# COMPARISON OF CAMERA CALIBRATION PARAMETERS USING PHOTOMODELER AND AUSTRALIS

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**Abstract**

Photomodeler and Australis are two common photogrammetry software that provide camera calibration, and the camera calibration parameters. Each software uses different calibration approach (circular point detection in Australis and intersection of lines in Photomodeler). This paper compares the calibration parameters of Canon IXUS S400 PowerShot digital camera using both Photomodeler and Australis. During calibration, several images were taken with the same camera setting and the distance from the camera to the calibration field was 0.8 meter. All seven camera calibration parameters obtained from the software are compared and tested for statistical significance. The seven parameters are focal length, xp, yp, radial distortion ( K1 and K2 ) and tangential distortion ( P1 and P2 ).

## 1.0 INTRODUCTION

The *Australis* photogrammetric software package is designed to perform highly automated off-line measurements using monoscopic measurement and convergent digital image networks from either using digital cameras or scanned film imagery. It is equally useful for high-precision metrology applications using 'metric' digital cameras (or scanned imagery) or using low to medium accuracy off-the-shelf, amateur still video CCD cameras. Through the integrated image measurement, preliminary orientation and bundle adjustment functionality, one can quickly and easily obtain three-dimensional object point coordinates and sensor calibration data from multi-sensor, multi-image networks of an effectively unlimited number of object points. Moreover, depending on the provision of an exterior orientation (EO) device and high contrast targets, the photogrammetric orientation/ triangulation and calibration processes can be carried out in automated and semiautomatic mode, or manual image point measurement (University of Melbourne, 2001). *PhotoModeler* software can use photographs taken by different types of cameras. For the software to use the image information in a photograph, it needs values for some specific parameters of the camera. Generally, we need to know the focal length of the lens, the digitizing scale (which is the CCD format size of a scanner or digital camera) and the principal point (where the optical axis of the lens intersects the photograph). To optimize accuracy, we also use parameters that describe the distortion characteristics of the lens (Eos Systems Inc., 2000). Both Australis and Photomodeler software compute three-dimensional coordinates of digitized points in the process of calibration. To obtain good three-dimensional object point coordinates, camera parameters must be obtained. In addition, both software compute the parameters during the calibration process. This paper compares the parameters obtained from these two software to check whether the two software give same parameter values. Consequently, test for accuracy was conducted to determine which software gives very accurate measurement.

## 2.0 METHODOLOGY

In this study, ten sets of observations were made using Canon IXUS S400 PowerShot digital camera. All the observations were processed in each software, resulted in 10 values of each parameter. However, because Australis and PhotoModeler use different definition in parameters $x_p$ and $y_p$, their values will not be compared in this paper. From the 7 calibration parameters, only 5 were compared because of this difference definition. **Figure 1** shows a diagram of focal length with $x_p$ and $y_p$ (Fryer, 1989).

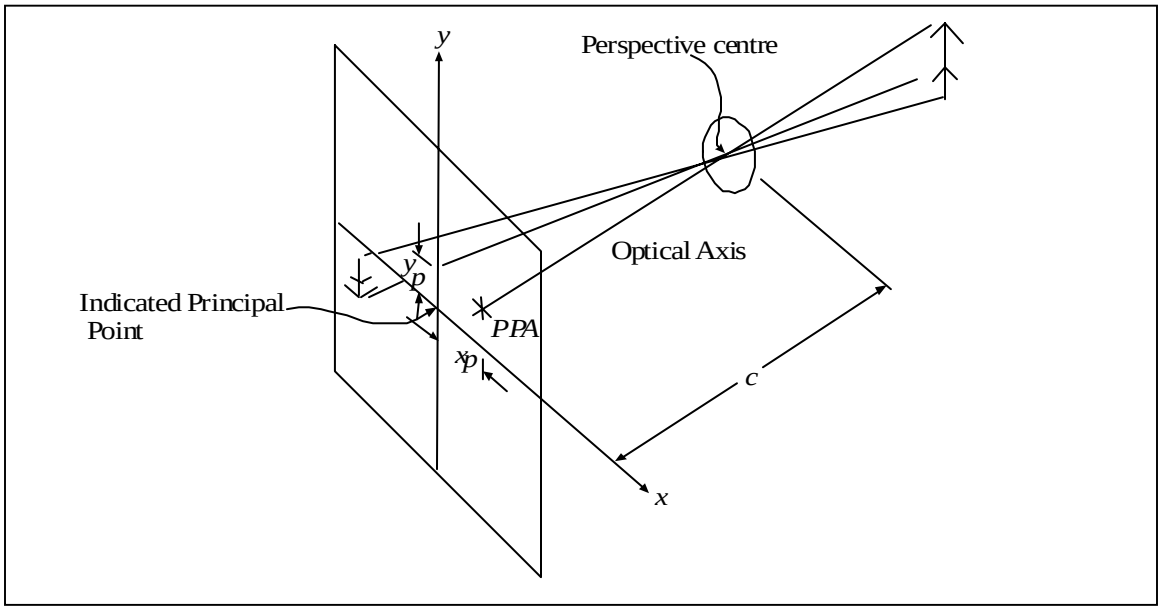


**Figure 1 : Focal length with $x_p$ and $y_p$**

where c = focal length

In PhotoModeler, only coordinate value of PPA in image coordinate system are given (PhotoModeler claim this value as Principal Point) while in Australis the value are the offsets of Indicated Principal Point and the PPA in coordinate image system (Australis claim this as $x_p$ and $y_p$ value). For example PhotoModeler gave 3.5448 for $x_p$ and 2.5977 for $y_p$ while Australis gave -0.046257 and 0.054073 for $x_p$ and $y_p$. **Figure 2** shows a diagram of one image in the matrix index and image coordinate system (University of Melbourne, 2001). The origin of matrix index is at the upper left corner while the origin of image coordinate system is at the lower left of image.

A pixel stands for *picture element* and it is the foundation upon which every digital image is built. A pixel is a tiny square of colour and a digital image is made up of hundreds of thousands, or even millions of these squares (Vandome, 2002). In **Figure 2** each squares represent one pixel and in one image, there is two system of coordinate. One system use matrix index and the other use image coordinate system. Each system uses different origin.

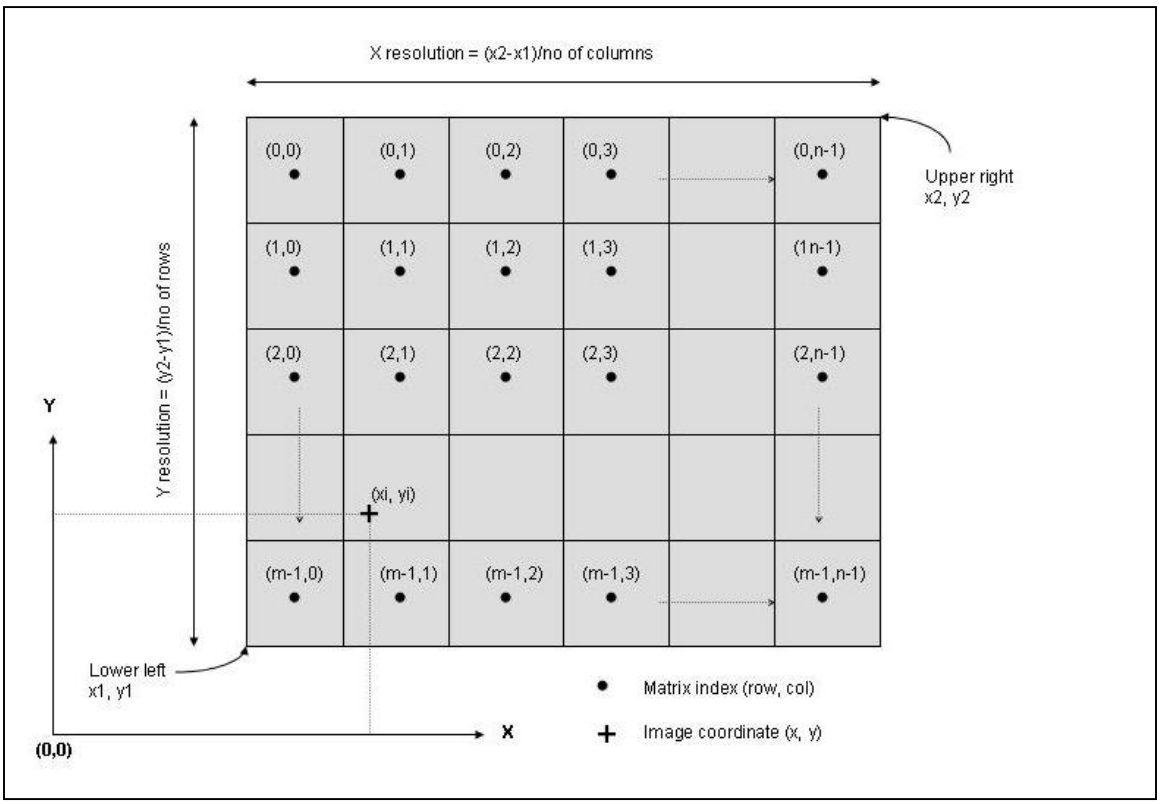


**Figure 2 : One image in matrix index and image coordinate system**

The five calibration parameters are focal length, radial distortion (K1 and K2) and tangential distortion (P1 and P2). Besides comparing the parameters, this research also compares the control measurement that was computed by the software. The control measurement was the length of a scalebar. The scalebar is a device that gives accurate distance in almost all condition. To carry out the calibration, PhotoModeler uses a special camera calibration slide (**Figure 3**). Australis can use any object to carry out the calibration. In this paper, a proper calibration frame was used to calibrate Australis (**Figure 4**).

**Figure 3 : PhotoModeler's slide calibration.**

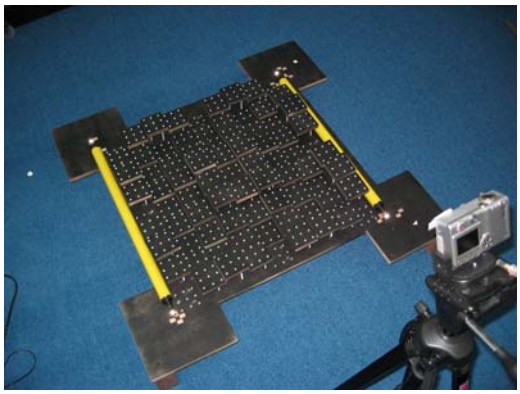

**Figure 4 : Calibration frame for Australis.**

To make a scalebar measurement test for PhotoModeler, it is important to make another step of processing besides the calibration process. This step is for digitizing images that have a scalebar in it. The first step of processing is to get the camera parameters, and the second step is to use the parameters in processing images that have a scalebar in it. In the calibration using Australis all the steps are combined as one and the same images are used. Each observation consists of 8 images (i.e. 4 normal and 4 rotated images). Two scalebars were used, one for controlling the processing scale and the other for checking and comparison (**Figure 5**).

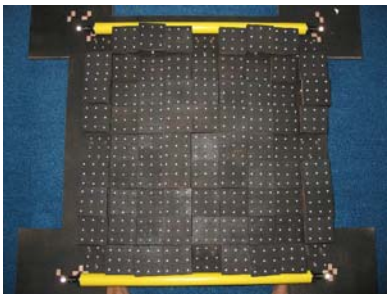

**Figure 5 : Two scalebars (yellow bar) were used for controlling scale and comparison**

Although the calibration processing used different calibration slide, the camera settings (such as resolution and others) were fixed. The distance from camera to object was fixed to 850 mm. Both slide images in Australis and PhotoModeler were optimized to fill the field of view of the camera.

## 3.0 STATISTICAL TEST

Several statistical tests were made to the parameters and the scalebar measurement that were obtained from both software. These tests were made to determine: 1) whether the parameters are the same and 2) the accuracy of the measurement is the same. *P-value* was used to make a test at $\alpha = 0.05$. The P-value (or probability value) is the probability of getting a sample statistic (such as the mean) or more extreme sample statistic in the direction of the alternative hypothesis when the null hypothesis is true. An important decision rule when using a *P-value* (Elementary Statistics, 2004): -

1. If *P-value* $\leq \alpha$, reject the null hypothesis.
2. If *P-*value $> \alpha$, do not reject the null hypothesis.

### 3.1 Parameters test

The first test is to compare each computed parameter from each software. Only five parameters were used because parameters $x_p$ and $y_p$ are different definition in both software. The hypothesis can be written as: -

$H_0 : \mu_1 = \mu_2$ and $H_1 : \mu_1 \neq \mu_2$ (claim)

where $\mu_1$ = mean for parameters obtained from PhotoModeler.

$\mu_2$ = mean for parameters obtained from Australis.

### 3.2 Comparison of scalebar measurement

The second test is to test the measurement from both software using scalebar. The scalebar distance was measured in both software and compared. The hypothesis can be written as: -

$H_0 : \mu_1 = \mu_2$ and $H_1 : \mu_1 \neq \mu_2$ ( claim )

where $\mu_1$ = mean for scalebar obtained from PhotoModeler.
$\mu_2$ = mean for scalebar obtained from Australis.

### 3.3 Comparison using difference in scalebar measurement.

The third test is to compare the differences of measurement from scalebar using both software. In this test each software gave 10 scalebar distances. Each of this distance were compared to the actual distance of scalebar (572 mm). The mean of these two software was calculated and compared to determine which software give a smaller difference. The hypothesis can be written as: -

$H_0 : \mu_1 \leq \mu_2$ and $H_1 : \mu_1 > \mu_2$ (claim)

where $\mu_1$ = mean for difference obtained from PhotoModeler.
$\mu_2$ = mean for difference obtained from Australis.

### 3.4 Comparison of the accuracy based on the software developer's claim.

The last test is to compare the accuracy based on the software developer's claim. For a project done with high resolution Kodak DCS and with reasonable user care, PhotoModeler has shown a relative accuracy in linear dimensions of around one part in two thousand (1:2,000) for man made objects (with 95% probability). Lower resolution cameras and imprecise marking can reduce the accuracy to one part in five hundred (1:500) or even lower (Eos Systems Inc., 2000). Users should expect something in the range 1: 5,000 to 1:10,000 using 'off-the-shelf ' camera. It is probably not likely that users will get better than 1:10,000 because of small instabilities in the interior orientation (Fraser, 2004). If users use unconstraint bundle adjustment the accuracy can be 1:12,000 and if the control points present then the accuracy can be as low as 1:1,400 (Hong, 2004). These claims from PhotoModeler developers and expert in Australis show that in PhotoModeler the accuracy will be more than 1:500 and less or equal 1:2,000. For Australis the accuracy is better than 1:1,400 and less or equal to 1:10,000.

The formula to get the accuracy is (Chong, 2004): -

$$1 : \frac{dif.}{object}$$

where *dif.* = difference measurement from software compared to actual scalebar distance ( mean ).
*object* = distance from object to camera ( 850 mm).

There are two hypotheses for each software. The hypothesis can be written as :-

PhotoModeler : -

1. $H_0 : \mu_1 \geq acc.$ and $H_1 : \mu_1 < acc.$ ( claim )
2. $H_0 : \mu_1 \leq acc.$ and $H_1 : \mu_1 > acc.$ ( claim )

where $\mu_1$ = mean for difference obtained from PhotoModeler.
*acc.* = accuracy ( 1:500 or 1:2,000 )

Australis: -

1. $H_0 : \mu_1 \geq acc.$ and $H_1 : \mu_1 < acc.$ ( claim )
2. $H_0 : \mu_1 \leq acc.$ and $H_1 : \mu_1 > acc.$ ( claim )

where $\mu_1$ = mean for difference obtained from Australis.
*acc.* = accuracy ( 1:1,400 or 1:10,000 )

## 4.0 RESULTS

All of the results are presented in tables, including the mean, variance and the standard deviation of each parameter. For each test, the result of *P-value* and a decision to $H_0$ also is also shown in the table for easy viewing.

### 4.1 Computed parameters.

**Table 1** shows parameters observation with scalebar distance obtained from PhotoModeler and **Table 2** shows observation for Australis. Both tables show the mean, variance and the standard deviation on each parameter and scalebar value.

**Table 1: Results of the PhotoModeler**

| Photomodeler | | | | | | |
|---|---|---|---|---|---|---|
| Obs. | Focal length | K1 | K2 | P1 | P2 | Scalebar |
| 1 | 7.564 | 0.00279 | -0.000043 | -0.00022 | 0.000180 | 569.410 |
| 2 | 7.5645 | 0.00233 | -0.000035 | 0.00008 | -0.000004 | 569.840 |
| 3 | 7.6086 | 0.00313 | -0.000061 | -0.00021 | 0.000112 | 571.980 |
| 4 | 7.524 | 0.00196 | 0.000008 | 0.00005 | -0.000031 | 570.340 |
| 5 | 7.5998 | 0.00217 | -0.000012 | -0.00019 | 0.000105 | 571.790 |
| 6 | 7.5757 | 0.00200 | 0.000000 | -0.00003 | 0.000022 | 570.170 |
| 7 | 7.6042 | 0.00282 | -0.000022 | -0.00037 | 0.000112 | 572.180 |
| 8 | 7.5894 | 0.00281 | -0.000027 | -0.00021 | 0.000149 | 571.880 |
| 9 | 7.5335 | 0.00195 | 0.000007 | -0.00018 | 0.000152 | 571.360 |
| 10 | 7.635 | 0.00244 | -0.000024 | -0.00009 | 0.000072 | 570.820 |
| Mean | 7.579870 | 0.00244 | -0.000021 | -0.00014 | 0.000087 | 570.977 |
| Variance | 0.001191 | 0.00000 | 0.000000 | 0.00000 | 0.000000 | 0.990 |
| Standard deviation | 0.034515 | 0.00043 | 0.000022 | 0.00014 | 0.000071 | 0.995 |

**Table 2 : Results of Australis.**

| Australis | | | | | | |
|---|---|---|---|---|---|---|
| Obs. | Focal length | K1 | K2 | P1 | P2 | Scalebar |
| 1 | 7.3492 | 0.00270 | -0.000027 | -0.00001 | 0.000082 | 571.790 |
| 2 | 7.3379 | 0.00252 | -0.000034 | 0.00004 | 0.000050 | 571.388 |
| 3 | 7.3532 | 0.00255 | -0.000038 | 0.00002 | 0.000047 | 571.842 |
| 4 | 7.3532 | 0.00275 | -0.000054 | -0.00002 | 0.000061 | 571.620 |
| 5 | 7.3581 | 0.00250 | -0.000034 | 0.00003 | 0.000033 | 571.751 |
| 6 | 7.3299 | 0.00249 | -0.000028 | 0.00003 | 0.000051 | 571.793 |
| 7 | 7.3239 | 0.00244 | -0.000019 | 0.00004 | 0.000053 | 571.805 |
| 8 | 7.3118 | 0.00240 | -0.000016 | 0.00003 | 0.000037 | 571.793 |
| 9 | 7.3332 | 0.00257 | -0.000028 | 0.00000 | 0.000057 | 571.817 |
| 10 | 7.352 | 0.00256 | -0.000036 | 0.00001 | 0.000038 | 571.721 |
| Mean | 7.340240 | 0.00255 | -0.000031 | 0.00002 | 0.000051 | 571.732 |
| Variance | 0.000235 | 0.00000 | 0.000000 | 0.00000 | 0.000000 | 0.019 |
| Standard deviation | 0.015316 | 0.00011 | 0.000011 | 0.00002 | 0.000014 | 0.136 |

### 4.2 Parameters test

In the parameters test, five parameters were compared. All of the parameters test result is show in **Table 3**.

**Table 3 : Test result for camera parameters.**

| Parameter | *P-value* | Reject $H_0$ |
|---|---|---|
| Focal length | $9.09 \times 10^{-14}$ | Yes |
| K1 | 0.4494 | No |
| K2 | 0.1928 | No |
| P1 | 0.0027 | Yes |
| P2 | 0.1321 | No |

From the test result there is enough statistical information to state that K1, K2 and P2 value is same in Australis and PhotoModeler but it is different for the focal length and P1.

### 4.3 Comparison of scalebar measurement .

From the computed measurement, PhotoModeler gave scalebar mean of 570.977mm with a standard deviation 0.995mm and Australis gave 571.732mm and 0.136mm in standard deviation. Although these values are very close between Australis and PhotoModeler, there is difference in the variance. This test will compare the value if it is the same or not.

***P-value*** = 0.0287
**Reject $H_0$** = Yes

After the test, *P-value* shows a sign to reject null hypothesis and accept the alternative. So there is enough statistical information to say that the scalebar value in PhotoModeler is different than Australis.

### 4.4 Comparison using difference in scalebar measurement

The test of the scalebar difference value ( **Table 4** ) shows a small difference using Australis than PhotoModeler. The results were tested statistically as in section 4.3.

**Table 4 : Scalebar value obtained from PhotoModeler and Australis.**

| Scalebar difference | | |
|---|---|---|
| Obs. | PhotoModeler | Australis |
| 1 | 2.59 | 0.21 |
| 2 | 2.16 | 0.61 |
| 3 | 0.02 | 0.16 |
| 4 | 1.66 | 0.38 |
| 5 | 0.21 | 0.25 |
| 6 | 1.83 | 0.21 |
| 7 | 0.18 | 0.19 |
| 8 | 0.12 | 0.21 |
| 9 | 0.64 | 0.18 |
| 10 | 1.18 | 0.28 |
| Mean | 1.0590 | 0.2679 |
| Variance | 0.9063 | 0.0185 |
| Standard deviation | 0.9520 | 0.1361 |

The results are shown below: -

***P-value*** = 0.0090
**Reject $H_0$** = Yes

From the test results there is sufficient statistical evidence to say that difference in PhotoModeler is greater than in Australis.

### 4.5 Compare the accuracy based on the software developer's claim.

Accuracy for PhotoModeler should be in range 1:500 to 1:2,000 and Australis 1:1,400 to 1:10,000. A test has been conducted to check whether the accuracy in both software is within the range. For an object distance at 850mm the accuracies are shown in **Table 5**.

**Table 5 : Accuracy value with equivalent to object distance of 850mm.**

| Accuracy | Value at object distance 850mm |
|---|---|
| 1:500 | 1.700mm |
| 1:1,400 | 0.610mm |
| 1:2,000 | 0.425mm |
| 1:10,000 | 0.085mm |

In another word, in PhotoModeler the difference should be 0.425mm<difference<1.7mm and Australis 0.085<difference<0.610. Four tests were made and all of the test results are shown in the **Table 6** for PhotoModeler and **Table 7** for Australis.

**Table 6 : Accuracy test result of PhotoModeler.**

| Hypothesis alternative (claim) | *P-value* | Reject $H_0$ |
|---|---|---|
| $H_1 : \mu_1 < 1.7mm$ | 0.0310 | Yes |
| $H_1 : \mu_1 > 0.425mm$ | 0.0322 | Yes |

**Table 7 : Accuracy test result of Australis.**

| Hypothesis alternative (claim) | *P-value* | Reject $H_0$ |
|---|---|---|
| $H_1 : \mu_1 < 0.61mm$ | $1.17 \times 10^{-5}$ | Yes |
| $H_1 : \mu_1 > 0.085mm$ | 0.011 | Yes |

From the test, there is sufficient statistical evidence to claim that PhotoModeler and Australis are in the range of the software developer's claim.

## 5.0 CONCLUSION

From the five parameters that have been compared, three of the parameters are the same in both PhotoModeler and Australis. The three parameters are K1, K2 and P2. However, the focal length and P1 parameter are different in both software. This may due to different calibration frame in both software. The distance from camera to calibration frame may have a slightly difference without a fix platform to fix the distance. The principal distance is related to the Z co-ordinate of the camera position (Clarke *et. al*, 1998). Two parameters ($x_p$ and $y_p$) cannot be compared due to different definition in both software. There is a strong projective coupling between the decentring distortion parameters ( P1, P2) and the principal point offsets ($x_p$ and $y_p$) (Fraser *et. al*, 1995). This difference definition may has influence over the P1 value that gave a difference result in the statistical test.

Both software gave different value of scalebar distance with a smallest difference obtained by Australis than PhotoModeler. This difference in value is a disparity from actual distance of the scalebar compared to the computed distance obtained from both software.

Australis gave a smallest standard deviation (0.136mm) than PhotoModeler (0.952mm). This results agree with the accuracy claimed by the software developer and experts.

In this paper both software have been shown to be in the range of accuracy as claimed by the software developers and experts. From our experience, PhotoModeler is best to use in a low accuracy project for modeling object with a texture and Australis is suitable to get three-dimensional coordinate with high accuracy without object modeling with a texture. However both software can obtain high accuracy with a proper method of digitizing and image capturing.

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