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Research on the Robot's Intelligent Inspection, Its Target Detection Method

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Abstract: Intelligent inspection robot has the characteristics of programmable, and can be applied to various inspection environments. In general, studies show the present trend is to replace humans with an inspection robot thereby reducing the risks and improving the inspection efficiency. The intelligent inspection robot is based on intelligent technology and has programmability. In this paper, based on the research of intelligent inspection robot technology, we analyze inspection techniques, their algorithms, functions, characteristics and other important parameters. The research mainly focuses on two things: the target detection, methods and improved Adaboost algorithm to improve the accuracy of target detection; the Camshift algorithm which is improved to complete tracking design, timely data acquisition, timely problem discovery and timely solution. The target detection and target tracking are studied and their algorithms are analyzed. We present that a tracking algorithm based on improved Camshift deals with the problems which exist in traditional Camshift algorithm. In addition, we present Meanshift algorithm improves the Camshift algorithm for the whole-process tracking, automation and intelligence level, and efficient tracking. Next, combined with relevant technologies and techniques, the algorithm is improved to complete the target detection design and tracking design, and to solve the problems of inaccurate target detection and untimely detection.

Keywords: Intelligent Inspection Robot, Target Detection, Improved Adaboost Algorithm, Camshift Algorithm

1. Introduction

Traditional inspection technologies involve higher risk, time consuming and an expensive approach [1]. The present trend is to replace humans with an inspection robot thereby reducing the risks and improving the inspection efficiency. The intelligent inspection robot is based on intelligent technology and has programmability [2-7]. A robot is a machine that automatically performs various tasks such as assembly, acquisition, product inspection, and testing. It can perform corresponding functions according to programming procedures and functions relies on accurate detection and identification of targets. With the development of technology, the functions of the intelligent inspection robot are gradually improved, making it simulate manual operation in the application process and replace the traditional manual inspection [8-11]. The intelligent inspection robot itself carries related equipment such as infrared thermal imaging cameras, which can identify and control the environmental factors of the automatic and manual inspection, fire warning, and fire protection during the inspection process [12-20]. The intelligent inspection robot is in the stage of rapid development, and its use scope is constantly increasing, but there are a series of problems, such as poor positioning accuracy, insufficient anti-interference ability, and difficulty in real-time tracking.

2. Analysis of the Target Detection and Tracking Algorithm

In this article, for the accurate solution for problems including poor positioning accuracy, insufficient anti-interference ability, and difficulty in real-time tracking, we focus on the inspection robot methods based on target detection method and Adaboost algorithm. Therefore, the main research contents include image smooth denoising, image binarization processing, image mathematical processing, image background update, and improved Adaboost algorithm to achieve real time online accurate detection, and improve the detection accuracy and anti-noise ability.

2.1. Target Detection Techniques

There are various types of intelligent inspection robots have provided productivity tools for automation in various industries [12]. For instance, in order to achieve intelligent feedback tracking of moving target, various tracking algorithms of target detection are designed. In fact, the target detection method is becoming more popular, and suitable for the dynamic target detection work.

2.1.1. Background Phase Subtraction Method

Background subtraction method based on computer vision applications applies to detect moving objects. In the background subtraction technique of a motion detection, the video sequence is composed of a series of video images which contains the features of geometry information of the target, extract relevant information to analyze the motion of targets then get detection results. The compression ratio was greatly improved [13].

The main principle of the method is described the following steps:

The first step: to take the video sequence as the selection threshold of the frame image, and select one or more frame images as required;

The second step: to design the background model to produce the background map;

The third step: based on the differential operation method, the background image and the existing image are differential processed, the purpose is to eliminate the background image;

The fourth step is to analyze the relationship between the pixel difference and the threshold. If there is a threshold that is less than the pixel difference, it is determined as a motion region, and otherwise, it is determined as the background region.

The fifth step: based on the above study, the specific motor target location is obtained.

2.1.2. Optical Flow Method

Detecting target motion is equivalent to detecting the anomalous optical flow [22]. In this technique, the light flow method takes the performance movement of the gray scale mode in the image as the light flow, and the speed of the physical point can be described by 3D positioning and projected on the plane to form the corresponding image. The specific steps of the methods are as follows:

In the first step, select the pixels in the image to ensure that they can meet the measurement requirements;

In the second step, a target set for each selected pixel to form an image motion field;

In the third step, the appropriate time is selected, then obtains the position of the point on the image and the corresponding point above the 3D object based on the projection relationship;

In the fourth step, the velocity vector characteristics of each pixel are summarized to analyze the motion of the image. When there is no moving target in the image, it can be determined that the light loss amount continues to change within the image area.

In the fifth step, the actual position of the moving object is obtained based on the above detection results.

2.1.3. Frame Difference Method

In the motion detection using background frame matching, two frames are required to detect movement. The method is very efficient method of comparing image pixel values in subsequent still frames captured after every two seconds from the camera. First frame is called reference frame and the second frame, which is called the input frame contains the moving object. The two frames are compared and the differences in pixel values are determined. The main objective of the method is to detect the moving objects from the difference between the existing frame and the reference frame [14]. The three consecutive frame image difference method, by which the motor target profile information can be extracted, and has a strong resistance to the impact of the motor target background. The specific steps are shown as follows:

In the first step, with three consecutive frames of the source image settings, you can use $f_{k-1}(x, y)$, $f_k(x, y)$, $f_{k+1}(x, y)$ the difference grayscale image in an adjacent state is measured by the absolute difference method.

The second step, to implement the binary processing, the specific object is $D_{(k-1, k)}(x, y)$, $D_{(k, k+1)}(x, y)$, yielding the corresponding binarized image respectively $b_{(k-1, k)}(x, y)$, $b_{(k, k+1)}(x, y)$.

The third step, for each different pixel position, the binarized image according to the above processing $b_{(k-1, k)}(x, y)$, $b_{(k, k+1)}(x, y)$, taking logical and operational processing to form the differential image $d_k(x, y)$. The specific calculation formula is as follows:

$$d_k(x, y) = b_{(k-1,k)}(x, y) \,\&\, b_{(k,k+1)}(x, y)$$

Through practical research, the advantages and disadvantages of the above three target detection algorithms are comparative analyzed as the basis for algorithm selection and application, as shown in Table 1.

Table 1. *Advantages and disadvantages of the target detection algorithm.*

	Algorithm	Superiority	Inferior strength or position
1	Background phase subtraction	This algorithm is highly adaptable and can be used for target testing in multiple situations	The background is complex, susceptible to interference and influence, and over time, the algorithms involved are relatively complex and detrimental to operation
2	Optical flow method	The observed object can be fully recorded in 3 dimensions, rich and accurate. The detection target can be set even if the scene information is not understood before the test. It can still be tested normally when the camera is moving	When there are occlusion and more light sources, the conservation condition of gray degree generated by the light flow equation is unscientific, and the accuracy of light flow decreases. This method does not apply for regions lacking variation. In addition, this method has high complexity, long time for measurement, high cost, and insufficient resistance to interference
3	Inter-frame difference method	Easy to computation, and suitable for real-time detection and monitoring, with a strong adaptability to the environment in a changing state	The camera must be in a static state, and the detection effect of the target area is poor. If the extracted target is incomplete, serious cases will be cavity and shadow problems will occur.

Table 2. *The advantages and disadvantages of the tracking algorithm.*

	algorithm	superiority	inferior strength or position
1	Model-based target tracking	Accurate tracking can be achieved for the targets in the moving state, and the tracking can still be completed when the object morphology changes	Influenced by the model, and it is difficult to establish an accurate geometric model, the application of this method is greatly limited
2	Area-based target tracking	Image information acquisition is more comprehensive and rich, and can be used in the targets with small targets and poor contrast, especially in the unblocked state, with high accuracy in using this method	The work is complex and inefficient, and the measurement accuracy is difficult to achieve the desired target
3	Features-based target tracking	Easy to computation, can quickly detect the results, and suitable for real-time detection and monitoring, with a strong adaptability to the environment in a changing state	The camera must be in a static state, and the detection effect of the target area is poor. If the extracted target is incomplete, serious cases will be cavity and shadow problems will occur
4	Target tracking based on the deformation template	No need to obtain the target information in advance, reduce the workload, for the targets with deformation can still be tracked, strong applicability	For multi-targetpoor, when choosing the actual edge of the target of interest. If the target of interest has a deep depression site, the model is not applicable

2.2. Target Tracking Algorithm

In this paper, we focus to analyze the target tracking algorithms, understand the challenges in the field of target tracking based on commonly used three approaches as follows. Tracking detection plays an important role in many applications such as motion analysis, object recognition, guidance technology, and intelligent user interfaces. There are many algorithms, in this article, three types of infrared object tracking method are mainly analyzed.

2.2.1. Model-Based Target Tracking

Model-matching methods focus on finding out the most similar object with maximum response by searching local area. The relevant tracking methods mainly use the corresponding model to carry out the tracking and determination of the object position information, and take the image sequence as the carrier to complete the tracking of the designed model. The more accurate the model design of target geometric objects, the more accurate the measurement effect it produces. Especially for the rigid-body movement targets, this method works better. For non-rigid body movement targets, the geometric model is not accurate affected by the irregular body changes and the test accuracy of this method is less accurate and not suitable for use. Among them, 3D models are the most commonly used which can take stereo space as a modeling place, and will be accurate.

2.2.2. Area-Based Target Tracking

This method belongs to the more common method, the specific steps are as follows:

In the first step, select the template containing the tracking target as a tracking tool. For template settings, manual setup and image segmentation methods can be taken. In terms of template shape requirement is low, as long as the target irregular shape can be used.

The second step, the design and the matching measure, should be as far as possible to improve the accuracy,

In the third step, search for the target image in the next frame image.

In the fourth step, select the best match point, namely the position when the measurement takes the extreme value.

2.2.3. Features-Based Target Tracking

In the feature-based tracking method based on fixed basis, an advanced signal processing presents each image patch as a linear combination of a few elements from a basis set called a dictionary. The principle is that once the object feature is determined, classifier design determines the tracking process [23]. When using the feature-based target tracking method, two important links mainly include feature extraction and feature matching. Among them, feature extraction, mainly with the target with selection tendency in sequence images, has more available methods. For example, in texture feature extraction, Fourier spectrum method, symbiotic matrix method can be used. Characteristic matching is the comparative analysis of target features and template features for the extracted existing frame image, and takes the comparative analysis results as a basis, set the target and track.

2.2.4. Target Tracking Based on the Deformation Template

Deformation template, whose deformation is mainly reflected in the texture or edge, can be changed appropriately based on the corresponding conditions to produce the desired curves and models. The current most commonly used deformation template is the active contour model, namely the Snake model. An in-depth interpretation of this model refers to realizing the deformation parameter curve, the function representing the corresponding energy change, and controlling the curve change through the parameter design adjustment, so as to minimize the corresponding energy function.

According to the above target tracking algorithm, the comparative analysis and its advantages and disadvantages are used as the basis for selecting the tracking algorithm in subsequent research.

3. Analysis of Target Detection Design, on Adaptive Boosting Algorithm

3.1. Airspace Method

According to studies, the target tracking feature selection based algorithm must have the high requirements for with high accuracy and good stability. Target tracking feature selection algorithm is one of research focuses in the machine intelligent vision technology [24]. We analyze the airspace method in this paper. When using the airspace filtering method, the common methods include three modes including mean filtering, Gaussian filtering, and median filtering. The median filter method is selected, and in this method, the two-dimensional median-filter representation formula is shown as follows:

$$g(x,y) = \mathrm{Median}\{f(x-k, y-l), (k,l) \in W\}$$

In the above formula, f (x, y) represents the unprocessed image and the processed image $g(x,y)$. W represents the selected window size, with the most commonly used size of 3.0 * 3.0, and 5.0 * 5.0. In terms of window shape, the commonly used two-dimensional median filter window shape is the current situation of circular ring, circular, square, cross shape, etc. In the application, it needs to be appropriately selected according to the actual situation.

3.2. Image Binarization Processing Method

Binary image, refers to the image gray scale level is only two black and white, where, black indicates the image with gray scale level 0, and 1 represents the image with gray scale level 1. In this study, the method used for the threshold selection is the large law. The operation steps are shown as follows:

In the first step, assume that the pixel (x, y) is f (x, y) with a range of {0,1,}. Also, the total number of pixels is {0,1, …, 255}. Assuming a gray-scale value of i is Ni. And the number of pixels in the image remains $N_{image} \sum_{i=0}^{255} N_i$, calculate the probability of the gray value of i.

$$P_i = \frac{N_i}{N_{image}} (0, 1, \cdots 255)$$

In the second step, the initial value of the selected threshold, recorded as T, and classified the images, specifically C_1 {0,1, …, T} and C_2 {T + 1, T + 2, …, 255}.

In the third step, the probability of emergence in different categories is calculated to derive its probability.

$$P_1 = \sum_{i=0}^{T} P_i$$

$$P_2 = 1 - P_1 = \sum_{i=T+1}^{255} P_i$$

In the fourth step, the mean and overall gray scale values were calculated for class C 1 and C 2 images.

$$\mu_1 = \sum_{i=0}^{T} iP_i / P_1$$

$$\mu_2 = \sum_{i=T+1}^{T} iP_i / P_2$$

$$\mu = \sum_{i=0}^{255} iP_i$$

In the fifth step, the maximum variance between class C_1 and class C_2 image classes was calculated, and the optimal threshold was determined based on this variance.

$$\sigma_b^2 = P_1 \cdot (\mu_1 - \mu)^2 + P_2 \cdot (\mu_2 - \mu)^2$$

$$Th = \arg max \sigma_b^2 (0 \le i \le 255)$$

3.3. Image Morphological Processing Method

At present, there are more operators for image morphology processing, and the basic operators are expansion and corrosion, which belongs to the formation of other operators. As a result of morphological filtering is initiated to remove the noise and solve the background interruption difficulty [27]. When using the expansion and corrosion operators, it can be operated together to meet the application needs. For example, first contraction by corrosion and then expanding through expansion. Assuming the structural elements of B and A, A was processed by B and the model is as follows:

$$A°B = (A\Theta B) \oplus B$$

Shrinking and then expanding, it can make the outline of the processed object clearer, remove some "useless" points, appropriately reduce the image size, and reduce the processing range and time. After completing the above operation, the expansion process makes the expanded object more accurate. In short, this joint mode is to achieve complementary advantages and strengthen the processing effect.

3.4. Image Background Update Method

The purpose of the image background update is to ensure that the image background is consistent with the reality, and to reflect a dynamic processing idea, so that it is consistent with the real state. The common methods are statistical averaging method and IIR filter method. Considering the adaptability of adaptive background update, we choose IIR filter method. The calculation formula is as follows:

$$B_k = (1 - \alpha)B_{k-1} + \alpha f_k$$

In the above formula, α representativethe constant with values between 0 and 1, $f_k$represent the k frame image and B_k represent the k frame background image. Through this method, the input of new features can be conducted in time according to the background.

3.5. Improved the Adaboost Algorithm

The Adaboost algorithm belongs to the mode recognition algorithm, which can be classified by voting. It can adjust the error situation of the weak learning algorithm, reduce the error rate and meet the real needs through iterative operation. This algorithm is trained on the selected samples according to the corresponding standards and requirements to strengthen the weak classifier. For specific operation, the haar feature extraction from each image is representative, and the optimal feature of haar is determined through training. Then, the optimal haar feature is transformed to form a weak classifier, adopt the overall idea, combine all weak classifiers to form a strong classifier and realize complementary advantages. In this paper, this algorithm has similarity to the ideas such as BP neural network and particle group algorithm. Can be properly integrated and improved.

3.5.1. Weak Classifier Establishment

When a weak classifier is established on haar features, which mainly include two rectangles, three rectangles and four rectangles, defined as follows:

$$\text{feature}_k = \sum_{i=1}^{N} w_i \text{RctSum}(r_i)$$

In the above formula, $w_i$the representativer_i weights, are closely related to the rectangular size, the larger the rectangular size, the smaller the weights. $\text{RctSum}(r_i)$ feature_k Represents r_i the integral case generated in terms of the gray image, feature_kincluding the number of rectangles N. For high quality and efficient measurement of haar-like features, an integrated image mode includes rectangular area pixels composed between the starting point and each point as the element of each numerical group is stored in memory, which can be directly quoted as the pixel sum of the required computational area.

3.5.2. Strong Classifier Establishment

The process of performing a strong classifier setting using the Adaboost algorithm is as follows:

In the first step, a corresponding weak classifier is reasonably selected for each key feature;

In the second step, it is processed iteratively, and T represents the number of iterations, and represents the selected T features to form the corresponding weak classifier hj(x);

In the third step, the T weak classifier weights wt are calculated;

The fourth step, T weak classifiers are weighted together to form a strong classifier.

3.5.3. Cascade Classifier Establishment

Cascading classifier has the advantage of "heavy first, then light", which can improve the efficiency of window detection and adapt to multiple window detection. The establishment steps of relevant aspects are as follows:

The first step, to select the representative important characteristics, and the number should not be too much, to establish a simple strong classifier;

The second step, to test the detection area, to get the general situation;

The third step, to gradually increase the number of features, and achieve the detailed description of obstacles;

The fourth step, when the requirements are met, the fine detection target is achieved.

3.5.4. Sample Acquisition and Training

The relevant sample selection criteria presented in this paper are formulated as follows:

First, select samples with different backgrounds and different light conditions to represent the overall characteristics; second, ensure that the samples used for testing and training have the same size; third, try to improve the detection rate, so take multiple angles and obtain the image; Fourth, adopt manual segmentation, image normalization, size of 30 * 30 (which can be set as required).

After completing the sample selection, the sample training was performed. The specific process is as follows:

The first step is to collect the samples and complete the preprocessing work to reduce the complexity of the sample training;

The second step, extracting haar features in the training sample, must ensure their representative and comprehensive, and the method adopted is the integral graph method;

In the third step, input the extracted Haar features and start training to form a hierarchical cascade classifier.

4. Target Tracking Design Based on the Improved Camshift Algorithm

In studies, a tracking algorithm based on improved Camshift deals with the problems which exist in traditional Camshift algorithm, such as artificial orientation and tracking failure under color interference as well as object's changed illumination occlusion [25]. Camshift algorithm based design can adapt to object size change automatically, but when the light is stronger, the interference of similar color background occurs and the tracking fails. In order to reduce the influence of illumination on tracking, the improved Camshift algorithm based algorithm is started to improve the peformance [26].

4.1. Establish the Target Color Model

(1) The RGB color model

The RGB color model refers to the model weighted by red (Red), green (Green), and blue (Blue) [14]. For calculation convenience, all colors were processed for normalization. Different color component values have the same range, all between 0 and 1 (Figure 1). Therefore, this model can be characterized by a cube, with the three-dimensional coordinates of R, G, and B. Based on this analysis, the color space belongs to the three-dimensional mode and has linear features.

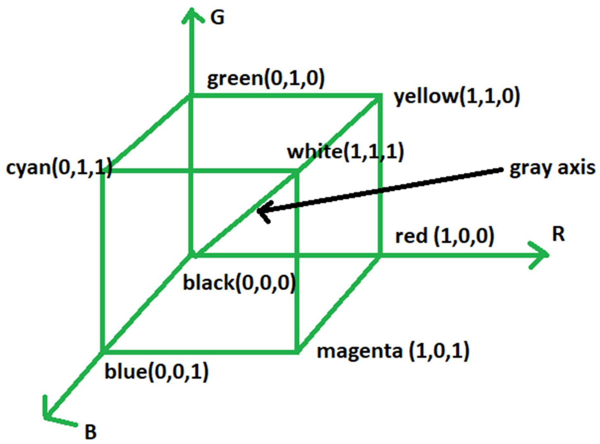

Figure 1. *RGB color model.*

(2) HSV model

The HSV model facilitates human eye recognition and perception, therefore, the design is widely used in computer vision, in composition, mainly includes Hue —— tone, Satuation —— saturation, Value—— brightness, three components. The specific model is shown in Figure 2.

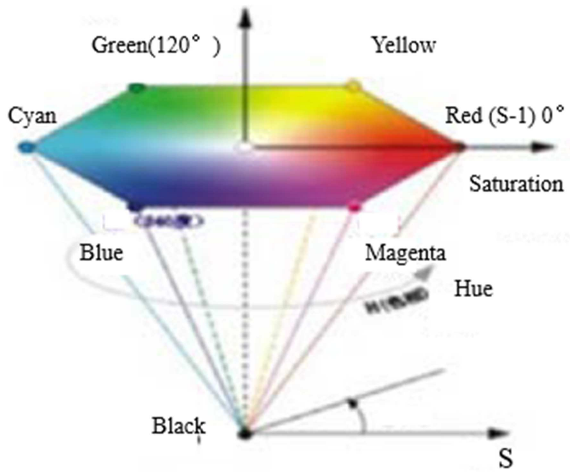

Figure 2. *The H S V color model diagram.*

According to this model, the saturation S takes values between 0 and 1, and the intensity and purity of the color are determined according to its numerical size.

4.2. Meanshift Algorithm

The Meanshift algorithm represents the mean offset, specifically referring to the mean vector of the offset. Its application to the field of computer vision design can be used to define the relationship between the offset and the mean offset in multiple cases, but the degree of influence changes. Meanwhile, the corresponding weight coefficients were set to characterize the importance of the different sample points. For the basic theory of Meanshift algorithm, we mainly include basic Meanshift and extended Meanshift. Among them, the basic Meanshift is mainly used to define the Meanshift vector Mk(x), which can be statistically analyzed in the SkThe number of sample points in the region (k) is summed, and the average is calculated based on the offset of the relative point X for the measurement. Extending Meanshift, which can be used to determine that the smaller the distance from X, the greater the sampling point when evaluating the statistical characteristics around X.

4.3. Camshift Algorithm

The Camshift algorithm is improved and improved based on the Meanshift algorithm, which can properly adjust the position and size of the search object to achieve the goal of tracking the target object. At the same time, the color information and the current frame position information can also be efficiently used to implement the position and size determination for the next prediction item.

4.3.1. Color Histogram and Color probability Distribution

The color histogram, based on the established color model, makes statistics the proportion of pixels of different types of tonal components to derive the color component proportion. For the specific operation, you can use the reverse projection method, and the specific operation steps are as follows:

First, for targets with a large tendency of interest, implement the RGB color model to the HSV model;

In the second step, the H component of each target region is measured to obtain the corresponding color histogram;

In the third step, for the obtained color histogram projection, the color probability distribution map is obtained.

4.3.2. Algorithmic Framework and Implementation

In this paper, using the method of the above research, for the shock hammer region positioning, followed by tracking using the Camshift algorithm, to enhance the level of automation.

When implementing the above algorithm, the specific steps are as follows:

In the first step, the target detection method of the previous chapter is used as a tool to obtain preliminary information on the search target;

In the second step, the initial information is used as a basis to form the detection center and calculate the H component of the target area based on the HSV to obtain the color histogram;

The third step, according to the color histogram, conduct the reverse projection, to obtain the current frame color probability distribution map;

The fourth step, for the target window, the zero-order and centroid position coordinates are measured;

The fifth step, move the center of the window to position it at the obtained center of mass, determine the window size and shape above the zero-order distance function, and repeat the third and fourth steps to meet the convergence requirements.

The sixth step, after which the conditions are met, the tracking is performed based on the location information and size information of the current frame and the target to be tracked, and a new search window is set in the next frame image, returning to the second step to complete the continuous adaptive tracking of the hammer.

4.3.3. Improve the Analysis of the Algorithm Test Results

In this paper, the experimental analysis of the above method adopts the video frame rate of 35 frames / second. The results of the experiment are obtained as follows:

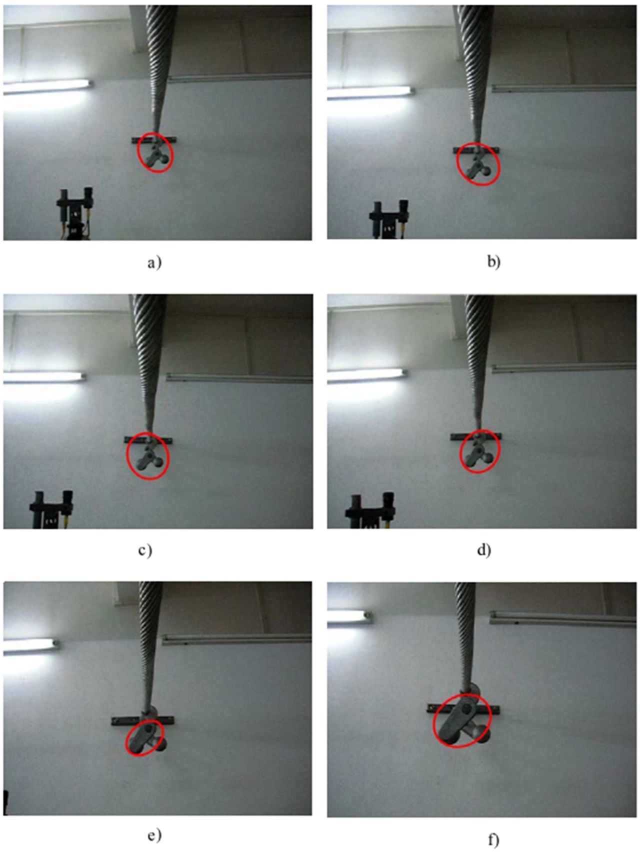

Figure 3. Shock hammer tracking effect.

Based on the analysis (Figure 3), this algorithm is adaptable and can search in a blind state, save search time and improve efficiency. At the same time, it can carry out automated implementation of monitoring, for the real-time tracking of the location of the target, strong effectiveness. Moreover, the image smoothing process is unnecessary, and the noise resistance is outstanding.

5. Conclusion

The research focuses on the target detection, methods and improved Adaboost algorithm, the Camshift algorithm for the whole-process tracking, automation and intelligence level, and efficient tracking.

Intelligent inspection robot is in the stage of rapid development, and its use scope is constantly increasing, however, there are a series of problems, such as poor positioning accuracy, insufficient anti-interference ability, and difficulty in real-time tracking. In order to solve the above problems, we try to analyze the target detection techniques, algorithms such as image smooth denoising, image binarization processing, image mathematical processing, image background update, improved Adaboost algorithm to achieve real-time online accurate detection, and improve the detection accuracy and anti-noise ability.

We analyze that a tracking algorithm based on improved Camshift deals with the problems which exist in traditional Camshift algorithm. In addition, we present Meanshift algorithm improves the Camshift algorithm for the whole-process tracking, automation and intelligence level, and efficient tracking.

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