The Application of Machine Vision in Intelligent Manufacturing

Cheng Wang

Qingdao University of Technology, Qingdao, Shandong, 266520, China

*Corresponding author. Email: 1455276154@qq.com

Abstract. Machine vision technology has a rapid development rate in recent year especially in intelligent manufacturing. The field of intelligent manufacturing will undergo a revolution. Machine vision technology is currently developing and becoming more sophisticated. The related hardware and software items are continuously improved. They increasingly became significant in the industrial production process. Machine vision can replace some human labor in intelligent manufacturing, which effectively increases production efficiency and product quality. As a result, it might help businesses achieve full production automation, quality control standardization, automation, and automation. This paper discussed the key technologies of machine vision technology used in intelligent manufacturing industry, as well as the application of machine vision in intelligent manufacturing. The Key technologies of machine vision include image acquisition, image segmentation, and image recognition. The current application of machine vision in intelligent mainly include manufacturing dimensional measurement, part inspection, and object localization.

Keywords: Machine Vision, Intelligent Manufacturing, Dimensional measurement, Part inspection, Object localization.

1. Introduction

Intelligent manufacturing combines new-generation intelligent information technologies such as artificial intelligence and big data. With the development of the manufacturing industry, intelligent manufacturing technology has become one of the key technologies for automation and flexibility of manufacturing to achieve rapid response to the market [1]. The global machine vision market was 13.23 billion in 2021. This number is going to increase 7.7% from 2022 to 2030 (Figure 1) [2]. The major applications include intelligent detection, fault diagnosis, identification, design, and optimization based on neural network, optimization design based on genetic algorithm, expert system based on rules and framework, knowledge system based on analogical reasoning, inductive learning and case-based reasoning, distributed intelligent manufacturing system based on Agent technology. Intelligent manufacturing mainly focuses on high-end equipment manufacturing, and conducts analysis, reasoning, judgment, thinking, decision-making and other activities in the manufacturing process. The transformation of intelligent manufacturing systems from energy-driven to information-driven has a high demand on the flexibility and digitization of manufacturing systems. In the intelligent manufacturing system, the collection of original information is the most basic work, which drives the decision-making and work of the entire system.

As one of the most popular technologies, machine vision technology has a high flexibility, which can adapt to various production environments. It has been widely used in intelligent manufacturing. The definition of machine vision is the technology and methods used to extract information from an image or real objects on an automated basis through optical devices and non-contact sensors[3]. Machine vision is usually to use a device to replace human eyes for measurement and judgment. With the development of machine vision technology over the years, it has been applied in various industries, such as in scientific research (material analysis, life science, etc.), military (aerospace, aviation, and mapping), civil (intelligent transportation, security, text recognition, identity verification, etc.), industry (quality inspection, product classification, product packaging, robot positioning). One of the most important characteristics of machine vision system is to improve the flexibility and automation of production [4]. In some dangerous working environments that are not suitable for human, machine vision is often used to replace the traditional visual identity. For example, in the process of large-

scale industrial production, using human labor to check product quality is inefficient and inaccurate. the use of machine vision detection can significantly improve production efficiency and automation.

With the further intelligentization of the production process of mechanical equipment, the collection and processing of production information is particularly important. Few studies have been conducted in this field due to the rapid growth of machine vision in intelligent manufacturing. The objectives of this paper are to: 1) present the key technologies of machine vision technology used in intelligent manufacturing industry; 2) discuss the application of machine vision in intelligent manufacturing; 3) make an analysis and prospect of the application prospect of machine vision.

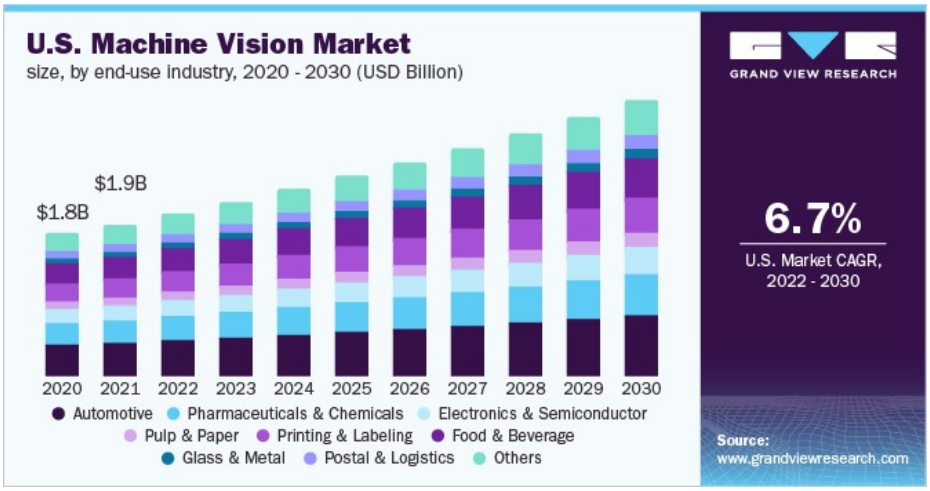


Fig. 1. Machine vision market will grow at a highest rate of 7.7% during 2020-2030[2].

2. Key Technologies of the Machine Vision and its Application in Intelligent Manufacturing

2.1 Key Technologies of the Machine Vision

Machine vision can allow machines to replace human labor and help the manufacturing industry to achieve automation and intelligence. At present, it is mainly used in the field of intelligent manufacturing. In recent years, the rapid development of artificial intelligence technology has significantly promoted the application of machine vision technology, and the demand for machine vision has soared or become a blue ocean market. The largest market for machine vision in China is electronics. As of 2020, the overall scale of the machine vision industry in China reached more than 60m RMB. According to the data from China Machine Vision Union (CMVU), this number grew 19.5% from 2018 to 2020 [5]. The Key technologies of machine vision include image acquisition, image segmentation, and image recognition.

Visual information is the basis of machine vision technology[6]. A typical visual information acquisition system in intelligent manufacturing is shown in Figure 2. The visual information acquisition system mainly includes light source, imaging, and data processing. The optical lens controlled by a light control circuit acquires the target image under the light source and is stored in the signal storage circuit by the sensor. After that, it will be processed by a signal amplification circuit and the computer and finally obtain the visual information of the target. Image segmentation is another foundation in the field of machine vision. According to the characteristics of the image such as color, texture, and shape, the image is divided into several regions. The algorithms of image segmentation mainly include simulated annealing method, dynamic programming method, and local energy minimization methods. Image recognition is based on image feature analysis, motion analysis, and pattern matching. The main algorithms include K-nearest neighbors algorithm, support vector machine algorithm, backpropagation algorithm, convolutional neural network, and transfer learning neural network.

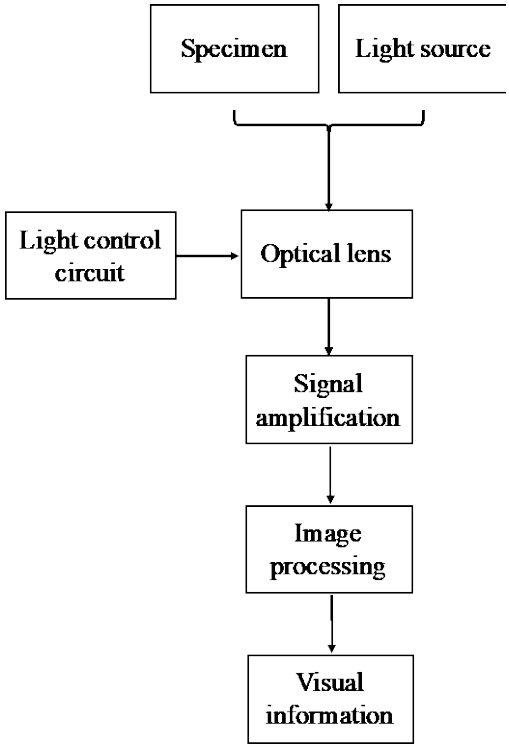


Fig. 2. Scheme of visual information acquisition system (by owner-draw).

2.2 The Application of Machine Vision in Intelligent Manufacturing

2.2.1 Dimensional measurement.

With the development of manufacturing technology, the shape design of large industrial components is becoming more and more complicated. At the same time, due to the volume and weight limitations of large components, the large industrial components cause many troubles to traditional measurement methods. Machine vision measurement technology has higher measurement accuracy and efficiency. According to different lighting modes and geometric relationships, visual detection methods can be divided into two types, i.e., passive visual detection and active visual inspection. Passive vision detection directly uses the original images, which are obtained in the industrial environment without obvious characteristics. The active detection method can actively generate the required feature information, thereby avoiding the difficulty of stereo feature matching. Therefore, it has a wide application in industry. Active vision detection methods include laser ranging, moiré interferometry, and structured light method.

2.2.2 Part Inspection

Machine vision technology is widely used in product inspection, the main applications include presence detection and defect detection[7]. Parts inspection is one of the most important applications of machine vision technology in industrial production. In the process of manufacturing, products are needed for quality inspection. There are many disadvantages in traditional manual inspection. First, the accuracy of manual inspection depends on the state and proficiency of workers. Secondly, the efficiency of manual operation is relatively low, which cannot well meet the requirements of mass production inspection. In addition, labor costs have also gradually increased in recent years.

2.2.3 Object Localization

Many traditional industrial manufacturing processes such as welding, and handling are gradually being replaced by machine vision technology. For industrial robots, these traditional industrial manufacturing processes only need to generate specified programs, and then execute them in sequence. During the operation of the robot, the initial state of the part such as position and attitude and the relative position of the robot are not fixed. It could cause a gap between the actual placement

position of the workpiece and the ideal processing position, and it is difficult for the robot to process according to the original program. With the development of machine vision technology and more flexible robotic arms, this problem has been gradually solved.

3. Conclusion

Machine vision technology is being developed at an exponential rate especially in the field of intelligent manufacturing. It will revolutionize the intelligent manufacturing industry. At present, machine vision technology is becoming more and more mature. The related software and hardware products are constantly enriched. They gradually play an important role in industrial production. The application of machine vision in intelligent manufacturing can reduce human labor, which efficiently improves production speed and product quality. Therefore, it could bring true production automation, quality control standardization, quality, and automation to enterprises.

Although the machine vision has made great progress in intelligent manufacturing, there are still some development bottlenecks in terms of the current application. The first problem is the uncertainty of the measurement uncertainty. Traditional manufacturing measurement dimensions usually have a standardized measurement accuracy, while machine vision is mainly measured by pixel-based resolution. Although there are big progress in the manufacturing process of lenses and photosensitive devices such as charge-coupled device (CCD) and complementary metal-oxide semiconductor (CMOS). However, the standardized measurement accuracy has not been established. Algorithmic reliability also effects the widespread use of machine vision. At present, various algorithms for machine vision applications in different scenarios have varied accuracy. Differences from different algorithms will not only result in different measurement results, but also increase the difficulty of integrating into one system. At present, the application of machine vision in China's market is immature. More research is needed since this market is far from saturated.

References

[1] Li, B.H., Hou, B.C., Yu, W.T., et al. (2017) Applications of artificial intelligence in intelligent manufacturing: a review. Frontiers of Information Technology & Electronic Engineering, 18(1), 86-96.

[2] Research and Markets. (2022) Global Machine Vision Market (2022 to 2030)-size, Share & Trends Analysis Report. GlobeNewswire News Room. Retrieved from https: //www.globenewswire.com/en/news-release/2022/06/03/2455929/28124/en/Global-Machine-Vision-Market-2022-to-2030-Size-Share-Trends-Analysis-Report.html

[3] Patel, K.K., Kar, A., Jha, S.N., et al. (2012) Machine vision system: a tool for quality inspection of food and agricultural products. Journal of food science and technology, 49(2), 123-141.

[4] Usuga Cadavid, J.P., Lamouri, S., Grabot, B., et al. (2020) Machine learning applied in production planning and control: a state-of-the-art in the era of industry 4.0. Journal of Intelligent Manufacturing, 31(6), 1531-1558.

[5] Imaging and Machine Vision Europe. (2022) Smart manufacturing to drive china vision sales. Smart manufacturing to drive China vision sales. Retrieved July 14, 2022, from https: //www.imveurope.com/analysis-opinion/smart-manufacturing-drive-china-vision-sales

[6] Fu, L., Zhang, Y., Huang, Q., et al. (2016) Research and application of machine vision in intelligent manufacturing. In 2016 Chinese Control and Decision Conference (CCDC), pp. 1126-1131, IEEE.

[7] Chen, Y.R., Chao, K., & Kim, M.S. (2002) Machine vision technology for agricultural applications. Computers and electronics in Agriculture, 36(2-3), 173-191.