

ROAD RECOGNITION TECHNOLOGY OF AGRICULTURAL NAVIGATION ROBOT BASED ON ROAD EDGE MOVEMENT OBSTACLE DETECTION ALGORITHM

基于道路边缘运动障碍物检测算法的农业导航机器人道路识别技术

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ABSTRACT

In order to recognize the road effectively, agricultural robots mainly rely on the tracking and detection data of road obstacles. Traditional obstacle detection mainly studies how to use multiple fusion methods such as vision and laser to analyse structured and simplified indoor scenes. The working environment of agricultural robots is a typical unstructured outdoor environment. Therefore, based on the environmental characteristics of agricultural robot navigation, the mean displacement algorithm is introduced to detect and study the obstacles aiming at the road edge. After explaining the advantages and principle flow of the mean displacement algorithm to effectively realize motion capture, the feasibility of target location and tracking research is discussed. After that, the bottom data acquisition and analysis model is constructed based on the road navigation data of agricultural robots. To capture the movement obstacles of road edge and build the foundation of road recognition technology. In order to improve the effectiveness of motion obstacle capture and detection, a moving target detection algorithm is proposed to optimize and update the mean displacement algorithm, and constructs a feature-oriented hybrid algorithm motion capture model. The simulation results indicate that the proposed optimization model can effectively improve the tracking efficiency of non-rigid targets in outdoor environment, and the number of evaluation iterations can reach 3.5621 times per frame, which shows that the research has good theoretical and practical value.

摘要

为了有效地识别道路，农业机器人主要依靠道路障碍物的跟踪检测数据。传统的障碍物检测主要研究如何利用视觉、激光等多种融合方法对结构化、简化的室内场景进行分析。农业机器人的工作环境是典型的非结构化户外环境。因此，根据农业机器人导航的环境特点，引入了平均位移算法来检测和研究针对道路边缘的障碍物。在阐述了平均位移算法有效实现运动捕获的优点和原理流程后，讨论了目标定位跟踪研究的可行性。然后，基于农业机器人的道路导航数据，建立了底层数据采集与分析模型。捕捉道路边缘的运动障碍，为道路识别技术奠定基础。为了提高运动障碍物捕获和检测的有效性，提出了一种运动目标检测算法，对平均位移算法进行优化和更新，并构建了一种面向特征的混合算法运动捕获模型。仿真结果表明，该优化模型能有效提高室外环境下非刚性目标的跟踪效率，每帧评估迭代次数可达 3.5621 次，具有良好的理论和实用价值。

INTRODUCTION

In the navigation system of mobile robot, road recognition and obstacle detection are the key technologies of the system. In the past, research on mobile robots focused on indoor and relatively simple environments. Obstacle detection is realized by fusion of sensors, radar, laser and other data sources. Since this method of reduction, the technology is relatively simple and the cost investment is small, but it can obtain relatively abundant technical data. In recent years, the birth of agricultural robots has made up for the gap of theoretical mobile robots. The working environment of this kind of robot is unstructured and the working scene is complex. At this time, the traditional indoor mobile robot cannot effectively complete the task. Therefore, in the research of agricultural robots, it is necessary to attach great importance to the detection and recognition of obstacles in motion, so as to better support the efficient identification of roads in robot navigation.

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Tracking and locating detection of moving targets is a new research field born with the development of computer technology intelligence and informatization. Computer vision has achieved a lot of applied results in replacing human visual function, such as face matching, face recognition in detection field, and real-time tracking and detection of moving objects in video surveillance. The main principle that can achieve such a wide range of application results is that machine vision system has more accurate and advanced memory function than human eye recognition. Machine vision can simulate and surpass the human eye's effective capture of moving objects. Based on a large number of data collected in the whole process, it can construct the control of the omni-directional change of motion. Motion target detection and tracking technology, which use computer technology to collect video image information of road edge motion obstacles, have changed the qualitative method of analysing motion and technical skills based on traditional experience and manual observation in the past.

Scholars have achieved many valuable academic achievements in obstacle detection technology. Gianni C mainly studied the obstacle detection technology in mission drones and proposed a multi-sensor obstacle detection method that could overcome the problem of typical targets being difficult to detect (*Gianni C., Balsi M and Esposito S., 2017*). *Gharani P.* built a visual impairment detection method for people with visual impairment, and proposed an image frame based on two connections to achieve effective detection of indoor obstacle points, which can be implemented on a smartphone and has good performance. (*Gharani P. and Karimi H.A., 2017*). In order to improve obstacle detection and classification of complex terrain such as farmland and orchard, *Kragh M.* combined appearance and geometric probability fusion detection methods, and used multi-mode fusion algorithm to realize obstacle detection in agricultural scenes (*Kragh M. and Underwood J., 2019*). Starting from the application needs of augmented reality technology in many fields, *Dawid P.* explored how to achieve real-time assessment of the real environment, using computer systems to provide you with early warning of possible obstacles (*Dawid P., Karolina K. and Kamil K., 2019*). *Hoang V.N.* believed that a hybrid structure model can be used to detect obstacles that were needed for people with tactile disabilities, especially in the detection and collection analysis of security factors in unfamiliar environments (*Hoang V.N., Nguyen T.H. and Le T.L., 2017*). Focusing on providing a safe environment for the elderly, *Tzung-Han L* proposed a line-laser barrier detection system based on imaging technology that can alert the elderly when an obstacle was detected (*Tzung-Han L., Chi-Yun Y. and Wen-Pin S., 2017*). *Fernando C* considered that reliable obstacle detection can only be achieved by using data collected by lidar sensors effectively. Based on the need of obstacle detection in the future Internet of Things, a scheme to improve the reliability of obstacle detection technology was proposed (*Fernando C., Gerardo B. and Alberto V., 2018*).

In order to achieve accurate tracking and detection and capture of motion trajectory, scholars have done a lot of research on tracking and detection algorithm of mean displacement algorithm. *Xue Ming* is a research on mean displacement algorithm in meteorology field. In order to detect and locate air particles effectively, the meridional and latitudinal data of displacement synthesis vectors were organically combined to improve the computational errors of non-uniformity and singularity MRDM in high latitudes (*Xue Ming. 2017*). In the study of proteins, based on the generalized Langevin theory, *Hirata F.* proposed an average squared displacement model for analysing incoherent aqueous data, focusing on the effects of physical mutations on temperature gradients (*Hirata F., 2018*). And *Kim A.* discussed how to use current-limited electronic-design-automation (EDA) tools in the study to track secondary power routing. By tracking the approximate voltage, designers can find problems in current limiting early in the design process (*Ball D, Upcroft B and Wyeth G., 2016*). In the case of graphic signal processing, *Wang X* proposed to construct a distributed least squares (DLSR) reconstruction algorithm to realize the iteration of unknown signals, which effectively improved the convergence of the algorithm and controlled the error range of the algorithm (*Wang X., Wang M. and Gu Y., 2015*). *Yuzhu C.* paid attention to how to effectively solve the problem of line-of-sight occlusion in image rotation processing and proposed a filter tracking algorithm. Based on the analysis of the reasons for the failure of target tracking, a classifier constructed by online support vector machine was proposed to improve the accuracy of tracking model. Experiments showed that the recognition rate of the optimized tracking model had been improved (*Yuzhu C., Dedong Y. and Ning M., 2017*). In the study of cardiovascular magnetic resonance myocardial function tracking technology, *Morais P.* explored the use of non-rigid elastic registration algorithm and its feasibility and effectiveness. Simulation experiments showed that the algorithm can provide better data support for myocardial function tracking (*Morais P. and Alberto Marchi. 2017*).

Based on the principle of dynamics, *Li J* proposed an extended Kalman tracking algorithm to predict the target position and optimize the measurement for the performance degradation of the attitude tracking algorithm. The reliability and efficiency of the method were demonstrated in the simulation of the algorithm (*Li J, Wei X and Zhang G., 2017*). *Peng L* studied how to improve the tracking algorithm for sunlight in photovoltaic systems. After analyzing the principle of distinguishing the variation of oscillation power and irradiance and the principle of disturbance, the cutting error method and the dynamic disturbance calculation step were used. Simulation experiments showed that the optimization scheme not only improved the tracking speed, but also improved the tracking accuracy (*Peng L, Zheng S and Chai X. 2018*).

Through the analysis and study of the obstacle detection by scholars, it can be seen that many good results have been achieved in the location of the obstacle, improving the efficiency, speed, robustness and reliability of the obstacle detection. In order to meet the need of road recognition application of agricultural navigation robot, the mean displacement algorithm is improved and optimized to improve the safety, reliability and efficiency of road edge obstacle detection and analysis.

The mean displacement algorithm is studied. Firstly, the theory of the mean displacement algorithm is summarized. Mean displacement algorithm, a typical data detection algorithm, is analysed in terms of its advantages. Then, the flow and model of the mean displacement algorithm are optimized and updated according to the needs and advantages of the agricultural navigation robot in using road recognition to detect motion obstacles. In order to achieve the reliability and validity of motion obstacle detection, a hybrid algorithm model is constructed by introducing tracking and location algorithm.

The study is mainly carried out in three parts. The first part is to analyse the advantages of the mean displacement algorithm in the application of agricultural navigation robot to the recognition of road edge motion obstacles, and to explore the feasibility of the mean displacement algorithm to enhance the detection effect. The analysis of the principle, theoretical basis and implementation process of the mean displacement algorithm are elaborated in the second part. In the third part, the optimization and improvement strategies are put forward to improve the reliability and efficiency of the mean shift algorithm. The main contents are as follows: in the second section, the principle and advantages of the mean shift algorithm are expounded, and the original intention is put forward. The design flow of the mean displacement algorithm is given in the third section. In the fourth section, the optimization strategy of the mean shift algorithm is proposed, and the performance characteristics of the optimization algorithm are introduced. In the fifth section, the research contents of mean displacement algorithm are summarized, and the direction of improving the detection effect of road edge motion obstacles is analysed.

MATERIALS AND METHODS

Mean shift algorithms

In the mean shift algorithm, there is no need to use specific parameters, and it has the characteristics of high efficiency in matching the mathematical algorithm of the target. The theoretical basis is a non-parametric kernel density estimation, which is a mathematical model for calculating the extreme points of probability density function iteratively by gradient method. In the pattern recognition of moving targets, the root of many problems is to use the probability density function of class conditions to estimate. Probability density estimation methods are divided into parametric method and non-parametric method. After a given function, the collected samples can be classified by algorithm. Nonparametric methods do not require prior knowledge, but only rely on training data to achieve estimation, which can be applied to any shape and density estimation, therefore are most widely used. Histogram density estimation is a classical algorithm model in nonparametric estimation. The principle of the algorithm is to construct a probability density with a set of samples. In the one-dimensional state, the real axis can be divided into many cells of equal size, and the density formula for the x point is expressed by the formula (1), where n_j is the number of samples in a cell that spans a point x that express width of dx . N is the number of cells and dx is the size of the cell. The unit existing in the multidimensional observation space can be expressed by the formula (2), where dV is the volume of the j^{th} unit box.

$$\hat{p}(x) = \frac{n_j}{\sum_L^N n_j dx} \quad (1)$$

$$\hat{p}(x) = \frac{n_j}{\sum_j n_j dV} \tag{2}$$

The size selection of cell dx has a direct impact on the shape and size of the estimation. Histogram estimation varies with cell size. Under normal conditions, the width of histogram cells represents the density effect, and the larger the density, the smoother it will be. The smaller the cell size, the more significant the details will be. Fig. 1 is the histogram estimation under three cell sizes, and the lowest right corner is the kernel density estimation graph, from which it can be seen that the estimation effect of the kernel function method is closest to the real density situation. This method is simple and easy to use, because it does not need to retain sampling points, the basic histogram will lack continuity of density estimation, and the effectiveness of high-dimensional space is not strong. With the exponential growth of cells, the number of data increases significantly when the density of spatial estimation is high.

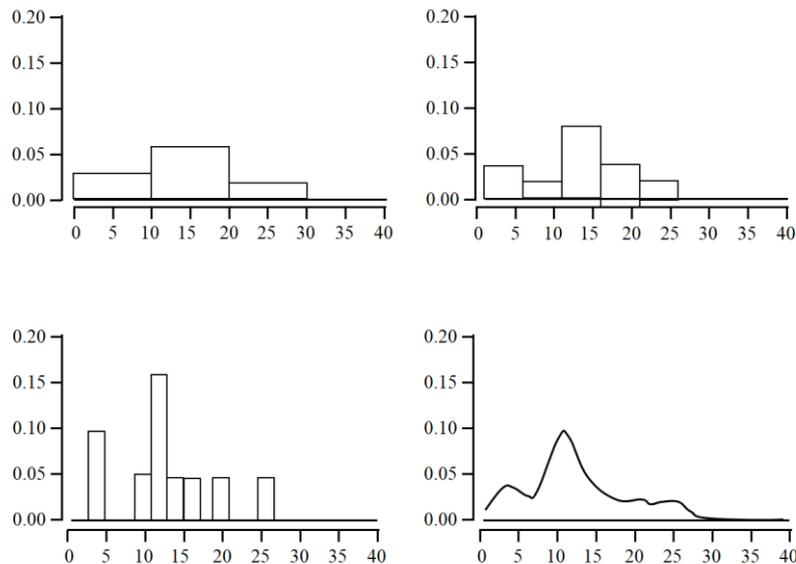


Fig. 1 - Histogram estimation under three cell sizes

In the derivation of the kernel function density estimation method, the first consideration is the one-dimensional condition. Assuming that $\{x_1, L, x_n\}$ is a set of observation data samples used to estimate the density. Formula (3) is the expression of probability density function, from which the relative frequency estimation equation of the sample can be obtained as shown in equation (4), where $\{x_1, L, x_n\}$ is the observation value and w is the rectangular weight function. The definition is shown in the formula (5), it can be estimated from the formula that $\hat{p}(x)$ is a property that accords with the probability density.

$$P(x-h < X < x+h) = \int_{x-h}^{x+h} p(t) dt \approx 2hp(x) \tag{3}$$

$$\hat{p}(x) = \frac{1}{n} \sum_{i=1}^n w(x-x_i, h) \tag{4}$$

$$w(t, h) = \begin{cases} \frac{1}{2h} & |t| < h \\ 0 & \text{other} \end{cases} \tag{5}$$

$\hat{p}(x) \geq 0$ and $\int_{-\infty}^{+\infty} p(t) dt = 1$ are applicable to all x . It can be accepted that this nuclear density estimation uses a rectangular window to observe nearby observation points. The probability density estimate of the fixed observation point is $1/n$ of the sum of the heights of all the rectangles covering this observation point. When h is increased, the width of the rectangle is also increased correspondingly, which increases the smooth state of the probability density function.

At this time, a trigonometric function and a Gaussian function can be used instead of the rectangular weight function. As shown in Fig. 2, based on the Gaussian function, the density estimates at $h = 0.5$ and $h = 1$, the function has been jagged.

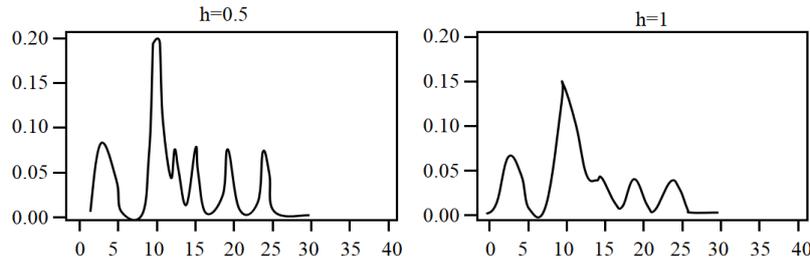


Fig. 2 - Density estimation based on Gauss's function (h=0.5,1)

Figure 3 shows the density estimation based on Gauss function at $h = 2$ and $H = 4$, and the shape of the function begins to become smoother.

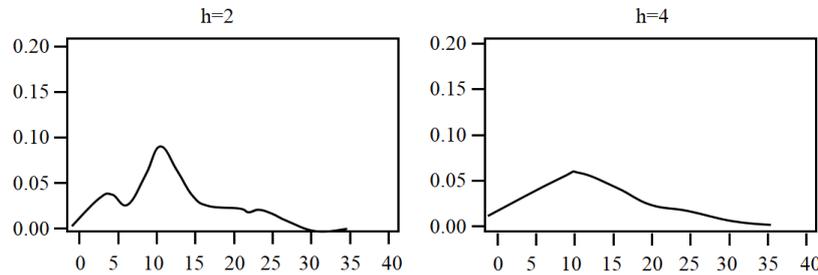


Fig. 3 - Density estimation based on Gauss's function (h=2,4)

Kernel is a standardized weight function, which plays a decisive role in the shape of the weight function. H in weight function $w(t, h)$ is also called smoothness parameter because it represents bandwidth. Bandwidth determines the smoothness of $p(x)$ estimation. Normal density function, a radially symmetric probability density function, can be used as a kernel function. However, some support kernels themselves do not have the characteristics of density, and can be expressed by negative values at some points, which will lead to negative estimates. When the kernel function and smoothing function are set, the kernel density estimation formula of $P(x)$ is expressed as formula (6), where elements K and H determine the properties of $\hat{p}(x)$. When the value of H is larger, the density display is smoother, but the details are blurred. When the value of H is small, the density estimation can reflect the detail structure more. When h is close to 0, there will be a spike. How to choose K and h to improve the performance of $\hat{p}(x)$ is the direction of algorithm optimization.

$$\hat{p}(x) = \frac{1}{n} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right) \tag{6}$$

Mean displacement optimization strategy

In the current computer tracking technology, the use of mathematical algorithms has a large amount of computation and a large number of processes, which leads to the need for computers equipped with high-performance computing capabilities, increasing costs and computing cycles, and other issues, which are the main factors affecting its application and promotion. Mean displacement arithmetic originates from statistical theory. The non-parametric technique can effectively improve the simplicity of statistics and probability respectively. The weighted kernel density method can reduce the influence of noise interference on the edge data points of the target, and can effectively improve the overall adaptability and reliability when the weight of the central region of the target is increased accordingly. When the mean moving vector is used to search the direction of density gradient rapidly, the efficiency and speed of the tracking algorithm can be improved effectively. So, the target tracking based on mean displacement algorithm has a good model foundation. To achieve target tracking is to make the search strategy and matching criteria of the target reliable in both moving and stationary background.

To achieve this goal, it is necessary to do in-depth research from three parts: generating target matching template, updating target motion position, and predicting target matching criteria.

$$\begin{aligned}
 P(\text{error}) &= P(x \in R_2, w_1) + P(x \in R_1, w_2) \\
 &= P(x \in R_2, |w_1)P(w_1) + P(x \in R_1, |w_2)P(w_2) \\
 &= \int_{R_2} p(x|w_1)P(w_1)dx + \int_{R_1} p(x|w_2)P(w_2)dx
 \end{aligned} \tag{7}$$

To locate the detection target that needs to be tracked, it is necessary to collect the corresponding feature identifier, so that the candidate target expression library of the target model can be established according to the feature. The problem of positioning detection in the frame image is converted into a mathematical problem in which the position y is selected in the current frame so that the corresponding density distribution $\hat{p}(y)$ is similar to the density \hat{p}_u distribution of the target model. Here, the mode reality measure is first defined and the degree of similarity of the pattern features is characterized. Starting from the similarity between the error probability and the two probability density distributions, the target location problem is transformed into the similarity estimate between the target model and the candidate model, and the Bayesian error is used to calculate. In pattern recognition theory, two situations are generally considered. First, it is assumed that the binary classifier uses a non-optimal way to divide the space into two parts, $R1$ and $R2$. The error classification occurs in the form that the real category is $W1$, and the observed value x is in the region $R2$. Or the real category is $W2$ and the observed value x is in region $R1$. These conditions are mutually exclusive and cover the entire space, and thus the error probability calculation formula is as shown in equation (7). The result in one-dimensional space is shown in Fig. 4. The two integrals in equation (7) represent the range covered by the density curve of the function $p(x|w_1)p(w_1)$ on the left and right sides of the decision point x , respectively. When the decision margin moves to x_B , the smallest area of the two regions is the state with the smallest error probability, which is the Bayesian error probability brought by Bayesian decision.

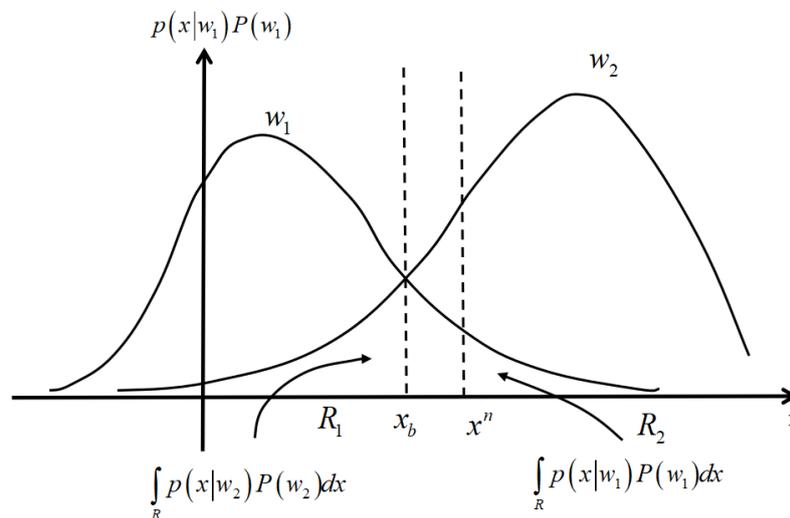


Fig. 4 - Bayesian error probability schematic of one-dimensional model

In the target similarity measure, it is necessary to select an appropriate target similarity measure function, which is processed by means of Bhattacharyya coefficient. The main thing is to confirm the similarity between the two vectors. The process of this confirmation is the process of solving the cosine value of the unit vector represented by the coefficient according to the geometric mathematical principle, as shown in Fig. 5. The measured value of the cosine function value here is to solve the similarity between the image model of the measurement target and the candidate target model.

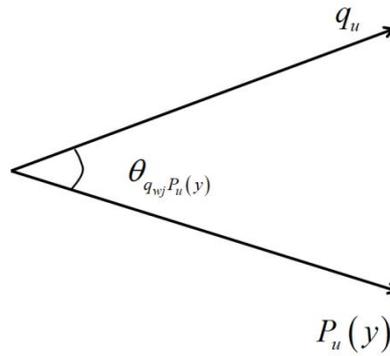


Fig. 5 - The geometric meaning of the coefficient

The Mean Shift tracking algorithm is used in the target positioning, which is welcomed because the moving target can be positioned in a short time and the search time has a great advantage. The principle of implementation is that the algorithm calculates the similarity probability density between the candidate target and the target template, and then uses the direction of the probability density gradient to search for the matching path. The characteristics of this tracking algorithm are that it can calculate the quantity and can track and process in real time. The weighted colour histogram reality is not sensitive to the deformation and occlusion of the target. The principle of using Mean shift algorithm to achieve target tracking is to analyse the RGB colour space in the target region based on statistics. The R.G.B subspace in RGB colour space is divided into k intervals of the same size, which is called bin feature space. The number of Bin represents the dimension of the feature space. The colour histogram here represents the area to be searched in the target model. Searching all the pixels and classifying them by RGB can get the corresponding histogram. These histograms are candidates for comparison in subsequent video image search. Figure 6 is the flow chart of Mean Shift tracking algorithm.

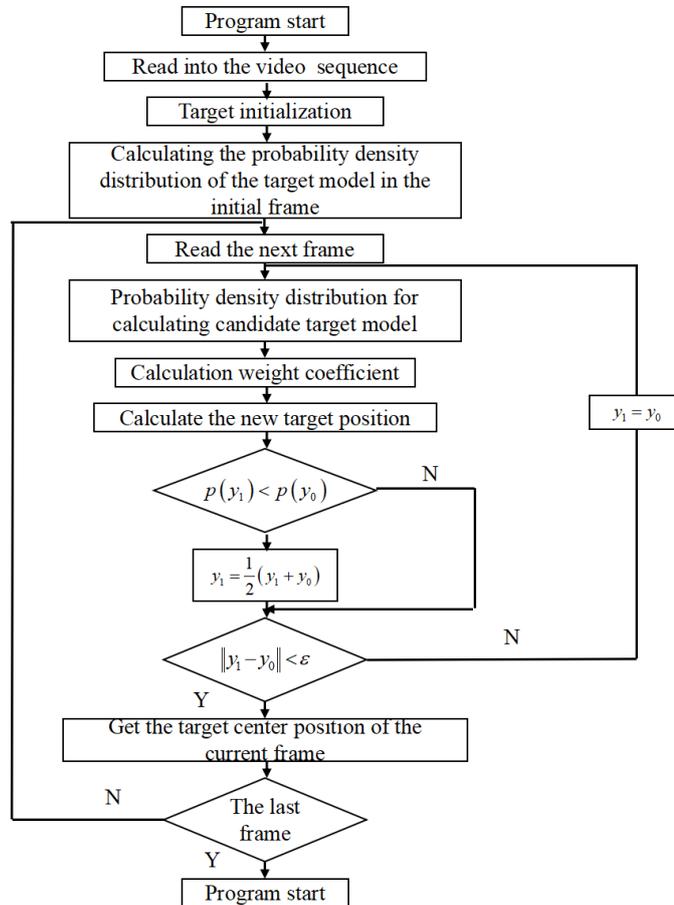


Fig. 6 - Mean Shift tracking algorithm flow chart

RESULTS

Experimental conditions and parameters

On the basis of the robot recognition algorithm, this study designed the agricultural robot. Figure 7 shows the photos of the robot in the field experiment. The main function of the robot is to collect and analyse the common diseases and insect pests and growth information of crops. The robot is a wheel type robot driven by four wheels. The distance between the front and rear wheels is short, which can adapt to the ups and downs of the terrain during field operation. In addition to the walking mechanism, the whole robot includes three modules: vision system, information storage system and energy system. The vision system mainly includes two cameras which are distributed up and down and can rotate freely. The camera is mainly used to collect crop information and road information. The information storage system is mainly used to store crop information. The energy system is responsible for providing energy for robot walking and information.



Fig. 7 - Field work of robot

Simulation experiments are used to verify the optimized mean displacement algorithm. In the navigation of agricultural robots, road edge images often occur, which results in inaccurate capturing and difficult locating of targets by computers. The experiment is aimed at this phenomenon, using the algorithm model which is a mixture of the mean shift algorithm and the colour histogram algorithm proposed in this paper to compare the location and capture efficiency. On the one hand, the stability and accuracy of mean shift algorithm for moving objects are tested. On the other hand, the adaptability of colour histogram is verified to dynamic video, rotating images and different observation perspectives according to the distribution of target colour. In the first frame, the target area is selected manually. In order to verify the performance of mean shift algorithm in different scenarios, video is selected for testing, and the results are marked with yellow box in the tracking process. The target trajectory is displayed by red lines. The experimental video is a game video of basketball players. The size of the video image is 352*240 pixels, the frame rate is 15 frames per second, and the total frame number is 80 frames. The main purpose of the video is to track the track of the road edge obstacles. In this video, the road edge and background are quite different, and the road edge is not occluded by other objects during the whole detection process.

Experiment on tracking effect of motion obstacle optimization algorithms

After tracking the movement of road edge obstacles, the tracking effect is shown in Figure 8. During the whole tracking process, the tracking display frame can lock the edge of obstacle and locate the target correctly. It keeps good similarity with the trajectory, and the tracking algorithm keeps good tracking effect. This is because the proposed optimal mean shift algorithm uses RGB colour to construct feature space, so as to ensure that the tracking process will not be affected by the target deformation, and can also achieve real-time tracking of this non-rigid object.

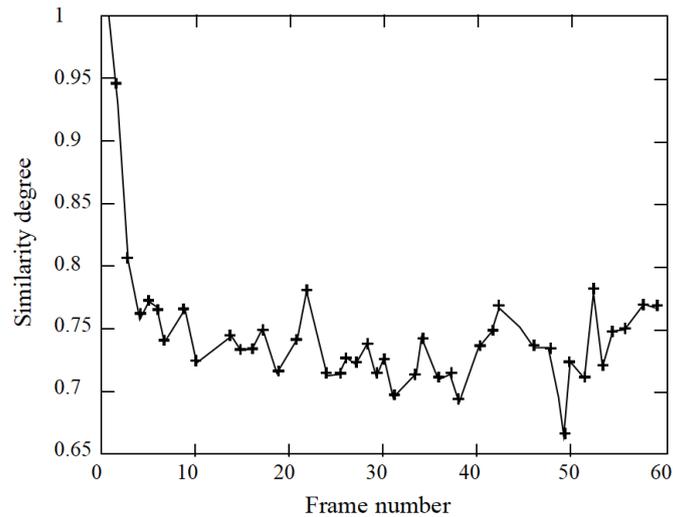


Fig. 8 - Study on similarity of road edge dynamic obstacle tracking process

Tracking performance experiments of motion obstacle optimization algorithms

In practical applications, the scene colour of agricultural robots will be more complex, especially in different lighting conditions, tracking target and site colour are similar, it is easy to appear that the target cannot be located. Therefore, it is necessary to establish tracking feature space based on multiple colours to ensure the stability and reliability of tracking. The statistical results show that the number of iterations for evaluating the video of road edge motion disorder can reach 3.5621 times per frame. Therefore, it can be concluded that the optimized mean displacement algorithm is a simple and efficient tracking algorithm, which has good real-time tracking effect and function. After applying the results of this tracking algorithm to the road recognition of agricultural navigation robot, the road can be accurately positioned and compared, which provides a reference for subsequent scientific decision-making. Figure 9 shows the tracking statistics after tracking the movement of road edge obstacles.

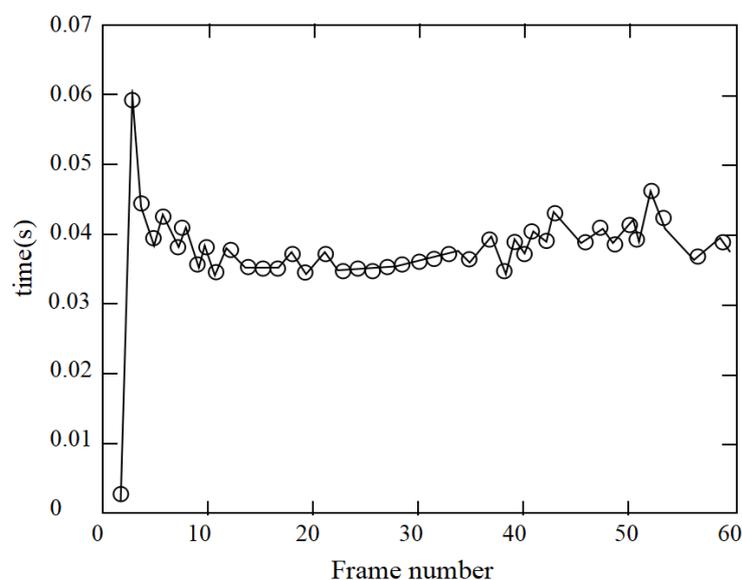


Fig. 9 - Study on tracking speed of road edge motion disorder

Figure 10 shows the performance comparison results of the design algorithm, eNet algorithm and segnet algorithm in parameter amount, calculation amount and different resolution. From the size of the parameters, the parameters of the algorithm designed in this paper are 0.357m, 1.45M for segnet algorithm and 0.993m for eNet algorithm.

From the size of the parameters, the parameters of the algorithm designed in this paper are the smallest. In terms of the amount of calculation, the parameters of the algorithm designed in this paper are 1.36mb, 5.34mb and 3.79mb, respectively. From the result of calculation, the calculation amount of the algorithm designed in this paper is also the smallest. For the image with 360 × 480 resolution, the recognition time of this algorithm is 10ms, the recognition time of eNet algorithm is 13ms, and the recognition time of segnet algorithm is 24ms. For large 512 × 1024 images, the recognition time of the three algorithms is further increased. The algorithm in this study is 26 ms, eNet algorithm is 31 ms, segnet algorithm is 44 ms. From the above results, the algorithm designed in this study is the best in terms of parameters, calculation amount and even key image recognition efficiency.

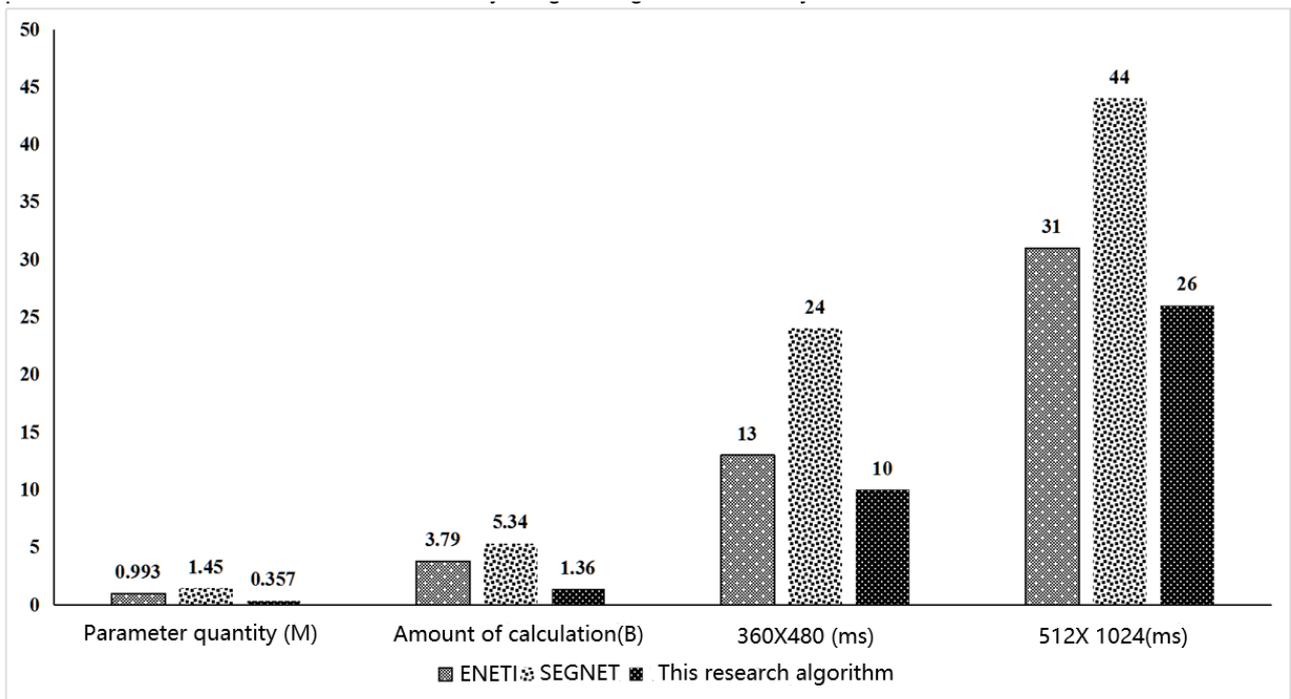


Fig. 10 - Study on tracking speed of road edge motion disorder

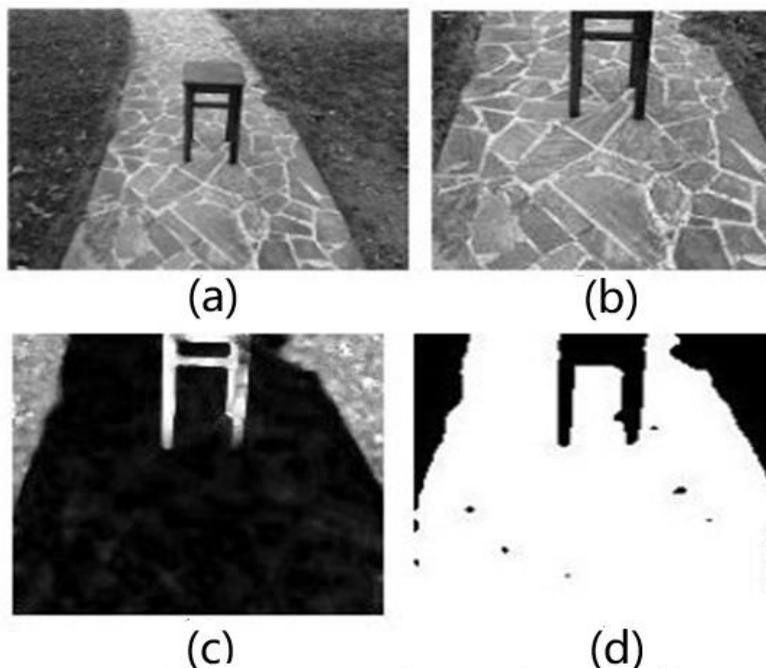


Fig. 11 - Application of agricultural robot road obstacle detection

Figure 11 shows the application results of agricultural robot road obstacle detection. As can be seen from the figure, the agricultural robot can accurately identify the chair in the road through the vision technology, which can effectively avoid the obstacles in the road in the process of agricultural robot moving.

CONCLUSIONS

Mean displacement algorithm is mainly used in the field of target acquisition and positioning. It is widely used in various safety object detection, trajectory capture and evaluation of moving objects. It is more advanced than the accuracy and memory of human eye observation, and also has good application effect in road edge obstacle motion recognition. Therefore, based on the mean displacement algorithm, the road edge motion obstacles in agricultural robot navigation road recognition are studied, which provides a scientific basis for road recognition system. Firstly, the principle and structure of the mean shift algorithm are analysed, and then the target capture technology based on the mean shift algorithm is studied according to the need of moving target tracking on the road edge, and a hybrid optimization algorithm model is proposed. By optimizing the similarity measure function of the target, the fast location of the moving obstacle target can be realized and the searching time of the target can be reduced. The tracking location algorithm is introduced to optimize the mean displacement algorithm, and a hybrid algorithm optimization model is established. Finally, the trajectory of road edge obstacles is selected for simulation test. Experiments show that the proposed optimization algorithm model can effectively improve the speed and accuracy of the algorithm, and make the tracking results be of higher quality. Moreover, the number of iterations for evaluating the video of road edge motion obstacles can reach 3.5621 times per frame, which can effectively improve the shortcomings of the traditional mean displacement algorithm that has a longer period after the increase of computation. It shows that the optimized mean displacement algorithm is a simple and efficient tracking algorithm with better real-time detection effect and function. However, from the results, there are still some improvements in this study. The next step is to improve the algorithm structure of moving target detection model.

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