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Article

Machine Vision based Grabbing Objects with Manipulator System Design

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Abstract. In recent years, machine vision technology and robot control technology have attracted lots of attention of the researchers. They provide people with fast and efficient services in many fields, which have an increasingly important impact on the modern manufacturing industry and the inspection industry. In this paper, a mechanical vision-based grab control system based on machine vision is developed and analyzed accordingly. This design employs industrial cameras with Gigabit Ethernet ports, six-degree-of-freedom servo drive robots. The Host computer control software is designed on the development platform provided by Microsoft and processed in machine vision image processing. The software has implemented an image processing algorithm. It aims to combine machine vision, robot control and other technologies to achieve precise positioning, recognition and capture of targets. In the end, the proposed method is displayed in the upper computer accordingly.

Keywords: Machine vision, manipulator control, image recognition.

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1. Introduction

With the advent of Industry 4.0, machine vision technology plays a very important role in industrial manufacturing and automated inspection. The combination of machine vision and robotic hands has already had very mature applications in industrial powers such as Germany and Japan [1]. A set of intelligent packaging systems developed by the German company Festo, which can pick, place and pack a wide range of products on the conveyor belt very accurately and quickly, greatly improving the efficiency of the production line. The four-axis manipulators of Japan's EPSON Corporation and the six-axis manipulators of Sweden's ABB Corporation are also widely used in the industry and have made outstanding contributions to the field of industrial automation [2].

At the same time, the needs of various industries in China for industrial automation and intelligence using machine vision technology have begun to appear widely [3]. In recent years, relevant domestic universities, research institutes and enterprises have also actively explored and tried in the field of machine vision technology. And gradually began to apply the layout in the industrial field [4].

Changchun University of Technology's six-axis robotic automatic sorting system based on machine vision, which studies the target positioning and automatic sorting of bottles in the essential oil filling process, using Halcon machine vision software from MVTEC in Germany and RV-4FL from Mitsubishi -D-type six-axis manipulator is an experimental platform that studies the image processing, system modeling, trajectory planning, intelligent control, and system experiments involved in filling bottle positioning and automatic sorting processes, while improving the sorting speed It can also guarantee the quality of sorting and monitor the entire sorting system [5,6].

Kunming University of Technology's industrial robot guidance and gripping system based on machine vision technology, for industrial robots to control the robot through offline programming, difficult positioning of high-precision and complex mold parts, robot teaching gripping positioning, large gripping errors, etc. A monocular vision guided grabbing technology was proposed, a new machine vision image processing algorithm was developed, and an independent and complete set of machine vision guidance systems based on KUKA six-axis industrial robots was developed [7,8]. Pachtrachai et al (2018) developed an adjoint transformation algorithm for Hand–Eye calibration with applications in robotic assisted surgery [9]. Zhang (2012) employs machine vision to design the embedded manipulator monitoring system [10]. Girshick et al. (2015) built up a rich feature hierarchy for accurate object detection and semantic segmentation [11]. He et al. (2016) did the research on deep residual learning for image recognition [12].

The machine vision-based snatch control system based on machine vision studied in this paper can be divided into three layers: decision-making layer, processing layer, and execution layer. This paper mainly intends to solve the following key technical issues: (1) Setting up the system hardware environment; (2) C ++ source code writing friendly human-computer interaction interface; (3) image processing algorithms for target recognition and target positioning; (4) secondary development of industrial cameras and speech recognition modules; (5) analysis of manipulator control instructions; (6) systematic Stability debugging.

The expected design of the system is to operate the system as a whole through the developed upper computer control software, identify, locate and grab the specified object by manual selection or voice, and then place it in advance Set a good location.

2. System Design

2.1. System Design Framework

This research develops a human-computer interaction interface based on the MFC framework under the Visual Studio platform. The software interface includes the display of captured images, the sending of control instructions, the receipt of feedback information, the operation of image processing, and the robot of control and adjustment of various parameters, etc. This paper mainly focuses on software programming and algorithm applications, among which software programming includes UI interface programming, data communication programming, and single-chip computer programming, and algorithm applications are machine vision image processing algorithms.

The machine vision image processing algorithm applies Halcon's own language, and the written algorithm is exported into C/C++ language, and then the code is transplanted into the image processing function module of the host computer control software. Three major algorithms are developed which include that camera calibration and hand-eye system calibration, Blob analysis and morphological processing, shape-based template matching and shape recognition.

The hardware part includes that black and white industrial camera of Da Heng image GigE Vision Mercury series; rectangular light source and ring light source; remake stage and camera light source bracket; Levosol's six-degree-of-freedom servo manipulator; speech recognition of single-chip system Module; TTL to USB level conversion module and various cables.

2.2. Software Development Platform and Framework

Microsoft Visual Studio is employed to develop the Host computer system. The version of the compiler and integrated development environment IDE used is the latest Visual Studio 2019 development platform as shown in Fig. 1.

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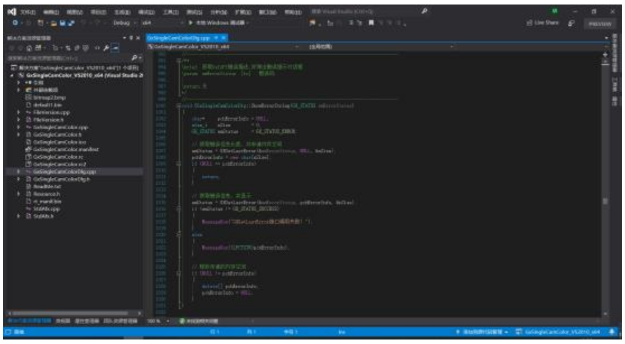

Fig. 1. Software development platform.

3. Image Processing Algorithms

3.1. Blob Analysis

Blob Analysis (connected domain analysis) is a collective term for processing processes, including: image acquisition, image segmentation, and feature extraction. As shown in Fig. 2, image acquisition is performed first.

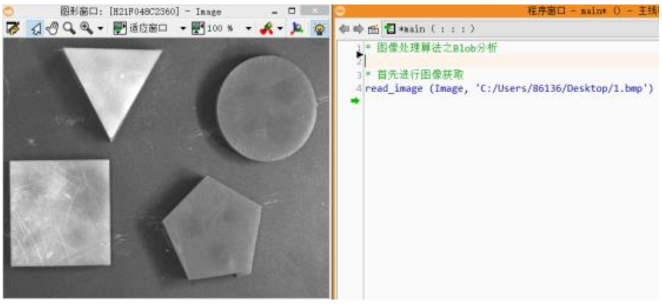

Fig. 2. Image acquisition.

Image segmentation mainly includes image noise filtering (filtering) and threshold processing. Common filtering methods are: mean filter, median filter, and gauss filter. Threshold processing is mainly divided into: Global threshold processing (threshold) and dynamic threshold processing (dynamic threshold) (local threshold).

Mean filtering is a typical linear filtering algorithm to suggest a template to the target pixel on the image, the template includes neighboring pixels around it, and then replaces the original pixel value with the average value of all pixels in the template. Mask Width and Mask Height express the product size of the filter matrix, and the average filtering effect is shown in Fig. 3.

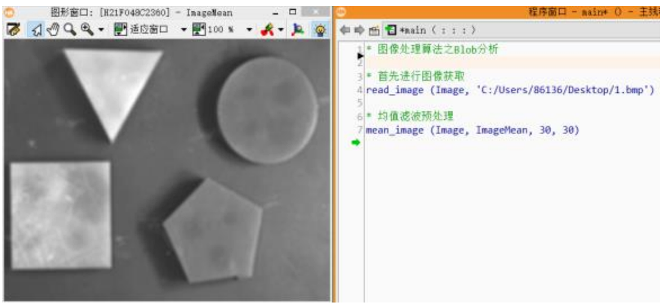

Fig. 3. Mean filtering.

Median filter is a kind of non-linear smoothing filter. Pixels Point gray scale value is set to all pixels in a neighborhood window at that point. The parameters of MaskType can set the type of the mask into Circle and Square. The parameter Radius represents the radius of the mask. The effect of median filtering is shown in Fig. 4.

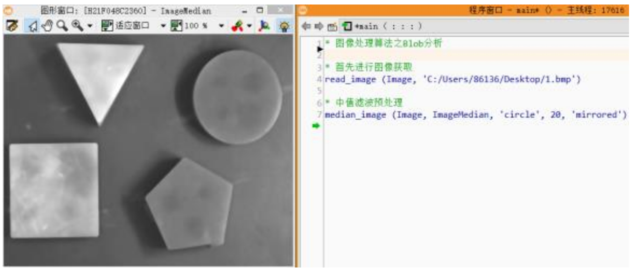

Fig. 4 Median filtering.

Gauss filter is a linear smoothing filter that is suitable for removing Gaussian noise. During the process of the weighted average, the value of each pixel is obtained by weighted average itself and other pixel values in the neighborhood. The smoothing effect increases with the size of the filter, and the Gaussian filtering effect is shown in Fig. 5.

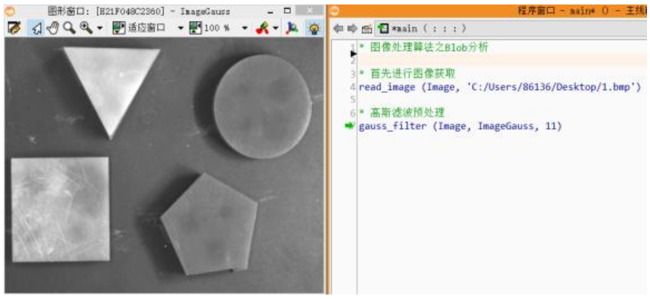

Fig. 5 Gaussian filtering.

After filtering the noise of the image, it is necessary to perform threshold process. For the case where the contrast between the foreground and background of the image is large, the global threshold processing is sufficient. For the case where the contrast is small, dynamic threshold processing must be used. It can employ the global threshold to deal with, which extracts rectangles and triangles with large contrast (because there is a lighting operation on the left side of the remake stage). The threshold processing effect is shown in Fig. 6.

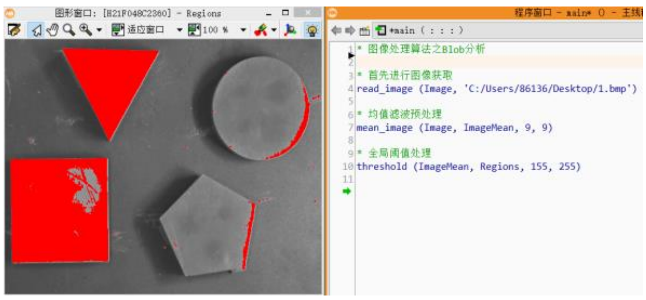

Fig. 6. Threshold processing.

After threshold processing, it can be clearly seen that the triangle part in the figure is extracted relatively well, while the rectangular part needs to be filled, and other

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areas are still extracted by mistake. At this time, mathematical morphology processing is needed. To further improve the extraction and segmentation of regions. Mathematical Morphology is one of the most widely used techniques in image processing. Recognition can capture the most distinguishing shape features of the target object. Morphology has two basic operations, namely corrosion and expansion, which combine to form an open operation and a closed operation. The open operation is to erode first and then expand. The closed operation is to expand first and then corrode.

Corrosion can make the area of the target area smaller, which causes the boundary of the image to shrink in nature and it can be used to eliminate small and meaningless targets. Corrosion can be based on structural elements with round or rectangular structures Elements to perform operations, the binary image corrosion operation is shown in Fig. 7, and the corrosion effect is shown in Fig. 8.

Dilate, which can make the range of the target area larger, merge the background points that the target area touches into the target, and expand the target boundary to the outside. The effect is to fill some holes in the target area and eliminate the noise of small particles contained in the target area. Dilation can be operated according to the structural elements with circular or rectangular structural elements. The binary image dilation operation is shown in Fig. 9. The dilation effect is shown in Fig. 10.

After the corrosion treatment, it can be clearly seen that the small and meaningless objects in the picture have been removed, and the shape of the vacancy inside the rectangle is clearer. At this point, the image segmentation is complete, and the vacancy inside the rectangle needs to be completely filled before performing feature extraction. Then, through feature extraction, the parts of the circles and pentagons that are erroneously extracted are cleared, so that the target rectangle and triangle areas that need to be extracted are completely rendered. The idea of feature extraction here is simple, and the area is processed. As shown in Fig. 11, the rectangle is filled. After feature extraction, it is shown in Fig. 12.

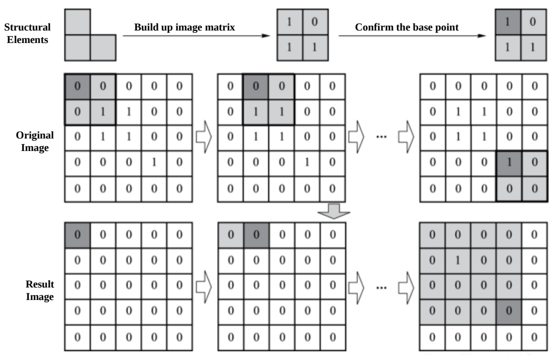

Fig. 7. Binary image corrosion calculation diagram.

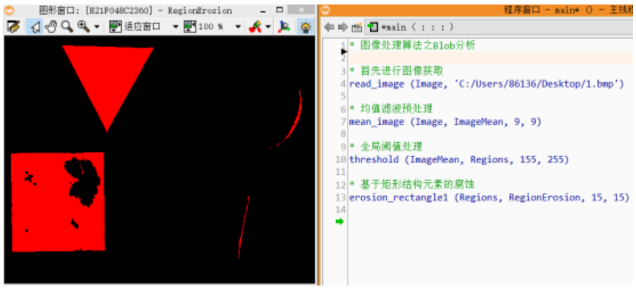

Fig. 8. Corrosion based on rectangular structural elements.

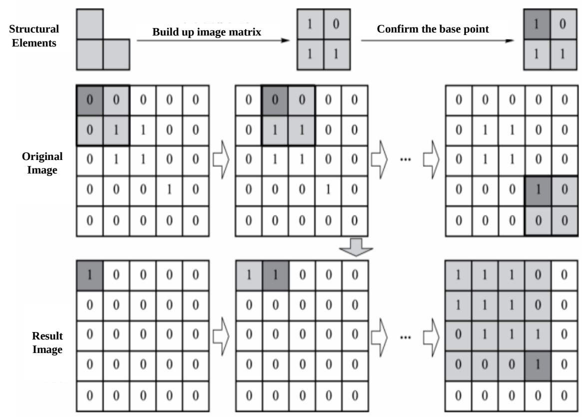

Fig. 9. Binary image dilation operation diagram.

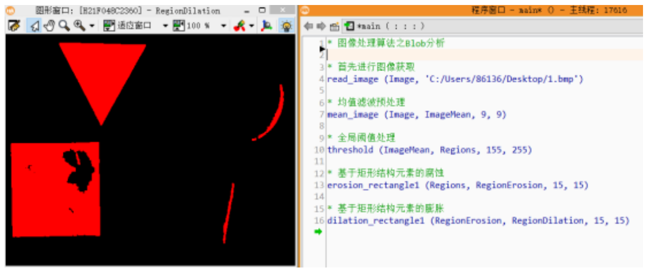

Fig. 10. Expansion based on rectangular structural elements.

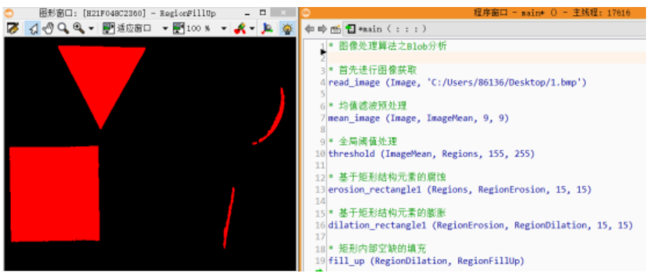

Fig. 11. Filling of vacancies inside a rectangle.

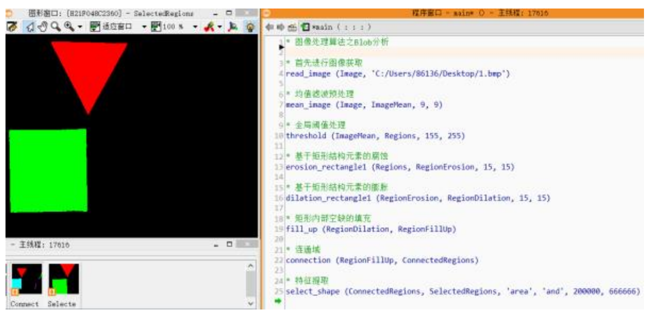

Fig. 12. Feature extraction.

The filled rectangular part is as complete as the triangular part. In addition, the image looks like four regions of different sizes, but they are essentially the same connected domain. If further image segmentation and extraction operations are needed, the four blocks need to be divided. The regions are scattered into different connected domains. Then the area is used for feature extraction, so that the required triangular and rectangular regions are completely extracted and exist independently.

Summarize the basic operation steps of Blob analysis: image acquisition, filtering preprocessing, threshold segmentation, morphological processing, and dispersion of target objects after different connected domains. After the analysis of Blob algorithm, the image processing algorithm in this system has been completed.

3.2 Shape-based template matching

Template matching is one of the most representative methods in image recognition. It extracts several feature vectors from the image to be recognized, compares them with the corresponding feature vectors of the template, calculates the distance between the feature vectors of the image and the template, and uses the minimum distance method to determine the category. Template matching usually establishes a standard template library in advance to find the most matching part of the template image in a referred image. Through traversing the target image in the image to be matched, the matching value of each starting pixel can be obtained by selecting a certain matching method, and the position with the largest matching value is the candidate matching position, which also achieves the effect of matching search.

The algorithm based on shape matching provided by Halcon machine vision image processing algorithm library is mainly a template established for ROI. The basic process of shape based matching is as follows:

Firstly, the rectangular range of ROI in the region of interest is determined, and the coordination of the upper left point and the lower right point of the rectangle is required to determine. Subsequently, the location of the center point of the rectangular area is obtained, as shown in Fig. 13.

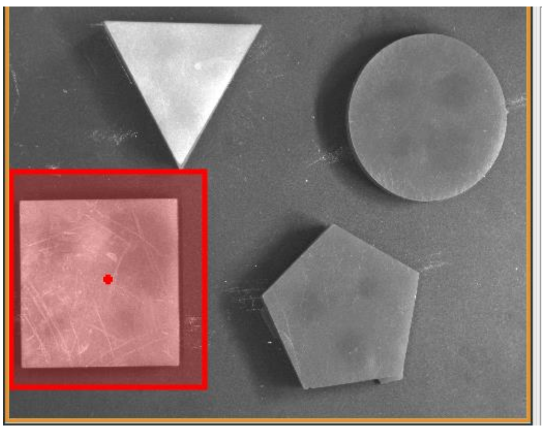

Fig. 13. Center point of the rectangular area.

Secondly, after the image data is converted to a region, a template is created. In the algorithm of template creation, there are some important parameters that need to be explained. The number of stages of the pyramid is specified by the parameter *Numlevels*. The larger the value, the shorter the time needed to find the target objects. The parameters *AngleStart* and *AngleExtent* determine the range of possible rotations, and *AngleStep* specifies the step size of the angle range search. For larger templates, the parameter optimization is used to reduce the number of templates. The parameter *Minconstraint* separates the template from the noise of the image. If the fluctuation range of the gray value is 10, its corresponding setting is 10. The parameter Metric determines the conditions for template recognition. If the parameter is set to *use_polarity*, the objects in the image and the template must have the same contrast. The effect of image conversion to area is shown in Fig. 14.

After creating a template, you need to monitor the template, which is used to check the applicability of parameters and help find the appropriate parameters. In addition, the outline of the template is required to obtain for later matching. The effect of creating template, monitoring template and getting template outline is shown in Fig. 15.

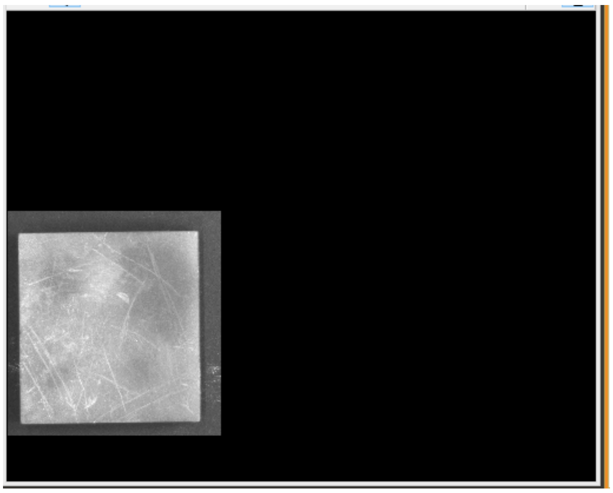

Fig. 14. The effect of image conversion to area.

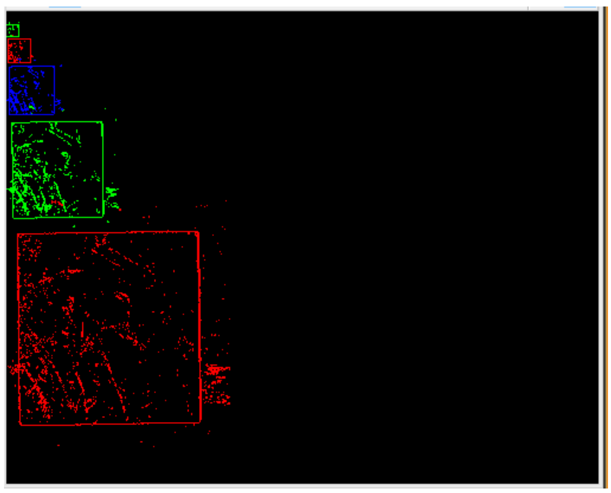

Fig. 15. The effect of creating template.

After creating the template, search for the template. The function of template search algorithm is to find the

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best matching template in a graph, and return the length, width and rotation angle of a template instance. The *SubPixel* parameter determines whether it is accurate to achieve the Sub-Pixel level, which directly affects the search accuracy. Parameters *MinScore* and *Greediness*, the former is used to analyze the rotational symmetry and similarity of template, the latter is used to search the greedy degree, which directly affects the search speed, on the premise of basically matching, increase its value as much as possible. The template search is shown in Fig. 16.

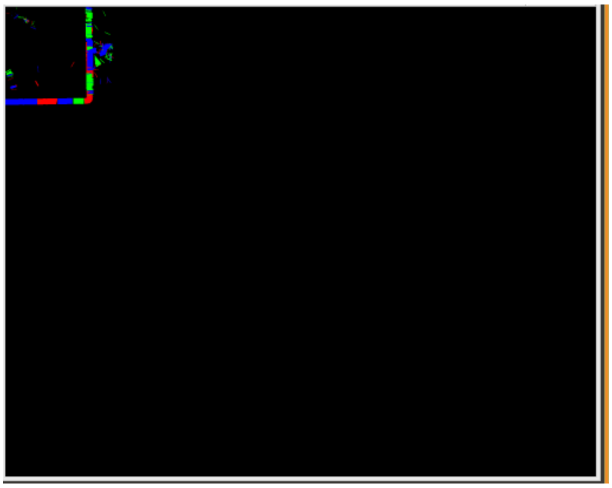


Fig. 16. The template search.

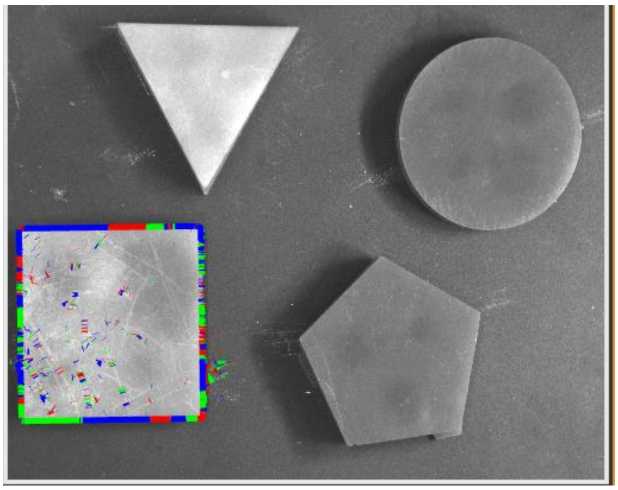
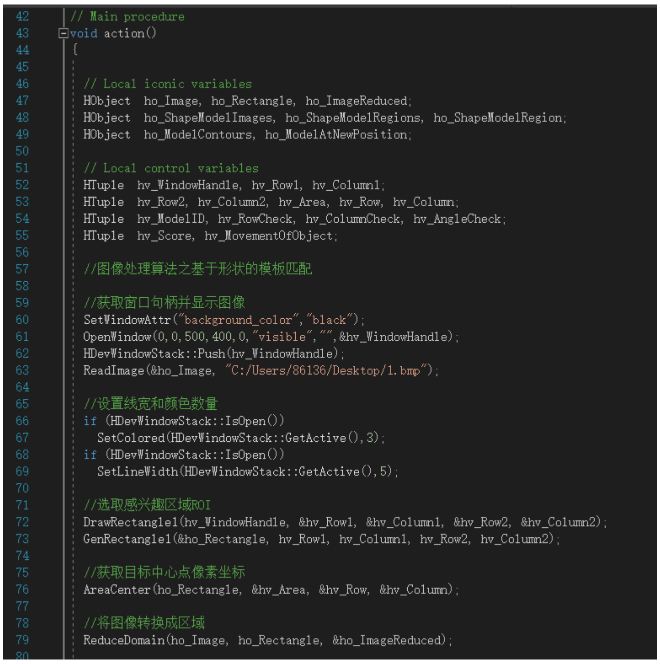


Fig. 17. The coordinate conversion.

After the template search, the affine transformation is used to display the coordinate transformation. Affine transformation is defined as an affine transformation or affine mapping between two vector spaces, which consists of a non-singular linear transformation (transformation by using a function) followed by a translation transformation. It changes the reference image of the searched template into the current image, and the coordinate conversion is shown in Fig. 17.

4. Upper Computer Image Processing

After the image algorithm is processed on Halcon, it is exported to C++ code. The action function is obtained in the generated .Cpp file, which has some properties and methods converted from Halcon as shown in Fig. 18.



```
// Main procedure
void action()
{

  // Local iconic variables
  HObject  ho_Image, ho_Rectangle, ho_ImageReduced;
  HObject  ho_ShapeModelImages, ho_ShapeModelRegions, ho_ShapeModelRegion;
  HObject  ho_ModelContours, ho_ModelAtNewPosition;

  // Local control variables
  HTuple  hv_WindowHandle, hv_Row1, hv_Column1;
  HTuple  hv_Row2, hv_Column2, hv_Area, hv_Row, hv_Column;
  HTuple  hv_ModelID, hv_RowCheck, hv_ColumnCheck, hv_AngleCheck;
  HTuple  hv_Score, hv_MovementOfObject;

  //图像处理算法之基于形状的模板匹配

  //获取窗口句柄并显示图像
  SetWindowAttr("background_color","black");
  OpenWindow(0,0,500,400,0,"visible","",&hv_WindowHandle);
  HDevWindowStack::Push(hv_WindowHandle);
  ReadImage(&ho_Image, "C:/Users/86136/Desktop/1.bmp");

  //设置线宽和颜色数量
  if (HDevWindowStack::IsOpen())
    SetColored(HDevWindowStack::GetActive(),3);
  if (HDevWindowStack::IsOpen())
    SetLineWidth(HDevWindowStack::GetActive(),5);

  //选取感兴趣区域ROI
  DrawRectangle1(hv_WindowHandle, &hv_Row1, &hv_Column1, &hv_Row2, &hv_Column2);
  GenRectangle1(&ho_Rectangle, hv_Row1, hv_Column1, hv_Row2, hv_Column2);

  //获取目标中心点像素坐标
  AreaCenter(ho_Rectangle, &hv_Area, &hv_Row, &hv_Column);

  //将图像转换成区域
  ReduceDomain(ho_Image, ho_Rectangle, &ho_ImageReduced);
```

Fig. 18. C++ code export.

The software will initially have some identification information above the image display area. The original picture control is required to load the window that comes with Halcon to set the ROI. The initial interface is shown in Fig. 19. Then click the control button Rectangle of the manipulator at the bottom right of the interface, and set the ROI region of interest by drawing a rectangular box, as shown in Fig. 20. Right-click indicates that the setting is complete, and the image algorithm will automatically start, and the recognition program will be displayed at the top of the interface. The progress bar at the bottom right of the interface shows the progress of real-time processing, as shown in Fig. 21. When the progress bar reaches 100%, it indicates that the processing is complete. It can be seen that the rectangle in the image area has been extracted, and the information at the top of the interface shows that it is recognized that this is a rectangle and the coordinate position of its center point, as shown in Fig. 22.

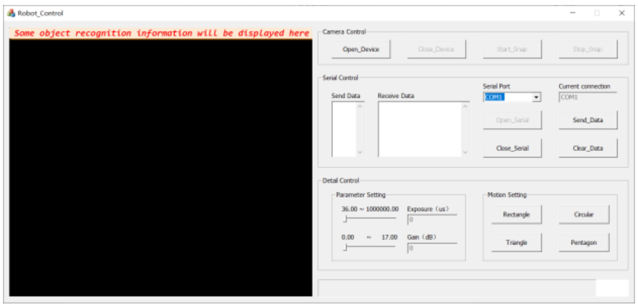


Fig. 19. The initial interface of the software.

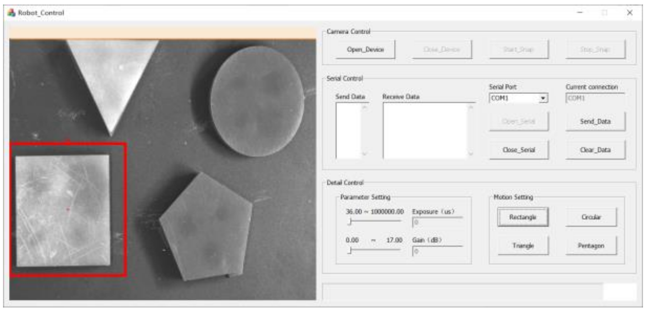


Fig. 20. Setting a rectangular ROI area.

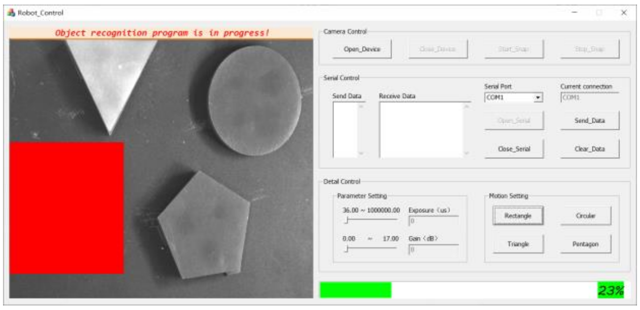


Fig. 21. Image algorithm processing.

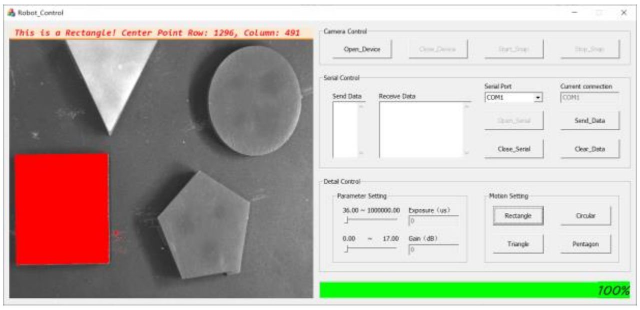


Fig. 22. Image algorithm completions.

5. Conclusion

Based on the design and research of the machine vision based snatch control system for mechanical manual parts, it can be concluded as the followings:

(1) In the overall design process of the system, the main portion is the development of the control software of the host computer. The application of manipulator control and image processing algorithms are included. Among them, the application of image processing algorithms and code transplantation are discussed detailed in the design system.

(2) In addition, the manipulator control is based on serial communication, and the data and the polling of the serial port are also analyzed accordingly which are also improved and optimized in this system to replace the black and white camera with a color camera and add color recognition to the image processing algorithm.

(3) The main design difficulties of this system are the machine vision image processing algorithm and the motion control of the manipulator. Owing to compatibility problem, its own control function is difficult to meet the design of this system, which needs to expand the control instructions in future.

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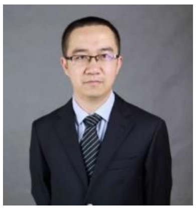

Xiangjun Yang was born in Zhangye, Gansu province, China in 1985. He received the B.S. degree in Mechanical Engineering from Chengdu University in 2009 and master's degree in Mechanical Engineering from Chengdu Technology University in 2017. From 2009-2013, he served in nuclear research institue as an project engineer. From 2013 till now, he works in Chengdu University, the school of Mechanical Engineering. Since 2015, he has been a lecturer and his research interests foucus on mechanical design and intelligne manufacturing. He chairs several provincial, municipal and university projects such as the department of technology of Sichuan province, the department of education of Sichuan province and the education innovation project of chengdu university, in the same time, he leads sevral national and provicial students competition projects and achieve excellent outcomes.

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