Research on Path Planning of Mobile Robot Based on Binocular Perception

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Abstract: This paper presents a design scheme for the path planning of mobile robots, which achieves the goal of the mobile robots' own road strength planning. In the scheme of this system, we use stereo vision to detect the environment, use the combination of image processing algorithms to separate the ground, background and object, and use boundary invariant moments to distinguish obstacles from objects, which improves the path planning of classical artificial potential field method. The experimental results show that the system is feasible.

1. Introduction

One of the main functions of mobile robots is to collect, perceive and analyze the external environment through its own sensors, so as to realize autonomous travel to the target and accomplish some specific tasks under the condition of obstacles. The autonomous travel of mobile robots involves many disciplines, such as kinematics, information theory, image science, artificial intelligence and so on. It embodies the latest achievements of computer technology and artificial intelligence. Therefore, in addition to the functions of automatic tracking, automatic driving and obstacle avoidance, mobile robots can further improve the level of these related technologies through the research of machine vision, information processing, artificial intelligence and other fields in the research process, which has important academic value and application significance in the fields of production, scientific research and exploration. In view of these situations, this paper focuses on the path planning and obstacle avoidance of the binocular perception-based mobile robot in autonomous travel, and introduces our research work and achievements in this field.

2. System Architecture Framework

The path planning and obstacle avoidance system of mobile robot based on binocular perception is designed in this paper. According to the hierarchical structure, it is divided into three layers: motion control layer, behavior control layer and behavior planning layer, as shown in Figure 1. In order to ensure the stability and expansibility of the system, modular design is adopted.

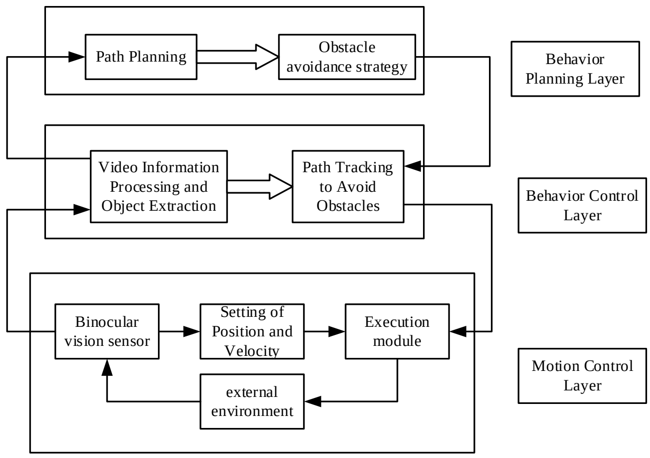

Fig. 1 Framework of obstacle avoidance system for mobile robot based on binocular stereovision

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Motion control layer includes binocular perception information acquisition module and motion control module. In the motion control layer, the environment information is detected by the binocular camera installed on the robot, and the information is transmitted to the behavior control layer through the wireless signal transceiver. The environment information is analyzed and the ranging operation is completed according to the image information obtained from the camera.

Behavior control layer includes video image processing module, object extraction module and obstacle object discrimination module. According to the received video data, the behavior control layer will get the road information, obstacle and target depth information after image processing, and then submit the size, shape and other parameters to the behavior planning layer.

Behavior planning layer includes path planning module and obstacle avoidance strategy module. The path planning module constructs a two-dimensional map by using the transmitted information, generates a path from the initial point to the target point according to the artificial potential field method, and then evades obstacles according to the obstacle avoidance strategy.

In the course of mobile robot moving, the corresponding coordinate value, speed and rotation angle are guided by the behavior control layer to guide the behavior of the motion control layer.

3. Motion control layer

Video signal acquisition, wireless transmission, frame synchronization and other functions are finished by binocular video acquisition module, and the sampled images need to be carried out the format conversion, so as to let they are more suitable to the demands of image processing module.

We achieve the real-time capture for the on-site videos by DirectShow based on Microsoft, video acquisition is adopted by DirectShow, we do not need to discuss the issues such as framework structure, data protection, synchronization and other details, so we can pay attention to the improvement of the functions and properties of the software. We achieve the image processing by OpenCV (open source computer vision library based on Intel, OpenCV defines the achievement of most current image processing algorithm including image analysis, structural analysis, motion analysis, pattern recognition and so on. Due to image sampling pSample is acquired in DirectShow is a section of continuous space that is accorded with the special format requirements in the memory, and the basic format of the images in OpenCV is IplImage data structure, therefore, This system sets up the acceptable IplI mage format that is converted from the sampling format of video image to OpenCV. After established the binocular perception acquisition module, we carry out the calibration for the camera parameters by Zhang's plane calibration method. And then get the camera has the properties by itself such as focus, optical centre and so on.

Visual distance measurement is divided into monocular defocusing distance measurement and multi-view stereo visual distance measurement. Including monocular defocusing distance measurement is applied to calculate the scene depth value by the degree of vague of the image boundary in multiple different defocusing status. It is achieved easily, but the accuracy of the distance measurement is not high, and the real-time performance is weaker, therefore, we adopt the multi-view stereo visual distance measurement that has the higher measurement accuracy and better real-time performance, so it is more suitable to robot system [9-10], the specific method is shown as below:

P is the target point, O_l and O_r are the optical centre of the left and right camera with the same focus. P_l and P_r are respectively the projection points of the spatial point P in the left and right camera. d is the distance from target point P to the camera, namely the depth value. According to the principle of the similar triangle, we have the formula

$$d = bf / (m + n) \qquad (1)$$

Including, (m+n) - the visual error of spatial target point in the left and right camera. Therefore, binocular camera distance measurement system converts the issue of the depth value is solved in three-dimensional space to the issue of the matched points are searched in two-dimensional image.

By the experimental analysis, comparison, we get the error of binocular distance measurement is larger with the increasing practical distance in the case of a certain f . In order to increase the effective distance measurement range of the binocular distance measurement system, the system adopts zoom distance measurement technology. By the specific analysis, we change the range of the parameters in formula (1) through changing the focus f value. The flow chart of the system zoom distance measurement is shown in Figure 2.

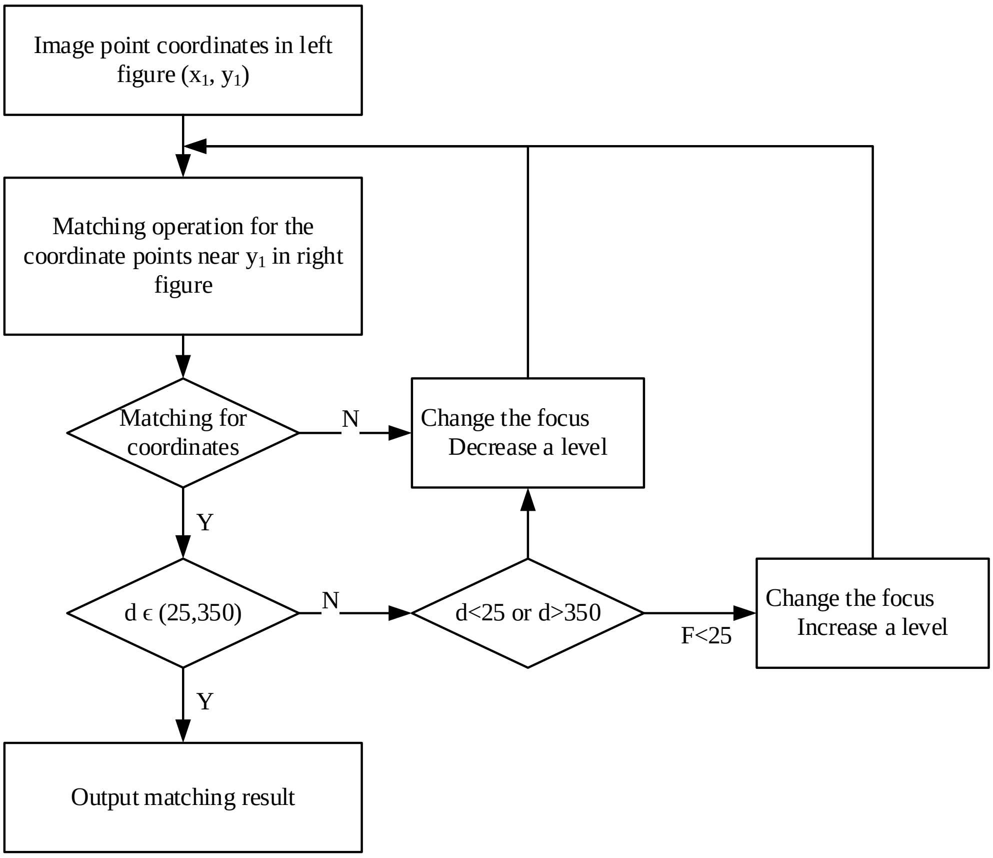

Figure 2 Zoom distance measurement process

3. Behavior Control Layer

In order to avoid obstacles for mobile robots, the collected environmental information must be analyzed, the background, road surface and objects in the image must be separated, and the obstacles and objects must be distinguished. There is a lot of noise in the video image obtained by video capture card, so image preprocessing must be done first. There are abundant color information in realistic scenes. Generally, the edge color difference of different objects is large. We use the boundary information of objects to separate background, road surface and objects. Binocular sensor must match left and right images to achieve object location. The mobile robot system uses improved template matching algorithm to improve the speed of the system. In the realization of distinguishing obstacles and targets, the system adopts moment invariant method.

3.1 Image Processing and Pavement Analysis

There are a lot of discrete noises in left and right images from binocular perception. In order to preserve the image information to the greatest extent and extract the object from the complex background, the system first processes the image to eliminate the discrete noise. According to the obvious color jump on the edge of the color world scene, the system uses the uniformity graph method to extract the edge of the image after noise elimination, and obtains a clear outline.

In order to extract obstacles and objects from video images, the system combines a series of classical image processing algorithms to separate the outlet, background, obstacles and objects. The image processing algorithms used include image erosion, binarization, seed filling, anti-seed filling and so on.

3.2 Binocular perception for object extraction

This system carries out the acquisition for the environmental information by binocular perception, before making and constructing the two-dimensional map, carry out the matching for the objects corresponding to the left and right images. Matching refers to find out the pixels generate the change in two photos that are taken in the same environment in the different time, and then to confirm the distance from the objects to the camera by the changes, namely depth information. We confirm the depth information of the objects by the improved NCC template matching algorithm. NCC template matching algorithm is a type of typical correlation algorithm based on grayscale. It is used to look for the position of a certain well-known image template in images through comparing the degree of similarity of the images.

In practical matching application, the search of the degree of similarity of the images and the template is measured by the measurement functions, The normalized correlation function is taken as similarity measurement, the definition is shown

$$R(i,j)=\frac{\sum_{n=1}^{M}\sum_{n=1}^{N}\left[S^{i,j}(m,n)-\overline{S^{i,j}}\right]\times[T(m,n)-\bar{T}]}{\sqrt{\sum_{n=1}^{N}\sum_{n=1}^{N}\left[S^{i,j}(m,n)-\bar{S}\right]^2}\times\sqrt{\sum_{n=1}^{M}\sum_{n=1}^{N}\left[T(m,n)-\bar{T}\right]^2}} \tag{2}$$

This method has the stronger white noise resistance ability, it has the high matching accuracy in the case of the grayscale change and geometric distortion are not significant, but it is easily affected by the partial illumination change, and the matching speed is slower. In order to enhance the template matching speed, we make the following processing for the formula (2):

In formula (2), $\bar{T}$ is the average value of template $T(N,N)$, $\overline{S^{i,j}}$ is the average value of the searched image $S(M,M)$ under the current window (i,j). And then set $T'=T(m,n)-\bar{T}$; due to one-time calculation is available, and then change the numerator part as: $\sum_{n=1}^{M}\sum_{n=1}^{N}S^{i,j}(m,n)T'-\overline{S^{i,j}}\sum_{m=1}^{M}\sum_{n=1}^{N}T'$. And because the sum of T' is 0, the numerator remains the first item, so we can carry out the convolution operation for the first item and the subgraph by difference summation method. Firstly, sort all pixels in the template, secondly, carry out the difference based on the sorting array, because a large number of same grayscale values are in the template, the array after difference will exist a good many of 0 or 1, the multiplication operation for 0 or 1 can be omitted. So we can save much operation time, and enhance the template matching speed.

And then the denominator in formula (2) is processed as below. The second item is only related with the template T,just need one calculation, The first item need to be calculated one variance under every moving window, roughly need $3N^2(M-N+1)^2$ operation in total, the operation is very large, therefore, for searching the image S, calculate the following accumulated quantity

$$A(i,j)=S(i,j)+A(i-1,j)+A(i,j-1)-A(i-1,j-1)$$
$$A^2(i,j)=S^2(i,j)+A^2(i-1,j)+A^2(i,j-1)-A^2(i-1,j-1)$$

And when $i,j<0$, at this moment, define the energy of image S under the window position (i,j) as

$$E_z(i,j)=S^2(u+N-1,v+N-1)-S^2(u-1,v+N-1)-S^2(u+N-1,v-1)+S^2(u-1,v-1)$$

Unfold the secondary item in $\sum_{n=1}^{M}\sum_{n=1}^{N}\left[S^{i,j}(m,n)-\overline{S^{i,j}}\right]^2$, we can directly put the calculated accumulated item S and calculate, 3 operations are required in total, it obviously reduces the calculation than the direct calculation.

4. Behavior Planning Layer

In order to avoid obstacles and reach the target point for mobile robots, correct path planning and effective obstacle avoidance strategy are important guarantees. We use artificial potential field method to plan the path of mobile robot. In order to eliminate the local minimum in this method, we propose a corresponding solution. With the guidance of the correct path, it is necessary to formulate corresponding obstacle avoidance strategies to achieve successful obstacle avoidance. The obstacle avoidance strategy based on fuzzy control is adopted in the system. In order to coordinate the synchronization of multiple modules in the system, Section 4.3 proposes several methods for synchronization control in obstacle avoidance.

5. Synchronization Control

In a time cycle, the system needs to complete the following tasks: collecting data from binocular cameras; synchronizing data from two video capture cards and transmitting them to memory; extracting background, ground and objects from two videos synchronously; template matching for two pictures: extracting obstacles and objects from the matched images; constructing two-dimensional map: path planning; Application of obstacle avoidance rules; transmission of motion strategies to mobile robots; implementation of motion control module. Because different functions require different response time, only successful synchronization control can make the system run successfully and have better real-time performance.

6. Conclusion

In this paper, a system framework of path planning and obstacle avoidance system for mobile robots is proposed. The design schemes of each module of the system are introduced in detail, and the experimental results of the system are given.

The design idea of layered modularization proposed by us has good stability and expansibility. Using zoom ranging technology to measure depth information can effectively expand the measurement range of the system; using improved NCC template matching algorithm to stereo matching to improve the speed of the system; using moment invariant idea to effectively distinguish obstacles from objects; using improved artificial potential field function to eliminate the local minimum point phenomenon of artificial potential field method; putting forward solutions; The problem of multi-module synchronous control in the system. Field experiments show that the path planning and obstacle avoidance system of mobile robot designed and implemented by us has good performance.

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