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3D Precise Inspection of Electronic Devices by Single Stereo Vision

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Abstract

It is very important to guarantee the quality of the industrial products by means of visual inspection. In order to reduce the soldering defect with terminal deformation and terminal burr in the manufacturing process, this paper proposes a 3D visual inspection system based on a stereo vision with single camera.

It is technically noted that the base line of this single camera stereo was precisely calibrated by the image processing procedure. Also to extract the measuring point coordinates for computing disparity; the error is reduced with original algorithm. Comparing its performance with that of human inspection using industrial microscope, the proposed 3D inspection could be an alternative in precision and in processing cost. Since the practical specification in 3D precision is less than 0.02 mm and the experimental performance was around the same, it was demonstrated by the proposed system that the soldering defect with terminal deformation and terminal burr in inspection, especially in 3D inspection, was decreased.

In order to realize the inline inspection, this paper will suggest how the human inspection of the products could be modeled and be implemented by the computer system especially in manufacturing process.

1. Introduction

It is indispensable to prepare for the spreading variations in product design and for the shortage in product life cycle, under the changing circumstances of portable phone, PC, and several electronic devices. Accordingly the inspection of the electronic devices must be shorten in development period, must be enforced in precision and also be refined in size.[1],[2],[3] Therefore image processing is becoming one of the important key technologies in this field.

This paper proposes a flexible image processing system for the inspections of electronic device's terminal lead such as small size connectors implemented on general purpose PC. [4],[5],[6]

In the real production line, inspection of electronic devices is categorized into two basic categories: visual inspection and size measurement. The former is a task for replacing human visual inspection and the latter is one for replacing human works using special measurement equipment. In order to introduce 3D measurement for the 3D form of the electronic devices of which form is complicated, and to introduce high precision measurement, an optical probe system or the optical cutting method are normally used for these 3D measurements.[7] However, the laser apparatus for lighting is needed and it will become an expensive and complicated system.

To do this in our research, we propose an inspection environment for realizing not expensive and highly precise 3D measurement scheme and its algorithm.

2. The necessity for 3D measurement

Figure 1 show the soldering state of a terminal lead, which consists of copper alloy. Since the size of the device and the number of terminals are not always fixed, inspection system must cope with the variations both in size and in number, and must cover 3D measurement supplemental to 2D measurement.

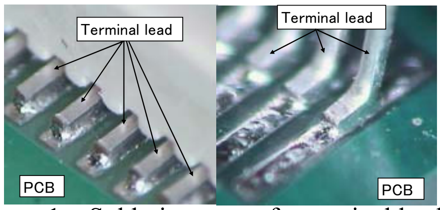

Figure 1. Soldering state of a terminal lead

Since the 2D measurement of the terminal lead with the deformation or terminal cutting burr that is difficult to extract only from the appearance information, it is necessary to measure the distance between the camera and a terminal's measurement point by stereo system. In order to detect simultaneously the deformation, bend, garbage adhesion and terminal burr as shown in Figure 2, 3D measurement is essential. The appearance of the defect of the terminal lead cannot be recognized from the direction shown as "B" in Figure 2. It is necessary to measure the 3D shape using the image information seen from the observable direction "A". Therefore, the system which performs 3D measurement and measures the distance is required.

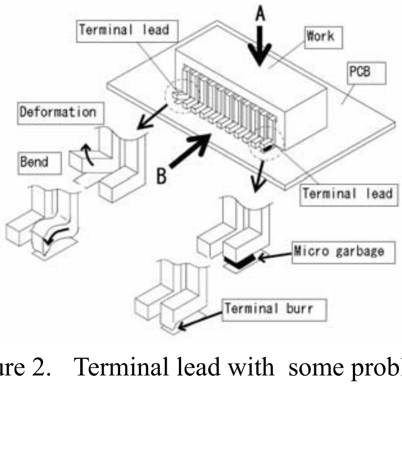

Figure 2. Terminal lead with some problems

3. Proposed method

In order to realize the function of stereo views with single camera, a mechanism shown in Figure 3 was fabricated, where a camera is fixed and the work is set movable along with the feeder, and the left and right stereo images were captured at the respective moment before and after the mechanical feeder motion. The base line was precisely calibrated by using the corresponding feature points extracted from these two images.

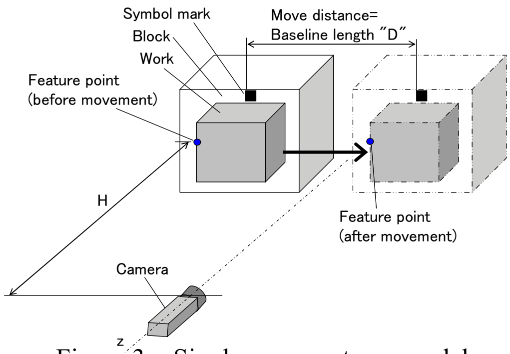

Figure 3. Single camera stereo model

Primal feature points can be extracted from the upper surface of the terminal lead, and these feature points can be utilized to detect the defects by measuring the respective distance between the point (h①, h②, …, h④ in Figure 4) and the camera along the edge of the terminal lead.

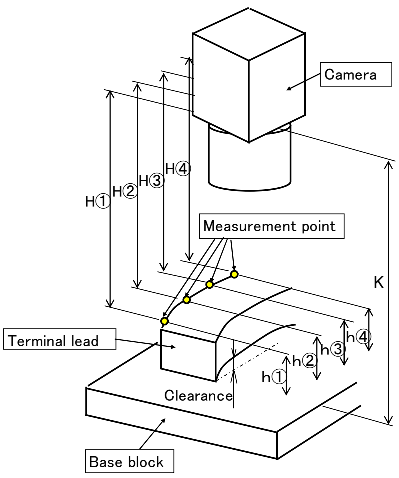

Figure 4. Inspection method model

4. The unstable element and measurement method of inspection

4.1. Why base line must be concurrently adjusted

At every time when the device feeder stops around in front of the camera, the feeded distance must be exactly measured, because the mechanical feeder does not perform so sufficient in precision that the base line length can be estimated. In addition, the device on the feeder is likely to fluctuate both horizontally and vertically.

In order to cope with these situations, we installed a hardware equipment not to suffer from the mechanical vibration, and we developed a software countermeasure to estimate the exact base line length by the image processing technique. The details of the algorithm will be presented in the next chapter.

4.2. The method of measuring point extraction

Accuracy is extremely important in the extraction of a measuring point in this system. An accurate measurement of the reference point of the device must be realized from a pair of stereo images in order to measure the real length of the movement of the feeder as the base line length.

Relative stabilization of the feeder motion For providing the accurate length of the base line, it is necessary to compensate the position variations of the mechanical control of the feeder due to the inertia of the feeder. Then we introduced the following countermeasure based on an image processing method applicable to a set of stereo images:

1) First let the symbol mark of the block stage be extracted.
2) Then let the coordinate system of the respective device be generated at the mark as an origin.
3) Step 1) and 2) are repeated at every motion of the feeder.
4) Let the difference of a pair of origins be calculated as the length of the base line.

Measurement points extraction Feature points are extracted from a pair of stereo images for providing the stereo correspondence by the following procedure:

1) A small local region is prepared for the intensive image processing based on the origin preliminary extracted.
2) Edge image is extracted from the small local region by using Laplacian-Gaussian processing.
3) In order to extract the local coordinate system on the device, a pair of perpendicular straight lines shown in Figure 5 is extracted from the edge image by RMS line fitting procedure.
4) Let the crossing point of these fitted lines be the origin of the local coordinate system of this device.
5) The circle of arbitrary radius and the intersection of RMS line centering on the origin are considered as the position of the feature point extraction (Figure 5).
6) All edge points are represented again based on this local coordinate system.

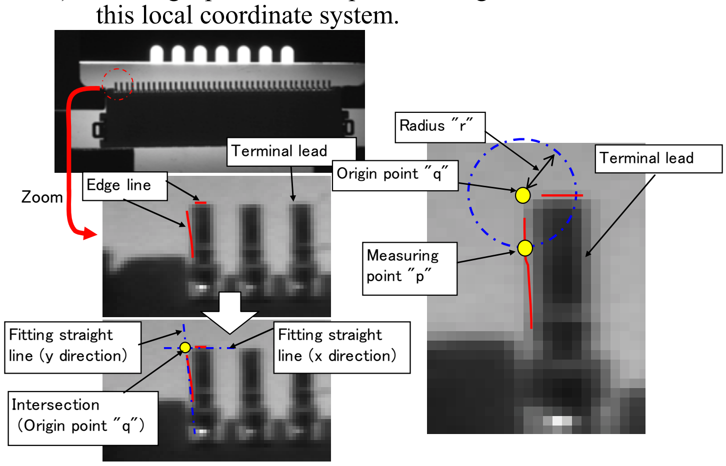

Figure 5. The measuring point extraction

4.3. Stereo correspondence algorithm

Affine transform for rotation Figure 6 shows an algorithm for compensating the rotation fluctuation of the device, and Figure 7 and Figure 8 shows the detailed definition of the origin O of the co-ordinate system.

When the origin on the measurement point *p(x,y)* moves to *p'(x',y')*, the correspondence between these *p* and *p'* is formalized by eq.'s (1), (2) and (3) where the angle $\theta 1$ and $\theta 2$ are the rotation and R is the radius of the rotation.

$$\Delta c = R\cos\theta_2 - R\cos\theta_1 \quad (1)$$
$$\Delta k = R\sin\theta_2 - R\sin\theta_1 \quad (2)$$

$$p'\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} \Delta c \\ \Delta k \end{pmatrix} \quad (3)$$

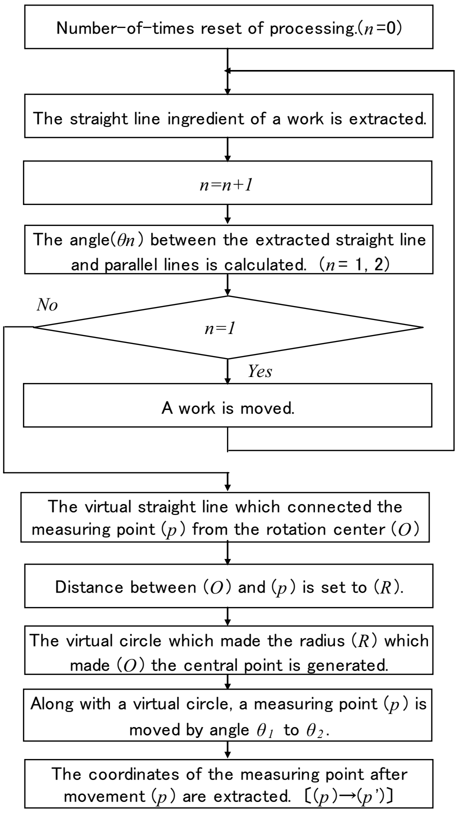

Figure 6. The flow of rectifies posture change of a work

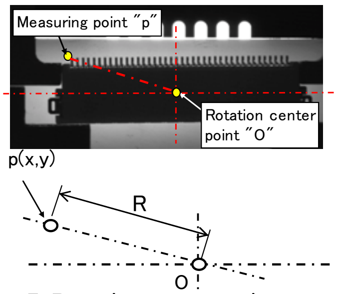

Figure 7. Rotation center point extraction

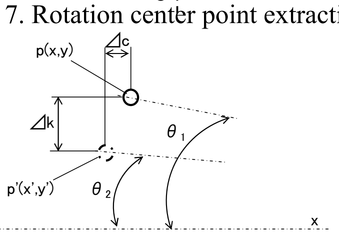

Figure 8. The measuring point after rotation compensation

Stereo measurement method Stereo measurement shown in Figure 9 is implemented based on the triangular principle given by eq.'s (4) and (5). The heights *H* and *h* of a feature point can be calculated from the disparity *d* and baseline length *D*. However we know the distance *K* between the base block and the camera. It is because this system is manufactured.

$$H = \frac{KD}{d} \quad (4)$$

$$h = K - H \quad (5)$$

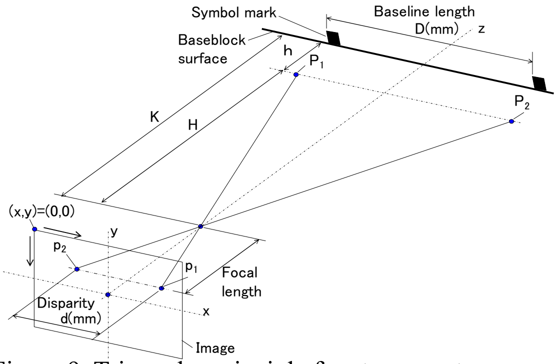

Figure 9. Triangular principle for stereo system

Inspection of terminal lead As shown in Figure 10, one terminal lead has four measuring points and the respective height of those measuring points is measured as height *h*① - *h*④. And as compared with the threshold *th*, the success and rejected judgments are carried out for the computed height of those four points given by eq. (6).

$$\begin{aligned} & h② \approx h③ \approx h④ <: h① : deformation \\ & h① \approx h④ < h② \approx h③ : bend \\ & h① < h② \approx h③ \approx h④ : ter\min al\_burr \\ & th < h① \approx h② \approx h③ \approx h④ : micro\_garbage \end{aligned} \quad (6)$$

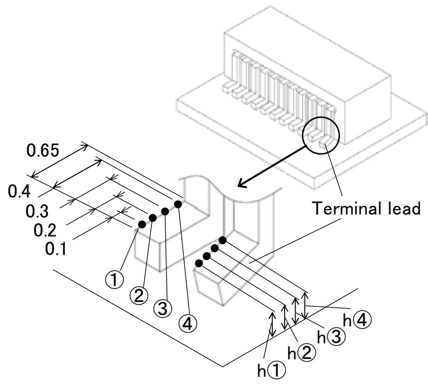

Figure 10. Terminal lead measurement points

5. Performance evaluation of inspection system

5.1. Common equipments

The inspection system was implemented on a PC with the following specifications:

1) PC processor: celeron 2.4GHz
2) OS: Windows2000
3) Software: HALCON (MV-Tec, LinX) Visual C++ (Microsoft)
4) Memory: from 100 to 150MB

5.2. Processing time

The processing time was *0.65sec* in average for one device (*40 terminals*).

5.3. Experimental performance evaluation

Inspection result of terminal lead The electronic devices of Figure11 with *40terminals* were able to be measured, and the detailed shape change of a terminal lead has been recognized. Figure 11 shows the graph of the terminal lead measurement result of four samples.

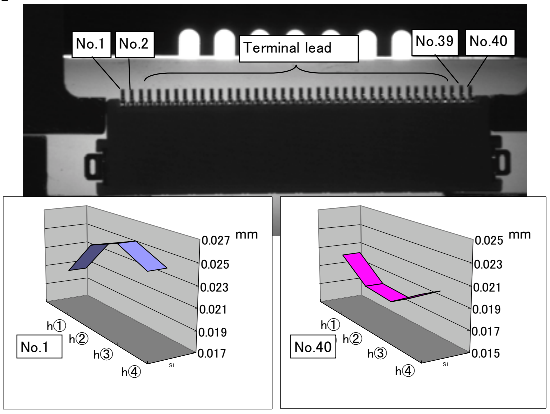

Figure 11. Terminal lead measurement points

Repetition measurement accuracy We conducted the experiments in 50 times for each device and we can show the deviations in the measurements. The length of a baseline has a maximum of about 0.2mm variation. However, for example in Figure 12, the range of the deviation was *0.013mm* in maximum.

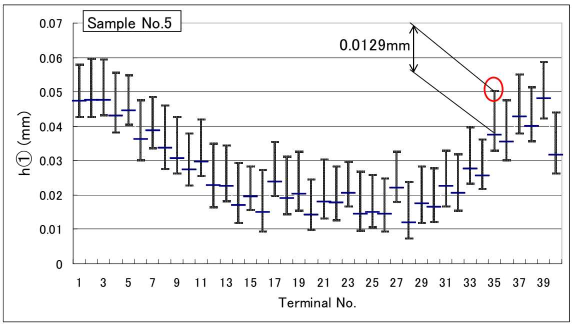

Figure 12. Deviation in measurements of the proposed system

Reliability of work movement distance In order to check the change of the measurement value *h*①, the movement distance of one sample is changed from *30mm* to *25mm*. When the tolerance level of the change was set up with the picture resolution of *0.03mm*, it became clear that the amount of change became to be *25.5mm* (*-4.5mm*)(Figure 13). Even when the movement distance of the work is changed more, the measurement accuracy was maintained. It means that the image capturing and the inspection of it are successfully achieved during the work movement.

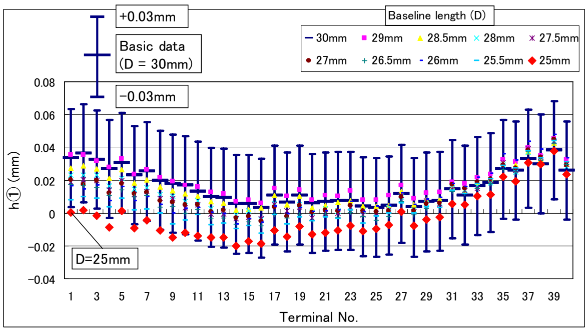

Figure 13. Experiment result of work feed distance

Reliability of work posture change In order to check the change of the measurement value *h*①, the amount of posture rotations of one sample is changed from *0.31degrees* to *1.58degrees* (Figure 8: $\theta 2$). When the tolerance level of the change was set up with the picture resolution of *0.03mm*, it became clear that the amount of change became to be *1.30degrees* (Figure 14).

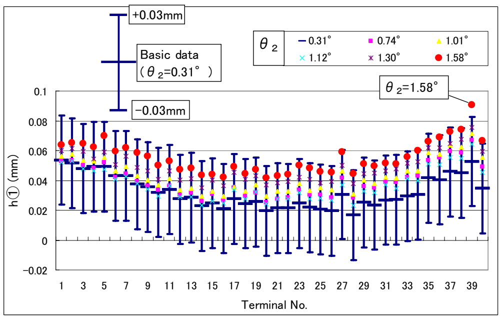

Figure 14. Experiment result of work posture rotation

6. Conclusion and future subjects

We evaluated the measurement accuracy and the adaptability to the posture change of a work by the experimental equipment.

The processing time was *0.65sec* for one device. This processing time was estimated based on *50times* experiments. And from the result of an experiment, when the baseline length changes with a maximum of *4.5 mm* or *1.3 degrees* of the device fluctuation in motion, it was clarified experimentally that the error in the positioning procedure was reduced to *0.02mm* or less.

Through these technical discussions, we could demonstrate that a high precision measurement system for small electronic devices can be developed even if the devices are fed without specialized mechanical stabilization both against the horizontal positioning and against the vertical regulation in posture.

In order to improve the performance and to put the system more practical, the followings should be solved:

1) A long term field test at the real production line should be executed to evaluate and enforce the performance.
2) It is also expected to make the proposed system to be applicable to the wider scope of the similar but different electronic devices.

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