Comparison of camera calibration method for a vision based meso-scale measurement system

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ABSTRACT – This research compared three types of CCD camera calibration techniques namely Bouget's Calibration Toolbox, Zhang's Calibration Toolbox and Heikkilla's Calibration Toolbox. Experimental data for both calibration and optimization were collected to further explain the experimental results. Statistical analyses such as T-Test and ANOVA were conducted on the collected data using Minitab and EXCEL software. The results of this research indicated that the best calibration technique (toolbox) for calibrating Omron F500 CCD Camera for the purpose of measuring dimensions of meso-scale component is the Heikkilla's Calibration Toolbox.

1. INTRODUCTION

Since the contact methods have drawback for the highly advanced manufacturing process that could produce a component smaller than a millimeter size, the non-contact methods that use optical capabilities are mostly focused by recent researchers [1,2]. Based on the survey done by Hibbard and Bono(2003)[3], it is found that current available measuring equipment are focused on components in the size of micrometer or nanometer which requires high investment. There is a gap of measurement size and lack of development being done for the component in the size of meso-scale.

In developing a vision based measuring system, the camera's precision has always been the bottleneck, and often being discussed. As a result none of the existing camera calibration techniques is perfectly suitable for this purpose [4]. The user, need to identify the type of image processing method (i.e edge detection) to be used in their measurement application before deciding which calibration technique to be selected. Furthermore, there is a need to determine simultaneously other parameters such as the image exterior orientation by a process of least squares adjustment.

Ricolfe and Sanchez [5] described that the precision of calibration depends on how accurate the world and image points are located. Studying how localization errors propagate to the estimates of the camera parameters is very important.

2. METHODOLOGY

The experiments were conducted by using Omron F500 Vision System CCD camera. Three samples were identified for this procedure namely checkerboard image pattern, fiducial image pattern and plumb-line image pattern.

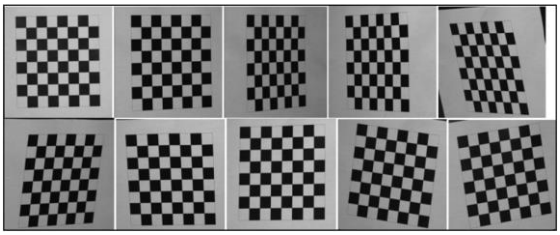
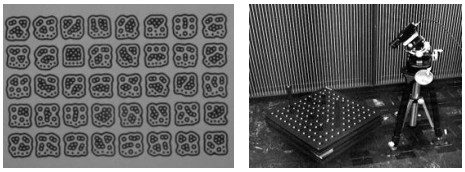


Fig 1 Checkerboard Image Pattern



(a) (b)

Fig 2 (a) Fiducial Image Pattern, (b) Plumb-line Image Pattern

Table 1 Table of comparison for calibration method

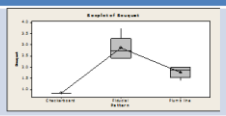
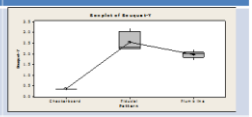
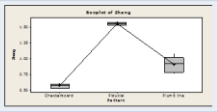
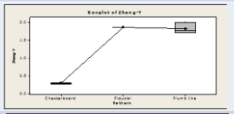
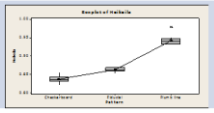
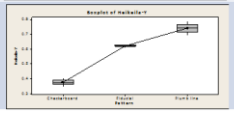
Calibration Method	Advantages	Disadvantages	Calibration Toolbox
Tsai's Method	This method splits the problem into two steps. It allows use of both planar and non- planar patterns.	This method assumes that optical center is located at image center and that skew is null. In the first step, the distortion is assumed null.	Heikkilla Calibration Toolbox
Heikkilla & Silven's Method	The model uses two coefficients for both radial and decentering distortion, and the method works with single or multiple images and with 2D or 3D calibration grids	Interior Orientation (IO) need to be refined by using Levenberg-Marquardt algorithm	Heikkilla Calibration Toolbox
Batista's Method	This method needs only one image of a planar pattern to calibrate a camera. It is a multistep and iterative method that uses a least squares technique at each step.	Distortion is modeled using only one coefficient	Bouget Calibration Toolbox
Zhang's Method	This method needs at least three different views of a planar pattern. Lens distortion is modeled using two coefficients.	Displacements between these views can be unknown.	Zhang Calibration Toolbox

The camera's parameters were fixed while all the three specimens with different angles were calibrated by the toolboxes.

3. RESULTS AND DISCUSSION

Based on the box-plot chart, each calibration toolbox showed that there are significant differences between the three image patterns used based on the P value which is >0.05. The individual 95% of confident interval (CIs) for each mean also indicates that there is no overlapping and significantly different between the three image patterns means as well. Checkerboard pattern showed the most consistent result : lowest pixel error and low variation(more precise). Comparison results of the three calibration toolboxes showed that Heikkilla Calibration Toolbox give the most precise value in all the three image pattern used. Refer to Table 2.

Table 2 Comparison (pixel error) of camera calibration toolboxes

CALIBRATION TOOLBOX	x - Axis	y - Axis
BOUGUET		
ZHANG		
HEIKKILLA		

Heikkilla's Calibration Toolbox has the best detection in terms of pixel error at x-axis and y-axis, and can be concluded that the best calibration toolbox required for optical component in non-contact measuring system. This is because the result gathered after experiments, supports the needs and purpose of camera precision in measuring dimensions based on edge detection. Refer to Table 3 and Fig 3.

Table 3 Image pattern vs. camera calibration toolboxes

Pattern / Toolbox	Checkerboard	Fiducial	Plumb Line
Bouquet	0.83213	2.85344	1.76862
Zhang	0.57581	1.55846	0.91260
Heikeila	0.83700	0.86243	0.94181

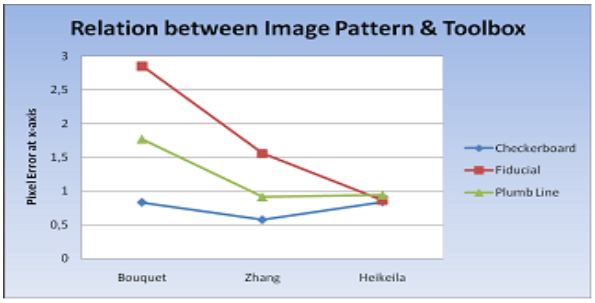


Fig 3 Relation Between Image Pattern and Calibration Toolbox

4. CONCLUSIONS

The research provides a guideline on the selection of calibration technique and calibration toolbox which can be utilized to enhance the precision of CCD camera in order to eliminate error in dimension measurements. The findings have been supported by statistical analysis.

According to this study, Heikkilla's Calibration Toolbox is the most suitable and a good calibration tool to be used in the field of image processing (edge detection). However, the purpose of using the camera, in terms of image processing methods, need to be clarified beforehand in order not to use the wrong calibration tools available.

For future research, the development of meso-scale non-contact method by using CCD camera and image processing shall be applied. The idea is to develop an in-house capability in producing measuring equipment to fulfill the requirement for measuring meso - scale components. If the proposed technique can produce acceptable readings (compared to other non-contact method), the prototype product can be promoted to the industries that require measurement for small components.

5. ACKNOWLEDMENT

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6. REFERENCES

[1] Mekid and Ryu. "Rapid Vision-based Dimensional Precision Inspection of Meso-scale Artifacts." *Proceeding of the institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, vol. 221, pp 659 -672, 2007

[2] Leach, R., Haycocks, J., Jackson, K., Lewis, A., Oldfield, S. and Yacoot, A. "Advances in Traceable Nanometrology at the National Physic Laboratory." *Nanotechnology*, vol. 12, pp. R1-R6, 2001

[3] Hibbard, R.L. and Bono, M.J. "Meso-scale Tools: A Survey of Relevant Tools and a Discussion of Their Strengths and a Discussion of Their Weakness." in *ASPE Winter Topical Meeting, Gainesville, Florida, USA*. 2003

[4] Ethrog, U. "CCD Camera Calibration based on the Sun's Images." *IAPRS*. vol. XXXVI, Part 5, 2006

[5] Ricolfe-Viala,C and Sanchez-Salmeron, A.J., "Camera Calibration Under Optimal Conditions." *Journal of Optics Express*, vol 19, pp 10769-10775, 2011.