TARGET DETECTION AND ANALYSIS OF INTELLIGENT AGRICULTURAL VEHICLE MOVEMENT OBSTACLE BASED ON PANORAMIC VISION
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基于全景视觉的智能农用车运动障碍物目标检测与分析

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ABSTRACT
Agricultural automation and intelligence have a wide range of connotations, involving navigation, image, model, strategy and other engineering disciplines. With the development of modern agriculture, intelligent agricultural vehicles are applied in many engineering areas. The operating environment of agricultural vehicles is very complex, especially as they often face obstacles, affecting the intelligent operation of agricultural vehicles. The traditional obstacle detection mostly uses the limited detection algorithm, in the case of which it is difficult to achieve the moving target detection of panoramic vision. In this paper, mean shift algorithm is selected to detect the moving obstacles of intelligent agricultural vehicles, and adaptive colour fusion is introduced to optimize the algorithm to solve the problems of mean shift. In order to verify the effect of the improvement and application of the algorithm, the video image obtained by the intelligent agricultural vehicle is selected for the simulation experiment, and the best combination (- 0.8.0.2) is obtained for the unequal spacing sampling method. In the process of colour selection, the coefficient needs to be adjusted continuously to improve the tracking accuracy of the algorithm. Further it can be seen that when using a variety of different quantitative methods for comparative analysis, the quantitative method of HIS-360 level is determined.

摘要
农业的自动化和智能化内涵十分广泛，涉及到了导航、图像、模型、策略等多个工程学科，随着现代农业的发展，智能农用车的应用越来越多，由于农用车的运行环境非常复杂，特别是会经常面临障碍物，影响到农用车的智能运行。传统的障碍物目标检测大多采用的是具有局限性的检测算法，难以实现全景视觉的运动的目标检测。此次选取 Mean-Shift 算法来实现智能农用车运动障碍物的目标检测，并引入自适应色彩融合来进行算法优化改进来解决单纯 Meant-Shift 存在的问题。为了验证该算法改进和应用的效果，此次选取智能农用车获取的图像视频进行仿真实验，针对不等间距采样方法得到了最佳组合为（-0.8.0.2），在进行色彩选取时，需要不断调整系数从而提高算法的跟踪准确率。进一步分析可以看出，在采用多种不同量化方式对比分析时，确定了采用 HIS-360 等级的量化方式。

INTRODUCTION
With the development of modern science and technology and the progress of industrial technology, the degree of industrialization of agricultural production activities is getting higher and higher. China has a vast territory and a vast agricultural planting area, and also attaches great importance to the development of agricultural machinery industrialization *(Casimero V. et al, 2001)*. However, due to the backward development of China's economy and science and technology, compared with the developed countries, the industrialization level of domestic agricultural machinery is also relatively backward. Among these agricultural machinery tools, agricultural vehicles are one of the most widely used and basic equipment, so they are also the key objects in the research of agricultural mechanization industry in various countries *(Guo-Qing D.U, 2013)*. With the rapid development of computer technology and information technology, people began to combine it with agricultural vehicles. In combination with computer technology and information technology, reasonable algorithm and mechanical operation are used to replace a large number of simple and repeated manual operations, so as to better reduce human demand and effectively improve

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agricultural work efficiency *(Hou M. et al, 2000)*.

At present, the research on agricultural vehicles mainly focuses on the detection of moving obstacle target of agricultural vehicles, which is one of the key factors for agricultural vehicles to have intelligent automatic driving function. After the automatic driving of agricultural vehicles is realized, the work efficiency of agricultural vehicles can be improved again, and the demand for manpower can be reduced, which is also the key factor for the improvement of agricultural production efficiency in the future *(Huang Y. et al, 1995)*. However, limited by the performance of the technical algorithm, at present, the detection and analysis of the obstacles in the movement of agricultural vehicles is still in the early stage of experimental testing, and the practical application of this technology needs to be further studied.

The Mean-Shift algorithm selected in this paper is an automatic tracking method that can be applied to target dynamic tracking detection. Using this method, we can get the histogram distribution of search window under the weighted values of calculation Kernel function, and use this method to calculate the corresponding window histogram distribution of the current frame. According to the principle of the maximum similarity of the two distributions, along the direction of the maximum increase of search density, we can move to the real location. Through the optimization of the algorithm, we can achieve more efficient, fast and more accurate dynamic target tracking detection.

The main innovations of this paper are as follows: (1) based on panoramic vision, this paper analyses the detection technology of moving obstacle of intelligent agricultural vehicles from multiple angles, uses the unique technical advantages of panoramic vision to comprehensively improve the detection ability of moving obstacle of agricultural vehicles, and optimizes the detection technology, and demonstrates the results (2) based on the mean shift algorithm, the optimization and improvement can effectively solve the problem that the target is easily lost when the background colour and pixel colour are similar, making the target more prominent.

There are four parts in this paper, the second part is about the analysis of the research status of the intelligent agricultural vehicle full view obstacle detection and target tracking detection methods at home and abroad; the third part is to analyse the principle and shortcomings of mean shift algorithm, and improve the shortcomings of the algorithm, considering the background colour and colour fusion, colour space, etc.; the fourth part is to put this algorithm into consideration. The algorithm is applied to the panoramic vision system of obstacle detection of intelligent agricultural vehicles, and the effectiveness and practicability of the algorithm are known through simulation analysis.

State of the art

Proposing a method of moving target detection and tracking for autonomous navigation of agricultural vehicles. Using panoramic vision for target tracking detection has the advantage of no blind area detection, and effectively solves the problem of overlapping in the process of target tracking. The specific operation is to first collect multiple images for panoramic evaluation, and automatically detect and track moving objects based on the kernel function algorithm of segmented image. Through application analysis and research, it can be seen that the memory consumption of the improved algorithm is reduced by 66% compared with the traditional kernel function algorithm, and the algorithm speed is increased by 35% *(Khalil S.M.S. et al, 2006)*. Aiming at the inertial navigation error of agricultural machinery, accurate modeling and compensation were made, thus extending the positioning working time and building the dynamic model of agricultural machinery *(Li Q. et al, 2010)*. Putting forward a method of obstacle detection and avoidance of AGV based on binocular vision. In the process of obstacle detection, put forward an algorithm of obstacle information acquisition based on frame subtraction, so as to realize the dynamic and static detection of obstacles. The result shows that the algorithm has good reliability, relatively small error, and further introduces fuzzy Algorithm, which verifies the feasibility and effectiveness of this method *(Min W. et al, 1999)*. Proposing a general method and framework for vehicle and pedestrian detection and tracking based on deep learning, which makes full use of depth information sources and local patterns to generate robust road vehicle and pedestrian recognition and detection. The algorithm has good robust performance and can identify the possible vehicles and pedestrian obstacles on the road *(Noguchi N, 2018)*. Based on the unsupervised deep learning method, *Rozsa et al*. proposed the problem of urban scene monitoring and obstacle tracking. They designed an innovative hybrid encoder and further proposed an effective method of obstacle location estimation and tracking based on scene density *(Rozsa Z. et al, 2018)*. *Teng Z.Q. et al.* fully considered the specific conditions of the road and reduced the workload of test data and preparation as much as possible, and designed an automatic hypothesis assistant system based on stereo vision algorithm *(Teng Z.Q. et al, 2009)*.

Tiemin Z. et al proposed a road obstacle detection method based on light insensitive features, conducted experiments using image sequences collected under different light conditions, and verified the effectiveness of the method *(Tiemin Z. et al, 2015)*.

The detection and analysis technology of agricultural vehicle moving obstacle has developed to the present and a large number of excellent research results have appeared. The detection and analysis technology of agricultural vehicle moving obstacle has been improved for several generations, but after all, the detection and analysis technology of agricultural vehicle moving obstacle is a new product, in the background of rapid development, it also needs rapid development. To carry out the development of agricultural vehicles, how to improve the detection and analysis technology of moving obstacles of agricultural vehicles is an urgent matter *(Wang L. et al, 2015)*. Only further research on the detection and analysis technology of moving obstacles of agricultural vehicles can provide a solid foundation for the development of agricultural vehicles and meet the basic requirements of modern agricultural production demand *(Wang L. et al, 2019)*. Therefore, based on panoramic vision, this paper analyses the moving obstacle detection of intelligent agricultural vehicles, improves the moving obstacle detection and analysis technology of agricultural vehicles, comprehensively improves the working efficiency of agricultural vehicles, and improves the moving obstacle detection and analysis technology of agricultural vehicles.

MATERIALS AND METHODS

Mean shift algorithm

Mean shift algorithm is a common algorithm in semi-automatic tracking algorithm, which needs to determine the search window w manually in order to determine the moving target. Its specific working principle is to calculate the distribution of W histogram under the weight of kernel function, and move it to the real position of target along the maximum direction of density increase according to the principle of maximum distribution similarity. When the probability density function is used to detect moving objects, it is difficult to estimate the continuous point density function effectively based on the sample observation method in the small area of continuous points. If we set the dimension d of a space and there is a point x in the current space, then we can calculate the estimated density probability value of this point:

$$\hat{f}(x)=\frac{1}{n}\sum_{i=1}^{n}K_H(x-x_i) \tag{1}$$

$$K_H(x)=|H|^{-\frac{1}{2}}K\left(|H|^{-\frac{1}{2}}x\right) \tag{2}$$

In the above formula, $d\times d$ broadband matrix is represented by H, the use of this matrix can greatly improve the flexibility of estimation and ensure that it has different width, but it will become more complex. In this case, it is necessary to consider that the broadband matrix is modified to the form of proportional unit matrix, i.e. $H=h^2I$, and the formula (1) is modified to:

$$\hat{f}(x)=\frac{1}{nh^d}\sum_{i=1}^{n}K\left(\frac{x-x_i}{h}\right) \tag{3}$$

In Figure 1, the real ink point in the centre is the centre of the kernel function. The white dots around the centre are all sample points. The offset of the centre point is indicated by arrows. The average offset will point towards the direction with higher sample point density, which is the gradient direction of the function. It can be seen that the direction of mean shift vector offset is the direction of density gradient. The closer it is to the centre of kernel function, the more important the estimation characteristics of sampling points are.

After the mean shift vector is introduced, the central point of kernel function will gradually converge to the point with the highest density, and the estimated density of this point is 0. The mean shift vector step size will be larger in the region of no interest features, and smaller in the region of interest, so the step size will decrease with the reduction of the distance from the maximum density, which shows that the mean shift algorithm belongs to an adaptive gradient rise algorithm.

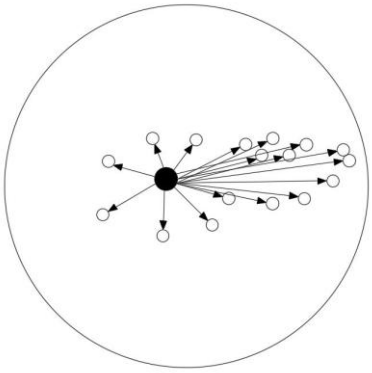

Fig. 1 - Mean shift vector diagram

Through further analysis, we can see that there are many factors that affect the convergence speed of mean shift algorithm. If the division of gray level is more detailed, the calculation speed of the algorithm is slower, but the corresponding anti-interference ability and tracking effect are better. If the gray level is not divided in detail, its anti-interference ability and tracking effect will also be reduced. The size of the window will also have an impact on the tracker broadband *(Zhang J. et al, 2013)*. Without considering the time-consuming factor, the larger the window, the slower the calculation speed, but the larger the tracking broadband. It can be seen from the comprehensive analysis that the mean shift algorithm has a great advantage in application, and its calculation is relatively low, so it can be used for real-time tracking when the target area is known. In addition, it is more convenient to be integrated as other algorithms and a single module, even if there is rotation, deformation and edge occlusion of the target, it also has low sensitivity.

However, mean shift algorithm has many shortcomings in application. If the moving speed of the target in the detection environment is faster, there may be overlapping areas between two adjacent frames, and the target may be converged to the background with similar colour distribution, not in the scene. On the other hand, mean shift algorithm is mainly used to select colour features for analysis, which is insensitive to deformation and rotation *(Zhong D. et al, 2014)*. Although the introduction of unimodal kernel function can make the pixels far away from the centre give smaller weight, so it can have better robustness. However, when the area of the target is occluded in a large proportion, it will lead to the failure of mean shift algorithm, which cannot track the target.

Optimization and improvement of mean shift algorithm

In view of the problem of operation speed in mean shift algorithm, we can see that, when collecting data information in the moving target area, is the speed can be easily limited to the local ashing degree, which needs to be improved. If the gray level is set to m, the m value directly affects the speed and tracking effect of the whole algorithm. If the gray space only considers the colour, then the brightness change will make the whole algorithm very sensitive to it. All experiments must be based on the condition that the brightness condition is stable. There will be loss of colour information in the process of converting RGB to gray space, so it is necessary to optimize and improve on the original basis and adopt RGB three primary colours quantization. After quantizing the RGB three primary colours collected in panoramic image, the target eigenvalues of three colour components are calculated, and the weighted average value is calculated. Although this method will affect the calculation speed to a certain extent due to the calculation of three target characteristics, it can significantly improve the tracking efficiency. When RGB quantization and grayscale quantization are used for colour quantization, the colour space contains colour information and brightness information, and the change of brightness will directly affect the colour. For the same target, when its brightness changes, the target characteristics will change correspondingly. This kind of change has little influence on the target features with big difference between the target colour and background colour, but has great influence on the tracking results with small difference between the background colour and the target colour. To solve this problem, this colour space model should be introduced to improve colour quantization. H represents chromaticity and does not contain brightness information in target features, so it can deal with the above problems well.

For the target with unbalanced length and width, if the selected template is elliptical, if the target is rotated, it will inevitably lead to the failure of target tracking due to the introduction of background area in the template area. Therefore, it is necessary to propose a tracking method based on the statistical characteristics of the target. Unlike the conventional method, it uses the horizontal and vertical second-order target. The rotation and tracking of the target are realized by the relationship between the moment and the angle of its axis of symmetry. Although this method can effectively solve the adverse effect of target rotation, it has a high requirement for target shape combination. It is required that the target shape must be symmetrical, so this method is limited in application. All are shown in Figure 2 and 3.

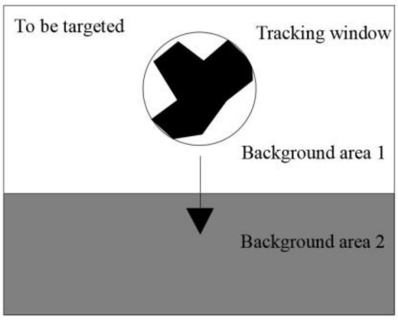

Fig. 2 - Irregular shape target tracking graph

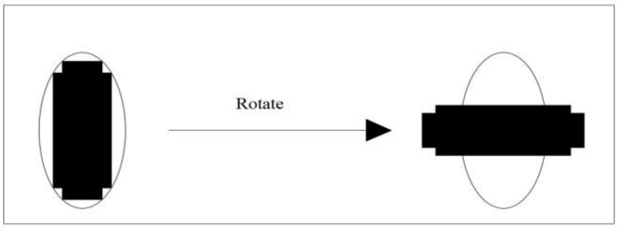

Fig. 3 - Long and wide unbalanced target tracking

RESULTS

The effect of obstacle target tracking in the process of intelligent agricultural vehicle movement

In order to verify the application effect of the proposed adaptive colour fusion mean shift algorithm in intelligent agricultural vehicles, the images and videos obtained by intelligent agricultural vehicles are selected for simulation experiments. The whole image in the target area of the image is taken as the background. In order to reduce the computation, the unequal interval sampling method based on the large background is adopted. The polar coordinates of the central point of the target are constructed to represent the image sampling process, and the target area of three times is taken as the boundary. The polar radius in this area is three-pixel step-by-step, while the polar radius outside the area is nine-pixel step-by-step. The sampling angle is 0.1rad step. See Figure 3, figure 4 and figure 5 for the core histogram after the fusion of H and S weights, where S stands for saturation.

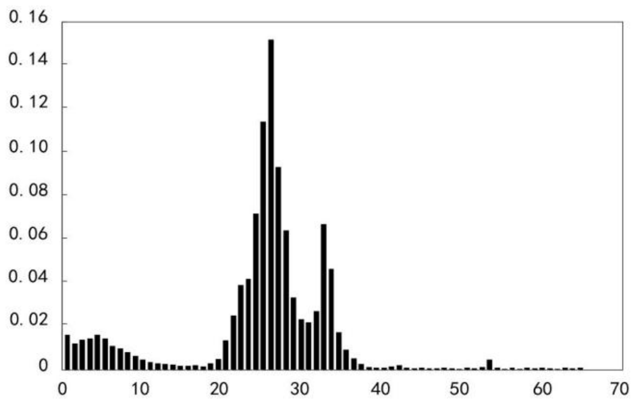

Fig. 4 - Background full sampling histogram

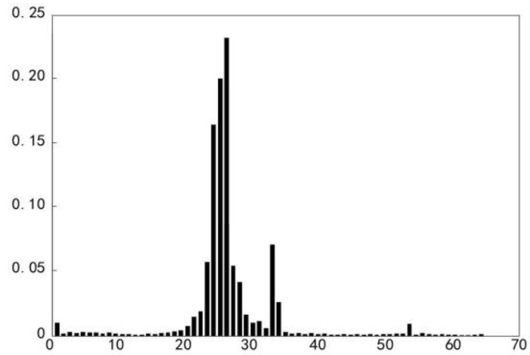

Fig. 5 - Three times target area histogram

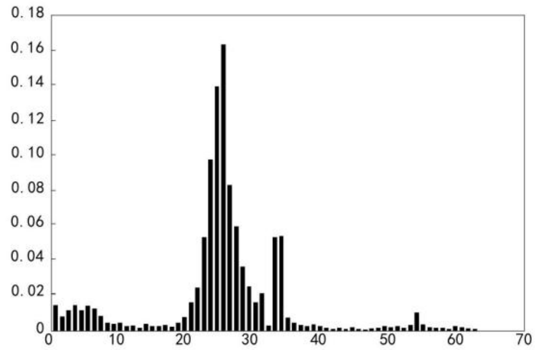

Fig. 6 - Sampling histogram with unequal spacing

From the analysis in the figure, it can be seen that the sampling method with unequal spacing can take into account the global characteristics of the image; on the other hand, it can also reflect the near-range colour characteristics around the target, which shows that this method can effectively obtain the colour characteristics around the target. Further processing with this method can calculate the BH value of each group of coefficients. The specific results are shown in Table 1. It can be seen from table 1 that the best combination is (- 0.8, 0.2).

Table 1

Better fusion coefficient and HH value

BH	1	2
0.362154	-0.8	0.2
0.365487	-0.8	0.1
0.367854	-0.7	0.1
0.367458	-0.9	0.3

It can be seen from the process of colour selection that the target and background can be distinguished better within the background range of feature selection. With the change of time, the background is also changing. The best colour fusion weight initially selected may not be suitable for the current frame, which requires adjustment of the weight. Using the above method to recalculate the BH value of all coefficient combinations will not only take longer time, but also seriously affect the real-time performance of the tracking algorithm. Therefore, it is necessary to adjust the coefficients to improve the accuracy of tracking. A coefficient adaptive adjustment neighbourhood method is proposed.

Panoramic application effect of improved mean shift algorithm

For a set of colour fusion coefficients ω_1, ω_2 , set the step size to 0.1, and the corresponding combination of colour fusion coefficients and a group of fusion coefficients adaptively adjust the neighbourhood L. When tracking the initial frame, a group of fusion coefficients which can distinguish the tracking target and the background region of the target are selected by the method of colour fusion. With similar objects approaching or background changing, the original fusion coefficient may not be the best fusion coefficient.

Table 2 shows the optimal colour fusion coefficient and corresponding BH coefficient of 7 consecutive frames obtained by an intelligent agricultural vehicle.

Table 2

Optimal Image Fusion coefficient and BH coefficient in Video sequence

BH	ω_1	ω_2
0.063254	0.3	0.8
0.062456	0.2	0.9
0.075842	0.2	0.8
0.125147	0.2	0.8
0.127654	0.3	0.8
0.114875	0.2	0.9
0.090424	0.1	0.9

From the data in the table, it can be seen that the optimal fusion coefficient of continuous images in a group of video sequences obtained by intelligent agricultural vehicles is mutual domain. The reason is that if the background changes slowly, then the optimal fusion coefficient will not jump in this case, and the original fusion coefficient can be adaptively adjusted to be searchable in the domain. Firstly, the target is selected, the optimal colour fusion coefficient corresponding to the initial frame is calculated, then the next frame image is collected, and the latest target position is obtained after the target is automatically tracked by mean shift algorithm. After calculating the BH coefficient of the adaptive colour fusion domain element of the new target, the core histogram of the target is obtained and the next image is collected. It has many advantages to choose the domain as the adaptive adjustment range. It changes continuously in the process of target and background tracking. This change is not sudden. The domain of the previous frame as the search range can better suppress the feature drift. From the further analysis in Table 3, it can be seen that the experimental results obtained by using the adaptive adjustment in the field are very reasonable.

In order to achieve better tracking efficiency, we set up a variety of different quantization methods to find the best one. We compare and analyse the time consumed by tracking operation and tracking results, as shown in the following table:

Table 3

Comparison Table of tracking results under different quantitative methods

Quantization method	HIS 360	HIS 60	RGB 32	Gray 64	Degree 16
Operation time (ms)	91.8	90.4	88.7	87.2	85.3
Tracking rate (%)	31.18	28.47	35.22	32.19	26.14

From the analysis in the table, it can be seen that the higher the level of quantization method is, the higher the tracking rate is, but the lower the operation speed is. The colour space quantization method of HIS-360 can achieve better operation speed and target tracking effect, so in the process of moving target tracking, it is best to use the quantization method of his360 level.

CONCLUSION

In the running process of intelligent agricultural vehicles, the tracking and detection of all kinds of targets is a dynamic process. The traditional static image tracking and detection algorithm is difficult to meet the use needs. This time, based on the mean shift tracking algorithm for optimization and improvement, first from the colour space to get different colour space differences, analysis of the mathematical principle of mean shift vector is made. Since there are many problems in the tracking algorithm, especially the problem that the target colour is similar to the background colour, which is easy to cause the target loss, an improved algorithm based on adaptive colour fusion is proposed. This method of target tracking considering background will analyse and study the background of target area, so as to highlight the target and effectively solve the problem of similar colour. In order to verify the related performance of the algorithm, the images collected by the intelligent agricultural vehicle in the process of operation are selected for simulation verification and analysis. Through this analysis, the accuracy, real-time and rapidity of the improved algorithm are verified. In this study, the optimization of mean shift algorithm is improved, which can be applied to the detection of obstacles in intelligent agricultural vehicles, but there are still some deficiencies in the detection of obstacles in panoramic vision.

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