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High Precision Measurement System of Micro-electronic Connector based on Machine Vision

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Abstract: Micro-electronic connector is widely used in electronic products and electrical equipments. The traditional quality detection method for micro-electronic connector relies on manual inspection, which is inefficient and susceptible to subjective factors. A high precision measurement system of micro-electronic connector has been developed based on machine vision in order to improve detection efficiency and measurement accuracy. Firstly the system architecture for high precision measurement is presented. Then the segmented image acquisition by cameras is introduced and unique ROI setting function of this system can realize the detection and measurement for various types of micro-electronic connectors. Finally an algorithm based on image processing is designed to achieve seamless splicing of segmental images. The experiments have proved the defect recognition rate of proposed system can surpass 95% and the measurement accuracy reaches 0.007 mm. The system performance can meet the high precision measurement requirements of micro-electronic connectors. Therefore this high precision measurement method can save the human resources and ensure the quality of micro-electronic connectors.

Key words: Machine vision, micro-electronic connector, precision measurement, region of interest

INTRODUCTION

With the rapid development of digital electronic technology, micro-electronic connector is widely used in electronics and electrical equipments, it can be greatly improved the production and maintenance efficiency of electronic products. However, since the plug-in type of connections are heavily used, the reliability of connection and resistance of contact points are more and more important for the quality of electronic products, therefore, the quality of micro-electronic connectors will directly affect the quality of electronic equipments. At present, most of micro-electronic connector manufacturing enterprises (including foreign-funded enterprises) are still labor-intensive mode of production in China, product quality detection in the manufacturing process is usually completed by specialized quality inspection worker. The manual inspection is high labor-intensive, high cost and low detection efficiency, it has seriously hindered the enterprises to improve product quality, reduce production costs and enhance the market competitiveness. Machine vision detection technology is the effective measures to solve this difficult problem (Park *et al*., 2011; Li *et al*., 2010; Cubero *et al*., 2011). Therefore, research and development of machine vision inspection system and its technology has a huge market value and application prospect.

After long-term development, machine vision has already been very mature in abroad (Chapman *et al*., 1990; Gordon and Novotny, 2012). Machine vision is mostly used in electron and semiconductor fields and roughly 40-50% is concentrated in semiconductor fields. In terms of electronic connector detection, foreign mature method is that the electronic connector is assembled on the instrument to collect data information and find faults. Aoyagi *et al*. (2009) put forward a practical automatic detection system, the system was used to detect whether a special waterproof soft shell of electronic connector and auto sliding locking devices were completely connected, then collect and analyze data information through miniature microphone, amplifier, a variety of power process and so on. Sun and Hong (2000) from Shanghai Jiao tong University, applied machine vision technology in the electronic connector manufacturing stamping stage, they detected quality defects on the shape of pins by matching the position information of target parts (including edge coordinates and starting corner) to the standard template parts. Meanwhile, some high-tech enterprises have made some molding equipments for the quality detection of electronic connectors but due to the small size of micro-electronic connector, low detection efficiency and high cost, various types of electronic connectors can't be online detected in the same device and the detection

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effect which is just relied on a single image of micro-electronic connector can't already meet the requirements of measurement accuracy.

Aiming at the existing problems in quality detection of micro-electronic connectors, a high precision measurement system of micro-electronic connectors is designed based on machine vision to improve the detection efficiency and measurement accuracy and the system also can eliminate defective products at the same time.

SYSTEM ARCHITECTURE

The high precision measurement system of micro-electronic connectors is automated non-destructive detection equipment based on machine vision, it mainly consists of the light source, industrial CCD cameras, lenses, frame grabbers, PLC controller, IPC (Industrial Personal Computer), subdivision bench, driver, position sensor, solenoid valves, eliminating mechanism and visual measurement software and other components.

The schematic of vision measurement system is shown in Fig. 1. Firstly, PLC controls subdivided bench's movement by driver, then the subdivision bench will trigger position sensors and the signals generated by position sensors are transmitted to the two area array CCD cameras, the images of micro-electronic connector in subdivision bench would be collected by cameras, segmented image acquisition can be realized through the intermittent motion of subdivided bench. Secondly, the images collected by cameras will be sent to IPC through frame grabber, detected and measured in turn by visual measurement software. Finally, the detected results are transmitted to PLC controller by IPC, the eliminating mechanism is controlled by the solenoid valve to eliminate unqualified micro-electronic connectors and trigger fault alarm.

IMAGE PROCESSING AND ROI SETTING

The vision measurement software is an important component of this system, it is developed in Visual C++. The software based on OpenCV (Open Source Computer Vision Library) (Bradski and Kaehler, 2008) can be used to extract and recognize the ROI (Region of interest) of various types of micro-electronic connectors.

Processing of segmented images: The software system consists of image acquisition, image preprocessing, ROI setting, global threshold segmentation, open computing, data traversing analysis, data integration analysis, defects recognization, database updates, defects elimination and other modules. The processing of segmented images is as follows. Firstly, the module of image acquisition will get the segmented images from image acquisition card and the segmented images are sent to the image preprocessing module. Then the segmented images will be set the ROI in the ROI setting module and the ROI of segmented images are segmented by the modules of threshold segmentation and open computing, then the ROIs will be sent to the data traversal analysis module to extract and analyze features, the results are temporarily stored in the data buffer of segmented measurement. Finally, all the results will be integrated, the system determines the defective

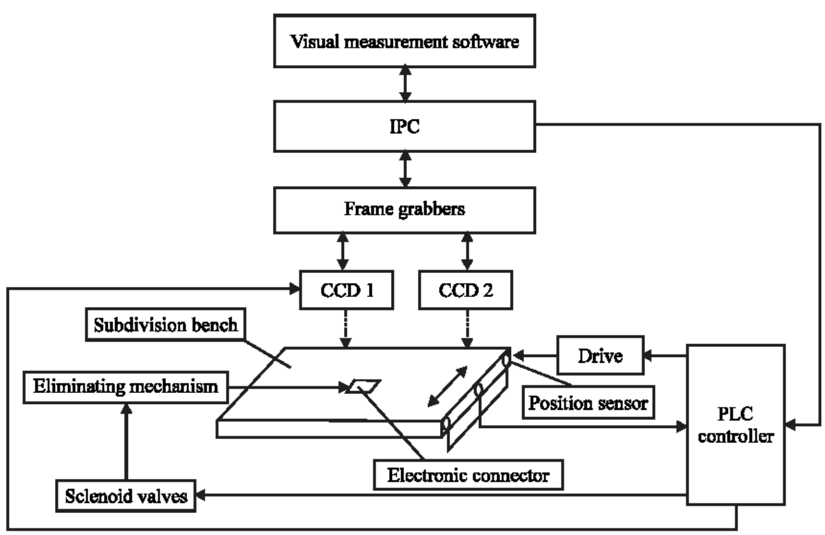

Fig. 1: Schematic of vision measurement system

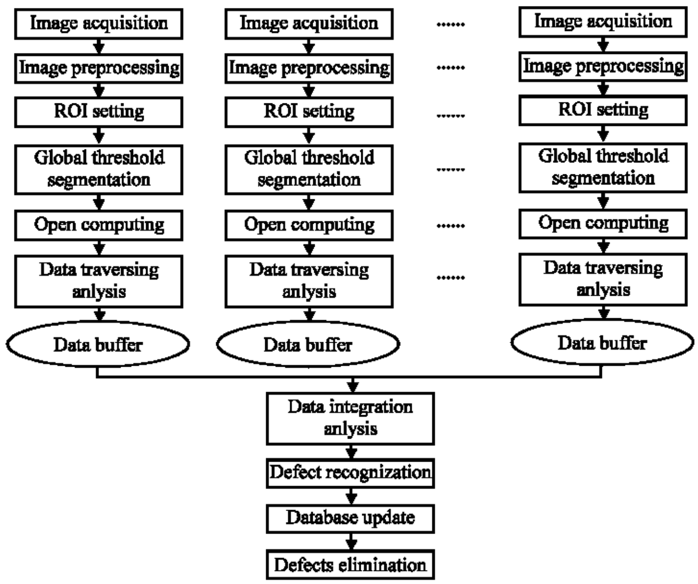

Fig. 2: Flow chart of segmented image processing

segmented images and saves the defect information to the database and the system accurately controls subdivision worktable movement and eliminates substandard products according to users' requirements. The flow chart of segmented image processing is shown in Fig. 2.

Image preprocessing: According to the system requirements, noise caused by uneven illumination or others should be eliminated, so it's necessary to preprocess the images. Since the system is mostly encountered Gaussian noise and a small amount of salt-and-pepper noise. Median filter (Deka and Choudhury, 2013) is a kind of linear filter, its main method is weighted average method and has well filtering effect for Gaussian noise. The experiment shows that the processing speed of median filter is obviously faster than other filters. Therefore, the median filter is applied to eliminate noise in this system.

ROI setting: In image processing field, ROI (Chen *et al*., 2012) selected on an image is the focus of the image analysis region for further processing, it can reduce processing time and increase measurement accuracy of image.

According to user needs, it needs to detect and measure various types of micro-electronic connectors on the same application platform. The vision measurement software adds the function of setting ROI, which is similar to Auto CAD, users can use the mouse to directly draw a (or multiple) rectangular region (namely ROI) and set the corresponding detection type for each ROI, then this software can realize automatic detection and measurement of each ROI. The ROI setting effects of various types of micro-electronic connectors are shown in Fig. 3 (the red rectangle is the ROI).

ALGORITHM DESIGN OF IMAGE STITCHING

The specific dimensions and tolerances of FPC series connector are shown in Fig. 4.

Since the size of connector pin is very small, in guarantee the images without distortion, the images are needed to be enlarged several times to enhance the image details. After debugging, the maximum field range of camera is adjusted to 15mm. In order to guarantee each connector pin in effective detection range, therefore the middle field range value 8mm is taken as the effective detection range. Since the total length of the connector is 23.5mm, integer length is 24 mm, so the number of detections N:

$$N = \frac{L}{P} = \frac{24}{8} = 3 \tag{1}$$

Therefore, the image of single connector is needed to be divided 3 segments to detect in order to greatly improve the measurement accuracy. FPC series connector generally has 30 pins. Assume that each pin from left to right are numbered for the p_0, p_1, p_2,..., p_{29}, the pin range of the first section image S_1 is selected as $\{p_0, p_1, p_2,......, p_{10}\}$, the pin range of the second section image S_2 is selected as

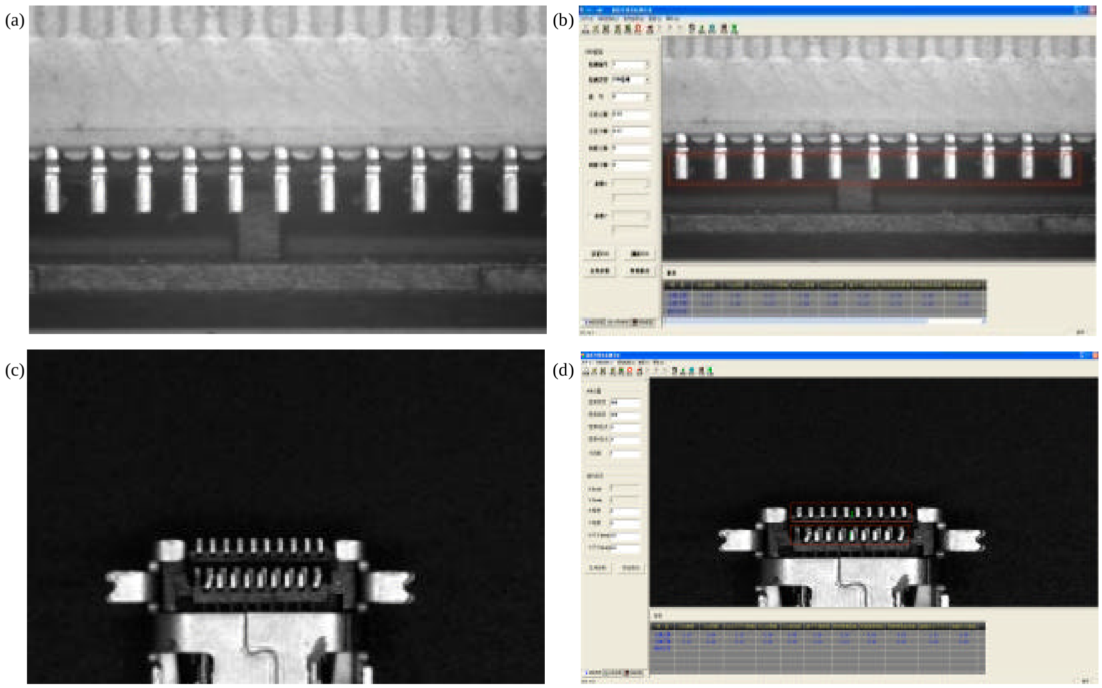

Fig. 3 (a-b): ROI setting effects of various types of micro-electronic connectors, (a) ROI setting effect of FPC series and (b) ROI setting effect of USB series

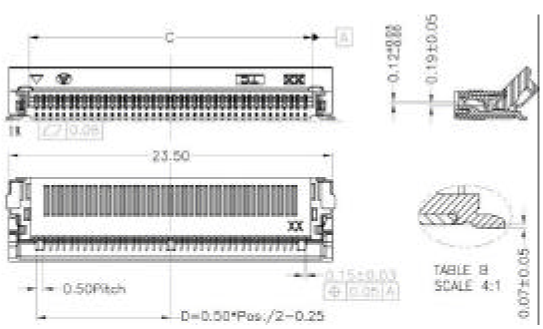

Fig. 4: Specific dimensions and tolerances of FPC series connector

$\{p_{10}, p_{11}, p_{12},\ldots\ldots, p_{20}\}$, the pin range of the third section image S_3 is selected as $\{p_{20}, p_{21}, p_{22},\ldots\ldots, p_{29}\}$. It can be seen that the overlap pin between S_1 and S_2 is p_{10}, the overlap pin between S_2 and S_3 is p_{20}, while the overlap pins p_{10} and p_{20} are taken as the coincident points of the three images.

The three connector images would be set ROI, then preprocessed and segmented in ROI, respectively. The binarized image edge of each pin is extracted as a 2D point set for further processing. For a given 2D point set, the function cvMinAreaRect2 () is used to establish convex shape and rotate shape to look for the minimum area rectangle (Dong *et al*., 2013). Where the return value of 2D box is defined as follows:

```
struct CvBox2D
{
 CvPoint2D32f center;//The center of box
  CvSize2D32f size;//Length and width of the box
  float angle;//The angle between horizontal axis and the first edge, in radians
};
```

Three equations can be obtained by Fig.5:

$$pt[1].x-pt[0].x = width*\sin(angle) \quad (2)$$

$$pt[2].x-pt[1].x = height*\cos(angle) \quad (3)$$

$$pt[2].x-pt[0].x = 2\,(box.center.x-pt[0].x) \quad (4)$$

The x value can be solved through simultaneous equations. Similarly, the solution of the y value is also true. According to the demand point pt[0], pt[1], pt[2],

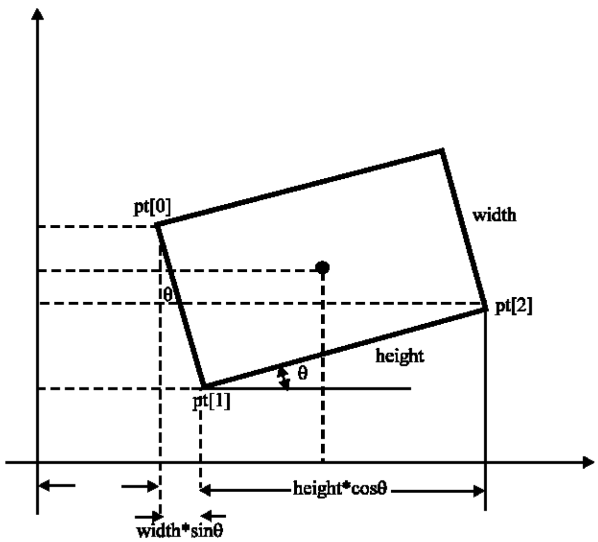

Fig.5: mathematical model of minimum area rectangle

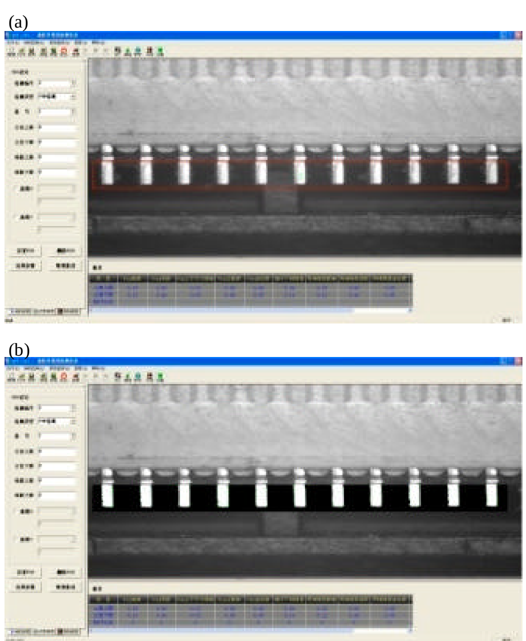

Fig. 6: Recognization effect of pins, (a) the original image of pins and (b) the detected image of pins

pt[3], the function CvBox2D () is called to draw minimum area rectangle. The recognition effect of pins is shown in Fig. 6.

Finally, the center coordinates of the rectangle:

$$cp\ (\frac{(pt[1].x+pt[2].x)}{2},\ \frac{(pt[0].y+pt[1].y)}{2})$$

Table 1: Center coordinates of pins in the three images

Segment No.	Pin No.	Center coordinates/pixel
1	0	(2247.000000, 112.499985)
	1	(2025.321167, 113.730347)
	…	…
	9	(300.682251, 114.468529)
	10	(84.086563, 110.828262)
2	10	(2276.871338, 110.859039)
	11	(2056.931641, 106.318588)
	…	…
	19	(319.375549, 109.943161)
	20	(102.704590, 105.423874)
3	20	(2267.901123, 105.461960)
	21	(1850.867065, 101.865615)
…	…	
	29	(112.500000, 106.000000)

corresponding to each pin can be calculated. Assume that the center coordinates of the rectangle corresponding to each pin $\{p_0, p_1, p_2, \ldots\ldots, p_{29}\}$ from left to right are numbered for the {cp[0], cp[1], cp[2], ……, cp[29]}.

According to each pin in the relative position of each image, the ordinate of the center coordinates of pin p_{10} in the image S_2 is very close to the ordinate of the center coordinates of pin p_{10} in the image S_1, the ordinate of the center coordinates of pin p_{20} in the image S_2 is also very close to the ordinate of the center coordinates of pin p_{20} in the image S_3.

Namely:

$$S_2 : cp[10].y \quad \rightarrow \quad S_1 : cp[10].y \tag{5}$$

$$S_2 : cp[20].y \quad \rightarrow \quad S_3 : cp[20].y \tag{6}$$

The center coordinates of each pin are shown in Table 1. The table shows that the pin p_{10} in the images S_1 and S_2, respectively meet the above conditions, the pin p_{20} in the images S_2 and S_3, respectively also meet the above conditions and both within the allowed error range, so it can be concluded that these pins are overlapping, respectively. Thus, the center coordinates of pin p_{10} and p_{20} in the image S_2 should be taken as splicing point for the three images, the three images would be connected from left to right in turn to realize the whole picture of seamless splicing.

The measurement data analysis of pins which have been spliced is shown in Fig. 7, where the red line represents the permissible error range of the measured value (including pin size and spacing, etc.) and the blue line represents the measured value curve of pins. The figure shows that the measured value of each pin is within the allowed error range, meets the requirements of measurement precision.

EXPERIMENTAL ANALYSIS

The software developed with visual C++ runs to process grabbed images and analysis

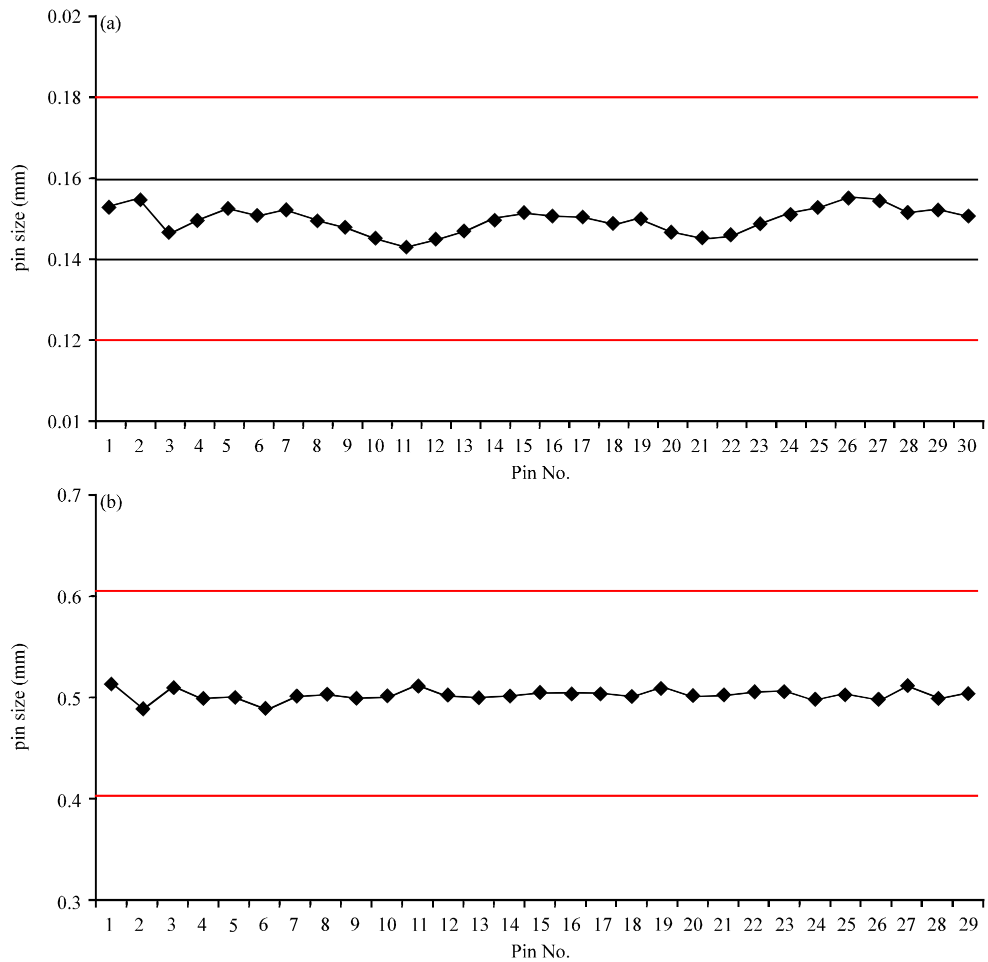

Fig. 7(a-b): Measurement data analysis chart of pins (a) Measured results of pin size and (b) Measured results of pin spacing

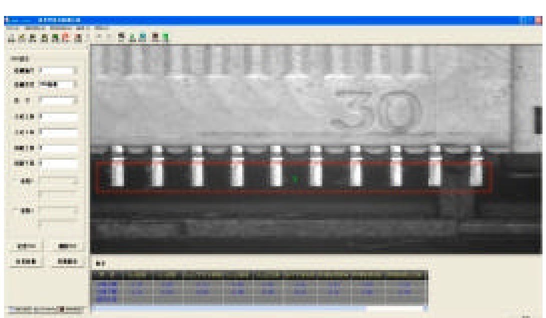

Fig. 8: Interface diagram of system operation

results are recorded into Access database. The detection interface is dumped in Fig. 8.

There are several major breakthroughs in the following aspects:

- Machine vision detection replaces traditional artificial detection, it realizes the automated detection and measurement of micro-electronic connectors and makes artificial sampling upgrade to full inspection. In addition, the unqualified products can be automatically eliminated by the eliminating mechanism
- The intermittent motion of subdivision bench is used to segmented detect the images of micro-electronic connectors in order to improve the measurement accuracy
- According to customer-defined ROI, vision measurement software can be reconstructed to suit various types of high precision defect detection and measurement for micro-electronic connectors

CONCLUSION

High precision measurement system of micro-electronic connector is automated non-destructive detection equipment, which is a collection of mechanical, electronic, optical, computer, software engineering. The speed of system is up to 10 pieces/min, more than the speed of artificial detection; the measurement accuracy is 0.007 mm, defect recognition rate is surpass 95% and the system is suitable for various types of micro-electronic connector detection and measurement. This system compared with traditional detection method has greatly improved the quality of micro-electronic connectors and obtained good economic benefits.

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