

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