Application of character verification system in the tire industry

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Abstract: With tire manufacturing enterprises leveraging smart factories, they have broken through the traditional production mode of tire companies, adopting advanced technologies such as information communication, digital control, and intelligent equipment to gradually achieve the matching of people, materials, equipment, and location information. The character verification system is a kind of detection equipment in the tire production process, primarily used to improve the efficiency and accuracy of tire surface information processing, which is of great significance. This article proposes the concept, composition, and working principle of the character verification system device from multiple aspects such as the definition, classification, coding, and application of characters in tires. At the same time, it analyzes the practical application advantages and effects of this system in the tire production process. Through this system, the efficiency of management and production has been effectively improved, and human errors have been significantly reduced. However, there are also many problems in the use of this system that need further optimization and improvement to make it more intelligent.

Key words: character verification; 3D camera; robot movement; machine vision

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1 Current development status of the tire industry and research significance of the character verification system

1.1 Background introduction

Currently, tire production capacity has been steadily increasing, entering a phase where supply exceeds demand. However, the overall tire market demand is also growing steadily, driven by the continuous increase in global car ownership. The market demand for new energy vehicle tires is particularly prominent, requiring higher performance such as lower rolling resistance, better durability, and higher safety. The tire industry is undergoing technological innovation and industrial upgrading. The application of new materials and processes, as well as the promotion of advanced manufacturing technologies such as intelligent and green manufacturing, are improving tire performance and quality, reducing production costs, and promoting sustainable development of the industry.

1.2 Significance of the study

The application of character verification systems in the tire industry is primarily manifested in tire character recognition. Tire characters encompass crucial information such as tire size, tire type code, manufacturer details, production number, and load index. Before automobiles leave the factory, identifying the characters of the assembled tires can prevent incorrect assembly or inconsistency among the four wheels, ensuring the safety and compliance of the vehicles. Traditional methods of tire character recognition primarily rely on manual visual inspection, but this approach is time-consuming and inefficient. Furthermore, humans cannot maintain high accuracy for extended periods, making it difficult to ensure high reliability in quality control. Therefore, the introduction of character verification systems becomes particularly crucial.

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2 Overview of character argumentation system

2.1 Introduction to the usage environment of the character verification system

During tire vulcanization, the segmented mold and segmented blocks used may suffer from human errors or wear and tear. If the character detection of the first tire is not performed, it can lead to the same error in the entire batch of tires. Therefore, the first tire character detection system addresses this issue by replacing manual detection and reducing human oversight.

2.2 System composition

Mitsubishi PLC control system: logic control of the control system;

3D detection device: scanning and collecting 3D data, including 3D camera and laser;

Robot motion device: control the movement and rotation of 3D detection device;

Servo motor motion device: controls the rotation of the turntable;

Stepping motor motion device: control the opening and closing of the fixed roller;

Industrial switch: Provides a working local area network;

Host computer: the processing mechanism for loading software;

Main display: used to display the host computer program, with multi-touch function;

Micro display: used for displaying the status of control programs and performing point-to-point movements, with touch functionality;

Encoder: installed on the turntable drive gear, used to provide data acquisition signals for the 3D camera.

2.3 System topology diagram

The system topology diagram is shown in Figure 1.

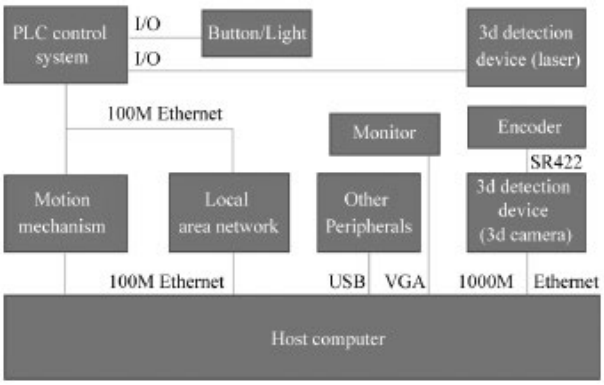

Figure 1 System topology diagram

2.4 Operating principle

2.4.1 Overall equipment diagram

The overall diagram of the equipment is shown in Figure 2.

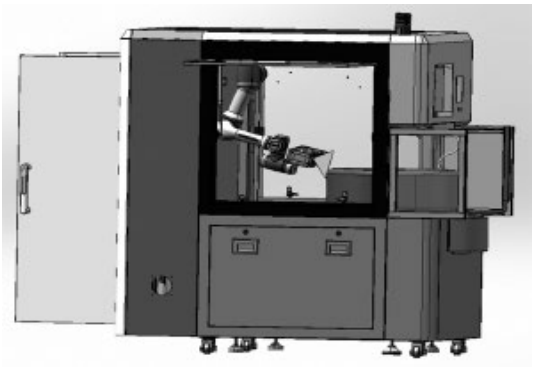

Figure 2 Overall view of the equipment

2.4.2 Operation area

The area for personnel operation system includes hardware buttons and software interaction. The left side is the main operation screen, responsible for displaying the detection software, while the right side is the auxiliary monitoring screen, assisting in status display and point control. The motion scanning area is used to place the tires to be detected. During operation, the robot drives the 3D camera sensor to move to the designated position, and then the turntable rotates. The sensor receives encoder signals to perform action scanning. The operation workbench is shown in Figure 3.

Figure 3 Operating workbench

3 Establishment of character verification system for tire formula data

Each time the first-tire character detection system conducts a test, there are two scenarios. If the system database does not contain a template for the specified specification, it is necessary to first establish such a template. The establishment process requires the use of 100% defect-free tires for 3D scanning to establish detection parameters. If a template for the specified specification already exists, one can directly select and use it for testing.

3.1 Understanding of interface control

Control various actions of the equipment through the manual interface: The controls on the left are the robot's control buttons, which allow for fixed-point movement, movement in different directions, change of movement speed, and resetting of the robot's status. On the right are other auxiliary action controls, including laser control, camera trigger control, fixed roller control, and constant speed and quantity rotation of the turntable. The operation interface is shown in Figure 4.

Figure 4 Operation interface

3.2 Process for storing the first tire information for character verification

3.2.1 Create/Modify Recipe

On the bottom left corner of the formula page, click the "Add Formula" button. By default, a formula with the current date as the name will be added. Note that a product formula includes both the front and back sides. When adding, it defaults to entering the front formula construction, but you can manually select the back side.

3.2.2 Alignment

In the first step of alignment, click "Auto Alignment", and the mechanism will automatically align according to the product size. Auto Alignment is to ensure that regardless of any changes in product size/position, the 3D camera can still maintain clear focus and within the scanning area. After auto alignment, each rectangular box indicates that the sensor will scan the area once. If there are multiple rectangles, the software will stitch the scanned images together. After auto alignment is complete, click "Step 2: Scan" to enter the scanning stage.

3.2.3 Scanning

In the second scanning step, click "Start Scan". The robot will control the sensor to move to the set position, activate the laser, and rotate the turntable to commence scanning the image. Upon completion of scanning, a progress bar will display the processing progress. After a brief moment, the scanning is finished, and the software interface will showcase the collected 3D data. The collected image is illustrated in Figure 5.

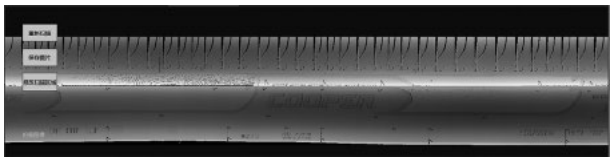

Figure 5 Acquisition image

Once the scanned image meets the requirements of being informationally complete and relatively clear, you can proceed to "Step 3: Recognition".

3.2.4 Recognition

In the third step of recognition, the goal is to extract the text and patterns on the tire sidewall and construct a template.

3.2.5 Record interface

The record interface contains a saved "Generate Report" list, and the recorded content includes: date, model (template name), positive detection result, positive detection report, negative detection result, negative detection report, and remarks information. Clicking the file icon can open the file for viewing. Double-clicking the remarks column of the record can modify the remarks information of that record.

3.2.6 Recipe Interface

Display the formulas currently stored in the system. Clicking on a formula will display the corresponding processing image. When detection is required, double-click the formula, and the system will load the formula and automatically switch to the detection homepage. Alternatively, you can obtain the specification number by scanning the barcode with a scanner.

4 Application advantages and effect analysis of character verification system in the tire industry

The character verification system, based on machine vision technology, utilizes a 3D camera to capture character information on the tire surface. Subsequently, it processes and analyzes the captured images using character recognition algorithms, thereby achieving automatic identification and verification of tire characters. This approach not only significantly enhances the efficiency and accuracy of tire character recognition but also saves considerable manpower and material resources. Specifically, the character verification system can identify and verify characters in real-time during tire production, ensuring that the character information of each tire meets standards and requirements. Additionally, the system can integrate with other equipment on the production line to facilitate automated production and quality control.

4.1 Improvement of production efficiency

Firstly, the character verification system utilizes advanced machine vision technology and OCR character detection technology to achieve precise and rapid recognition of tire characters. Compared to traditional manual visual inspection, this system significantly reduces inspection time and minimizes errors caused by human factors. Through automated recognition, workers on the tire production line can focus more on other critical tasks, thereby enhancing overall production efficiency. Secondly, the character verification system is capable of collecting and analyzing data during the production process, and can be integrated with other enterprise information systems to enable data sharing and interoperability. This enables enterprises to gain a more comprehensive understanding of production conditions and formulate more scientific production plans, thereby further improving production efficiency.

4.2 Reduction in production costs

Firstly, the character verification system has significantly enhanced production efficiency, enabling the rapid completion of character recognition and verification for a large number of tires, thereby reducing the need for manual operations on the production line. This not only cuts labor costs but also avoids errors and delays caused by human factors, making the production process more efficient and stable. Secondly, by accurately identifying characters on tires, the system effectively prevents issues such as incorrect assembly or inconsistent four-wheel alignment. This reduces additional costs associated with product defects, such as returns and repairs, enhancing product quality and customer satisfaction. Additionally, it can monitor anomalies in the production process in real-time, promptly identifying and resolving issues, thus avoiding potential production risks.

4.3 Enhancing market competitiveness

High-quality tire products often win the trust and favor of consumers. The application of character verification systems makes tire products more competitive in terms of quality and information accuracy. At the same time, by reducing errors and rework in the production process and lowering production costs, companies can price more competitively, further increasing their market share and enabling them to stand out in the fierce market competition.

5 Issues and challenges

5.1 Technical challenges that may be encountered in the application of character verification systems in tires

The technical challenges that character verification systems may encounter in tire applications mainly include issues such as size, difficulty in positioning, and low contrast. These challenges can lead to inaccurate character recognition, low efficiency, and even system failure. To address these issues, the following are corresponding solutions:

5.1.1 Technical challenge 1: Small size

Problem: The tire diameter ranges from 500 to 800 mm, while the size of the imprinted characters is relatively small, even down to the millimeter level, making it difficult for ordinary area array cameras to capture clear images.

Solution:Use a high-resolution camera: Choose a camera with high pixel count and high resolution to capture finer character details.

Optical magnification technology: Through special optical designs, such as using macro lenses or zoom lenses, the character area is magnified to obtain a clearer image.

5.1.2 Technical challenge 2: Difficulty in localization

Problem: The imprinted characters on the side of the tire

occupy a relatively small area, and the camera needs to move at high speed, making it difficult to capture the characters clearly and achieve local shooting.

Solution:Full tire imaging technology: Through high-angle ring light or 3D scanning technology, the entire tire surface is imaged, and then the character position is located through software algorithms

Dynamic tracking system: For rotating parts, robotic high-precision positioning, as well as high-pixel cameras and image processing technology, can be employed to track the position of characters in real time, ensuring accurate capture.

5.1.3 Technical challenge three: low contrast

Problem: The tire surface is black and freshly vulcanized, with no dust on the surface, making it relatively clean. This results in extremely low contrast between various parts, making it difficult for conventional cameras to distinguish the presence or absence of characters.

Solution: High-angle ambient lighting: By utilizing a specific light source design, the contrast between characters and the background is enhanced, making the characters more prominent.

Image processing enhancement technology: After image acquisition, software algorithms are used to enhance the image, such as contrast stretching and edge sharpening, to improve the character recognition rate.

5.2 Market acceptance and promotion of character verification systems in the tire industry

5.2.1 The system is gradually gaining attention and recognition from the market, and its market acceptance is steadily increasing

This is primarily attributed to the system's remarkable advantages in enhancing the accuracy of tire information, boosting production efficiency, and reducing error rates. However, due to the relatively new technology involved in the system, some tire companies may be cautious about its performance and stability, thus the market acceptance still needs further improvement.

5.2.2 Optimize after-sales service and technical support

Establish a comprehensive after-sales service system and technical team to promptly respond to the needs and issues of enterprises. By providing excellent after-sales service and technical support, we aim to enhance the trust and loyalty of enterprises, and promote the widespread application of the system.

6 Conclusion and outlook

With the continuous advancement of artificial intelligence and machine vision technology, the recognition accuracy and speed of the character verification system will be further enhanced. Simultaneously, the system will become more intelligent, capable of automatically adapting to character features of different specifications, and reducing the misrecognition rate. In the tire warehousing and logistics processes, this system can automatically identify tire information, enabling rapid and accurate inventory management for inbound and outbound operations. This aids in enhancing the efficiency of warehousing and logistics, and reducing operational costs. The system holds vast potential application prospects in areas such as tire traceability and anti-counterfeiting, intelligent warehousing and logistics, customer service, and after-sales support. As technology continues to advance and application scenarios expand, this system will bring a more efficient and intelligent production and service experience to the tire industry.