

**A METHOD AND MEANS FOR MEASURING POSITIONS OF CONTACT
ELEMENTS OF AN ELECTRONIC COMPONENTS**

FIELD OF INVENTION

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The invention relates to the field of machine vision inspection and measurement of contact element positions on an electronic component.

BACKGROUND OF THE INVENTION

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In the prior art, method and means for measuring positions of contact elements of an electronic component utilizes two camera set up over a triangulation angle to capture a first and second image respectively for the determination of the relative z-position of the contact elements to the bottom surface of an electronic device. The accuracy of the
15 determined positions of the contact elements are affected by triangulation angle between the two cameras set up to record the first and second images. There is however a limitation to the accuracy of the calculated triangulation because the data used are derived from 2D information. Furthermore, the accuracy of the calculated triangulation angle can also be affected by lens distortion and non-uniform
20 illumination can contribute error to the derived equation. Therefore, it is advantageous to provide an alternative method that is more robust and unaffected by many uncertain factors during calibration and measurement to provide 3 dimensional positions of measured contact elements.

25 **SUMMARY OF THE INVENTION**



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The present invention relates to a method for measuring respective positions of contact elements of an electronic component comprising the steps of: bringing said contact elements into a calibrated space; illuminating said contact elements; recording a first image of said contact elements with a first camera having a first image plane extending
5 substantially parallel to a calibration plane; recording a second image of said contact elements with a second camera; processing said first image to determine a first image point for each said contact element on each said contact element, wherein each said first image point is a point located on each said contact elements; processing said second image to identify a second image point for each said contact element on each
10 said contact element; wherein said second image point and said first image point for each said contact element corresponds to a same point on each said contact element; determining within said second image a third image point by a position mapping algorithm; and determining within said second image a displacement between said second image point and said third image point, wherein said third image point is said
15 first image point orthogonally projected to said calibration plane.

The present invention also relates to a means for measuring respective positions of contact elements of an electronic component comprising: an illumination source for illuminating said contact elements predisposed in a calibrated space; a first camera and
20 a second camera; said first camera and said second camera being provided for recording a first and second image of said contact elements respectively; a processing device, wherein said processing device is connected to said first camera and said second camera for retrieving positions of a first image point in said first image for each said contact element and a second image point in said second image for each said
25 contact elements, said first image point and said second image point for each said contact elements corresponds to a same point on each said contact element, retrieving by a position mapping algorithm in said second image position a third image point, said third image point is a point orthogonally projected from said first image point, and determining displacement between said second image point and said third point.

Additional third camera may be included to compensate for image point recorded on first camera that could not be recorded on the second camera. The inclusion of the third camera also shortens the overall inspection time.

5 BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the
10 drawings, wherein:

Figure 1A and 1B illustrate schematically the set-up of the illumination and the cameras according to the present invention.

15 Figure 2A, 2B, 2C respectively show example of a first, second, third image of a BGA component such as recorded by the first, second and third camera.

Figure 3 shows an example of a multiple layer reticle for calibration means.

20 Figure 4A, 4B, 4C show an example of images of the reticle for calibration means such as recorded by the first, second and third camera.

Figure 5 illustrates the mapping algorithm of co-ordinates from the first to the second calibration image.

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Figure 6 illustrates the measurement principle according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

The method according to the invention is designed for the automatic computation of
5 the three dimensional position of contact elements of electronic components such as
BGA (Ball Grid Array)/CSP (Chip Scale Packaging), flip-chip devices, leaded devices
(QFP, TSOP) and leadless devices (MLP, QFN). The invention is able to
automatically compute 3 dimensional position of combination of contact elements
found on a single device, for example a combination of BGA/CSP device (1) with
10 leaded device as illustrated in Figure 1.

Figure 1 illustrates the electronic component (1) is predisposed in a calibrated space, in
such a manner, that its contact elements (2) and (3) are illuminated by illumination
sources (7) and (8). A first camera (4) is located substantially perpendicular to the
15 calibration plane to record a first image from the bottom of a component as illustrated
in Figure 2A. A second (5) and third camera (6) are located to record a second and
third images of side perspective views of the electronic component such as
respectively illustrated in Figure 2B and 2C. In a first embodiment of the invention,
only two cameras are needed for determining the 3 dimensional position of contact
20 elements of the electronic components. Third camera is used to record the image of
contact elements of the electronic components in case these contact elements cannot be
viewed from second image. The use of a third camera also allows for shorter overall
image acquisition time. When the third camera is used, the method and means for
measuring the positions of other contact elements recorded in respective first and third
25 image of the first and third camera are the same as the method and means used by the
first and second camera. Therefore, the operation of the invention is described using
the first and second camera only.

Preferably, camera 1 and 2 is positioned relative to each other in such a manner that both cameras are directed towards the electronic components as illustrated in Figure 1A and 1B. Furthermore, camera 1, 2 and 3 can be placed at different positions as long as all the contact elements of the entire electronic component can be viewed by at least two different cameras. For example, both Figure 1A and 1B illustrate together that all three cameras are located at different x, y and z coordinates so that all the possible locations of the contact elements are in the view of at least two different cameras.

- 10 The apparatus for measuring the 3 dimensional contact elements is calibrated before the measurement of the positions of the contact elements can be started. The calibration establishes a relationship between a position X1 in the first image and a corresponding position X3 in the second image, i.e. an image point orthogonally projected to the calibration plane. A calibration reticle means (9) as illustrated in
- 15 Figure 3 is used for the calibration. It comprises a number of predetermined markings which are represented, for example, by squares which positions are accurately known. This reticle (9) is for example, made of a substrate which is placed at the location provided for predisposing the electronic component to be measured. The substrate is, for example, composed of multiple layers of glasses disposed, preferably in an array
- 20 manner on a base glass layer. Squares are printed on each of these glass layers by using a highly accurate screen-printing process. The thickness of all these higher layer glasses is accurate and the accurately printed markings are clearly defined for easy detection by the cameras. Though not illustrated, it is possible that calibration reticle means described beforehand is replaced by other calibration reticle means such
- 25 as a reticle with vertical structure projecting out from a layer at accurately known position.

In order to obtain accurate calibration, the position and the size of the squares printed on the calibration reticle means are preferably known to an accuracy of 0.1 microns.

The area and volume spanned by the calibration reticle means defines the space that can be calibrated in x, y and z direction. Therefore, a larger space is available for taking measurement for larger electronic component when a larger space and area are covered by the calibration reticle means in the x, y and z direction. When
5 measurements are carried out later, it is not necessary that the plane in which the contacts are situated is located exactly on the calibration plane (11). Measurements can be carried out as long as the plane in which the contacts are situated is within the established calibrated space.

- 10 Figure 4A, 4B and 4C respectively illustrate the first, second and third image of the calibration reticle means recorded by the first, second and third camera respectively. Since the individual markings, such as squares on the calibration reticle means can be identified, a mapping algorithm is determined through the calibration procedure to enable mapping between both images later on as illustrated figuratively in Figure 5.
- 15 The first (4) and second camera (5) each record its calibration image of the calibration reticle means, as shown in Figure 4A and 4B respectively. As shown in Figure 4A and 4B, the calibration comprises the determination of the position of the same squares (10) (11) or similar features in the first image (Figure 4A) and the second image (Figure 4B) such as recorded by the first (4) and second camera (5). A position
20 mapping algorithm is derived from the positions for each corresponding feature that have been determined in each first and second image. For example, as illustrated in Figure 5, the co-ordinates of a point (111) in the first image is mapped to its corresponding point (111') in the second image. Hence, plane (11) is the calibration plane since features on its surface are used for mapping pixels in the first image plane
25 to the second image.

According to Figure 5, a bilinear interpolation technique is used to determine the co-ordinates for all the positions in between any two markings. For example the position of a point X1 in the first image will be expressed in fractions of dx and dy and
30 considered with respect to coordinates (111), (112), (221) and (222) that is formed by

a rectangular matrix on the first image. Point X3 in the second image is a point orthogonally projected from point X1 in the first image and the former is expressed in fractions of dx' and dy' . The position mapping algorithm between a first image point in the first image and an image point in the second image, wherein the image point in the second image is a point orthogonally projected from the first image point on to the calibration plane, is obtained by determining the relationship relating dx and dx' and the relationship relating dy and dy' . For example, the position mapping algorithm relating X1 in the first image plane and X3 in the second image plane is a relationship relating dx and dx' for the x-coordinate and a relationship relating dy and dy' for the y-coordinate. The position mapping algorithm is then used during measurements for determining a point in the second image plane which is a first image point orthogonally projected on to a calibration plane.

Referring to Figures 3, 4A, 4B and 5, a z-scaling factor is determined by firstly determining the respective pixel coordinates X1 and X2 in the first and second image respectively, for features, such as squares (10), on the calibration reticle means. X3 is a point orthogonally projected on to the calibration plane from the point X1 by using the position mapping algorithm. Since the z distance between X2 and X3 is accurately known, respective z-scaling factor in the second image (4B) and third image (4C) can be determined. For example, suppose that the distance between X2 and X3 is 10 mm and their corresponding distance on the second image is 25 pixel, the z-scaling factor would be $10\text{mm}/25 \text{ pixel} = 0.4 \text{ mm/pixel}$.

After completing the calibration procedure, an x-y coordinate position mapping algorithm and a z-scaling factor have been obtained to determine a position of the contact elements on the component in the first and second image. In addition, distances between the contact elements X, Y and Z-axis can be determined from respective x, y and z-scaling factors. As the position is accurately determined by the calibration reticle means, the position of the contact elements can also be determined accurately in microns. The calibration procedure also enables a camera-to-camera

calibration to be carried out, establishing the relationship between the first (4) and second camera (5). The relationship of the third camera with the first camera is also established in the manner described herein.

- 5 Now that the space for measurement has been calibrated and the set-up of the first and second camera has been explained, the measurement principle according to the present invention will be explained with the help of Figure 6. The third camera (6) is set up with respect to the first camera (4) in a manner similar to the second camera. Suppose an electronic component is brought in to the calibrated space and one of its contact
- 10 element is located at a point P with respect to the calibration plane, p. The first camera records a first image of the contact elements and selects a first point P. The position of a first image point X1 for first point P in the first image of the contact element is determined.
- 15 The second camera (5) records a second image of the contact element with the point P and point P is identified as a second image point X2 in the second image. The point P is orthogonally projected using the position mapping algorithm on to the calibration plane, p giving a second point P'. In the second image, the third image point X3 is then the image point of position P'. X3 is the expected position in case the contact
- 20 element P would be localized in the calibration plane p. The position of a point X3 in the second image is determined by the position mapping algorithm. The displacement between X2 and X3 is due to the fact that the real contact element is usually not exactly located on the calibration plane but at a height difference, DELTA.z, which is to be measured. Following the foregoing, the displacement DELTA.z is determined
- 25 by the multiplication product of the distance between X3 and X2 (i.e. DELTA.z') and z-scaling factor in Z-axis of second image.

Since the invention enables measurements of a point within the calibrated space, it is evident to a person reasonably skilled in the art to utilize the invention to measure the

distance between any two points using the invention, as long as the two points are located within the calibrated space.

It is therefore apparent to anyone skillful in the art as to the practicality and usefulness
5 of such a system and method for measuring the distances between contact elements of
a component and the distance of the contact elements from a calibration plane within a
calibrated space, which can be an integrated circuit which the contact elements are
situated on. Therefore, the above description is descriptive and is by no means
limitation of the essence of the invention itself which scope and embodiment is
10 claimed as below.

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CLAIMS

1. A method for measuring respective positions of contact elements (2, 3) of an electronic component comprising the steps of:
 - 5 bringing said contact elements (2, 3) into a calibrated space;
illuminating said contact elements (2, 3);
recording a first image of said contact elements (2, 3) with a first camera (4) having a first image plane extending substantially parallel to a calibration plane;
recording a second image of said contact elements with a second camera (5); - 10 processing said first image to determine a first image point for each said contact element (2, 3) on each said contact element (2, 3), wherein each said first image point is a point located on each said contact element (2, 3);
processing said second image to identify a second image point for each said contact element (2, 3) on each said contact element (2, 3); wherein said second image point
15 and said first image point for each said contact element (2, 3) corresponds to a same point on each said contact element (2, 3);
determining within said second image a third image point by a position mapping algorithm; characterized by
deriving a z-scaling factor by determining the respective pixel coordinates of the first
20 image point and the second image point on the calibration plane of a calibration reticle means (9), wherein said calibration reticle means (9) comprising a base layer having features disposed thereupon and multiple layers having features thereupon, said multiple layers having accurately known thickness and their features being accurately positioned relative to said features upon said base layer; and
25 determining within said second image a displacement between said second image point and said third image point, wherein said third image point is said first image point orthogonally projected to said calibration plane, said displacement determination is by multiplying the z-scaling factor and the coordinate difference of said second

image point and said third image point.

2. A method as claimed in claim 1, further comprising the step of deriving said position mapping algorithm for a particular relative position between said first and
5 second camera (5).

3. A method as claimed in claim 1, further comprising the step of determining displacement between any two points within the calibrated space.

10 4. A means for measuring respective positions of contact elements (2, 3) of an electronic component comprising:

an illumination source (7, 8) for illuminating said contact elements (2, 3) predisposed in a calibrated space;

a first camera (4) and a second camera (5);

15 said first camera (4) and said second camera (5) being provided for recording a first and second image of said contact elements (2, 3) respectively;

a processing device, wherein said processing device is connected to said first camera (4) and said second camera (5) for retrieving positions of a first image point in said first image for each said contact element (2, 3) and a second image point in said
20 second image for each said contact elements (2, 3), said first image point and said second image point for each said contact elements (2, 3) corresponds to a same point on each said contact element (2, 3), retrieving by a position mapping algorithm in said second image position a third image point, said third image point is a point orthogonally projected from said first image point, and determining displacement
25 between said second image point and said third point; characterized by

a calibration reticle means (9) which image is recorded by said first and second cameras (4, 5) and said processing device derives said position mapping algorithm from said images of said calibration reticle means for a particular relative position

between said first and second camera (4, 5), wherein said calibration reticle means (9) comprising a base layer having features disposed thereupon and multiple layers having features thereupon, said multiple layers have accurately known thickness and are accurately positioned relative to said features upon said base layer.

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5. A means for measuring respective positions of contact elements (2, 3) of an electronic component as claimed in claim 4, wherein said processing device determines said displacement by multiplying a z-scaling factor and coordinate difference of said second image point and said third image point.

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6. A means for measuring respective positions of contact elements (2, 3) of an electronic component as claimed in claim 4, wherein said processing device derives a z-scaling factor for determining the displacement of said second image point and said third image point.

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7. A means for measuring respective positions of contact elements (2, 3) of an electronic component as claimed in claim 5, wherein said processing device determines displacement between any two points within the calibrated space.

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8. A means for measuring respective positions of contact elements (2, 3) of an electronic component as claimed in claim 4, further comprising a third camera (6) connected to said processing device for recording a third image of said contact elements, said third image having a fourth image point and a fifth image point, wherein said fifth image point is a point orthogonally projected from said first image point and is not recorded in said second image, and said processing device determines a displacement between said fourth image point and said fifth image point.

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