A NEW VISION-BASED METHOD IN MEASURING THE OBJECT REAL SIZE

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Abstract - The focus of this article is on applying the image processing algorithms to calculate the dimensions of 3D objects. Coordinate measuring machine (CMM) is a device applied in measuring the dimensions of a physical object. This device is applied in checking the accuracy of delicately manufactured. In the past, these measuring devices were installed on mechanical robots, but they are now equipped with laser scanners which is a technology used in various industries, including automotive, food, and medicine, to determine the quality as well as to inspect and control the production process. The new measuring approaches are based on machine vision and are more flexible than the previous ones. In this article it is sought to measure the dimensions of objects by applying the machine vision techniques, which reduces the cost of measuring compared to mechanical robots or laser scanners. To measure each object’s size, determining the reference object to begin with is of essence, next, the dimensions of the reference objects will be applied in calculating the other objects’ size. By scanning the image and checking the neighboring pixels of each pixel, the polylines are drawn and by connecting the first point to the last point, the polygon is formed. By having the actual size of the reference object and converting the pixel therein into millimeter, the sides of the target object are calculated.
Experimental results indicate that this proposed method can reliably measure the real size of objects, and outperforms its counterparts.

Keywords - Object Size, Edge Detection, Accurate Measuring, Polygon Detection, Object Circumference.

I. INTRODUCTION

In machine vision systems, sensors are applied to receive vision signals form a target object which are analyzed through computers or other signal processing devices. Machine vision is applied as an engineering tool in digital devices and in computer networks for industrial purposes like controlling the arms of a robot or removing defective equipment (Davies, 2004).
Machine vision is highly applied in industrial, food, and pharmaceuticals products’ revision process. These devices will gradually replace human workers due to their considerable advantages as to not being affected by fatigue and adverse environmental conditions that lead to errors (Davies, 2004).
Real-time detection and exact dimensioning of objects is an important issue in areas of industry. This is an important topic in the computer vision applications like autonomous mobile robot and quality control in manufacturing plants (Shahdib et al., 2013). Many new approaches are emerging every day to make this process as accurate and fast as possible.
Coordinate Measuring Machine (CMM) is a probe that measures the coordinates of physical objects’ discrete points on its surface. There exist different types of probes, like the mechanical, optical, and laser. Depending on the machine type, the position of the probe is controlled manually by an operator or by a computer (Metrology, 2013).
Due to lack of proper technology introduced in maintaining the accuracy of coordinate measuring machines, these devices are applied separate from the production line; therefore, the product has to be taken out of the production line and, under certain conditions, transferred to the measurement room. The delay caused here, makes it impossible to constantly control the production line and, in case of a problem, a great number of defect products are produced (MohsenDokht, 2017). With the advances made in technology, coordinate measuring machines are gradually being applied in the production line, thus complete control of the production line and a reduction in defect products down to around zero (MohsenDokht, 2017). The purpose of CMM is to measure the dimensions of mechanical parts in a three-dimensional space with a high accuracy. In the past, these machines were based on mechanical robots, but they are now equipped with laser scanners and/or machine vision systems.
In vision-based systems, computers first capture images through cameras and then process and analyze them through appropriate algorithms, and next, they make necessary decisions based on the objects recognized in the image. Usually, a machine vision system is connected to one or more cameras and analogue-to-digital converters, the output of which is sent to a computer controller or a robot (Abadarian, 2017). In general, the vision-based methods are less expensive, simple, and more flexible than size-determining robots and laser scanners.

II. BACKGROUND

Raab et al. (2005), developed a portable coordinate measuring machine to measure the position of an object in a selected volume. This machine consists of an adjustable arm with a moveable thermal laser scanner probe mounted on.

Another portable measuring machine with three transforming arm capable of precise measuring is developed by Ferrari (2010). These arms are connected to pieces that allow relative rotation of adjacent members with about two degree to freedom. Encoders are applied in measuring the relative rotation of each degree of freedom. Encoder signals can be digitized through the processor boards placed inside the transferring parts.

Fan et al. (2010), designed a new scanner with high precision capable of measuring miniature components in the micro/nano coordinate system. The touch probe of this device is made up of a ball-point fiber pen, a floating plate, and focus sensors, attached to the floating plate which is connected through four elastic wires to the chamber of the probe.

A coordinate measuring machine is devised by Bridges et al. (2015) which measures the position of a distant target by applying laser machine consisting of a fixed part, a rotating part, and at least one optical fiber. The fixed part has at least one primary source of laser beam and at least one optical detector. The laser beam is emitted towards a distant target and the reflected beam controls the target through the direction of the beams and rotation of the rotating part.

According to Kopparapu& Desai (2001), the routine of machine vision methods consist of three different sub-routines: 1) looking for features in the image, 2) analyzing the features to obtain the information about the image and 3) retain the only information about each object in the image and following this, the image which can be applied in producing the original scene is represented.

Kainz et al. (2015), proposed a solution for estimating the object size from static image by applying one camera. In their method, detection of an object in a picture is based on the processing of two images taken in the same environment with and without the object, following the given requirements. The detected object is characterized by the aria of its 3d coordinate. The values obtained from the processing of these images applied used as input parameters in the equations for calculating the estimated size while the deviation of the measurement is smaller than 10%.

Othman et al. (2018), presented a technique for detecting objects and computing their measurements in real time from video streams. They suggested an object measurement technique for real-time video by applying the OpenCV libraries, where the canny edge detection, dilation, and erosion algorithms are involved. They applied a reference object which is always the left-most object, in the image, to calculate each object’s size. The technique consists of four: 1) identifying an object to be measured by through the canny edge detection algorithm, 2) applying the morphological operators that include dilation and erosion algorithms to close the gaps between edges, 3) finding and sorting contours, and 4) measuring the dimensions of objects stages, with almost 98% success.

In this article, a new simple vision-based method for object real size measurement, where a digital camera, a reference triangle as a reference object with predetermined dimensions for Scale adjustment are applied. By scanning the image and checking the neighboring pixels of each pixel, the polylines are drawn and by connecting the first point to the last point, the polygon is formed. By having the real areas of the horizontal and vertical sides of the reference object and converting the pixel to millimeter, the whole area of the target object is calculated.

In this proposed method, next to accurately measuring the object, the sides of the objects are identified and calculated separately to obtain the object’s circumference, while, in other methods a hypothetical rectangle is drawn around the object. The length and a width of which are considered as the target object size.

III. MATERIALS & METHODS

To set up the measurement system and the imaging platform, the reference triangle as a reference object is fixed in a specified location on the imaging desk where it can be seen below the target object in the 2D images. The camera is set on a tripod, placed in a specified position on the imaging platform parallel to the object at a constant distance for all images, Fig. 1.

Fig. 1. The imaging environment

The object image is captured for three times from different angles. The proposed software receives these images and calculates the real size of the object as its output. Fig. 2, shows the block diagram of the recommended system. In the following, the different steps of this method are explained.

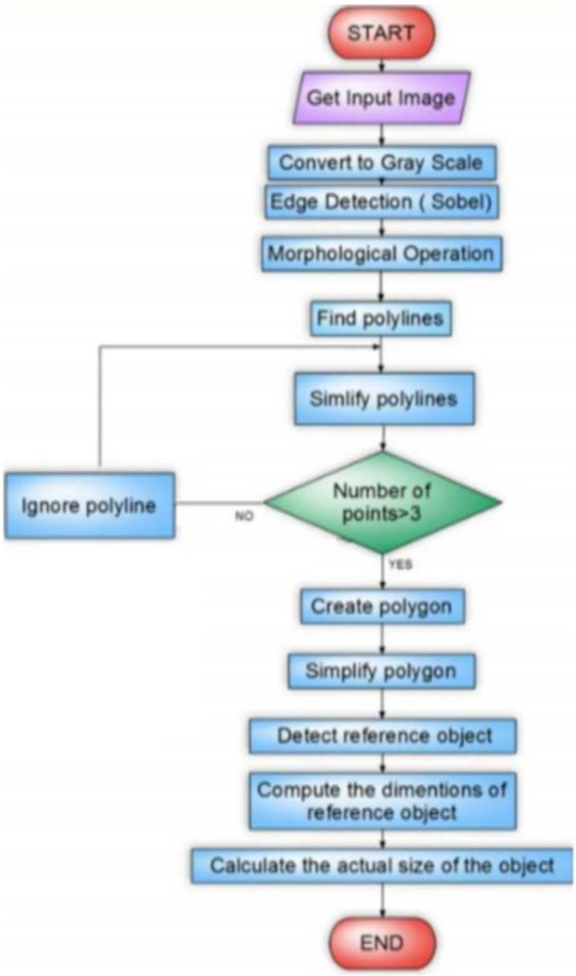

Fig.2. Block diagram of the recommended system

3.1. Locating the Reference Object

To calculate the real size of each object, first, the reference object (a reference triangle in our experiments) must be determined, next, the dimensions of the reference objects will be applied in calculating the target objects' size.

The reference object should have two important properties. The first is that we should know the exact real size of this object in a measurable unit such as millimetres, inches, etc. The second feature is that we should be able to easily detect this reference object in an image, either based on the placement of the reference object in images or from its appearances like being a distinctive colour or shape, unique and different from all other objects in the image. In either case, our reference should be uniquely identifiable in some manner.

The reference triangle is applied as the reference object in the experiments and is placed in a sense that it can be seen below the target object in all images. One of the input images of this proposed system is shown in Fig. 3, where the target object and the reference object are specified separately.

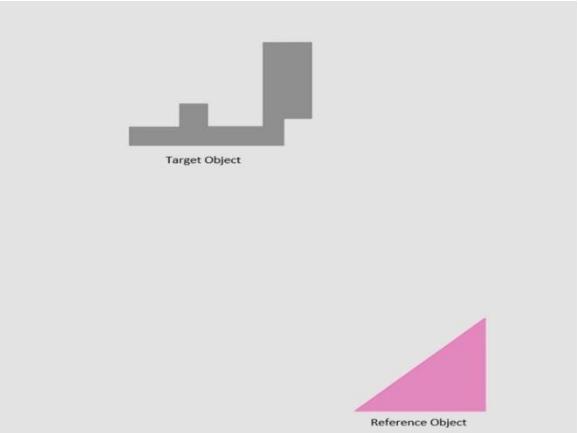

Fig.3. One of the input images

3.2. Edge Detection and Area Opening

After receiving the input image and converting it to the gray-scale image, the Sobel edge operator is applied to detect the sides from the gray-scale image. The Sobel edge operator makes a 2-D spatial gradient measurement on an image and by focusing on regions of high spatial frequency that correspond to sides. Typically it is applied in finding the approximate absolute gradient magnitude at each point in an input grayscale image. Following this, an area opening as a morphological operator is applied to remove all connected components (lines) the areas of which are smaller than the predefined threshold, consequently, the main lines of objects remain and the extra lines are removed. Fig. 4 and Fig. 5.

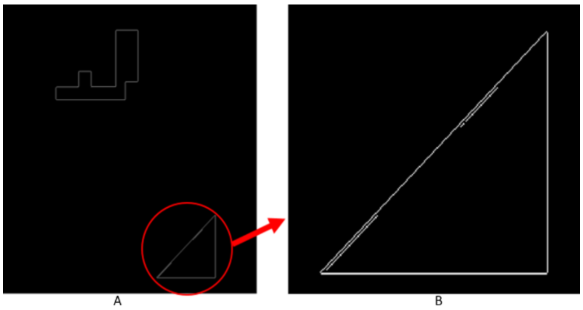

Fig.4. Result of Sobel edge detector

In these figures, the value of pixel is 1, where there are lines, and 0 for the background. In the next step, the rough lines are smoothed to some extent, where a morphology filter is applied.

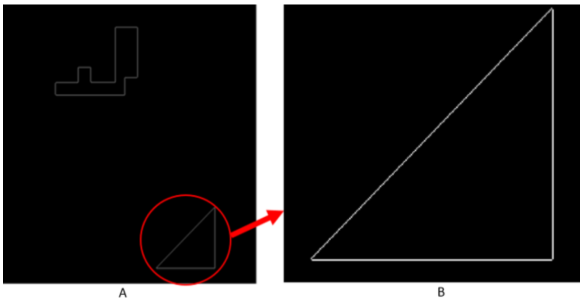

Fig.5. Result of area opening operator

3.3. Polylines Detection

In this step, the lines must be highlighted, for which a top-bottom process is run on the first row to the last rows, and all columns in every row are checked. Because the subject binary image has a margin of '0', it can be concluded that the first row is always black. In this top to bottom process, if '1'pixel is met, that pixel could be both the beginning point of line detection and reference pixel, here.

Eight pixels are checked around the reference pixel which are either black ('0') or white ('1'): if white, a line is drawn between the reference pixel and the white pixel, making the new white pixel the new reference pixel, and this process repeats in a recursive manner, Fig. 6.

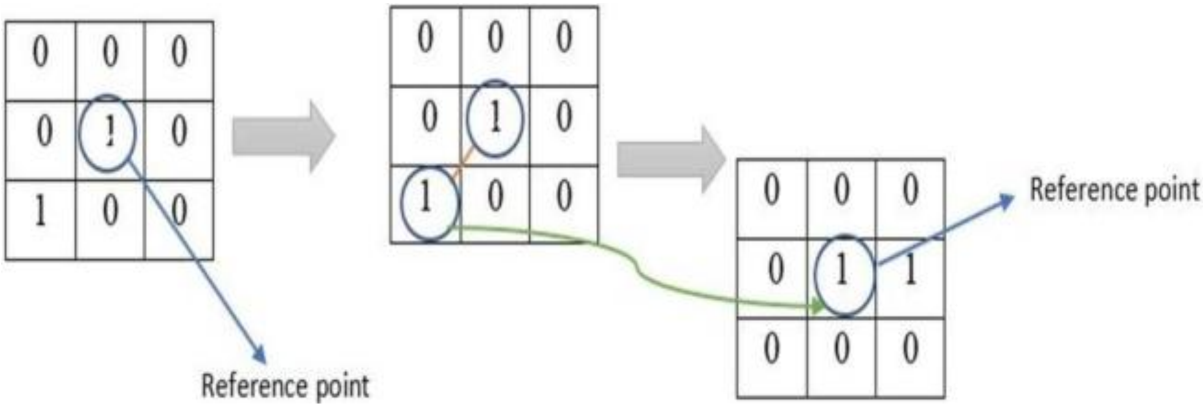

Fig.6. The steps of line detection

In this manner a line appears and continues until it is interrupted by the background pixels. If there are no white pixels around this interrupted point, it is indicative of the line end which lids to formation of a perfect polyline.

At the end, the whole image is swept, and all polylines are detected. In this point, the detected polylines have many points/line segments. In this case, if there is a bias somewhere, it can be detected with a very small tolerance (e.g. 3 pixels above and below). If a line is not out of this threshold, it should be removed and replaced with a single line segment. For this, the method proposed by Schwanghart (2020), which takes a polyline that includes too many points (sub-lines) with a tolerance, and then it returns a simplified polyline is applied.

3.4. Polygon Formation

In this step, there may be some lines where this simplified polyline has fewer than three points, and it is a plain line and cannot form a polygon, consequently, polylines with less than three points will be ignored and finally, the simplified polylines are obtained, which are applied to form polygons or the final objects.

In this step the polygons may need to be simplified in corners where cannot be done in polyline simplification, therefore, the Bone (2020) method is applied for polygon simplification, Fig. 7.

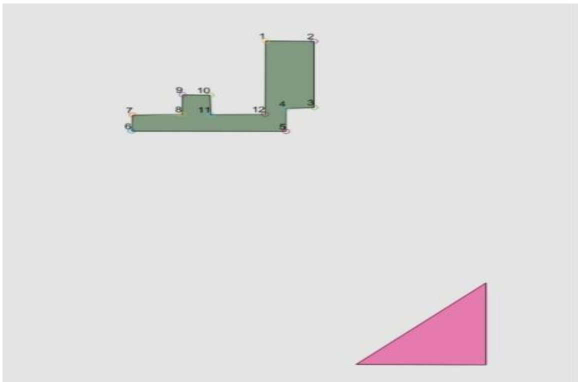

Fig.7. Steps of polygon creation and simplification

3.5. Real Size Measurement

The three corners of the reference triangle are identified first, next, and next, through the slob of the lines it is determined whether the line is horizontal or vertical. With the slope of the lines, the vertical and horizontal sides of the triangles are distinguished. Since the real dimensions of the reference object are known, the calibration rate is determined by comparing the actual size of the horizontal and vertical sides with the sizes obtained from the software. Now, the points of the corner obtained in the previous step are converted into millimeters by applying this scale coefficient from pixels, and then by applying the equation below the length of the line segment length is calculated through the following equation:

Line segment length = $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

IV. RESULTS

A few experimental setups are presented to test this correctness of the proposed method. This proposed system is implemented in MATLAB 2016 S/W. Some example of input objects with their physical real size are shown in Fig. 8.

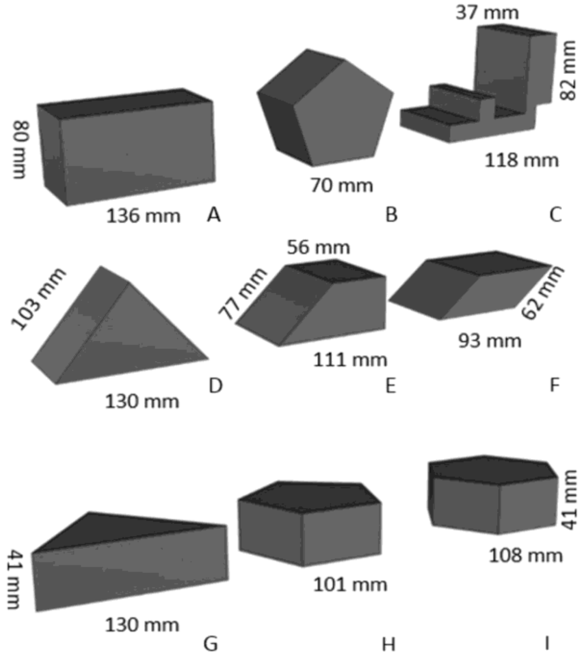

Fig.8. Some example of input objects

For each 3D object, three 2D images are captured and analyzed separately. The dimensions of the object are estimated in three different view. An example of 3D object and related 2D image are shown in Fig. 9. The measurements are made through the same software and compared with the actual size of the objects and the measurement error is determined by up to two decimal places through the following equation:

$$\text{Measurement error} = \frac{|\text{Measured size} - \text{Actual size}|}{\text{Actual size}}$$

The details of this proposed method for a 12 sided of the object of Fig. 9 compared with real size are tabulated in Table 1. The minimum, maximum and average errors in estimating the size of different objects are tabulated in Table 2. The Content of Table 2 reveals the error in measuring the sides of an object in three views.

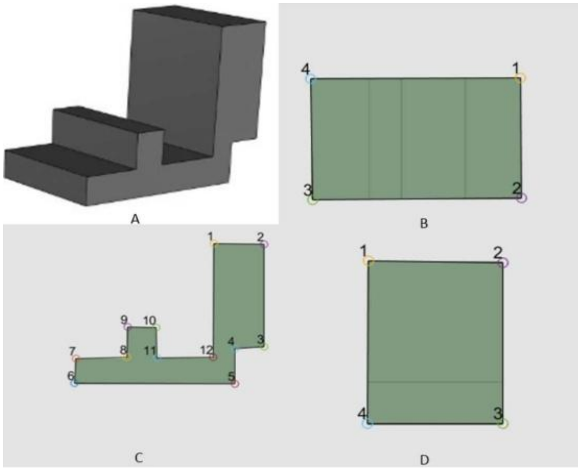

Fig.9. Example of 3D object and related 2D images

Identifying the polygonal constituent lines is one of the most important steps in this proposed system, where applying Hough function is assumed to be the common choice. This function does not reveal the required accuracy in the experiments, therefore, a new way for polyline detection is proposed. A comparison of the results here with the Hough function for one of the sample objects with 4 sides is tabulated in Table 3, where, this proposed method outperforms Hough function.

In the method proposed by Othman et al. (2018), a hypothetical rectangle is drawn around each object, and finally the length and width of the covering rectangle are reported as the object size, while, in this proposed method, the length of each sideis calculated separately, and it’s clear that this method of measurement is more delicate and accurate than that of Othman Othman et al. (2018),Fig. 10 and Table 4 show the difference between these two methods of measurement.

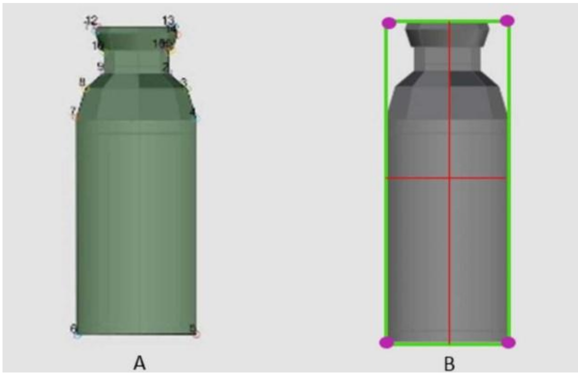

Fig.10. The difference between these two methods of measurement

In general, by analyzing the results of several experiments on different objects, it is concluded that the average error of this proposed method is less than 1.24% and is better than that of 2% obtained in Othman et al. (2018) and 10% obtained in Kainz et al. (2015). This indicates the outperformance of this proposed system versus its counterparts, Table 5.

	Sides	Proposed Method (mm)	Real Size (mm)	Error	Minimum Error	Maximum Error	Average Error
View 1	P1 - P2	86	86	0	0	0.011	0.004
	P 2 - P3	140	140	0			
	P 3 - P4	87	86	0.011			
	P 4 - P1	141	140	0.007			
View 2	P1 - P2	37	37	0	0	0.068	0.023
	P 2 - P3	81	82	0.012			
	P 3 - P4	22	21	0.047			
	P 4 - P5	27	29	0.068			
	P 5 - P6	121	118	0.025			
	P 6 - P7	20	20	0			
	P 7 - P8	38	39	0.025			
	P 8 - P9	24	25	0.040			
	P 9 - P10	21	21	0			
	P 10 - P 11	23	24	0.041			
	P 11 - P 12	42	43	0.023			
	P 12 - P 1	90	90	0			
View 3	P1 - P2	85	86	0.011	0	0.011	0.007
	P 2 - P3	110	111	0.009			
	P 3 - P4	86	86	0			
	P 4 - P1	112	111	0.009			

Table 1: The details of this proposed method for a 12 sided of the object compared with real size

	Views	Minimum Error	Maximum Error	Average Error
Shape 1	1	0	0.007	0.001
	2	0	0.012	0.007
	3	0	0.037	0.016
Shape 2	1	0.008	0.014	0.011
	2	0	0.014	0.011
	3	0	0.009	0.005
Shape 3	1	0	0.011	0.004
	2	0	0.068	0.023
	3	0	0.011	0.007
Shape 4	1	0	0.014	0.007
	2	0	0.015	0.008
	3	0	0.014	0.007
Shape 5	1	0	0.009	0.004
	2	0	0.018	0.009
	3	0	0.022	0.011
Shape 6	1	0	0.007	0.003
	2	0	0.021	0.014
	3	0.011	0.024	0.020
Shape 7	1	0	0.009	0.006
	2	0	0.024	0.011
	3	0	0.024	0.012
Shape 8	1	0	0.032	0.012
	2	0.024	0.099	0.061
	3	0	0.024	0.013
Shape 9	1	0.018	0.074	0.036
	2	0	0.048	0.020
	3	0	0.024	0.011

Table 2: The minimum, maximum and average errors in estimating the size of different objects

	Sides	Proposed Method (mm)	Hough Method (mm)	Real Size (mm)	Errors of Proposed Method				Errors of Hough Method			
					Error	Minimum Error	Maximum Error	Average Error	Error	Minimum Error	Maximum Error	Average Error
View 2	P1-P2	37	N/A	37	0	0	0.068	0.023	N/A	N/A	N/A	N/A
	P2 - P3	81	81	82	0.012				0.012			
	P3 - P4	22	N/A	21	0.047				N/A			
	P 4 - P5	27	N/A	29	0.068				N/A			
	P 5 - P6	121	116	118	0.025				0.016			
	P 6 - P7	20	N/A	20	0				N/A			
	P 7 - P8	38	N/A	39	0.025				N/A			
	P 8 - P9	24	N/A	25	0.040				N/A			
	P9-P10	21	N/A	21	0				N/A			
	P10-P11	23	N/A	24	0.041				N/A			
	P11-P12	42	N/A	43	0.023				N/A			
	P12-P1	90	N/A	90	0				N/A			

Table 3: A comparison of the results here with the Hough function for one of the sample objects

	Glasses	Cup	Bottle	Potato
Proposed Method	0	0.003	0.004	0.018
Othman et al.(2018)	0.047	0.035	0.016	0.034

Table 4: The difference between these two methods of measurement

	Error	Calculate the object's circumference
Proposed Method	1.24%	Yes
Kainz et al. (2015)	10%	No
Othman et al. (2018)	2%	No

Table 5: Compare the proposed method with Othman et al. and Kainz et al. methods

V. CONCLUSION AND SUGGESTION

Measuring the object real size is vital in automated inspection and is highly contributive in faster, more efficient, and more accurate quality control. This type of measurement prevents defective goods production. Measurements made by machine vision could be highly contributive in controlling the statistical process associated with enhancing product quality, reducing waste products, and improving productivity and manufacturing process.

A system is proposed to measure objects in a simple vision-based manner. This proposed method, while simple and inexpensive, is accurate enough to measure the dimensions of different objects. The length of each side is calculated separately and is not limited to the covering rectangle. Its costs are much less than expensive robots or laser devices. This method also solves the problem of non-portability of available devices. This software can be applied to increase the precision of manufacturing of more sophisticated objects. The obtained results indicate that outperformance of this method vs. its counterparts.

In this proposed method, three separate 2D photos are taken for the target object. Then, each picture is analyzed separately. In the follow up of this research, combining the results of these photos can increase the accuracy of the proposed method. This combination will produce a better representation of a 3D object, and will likely lead to a more accurate measurement.

REFERENCES

[1] Abadarian D. 2017. Machine vision, Science processing images. Available at https://www.enline.ir (accessed 18 May 2020).

[2] Bone P. 2020. Polygon simplification. Available at https://www.mathworks.com/matlabcentral/fileexchange/45342-polygon-simplification (accessed 30 May 2020).

[3] Bridges R. E, Brown L. B, West J. K, & Ackerson D. S. 2015. U.S. Patent Application No. 14/035,527.

[4] Davies E. R. 2004. Machine vision: theory, algorithms, practicalities. Elsevier.

[5] Fan K. C, Cheng F, Wang W, Chen Y, & Lin J. Y. 2010. A scanning contact probe for a micro-coordinate measuring machine (CMM). Measurement Science and Technology, 21(5), 054002.

[6] Ferrari P. 2010. U.S. Patent No. 7,774,949. Washington, DC: U.S. Patent and Trademark Office.

[7] Kainz O, Jakab F, Horečný M. W, &Cymbalák D. 2015. Estimating the object size from static 2D image. In 2015 International Conference and Workshop on Computing and Communication (IEMCON) (pp. 1-5). IEEE.

[8] Kopparapu S. K, &Desai U. B. 2001. Bayesian approach to image interpretation (Vol. 616). Springer Science & Business Media.

[9] Metrology C. 2013. Coordinate Measuring Machine History – Fifty Years of CMM History leading up to a Measuring Revolution. Available at http://www.coord3-cmm.com (accessed 20 May 2020).

[10] MohsenDokht M. 2017. Coordinate Measuring Machine. Available at http://cmm-machine.blogfa.com (accessed 22 May 2020).

[11] Othman N. A, Salur M. U, Karakose M, & Aydin I. 2018. An Embedded Real-Time Object Detection and Measurement of its Size. In 2018 International Conference on Artificial Intelligence and Data Processing (IDAP) (pp. 1-4). IEEE.

[12] Raab S, Sajedi, S. A, Helm, C. A, &Hobden, R. 2005. U.S. Patent No. 6,965,843. Washington, DC: U.S. Patent and Trademark Office.

[13] Schwanghart W. 2020. Line Simplification. Available at https://www.mathworks.com/matlabcentral/fileexchange/21132-line-simplification (accessed 30 May 2020).

[14] Shahdib F, Bhuiyan M. W. U, Hasan M. K, & Mahmud H. 2013. Obstacle detection and object size measurement for autonomous mobile robot using sensor. International Journal of Computer Applications, 66(9).

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