The Role of Machine Vision Technology in the Manufacturing of Vehicles in Industry

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Abstract: With the rapid development of machine vision technology, the characteristics of computer vision techniques such as rapidity, precision, and intelligence have gradually been widely used in various fields of modern industry, especially in the automobile manufacturing industry. The three main applications of machine vision in the industrial field are visual measurement, visual guidance, and visual inspection. The visual measurement technology can ensure the quality of the factory products by measuring the key dimensions, surface quality, and assembly effects of the product; the visual guidance technology can significantly improve the manufacturing efficiency and body assembly by guiding the machine to complete automated handling, optimal matching assembly, and precise hole making, etc. Visual inspection technology can monitor the stability of the body manufacturing process, and can also be used to ensure product integrity and traceability, which is conducive to reducing manufacturing costs. It is foreseeable that with the improvement of the performance of core hardware such as cameras, lenses, computers, and the development of software technologies such as image processing and deep learning, the role of vision technology in various fields will become more prominent in the future, and the development space will also be broader.

Keywords: Automation; computer vision; machine vision; visual-guidance; optimal localization.

1. Introduction

As early as the 1980s, the US National Bureau of Standards predicted that 80% or even 90% of the inspection tasks will be completed by visual measurement systems. This prediction has become a reality. In recent years, with the rapid development of machine vision, the rapidity, accuracy, and intelligent characteristics of machine vision technology have been widely used in all walks of life in the modern industry [1-4]. Moreover, in the context of the current Industry 4.0 era with smart manufacturing as the core, the strategic deployment of Made in China 2025 has gradually deepened, and the industrial robot industry market has shown explosive growth [5], and machine vision systems that serve as "eyes" for industrial robots also contribute It must be.

The machine vision system is a non-contact optical sensing system, which integrates software and hardware at the same time, and can automatically obtain information or generate control actions from the collected images [6]. In short, it uses a computer to simulate the visual function of the human eye, extract information from an image or image sequence, process and understand it, and finally use it for detection, measurement, and control [7]. A typical industrial machine vision system uses a camera to collect the image information of the measured target, and then converts the analog image information into a digital image signal and sends it to the digital image processing system of the host computer. And information such as color, calculate the information such as the pose and shape of the measured object, and finally control the drive actuator to respond according to the information obtained by the test. At present, machine vision has been used in agricultural product sorting [8], medical imaging [9], product packaging inspection [10], and industry [11-13] and other fields.

Machine vision is widely used in the industrial field and has three main functions: vision measurement, vision guidance, and vision inspection. The visual measurement is aimed at some parts with high accuracy requirements, and the accuracy requirements are millimeters or even micrometers [14]. The human eye cannot complete the use of the machine, such as the size of the high-precision threaded screw hole needs to be passed through the machine Visual measurement, to ensure the gap and accuracy of the connection [15]; visual guidance is to require machine vision to quickly and accurately find the part to be measured, and confirm its position, guide the robot arm to accurately grasp [16], such as visual guidance Random gripping, by scanning randomly distributed parts in the toolbox to obtain a three-dimensional image, using pattern recognition to obtain the best point of the robot arm to grip the workpiece in the three-dimensional image, and guiding the gripping to achieve automated production; visual inspection uses the machine The vision system detects the quality of the products on the production line, and checks their aesthetics, comfort, and performance [17], which is the link that replaces the most labor. For example, machine vision is used to detect the geometric shape of potatoes at home and abroad, surface defect detection, from the classification of potatoes based on these characteristics [18]. Machine vision greatly improves the flexibility and automation in industrial production [19] and can complete some tasks that are difficult for humans to complete in hazardous operating environments, greatly reducing the use of labor in large-scale production and improving and ensure the quality of production.

It is worth noting that the application of machine vision technology in the automobile industry, which is typically represented by modern industry, has been very extensive. This article will also take automobile manufacturing as an example, focusing on the typical application of machine vision technology in modern automobile manufacturing. As one of the largest and most important industries in the world, the automobile manufacturing industry has a history of more than 100 years [20]. Compared with other manufacturing industries, the automobile manufacturing industry has several typical characteristics: huge output and still maintaining rapid growth; rapid vehicle model replacement; and very complicated manufacturing process. The application of machine vision technology in the automobile manufacturing industry has greatly improved the operation quality and efficiency of the process and reduced the labor intensity. It has been successfully applied to many domestic and foreign auto OEMs, including automatic detection of vehicles and parts, three-dimensional positioning of parts, body assembly/processing, parts traceability, etc. [21-25]. The application of machine vision technology has been throughout the entire automotive body manufacturing process, including the development of initial raw material quality testing to 100% online measurement of automotive parts, and then control the welding, gumming, punching and other processes in the manufacturing process. Finally, the quality of the vehicle body assembly and the finished vehicle are checked.

At present, machine vision has been widely used in various fields of modern industry, and the development space in the future will be broader. Machine vision technology must become a "smart eye" to guide the era of the higher, faster, and more stable automation industry. However, it has to be pointed out that machine vision technology is also restricted by certain factors in modern industrial applications, which requires targeted improvements and enhancements in the future. Obtaining a good image needs to be restricted by a series of factors such as light source, lens selection, sensor selection, beat considerations, installation layout, and workpiece state changes.Therefore, changes in a certain part may affect the quality of the picture and thus affect the normality of the algorithm.So, the robustness of the machine vision algorithm needs to be further improved. Besides, the intelligence of computer software is still far from enough. The deep learning neural network in the field of computer vision is currently less successfully used in the field of machine vision. When the target objects are variable, the features are complex, and the number of samples is not enough however, deep learning cannot be used, but we still have to return to the traditional old road. Considering the strict requirements of real-time, machine vision especially needs a new intelligent method that is widely used in most fields. The industry is a three-dimensional component, and two-dimensional imaging is, after all, a kind of morbid data collection in the actual situation of three-dimensional space. Around 3D machine vision inspection, measurement, robot guidance, and other projects and applications will be more and more Visual inspection will be more applied to industrial production. The climax of machine vision will also be ushered in many other civilian fields. Modern manufacturing, medical, electronics, warehousing, and other fields will have a variety of new applications to promote the development of intelligence in the new era; machine vision hardware systems will also Towards the direction of embedded development, computing efficiency and intelligence are getting higher and higher.

2. Visual Measurement

Initially, the quality of automobile manufacturing mainly relied on CMM measurement [26]. As shown in Figure 1, its efficiency is low and can only be measured offline. It usually takes 2 ~ 3 hours to complete a body-in-white measurement, and the amount of measurement data is seriously insufficient. With the introduction of visual non-contact measurement technology to the body quality monitoring link, gradually developed online measurement systems such as fixed online measurement stations and robot flexible online measurement stations, which can strictly monitor body size fluctuations, provide data support for production process improvement, body measurement Achieve the transition from offline measurement to 100% online measurement; in addition to traditional three-coordinate measurement and laser online measurement, visual measurement methods such as blue-ray scanning measurement and surface defect measurement have gradually become an important means of automobile quality control. More precise measurements can provide efficient and high-precision monitoring of basic body dimensions, body assembly effects, and defects. At present, a variety of monitoring and measurement methods are combined to achieve full-range monitoring and measurement of the body from parts, components, and the entire vehicle, to ensure zero defects in production parts, and to ensure the quality of the complete vehicle manufacturing. Not only the measurement of the body size is realized but based on the measurement data, detailed and diverse analysis of the car can be performed and reports can be automatically generated to realize real-time alarm.

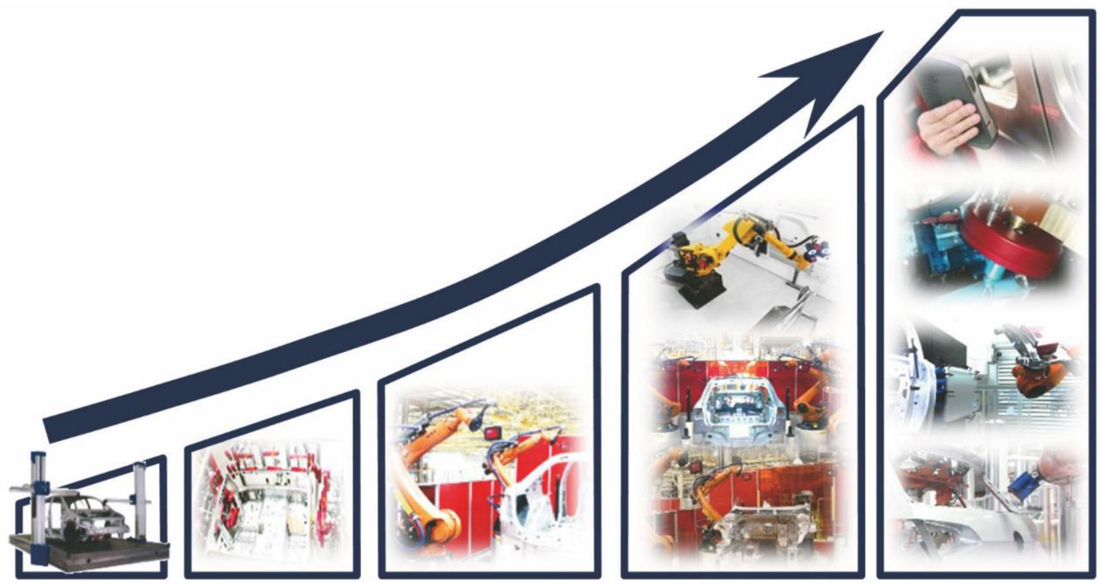

Figure 1. Evolution of visual measurement method for quality determination.

2.1 Laser Online Measurement

The automobile body-in-white is the basic carrier of all the components of the car. The manufacturing dimensional accuracy of the body-in-white directly affects the shape, aerodynamic performance, and manufacturing cost of the automobile body. Therefore, the manufacturing of the dimensional control mechanism is one of the necessary conditions to improve the quality of the body. The advanced detection method of body size is a key method to control the dimensional accuracy of automobile manufacturing [27]. At present, body measurement systems widely used in automobile manufacturing companies mainly include coordinate measuring machines and laser online measurement systems. In the quality control process of the welding shop, the three-coordinate measuring system is widely used in the measurement of the body size to monitor the size fluctuations, which has the advantages of high measurement accuracy and good reliability. However, there are problems such as low measurement efficiency and long response period, which cannot realize the real-time monitoring of the body-in-white production process. The laser online measurement system has low environmental requirements and high measurement efficiency. It can realize a 100% real-time three-dimensional measurement of the car body [28]. The computer can output reports based on the measurement data, automatically analyze the operation status of the production line, and display the dimensional deviations and trends in time. It is more conducive to the quality control in the body manufacturing process and has a good application prospect.

The laser online measurement technology is based on the principle of triangulation, which uses a linear laser to construct the measured feature, combined with effective illumination, to obtain the surface information of the measured feature, the camera takes the feature image, and obtains the second feature of the measured feature on the image through image processing technology. Dimensional (2D) coordinates, and then convert the 2D coordinates into three-dimensional (3D) space coordinates in the sensor coordinate system through the triangulation model. According to different application scenarios, online measurement technology can be divided into fixed online measurement system and robot flexible online measurement system, as shown in Figure 2. The fixed online measurement system includes multiple measurement sensors, each sensor has a fixed position, and the sensors are measured in their respective coordinate systems (sensor coordinate systems) to obtain the coordinates of the measured point under the sensor coordinate system. Convert the measurement result of the measured point to the body coordinate system to complete the measurement. The robot's flexible online measurement system is composed of a multi-degree-of-freedom industrial robot and a flexible sensor installed at the joint of the robot end. When the robot receives the start of the measurement signal, it drives the movement of the visual sensor according to the pre-planned measurement path and enters the measurement point into the measurement area of the sensor in sequence, and the measurement is completed by the vision sensor and the measurement host [29-30]. The robot's flexible online measurement system is more flexible and can measure the features that the robot can reach on the body. The fixed online measurement system can only measure a fixed limited range, which is suitable for measuring features that the robot cannot reach (such as features on the floor).

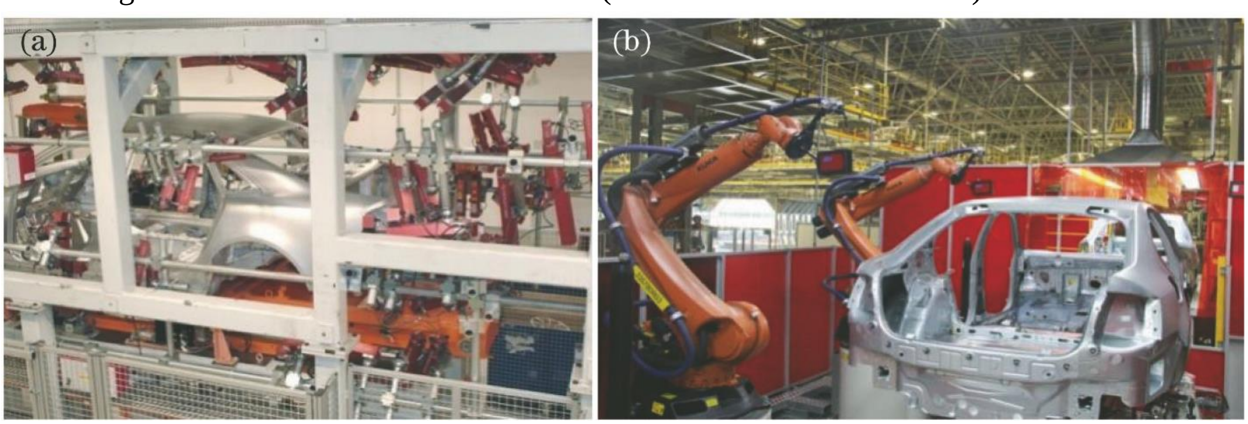

Figure 2. Illustration of online Laser measurement: a) fixed; b) robotic.

In recent years, companies such as Shanghai Volkswagen, FAW-Volkswagen, Shanghai General Motors, and Dongfeng Motor have introduced online measurement systems to monitor size fluctuations and study process capabilities [27]. In general, online inspection technology is in the stage of popularization, development, and progress in the Chinese automotive industry.Usually, a welding assembly line will be equipped with a floor online measurement station and a body assembly online measurement station, which are used to monitor the floor assembly and body respectively. The manufacturing quality of the total fight, however, the current application of online measurement equipment in most OEMs is still in its infancy. How to promote and use the online measurement system reasonably is an important issue that needs to be solved urgently in a workshop production. For the quality produced in the automobile body-in-white, in a compact production cycle, how to optimize the online measurement frequency, measure more feature points, maximize the efficiency of the measurement equipment, and ensure accurate and timely control of the body quality, become white Key technical issues in body manufacturing quality control [27]. The body-in-white online measurement system mainly has room for improvement in the areas of measurement location optimization and measurement frequency optimization. However, because the online laser measurement system uses a line laser sensor for measurement, it is suitable for measurement occasions with less detailed data indicators. When the demand for the surface information of the measured feature becomes larger, the efficiency of the laser online measurement system cannot meet the measurement needs.The blue-ray scanning measurement system shows great advantages.

2.2 Blu-ray scanning measurement

The rapid development of high-end advanced equipment manufacturing, such as automobiles, puts more demands on the measurement of product geometric dimensions, more diversified product structure forms, and detection functions, more detailed detection of local details, and higher requirements on measurement efficiency, digitization, and automation. In automobile production, shape measurement is an important part of product quality control. The appearance accuracy of the car body outer cover directly affects the assembly and airtightness of the car parts, and the abnormal size and shape of the car body outer cover can be found in time to greatly reduce the defect rate of the factory products, and the precise acquisition of the car body outer cover It can also reflect the working state and life of the die in the stamping process.

Blu-ray scanning measurement technology has got rid of the limitation of single feature measurement of traditional CMM, can realize the measurement and analysis of the overall shape and size, has higher measurement efficiency, more comprehensive feature evaluation, and is easy to install and debug. Blu-ray scanning technology can obtain high-density measurement data to deal with the changeable topography and curvature of complex curved surfaces, and effectively realize the refined measurement of complex curved surfaces. Its scanning measurement accuracy can reach ± 0.02 mm, within a single range of 0.5 m. Obtain tens of millions of high-density point cloud data. By adopting high-precision stitching technology, blue-ray scanning measurement can effectively unify the local measurement data to the global coordinate system to meet the requirements of the measurement range of large components.At the same time, by combining the robot motion platform, the measurement efficiency and automation level can be improved Human intervention work, based on these characteristics, can carry out a very detailed quality evaluation of body parts and the entire vehicle, including surface morphology evaluation and local feature evaluation.

Figure 3 shows the blue light scanning measurement system. The system consists of a 3D scanner, a multi-axis robot, programming software for robot motion and measurement steps, inspection and analysis software, and a safety system. The measurement system uses a scanner mounted on the robotic arm to measure the 3D shape of the car body. At the same time, based on the theoretical design model, the measurement results are automatically compared with the theoretical model to check the shape of the manufactured part, the size and angle of the measured part, and other information. Besides, the system is equipped with a walking track for the robot to move back and forth, and an automatic rotating table for the body to rotate, which automates the entire system measurement and achieves high-precision and high-speed whole-body measurement. The blue light projection technology used by the scanner of the blue light measurement system is composed of two left and right high-resolution industrial CCD cameras and a fringe projection unit. Using a structured light measurement method, the projection unit projects fringes containing different interval and phase information to the surface of the workpiece to be measured, two left and right high-resolution industrial cameras simultaneously acquire fringe images. Using the principle of binocular stereo vision measurement, three-dimensional data of high-density point clouds are acquired in a very short time. Marking point stitching technology is used to achieve automatic alignment of measurement data at different angles and positions, and finally obtain complete measurement data.

Due to the characteristics of rich measurement data and diversified data analysis methods of the blue-ray scanning measurement system, high-end car manufacturers such as Mercedes-Benz, BMW, Volkswagen, and GM have introduced the blue-ray scanning measurement system to measure the body assembly and the four-door two-cover assembly. Dongfeng Motor, Changan Automobile, and other domestic automobile factories have also introduced blue light scanning measurement systems. The blue-ray scanning system can realize full-automatic measurement, and can provide richer data based on covering the traditional three-coordinate measurement data. Therefore, more and more OEMs currently use blue-ray measurement equipment to replace the three-coordinate machine for parts and integration. Car measurement. However, to ensure the measurement accuracy, the current blue light measurement system needs to use point attachment to achieve point cloud data stitching, which affects the overall measurement efficiency. How to achieve high-precision data stitching in a scene without point attachment is an important direction for the subsequent development of the blue light measurement system. Besides, the blue-ray scanning system uses multiple cameras and projectors to form a measurement system, and the system cost is higher than other measurement costs.

Figure 3. Illustration of scanning measurement by blu-ray method.

2.3 Surface Quality Inspection

Automobile painting is an important part of the automobile manufacturing process. Body spraying can not only provide exterior decoration but also protect the body's surface. However, in the actual painting production, due to the influence of the environment of the painting workshop, the quality of the paint and the painting process are different, it is easy for the painted car body to produce different types of defects [31], such as impurities and spray pollution Such as typical surface defects, how to measure the quality of the automotive surface coating accurately and automatically is extremely critical.

At present, the measurement of automobile surface quality is mainly done by artificial vision. Its efficiency is low and it is easily affected by human factors. It has become one of the key factors restricting the efficiency of quality monitoring of painted car bodies [32]. To improve efficiency and reduce manpower, the measurement of automotive surface quality based on machine vision has begun to be applied in the field of automotive coating inspection, as shown in Figure 4. Compared with the traditional manual visual measurement, the visual surface quality measurement adopts full-automatic detection, which has extremely high sensitivity and a large field of view, which can efficiently, accurately, and comprehensively detects the quality of automotive coatings, avoiding the maximum adjustment ofcar rework.

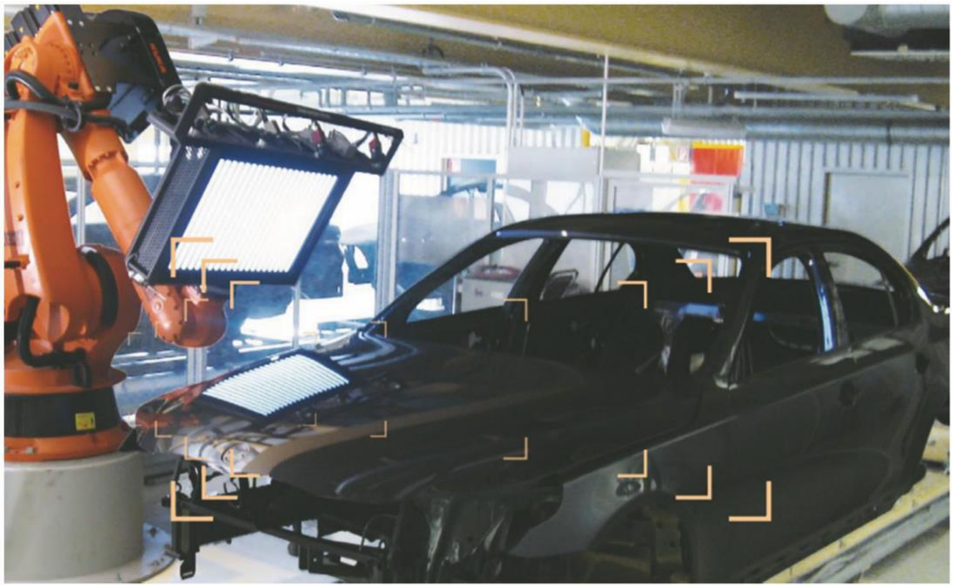

Figure 4. Paint test quality measurement through the surface quality method.

Because the painted surface of the car is smooth and has a large range of irregular freeform surfaces, the measurement of the quality of the painted surface of the car is difficult. Among the many freeform surface shape measurement methods, the reflective stripe deflection method has high resolution and curvature measurement. It has a wide range, simple structure, and is not sensitive to environmental changes. It has important application prospects. At present, the mainstream surface quality measurement systems of automobile manufacturers are based on the reflective stripe deflection method. The surface quality measurement system mainly includes robots, monitors, computers, and cameras. During the measurement, the computer controls the monitor to project the sinusoidal fringe onto the surface to be measured and then collects it by the camera after reflection. The change of the surface shape on the measured surface will deform the fringe. Using the phase extraction algorithm to extract the phase information of the fringe, the surface shape of the measured surface can be measured. The method has a simple structure, low cost, measurement resolution can reach nanometer level, and the curvature measurement range is large. At the same time, the monitor, camera, and other equipment are mounted on the robot after teaching, and the large-scale surface quality measurement of the whole body can be achieved through the large-scale movement of the robot.

The automobile paint film defect automatic detection system has been tested and used in several automobile companies. The main application areas are Europe, America and Japan, and other areas with developed automobile technology. There are no examples of domestic applications in production. Ford Motor Co., Ltd. has adopted the self-developed paint film 3D defect detection system in the coating lines of three factories around the world [32]; BMW Germany and Mercedes-Benz Motor Company have also applied the paint film defect detection system in succession. In production, the system can guarantee a defect-recognition rate higher than 99.5% and an error rate lower than 5%. The time for four sensors to detect a vehicle is only 60 s. Using reflective fringe deflection to measure the surface quality of the car body can realize automatic detection and quality supervision, but the optical path adjustment of the reflective fringe deflection measurement method has a certain complexity, and there are still certain technical difficulties in application promotion.

3. Visual Guidance

Vision guidance technology combines a variety of visual inspection technologies and robot kinematics principles and is designed to install "eyes" for each robot on the industrial site. The visual guidance system will break through the limitation that the robot can only repeat the teaching trajectory, so that it can adjust the working trajectory in real-time according to the changes of the operated workpiece, improve the robot's intelligence level, promote production efficiency, and improve product quality, such as by guiding the robot to automatically move up and down Material and guide logistics and positioning of conveying equipment, etc. Later, visual guidance technology gradually penetrated the entire process of automobile manufacturing, such as guiding robots for optimal matching installation, precise hole making, welding seam guidance, and tracking, spraying guidance, windshield glass loading guidance, etc., as shown in Figure 5. At present, the application of visual guidance technology in the process of automobile manufacturing is more and more extensive, and it plays an increasingly important role in the development of automobile manufacturing in the direction of intelligence.

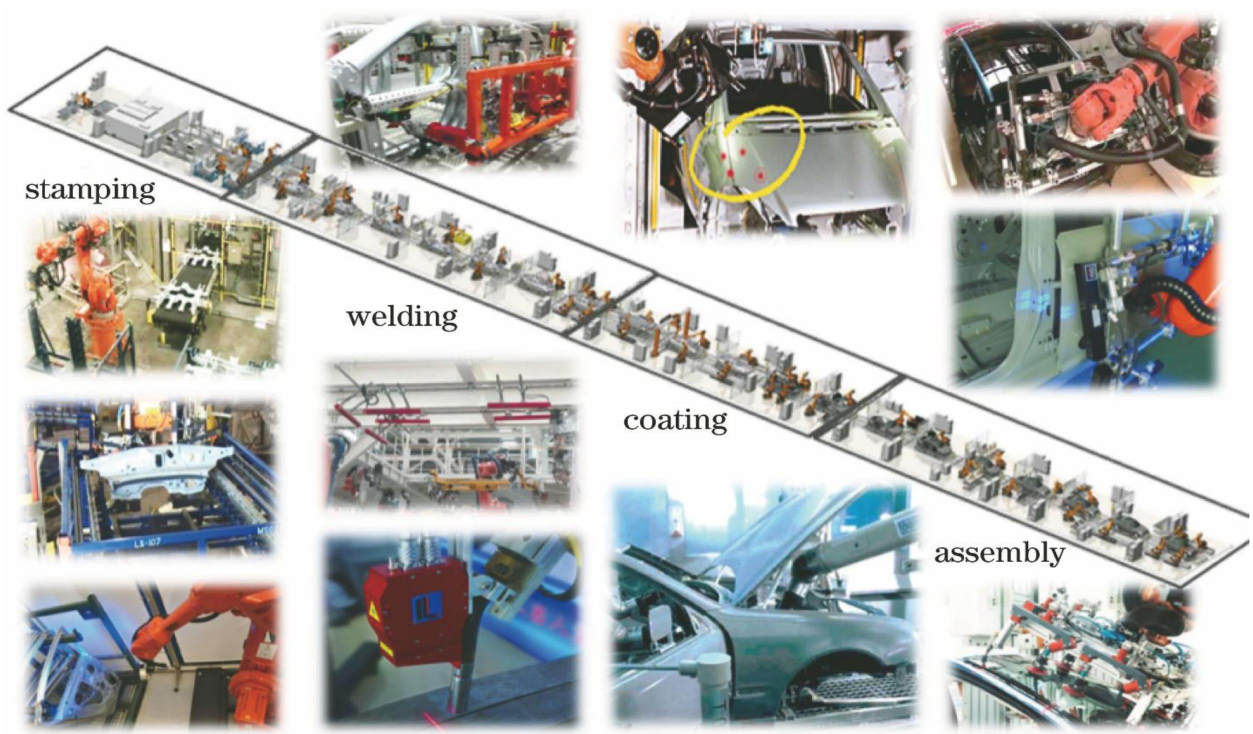

Figure 5. Illustration of the deployment of visual guidance method in the process of body vehicle manufacturing.

3.1 Vision Guided Crawling

The welding process in automobile manufacturing is mainly to assemble various parts into various sub-assemblies through welding, gluing, and other connecting processes, and then assemble each sub-assembly into a body-in-white assembly. At present, the parts are mainly transferred from the stamping workshop to the welding workshop by using the material box. Various sub-assemblies are also circulated in the workshop through the material box or EMS and other mechanical transport devices. How to realize the robot automatically from the material box, EMS and other devices Retrieving parts has always been a problem to be solved in the body-in-white manufacturing process. Since cars are generally made of metal and have a heavyweight, traditional manual transportation and transportation not only occupy a lot of labor, high production costs, but also low efficiency of handling and stacking, which is likely to cause certain dangerous safety accidents during transportation and achieve high efficiency and low cost. The automatic loading of robots has become an urgent demand for many OEMs.

The loading mode in the car body workshop is mainly divided into manual loading, ultra-high-precision bin loading, and visual guide to grasp the loading. At present, most domestic car manufacturers mainly use manual loading for loading and unloading, that is, on-site workers carry door and other accessories from the material box to the body.This method takes up a lot of manpower and introduces human interference factors; to reduce personnel costs and improve the installation accuracy, the ultra-high-precision bin loading method came into being. It cooperates with the robot and the high-precision bin. The robot plans the running track in advance and mechanically grabs the auto parts in the bin. This method gets rid of human operation. However, the process is relatively rigid and requires robots, bin positions, and internal accessories to maintain a fixed posture relationship; and mainstream joint venture factories such as Volkswagen and General Motors have adopted visually guided uploads on a large scale. In combination, it breaks through the limitation that the robot can only repeat the teaching trajectory so that it can adjust its working trajectory in real-time according to the position change of the operated workpiece, accurately grasp the workpiece, and directly improve the automation efficiency of the entire body manufacturing process, as shown in Figure 6.

Figure 6. Deployment of robotic grab based on visual guidance.

In the vision-guided gripping method, it is necessary to separately integrate and calibrate the ranging sensor and the visual sensor on the robot, and first read the value of the rangefinder during gripping to sense the relative position of the part and the robot in real-time and guide the robot to approach the bin; secondly, through the visual sensor Take photos of the accessories in the bin, and combine the three-dimensional information of the parts' characteristics (such as holes, corners, etc.) to achieve 6 degrees of freedom (3-direction position and 3-direction rotation angle) of the part relative to the initial state, and then calculate the position of the workpiece And the angle deviation, feedback to correct the picking trajectory of the pickup robot.

At present, vision-guided gripping parts have been widely used in GM, Volkswagen, and other OEMs, and Changan, Guangzhou Automobile, Dongfeng Motor, etc. have also tried to introduce this technology. However, the vision-guided grippers are mainly used for medium and large parts such as four-door inner and outer panels, side wall inner and outer panels, and bottom plates. However, many small parts such as door hinges and front longitudinal beam baffles cannot be automatically grasped. The small parts of the car body are usually randomly scattered and stacked, and the handling of loose parts faces many difficulties such as high-precision positioning of parts, robot trajectory planning, and collision avoidance of robots.

3.2 Vision Guided Assembly

Automated assembly of robots based on vision guidance has become the mainstream development direction of the body assembly. It combines machine vision technology with industrial robots. Through visually guided robots, high-precision installation of auto parts is achieved, which greatly improves environmental adaptability and intelligence. In the process of robot assembly, only considering the assembly requirements of visual guidance and positioning technology can the technical advantages be fully utilized to improve the accuracy of robot grasping and placement [33], as shown in Figure 7, taking the top cover as an example, If the opening of the top cover and the sidewall of the vehicle body does not reach the best matching load, the lap clearance of the top cover flow channel flange and the side beam assembly upper side beam flow channel will be large, which will cause the top cover welding point to undercut and affect the coating injection Processes, and cause water leakage in the final assembly, usually need to repair the body-in-white, which wastes costs and seriously affects the orderly production.

Figure 7. Vision-guided robot assembling the top cover.

Vision-guided assembly is different from vision-guided grasping. It requires high precision to ensure the consistency of the relative posture of the accessories and the body. Therefore, the vision-guided assembly system needs to be equipped with multiple laser vision sensors. Figure 7 shows the guided loading of the top cover based on machine vision. Before the top cover is guided and loaded, the body side opening and the top cover are measured respectively, and the robot is guided to place the top cover on the top cover based on the status of the side cover and the top cover. In the center position of the open file, the unevenness of the gap between the top cover and the left and right-side walls can be controlled within ± 0.5 mm. The sensor measures the 3D coordinate dimensions of the fixed features of the accessory, accurately locates the 6-degree-of-freedom deviation (3-direction position and 3-direction rotation angle) of the part to be assembled and the car body from the initial state, and builds a part coordinate system based on the measurement results of the feature, so that the part is referenced 3D positioning in the coordinate system (movement and rotation in the x, y, and z directions of the reference coordinate system), feedback the robot through the positioning information and guide the robot to move.

In addition to the top cover guided loading, visual guide assembly is also applied to the best matching installation of four doors and two covers, automatic loading of windshields, etc.Figure 8 shows the guided loading of the four doors and two covers of the car body, through machine vision and industrial robots. The combination of the two, respectively, realizes the automatic assembly of cars. At present, the top cover guide loading system has been widely used in automobile factories such as SAIC-GM, Beijing Automobile, Geely Automobile, and so on. At the same time, major OEMs are also actively exploring the technology of automatic installation of four doors and two covers with visual manufacturers.

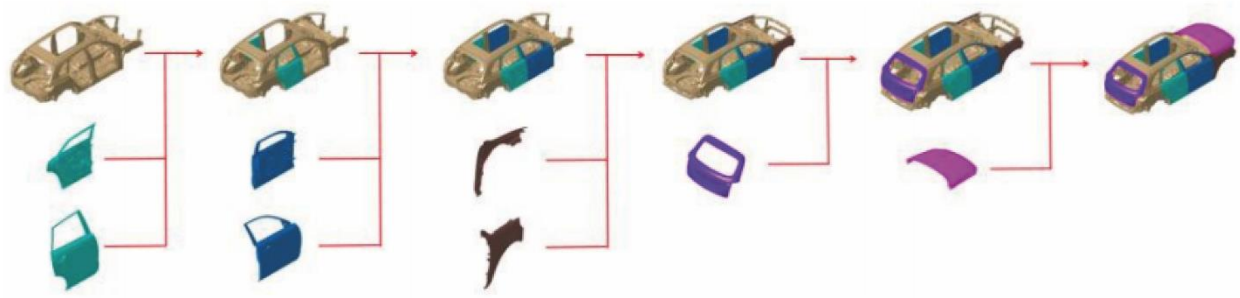

Figure 8. Installation of doors and covers in the automobile using a vision-guided robot.

3.3 Vision-guided Processing

Vision-guided processing refers to the use of visual measurement technology to measure the size information of a specific area of each car, and guides the robot to accurately cut, make holes, and polish according to its actual state. Laser processing technology has advanced, fast, flexible, and accurate features, such as laser welding, laser cutting, and other technologies are more and more widely used in automobile manufacturing, and the combination of robotics, laser processing technology and machine vision technology can be fully utilized Their respective advantages enable automated high-precision processing, as shown in Figure 9.

Traditional cutting methods rely on stencil cutters. Because the shape of the parts to be processed may be irregular and the shape of the edges is complicated, it is very difficult to manufacture the die cutter. Some special shapes cannot be cut [34]. If the machine vision technology is used to replace the traditional template, and the laser method is used to achieve cutting, the cutting process is more flexible, and the flexibility of the cutting system is greatly improved.

During the processing and cutting process, first of all, the relationship between the robot, the laser, and the visual sensor must be calibrated. The size and processing position of the parts to be processed are loaded into the computer, and the characteristics of the parts to be processed can be accurately measured by the visual sensor, and the Cutting edges, establishing intelligent cutting paths, the robot guides based on the designed route, and adopts an adaptive algorithm to avoid the cutting inaccuracy caused by the flexible deformation of the cutting target [35].

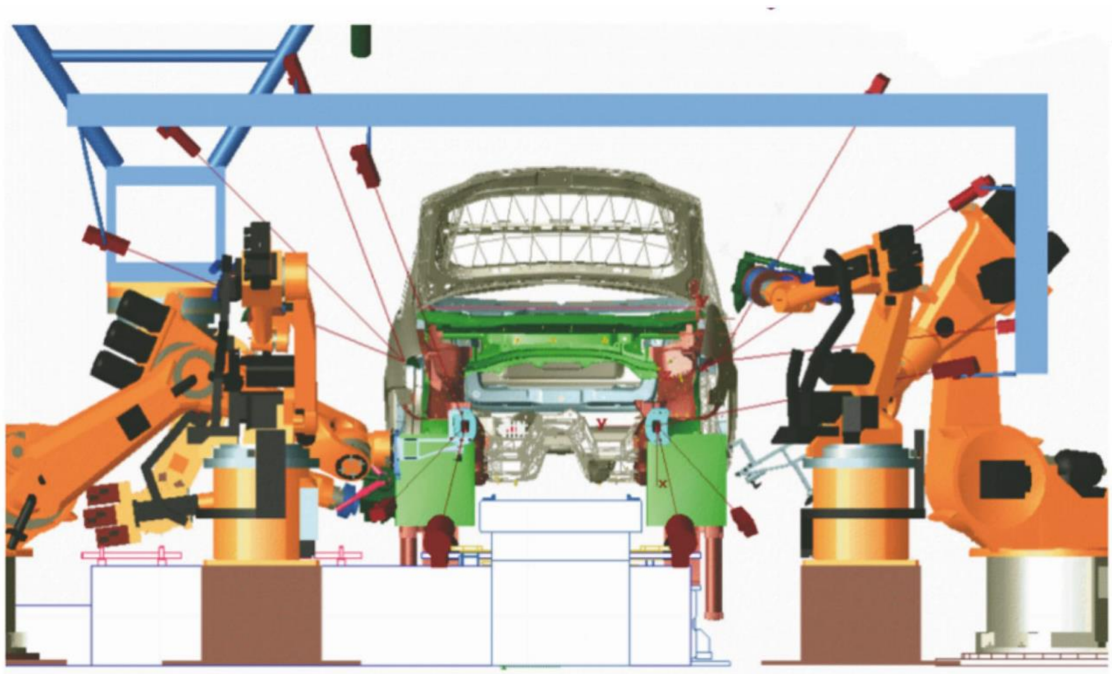

Figure 9. Hole creation using the visual-guided robot.

4. Visual Inspection

Today's product production and inspection are closely related to machine vision [5]. Through machine vision inspection, products can also be tested for manufacturing processes, automated tracking, traceability, and control. These include obtaining body part codes through optical character recognition (OCR) technology to ensure traceability of parts throughout the manufacturing process, ensuring the integrity of component assembly by identifying the presence or absence of parts, and identifying product surfaces through visual technology Whether defects or processing tools are defective to ensure product quality.

4.1 Manufacturing process inspection

Welding, gluing and other connection processes are widely used in the manufacturing process of the car body. The gluing process can play a role in strengthening the structure, fastening vibration isolation, sealing protection, and so on. Due to its harsh working environment, high working intensity, high motion accuracy, and good stability, the glue application process has gradually changed from manual glue application to robotic glue application, and the automation of glue application has gradually become a trend [36]. Traditional glue quality inspection methods include manual inspection and offline visual inspection. Manual inspection is carried out by the quality inspection staff with their own experience, using special tools to inspect, this method is uncertain and takes up labor costs; the offline visual inspection is to shoot through the camera after the glue is completed, and the post-image processing the final glue quality evaluation, this method wastes a lot of time and cost.

The current glue inspection process for automatic inspection based on machine vision can already achieve edge-to-side inspection. The maximum inspection speed can reach 500 $mm \cdot s^{-1}$ or even higher, where the quality of the glue is controlled by visual inspection. As shown in Figure 10, when applying glue, the detection equipment such as the glue gun and the visual sensor are fixed on the robot at the same time, the working field of the vision sensor is adjusted to the glue application area, and the vision sensor follows the glue gun to complete the glue application. During this process, the vision sensor collects the glue image in real-time for subsequent processing and analysis. Then, the image processing method is used to detect and analyze the collected strip photos to ensure the quality of the glue and the continuity of the glue.

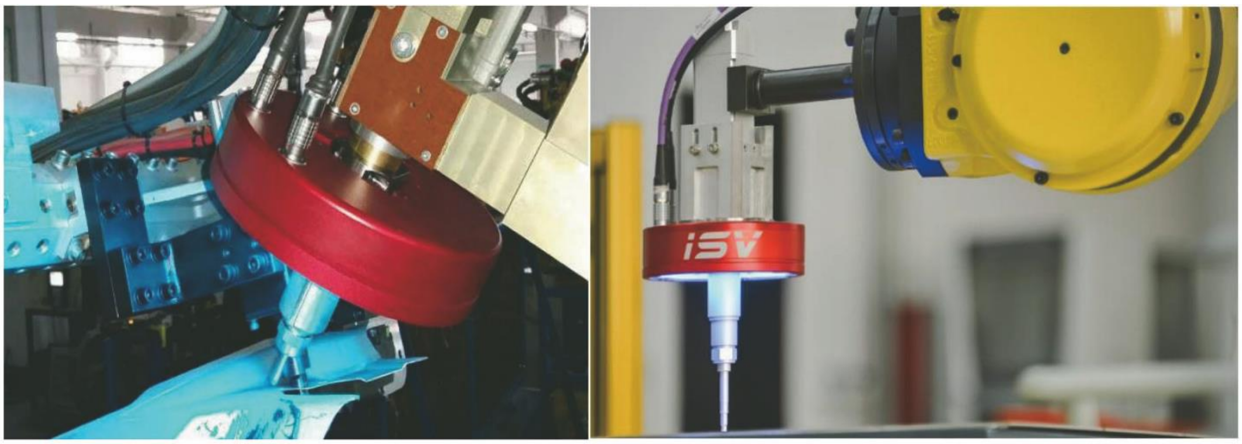

Figure 10. Automobile coating quality measurement.

Welding plays a very important role in the formation of structural parts. Polishing the weld after welding is the key technology to eliminate the internal stress of the welding material and generate a smooth welding surface. However, the industrial site mainly relies on the human eye to observe the appearance of the weld seam, which has low labor efficiency and detection will introduce human eye errors. The appearance of visual inspection is helpful for the evaluation of the quality of the robot's autonomous polishing welding seam. Its good stability and high efficiency will certainly replace the traditional artificial visual detection method.

Weld seam residual height and fusion width are the key elements for evaluating welding quality. The most widely used is the combination of line structured light vision and industrial robots. Line structured light vision sensors are installed on the robots, and the entire robot is tracked through the teaching Weld seam and use the visual sensor to photograph the weld seam information. However, due to the presence of interference factors such as splashes, arcs, and even high temperatures in the welding process, welding seam guidance, and welding seam tracking have high requirements for the protection function of the visual system. The image processing algorithm is used to analyze and extract the features of the captured pictures. Accurately obtain the weld residual height and fusion width, as shown in Figure 11.

In the process of welding seam detection, firstly provide relevant parameters for the robot to automatically grind the welding seam, plan the robot grinding and polishing path, and drive the welding gun to cooperate with the visual sensor. Weld seam residual height and melt width information, process the captured images at high speed, extract the weld seam residual height and melt width information, evaluate the welding quality, and realize the intelligent and flexible welding process. However, due to the external interference in the welding process, the visual sensor needs to increase the protection function, meet a certain protection level, and be able to prevent splashing and self-cooling.

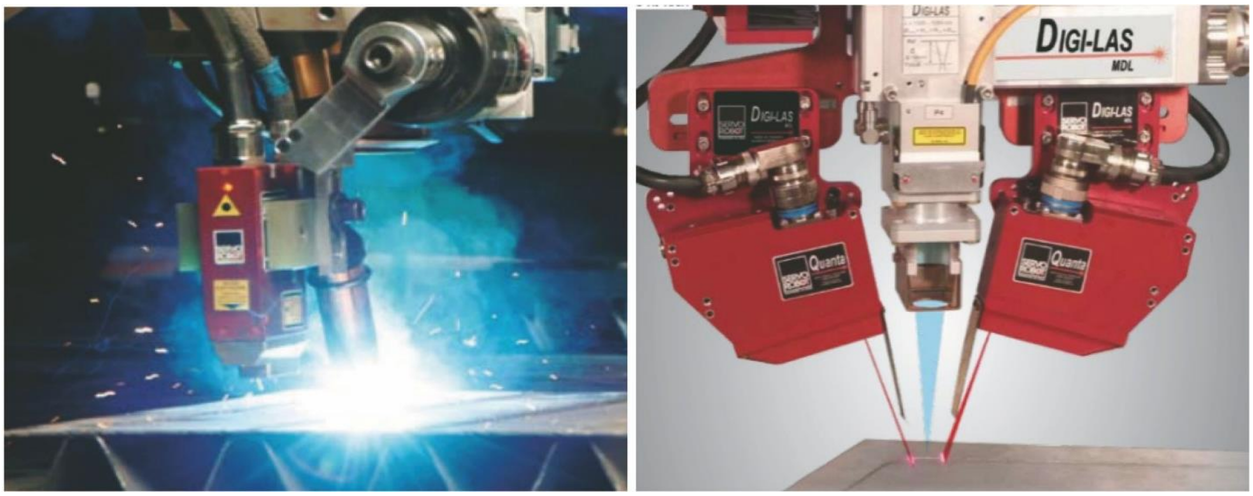

Figure 11. The process of welding-guidance.

4.2 Presence / absence Detection

Machine vision can also be applied to the quality inspection of automobile parts and the identification of related signs. It can help to improve production efficiency, enhance the degree of automation, and improve the reliability and traceability of the operation process. Specific applications include type identification and error prevention, such as top cover type identification, crossbeam, and front cover type error protection; presence/absence detection to ensure the integrity of parts, such as stud integrity detection; visual code reading to ensure that parts are manufactured throughout Traceability in the processor throughout the life cycle.

There are up to hundreds of studs in the car, and welding studs are different from conventional studs. Often due to fatigue wear of the torch guide jacket, setting the extension length (preload) and lifting distance is unreasonable, indirectly affecting the arc process of melting-mold pool solidification-welding seam formation leads to quality defects and then de-soldering, which affects the integrity of the stud [37].

Machine vision technology can be applied to automotive visual code reading technology. Reading or verifying character codes through visual sensors [38] can achieve traceability of parts in the production process and avoid production errors, as shown in Figure 12. In automobile manufacturing, visual code reading can realize various functions such as parts missing tracking, defect behavior tracking, and assembly wrong behavior proof. For example, tire companies need to use vulcanized labels for trace management of each tire and carry out comprehensive tracking.

The main method is to paste one-dimensional label barcodes within any range of the tire radius. An important part of the system (MES), the customer requires that the product can accurately read the barcode at any angle during the movement [38], and the high-performance one-dimensional visual sensor can collect the label barcode at high speed, and cooperate with the image processing algorithm Identification of tag codes.
Most of our tasks are depended on AI and ML and are solved by them. Personal information, financial information, health information, etc are also shared, stored and processed by the AI [39]. This study is intended to provide a deep understanding of the importance of privacy protection problems and the application of machine learning in this regard [39].

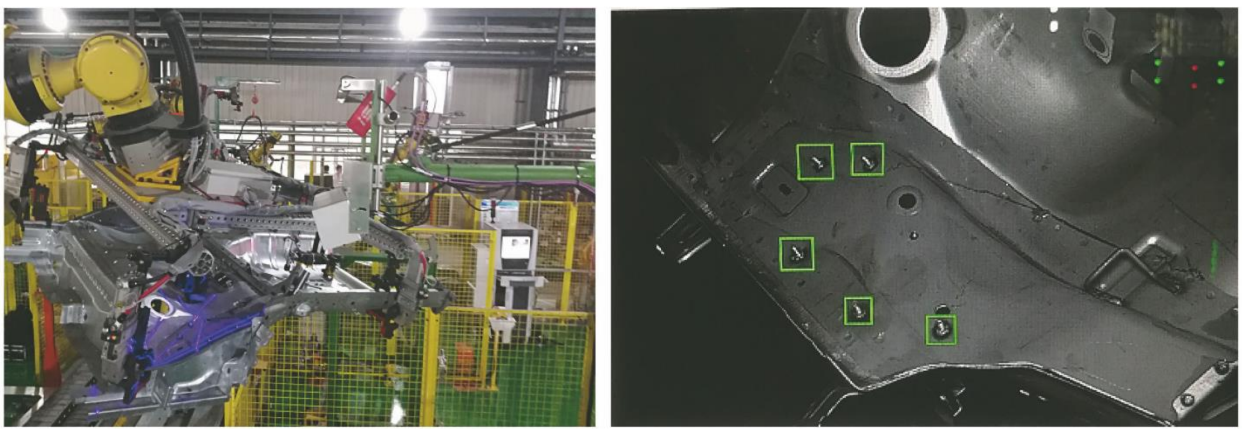

Figure 12. The process of stud detection and identification.

5. Conclusions

Machine vision has been widely used in various fields of modern industry, especially the automobile manufacturing industry. In the future, visual inspection technology and various visual products will be distributed in the entire automobile manufacturing line, escorting the entire body manufacturing process, and rapidly expanding to all links of the automotive industry chain. At the same time, with the development and maturity of technologies such as augmented reality, virtual reality, cloud services, and artificial intelligence, the information obtained by visual inspection in the future will interact with humans in multiple and multi-dimensional interactions, and detection will take many forms Interact with users. Moreover, with the wide application of visual inspection systems in manufacturing sites, the measurement data will become more and more huge. Correlating and analyzing the measurement data with the automobile manufacturing process can form a guiding opinion for manufacturing process improvement. The current vision technology has played a vital role in automobile manufacturing, and the future development space will be broader, and machine vision technology will become a "smart eye" to guide the higher, faster, and more stable era of the automation industry.

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