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Real time Application of Image Recognition Technology in Defect Detection of Mechanical Products

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Abstract: Image recognition technology is a technique that utilizes computers to analyze, process, and recognize images. It can achieve recognition and classification of target objects through image acquisition, preprocessing, feature extraction, and comparison steps. In order to use image recognition technology to quickly and accurately detect product defects in mechanical product defect detection, improve production efficiency and product quality. This article delves into the real-time application of image recognition technology in mechanical product defect detection, as well as its advantages and potential development directions. In the production line, real-time monitoring of mechanical products through image recognition technology can timely detect product defects. The role of topology analysis and research in image recognition of geometric and mechanical products themselves, and the construction of corresponding image description models, machine vision detection systems, and algorithm designs. In summary, image recognition technology has broad application prospects and huge development potential in mechanical product defect detection. Through real-time monitoring, automatic classification, and intelligent decision-making, image recognition technology can significantly improve production efficiency and quality, and reduce production costs.

Keywords: image recognition; geometric features; product defects; visual inspection; geometric characteristics

1. Introduction

Machine vision technology applications have brought a lot of convenience in the engineering of the actual detection, measurement, defect identification and control [1]. It speeds up the production speed and improves product quality. But mechanics industry manufacturing production of parts and components will usually be due to processing, installation and other factors led to its entities continue to change, but with the provisions of the measured geometric characteristics of a certain amount of deviation [2, 3].

Traditional visual inspection methods can only solve one problem. It can not achieve the desired testing due to the environment and conditions. This is because these traditional methods are relatively simple to use and do not take into account the sensitivity of the visual system in the on-line detection of mechanical products to the structure, characteristic parameters, and edge morphological changes of the captured images. Therefore, it is necessary to have a certain anti-interference ability and feedback function of machine vision image recognition method to improve the current status of machine vision online inspection.

Unable to locate encountered on-line visual inspection in mechanical products, can not find the feature points and so on, often because there is no corresponding image description model does not match the description model and the actual situation or the resulting algorithm. The geometric features and geometrical features of mechanical products are the effective factors for digital image description. Therefore, the number of image descriptions can be established by analysing the geometric characteristics of mechanical products learning model.

From the point of view of signal and system, the input of machine vision system is digital image, and the output is the symbolic quantity information of shape, category, and position coordinate and characteristic size of the object to be measured. The design of visual system is to study how to establish the relationship and constraints between input images and output information [4]. Image description refers to a set of descriptors to parse and represent the features of an object in an image and the relation between them. An image descriptor uses a set of data, or qualitative or quantitative notation, to illustrate the characteristics or relationships of the object being described. Through the image description, the characteristic model of the object to be measured can be used as the detection basis of the corresponding image processing and recognition algorithm. For mechanical products, the characteristic information that can be mapped through the typical mapping between the image and the mechanical entity includes the identity of the parts, class features, abstract shapes and structural features, and non geometric features.

Identify the class information of mechanical product refers to the parts of the surface of the coating, name, casting or graphic number; including the abstract shape and structural features of parts: the overall and local parts, parts of the boss and the groove, hole, relationship of mutual position between the various parts of the composite parts; including non geometric features: the parts size precision and shape precision, surface texture and surface roughness requirements [5].

The marking information and shape and structure features of mechanical parts can be transformed into the feature of image domain through simple direct mapping relation, which is suitable for calculation and measurement by image processing [6,7]. For the non geometric features in the image, because of the complex mapping process, after disturbance variation is very large, it is difficult to deal with. Therefore, in practice, the image features produced by the first two features of mechanical products are usually analysed and processed by topology. At the same time, identification class information can also be processed by shape and structure characteristics. One is caused by the difference in the composition of the visual system and the manufacturing of optical devices. Another is due to mechanical products due to processing and assembly of random differences and changes in field lighting conditions caused by interference factors.

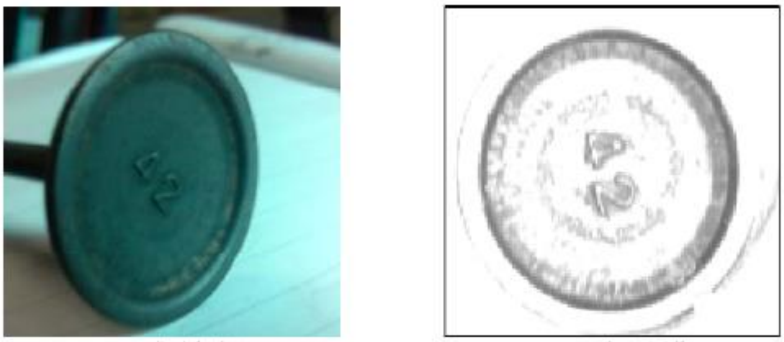


Figure. 1 An engine valve and its digital image

Fig. 1 is a mechanical part, an engine valve and its digital image. There is a consistent mapping relationship between the image of the mechanical product and the product itself. The external dimensions of the valve face and its circular shape remain unchanged in its image, and the casting character "42" in the middle of the valve face is mapped to 2 white connected regions in the image. Both essentially have the property of homeomorphism equivalence [8].

Integrated management model of engineering project is a new and highly effective project management model based on information technology. According to the characteristics of the project and project management, system integration, based on the idea of considering the efficient transmission and sharing of data and information in the whole process of the dynamic relationship between project from the early decision to post operation and maintenance in the whole life cycle of the various elements of mutual relations, parties involved in the project implementation process and project. From the overall project of the implementation of the whole process of the organization, the main factors and information on the project of scientific management system are to achieve a comprehensive optimization in quality, schedule and schedule objectives of the project [8]. That is based on the implementation of information security sharing, through the project management institutions to establish the participation of Fang Ping coordination, and the mechanism in the whole process of life cycle of project implementation of the project decision-making and management, and improve the project management level and management efficiency, makes up the project implementation process is unfavourable situation artificially separated [9].

2. Image description based on geometric features

There is a mapping relationship between the mechanical product and its digital image, and the shape of the body is represented as a set of points in the image. The topological relation of the whole mechanical product the topological relation of the set of points represented in different images in the image. Therefore, the topological space of two valued images can be regarded as a collection of graphs of different shapes. By analysing and calculating the relation of the set of these graphs, the topological relation matrix between them can be established to represent the topological space of the image of the mechanical product [10, 11]. The topological relationship of mechanical products refers to the topological relationship between point sets represented in different images. This topological relationship describes the shape characteristics and structural relationships of mechanical products in different views or angles. By analyzing the topological relationships between these point sets, the overall shape, size, and position information of mechanical products, as well as their relative relationships, can be obtained [12].

In image recognition, topological relationships can help determine the relationships between point sets represented in different images, thereby achieving product matching, alignment, and stitching operations [13]. For example, in stereo vision, the three-dimensional structure of an object can be determined by analyzing the topological relationship between feature point sets in left and right images. In addition, topological relationships can also be used for shape verification of products and matching problems during assembly processes [14]. For example, during the assembly process, by analyzing the topological relationships between point sets in part images, the correctness of the parts and the feasibility of assembly can be verified [15].

In summary, the topological relationship of mechanical products is one of the important features in image recognition, which helps to understand the overall shape and structure of the product, as well as their relative positions and relationships. The analysis of this relationship is of great significance for application scenarios such as product detection, matching, verification, and assembly [16].

2.1 Represents the image with a collection

In the integration of organization management, set up for the realization of common project goals through integration, organizational structure can bear their respective project tasks, establish the corresponding work flow, responsibility system, risk management and incentive mechanism, so that all parties involved in the sharing of benefits and risks with their own interests, to better serve the construction project target. In the whole life cycle of project management process, using management science, system science, natural science, engineering technology and information technology management means and methods of the parties involved in the tasks and responsibilities of the integrated management [17]. Because the project has many factors, such as quality, cost, schedule, safety, risk and communication, etc., it is necessary to plan the integration of these factors. Project participants should emphasize the consistency of multi elements of target, sharing of benefits and risks, to prevent damage to the other party for all parties involved in their own interests and the interests of the target, is the only factor of the whole project implementation, in order to achieve the goal of each participant.

Take the example of the valve installation situation shown in figure 2 for example. Basically, the whole image contains the engine cylinder head, air chamber outline, two intake valve images, two exhaust door images, and six big parts of the centre spark plug threaded whole image. Each part can be subdivided, for example, the valve image can be divided into valve outer circle outline, sub outer circle, centre casting character mark or shape mark. Then the image is represented in a collection as shown in figure 3.

Figure. 2 An image of a mechanical product

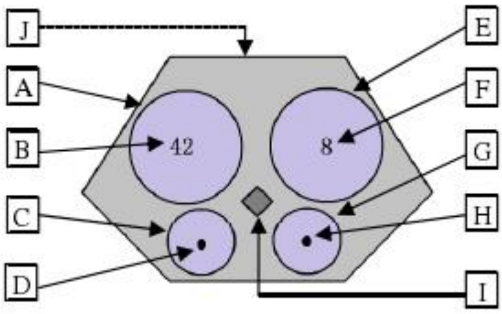


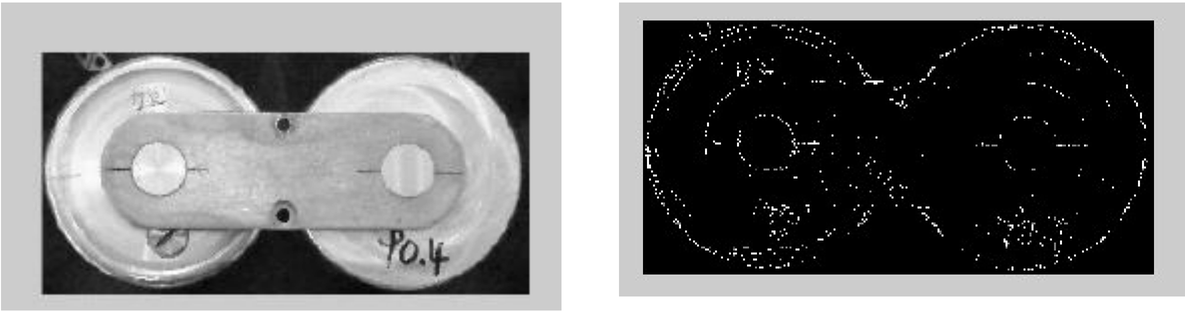
Figure. 3 A topological subset description

2.2 Image distortion analysis in industrial field

In the application of machine vision in industrial field, often find the image by CCD camera to collect the edges of varying degrees of distortion or alteration [18]. In addition to the visual system source part to make the necessary adjustments, suitable for extracting contour measurement is feasible by using the edge processing method suitable to the first, and the contour of the image model description based on fractal theory. Integrated management refers to the process of forming, maintaining and developing the integration activities of specific factors and the formation, maintenance, development and change of an integrated entity, so as to achieve the goal of integration and efficiency [19]. And the integrated management is the main target of the integrated elements, including the collection process of public property with the elements of management, including maintenance of formed elements through the collection of the whole or system, and Research on the development of the whole system, changes in the external environment under the action of it [20]. In the industrial field, image distortion is a common problem, especially in applications involving machine vision and image processing. Image distortion refers to the decrease in image quality caused by various reasons during the acquisition, transmission, processing, and display of an image, manifested as blurred details, color deviation, and reduced contrast. During the image display process, factors such as the resolution and color space conversion of the display device may lead to inaccurate color and detail representation of the image, resulting in distortion. For example, poor color accuracy on a monitor may lead to color deviation, and insufficient resolution may result in blurry details [21]. During the image acquisition process, factors such as camera settings, lighting conditions, and lens distortion may cause distortion in the acquired image. For example, uneven lighting may lead to excessive or insufficient local exposure of the image, and lens distortion may distort the geometric shape of the image. During image processing, design and implementation issues with algorithms such as image enhancement, denoising, and feature extraction may lead to image distortion. For example, improper filtering algorithms may lead to blurred image edges, and feature extraction algorithms may introduce additional noise [22].

The field production and assembly of mechanical industry are characterized by many kinds of materials, complex structure, high speed of production and assembly process, and interference factors such as light, sound and dust on the job site. Therefore, the images collected in the industrial scene have varying degrees of distortion and distortion. One is caused by the difference in the composition of the visual system and the manufacturing of optical devices. Another is due to mechanical products due to processing and assembly of random differences and changes in field lighting conditions caused by interference factors [23].

The principle of the first kind is distortion in the vision system, optical imaging system can make the image and the object to be measured strictly satisfy the central projection relationship in the whole field of view, the central projection ray bending, resulting in radial distortion and tangential distortion. Radial distortion is the location error of an image point from its ideal position inward or outward, mainly due to the defect of the radial curvature of the lens surface. The result is shown in figure 4



Original image Roberts operator

Figure. 4 Detecting edge of a cylindrical part by traditional edge operator

Barrel or pincushion distortion is the main factor affecting the accuracy of visual inspection. A lot of calibration methods have been used to correct the distortion. In this article, we don't discuss it too much. The second type of distortion is difficult to avoid in industrial images. This type of image distortion is affected by the shape changes of the detected mechanical products and the interference factors that are not controlled. Under such conditions, the acquired image is only "undistorted" relative to the imaging system itself, but it can not be used to detect the characteristic parameters and defect identification of mechanical products.

All kinds of deformation for various reasons such as physical mechanical components in processing the collection in the visual system to the same kind of measured object image edges are not entirely consistent with a variety of defects or randomly generated. The contour and central coordinates obtained from such image processing have some errors with their standard values. Such edges are not suitable for measuring edges of images, because random errors lead to errors or deviations in feature calculation, which can lead to errors in recognition results. Taking a cylindrical part image as an example, Roberts's operator, and Prewitt operator, Lo G operator and Canny operator are used to perform the two values and edge extraction of the image..

3. Establishment and transformation of image geometric feature space

In the last section, a description model of image structure, shape space and contour measurement is established theoretically. This section focuses on how to obtain the geometric features of the image and the complexity of the image feature space through the calculation to represent the parameters - the structure dimension. The coordinate transformation of images, algorithms, model transformations and image segmentation theories and methods are the basis and difficulty of the establishment and transformation of image geometric feature space.

3.1 The geometric characteristics of images are computed

An image of a connected domain in the same pixel value is usually called a speckle. Spot analysis refers to the analysis of such connected domains, also known as BLOB analysis. Through BLOB analysis, the number, location, area and perimeter of the spots in the detected image area can be obtained, and the topological structure between the spots can also be obtained. This image analysis algorithm is more suitable for two valued images and in a certain range of memory in the rotation invariance requirements of the image. Especially, the number and location of the image defects can be identified when the defect image is the image itself or the image associated with the geometrical features of the speckle. Before BLOB analysis, image enhancement, threshold segmentation and two value processing are used to segment the image into the set of pixels in the speckle and local background, and then extract the image Eigen values. BLOB analysis can get the information of the area, perimeter, spot and centre of the spot image. For the two valued image, there is only black and white, and its area is the number of pixels in the region as the target. Another is due to mechanical products due to processing and assembly of random differences and changes in field lighting conditions caused by interference factors.

At present, China's project management is in the stage of exploration and development. With the development of the pace of reform and opening up, developed countries, scientific project management mode has caused great impact on the traditional project management model in China, the project management mode of domestic still has stalled in the traditional level. This kind of traditional project management model has the following problems: usually only pay attention to the management of a certain stage of the project; lack of scientific and systematic analysis of the project from the perspective of the whole process. At each stage of the whole process of project information has many islands of automation reduced to fragments, or information island; participation of the engineering departments are independent of each other, adopt different management methods to obtain their own interests; the decision design stage information is difficult to be applied to the construction, operation and feedback stage, the short term is difficult to achieve three the traditional control target. For example, the management of the construction phase of the project often appear in a large number of engineering changes, the reason is that the project managers usually only pay attention to the construction stage of quality management, the quality management of the design phase of the lack of consideration and left engineering risks, and resulted in increased costs and time delays. These illegal construction procedures have brought great harm to the construction of our country's engineering projects. Not only reduce the quality of the project, delay the construction project duration, increase the accident induced frequency, but also increase the cost of the project, resulting in some projects cannot be completed, or long-term losses after construction. These are all new situations, and they should not be neglected.

If the black pixel connectivity region is defined as the goal, by BLOB analysis of the connected domain concept is calculated to detect when the first pixel value is 1 pixels, the pixels near it determine whether 4 or 8 is connected. If so, calculate the number of black spots in the area, add one, and then detect the next connected black spot. The area values of a single shape are obtained by adding the number of connected black dots.

There are many circular parts in mechanical products. In order to recognize this kind of object, the coordinate position feature of the centre can be used. In the mechanical part image, the contour of the original image is distorted or distorted, and the ellipse shape is formed. The method of obtaining the centre of gravity coordinate value can not obtain the vertical bisector intersection point of many groups of two points on the edge according to the ideal circle. Otherwise, the deviation of the coordinate value of the centre of gravity will be very obvious. In this paper, a mathematical model of ellipse gravity centre based on the least square principle is introduced calculation method. Since the method is approximately linear fitting, the calculation speed is fast and the calculation accuracy can reach sub-pixel level.

In the topological space of the image, the change of the distance between the fixed point and the fixed base of the image will not cause the change of topology. But the size of the distance is used to detect the location parameters of each part of the image, which is usually determined by calculating the distance measurement function between pixels in the image.

3.2 Coordinate transformation of image and algorithm model transformation

In the calculation of geometric features of the image, in order to strengthen some features of the image or make it easier to process the algorithm, the coordinates of the image will be transformed. Many parts of mechanical products have revolving structure. A structure forms a cylinder or a cylinder. The image obtained by image acquisition is usually an approximately circular image. Such images are processed in Cartesian coordinates and can not get good results, especially if often have some angle mechanical products detected rotation processing under the Cartesian coordinate system will become extremely difficult. But in the polar coordinate system, this will become a. One way of thinking is to coordinate the collected images. The transformation of an image from a Descartes coordinate system to a polar coordinate system is often referred to as a P2C transformation. In order to ensure the image quality, image quality and short conversion time after P2C conversion, bilinear interpolation method can be used. The method of bilinear interpolation is one of the methods of gray interpolation, which is mainly to improve the accuracy of interpolation calculation. The advantage of the coordinate model in the transformation algorithm is that the algorithm is faster and does not need pixel interpolation. The parameters calculated by the scanning method are positive linear correlation with the values in the converted rectangular image. When calculating the area, perimeter and other parameters of the image, the pixels in the original image are still used, and there is no distortion caused by the image deformation. At the same time, the feature data, distance length, coordinate point position of the image obtained by the coordinate model of the transformation algorithm model are consistent with the image basic feature space which is composed of the essential features of the image. The calculation model and method of this chapter studies the geometric features of the image of the typical, will change the complicated high dimensional feature space image to simple mechanical products easy to calculate the lower dimensional feature space facilitates the calculation of image segmentation and image features, the image feature space model can meet the application requirements of the actual visual detection algorithm.

3.3 Image recognition system and evaluation

Research on image recognition technology involves many related fields of knowledge, such as image pre-processing, image sampling, image edge extraction, image segmentation, feature extraction, and combining with the machine vision, signal processing and numerical calculation. Image recognition technology is closely related to image fusion, image matching and other research directions. It is the research foundation of image understanding and image restoration. The basic image recognition system can be divided into four parts. The first part is the acquisition of the original image, which is to establish an image acquisition system to change the relative position between the CCD camera and the measured work piece to obtain the appropriate image. The second part is the image pre-processing, image transform, the purpose is to strengthen and repair operation to exclude significant difference of image noise and image, the original image will become suitable for the recognition algorithm for feature extraction form. The third part is the image feature extraction, and calculates the symbolic features that can reflect the nature of the object, such as pixel area, central coordinates and so on. The fourth part is the classification decision, according to the extracted feature parameters, the classification and recognition rules are used to classify and recognize the symbolic image information. In the same kind of image matching, the statistical matching algorithm based on the normalized maximum correlation method has become a common method. Template matching is one of the most widely used methods for image recognition. Its practical operation is relatively simple. The samples are trained by neural network or manually matched sample images, and then the target images are matched. But its use is highly skilled. For example, to detect a rotating valve in any direction, the method of pattern matching must be used to calculate the similarity of the template at a certain angle within 360 degrees. If the input image is large, then the search time becomes very long, resulting in a large amount of matching calculation and the computational efficiency is not high. Therefore, we need to use some mathematical models to guide the selective matching operations.

In the process of image recognition, redundant image input information must be eliminated and key image feature information is extracted. At the same time, it is necessary to have a system that integrates feature information into a complete set of feature libraries and decision rules. The method of image recognition based on geometric features can meet this requirement. Through the establishment of model and image element space model based on the geometric characteristics of the image, the image structure dimension can be calculated under different figures, according to the complexity of establishing the recognition database or template library. The method of BLOB analysis is used to recognize a single connected domain image. Therefore, it is necessary to establish a feature library of target connected domain before identification. In the third chapter of this paper, we have given the calculation method of geometrical feature indexes such as spot area, perimeter, central coordinate, graph centre of gravity, distance of feature points, etc.. By computing the sample images of these parameters, which is stored in the profile of different types of products, in recognition to read the file, calculate the characteristic parameters of the input to identify the sample image feature and feature library file read value by matching with linear decision criteria and comparison. The basis of the recognition algorithm is to establish the image segmentation region by analysing the feature space, and then use the feature library to calculate the decision or template matching method to find the required image features. According to the current experimental conditions, to compare the recognition speed through the establishment of feature library, so the database comparison recognition strategy in this paper, to a certain extent, accelerates the speed of recognition, improving the recognition accuracy.

4. Conclusion

This paper studied the image processing of image, especially the topology and fractal geometry in the literature, several key problems in the research of digital image from the unified mathematical proof, and its mechanical product image is a topological space, the geometric features of equivalence relations. On this basis, the basic feature space description model of machine product image is put forward, which is the basis of image processing algorithm design. Based on fractal theory, a new algorithm model of contour reconstruction for image measurement is proposed. The geometric feature analysis and defect recognition technology of mechanical product image are applied to machine vision inspection system in manufacturing field. Some specific mathematical models and related detection algorithms are proposed. The calculation model and method of this paper studies the geometric features of the image of the typical, will change the complicated high dimensional feature space image to simple mechanical products easy to calculate the lower dimensional feature space facilitates the calculation of image segmentation and image features, the image feature space model can meet the application requirements of the actual visual detection algorithm. This article conducts in-depth research on the geometric features of typical images using computational models and methods. By transforming complex high-dimensional feature space images into simple mechanical products, not only does it simplify the calculation process, but it also makes the calculation of low dimensional feature spaces more convenient. This transformation process provides convenience for image segmentation and feature extraction, thereby enabling the image feature space model to better meet the application needs of practical visual detection algorithms. However, in mechanical product defect detection, selecting the correct features is crucial for accurate identification. Improper feature selection may lead to misjudgment or omission. Continuous feature optimization and the use of machine learning techniques may help improve this. Real time detection requires efficient image processing capabilities. For large-scale production lines, fast and accurate defect detection may require strong hardware support, which may increase costs.

As the demand for interpretability of artificial intelligence models increases, efforts to understand how models make decisions will help increase people's trust in the technology.

Continuous monitoring and intelligent maintenance: With the development of the Internet of Things and sensor technology, image recognition technology is expected to be combined with continuous monitoring and intelligent maintenance systems to achieve more advanced mechanical product defect detection and management.

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