Mechanical Optimization Design and Automation Application Based on Machine Vision Technology

Yu Song¹, Jingui Lu¹,*
¹Nanjing Tech University, Jiangsu, China
*Corresponding author e-mail: lujg@njtech.edu.cn

Abstract. The application of related tech represented by machine vision in mechanical design has gradually deepened, which has greatly ameliorated the automation of mechanical design. Based on this, this paper first analyses the principle and important composition of machine vision tech, then studies the utilization value of machine vision tech in mechanical design, and finally analyses the typical practical utilization of machine vision tech in workpiece detection, workpiece measurement and high-precision measurement in mechanical design.

Keywords: Mechanical Optimization, Automation, Machine Vision Tech

1. Introduction
At present, with the iterative development of socialized mass production, the pursuit of production efficiency in various fields is constantly improving. Under this background, the related industries represented by mechanical design are constantly developing towards automation and intelligence [1]. The mechanical design industry continues to optimize the technical system and technical links, so that the utilization of relevant tech represented by machine vision is gradually deepened, and the automation of mechanical design is greatly ameliorated [2]. Relying on machine vision tech, the mechanical design process reduces the dependence on manual participation to a great extent, making the environmental adaptability of relevant links stronger, so as to greatly ameliorate the efficiency of the mechanical design process and reduce the process cost.

As a highly comprehensive and systematic tech, automation tech organically integrates several disciplines and specialties as shown in Figure 1 below. Its utilization in the mechanical design process can not only release the workload and working pressure of relevant operators, but also carry out more accurate control and process monitoring, and significantly ameliorate the efficiency of mechanical design and processing process. As a comprehensive tech of fusion power, infrared imaging, video, image analysis and other disciplines, the integration of machine vision tech and mechanical automation further ameliorates the ability of accurate target recognition and measurement, so as to ensure the more intelligent and automatic development of mechanical design and manufacturing process [3].
In addition, the utilization of mechanical vision tech makes the relevant design process and processing process more flexible and freer, and gets rid of the disadvantages of being easily affected by the environment and scene in the traditional design and processing process to a great extent [4]. With the help of machine vision tech, mechanical design process and automatic process monitoring can ameliorate efficiency and reduce error probability and labor cost [5]. Therefore, the research on mechanical optimization design and its automation utilization based on machine vision tech has important practical value.

2. Principle and important components of machine vision tech

2.1. Principles of machine vision tech

Machine vision tech organically integrates lens tech, camera tech, light source tech, image acquisition card and camera calibration tech [6]. As an important part of the machine vision system, the light source is mainly responsible for providing illumination, and the lens is responsible for imaging the relevant scene onto the CCD sensor. The sensor converts the scene target image info into electrical signal, and further converts it into digital image with the help of image acquisition card. The computer system is responsible for storing and processing the digital image info, and outputting and controlling the measurement results. The principle architecture of a typical machine vision system is shown in Figure 2 below.

2.2. Hardware composition of machine vision tech

As the key hardware system of machine vision tech, its vision equipment is mainly composed of light source, camera equipment and processing unit [7]. The digital image of the object to be detected is collected through the camera end, and displayed intuitively on the display terminal of the computer system. Secondly, as another key component, the main function of the lens component is to obtain clear component images and provide different display effects according to specific scene requirements. In addition, as an important technical parameter of machine vision optical system, the relationship between field angle and focal length is shown in Figure 3 below.
Figure 3. Schematic diagram of the relationship between field angle and focal length

As the distance from the lens center to the imaging plane such as CCD, the focal length is calculated as shown in equation 1 below. Where, \( d \) is the CCD size and \( \alpha \) is the field angle. The scene range and \( d \) have strong consistency, and allowance should be left in the selection of actual size, that is, the actual focal length value is required to be less than the calculated focal length value.

\[
\alpha = 2 \cdot \theta = 2 \cdot \arctan \left( \frac{L}{2V} \right) = 2 \cdot \arctan \left( \frac{d}{2f} \right)
\]

\[
f = \frac{d}{2 \cdot \tan \left( \frac{\alpha}{2} \right)}
\]

2.3. The calibration tech of machine vision is imaging model

The geometric position of space object surface is mainly determined by imaging model, and these model parameters need to be obtained by experiment and calculation \([8]\). Secondly, in the process of machine vision calibration, it is often inseparable from using mathematical calculation to obtain data processing results. The imaging geometric model of machine vision is shown in Figure 4 below.

Figure 4. The imaging geometric model of machine vision

The physical image coordinates of point P under the imaging model are calculated as shown in equation 3 below.
$$x_u = f \frac{X_c}{Z_c}, \quad y_u = f \frac{Y_c}{Z_c}$$

(3)

In which, \((X_c, Y_c, Z_c)\) is the coordinate of 3D coordinate system; \((x_u, y_u)\) is the image-coordinate of point \(\rho\) under the model, and \(f\) is the focal length. \((u, v)\) is the actual image-coordinate of the imaging point of any point \(\rho\) in the image coordinate system.

3. Utilization value of machine vision tech in mechanical design

3.1. The necessity of applying machine vision tech in mechanical design

As a cutting-edge utilization tech in the field of mechanical design, the utilization of machine vision tech can effectively strengthen the technical level of mechanical design process, and significantly ameliorate the automation, intelligence and visualization level of mechanical design. Secondly, in the process of mechanical design, machine vision tech is organically integrated with infrared imaging and video tech to make it have extensive characteristics, so as to complete the function of object recognition [9]. In addition, the realization of mechanical design optimization and automation is inseparable from precision measurement and automatic working mode analysis. With the help of ANN network and intelligent vision, the info extraction of items can be more refined, which can not only meet the optimization of design efficiency, but also make it more extensive adaptability and matching, and better meet the needs of info processing of mechanical design.

3.2. Utilization value of machine vision tech

The utilization of machine vision tech in mechanical optimization design and automation mainly relies on the integration with other disciplines and disciplines to ensure its utilization mode value. Specifically, the utilization value of machine vision tech is mainly reflected in the dimensions of objectivity, impartiality and adaptability [10]. Firstly, at the level of objective value, machine vision is used to monitor the mechanical design process, test the parameters of product models, and ensure the consistency, accuracy and objectivity of the results. Secondly, at the level of fairness utilization value, the machine vision function completes the comprehensive monitoring of mechanical automation products, ensures the authenticity of data, ameliorates the reliability of test data, and ensures the accuracy and efficiency of test data. In addition, at the value level of adaptability, machine vision tech can significantly ameliorate the measurement accuracy and detection efficiency.

4. Utilization of machine vision tech in mechanical optimization design

4.1. Utilization of machine vision in workpiece detection and measurement

The utilization of machine vision in workpiece detection can first identify the defects of the workpiece efficiently and accurately, so as to meet the needs of industrial mass production for rapid flow operation and high-quality delivery. Secondly, machine vision can significantly ameliorate the standard of workpiece detection, reduce the dependence on manual participation, and avoid various deviations caused by subjective factors, so as to better ensure product performance. In addition, machine vision detection can obtain standard data results by converting the reflected image into electronic signals and comparing it with the standard image. Machine vision can complete the scanning of mechanical parts in a very short time, build the three-dimensional model of the measured object, and significantly optimize the design efficiency.

4.2. Utilization of machine vision in high precision measurement

The utilization of machine vision tech in measuring the size of equipment components is mainly to measure in motion through optical lens group and camera array, and calculate the corresponding two
measured values according to the displacement and displacement deviation. Machine vision system is especially suitable for assisting batch production line products to realize on-line detection and ameliorate detection efficiency. The precision measurement based on machine vision can not only ameliorate the production efficiency and dimensional accuracy, but also measure the workpiece with special configuration and effectively measure the tool wear. In addition, by flexibly adjusting the rotation angle of imaging components, the measurement range of machine vision system can be effectively ameliorated and the utilization process of precision measurement automation can be simplified. The integration of machine vision and automatic control significantly ameliorates the measurement accuracy, simplicity and work efficiency.

5. Conclusion
In summary, the utilization of machine vision tech in the mechanical design process can not only release the workload and work pressure of relevant operators, but also carry out more accurate control and process monitoring, and significantly ameliorate the efficiency of mechanical design and processing process. Through the research on the principle and important components of machine vision tech, this paper analyzes the calibration tech of machine vision, which is, imaging model. Through the analysis of the utilization value of machine vision tech in mechanical design, this paper studies the necessity and practical value of the utilization of machine vision tech in mechanical design. Finally, it analyzes the typical utilizations of machine vision tech in workpiece detection, workpiece measurement and high-precision measurement in mechanical design.

References
[1] Chen Yali. Progress of Aviation Composite Automation Tech [J]. Aviation science and tech, 2011 (04): 15-16.
[2] Gao Yanqing. Analysis of machine vision tech and its utilization in mechanical manufacturing automation [J]. China Science and tech, 2017 (21): 36-38.
[3] Guan Baolong. Machine vision tech and its utilization in mechanical manufacturing automation [J]. Engineering Tech: Abstract edition, 2016 (11): 240.
[4] Li Renjie. Machine vision tech and its utilization in mechanical manufacturing automation [J]. Science and tech innovation, 2016 (12): 80-80.
[5] Sun Xiaofeng. Machine vision tech and its utilization in mechanical manufacturing automation [J]. Science and wealth, 2018 (11): 61.
[6] Sun Xin. Research on automatic precision drilling process of Aeronautical Materials [D]. Nanjing: Nanjing University of Aeronautics and Astronautics, 2014: 87-92.
[7] Wang Hongtao. Analysis on the utilization of machine vision tech in mechanical manufacturing automation [J]. Electronic manufacturing, 2012, 11: 137 + 157.
[8] Wang Youguang. Development of sensor real-time target online detection system based on machine vision and motion control [D]. Guangdong University of tech, 2014, 17-18.
[9] Yang Gang. Analysis of machine vision tech and its utilization in mechanical manufacturing automation [J]. Scientific and technological innovation and utilization, 2015, 24: 143.
[10] Zhang Ping. Machine vision tech and its utilization in mechanical manufacturing automation [J]. Journal of Hefei University of Tech, 2017, 10: 1292-1295.