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Assessment on different digital camera calibration software for photogrammetric applications

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ABSTRACT

Camera calibration has always been an essential component in photogrammetric measurement. Nowadays, self-calibration is being integral and routinely applied operations within photogrammetric triangulation, especially in high accuracy close range measurement. This study is to compare the accuracy of different types of software in order to determine the correct technique based on two different calibrations software. The objective of this study is to analyze the accuracy based on different resolution, to assess the calibration result based on two different software and to evaluate the best technique in camera calibration. Based on this study, the data involves are image of calibration sheet from different camera resolutions, good and bad light conditions and different flash conditions. This is the three types of data needed in this study before next process can be done. After all the data has been acquired, it undergoes data processing to assess the RMSE value for each result. This process used PhotoModeler software and GML C++ Camera Calibration Toolbox. The result shows the Olympus camera has better result than the other two camera used. In conclusion, the self–calibration method is easy to perform and save time compare to other method that required cost and more complex.

Keywords:
Calibration, GML, PhotoModeler, Size, Camera, Accuracy

1. Introduction

In photogrammetry, there are several type of camera that can be used such as metric camera and non-metric camera. Usually metric camera used for the purpose of mapping since the development of airplane. With the current technology, the non-metric camera is used to replace the metric camera. Apart from metric camera, non-metric camera which have video camera and digital camera can also be used for aerial photogrammetry [1],[5]. The non-metric camera especially digital camera provides many advantages compared to metric camera. The advantages of non-metric camera is easy to use, handy, cheap, the images are in digital form which is ready to be used and does not need

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aircraft. In addition, the digital camera can be attached at a balloon, light aircraft such as UAV or other platform. There are many types of digital cameras such as Nikon, Canon and so on. According to Kuo *et al*. [3], the non-metric camera capability to carry out deformation survey has been proven nowadays.

Even so, amateur digital camera is not produced for the purpose of photogrammetry usage. Due to the variety of range for different model of amateur digital cameras, methodology and quality of the camera calibration is the issue especially in long term consistency. Camera calibration is an important phase for non-metric cameras as being a necessary element for photogrammetric assessment. Hence, every instrument that will be used for observation must be calibrated to provide the high accuracy of data. In recent years, lens calibration is not popular than in the period from 1950 until 1970. This is because the maturity of understanding of aerial lenses which in give much for the improvement of model and calibration methods. There are various types of camera calibration according to Jung *et al*. [2], such as In-situ calibration, precision multi-collimator instruments and self-calibration. The use of self-calibration using bundle adjustment method has received much attention nowadays. Calibration must be carried out to determine that the instruments in a suitable condition to carry out the work. Schillebeeckx and Pless [6] discussed that camera calibration methodology purpose is to distinguish wholly the light rays when it was exposed when entering the camera. In camera calibration, there are 3 orientations that are required to be oriented. They are interior orientation, relative orientation and absolute orientation. According to Menna *et al*. [4], when the interior orientation parameters are known, the camera is considered to be calibrated. The images are taking by using camera where all the essential parameters of the camera are determined from the information of the images during the self-calibration process. Based on the bundle adjustment, the calibration software is chosen [7-10].

On the market nowadays, there are many types of camera calibration software that can be downloaded for free. There are Photomodeler, GML C++ and Australis camera calibration software. Certain method of self-calibration requires 3 dimensional calibration models while several require 2 dimensional calibration sheets. Besides that, self-calibration method is carried out in the laboratory. Hence, there are different accuracy which are obtained from each calibration software. The camera calibration accuracy can give result from micron until meter level. This study is compare the accuracy of different types of software in order to determine the correct technique based on two different calibrations software. The aim of this study is to investigate the accuracy of camera calibration based on two different software and technique.

2. Methodology

In this study, methodology shows the general process that will be carried out. The process consists of four phases; phase one is a background study that involves software selection, work planning and case study. Phase two involves data acquisition process which consists of data collection of image from camera. Phase three involves data processing by using different types of calibration software and lastly phase four involves the result and analysis process. The results of accuracy from different types of camera calibration software based on different calibration technique were discussed. Figure 1 shows the general methodology for this study.

Preliminary study is the first stage of this study that define the literature review of digital camera, camera calibration, type of calibration, problem identification related to camera calibration and type of calibration software available in the market. In addition, the selection of software and study area was considered at this stage. Work planning process also include in this stage because it important to make sure the progress is on the right track. The revision of previous study is also conducted at this stage. Based on this study, the data involves are image of calibration grid from different resolutions, good and bad light conditions and different flash conditions. This is the three types of data needed in this study before next process can be done. The data have collected by using three different types of camera resolutions, different light condition and different flash condition. Figure 2 shows the example of camera calibration sheet.

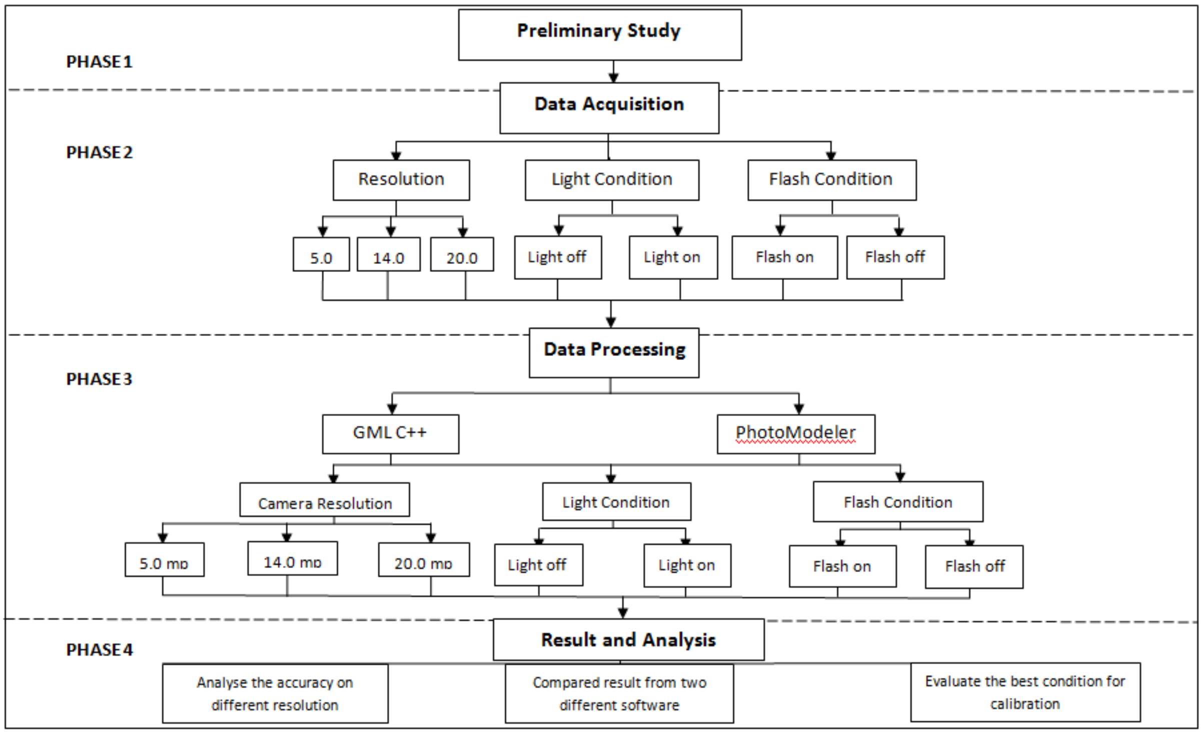
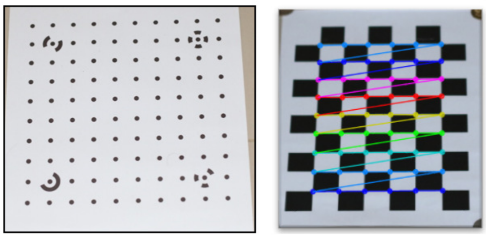


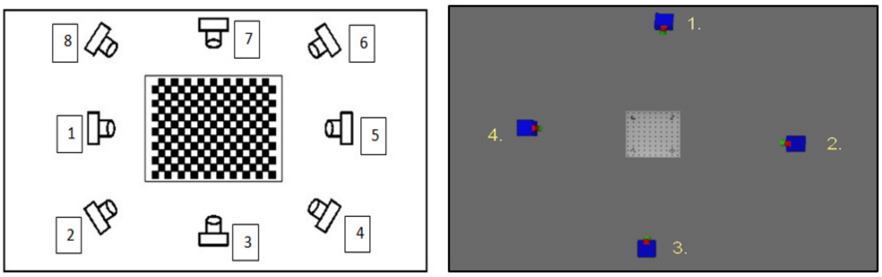
Fig. 1. Research Methodology



(a) (b)

Fig. 2. Calibration target; a) photomodeler, b) GMLtest pattern for Photomodeler

The calibration grid used in this study is printed on an A4 and A3 paper size. Firstly, the calibration grid is placed on the ground and to make sure the paper stay at their placed, put a tape on it. Next, the camera is mounted on the tripod and place at position 1 until 8 in landscape mode where all the chessboard point is visible in the image as shown in Figure 3. After that, rotated the camera 90 clockwise where the image is taken in portrait mode. The total image taken for GML is sixteen images. Then, transfer the image into the computer for processing.



(a) (b)

Fig. 3. Camera position; a) GML, b) PhotoModeler

The process for image capturing is almost same with GML software procedure but it have a bit different in a number of images taken. Firstly, the calibration grid is placed on the ground. Then, start taking the image at position 1, 2, 3 and 4 as shown in Figure 3. For the first session, the image is taken in landscape mode where all the four control points are visible in the image. Next, rotated the camera 90° clockwise where the image is taken in portrait mode. The total image taken is eight images and lastly transfers the image into computer for processing.

2.1 Light Exposure

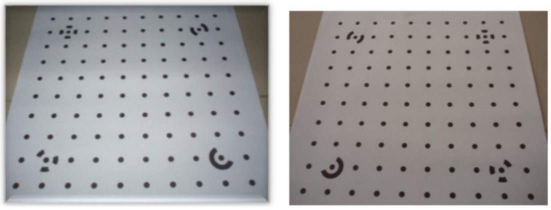
This study will determine the accuracy of the image under two light conditions. There are two different of light condition in this study. First condition is image was taken under good light condition which is at bright place. It was taken under fluorescence light that give the image become clear compared to the other condition as shown in Figure 4a. The second condition is image was taken under poor light condition which is at less bright place as shown in Figure 4b. This condition is taken without fluorescence light and the place is darker than the first condition. The image taken maybe will become better or less good than under fluorescence light.

(a) (b)

Fig. 4. Light condition; a) Good, b) poor

2.2 Camera Flash

This study also compares the accuracy of the image with and without camera flash. The camera flash is used under different light condition to compare the accuracy of image with and without flash. The images are taken using cameras that have been setting in no flash mode for the first session and after all images have been taken, the mode is change to automatic mode with flash. The comparisons between image with camera flash and without camera flash are shown in Figure 5a and 5b.



(a) (b)

Fig. 5. Image taken; a) with camera flash, b) without camera flash

3.0 Data Processing

3.1 GML C++

The processing process using this software is quite easy to handle and there are not many procedure that need to be taken. To perform this process, it needs minimum three images while this study used sixteen images. To start the process, it required the dimension of the chessboard pattern such as 5 x 6 or 5 x 8 and also the square size for verify the calibration pattern. If the dimension or square size is wrong, the software cannot perform this process correctly. For this study, the dimension used is 7 x 10 and the square size is 29.5 mm for A4 paper size and 35mm for A3 paper size as shown in Figure 6. The next process is add the calibration pattern image before can start the calibration. Then, the software can detect the image and give the calibration result as shown in Figure 6. The results consist of RMSE error, focal length, principal points and distortion value.

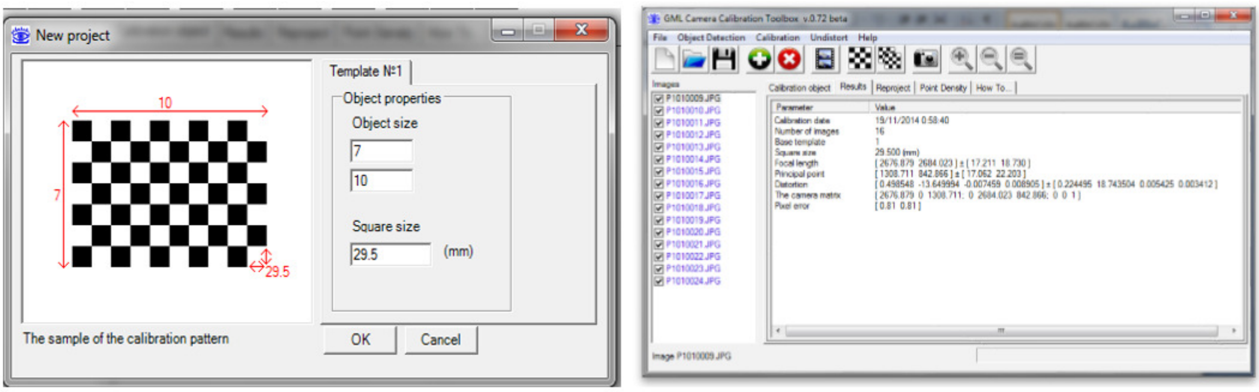


Fig. 6. Pattern dimension and size and Result for GML software

3.2 PhotoModeler

The other software use in this study is PhotoModeler version 10.0 that easy to use and handle. Camera calibration is executed to determine the internal parameters of the camera. The process starts by upload the images that consist of eight images from one camera. The minimum image required for this software is eight as shown in Figure 7. Then, the software start the process by detects the four main points and other point on the calibration paper. By using algorithm, it detect at the center of the four main points and every image should pass at least three points. If lower than that, it become insufficient good calibration number and need to take an image for one more time. The image should be clear to success to verification process. After all images have been success, the results appear on the screen as shown in Figure 7. On the result shows the RMSE value, lens distortion, principal points and focal length.

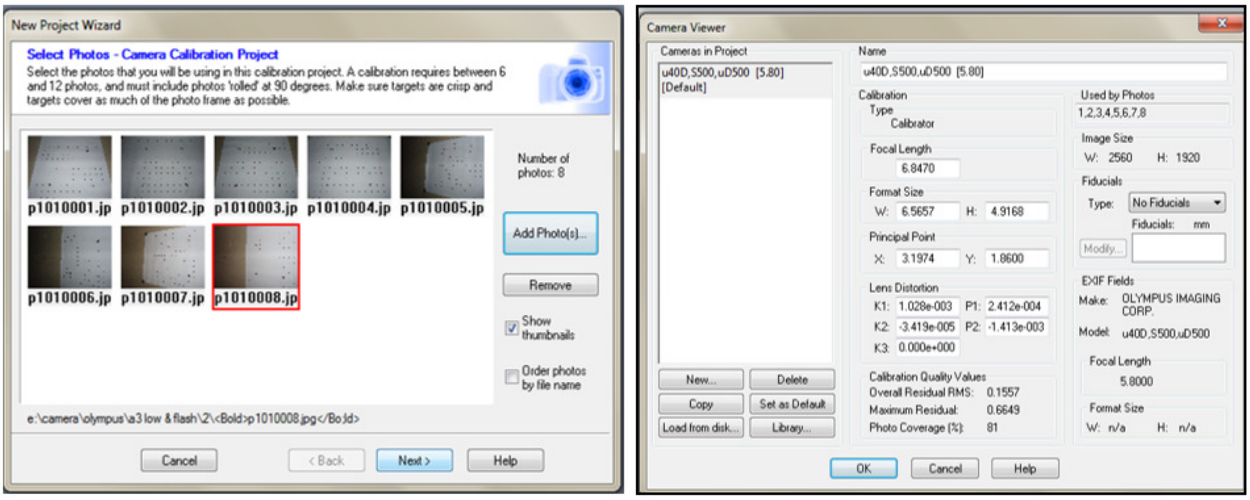


Fig. 7. Add data process and Camera Viewer Window Displaying Camera Parameter

4.0 Results and Analysis

4.1 Assessment of Light Conditions

Based on the result in Figure 8, there are two different type of software and two difference paper size used. Besides, this figure shows the difference between poor light and good light condition based on paper size and camera. For Olympus camera, the difference is ±0.17 μm for A4 size and ±0.24 μm for A3 size that has been process using GML software. The difference by using A4 paper size is small and the difference using A3 size is more than A4 size. The second camera using GML software is Nikon it shows the difference of light condition using A4 paper size is ±0.07 μm while for the A3 size the difference is ±0.28 μm. Based on the figure, comparison between A4 paper size is small because the RMSE result for both poor and good light condition is almost same. The comparison between A3 size results for both conditions is quite large difference and because of that the difference is large. The third camera is Canon DSLR it shows the difference between light conditions using A4 paper size is ±0.27 μm while for the A3 size, the difference is ±0.1 μm. The difference between A4 size is large because the RMSE for poor light and good light is quite different. Meanwhile, the RMSE result for A3 size is almost same. For PhotoModeler software, the difference is ±0.0247 μm for A4 size and ±0.0034 μm for A3 size by using Olympus camera meanwhile for Nikon camera in A4 size, it shows ±0.5129 μm and for A3 ±0.6902 μm that quite high between other two cameras. The difference for Olympus camera is small for both paper size and for Nikon camera, there are huge differences for both paper size. It is because the RMSE results for poor and good light condition have a large difference. Lastly for camera Canon DSLR, the result shows difference is ±0.0267 μm and ±0.0538 μm. Based on the figure, both of paper size has small difference for both condition.

Figure 9 shows the difference flash between poor light condition and good light condition using A4 paper size. The process is done by using two software which is GML and PhotoModeler calibration software. For the GML software, the first camera is Olympus 5.0 mp. From the chart, both of conditions have same difference value which is ±0.01 μm. It means, both of conditions have almost same RMSE value. The second camera is Nikon 14.0 mp shows the difference at poor light condition is ±0.02 μm meanwhile at good light condition, the difference is ±0.01 μm. Based on the figure, comparison between A4 paper size is small because the RMSE result for both poor and good light condition is almost same. It also showing that image taken using camera flash and without camera flash not give huge effect in RMSE result using this camera.

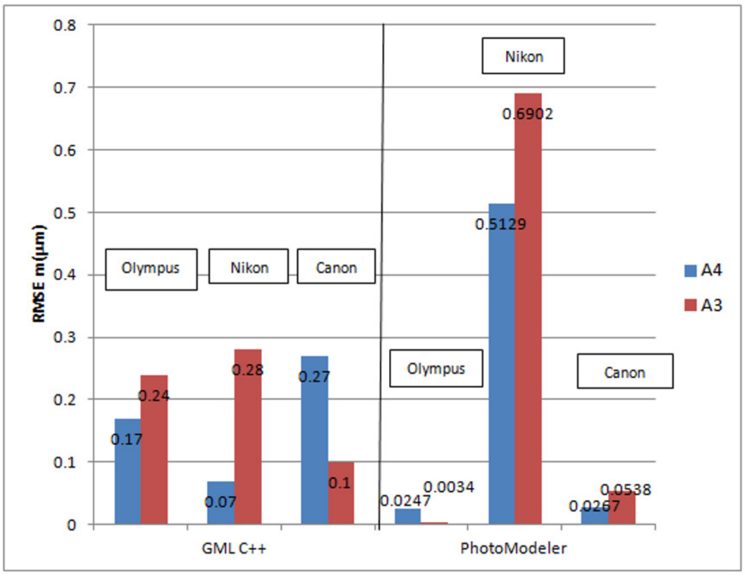


Fig. 8. Light

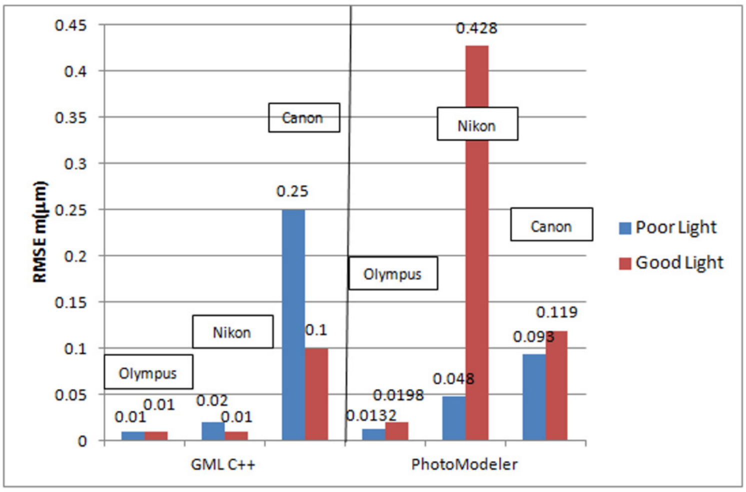


Fig. 9. Camera Flash Condition based on 3 cameras and 2 software's (A4 size)

Third camera is Canon DSLR 20.0 mp shows the difference flash between poor light condition is ±0.25 µm meanwhile at good light condition the difference is ±0.1 µm. The difference is quite large for the flash in poor light condition meanwhile difference in good light condition is small between using flash and without flash. The next result is the difference for PhotoModeler software. The first camera using this software is Olympus 5.0 mp which is shows the difference flash in poor light condition is ±0.0132 µm. Based on the result, it show the value between using flash and without using flash in poor light condition is almost same and have small difference. In good light condition, the difference between flash and without flash is ±0.0198 µm. The second camera is Nikon 14.0 mp that shows the difference flash in poor light condition is ±0.048 µm meanwhile for good light condition is ±0.428 µm. Based on the result, it show the value between using flash and without using flash in poor light condition is not very different but in good light condition, the difference is large and it is the highest different plot in this chart. Lastly is for Canon 20.0 mp camera show the difference result is ±0.093 µm in poor condition meanwhile ±0.119 µm in good light condition.

4.3 Assessment of Camera Flash Condition (A3 size)

Figure 10 shows the difference flash between poor light and good light using A3 paper size. For the first software which is GML, the result for difference flash in poor light condition is ±0.01 μm and ±0.02 μm in the good light condition taken from Olympus 5.0 mp camera. The chart described the RMSE value for both of this condition is not change significantly. The second camera is Nikon 14.0 mp shows the difference at poor light condition is ±0.02 μm meanwhile at good light condition, the difference is ±0.04 μm. Based on the figure, comparison between A4 paper size is small because the RMSE result for both poor and good light condition is almost same. It also showing that image taken using camera flash and without camera flash not give huge effect in RMSE result for this condition by using this camera.

The third camera Canon DSLR 20.0 mp shows the difference flash between poor light condition is ±0.18 μm meanwhile at good light condition the difference is ±0.09μm. The difference is quite large for the flash in poor light condition meanwhile difference in good light condition is small between using flash and without flash. The next result is the difference for PhotoModeler software. The first camera using this software is Olympus 5.0 mp which is shows the difference flash in poor light condition is ±0.11 μm. Based on the result, it show the value between using flash and without using flash in poor light condition is quite large. In good light condition, the difference between flash and without flash is ±0.013 μm and can be arguably the RMSE is almost same. The second camera is Nikon 14.0 mp that shows the difference flash in poor light condition is ±0.572 μm meanwhile for good light condition is ±0.062 μm. Based on the result, it show the value between using flash and without using flash in poor light condition is quite difference and it is the highest different plot in this chart. The last is Canon 20.0 mp camera show the difference result is ±0.0007 μm in poor condition meanwhile ±0.001 μm in good light condition.

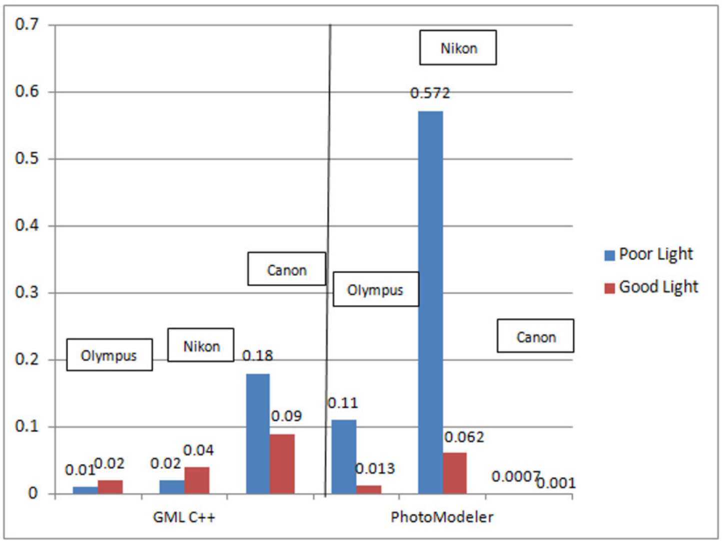


Fig. 10. Camera Flash Condition based on 3 cameras and 2 software's (A3 size)

4.4 Assessment of GML Software

The difference value for comparison between poor light condition and good light condition using GML software has been explained in Figure 8. The difference also has been compared between different types of software which is GML and PhotoModeler. Besides that, the difference in condition of flash during poor and good light condition also has been explained in Figure 9 and Figure 10. In this study, there are four conditions that need to be analysed which is analyse about the comparison of paper size, comparison of different camera resolution, analyse light condition during taken the image and analyse about the flash condition during poor light condition and good light condition. The first objective is the comparison between A4 and A3 paper size by using GML software. Figure 4.11 describes the A4 paper is suitable used than A3 paper size using GML software. All the RMSE has been plotted under one chart and this chart show the significant changes between A4 size and A3 paper size. Most of the result for A4 size is better for all camera resolution and light condition. The lowest value for A4 size is 0.8 �m meanwhile the lowest value for A3 size is 1.18 µm. Therefore, A4 size is the best size used for GML software. The reason because by using A4 size, the calibration grid is smaller and the accuracy for algorithm to detect the grid line is better than A3 size. Next, the graph describes the comparison between camera resolution. Based on the chart, it shows three different type of resolution consist of 5.0 mp, 14.0 mp and 20.0 mp. The chart shows the 5.0 mp has a better result than other two camera resolution. Camera with 14.0 mp is the second highest and camera with 20.0 mp is the highest result in RMSE value. Most of the result is better using A4 size but when using the A3 size, the RMSE value will increase significantly. From this study, every camera has a different focal length with the Canon DSLR have the highest which is 50 mm while the other camera is 5.80 mm for Olympus 5.0 mp and 4.60 mm for Nikon 14.0 mp. Other than that, compact camera is more easy to use than digital camera because the image taken will become blur if the camera setting is incorrect.

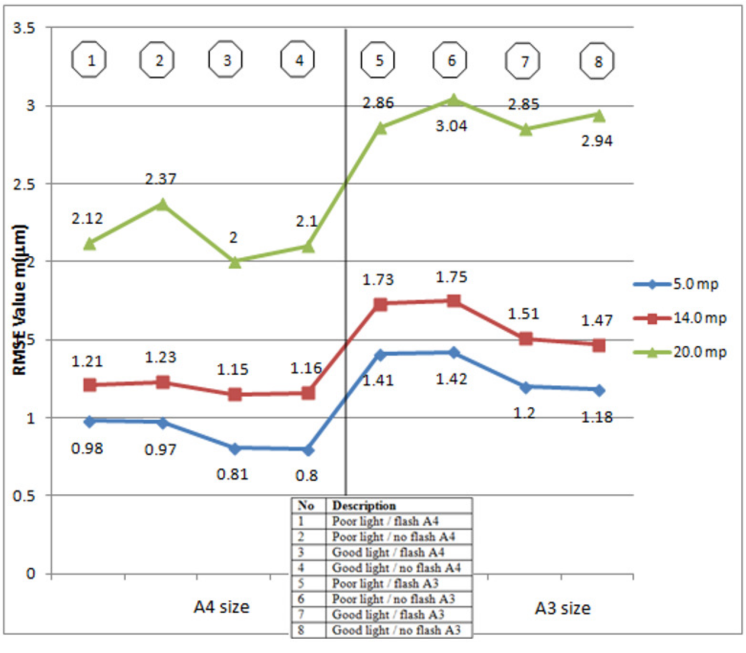


Fig. 11. GML results based on 3 cameras, 2 paper size and 8 conditions

Next is analyse about the light condition during taken the image. Based on Figure 11, the first and second point is taken in poor light condition while the third and fourth point is taken at good light condition for both paper sizes. From the graph, the image taken under good light condition is better than poor light condition. It show when image taken under poor light condition the RMSE is high but when image taken under good light condition, the RMSE will decrease significantly for all camera. Same as A3 size, the most of the result also show the same movement. Based on the result, it can be analyse that image taken under good light condition is better than poor light condition because at good light condition, the image will become clear and camera easy to detect the grid line. But under the poor light condition, there are many reasons that can be associated such as the image will become blur when it is taken. Then, most of the camera need a sufficient light to get the better result and at this condition, the camera do not have sufficient light to perform its job perfectly. Lastly is about the flash condition under poor and good light condition. Based on the figure, when the image taken without flash, the RMSE will increase slightly compared to image taken with flash. The result also effect the A3 size which is on the poor light condition without flash, the RMSE will slightly increase but when the image taken with flash, the result will slightly decrease. From the result, camera flash also gives an effect for the calibration process because at poor light condition, camera flash will be used as a medium to make the image taken is visible. At good light condition, flash will be used as a medium to help the image become clear.

4.5 Assessment of PhotoModeler Software

Figure 12 describes the graph comparison based on PhotoModeler software. First, analyse the comparison between paper sizes. From the graph, by using PhotoModeler software, the A3 size is give better result from A4 paper size. All the RMSE has been plotted under one chart and it shows the significant changes between A4 size and A3 paper size. Most of the result for A3 size is better for most of camera resolution and light condition. For the example, the lowest value for A4 size is 0.164 μm meanwhile the lowest value for A3 size is 0.149 μm using 5.0 mp camera. Therefore, A3 size is the best size used for PhotoModeler software. The reason because by using A3 size, the calibration grid is smaller and the accuracy for algorithm to detect the point grid is better than A4 size. The calibration grid for A4 size is much larger than A3 and it difficult for the algorithm to detect the point grid.

Next, the graph describes the comparison between pixel sizes. It shows three different type of resolution consist of 5.0 mp, 14.0 mp and 20.0 mp. It is found that the 5.0 mp pixel also has a better result than other two camera resolution. Camera with 20.0 mp is the second highest and camera with 14.0 mp is the highest result in RMSE value. From this study, every camera has a different focal length with the Canon DSLR have the highest which is 50 mm while the other camera is 5.80 mm for Olympus 5.0 mp and 4.60 mm for Nikon 14.0 mp. One of the advantages using compact camera is it easy to use than digital camera. Although Canon DSLR has a highest camera resolution but it cannot give the best RMSE because of the image taken will become blur if not setting correctly. Moreover, the software requires each image must exceed 80 percent coverage. The requirement for the coverage is hard to perform because when the camera is rotated to portrait orientation, the image cannot cover the entire image. Next is analyse about the light condition during taken the image. Based on Figure 12, the first and second point is taken in poor light condition while the third and fourth point is taken at good light condition for both paper sizes. From the graph, the image taken under good light condition is better than poor light condition. The image taken under poor light condition records the high RMSE while image taken under good light condition, the RMSE will decrease significantly for all cameras.

Same as A3 size, the most of the result also shows the same movement. Based on the result, it can be analysed that image taken under good light condition is better than poor light condition because at good light condition, the image is clear and camera easy to detect the point grid. But under the poor light condition, there are many reasons that can be associated such as the image will become blur when it is taken. Then, most of the camera need a sufficient light to get the better result and at this condition, the camera do not have sufficient light to perform its job perfectly. Lastly is about the flash condition under poor and good light condition. Based on the figure, the image acquired without flash, the RMSE will increase slightly compared to image acquired with flash. The result also effect the A3 size which is on the poor light condition without flash, the RMSE will slightly increase but when the image acquired with flash, the result will slightly decrease. From the result, camera flash also gives an effect for the calibration process because at poor light condition, camera flash will be used as a medium to make the image taken is visible. At good light condition, flash will be used as a medium to help the image become clear.

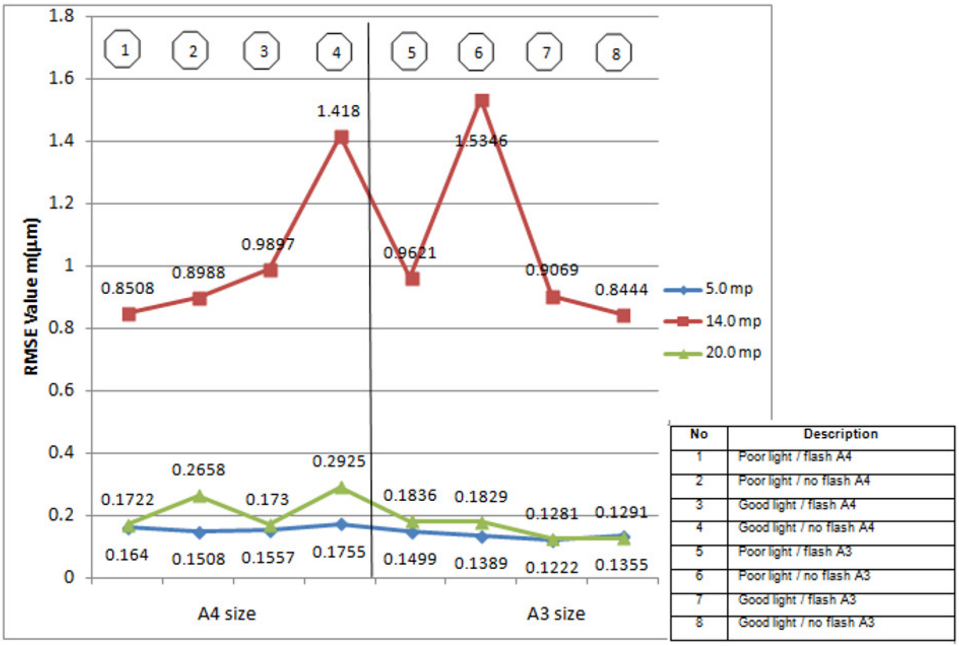


Fig. 12. PhotoModeler results based on 3 cameras, 2 paper size and 8 conditions

5. Conclusions and Recommendations

The aim of this study is to investigate the accuracy of camera calibration based on two different software and techniques. The software used in this study is GML C++ and PhotoModeler software. There are two different techniques used to support the aim of this study. First technique is the comparison between poor light condition and good light condition. The second technique is the comparison by using camera flash and without camera flash under different light condition. First objective is to analyse the accuracy based on different camera resolution. Based on the result, the camera resolution give effect in RMSE value but the most important thing is the technique to acquire the image. It also give an effect whether the result is good or not. Second objective is to assess the calibration result based on two different types of software. The software used are GML C++ and PhotoModeler. Based on the result, the RMSE for GML software is larger than PhotoModeler although the process is simple meanwhile RMSE result for PhotoModeler is smaller although the process is complex. The third objective is evaluate the best technique in camera calibration. Based on the result for light condition, the good light condition suitable for camera calibration because the image is clearer and the RMSE is small compared to poor light condition. Meanwhile based on the result for camera flash comparison, the results shows flash under good light condition is better compared to other condition. In addition, the self–calibration method is easy to perform and save time compare to other method that required cost and more complex. Besides that, this study helps the future researcher to compare the best software to perform camera calibration. Also, this calibration can be perform whether at outdoor or indoor condition. This study can be expanded to more technique and condition besides other software.

Based on the study, there are several suggestion and recommendations which may be beneficial for the further research in the future. The first recommendation for this study is the camera resolution used should be higher such as 10 megapixel, 15 megapixel and 20.0 megapixel. In addition, the calibration will be only use camera from the same manufactured for all camera resolution. This is to make sure the result get from this calibration is same camera manufactured and the result can be analysed more accurately. Second recommendation is to perform the calibration by using other software in order to perform more analysis about the accuracy of camera calibration software. The third recommendation is to perform the calibration at outdoor condition and indoor condition. The fourth recommendation is using other technique that suitable to perform the camera calibration. For future study, there are several methods and techniques that can be used in camera calibration.

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