Floating glass on-line detection system based on defect feature maximum value method

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Abstract. This paper designs a glass defect online detection system based on ARM and DSP dual-core processor. The system is based on ARM LPC2200 and TMS320C6416 DSP chip, and the peripheral functional modules form the hardware. This paper also designs the extraction and analysis algorithm of defect information. This algorithm uses the defect feature maximum value method to complete the detection of the size, area, location and properties of glass defects. The experimental results have broad development prospects and practical value in the field of glass industry production.

1. Introduction
In the production process, glass produces various defects such as bubbles, streaks and stones. In general, a large number of obvious defects are not allowed in the glass, otherwise it will affect the appearance quality of the glass. It also reduces the uniformity, light transmission and mechanical strength of the glass, resulting in a large amount of waste and defective products. At present, China does not have a good automated detection method for glass defects[1]. This paper introduces an on-line glass defect detection system based on ARM and DSP processor, which can automatically detect, mark and optimize cutting of glass defects.

2. Architecture Design of On-line Detection System for Float Glass Defects
The system consists of illumination source and optical system, linear array CCD image sensor and its driving circuit, embedded video acquisition and compression system based on ARM and DSP, defect marking circuit and marking mechanism, and glass optimized cutting mechanism. Among them, the embedded video capture compression system is the core part[2].

During the production process, the system uses a CCD camera to detect the flat glass on the assembly line. The captured image signal is converted to an analog video signal by an amplifier and a sample and hold circuit. This signal is processed by a dedicated video AD converter SAA7114H to obtain a digital image signal conforming to the CCIR.601 standard. The image size is 720 × 576, 25 frames / sec (PAL system) or 720 × 480, 30 frames / sec (NTSC system).

The signal is compressed into a standard-compliant data stream by a high-speed C6416 DSP, and then transmitted to the embedded microprocessor chip ARM LPC2200 through the xBUS of the DSP. Data is packaged via the TCP/IP or UDP/IP stack of the embedded operating system µcLinux. The digitized image information will be subjected to preprocessing, image segmentation, image analysis, and template matching in sequence[3]. The system automatically detects, identifies and classifies the defected glass, and sends a control signal to the defect marking circuit and the glass optimized cutting.
mechanism according to the obtained detection result, marking the defect and optimizing the cutting, thereby obtaining high quality glass. In addition, the client can remotely access via the Internet, such as real-time monitoring, issuing control signals, and so on. The system schematic is shown in Figure 1.

Figure 1. The system schematic

3. System hardware design
The entire video compression system can be divided into six parts: video AD input decoding module, main processor module, DSP memory module, embedded microcontroller module, microcontroller memory module, power module. Its principle block diagram is shown in Figure 2.

The video AD input decoding module mainly includes the SAA7114H video AD converter and its associated FIFO AL440B. The function of this module is mainly to receive the analog video signal collected by the CCD camera, convert it into a digital video signal conforming to the CIR.601 standard, and then transmit it to the DSP for further compression and coding through the buffer FIFO[4].

The main processor module consists of the TMS320C6416 DSP and the EPM7128S CPLD. The C6416 DSP implements compression encoding processing of video data, while CPLD mainly performs timing control between video AD and FIFO, FIFO and DSP. In addition, the system connects to the embedded chip through the xBUS slave mode of the C6416 DSP, and transmits the compressed data to the microcontroller module.

The embedded microcontroller module uses the ARM 32-bit RISC processor LPC2200, which packages and compresses the DSP compressed video stream to the Ethernet through the network protocol stack. The microcontroller's memory module uses 2MB of Flash to store the bootloader and operating system code. In addition, in order to speed up the system, 16MB SDRAM memory is expanded.

4. Design of defect detection algorithm
In the design of this system, the use of efficient algorithms to extract, analyze and transmit the defect data is one of the keys of the system.

4.1. Design of defect extraction software
The extraction of the defective pixel information is selective, that is, the normal pixel is not processed, but only the defective pixel is extracted, and the pixel gray value and the positioning value need to be recorded [5].

According to the accuracy requirements, the CCD is set to have a line scan frequency of 5461 Hz and a data rate of 400 MHz. In a row scan cycle, each digital output of the CCD outputs 7680 8-bit data, corresponding to 4096 actual pixels. So there are 7680 idle periods in each row scan cycle. These idle periods consist of exposure time and wait time.

The defect grayscale threshold is set according to the actual situation. According to the detection accuracy to reach the requirements of 0.1mm, that is to say the defect is judged to be accurate to each pixel. When there is a defect, the defect grayscale threshold value may be set to be greater than or less.
than the normal pixel dot grayscale value of 10 or more.

4.2. Design of defect data analysis software

The data is extracted based on the grayscale features of the defect. Based on these data, we analyze the number, size, location, area, and type of glass defects. According to the experience of the production line, as well as the building-grade glass qualification standards, the diameter of the largest point defects that can occur on the glass plate should be less than 5 mm, and the distance between the defects should be greater than 5 mm. In this case, the following assumption can be made: the maximum defect is 5 mm, and the minimum defect distance is 5 mm [6]. When testing each glass of a certain length, we open up a certain number of arrays of defects. More defects than this number can be considered too many defects, the system issues an alarm. When the defect is below this quantity standard, the system will perform a detailed inspection of each defect.

Here is a method of first sorting and then analyzing. According to the feedback information on the production line, even if the point defects are the densest, the distance between the defects is greater than 5 mm. Therefore, the division of defect data can be performed using the distance-based sorting idea. The basic idea is shown in Figure 4.

![Figure 2. Flow chart of defect data analysis](image)

The three eigenvalues of one pixel are taken from the defect matrix and placed in the matrix of defect 1. Then take the second pixel and calculate its distance from the last sorted pixel in defect 1. If the distance is less than 5 mm, it is considered to be the data of defect 1, and it is placed in the matrix of defect 1. If not, then consider it to be another defect 2 data, we open up a matrix and put it in.

Then we take the third pixel and calculate its distance from the last sorted pixel in defect 1. If it is less than 5 mm, it is considered to be the data of defect 1 and is put into the matrix of defect 1. If not, then consider it to be another defect 2 data, if yes, put it into the matrix of defect 2, if not, continue to compare with the next one......

This method embodies the idea of a query: each time a pixel is taken, and then it is sequentially queried from defect 1 to defect n. Judging is based on whether the pixel distance is less than 5 mm.

We analyze defects by knowing its location, size, area, and type without knowing what shape it is. Its position can be determined by its centroid. Its diameter can be calculated from the maximum values of the abscissa and the ordinate. The area of the defect can be obtained from the number of defective pixels. The biggest difference between bubbles and stones is the difference in gray values. The maximum gray value of the bubble is close to or greater than the normal value, and the minimum gray value is less than the normal value. The maximum gray value and the minimum gray value of the stone are much smaller than the normal value. These basic features are related to their extremum and can be
derived directly from the relevant extremum. Through this algorithm, we can greatly reduce the amount of calculation without losing key information. Therefore, the algorithm calculates the size, area, nature and location of the defect based on the maximum value of the coordinates and the maximum value of the pixel gray scale.

5. Data processing experimental research
Various experiments on glass images are performed through embedded data processing modules, including verification of defect extraction and analysis algorithms, and verification of online real-time processing capabilities.

In the experiment, the glass image data was input line by line into a single camera data processor module. Each pixel represents an actual glass length of 0.1 mm.

Bubble defects are shown in Figure 3. Its horizontal width is approximately 42 pixels.

![Figure 3. The bubble defect map](image)

After the defect extraction algorithm is applied to Figure 3, the obtained bubble defect data is as shown in Table 1.

| Defect data | X coordinate | Y coordinate | grayscale value | X coordinate | Y coordinate | grayscale value |
|-------------|--------------|--------------|----------------|--------------|--------------|----------------|
| 297         | 136          | 133          | 297            | 151          | 37           |
| 298         | 136          | 132          | 324            | 152          | 21           |
| 301         | 136          | 131          | 288            | 152          | 25           |
| 308         | 136          | 128          | 284            | 154          | 11           |
| 306         | 139          | 39           | 295            | 150          | 16           |
| 310         | 159          | 46           | 250            | 161          | 24           |
| 288         | 140          | 55           | 281            | 162          | 16           |
| 294         | 140          | 44           | 325            | 162          | 99           |
| 306         | 141          | 54           | 299            | 163          | 41           |
| 238         | 149          | 2            | 259            | 163          | 45           |

After the DSP processing, the obtained processing results are shown in Table 2.

| Nature | Diameter | Area | Position |
|--------|----------|------|----------|
| bubble | 42       | 1409 | (303, 153) |

The processing module completed the detection of a bubble having a diameter of 4.2 mm, which required 23.6 milliseconds. At a running speed of 500 mm/s, the glass conveyor belt traveled 11.8 mm forward during the processing period. The analysis accuracy of the defect reached 0.1 mm[7].

6. Summary of the experiment
Under experimental conditions, the embedded data processing module processes the glass image every
100 milliseconds. It can correctly identify glass defects within 100 milliseconds, analyze features such as defect location, diameter, size, and nature, and notify the host to read the data. It also allows enough time for the host to mark, display, optimize the cutting and other subsequent operations, achieving real-time processing requirements[8]. Through experiments, we not only verified the feasibility of the data processing method, but also verified the correctness and real-time of the defect extraction and analysis algorithms.

Therefore, the detection system data processing module is designed to meet the online inspection requirements of glass conveyor belts with a maximum speed of 500 mm/s. If a higher performance DSP chip is used, the processing speed of the system can be increased by more than 5 times, which can fully meet the requirements of higher detection speed.

7. Conclusion
In this paper, the traditional PC-based glass defect detection system is studied, and the design scheme of glass defect online detection system based on ARM and DSP processor is proposed. This paper also studies the key technologies of acquisition, processing and defect classification of massive glass image data, and designs the extraction and analysis algorithms of defect information. This algorithm uses the defect feature maximum value method to complete the detection of the size, area, location and properties of glass defects.

In this paper, the feasibility of the design scheme and the correctness and real-time of the data processing method are verified by experiments. The experimental results have broad development prospects and practical value in the field of float glass production.

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