STRATEGIES FOR IMPROVING THE DETECTION ACCURACY OF COMPUTERIZED MACHINE VISION CONSIDERING SPATIAL APPLICATIONS

Mincheng Piao*

- School of Computer Science of South-Central Minzu University, Wuhan, Hubei, 430074, China
- E-mail: piaomincheng@163.com

Meng Song

- School of Textile Science and Engineering of Wuhan Textile University, Wuhan, Hubei, 430200, China

Reception: 27 December 2023 | **Acceptance**: 24 January 2024 | **Publication**: 13 February 2024

Suggested citation:

Piao, M. and Song, M. (2024). **Strategies for improving the detection accuracy of computerized machine vision considering spatial applications**. *3C TIC. Cuadernos de desarrollo aplicados a las TIC, 13*(1), 76-94. https://doi.org/10.17993/3ctic.2024.131.76-94

ABSTRACT

In this paper, strategies in image preprocessing, hardware composition and detection methods are considered to improve computerized machine vision detection accuracy. First, image preprocessing and image enhancement are performed to improve the quality of the input image. Second, the hardware composition of the computer vision online inspection system is optimized by focusing on the light source selection and the performance of the image acquisition card in spatial applications. Combined with spatial application calculations, methods such as frequency domain method and Canny operator are used in order to improve the accuracy of machine vision detection. Finally, in the same test environment, the machine vision detection requires only 400MB and the detection accuracy ranges from 85.13% to 99.42%. With these comprehensive strategies, this paper provides a comprehensive and effective approach for computerized machine vision detection in spatial applications to improve detection accuracy and meet demanding application scenarios.

KEYWORDS

Image preprocessing; machine vision detection; hardware composition; frequency domain method; Canny operator

https://doi.org/10.17993/3ctic.2024.131.76-94

INDEX

https://doi.org/10.17993/3ctic.2024.131.76-94

1. INTRODUCTION

With the continuous progress of science and technology, computerized testing has developed rapidly, and the categories of computerized products are getting richer and richer, and the quality requirements for testing are getting higher and higher [1]. In machine management, the accuracy of the detection results is very critical [2]. Due to the influence of factors such as the failure of traditional detection equipment or operational errors in the detection process, the detection results have some errors [3]. The spatial environment has a serious impact on the results of computer testing, which not only causes economic benefit loss to the relevant enterprises, but also seriously affects the competition of the computer industry in the international arena [4]. At present, most of the computer testing relies on manual to detect and identify the fault point, however, the manual detection method has limited detection accuracy, detection speed is not high, the test results are easy to be affected by the subjective factors of manual, high labor costs [5]. Thus making the computer in operation there are potential quality hazards, which directly leads to the inefficiency of machine vision inspection, reducing the competitiveness of the computer industry, and ultimately may face the end of being eliminated from the market [6]. Therefore, how to carry out rapid and effective detection of computers to improve the detection accuracy is an urgent problem to be solved.

Although the existing computerized detection methods have achieved some success in various aspects, the influence of spatial environmental factors has not been considered. In this paper, the input image is optimized and its quality is enhanced through computer image preprocessing. Various components required to construct an online workpiece inspection system for computer vision, especially in spatial applications, light sources adapted to the spatial environment are considered to improve the clarity and contrast of the workpiece. In the frequency-domain method, the fluctuation characteristics specific to spatial applications are emphasized to better adapt to the spatial environment. The application of Canny operator further improves the sensitivity to edges and enhances the detection effect. The accuracy enhancement strategy includes optimizing the preprocessing process, choosing a hardware composition adapted to the spatial environment, adjusting the light source, and improving the spatial application calculation method.

2. LITERATURE REVIEW

Sangirardi, M et al. showed that detecting the onset of structural damage and its gradual evolution is essential for the assessment and maintenance of the built environment, and in their study presented the application of a computer vision based structural health monitoring methodology for shaking table investigations [7]. Liu, G et al. addressed the fact that traffic management systems can capture large amounts of video data and use video processing techniques to detect and monitor traffic accidents. The collected data is traditionally forwarded to a traffic management center for in-depth analysis, which can exacerbate the problem of network paths to the traffic

 https://doi.org/10.17993/3ctic.2024.131.76-94

management center. In the study, it is pointed out to utilize edge computing to equip edge nodes close to the camera with computational resources [8]. Wu, Z et al. proposed a computer vision based weed detection method, which explores the solution to the weed detection problem in terms of both traditional image processing and deep learning. Various weed detection methods in recent years were summarized, the advantages and disadvantages were analyzed, and relevant plant leaves, weed datasets, and weeding machines were introduced [9]. Li, Z et al. proposed a static software defect detection system design based on big data technology, which aimed to optimize the design of the traditional system. By predicting potentially defective program modules, the system design improves the hardware and software structure and achieves efficient allocation of testing resources, thus improving the quality of software products [10]. Lee, H et al. proposed a feature descriptor-based computer vision method for detecting rail corrugations to achieve automatic differentiation between corrugated and normal surfaces. The authors extracted seven features and combined them into a feature vector for constructing a support vector machine. The results show that the method is more effective than References in the recognition of corrugated images [11].

Qiao, W et al. redesigned the structure of DenseNet and improved it by adding the Expected Maximum Attention (EMA) module after the last pooling layer. The EMA module plays a significant role in bridge damage feature extraction. In addition, a loss function considering pixel connectivity is used in the paper, which shows good results in reducing the breakpoints of fracture prediction as well as improving the accuracy of fracture prediction, and the application in computer vision inspection helps to improve the accuracy and precision of bridge damage [12]. Shi, H et al. worked on the quality of steel wire ropes in lifting equipment, and used an industrial video camera to acquire infrared images of steel wire ropes. The wire rope contour was extracted by Canny edge detection and the diameter of the wire rope was corrected by one-dimensional measurements and directional fitting. The combination of computer vision inspection is expected to play an important role in improving the accuracy and efficiency of wire rope quality inspection [13]. Ljubovic, V et al. introduced a novel approach to source code repository construction by storing each editing event in the program source as a new commit, resulting in an ultra-fine-grained source code repository. Machine learning techniques were applied to detect suspicious behavior, thus significantly improving the performance of traditional plagiarism detection tools [14]. Roy, S. D et al. used a variety of feature extractors, including texture features such as SIFT, SURF, and ORB, as well as statistical features such as Haralick texture features, to form a dataset containing 782 features. Then, by stacking these features using multiple machine learning classifiers and using Pearson's correlation coefficient for feature selection, a dataset containing four features was finally generated for classification. This study combined the advantages of computer vision and machine learning to achieve good performance in feature extraction and classification tasks [15]. Huang, H et al. utilized a combination of computer vision, machine learning, and edge computing to provide an efficient and accurate solution for the citrus detection task. To

https://doi.org/10.17993/3ctic.2024.131.76-94

facilitate the deployment of the model, a pruning approach was used to reduce the computational effort and parameters of the model [16].

3. COMPUTERIZED IMAGE PREPROCESSING

3.1. PRETREATMENT PROCESS

Considering the conditions of spatial factors, when computer detection is carried out with the help of computer vision technology, it is necessary to pay attention to the image pre-processing technology, which is closely related to the subsequent image processing and analysis [17]. Figure 1 shows the image preprocessing process, to first extract the relevant information data of the image, and then effectively integrate the image preprocessing technology and template technology, thus reducing the technical difficulty of the actual monitoring. Based on the actual technical requirements, during the implementation of image pre-processing, the efficiency of the use of images should be improved. After completing the pre-visualization process, carry out the two-dimensional numerical execution of the marginalization extraction operation, effectively input the whole frame of image data, extract the image edges, and clarify the key nodes of the processing technology, so as to make it meet the stability requirements. In addition, in the course of practice, the previsualization processing should be performed several times.

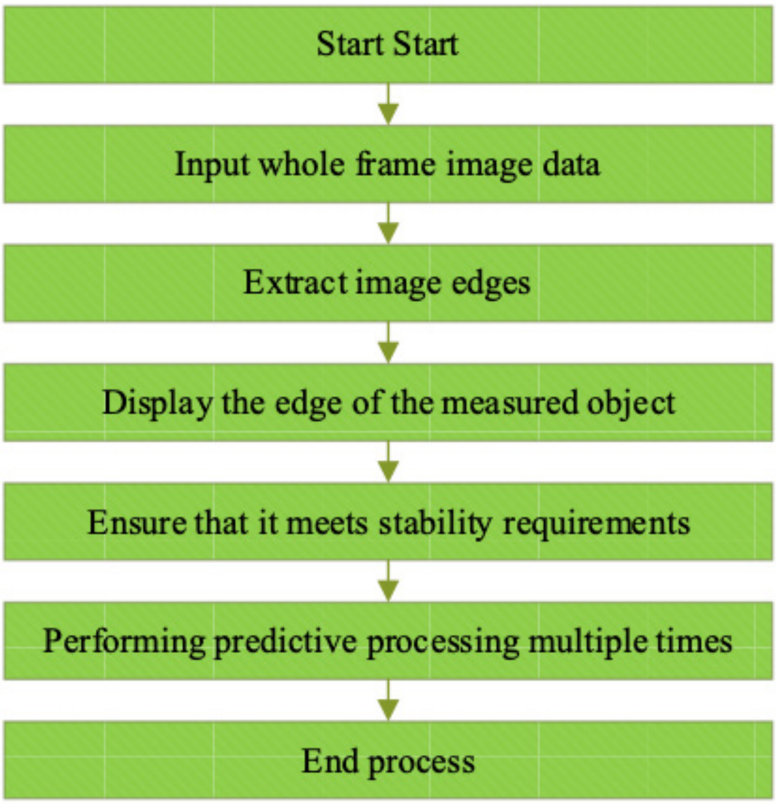

Figure 1. Image preprocessing process

https://doi.org/10.17993/3ctic.2024.131.76-94

3.2. IMAGE ENHANCEMENT

Image enhancement techniques are spatial domain processing method and frequency domain processing method, the spatial domain processing method mainly focuses on direct operations on image pixels in the spatial domain [18]. In this paper image enhancement technique using spatial domain method is described by the following equation:

$$g(x,y) = f(x,y) \cdot h(x,y) \tag{1}$$

Where $f(x,y)$ is the image before processing, $g(x,y)$ denotes the image after processing and $h(x,y)$ is the spatial operation function. The frequency domain processing method of image enhancement is to process the transformed values of an image in some transform domain, usually the frequency domain, by performing some kind of operation on the transformed values of the image and then transforming back to the spatial domain. It is an indirect processing method with the following process:

1. First input the original image $f(x,y)$ for positive transformation.
2. After the positive transformation, $F(\mu,v)$ is obtained, which is corrected to obtain $H(\mu,v)$.
3. After transforming $G(\mu,v)$, inverse transform is performed and the enhanced image $g(x,y)$ is output.

The above mathematical description is as follows:

$$F(\mu,v) = \mathrm{T}\{f(x,y)\} \tag{2}$$

$$G(\mu,v) = H(\mu,v) \cdot F(\mu,v) \tag{3}$$

$$g(x,y) = T^{-1}\{G(\mu,v)\} \tag{4}$$

Where $T\{\}$ denotes some frequency domain positive transform, $T^{-1}\{\}$ denotes the inverse transform of that frequency domain transform $F(\mu,v)$ is the result of the $g(x,y)$ frequency domain positive transform of the original image, $H(\mu,v)$ is the number of positives in the frequency domain $G(\mu,v)$ is the result of the correction, and $g(x,y)$ is the result of the $G(\mu,v)$ inverse transform, which is the enhanced image.

https://doi.org/10.17993/3ctic.2024.131.76-94

4. HARDWARE COMPOSITION OF COMPUTERIZED MACHINE VISION ONLINE INSPECTION SYSTEM

4.1. COMPOSITION OF COMPUTER VISION ONLINE WORKPIECE INSPECTION SYSTEM

Computer vision online workpiece inspection system belongs to the application of computer vision system in detecting parts, and the system is required to be able to accurately observe the target and make effective decisions on which parts can pass the inspection and which need to be discarded [19-20]. The computer vision online workpiece inspection system is shown in Fig. 2, which should include several parts such as light source, optical system, CCD camera, image acquisition card, image processing module and fast and accurate actuator.

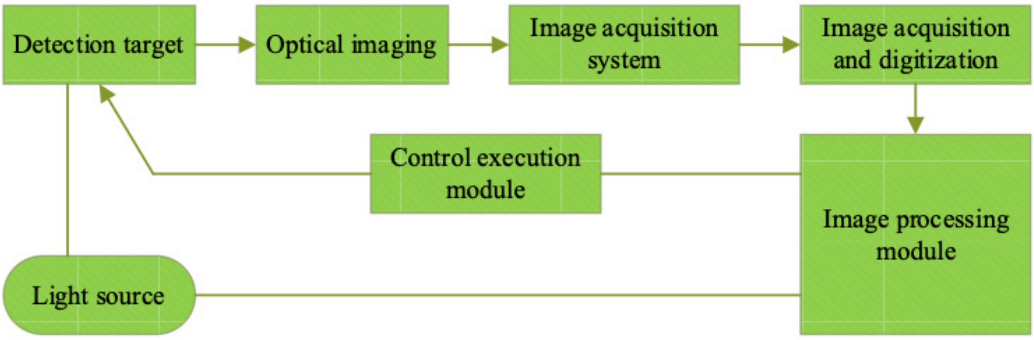

Figure 2. Structure of computer vision on-line workpiece inspection system

4.2. DETECTION LIGHT SOURCE SELECTION CONSIDERING SPATIAL APPLICATIONS

In computer vision application systems, a good light source and illumination scheme is often the key to the success or failure of the whole system, and plays a very important role [21]. The cooperation of light source and illumination scheme should highlight the amount of object features as much as possible, in the part of the object that needs to be detected, and those unimportant parts should be as much as possible to produce a clear difference between the parts to increase the contrast. It should also ensure that the overall brightness is sufficient, and changes in the position of the object should not affect the quality of the image. Transmitted light and reflected light are generally used in vision inspection applications. For the reflected light situation should fully consider the relative position of the light source and optical lens, the texture of the object surface, the geometry of the object and other elements. The choice of light source equipment must be consistent with the desired geometry, illumination brightness, uniformity, the spectral characteristics of the light emitted must also meet the actual requirements, but also consider the luminous efficiency and service life of the light source. In short, different forms of light sources should be

https://doi.org/10.17993/3ctic.2024.131.76-94

selected and designed according to the actual task in order to achieve the best state of object imaging.

Table 1 shows the classification of commonly used light sources. LED light source has the advantages of free shape, long service life, fast response speed, as well as free choice of color and low comprehensive running cost, which makes it the most suitable dedicated light source for computer vision inspection system applications.

Table 1. Classification of common light sources

	Complex design	Service life	Temperature effect	Degree of stability	Costs	Luminance
Fuorescent tube	Lower	General	General	Differ from	Lower	Lower
Halogen lamp + fiber optic conduit	General	Differ from	Differ from	General	Above average	Above average
LED light source	Above average	Good	Lower	Good	General	General

Space due to some of the measured object surface reflection phenomenon is very serious, you can use diffuse reflection light illumination method for illumination. Both to avoid the appearance of reflections, but also to facilitate the subsequent various image processing algorithms. Lambert's law states that the effect of diffuse reflection is related to the orientation of the surface with respect to the light source, that is:

$$I_d = I_p \cdot K_d \cdot \cos\theta \quad (5)$$

Where I_d is the brightness of a point on a visible surface caused by diffuse reflection. I_p is the brightness caused by incident light from a point source. K_d is the diffuse reflection coefficient, which takes values between 0 and 1 and varies with the material of the object. Is the angle of incidence between the visible surface in the direction normal to N and the point light source in the direction L, which should be between 0° and 90°.

4.3. IMAGE ACQUISITION CARD

At present, there are many types of image acquisition cards, according to different classification methods, there are black and white image and color image acquisition cards, analog and digital signal acquisition cards, composite signals and RGB component signal input acquisition cards. Figure 3 for the image acquisition card structure framework, image acquisition card generally has the following functional modules:

1. Image signal reception and A/D conversion module, responsible for image signal amplification and digitization.

https://doi.org/10.17993/3ctic.2024.131.76-94

2. Camera control input and output interfaces, mainly responsible for coordinating the camera for synchronization or to achieve asynchronous reset photo, timed photo and so on.

3. Bus interface, responsible for high-speed output of digital data through the computer's internal bus, generally PCI interface, the transmission rate can be as high as 130Mbps, fully capable of high-precision image transmission in real time, and occupies less CPU time.

4. Display module, responsible for high-quality image display in real time.

5. Communication interface, responsible for communication.

When selecting the image acquisition card, the main consideration should be the functional requirements of the system, the image acquisition accuracy and the matching of the output signal with the camera and other factors.

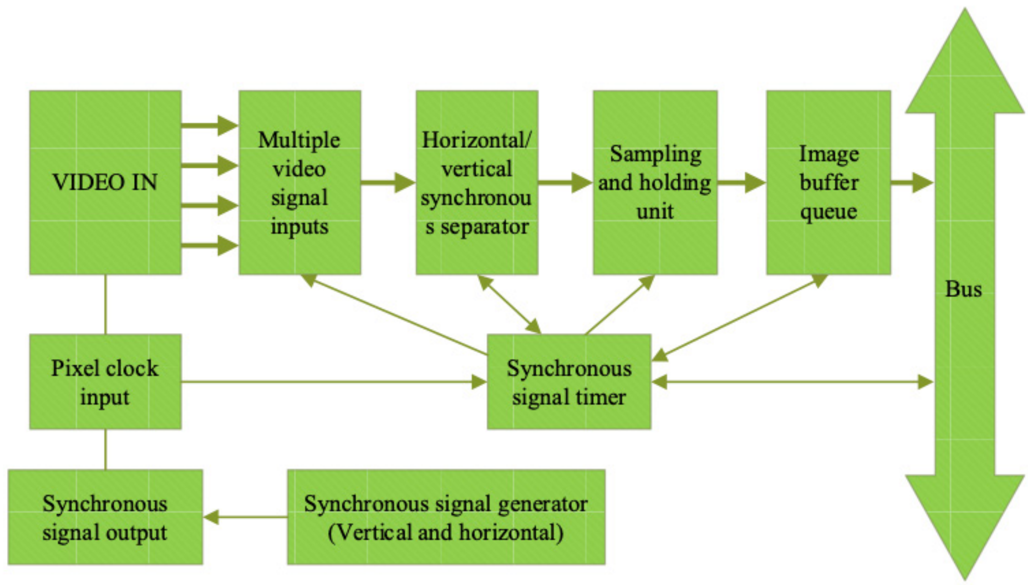

Figure 3. Acquisition card structure framework

5. CALCULATION PROCESS OF MACHINE VISION INSPECTION METHOD

5.1. IMAGE SEGMENTATION

In computers, including the four primary colors cyan, magenta, yellow and black, which are used in the usual space, the accuracy detection algorithm is based on black in order to calculate the distance between each monochrome color to the black baseline [22]. Therefore, it is necessary to convert the acquired RGB mode image to CMYK model, and the conversion is shown in Eq:

https://doi.org/10.17993/3ctic.2024.131.76-94

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{6}$$

In the RGB to CMYK conversion formula, the black color separation (K) is calculated from red (R), green (G) and blue (B). Specifically, the value of the black color separation is:

$$K = \min(C, M, Y) \tag{7}$$

5.2. SPATIAL FILTERING CALCULATIONS

Spatial filters can be subdivided into linear and nonlinear filters depending on whether the processing is linear in the image system [23]. A linear spatial filter is at any point (x, y) in the image, and the sum of the product of the coefficients of this type of filter and the corresponding pixel values of the region scanned by the mask is the filter response $g(x, y)$ at that point.

Nonlinear spatial filtering is the same as linear spatial filtering in that it scans the image to be processed with a pre-defined mask, but it cannot be used directly with the filter coefficients, and the product and sum of the corresponding pixel values of the area city scanned by the mask to obtain the response value at this point. Nonlinear spatial filters include median filters, statistical ordering filters, and so on. The median filter can protect the edge pixel points of the image, and has a low degree of smoothing and blurring compared with the linear spatial filter of the same size. The nonlinear spatial filter filtering mechanism is to replace the pixel value at the origin with the maximum value pixel, or the minimum value pixel after sorting the pixel points in the neighborhood.

5.2.1. FREQUENCY DOMAIN METHOD

An ideal low-pass filter will pass all frequencies without attenuation in a circle centered at the origin and radiused at D_0. The functional expression is given in equation (8):

$$H(u, v) = \begin{cases} 1 & D(u, v) \le D_0 \\ 0 & D(u, v) > D_0 \end{cases} \tag{8}$$

where D_0 is the cutoff frequency, i.e:

$$D(u, v) = \left[(u - P/2)^2 + (v - Q/2)^2\right]^{1/2} \tag{9}$$

Where P, Q is the size of the image to fill the image with complementary zeros.

5.2.2. ANNY OPERATORS

Canny operator algorithm has low error rate, no pseudo response and can detect real edges when dealing with edge detection of images. Firstly, the smoothing filter of the image to be processed is carried out, here the smoothing filter is a Gaussian filter and the gradient is calculated, and the intensity and direction of the edge pixel points are estimated using the obtained gradient size and direction. Then the non-maximum value suppression method is used for edge refinement, and the edge direction of the center point of the neighborhood is quantized into horizontal, vertical, and two diagonal directions, and the image edge direction is determined by the edge normal direction. Finally, to reduce the detection of pseudo edge points, the sub-detection of the true edge of the image, using the lagged intrusion value method, that is, in the range of Min value to take out the high value and low Que value, and set the ratio of 2:1 or 3:1.

The image to be processed is $f_s(x,y)$ and the Gaussian function is $G(x,y)$, then it can be expressed as:

$$G(x,y) = e^{-\frac{x^2+y^2}{2\delta^2}} \tag{10}$$

Where δ is the standard deviation.

After performing Gaussian filtering the image is $f_s(x,y)$ which can be expressed as:

$$f_s(x,y) = G(x,y) * f(x,y) \tag{11}$$

5.3. DETECTION PROCESS

Based on the above, the software detection process is shown in Fig. 2, where the user can specify the model to be used in image processing by selecting the model, involving different algorithms or techniques. Subsequently, in the image enhancement stage, the visual quality of the image can be improved to make it more suitable for analysis for spatial applications. Next, in the image feature extraction stage, meaningful features are involved to be extracted from the image that are essential for improving the accuracy of computerized machine vision detection for spatial applications. In the import modeling computation step, a machine learning model is introduced for image processing. In addition, the user can ensure effective communication between the image processing device and the computer by connecting the computer. For the wide only image set to be detected, it may refer to a wide set of images prepared to be detected. Subsequently, image acquisition and image acquisition involves acquiring image data by means of a camera, a scanner, and the like. In a filtering and noise reduction step, noise is removed from the image by using filtering techniques to improve the image quality. Next, image segmentation and edge extraction involves segmenting the image into different regions and detecting edges of objects in the image. The image preprocessing stage may then

https://doi.org/10.17993/3ctic.2024.131.76-94

include further enhancement and preparation of the image to ensure adaptation to subsequent analysis needs. Upon completion of the image processing, the user may be given the option to display the data to view the processed image or data and store it for future reference by saving the data. Finally, an exit option is used to end the image processing program or system. The entire process also includes a computerized accuracy check, which is used to assess the accuracy of the computer algorithms during processing.

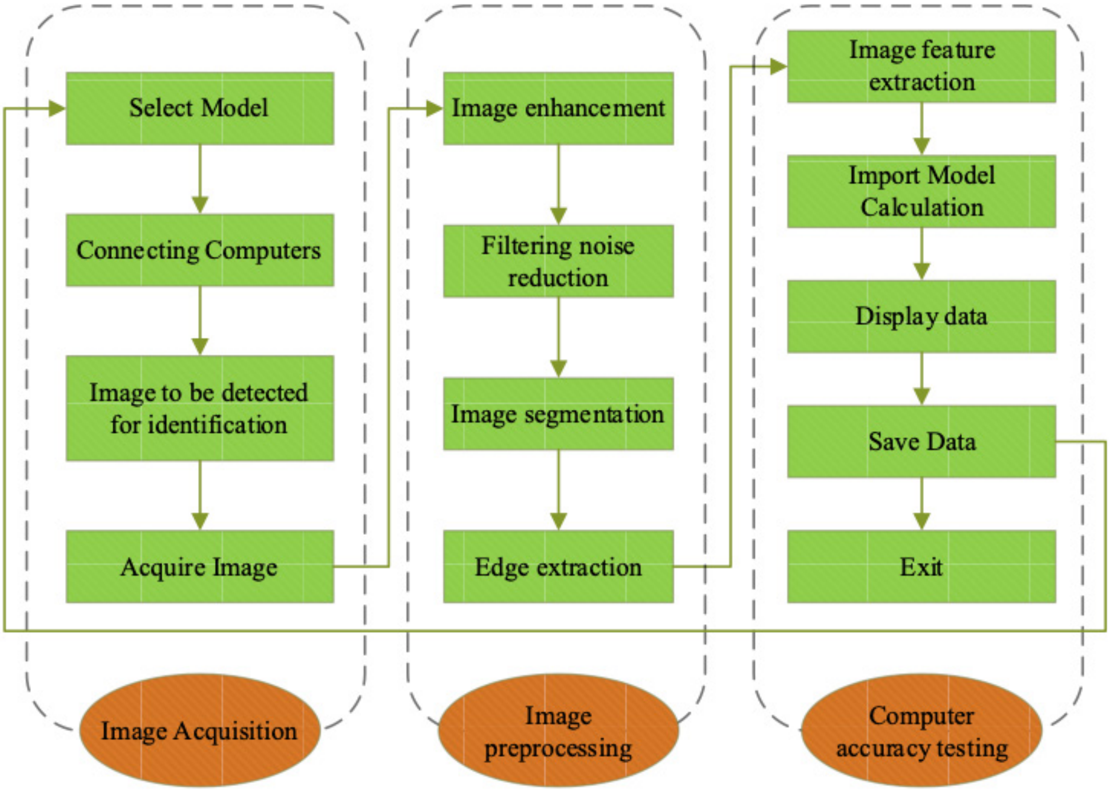

Figure 4. Software testing process

6. DETECTION ACCURACY IMPROVEMENT STRATEGY ANALYSIS

6.1. DETECTION ERRORS

In order to evaluate the performance of the proposed machine vision inspection enhancement strategy on different inspection samples, the variation of the detection error is first analyzed and Table 2 shows the variation of the detection error. The detection error varies between samples, but generally stays at a low level. The error ranges from 1.4% to 3.4%, which indicates that the proposed strategy can achieve accurate detection in most cases. There are some differences between the actual data and the test data, and the errors are mainly due to the deviation between these two. However, this deviation is relatively small in most cases. In summary, the proposed strategy for improving the accuracy of machine vision detection shows high

https://doi.org/10.17993/3ctic.2024.131.76-94

accuracy under multiple detection samples, and the error is kept within a reasonable range, which helps to improve the performance of computerized machine vision in spatial applications.

Table 2. Detection errors

Test sample	Actual data	Test data	Error
10	102.5	100.2	2.3
20	98.7	97.1	1.6
30	115.2	118.6	3.4
40	92.8	94.3	1.5
50	105.6	103.8	1.8
60	99.3	97.9	1.4
70	110.7	112.2	1.5
80	97.6	99.0	1.4
90	103.8	102.2	1.6
100	112.1	110.5	1.6

6.2. COMPARATIVE VALIDATION

In order to examine the accuracy of computerized machine vision data detection in spatial application scenarios, four different methods are compared, namely the proposed strategy, deep learning, artificial intelligence, and virtual reality. The performance of these methods in dealing with complex spatial data is evaluated and compared by analyzing 20 different detections. Figure 5 shows a comparison of the detection accuracy of the different methods, and the accuracy of the proposed computerized machine data detection for considering spatial applications ranges from 85.13% to 99.42%, which shows an extremely high detection accuracy. In particular, 99.42 is achieved in the number of detections 8, and on 97.54% for the number of detections at 7. The proposed strategy demonstrates significant high accuracy. The accuracy of deep learning ranges from 62.84% to 89.01%. Deep learning performed poorly on most data points compared to the proposed strategy, but reached 89.01% at 15 times. As well as performing better on 16 times at 88.99%. The accuracy of Artificial Intelligence ranges from 60.26% to 89.17%. Similar to Deep Learning, Artificial Intelligence lagged behind the proposed strategy on most data points, but had a high performance on 89.17% at the 3rd time and 87.24% at the 12th time. The accuracy of Virtual Reality ranges from 50.97% to 79.84%, which is the lowest of the four methods. This indicates that virtual reality faces some challenges in terms of detection accuracy in cases where spatial applications are considered.

https://doi.org/10.17993/3ctic.2024.131.76-94

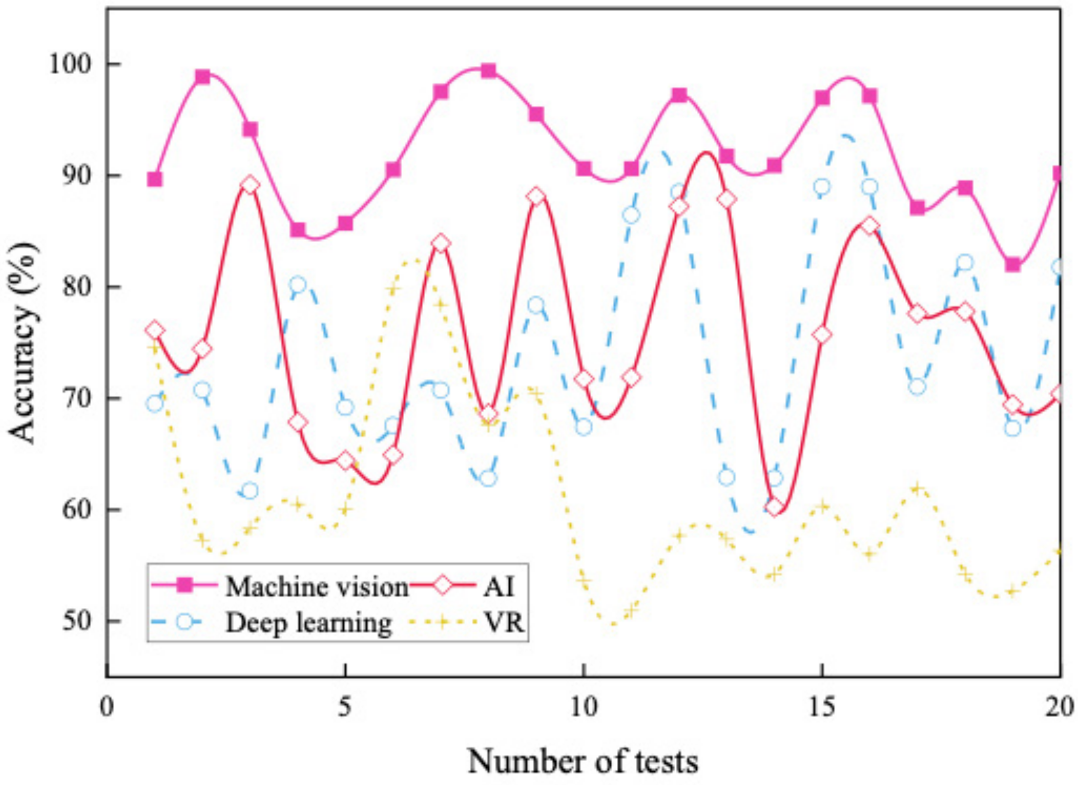

Figure 5. Comparison of detection accuracy

6.3. ALGORITHM PERFORMANCE VALIDATION

In this paper, a series of identical run time points, from 1 to 10 seconds, were chosen to ensure a fair comparison. The computerized machine vision detection algorithm and the traditional AI method were run separately and the CPU utilization at each time point was recorded. Figure 6 shows the results of the algorithm performance test, where the traditional AI method typically has higher resource consumption than the machine vision detection algorithm for the same run time. For example, the traditional AI method consumes 500 MB of memory in 10 seconds, while the machine vision detection only requires 400 MB. Secondly, the traditional AI method also typically exhibits higher CPU utilization. The resource consumption of both methods tends to increase linearly as the runtime increases, but the traditional AI method increases at a faster rate. Within 10 seconds, the CPU utilization of the traditional AI method reaches 50%, while the machine vision detection algorithm uses only 40%. In addition to this, the CPU utilization of both methods also shows a linear growth trend, but the CPU utilization of machine vision detection grows at a slower rate. For computerized machine vision inspection accuracy improvement strategies for spatial applications, there is a need to weigh performance requirements and resource availability. If computing resources are limited, algorithms or hardware need to be optimized to reduce the growth rate of CPU usage to ensure system stability and performance.

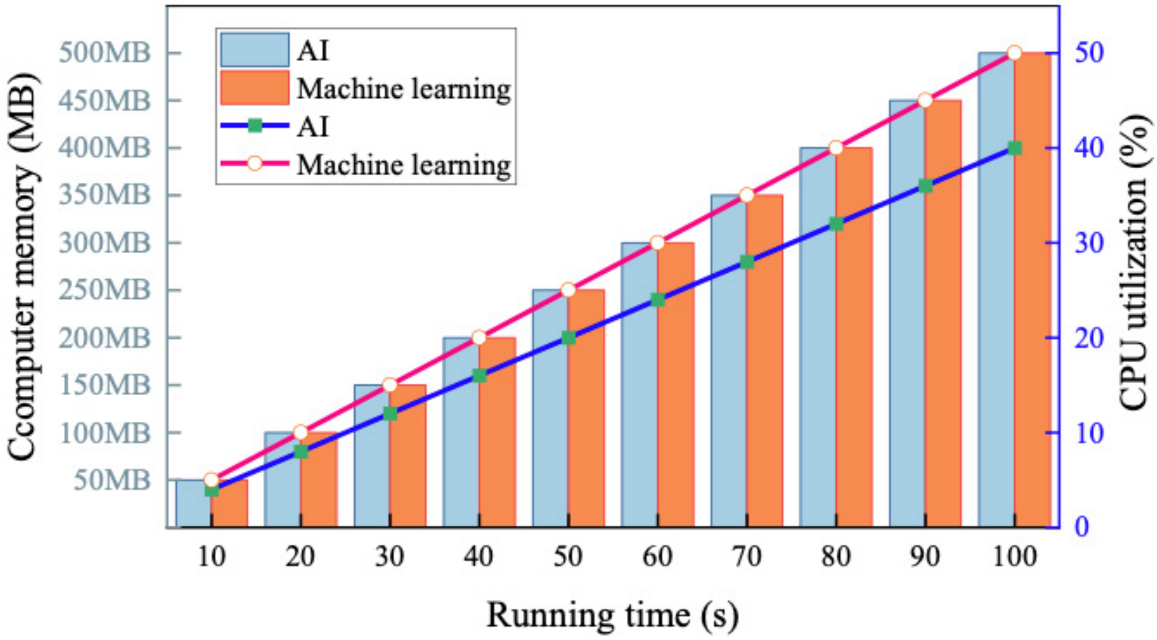

Figure 6. Algorithm performance verification

6.4. COMPARISON OF THE AMOUNT OF DETECTION ERRORS

In spatial applications, the performance of computerized machine vision detection systems is critical and is directly related to the successful execution of the task and the safety of the system. By comparing the detection quantities of machine learning, artificial intelligence and virtual reality on different error types, key performance bottlenecks can be identified and effective strategies can be developed for improving the detection accuracy of the system. Table 3 shows the comparison of the amount of errors detected by different methods, with machine learning detecting 25, AI 16, and virtual reality 22. Robotic arm damage, as a high-frequency error type, requires focusing on optimizing the algorithm, especially in machine learning for performance improvement. For this problem, the introduction of more sophisticated feature extraction and fusion methods can be considered to enhance the accurate detection of the state of the robotic arm. Inclement weather or poor lighting conditions are a prominent challenge, corresponding to a number of detections of 23, 15, and 20, respectively. In this regard, adaptation to inclement weather and lighting conditions should be optimized to ensure the reliability of the system in complex environments. By taking these error types into account, a comprehensive enhancement strategy including improving algorithm robustness, enhancing adaptation to specific environments, and optimizing the quality of simulation of computer environments is developed to improve the accuracy of computerized machine vision detection for spatial applications.

https://doi.org/10.17993/3ctic.2024.131.76-94

Table 3. Comparison of error amount detected by different methods

Error type	Detection quantity comparison		
	Machine learning	Artificial intelligence	Virtual reality
	19	8	12
Packet loss or error in data transmission	22	12	18
Low battery	8	4	6
Mechanical arm failure	25	16	22
Image distortion or artifact	8	7	6
Positioning deviation	19	10	14
Algorithm execution error	11	6	9
Bad weather or poor light conditions	23	15	20
Dangerous object intrusion	6	2	4

7. CONCLUSION

The computerized machine vision inspection accuracy enhancement strategy considering spatial applications proposed in this paper provides a reliable inspection solution for spatial applications, and the conclusions are as follows:

1. The machine vision detection accuracy proposed in this paper for spatial applications ranges from 85.13% to 99.42% while maintaining a low error range of 1.4% to 3.4%. The proposed strategy performs better compared to deep learning and traditional AI.

2. In terms of resource consumption, the traditional AI method consumes 500MB of memory in 0 seconds, while machine vision detection only requires 400MB, making the machine vision detection algorithm more efficient.

3. By comparing the amount of detection errors, the number of machine learning detection is 25, artificial intelligence is 16, and virtual reality is 22. It reflects the reliability and efficiency of the proposed method, which provides a strong support for the development of machine vision detection systems in spatial applications.

In conclusion, it is proved that the proposed method is not only better than the traditional method in terms of accuracy, but also more efficient in terms of resource consumption, which provides a strong support for the development of machine vision detection systems in future space applications.

ABOUT THE AUTHORS

Mincheng Piao was born in Qingdao, Shandong, P.R. China, in 2002. He obtained a bachelor's degree from South-Central Minzu University in China. I am currently studying at the School of Computer Science, South-Central Minzu University. My main research direction is Information fusion technology and Computer Vision.

Meng Song was born in Heze, Shandong, P.R. China, in 2002. she obtained a bachelor's degree from Wuhan Textile University in China. I am currently studying at the School of Textile Science and Engineering, Wuhan Textile University. My main research direction is Textile Engineering and Material Analysis.

REFERENCES

(1) Sun, X., Liu, X., Yang, X., & Song, B. (2021). Computer-aided three-dimensional ceramic product design. *Computer-Aided Design and Applications, 19*(S3), 97-107.

(2) Huang, J., Guixiong, L., & He, B. (2021). Fast semantic segmentation method for machine vision inspection based on a fewer-parameters atrous convolution neural network. *PloS one, 16*(2), e0246093.

(3) Althubaiti, A., Elasha, F., & Teixeira, J. A. (2022). Fault diagnosis and health management of bearings in rotating equipment based on vibration analysis–a review. *Journal of Vibroengineering, 24*(1), 46-74.

(4) Yin, J., Huang, S., Lei, L., & Yao, J. (2021). Intelligent monitoring method of short-distance swimming physical function fatigue limit mobile calculation. *Wireless Communications and Mobile Computing, 2021*, 1-6.

(5) González-Gaspar, P., Macías-Carballo, M., Cadena-Mejía, T., Landa-Jiménez, M. A., Montes-González, F. M., López-Meraz, M. L., ... & Morgado-Valle, C. (2021). Analixity: An open source, low-cost analysis system for the elevated plus maze test, based on computer vision techniques. *Behavioural Processes, 193*, 104539.

(6) Talaat, M., Arafa, I., & Metwally, H. M. B. (2020). Advanced automation system for charging electric vehicles based on machine vision and finite element method. *IET Electric Power Applications, 14*(13), 2616-2623.

(7) Sangirardi, M., Altomare, V., De Santis, S., & de Felice, G. (2022). Detecting damage evolution of masonry structures through computer-vision-based monitoring methods. *Buildings, 12*(6), 831.

(8) Liu, G., Shi, H., Kiani, A., Khreishah, A., Lee, J., Ansari, N., ... & Yousef, M. M. (2021). Smart traffic monitoring system using computer vision and edge computing. *IEEE Transactions on Intelligent Transportation Systems, 23*(8), 12027-12038.

(9) Wu, Z., Chen, Y., Zhao, B., Kang, X., & Ding, Y. (2021). Review of weed detection methods based on computer vision. *Sensors, 21*(11), 3647.

 https://doi.org/10.17993/3ctic.2024.131.76-94

(10) Li, Z. , Zhu, J. , Arumugam, K. , Bhola, J. , & Neware, R. . (2022). Research on computer static software defect detection system based on big data technology. *Journal of Intelligent Systems, 31*, 1055 - 1064.

(11) Lee, H., Hong, J., Wendimagegn, T. W., & Lee, H. (2021). Rail corrugation detection and characterization using computer vision. *Sensors, 21*(24), 8335.

(12) Qiao, W., Ma, B., Liu, Q., Wu, X., & Li, G. (2021). Computer vision-based bridge damage detection using deep convolutional networks with expectation maximum attention module. *Sensors, 21*(3), 824.

(13) Shi, H., Zheng, L., Sun, S., Zhang, L., & Wang, L. (2020). Research on wire rope wear detection based on computer vision. *The Journal of Engineering, 2020*(13), 517-519.

(14) Ljubovic, V., & Pajic, E. (2020). Plagiarism detection in computer programming using feature extraction from ultra-fine-grained repositories. *IEEE Access, 8*, 96505-96514.

(15) Roy, S. D., Das, S., Kar, D., Schwenker, F., & Sarkar, R. (2021). Computer aided breast cancer detection using ensembling of texture and statistical image features. *Sensors, 21*(11), 3628.

(16) Huang, H., Huang, T., Li, Z., Lyu, S., & Hong, T. (2021). Design of citrus fruit detection system based on mobile platform and edge computer device. *Sensors, 22*(1), 59.

(17) Zhang, Y., Guo, Q., Zhang, Y., & Zhang, C. (2020). Fast and robust superpixel generation method. *IET Image Processing, 14*(17), 4543-4553.

(18) Lecca, M., Torresani, A., & Remondino, F. (2020). Comprehensive evaluation of image enhancement for unsupervised image description and matching. *IET Image Processing, 14*(16), 4329-4339.

(19) Nassu, B. T., Marchesi, B., Wagner, R., Gomes, V. B., Zarnicinski, V., & Lippmann, L. (2021). A computer vision system for monitoring disconnect switches in distribution substations. *IEEE Transactions on Power Delivery, 37*(2), 833-841.

(20) Hou, B., Zhang, C., & Yang, S. (2020). Computer vision tool-setting system of numerical control machine tool. *Sensors, 20*(18), 5302.

(21) Hsia, S. C. , Wang, S. H. , Cheng, W. C. , & Chang, C. Y. . (2021). Intelligent blowgun game scoring recognition system based on computer vision. *IEEE Access, PP*(99), 1-1.

(22) Duffy, T., Zachary, F., Hill, C., Sharp, A., Turner, S., Williams, J., ... & O'Brien, H. (2021). The Effect of Image Stack Resampling on Manual Segmentation of the Putamen from Magnetic Resonance Imaging. *The FASEB Journal, 35*.

(23) Feng, S., Hu, K., Fan, E., Zhao, L., & Wu, C. (2021). Kalman filter for spatial-temporal regularized correlation filters. *IEEE Transactions on Image Processing, 30*, 3263-3278.