APPLYING MECHATRONICS-BASED INTERNET OF THINGS IN ARTIFICIAL INTELLIGENCE IMAGE DETECTION

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Abstract - The development of artificial intelligence (AI) technology and the Internet of Things (IoT) platform in recent years has allowed image detection systems to efficiently and gradually process data. The following study will be done in this paper to examine the image detection of AI based on mechatronics IoT technology. It is necessary to first describe the substance of mechatronics, the IoT, and other technologies, incorporate them into the IoT, and then examine and discuss the IoT's application potential. The second stage explains the fundamental ideas and various digital image detection algorithms that are really used in processing, and on the basis of these ideas, it suggests a number of automatic recognition processing approaches. In the third stage, different photos are classified using the Support Vector Machine (SVM) classifier based on AI and neural network technology, and the feature vectors of the target area are obtained through analysis and calculation. These are the conclusions: (1) The fusion of mechatronics and IoT technology has helped the AI industry innovate and grow to some level, which is helpful for fulfilling the fundamental criteria of an environment for intelligent picture recognition and detection. (2) An intelligent simulation model for image detection with recognition accuracy of over 95% and features of high speed, high precision, and high automation has raised the bar for detection and intelligent machine vision technology in China. (3) When SVM and neural networks are tested, the absolute error of the classification target value is very low, allowing them to meet the requirements for detection accuracy following error processing and a recognition rate of 90%.

Keywords: Mechatronics; Internet of Things; Artificial intelligence; Image detection; Detecting algorithm; Support Vector Machine.

1. Introduction

The use of mechatronics and the Internet of Things (IoT), which are integral to people's daily lives and have a significant impact on a nation's economic development, is widespread. The conceptual design stage is a crucial and highly creative step in the design process of mechatronics devices. The survey found that the conceptual design stage, which only costs 5% of the total, influences more than 70% of the product design quality and 85% of the cost of the product life cycle [1]. For instance, the development and deployment of the IoT based on mechatronics in artificial intelligence (AI) image detection system is more in line with the traits and specifications of image detection applications on the market. In order to maximize the impact of AI image detection, reasonable cloud image processing and analysis, image feature acquisition, image synthesis, and other functions are designed and applied in specific image detection [2]. The importance of mechatronics and IoT technology is highlighted by this. This paper presents an overall design plan of an intelligent image recognition machine based on IoT technology and discusses the structure and functions of each component in detail on the basis of researching pertinent data in China and other nations. In this paper, the ideas of mechatronics, the IoT, and other technologies are discussed. Mechatronics is integrated into the IoT, and its application potential is examined and discussed. On this basis, a collection of simulation models for detection and processing are given. These models make reasonable use of the fundamental ideas and techniques of digital image detection that are engaged in actual processing. Different photos are classified using the Support Vector Machine (SVM) classifier, which is based on AI and neural network technology. The feature vectors of the target area are obtained by analysis and calculation.

The rapid advancement of digital high-speed camera technology, which can better enable high-speed moving target testing, is the basis for the research relevance of this paper. The important technology for high-speed photography is high-speed moving picture processing, which is also one of the challenges. Traditional image processing techniques struggle to accurately extract fragments due to a variety of issues, therefore this paper processes images using AI and incorporates mechatronics and IoT technologies to get around practical issues. In spite of the fact that there are numerous ways to test research, this paper specifically examines the use of AI in image testing in China, where there has been relatively little discussion and implementation of the technology in recent years.

2. Literature Review

In the past 20 years, mechatronics has become a highly popular engineering specialty. Its greatest advantage is the development of compound applied talents who are knowledgeable in mechanical, electrical, control, and other specialties. The approach based on software interface and the method based on unified modelling language are the two basic interdisciplinary coupling modelling techniques for complex mechanical and electrical goods that Delbecq represents [3]. On this foundation, Nguyen utilized the excellent model libraries and mature modules of simulation software from multiple disciplines, maximizing the benefits of these tools in their respective professions [4]. Ma has developed the unified interdisciplinary modelling language-based multidisciplinary coupling modelling approach for complex mechanical and electrical goods [5]. On the software machine platform, Mu et al. successfully integrated the simulation and optimization of a mechatronics system using the dynamic simulation program Automatic Dynamic Analysis of Mechanical Systems (ADAMS), static analysis software Ansys, and Matlab [6]. Three-phase asynchronous motor was used as the controlled object by Zhong et al. as they compared and contrasted several joint simulation techniques based on Simulink and Saberrd software [7]. Le et al. used the separation of a missile as their research object. They first used the ADAMS software to analyze the dynamics of the missile separation process. After that, they took into account the coupling between space motion and aerodynamic drag and conducted a joint simulation analysis using the Fluent and ADAMS software [8].

The aim of target detection in the field of image recognition is to identify the object of interest in the image and determine its location and size. Since 2014, traditional target identification techniques have primarily been built on deep learning algorithms.

They were primarily created between 1998 and 2014. The Sun Deformable Parts Model (DPM) algorithm's fundamental principle is used to extract the static properties of images, and the incentive mechanism is built in accordance with the needs of target identification. The target position may then be determined by incentive through sliding computation [9]. Target detection has primarily relied on deep learning algorithms in recent years. Before training, Khan clustered a collection of rectangular boxes on the training set using the k-means algorithm and other techniques, and then categorised and regressed them based on the rectangular boxes during prediction [10]. Incorporating linear scanning technology for the first time, Wang's Trouble of Moving Freight Car Detection System (TFDS)-3 system achieved seamless continuous shooting from a single camera, making it easier for operators to spot problems and laying the groundwork for later automatic fault detection [11]. Despite every generation of TFDS systems' commitment to enhancing image acquisition quality, hardware dependability, detection standards, network topology, and other features, according to Sarieddeen, most systems still struggle with image recognition. The safest solution to this issue is still to manually check images [12].

In conclusion, there is still a lot that can be done to advance picture detection. The uniqueness of this work lies in the introduction of the mechatronics model and idea, the strengthening of the IoT technology application based on the original AI image detection, and the further improvement of the recognition rate and accuracy of image detection.

3. Establishment of Optimization Model of Construction Parameters

3.1 Concept and Development of Mechatronics and Internet of Things

Mechatronic system is a high-tech product that integrates many advanced technologies, mainly including mechanical structure, power source, sensor, control device and actuator. With precise structure and high integration, it is widely used in enterprise production [13]. The functions of mechatronics can be divided into the following types, as shown in Figure 1.

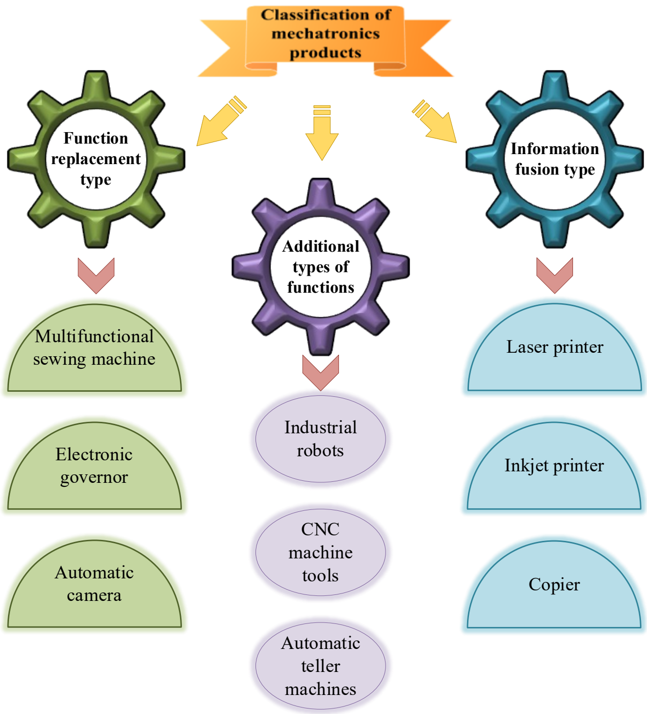

Figure 1: Functional types of mechatronics

The rapid development of mechatronics products is the comprehensive result of the continuous development of semiconductor and integrated circuit technology, the continuous updating of computer and its programming language, the continuous progress of control technology and simulation technology, and the continuous emergence of small but powerful sensors and driving devices.

In mechatronics, the application of IoT blurs the boundary between the control unit and the sensing unit of the existing mechatronics technology, which will lead to the overlapping of the original system contents, so it needs to be integrated to make it more comprehensive. In recent years, with the development of information technology, the IoT, as an important branch, has begun to be widely used, and industrial informatization has advanced rapidly. A large number of parts, components, sensors, controllers and hydraulic start-up components based on IoT have appeared in modern industrial sites. The new industrial revolution of IoT has begun, and the demand of enterprises for highly skilled talents is also changing [14]. Figure 2 shows the flow chart of the main program of the integration of IoT technology with mechatronics products.

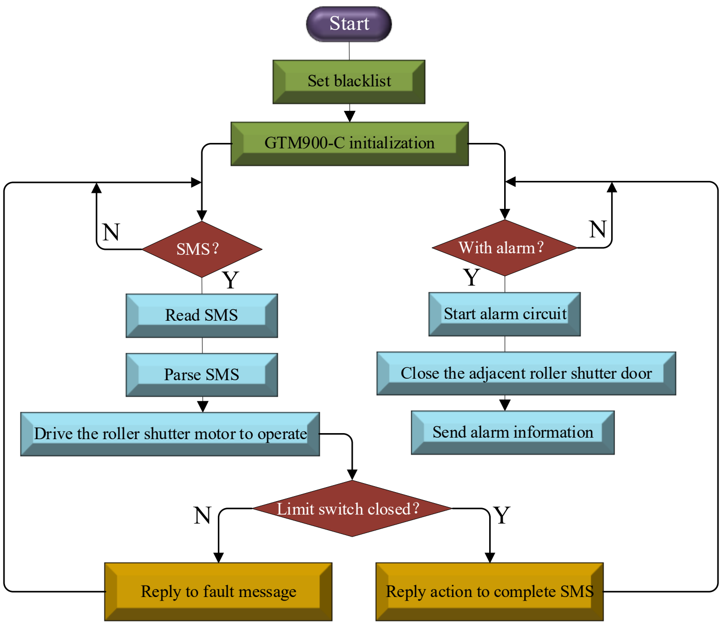

Figure 2: The main program flow chart of the integration of Internet of things technology and mechatronics products (SMS: Short Message Service)

With the rapid development of IoT technology, the professionalism and practical operability of mechatronics have been greatly improved. However, people should actively learn from the experience of all parties, pay close attention to the development status of the mechatronics industry in time, and make timely adjustments accordingly to ensure the innovation and stability of the mechatronics industry.

3.2 Intelligent Image Acquisition Algorithm

The detection software of the system is responsible for analyzing and processing the images collected by the system to draw the conclusion whether the detected object is qualified or not, and inform the main control computer of this conclusion. Usually, the edge diagram of an object appears in a discontinuous form, such as sudden change of gray value, sudden change of color, and so on. In essence, edge usually means the end of one area and the beginning of another, and it is the boundary between two different areas.

3.2.1 Gradient Algorithm

Edge detection can be regarded as a vector with amplitude and direction. Where the amplitude of the edge is the amplitude of the gradient, and the direction of the edge is the direction that the gradient direction rotates 90 degrees clockwise [15]. The magnitude and direction of the gradient can be calculated by the following equation:

$$|grad(x,y)| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \quad (1)$$

$$\varphi = \arg\left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right) \quad (2)$$

In practice, in order to simplify the calculation, difference is used instead of differential, and approximation algorithm is often used instead of square sum and square root operation, as shown in equations (3) and (4).

$$G[f(x,y)] \approx |\Delta x f(x,y)| + |\Delta y f(x,y)| \quad (3)$$

$$G[f(x,y)] \approx \max(|\Delta x f(x,y)|, |\Delta y f(x,y)|) \quad (4)$$

Robert operator in edge detection is calculated by using the difference between adjacent pixels in diagonal directions in four fields as the difference. The equation is as follows:

$$\begin{cases} \Delta x f(x,y) = f(x,y) - f(x-1,y-1) \\ \Delta y f(x,y) = f(x-1,y) - f(x,y-1) \end{cases} \quad (5)$$

Robert operator is one of the fastest operators because of its better effect and simple calculation when the gray value jumps steeply. However, this operator is highly sensitive to noise because it uses fewer pixels to approximate the gradient.

Sobel operator is weighted average first, and then differentiated. The calculation equation is as follows:

$$\begin{cases} \Delta x f(x,y) = [f(x-1,y+1) + 2f(x,y+1) + \\ \quad f(x+1,y+1)] - [f(x-1,y-1) + \\ \quad 2f(x,y-1) + f(x+1,y-1)] \\ \Delta y f(x,y) = [f(x-1,y-1) + 2f(x-1,y) \\ \quad + f(x-1,y+1)] + [f(x+1,y-1) + \\ \quad 2f(x+1,y) + \\ \quad f(x+1,y+1) \end{cases} \quad (6)$$

Sobel operators can also be expressed in the form of convolution templates. Commonly used convolution templates are as follows:

$$h_1 = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, h_2 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (7)$$

where h_1 and h_2 correspond to y and x, respectively. Sobel operator has a certain ability to suppress noise, and the edge width obtained by edge detection is 2 pixels. Sobel operator has strong directionality, and the above templates are most sensitive to horizontal and vertical edges.

3.2.2 Expert Decision Algorithm

According to the characteristics of object detection, an expert decision algorithm is used here. The expert decision algorithm shown in Figure 3 has the characteristics of high speed and good practical effect, and can be used for high-speed image detection.

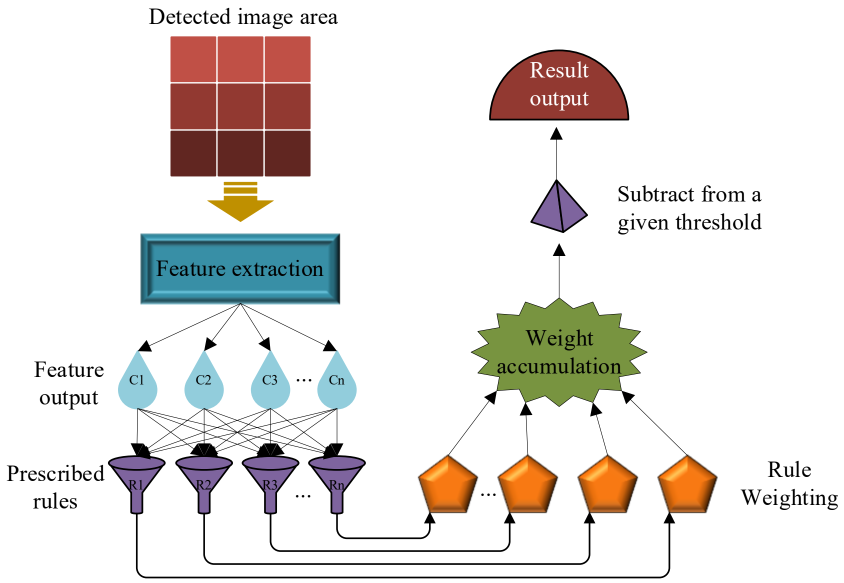

Figure 3: Architecture diagram of expert decision algorithm (C1: Characteristic 1; R1: Rule 1)

First, according to the collected images and the actual objects, experienced inspectors provide a variety of recognition rules and corresponding initial weights according to their own experience. The computer completes the image pre-processing within the predetermined detection time, and then extracts the image features according to the requirements of the recognition rules, such as the sum of gray levels, the sum of gray differences, the sum of pixels with gray values below a certain threshold, etc. The algorithm recognizes and judges these features according to the rules and weights provided in advance, and determines whether there are defects or foreign objects in the detected image by weighted summation [16].

3.2.3 Internet of Things Storage Template Matching Algorithm

In order to detect an object with a known shape in an image, the shape template of this object can be used to match the image. Under certain agreed criteria, the international standard image can be detected, which is usually called template matching algorithm, which can detect straight lines, curves, edge patterns and so on in the image [17].

Set template W:

$$W = \begin{vmatrix} w_{-1,-1} & w_{-1,0} & w_{-1,1} \\ w_{0,-1} & w_{0,0} & w_{0,1} \\ w_{-1,-1} & w_{-1,-1} & w_{-1,-1} \end{vmatrix} \tag{8}$$

Window pixel F:

$$F = \begin{vmatrix} f(m-1,n-1) & f(m-1,n) & f(m-1,n+1) \\ f(m,n-1) & f(m,n) & f(m,n+1) \\ f(m+1,n-1) & f(m+1,n) & f(m+1,n+1) \end{vmatrix} \tag{9}$$

Then the process of template matching can be regarded as calculating the correlation coefficient between the window pixel centered on (m,n) in the image and the template $w(i,j)$.

$$(F,W) = \sum_{i=-1}^{1}\sum_{j=-1}^{1} f(m+i,n+j)w(i,j) \tag{10}$$

When using dotted template for detection, the principle of detection is to find the maximum projection of image f on the template set, namely:

$$f^T w = \max[f^T w_i], i = 0,1,\dots,k \tag{11}$$

A threshold value t can also be set during processing, and when $f^T w \geq t$, it is considered that the target is searched.

3.3 Automatic Image Recognition Method based on Support Vector Machine Classification

SVM is based on statistical learning theory and the principle of structural risk minimization. Its basic idea is to map the samples in the input space to the high-dimensional feature space through nonlinear transformation, and then find the optimal classification surface that linearly separates the samples in the feature space. The algorithm uses classification interval to control the capacity of linear learning machine, so as to minimize the structural risk and make it have strong generalization ability under limited samples. In the detection, the video imaging scheme uses multiple light emitting diodes as built-in light sources to illuminate the inside of the real object, and directly uses Charge Coupled Device

(CCD) to capture images. The advantage is simple structure, but the disadvantage is that the center part of the field of view with good image quality is abandoned and not used, while the edge part of the field of view with poor image quality is used as the main part of observation [18]. The identification process is shown in Figure 4.

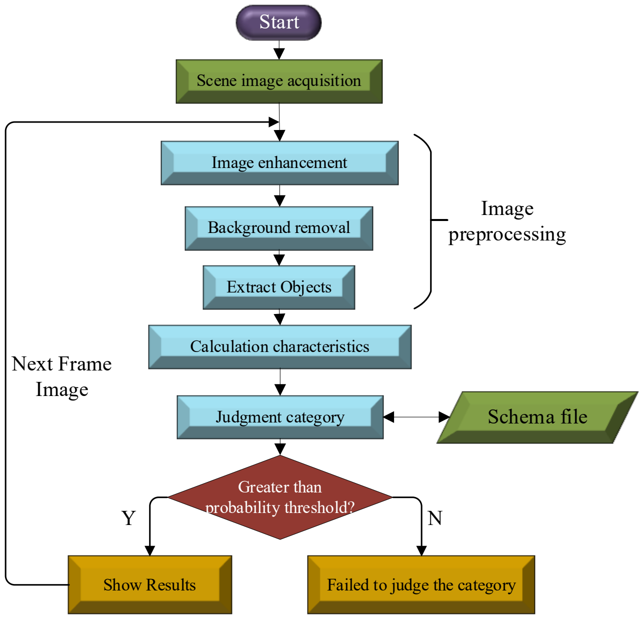

Figure 4: Flow chart of support vector machine image recognition

To overcome the shortcomings, SVM can adopt wide-angle lens and white light source. Meanwhile, the CCD camera with high resolution is selected. The CCD camera is loaded by the mobile machine, the environmental image is taken, and the video data is processed by the image processing method to extract the features of the diseased objects. After learning these features, the AI method has the ability to recognize and classify the objects badly.

SVM is developed from the optimal classification surface in the case of linear separability. The so-called optimal classification surface requires that the classification surface can not only correctly separate the two categories, but also maximize the classification interval [19].

3.4 Image Detection Simulation Design

3.4.1 Design of Image Analysis System

Intelligent data architecture is suggested as the core technology in image analysis system, mainly because this kind of technology has extremely high data information storage performance, data operation performance and image dynamic processing performance, and it has high coupling and accuracy in the process of interacting with the IoT, so it is worth popularizing and applying. Figure 5 shows the design process of the image analysis system.

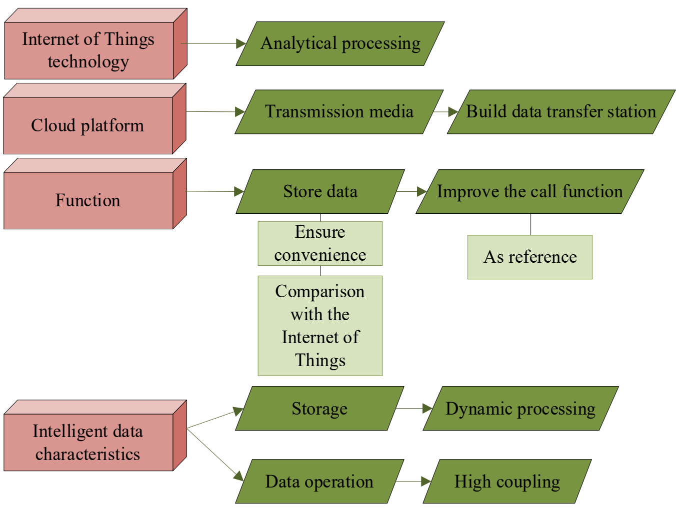

Figure 5: Design architecture diagram of image analysis system

In addition, in the construction of image analysis system, it is necessary to improve the architecture of system operation: through the image analysis system to interact with the IoT resources, the images stored in the network are extracted, compared and analyzed, the extracted data with the image data are detected, and signal feedback is made.

3.4.2 Design of Image Acquisition System

The above-mentioned design concept of image analysis system is mainly to provide services for image feature collection, and in order to effectively detect images, it is necessary to focus on the design of image feature collection system. Figure 6 shows the design process of the image acquisition system.

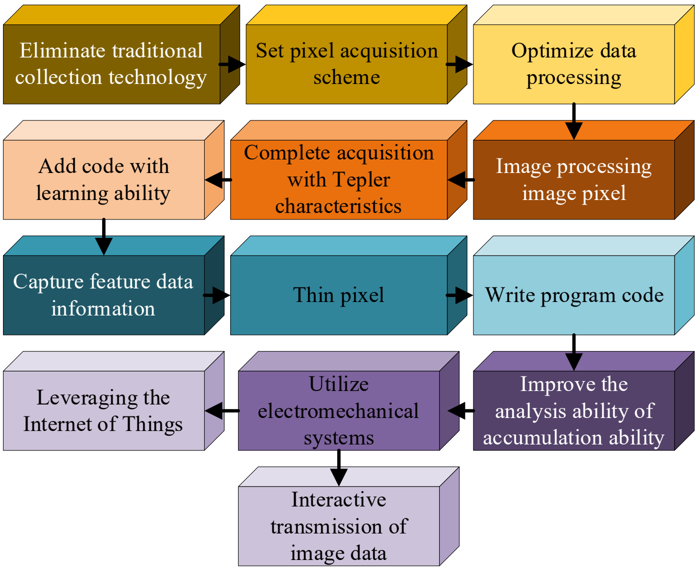

Figure 6: Image acquisition process

In the process of image analysis and feature data acquisition, it is necessary to construct the corresponding data transmission protocol to ensure the accuracy and reliability of all kinds of data information, and to ensure the timeliness of the system to upload data and images. In the specific image feature data acquisition process, due to the differences in the pixel arrangement of different images, the visual features are different. Therefore, in the actual implementation process of the image feature data acquisition system, the technical method of AI pixel feature acquisition can be used to capture the features and data information of different images, and the corresponding algorithms can be used to streamline and analyze the pixels of various types of images.

3.4.3 Design of Image Integration System

In the AI image detection system based on IoT technology, the design and implementation of image integration system is very important. Therefore, people should focus on the needs of AI image detection and reasonably adopt IoT technology to build an image integration system. Figure 7 shows the design process of the image integration system.

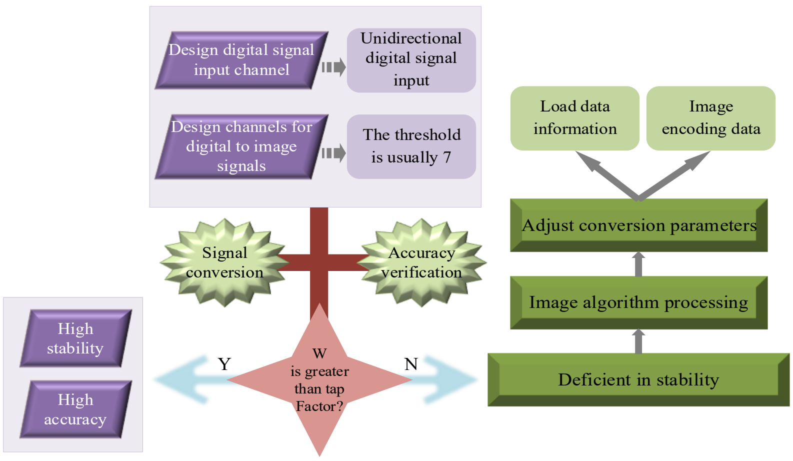

Figure 7: Process diagram of image integration

In the system, photosensitive sensor hardware and light-filling lamp hardware are set to detect the brightness of the external environment and transmit data information to the controller system. When the brightness of the external environment is very low, the controller can send an instruction to the light-filling lamp to turn on the lighting, effectively collect the images of objects, improve the overall image collection effect and provide help for the detection and operation of the system.

3.4.4 Simulation Debugging

After the design of the AI image detection system based on the IoT technology is completed, it is necessary to focus on the simulation and debugging of the system to ensure the good operation of the whole system and provide assistance for accurate image detection and high-resolution image detection. Figure 8 shows the system simulation and debugging process.

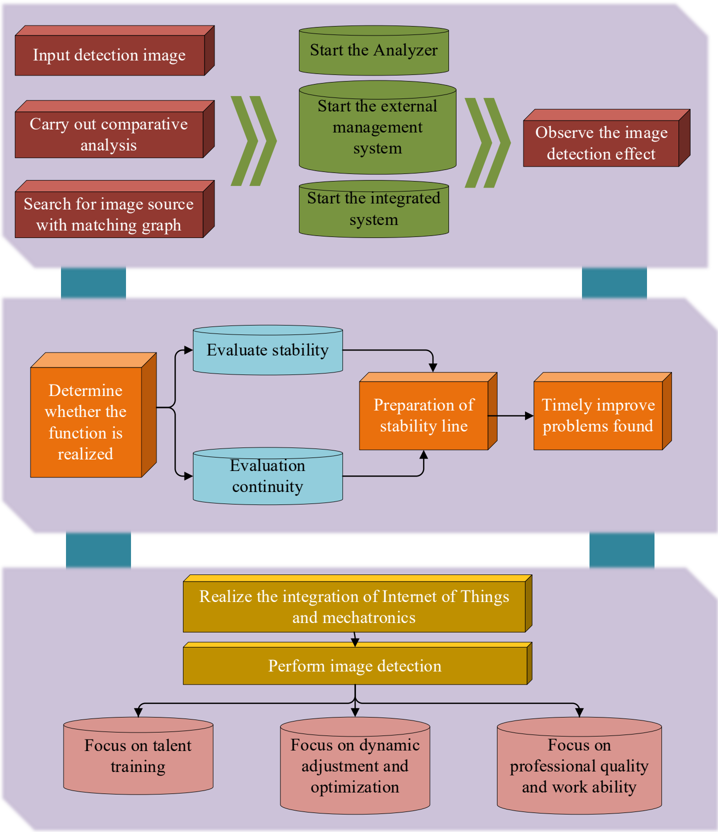

Figure 8: System simulation and debugging architecture diagram

In the process of system implementation, it is also necessary to take into account the rapid development of Internet technology and artificial intelligence technology in China in recent years, the constant changes of various technologies and the increasingly strict requirements for image detection. The overall image detection system should be dynamically adjusted and optimized according to the technological changes and updates, so that the system can meet the application requirements of keeping pace with the times.

4. Test of Construction Parameter Optimization Model

In order to train mechatronics and verify the accuracy of mechatronics system, the following experiments are conducted. 50 images of the cup mouth and 50 images of the cup body are collected respectively. Firstly, the images of the bottle mouth and the bottle body are manually interpreted by comparing with the actual empty bottle, and the conclusion of whether the quality is qualified or not is drawn.

Then, 15 images of the bottle mouth and 15 images of the bottle body are used as samples. The characteristics of bottle mouth and bottle body are extracted respectively, which can be used as the learning basis of mechatronics system. The learning rate of the network is set to 0.3, and the initial values of weights are set to random values between [0.2,0.5]. After artificial learning, the features of other images are extracted and discriminated by neural network. The result shows that the accuracy of the cup body is 95.5%, and the accuracy of the cup mouth is ninety-seven percent.

It shows that the combination of mechatronics and IoT technology has promoted the innovation and development of the AI industry to a certain extent, and is conducive to meeting the basic requirements of intelligent image recognition and detection environment. The original algorithm and the algorithm in this paper respectively calculate the following three kinds of evaluation indexes in the image, as shown in Figure 9.

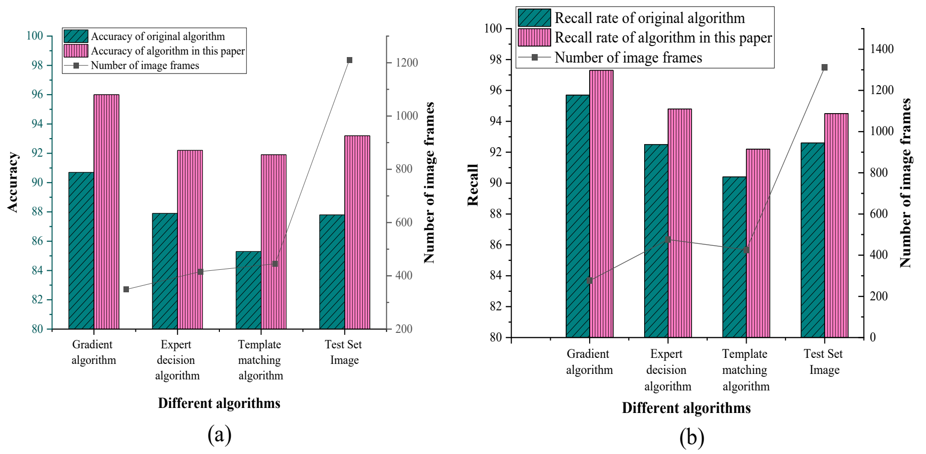

Figure 9: Comparison of image detection performance of different algorithms ((a) is the accuracy of image detection performance; (b) recall rate for image detection performance)

The figure shows that in the gradient algorithm, the accuracy rate is increased by 5.3%, the recall rate is increased by 1.6%, and the average recognition rate is increased by 4.6%; In the expert decision algorithm, the accuracy rate increased by 4.3%, the recall rate increased by 2.3% and the average recognition rate increased by 5.5%. In the template matching algorithm, the accuracy rate increases by 6.6%, the recall rate increases by 1.8% and the average recognition rate increases by 6.4%. In the whole test set images, the accuracy rate increased by 5.4%, the recall rate increased by 1.9% and the average recognition rate increased by 5.5%.

Compared with the original algorithm, the performance of this algorithm has been improved to a certain extent, which shows that this algorithm has better detection effect and higher accuracy.

For multiple objects, the algorithm can detect them well, effectively reducing the missed detection rate. In addition, the original algorithm completely suppresses the adjacent areas, which affects the final detection performance. The algorithm in this paper solves this limitation well.

The algorithm in this paper is compared with the algorithms in other literature in terms of accuracy, recall and average recognition rate of target detection. The test results are shown in Figure 10.

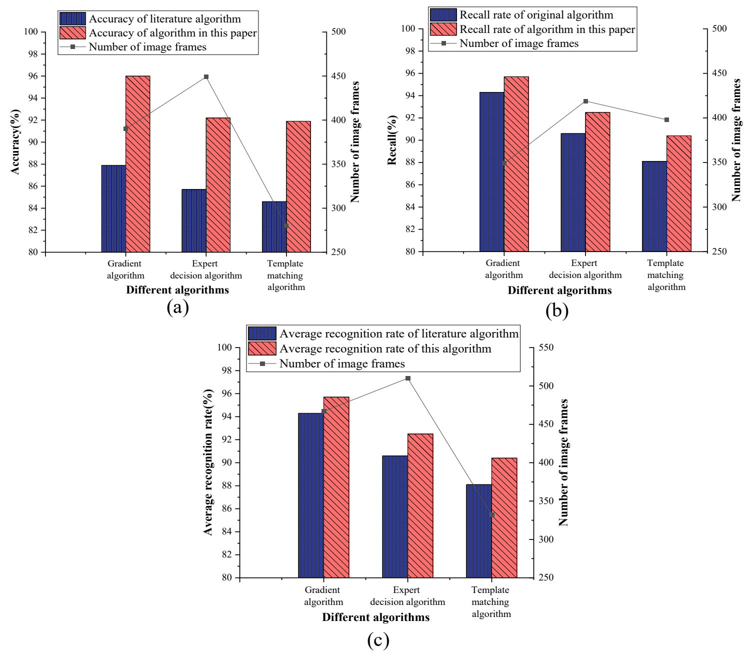

Figure 10: Comparison of image target detection performance ((a) image detection accuracy; (b) recall rate; (c) average recognition rate)

Among the images of the three algorithms, the highest accuracy rate of literature is 87.9% and 90.7% respectively, the highest accuracy rate of this algorithm is 96.0%, which is increased by 8.1%, the highest recall rate of literature is 94.3% and 95.7% respectively, and the highest recall rate of this algorithm is 97.3%, which is increased by 3%. The highest average recognition rate of literature is 90.2% and 91.3% respectively, and the highest average recognition rate of this algorithm is 96.2%, which is increased by 6.0%.

According to the analysis of the data in the figure, the algorithm in this paper has improved in three aspects: accuracy, recall and average recognition rate.

This paper compares the feature matching between dynamic images based on SVM and dynamic images based on mechatronics to calculate the matching accuracy of the two methods in the sequence dynamic images in this paper, as shown in Figure 11.

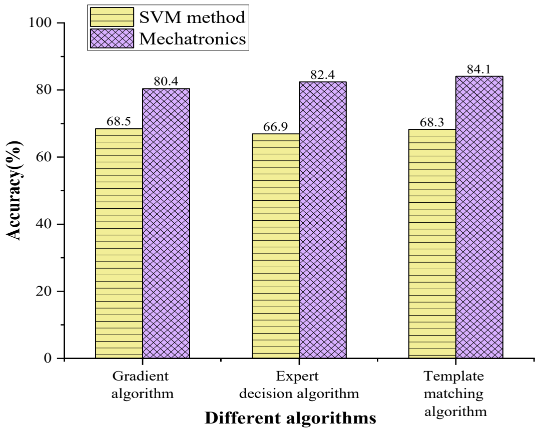

Figure 11: Comparison chart of matching performance

From the figure, the matching accuracy of the original SVM method is not high because the feature information data of the front and back frames, that is, the training set and the test set are not equal, and the accuracy rate in the expert decision algorithm is only 66.9%. The artificial intelligence model is used to improve it. Because this structure can recursively divide the parameter space towards the data axis, it can improve the accuracy of the final high retrieval rate. The highest accuracy rate in the template matching algorithm is 84.1%, which is 14.4% higher on average among the three algorithms.

The data set is prepared according to the format required by SVM. The usual data set format is a one-dimensional vector.

In order to calculate the efficiency, the obtained feature vector is normalized to the (-1,1) interval. Like the neural network, the normalization of the feature vector is very important for the SVM classifier. The main advantage of this is that it can avoid the larger values in the attributes from submerging the smaller feature values. Another advantage is that it solves the problem of excessive calculation. Because the value of the kernel function usually depends on the inner product of the feature vector, too large feature values may lead to computer variables that cannot be represented. After feature normalization, the data results are shown in Figure 12.

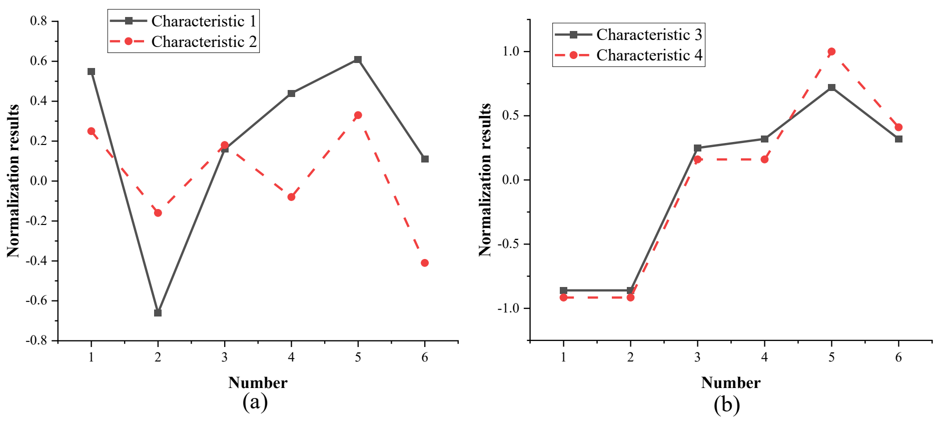

Figure 12: The result of sample normalization ((a) the normalization result of feature 1 and feature 2; (b) the normalized results of feature 3 and feature 4)

The next step is to learn and practice, and the results are kept in the pattern file. When training, the type of SVM and the type of kernel function should be specified, and the learned pattern file can be obtained.

The pattern file after training is the result of learning, and it is the pattern file that determines which category a feature vector belongs to. The comparison results of the recognition effects of the scene images by the IoT technology and neural network and SVM algorithm are shown in Figure 13.

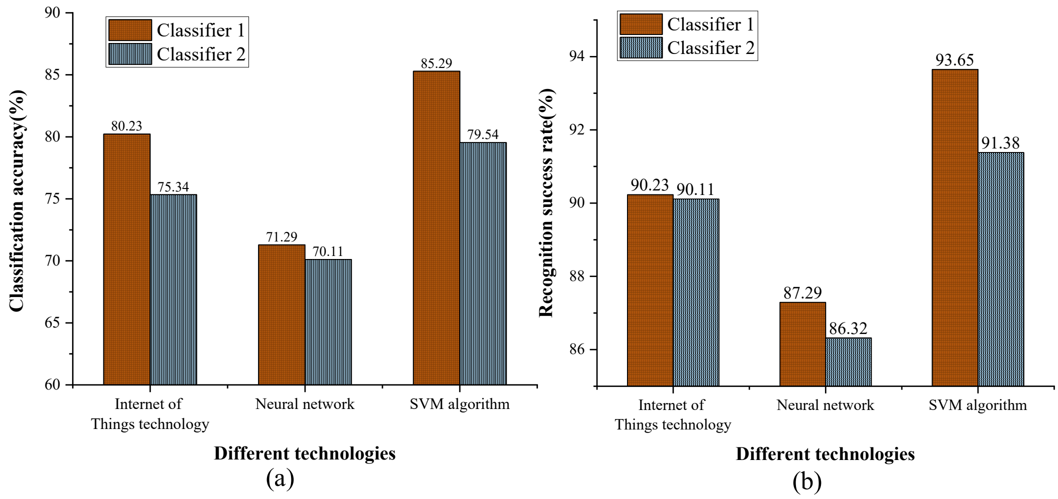

Figure 13: Comparison results of recognition effects of scene images ((a) the recognition accuracy of the classifier; (b) the recognition success rate of the classifier)

The classification target value of the data minus the original target value is the absolute error of the classification. The above data shows that the absolute error of the classification target value is very small. After error processing, it can basically meet the recognition rate of 90 %, which can meet the actual needs. In order to compare with other algorithms, the neural network method is also used to compare and calculate. The data show that the absolute error value of neural network recognition is greater than that of SVM recognition, but its absolute value is also very small. After processing, it can also meet the recognition accuracy requirements.

5. Conclusions

This paper simulates the picture analysis, acquisition, and integration processes using mechatronics, IoT technology, and AI. It then presents a set of automatic recognition processing methods based on the design of SVM classification methods and the optimization of various algorithms. The feature vectors of the target area are then obtained after analysis and calculation using the SVM classifier, which is based on AI and neural network technology. These are the conclusions: (1) The fusion of mechatronics and IoT technology has helped the AI industry develop and innovate in various ways, which is helpful for satisfying the fundamental criteria of an environment for intelligent picture recognition and detection. (2) An intelligent simulation model for image detection with recognition accuracy of over 95% and features of high speed, high precision, and high automation has raised the bar for detection and intelligent machine vision technology in China. (3) After SVM testing, the classification target value's absolute error is very low, and after handling errors, a recognition rate of 90% may be achieved, meeting the demands for detection accuracy. The paper's disadvantage is that the detection algorithm's improvement focus is mostly on improving the capacity to detect obscured and overlapped items in images, but the detection performance of objects with murky picture contours and virtual shadows is subpar and requires additional study. Second, this paper focuses on image detection and matching in a single indoor scene. However, in more complicated scenes or chaotic situations, different types of targets are frequently mixed together, necessitating the need to identify and distinguish the targets in the scene. This aspect of the paper's content requires additional research and development.

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