High Accuracy Real Time Machine Vision for Diameter Measurement Using Simpson Algorithm

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***Abstract*— Diameter is one of the important parameters for quality measurement. Fruit classification, for example, takes diameter as one important indicator, apart from other indicators. Precision measurement has been observed and experimented for example it can be done using laser technology, however the instrument requires a lot of space, therefore mobility is almost impossible. When speed is necessity while doing measurement, a real-time measurement using camera and image processing can give a lot of contribution compared to manual measurement. This paper introduces a diameter measurement method using Simpson algorithm in real-time, using regular camera. Simpson algorithm gave high accuracy measurement with high computation speed. The design indicated good result with accuracy ranged from 93% to 99% depending on calibration.**

Keywords—size measurement, camera vision, automatic measurement, size classification, simpson algorithm

I. Introduction

Size measurement has been an important factor in many aspects. In medical domain, size play important role to determine patient care and management. Cancer size for example, indicates the disease progress, therefore proper treatment can be taken upon [1] [2]. Agriculture domain also indicate the necessity of size measurement. Fruit grading takes size as one of important parameter, fruit diameter in this case [3]. Post harvest treatment has involved different type of technology to increase the processing speed. One of the examples is automatic fruit sorting [4]. Other agricultural aspect also indicates the need to measure leaf size to calculate plant growth and productivity [5].

In building and infrastructure, cracks is and indicator o failure, therefore early detection needs to be made. Road crack measurement and surveilance needs to be made periodically [6]. Manual observation will consume a lot of time and cost, while using automatic crack detection will increase the reliability and reduce cost [7].

II. Size Measurement

A. Manual measurent

The most used methods is using ruler or measuring tape. The method is reliable and accurate, however when involving high amount of measurement and irregularly big size, this method will give diffulties. Scale paper is also used for small area measurement, however it will also give difficulties when dealing with large area. Manual measurement will only give reliable result when applied to small amount of measurement [8].

B. High tech precision measurement

Although precision measurement can be done using a cheap instrument, this method is limited only for small objects, using caliper or micrometers. Caliper or micrometer technique could result in precise measurement as high as 1:1000 mm. Laser technology also contribute to precision measurement for either small small objects or big objects. While small measuring devices are mobile, laser mesurement often needs a lot of space therfore less of none mobile. Laser technology measurement resolution can go as low as 1 micrometer [9].

C. Computer vision measurement

Computer has been used for many measurement intruments, either for calculation or acquisition processes. When combined with camera, computer could act as an eye for obect detection and using proper software technology it could also measure the size of an object. With proper callibration, this method can be applied to small to large objects. Image processing techniques could increase the reliability of the measurement [10].

III. Previous Works and Proposed Method

A. Previous works

Machine vision as been used widely for different application. Fruit grading and classification for post harvest processes using this technique has been done for papaya. The papaya were measured for weight and volume resulted in 90% accuracy [11]. For plant productivity calculation, leaf area meter using smartphone has also been developed. The method used an A4 paper as reference to determine the leaf size. Using smartphone, this technique resulted in high mobility and high reliability with accuracy reach as high as 99% [12]. Processing speed has also been investigated using the same algorithm with different window sizes. Average processing time became higher with smaller window size as indicated in fig 1.

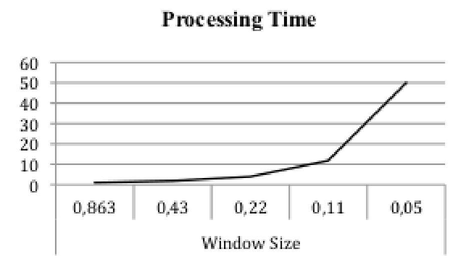

Fig. 1. Processing speed against window size

Both techniques used image processing for either detection or calculation to increase reliability. Fruit grading analysis used neural network algorithm, while the leaf size used simple Simpson algorithm. However, the result indicated that Simpson algorithm gave better result.

Project for diameter error prediction using Fuzzy Logic algorith was aslso introduced in the nylon manufacturing. Since nylon diameter were small, better algorithm technique must be used. The fuzzy algorithm resulted in accuracy reached 95%, in the nylon manufacturing process [13][14].

Crack detection for tunnel monitoring was done in Beijing. This technique involved Black Top-hat transform, radial basis function neural network, support vector machine and K nearest neighbors algorithm. This project resulted in 94% accuracy. [15].

Simpson algorithm although as a classic method for area measurement gave better result, therefore it was used in the diameter measurement in this project.

B. Proposed method

Basic Simpson algorithm was dividing an area into smaller area called window with an exact size. The total area then calculated by multiplying the number of windows with windows size. The smaller the windows, the better the accuracy, however it can increase processing time [16].

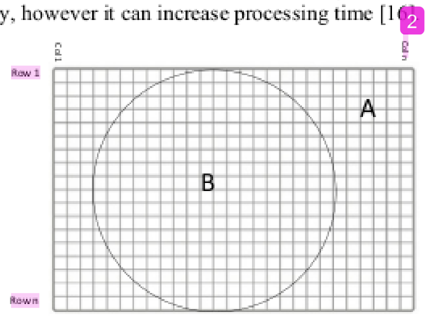

Fig. 2. Area of interest and windows

Fig. 1 demonstrated a circle as the area of interest and rectangular area divided into smaller rectangels as windows. Machine vision measurement required a reference to calculate size. For instance, if rectangle A in fig 1 was the size of A4 paper, the area B inside the circle can be easily calculated since windows size were known. The area in the perifer in the circle were not perfectly square, therefore resulted in error measurement. This illustration easily explained why smaller window size gave higher accuracy. Simpson algorithm for calculating area of interest is as follows:

```
For row = 1 to n
    For column = 1 to n
            Detect color
            If color = bkground then
                    Size = size + 0
            Else
                    Size = size + 1
    Repeat until column = n
Repeat until row = n
Size = size * windows_size
```

The algorithm indicated the need for image processing to clearly distinguise object of interest and back ground. The following steps were done during the process.

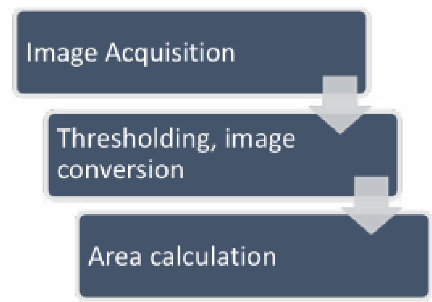

Fig. 3. Process Block Diagram

For diameter calculation, a modification to the fore-mentioned algorithm has been done. Diameter was based on the highest window counts either in columns or rows. The area of interest for diameter measurement is depicted below:

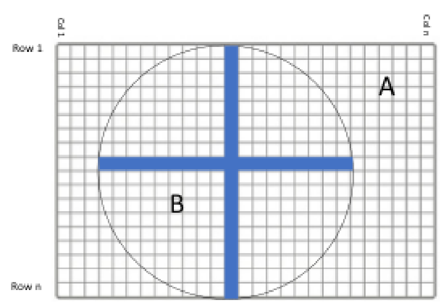

Fig. 4. Area of interest in diameter measurement.

In Fig 3, the shaded area in B was investigated, to find the highest count, software must observe windows count in every column and every row. Final object diameter was determined by the highest window count either in columns or in rows. The algorithm that was used to determine the diameter is as follows:

```
For row = 1 to n
    For column = 1 to n
            Detect color
            If color = bkground then
                    size = size + 0
            Else
                    csize = csize + 1
```

```
        Repeat until column = n
    Repeat until row = n
    csize = csize * windows_length
    For column = 1 to n
        For row = 1 to n
                Detect color
                If color = bkground then
                        rsize = rsize + 0
                Else
                        rsize = rsize + 1
        Repeat until row = n
    Repeat until column = n
    rsize = rsize * windows_length
    if csize > rsize then
        diameter = csize
        else if diameter = rsize
```

Area calculation or diameter calculation, as mentioned, was very much determined by windows size. In this case the windows size was the camera resolution, since this was the smallest window available.

C. Hardware design

Hardware had to be designed to meet the precision criteria. A small dome was designed carefully, the distance between camera and object was measured. The distance will affect the object measurement, since the longer the distance the object will appear smaller in the acquired image. Once the distance was measured, the value will be put on the software for calculation.

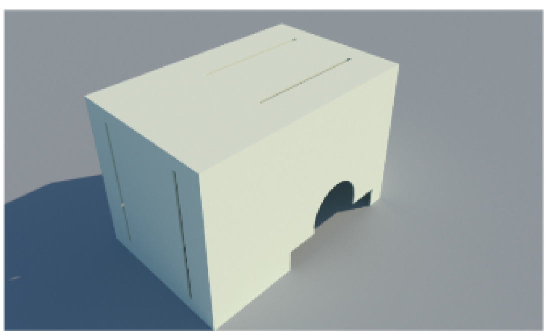

Fig. 5. Dome for image acquisition

Dome depicted in fig. 4, contain a camera and a set of LED lamp. Object was put inside the dome under the camera, and then the object measurement was initiated. LED lam inside the dome was carefully designed to give adequate lighting. Shadow resulted by the lighting system was avoided as this will give error measurement. LED light gave illumination with color temperature around 6500 K for natural lighting effect [17]. Camera installation had to be perpendicular with the object measured.

D. Calibration

Calibration is a process of determining a value for reference. Further measurement must be quantified according to this reference [18]. There are several types of calibration the simple methods were one point and two points calibration (intra/extrapolative). Two points calibration basically finding gradient in linear equation, any point between the two calibration points correspond to measured value. Two calibration points works best in linear condition.

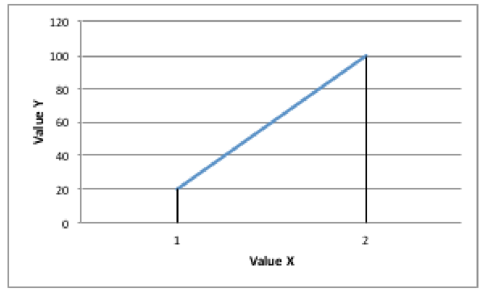

Fig. 6. Two points calibration.

Measurement in this project used one-point calibration, the calibration was to determine the window size. The calibrated value then stored in the software for calculation reference.

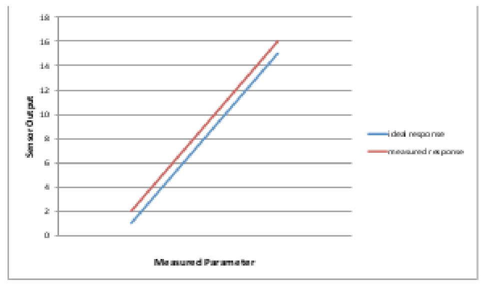

Fig. 7. One-point calibration

Calibration data is shown below

TABLE I. CALIBRATION RESULT

	X value	Y value
Calibration 1	**98**	**100**
Calibration 2	**99**	**100**
Calibration 3	**99**	**99**
Calibration 4	**99**	**99**

Table 1 was derived from calibration trial using object size 52 x 52 mm. The data shown in table I indicated a relatively consistent data. Some slight different between x value and y value which were column and row respectively, also predicted slight error in the measurement. Since the minimum window size for this measurement was the size of the pixel, therefore X and Y value also corresponded to the maximum pixel count in columns or rows.

IV. RESULT AND ANALYSIS

Experiment on the designed measuring device was done to measure the size of different type of fruit. Error was predicted when one calibration point applied to wide range of object sizes. Therefore, measurement calculation was done using different calibration values. Several calibrations were used to measure fruit diameter for best result. Every object was measured several times. The result is shown in table II.

TABLE II. MEASUREMENT WITH CALIBRATION 47MM

No	Object	Real Dia	Px Value	Meas Dia	Accuracy
1	**Object 1**	**56**	**104**	**55**	**98%**
2	**Object 2**	**57**	**111**	**59**	**96%**
3	**Object 3**	**60**	**119**	**63**	**95%**
4	**Object 4**	**63**	**126**	**67**	**94%**
5	**Object 5**	**67**	**135**	**72**	**93%**

6	Object 6	72	145	77	93%

TABLE III. MEASUREMENT WITH CALIBRATION 52MM

No	Object	Real Dia	Px Value	Meas Dia	Accuracy
1	Object 1	56	104	55	98%
2	Object 2	57	111	58	98%
3	Object 3	60	119	62	97%
4	Object 4	63	126	66	95%
5	Object 5	67	135	71	94%
6	Object 6	72	145	76	94%

TABLE IV. MEASUREMENT WITH CALIBRATION 63MM

No	Object	Real Dia	Px Value	Meas Dia	Accuracy
1	Object 1	56	107	53	96%
2	Object 2	57	111	55	96%
3	Object 3	60	119	59	98%
4	Object 4	63	126	62	98%
5	Object 5	67	135	67	99%
6	Object 6	72	145	72	96%

As predicted, the tables demonstrated that accuracy reached higher when the diameter of measured object closer to the calibrated diameter. Figures below explain clearly the relation between calibration, measured diameter and accuracy.

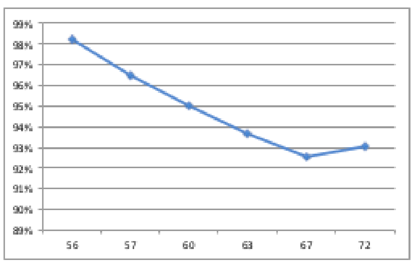

Fig. 8. Accuracy chart for 47mm calibration

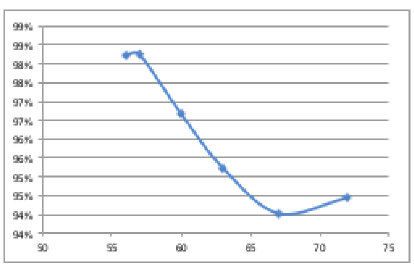

Fig. 9. Accuracy chart for 52mm calibration

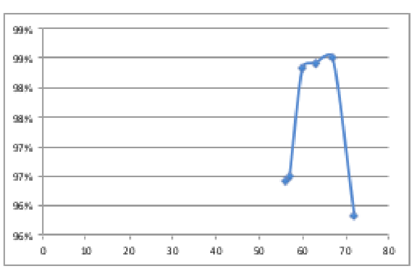

Fig. 10. Accuracy chart for 52mm calibration

From the chart above the accuracy of the measurement can be seen clearly that:

- Measurement accuracy was very much affected by calibration
- High difference between measured object diameter and calibration diameter resulted in higher error.

V. CONCLUSION AND DISCUSSION

Design of the hardware and software for diameter measurement has been successful. From the analysis it can be concluded that:

- Lowest accuracy measured was 93% when the difference between measured object and diameter was 20-25 mm
- Highest accuracy measured was 99% reached when there was no different between measured and calibrated diameter.
- Adequate measurement with max error of 5% resulted when the difference between measured and calibrated diameter was more or less 13mm.

This project design is best used when measurement do not require high precision and when real time with high amount of measurement occurs. Fruit selection, for example, with moving object in a conveyer belt can apply this measurement method.

Calibration must be changed for best result when the average diameter varies to high. Therefore, a system to memories different calibration result is best suited in the system to avoid work delay for making new calibration.

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