MEASURING GEOMETRIC MEAN DIAMETER OF FRUIT AND VEGETABLE USING COMPUTER VISION

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ABSTRACT

This paper proposes a new technique to measure the Geometric Mean Diameter (GMD) of selected fruit and vegetable calculated from three-dimensional (3D) image by computer vision system (CVS). From the single view of image data, linear laser light projected onto the top of sample through the center in order to mark the measurement points. The planar metrology and the measurement between planes are employed to calculate the width and height of samples. Homography transformation and cross ratio are the mathematical applied to calibrate the image data to the real world distance (in metric system). This technique can get the GMD of object in a single view. The percentage of error of GMD obtained from CVS comparing with GMD measured with vernier calipers is about 0.03-5.14 affecting from shape of objects. It can be concluded that this technique is worthwhile for measuring GMD of symmetrical objects.

Keywords: Computer Vision, Geometric Mean Diameter, Fruit, and Vegetable

1. INTRODUCTION

A computer vision system has been researched and developed since 1920s. It is one of the non-destructive methods that has been applied in several areas such as medicine, biology, satellite, commercial documents, archaeological data, forensic data, industrial processing, etc [1]. It is also used in the application of agriculture. Geometric Mean Diameter of fruit and vegetables is one of the important physical properties for grading the size of samples. There are many articles reporting about a classification of color and size of fruit and vegetables using the computer vision and image processing; however, most of them have been used in the 2-D image [2]. The objective of this paper is to present the measuring of GMD of object from its three-dimensional image captured with a camera in a single view.

2. THEORIES

2.1 GEOMETRIC MEAN DIAMETER (GMD) [4]

Not yet ka

GMD can be calculated from the equation as shown in Fig. 1.

\[
\text{GMD} = \left( \frac{a b c}{3} \right)^{1/3}
\]

Fig. 1 Geometric Mean Diameter

where \( a \) = longest intercept, \( b \) = longest intercept normal to \( a \), and \( c \) = longest intercept normal to \( a \) and \( b \). The intercepts need not intersect each other at a common point.

2.2 STRUCTURED LIGHT SECTIONING

The light sectioning method is a well-known measurement technique for optical determination of object sections [1]. A light plane is projected onto the object from one direction. Most commonly a laser serves as a light source. The three-dimensional image is captured with a camera while the top of object is cross-sectionally projected with linear laser light. The position of samples, light source, and camera are set as showed in Fig. 2.
2.3 PLANAR METROLOGY [1]

The planar metrology is the method to measure the geometry on plane. It is necessary to know the real world data being the reference coordinate. A point in the plane is defined in homogeneous coordinates as

\[
p = \begin{bmatrix} x \\ y \\ w \end{bmatrix}
\]

In two dimensions, the homography projection \(H\) of \(p\) to a point \(p'\) on an other plane can be formulated as

\[
p' = Hp
\]

\[
p' = \begin{bmatrix} x' \\ y' \\ w' \end{bmatrix}
\]

where, \(p'\) and \(p\) are the homogeneous coordinates of the corresponding points \(p\) (pixel coordinates) and \(p'\) (real-world) and \(H\) is a homography matrix as,

\[
\begin{pmatrix}
 x' \\
 y' \\
 w'
\end{pmatrix} = \begin{bmatrix}
 h_{11} & h_{12} & h_{13} \\
 h_{21} & h_{22} & h_{23} \\
 h_{31} & h_{32} & h_{33}
\end{bmatrix}
\begin{pmatrix}
 x \\
 y \\
 w
\end{pmatrix}
\]

One of the nine parameters within \(H\) can be interpreted as scaling. The remaining eight entries can be determined by using 4 points given in the two planes. A linear algorithm can be derived by expanding equation (4) for a given point correspondence, and normalizing with respect to the homogeneous component to yield,

\[
\begin{pmatrix}
 x' \\
 y' \\
 w'
\end{pmatrix} = \begin{bmatrix}
 h_{11}x + h_{12}y + h_{13} \\
 h_{21}x + h_{22}y + h_{23} \\
 h_{31}x + h_{32}y + h_{33}
\end{bmatrix}
\begin{pmatrix}
 x \\
 y \\
 w
\end{pmatrix}
\]

In this case, the point correspondences are assumed to be image coordinates, hence homogeneous component \(w_i = w'_i = 1\) then the homography matrix can be rewritten as follows.

\[
\begin{pmatrix}
 x_1 & y_1 & 1 & 0 & 0 & x'_1, x_1 & x'_1, y_1 & x'_1 \\
 x_4 & y_4 & 1 & 0 & 0 & x'_4, x_4 & x'_4, y_4 & x'_4 \\
 0 & 0 & 0 & x_1 & y_1 & 1 & y'_1, x_1 & y'_1 \\
 0 & 0 & 0 & x_4 & y_4 & 1 & y'_4, x_4 & y'_4, y_4
\end{pmatrix} = \begin{pmatrix}
 h_{11} \\
 h_{21} \\
 h_{31} \\
 h_{12} \\
 h_{22} \\
 h_{32} \\
 h_{13} \\
 h_{23} \\
 h_{33}
\end{pmatrix}
\]

The homography matrix can be determined the solution by linear equation system. Singular value decomposition (SVD) is a lease square estimation that can be applied on this matrix to fine non trivial solutions of the homography. And then the real world coordinate can be calculated using the multiplication of matrix \(H\) and \(p\).

2.4 MEASUREMENT BETWEEN PLANES

This method [3] was applied to measure the height of the sample. The reference platform (A4 or A5 paper) is the rectangular shape that can be obtained a set of planes being parallel. This can measure relative distances between planes. The cross ration is determined from the relative distance between camera point and vertical vanishing point. Knowing the absolute distance (reference object) of object that lies on the same plane is the requirement to measure the height of the sample. Fig.3 shows relative distance on the plane and the camera point calculated from two vanishing points from the reference rectangular platform. And the vertical vanishing supposes to be point at infinity. The cross ratio \(R\) can be formulated as,

\[
R = \frac{d(x',c)d(x,v)}{d(x,c)d(x',v)}
\]

where \(Z\) is the absolute distance and \(Z_c\) is the distance from camera to the plane. The calibration process of this measurement must know the real world distance of \(Z\) and then the \(Z_c\) can be obtained. The next step is to determine the height of the sample from knowing of \(Z_c\).
3. MATERIALS AND METHODS

The experiments were performed on the measuring of the dimension of the selected fruit and vegetable by off-line image processing. The proposed technique was used to measure the GMD of three sizes (Large, medium, and small) of apple, orange, and lime. Program was written in MatLab version 6.5 to process data. A digital camera (Olympus C-750, 4.0 million pixels, optical zoom 10x) was used to capture an image of each object. The GMD calculated from computer vision system was then compared with the GMD measured with vernier calipers. Ten replicates were done in the test.

The linear laser diode performing structured light is used to define the projective points on the object as shown in Fig. 4. Sample was put on the same plane with a known size of reference object and captured a 3-D image in a single view with a digital camera. Planar metrology and distance between two planes were applied to determine the width and the height of the samples. Consequently, the GMD can be calculated from the image.

4. RESULTS AND DISCUSSION

Table 1 presents the ratio of b/a, c/a, and GMD of apple, orange, and lime measured with vernier calipers, GMD measured from CVS, and the percentage of error of GMD\textsubscript{CVS} comparing with GMD\textsubscript{V}.

GMD of apple is about 8.2 mm for large size, 7.8 mm for medium size, and 6.3 mm for small size. GMD of orange is about 6.7 mm for large size, 5.7 mm for medium size, and 4.5 mm for small size. GMD of lime is about 4.8 mm for large size, 3.8 mm for medium size, and 3.3 mm for small size. From the results, it can be observed that GMD can be a parameter used to classify the grade of sample determining by size.

Computer vision technique in this paper is capturing a 3-D image of object in a single view. The width (a) and height (c) of an object was calculated from the recorded image (Fig. 4). In this study, the shape of sample was assumed to be symmetry; therefore, ‘b’ value was assumed to be equal to ‘a’ value. The percentage of error of GMD\textsubscript{CV} comparing with GMD\textsubscript{V} is about 0.03-5.14 (Table 1). We can roughly observe that the error of measuring GMD\textsubscript{CV} of oranges and limes is lower than that of apples. It is due to the sample shape. According to in this study the width and height of sample was calculated from 4 points in a sample image, the high error was found in either non-symmetry or abnormal shape of sample. Generally, we found that if the ratio of a/b (width) is nearly 1 and ‘c’ (height) at different positions of sample is nearly the same, the percentage of error will be low. An error also occurred from the human during marking points on the image.

Therefore, it can be concluded that at the present this technique is a suitable method for a symmetrical object having ratio of b to a (b/a) nearly 1 and having a normal shape.
Table 1 Diameter of object measured with vernier calipers and computer vision system technique

<table>
<thead>
<tr>
<th>Size</th>
<th>Apple</th>
<th>Orange</th>
<th>Lime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b/a</td>
<td>c/a</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.97</td>
<td>0.91</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.91</td>
<td>8.17</td>
<td>8.17</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>8.18</td>
<td>8.18</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.99</td>
<td>0.88</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.98</td>
<td>7.76</td>
<td>7.76</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
<td>7.58</td>
<td>7.58</td>
</tr>
<tr>
<td>Small</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.93</td>
<td>6.24</td>
</tr>
<tr>
<td></td>
<td>0.94</td>
<td>6.36</td>
<td>6.36</td>
</tr>
<tr>
<td></td>
<td>0.93</td>
<td>6.24</td>
<td>6.24</td>
</tr>
<tr>
<td></td>
<td>0.98</td>
<td>6.28</td>
<td>6.28</td>
</tr>
</tbody>
</table>

**GMD** Measuring Geometric Mean Diameter using vernier calipers
**GMDCV** Measuring Geometric Mean Diameter using computer vision system

5. CONCLUSIONS AND RECOMMENDATIONS

- This technique is capturing a 3-D image of an object in a single view with a digital camera, and then processed with a self developed program in MatLab software. Planar metrology and distance between two planes are applied to calculate width and height of object.
- It can work anywhere without controlling the environment.
- It can be applied to measure the GMD of selected fruit and vegetable (apple, orange, and lime) with 0.03-5.14 percentage of error.
- It is a suitable technique for measuring the GMD of a symmetrical object, for example, orange and lime.
- An abnormal shape of object and human working are a cause of high percentage of error.
- Further research is to work with multiple-view object images to measure the object volume.
- This system could be benefit to design the automatic grading machine in the future.

6. REFERENCES