Research on the Robot’s Automatic Road Detection Technology with SRPS

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Abstract. Road detection technology has been widely used in many fields, such as vehicle’s assisted driving, robot autonomous navigation, military defense, public security and so on. In this paper, the road detection method based on sensitive region pixel sequence (SRPS) solution is studied. Firstly, the recent advances of the road detection method based on machine vision are summarized. Secondly, analyses the principle of road detection technology based on sensitive region pixel sequence (SRPS) solution to improve road detection efficiency and accuracy of the vision method. Finally, experimental results show that the sensitive region pixel sequence (SRPS) solution has an important significance to reduce the calculation cost of the robot’s road detection system.

1. Introduction

Since the 1980s, automatic road detection has been a core technology for autonomous driving. In recent years, some institutes and enterprises carried out a detailed study of road detection technology, and obtained some certain achievements [1]. With the development of machine vision algorithm and artificial intelligence technology, vision measurement technology has become more widely applied in the research on robotics. The vision detection technology in the early study is limited by the level of hardware. With the development of computer hardware, the research of vision detection technology and its application system have gained great achievements, such as ALVINN system designed by Carnegie Mellon University, VAMP system designed by Germany Federation of Munich National Defense University, GOLD system designed by Italy Parma University and so on. Furthermore, it is easy for vision detection method to subdivide and judge the road type by deep learning. Researchers in China have begun the study of driverless cars too. In 2005, the first city driverless car was developed at the Shanghai Jiao Tong University [2].

The road information acquisition methods mainly include the laser radar detection and the vision detection. With the laser radar detection method, the accurate three-dimensional information of the road can be obtained, which is more suitable for the judgment of the moving object, but the cost of this method is high. With the vision detection method, the road conditions are to be observed through the camera, which has the characteristics of low cost and high precision.

In recent years, the vision detection method has become a key technology in the road detection system, a variety of different road models are identified by image processing and understanding. [3] Vision detection method can be divided into monocular vision, binocular vision and multi-vision. [4]
1) With monocular vision method, the road’s image is acquired with a single camera, and the road’s image depth information is lost. It is difficult for the automatic pilot robot or car to make the precise judgment of the road with the monocular vision method.

2) Binocular vision is a method of obtaining the object’s three-dimensional geometric information by two cameras based on the disparity principle. The two images of the same object from different locations are obtained, and calculate the locations of the corresponding points in the image. In the binocular vision system; the two cameras can help the automatic pilot robot or car to get more environmental information of the road’s.

3) With multi-vision method, the road’s information is acquired with more than two cameras. The acquisition of the road’s position information is more abundant, but sometimes becomes more prone to ambiguity. [5,6]

In the existing literature, many researchers have done a lot of research on the road detection technology based on machine vision. Azevedo, V B [7] proposed a vision approach for real-time mapping of traversable road surfaces with a stereo camera. The road detection system based on machine vision should solve a complex pattern recognition problem, which has become a concerning focus in the research on the automatic pilot robot or car.

The current road detection system has solved many problems of road recognition, still with some defects. A common road detection system does not exist. The research on the road detection technology with adaptive and self-learning ability is a difficult task, too. [8]

One of the important challenges is that the heavy calculation load leads to the poor real-time performance of the road detection system. The complexity of traffic environmental information reduces the calculation precision and efficiency of the road detection. Further, the widely-used machine learning method learns from the training samples, and the increasing time cost of training samples will reduce the learning accuracy consequently, which leads to the poor adaptability of self-learning to the changing road environment.

To solve this problem, it’s necessary to reduce calculation cost of the road detection system. In the course of this research, the SRPS solution has been put into application.

2. Principle of road detection technology based on SRPS

In order to improve the speed and efficiency of image matching, multi-resolution image matching algorithm has been proposed. Crowley [9] proposed a multi-resolution image pyramid for the first time. In 2004, David G Lowe [10,11] proposed a local feature description SIFT operator of the multi-resolution image.

In principle, multi-resolution image matching algorithm can be divided into two stages: multi-scale spatial decomposition stage and reconstruction stage.

1) In multi-scale spatial image decomposition stage, the image is down sampled with vertical direction and horizontal direction, and an image pyramid is formed. The spatial resolution at higher level will have a smaller pixel size, otherwise, the reverse (shown in Figure 1).

In 1988, Mallat proposed the orthogonal wavelet construction method and the fast orthogonal wavelet transform algorithm[12,13].

Suppose $f(t) \in L^2(R)$ and $\{C_n\}_{n \in \ell^2} \in \ell^2$, make $f(t) = \sum_{n \in \ell^2} C_n \phi_n(t)$, the decomposition algorithm for Mallat is described as flow.

$$C_n^j = 2^{-j/2} \sum_{k \in \ell^2} h_{2k-n} C_k^{j-1}$$

$$D_n^j = 2^{-j/2} \sum_{k \in \ell^2} g_{2k-n} C_k^{j-1}$$

Using the decomposition of the low frequency coefficient $C_n^j$ and the high-frequency coefficient $D_n^j$, the multi-resolution representation of image information is performed.
2) In the step of the image reconstruction, the image reconstruction is done, which is the reverse process of the multi-resolution image decomposition.

![Figure 1. Multi-resolution image pyramid](image)

Image fitting analysis in the road detection system is feasible in principle and has the characteristics of higher speed in computation, but this method has been lack of the ability in judging the road type. By contrast, image matching analysis has the characteristics of higher precision and good computational stability. On the basis of the study, the SRPS solution is studied. SRPS means the sensitive region pixel sequence of an image. The main two steps of the SRPS solution are as follows:

Firstly, obtain the SRPS’s feature pixels of a road image by the image segmentation at different higher levels, and create a data set corresponding to the sensitive region pixel sequence.

Secondly, calculate the correlation with a single-dimensional arrays corresponding to the SRPS at different higher levels.

An effective choice is to reduce the dimension of the road image, and change the road image gray value to one-dimensional data. The strength $S$ calculation of the one-dimensional data can be defined as

$$S = a \ast b^T$$  \hspace{1cm} (3)

Where, vector $a$ is a one-dimensional pixel gray value of the road template, vector $b$ is the one-dimensional pixel gray value of the real road image at the designated address corresponding to the one-dimensional array.

3. Experiment

In order to verify the feasibility of the SRPS solution, the experiment with SRPS solution has been conducted. The experiment goal is to detect the blind road. With the development of barrier-free design and upgrading of the attention of the community for the blind groups, the blind road has become an important barrier-free facility, which specifically helps the blind people to walk. The blind road generally consists of two kinds of blind road, including the marching blind road and the prompt blind road. The former is made up of the guide bar bricks, which can guide the blind to walk forward; the latter is made up of the bricks with a dot, which can remind the blind people of the road obstacles ahead.

Take the blind road’s picture and calculate the SPRS feature pixels in the selected ROI region. The effect of a blind road’s multi-resolution image with neighborhood average filter is shown in Figure 2. In this way, the blind road line is fitted with SRPS solution and the location of the road line is found, which is shown in Figure 3. The original blind road image is shown in Figure 3(a). The feasible path of the road obtained by the SRPS solution is shown in Figure 3(b).
Figure 2. Multi-resolution images of a blind road

Figure 3. The blind road line’s fitting result with SRPS solution

Besides this, the blind road line’s matching result is shown in Figure 4. Five matching instances are obtained, and the feasible path obtained by the SRPS solution is accurate.

Figure 4. The blind road line’s matching result with the SRPS solution
Comparing the traditional method, the total time of the road image processing with the SRPS solution is significantly reduced, which saves about 1/3 of the time of the traditional method’s.

The experiment proves the feasibility of the SRPS solution. The further experiment on the SRPS solution will need to be the focus of our future research.

4. Conclusion
This paper does a principle analysis of the road detection method based on SRPS solution in order to improve the efficiency and accuracy of the vision detection method. The proposed solution has an important significance to reduce calculation cost of the road detection system, which is helpful to enhance the early-warning performance for the automatic pilot robot. Experimental results show that the SRPS solution has a positive significance for the improvement on the automatic road detection technology.

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