

## ASSESSING THE PHOTOGRAMMETRIC POTENTIAL OF CAMERAS IN PORTABLE DEVICES

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### ABSTRACT:

In recent years, there have been an increasing number of portable devices, tablets and Smartphone's employing high-resolution digital cameras to satisfy consumer demand. In most cases, these cameras are designed primarily for capturing visually pleasing images and the potential of using Smartphone and tablet cameras for metric applications remains uncertain. The compact nature of the host's devices leads to very small cameras and therefore smaller geometric characteristics. This also makes them extremely portable and with their integration into a multi-function device, which is part of the basic unit cost often makes them readily available.

Many application specialists may find them an attractive proposition where some modest photogrammetric capability would be useful. This paper investigates the geometric potential of these cameras for close range photogrammetric applications by:

- investigating their geometric characteristics using the self-calibration method of camera calibration and comparing results from a state-of-the-art Digital SLR camera.
- investigating their capability for 3D building modelling. Again, these results will be compared with findings from results obtained from a Digital SLR camera.

The early results presented show that the iPhone has greater potential for photogrammetric use than the iPad.

## 1. INTRODUCTION

### 1.1 Background

In recent years, there have been an increasing number of portable devices, tablets and Smartphone's employing high-resolution digital cameras to satisfy consumer demand. In most cases, these cameras are designed primarily for capturing visually pleasing images, recording bar codes or some form of image coding. They are extremely mobile and convenient to carry and access as many people carry a phone or portable computer as part of everyday activities. The bulk and weight of digital single lens cameras has significantly reduced over the years as new plastics and materials in general have become stronger and lighter. However, they are still an additional item to carry around although the user does have significantly more control over the image captured. This is not just from the numerous manual settings that are available but they normally have the ability to accommodate interchangeable lens of different types and sizes. This flexibility and their high image quality normally make them the choice of the professional photographer or enthusiastic amateur.

Clearly, the convenience of cameras built into portable devices makes them attractive to many people and they are developing at an alarming rate. The Nokia 808 Pureview smart phone includes a 41-mpixel camera. It is not just about taking pictures or videos with these devices it is also the other integrated

functionality that these devices possess such as instant, direct link with the internet, integrated GPS and accelerometers, etc. (Nokia808, 2012).

There are also many open source software packages for the amateur photogrammetrists to use with internet sites for building 3D models. This is now delivering 'photogrammetry', often without naming it, to the general public for interest and pleasure.

This leads us to the question, when will smart phones be of serious interest to the photogrammetrists? At the moment, the potential of using Smartphone and tablet cameras for metric applications remains uncertain.

The compact nature of the host devices leads to very small cameras and therefore small geometric characteristics. Of course, this is what makes them extremely portable and the integration into a multi function device often makes them readily available, as they are part of the basic unit cost. It also enables them to be an ideal tool for crowd sourcing of information which is becoming popular for 3D location modelling using open source software from 'holiday pictures'. The question the more serious photogrammetrist or surveyor would ask is 'how accurate are the models?' The answer starts with an examination of the imaging camera then an investigation in to the quality of 3D building models.

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## 1.2 Aims and objectives

The overall aim of the research undertaken at The University of Nottingham is to investigate the photogrammetric potential of the cameras in portable devices. The aim of this paper is to present results from the initial stage of this research, which is investigating the camera geometric characteristics and the cameras potential for 3D building modelling. More specifically the following objectives have been investigated:

1. Using the self-calibration method of camera calibration an investigation will be undertaken into the geometric characteristics of cameras. The camera calibration results will be analysed, and compared with results from a state-of-the-art digital SLR camera.
2. Images will be used with close range photogrammetric processes for 3D building modelling. Again, these results will be compared with findings from results obtained from a state-of-the-art digital SLR camera.

## 1.3 Methodology

The methodology is based on understanding the camera systems, the three cameras to be used are the iPhone 4G, the iPad 2 and the Canon EOS 5D Mk II. The PhotoModeler software was used to undertake the following stages:

1. Camera calibration using a planar target field (as required by the software) to fulfil objective 1. The comparison is undertaken by statistical differences and graphical representation of the radial lens distortion.
2. The creation of 3D building models by using the Nottingham Geospatial Building (NGB) as a test site to fulfil objective 2. The comparison of building models is undertaken by performing a 3D analysis between a reference building and the 3D models from the portable device cameras. The 3D comparison is performed using Geomagic Studio enabling the comprehensive assessment of any differences that exist between the two building models.

## 2. TECHNOLOGY

### 2.1 The cameras and devices

The cameras used in this project are shown in figure 1. The iPhone 4G is one of the latest range of phones which contain a digital camera. A summary of a few basic features are given in table 1 (iPhone 2012, iPad 2012, Canon 2012).

Feature	iPhone 4G	iPad 2	Canon EOS 5D Mk II
No of pixels (mpixels)	5	0.6	21.1
Nominal focal length (mm)	4.2	2.6	28

Table 1. Camera characteristics



Figure 1. Images of the Canon EOS 5D Mk II, iPhone 4G and iPad 2 (left to right respectively)

## 3. TRIALS, RESULTS AND ANALYSIS

### 3.1 Calibration frame results

#### 3.1.1 Observations and computations

The camera calibration was undertaken using a self-calibrating bundle block adjustment in PhotoModeler version 6 (PhotoModeler, 2012). PhotoModeler uses a camera calibration template shown in figure 2. This approach was used as the iPad and the iPhone does not allow a flash to be used to enable the use of the 3D calibration frame available at The University of Nottingham with coded retro reflective targets.

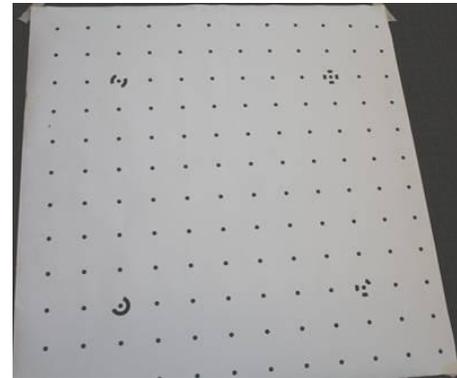


Figure 2. Calibration template used by PhotoModeler software

### Camera self-calibration trials - iPhone 4G camera

Twelve photos captured from the iPhone 4G were used for the calibration process. The results are listed in table 2.

Parameter	Value mm	Standard deviation mm
Focal Length	4.198	0.010
Xp - principal point x	2.195	0.001
Yp - principal point y	1.632	0.004
Fw – CCD format width	4.372	0.001
Fh – CCD format height	3.265	0.001
K1 - radial distortion	0.002078	0.00011
K2 - radial distortion	0.000e+000	0
K3 - radial distortion	0.000e+000	0

Table 2. Self-calibration results for the iPhone 4G camera

Pixel size 1.7 $\mu$ m  
Image measurement precision:  
Overall RMS: 0.151 pixels  
Maximum: 0.707 pixels  
Minimum: 0.140 pixels

**Camera self-calibration trials - iPad 2 camera**

Twelve 12 photos captured from the iPad 2 were used for the calibration process. The results are listed in table 3.

Parameter	Value mm	Standard deviation mm
Focal Length	2.680	0.022
Xp - principal point x	1.169	0.001
Yp - principal point y	0.763	0.007
Fw – CCD format width	2.286	0.005
Fh – CCD format height	1.713	0.005
K1 - radial distortion	0.001903	0.00047
K2 - radial distortion	-0.0005714	0.00015
K3 - radial distortion	0.000e+000	0

Table 3. Self-calibration results for the iPad 2 camera

Pixel size 2.3 $\mu$ m  
Image measurement precision:  
Overall RMS: 0.628 pixels  
Maximum: 2.420 pixels  
Minimum: 0.157 pixels

**Camera self-calibration trials - Canon EOS 5D Mk II**

Twelve photos captured from the Canon EOS 5D Mk II were used for the calibration process. The results are listed in table 4.

Parameter	Value mm	Standard deviation mm
Focal Length	29.396	0.009
Xp - principal point x	18.056	0.002
Yp - principal point y	12.166	0.002
Fw – CCD format width	36.497	0.001
Fh – CCD format height	24.333	0.001
K1 - radial distortion	0.0001259	0.00000033
K2 - radial distortion	-0.0000001535	8.8e-010
K3 - radial distortion	0.000e+000	0

Table 4. Self-calibration of Canon EOS 5D Mk II

Pixel size 6.5 $\mu$ m  
Image measurement precision:  
Overall RMS: 0.102 pixels  
Maximum: 0.496 pixels  
Minimum: 0.082 pixels

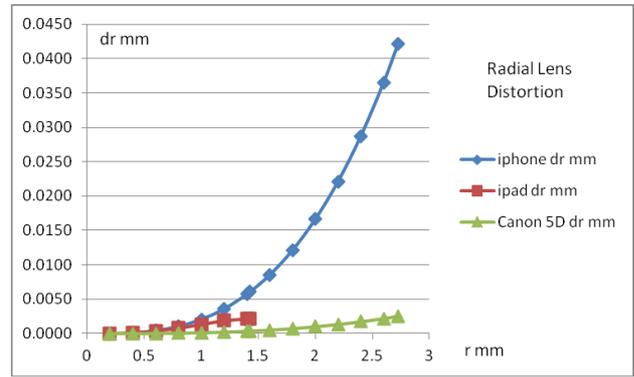


Figure 3. Radial lens distortion over the maximum radial distance of the iPhone

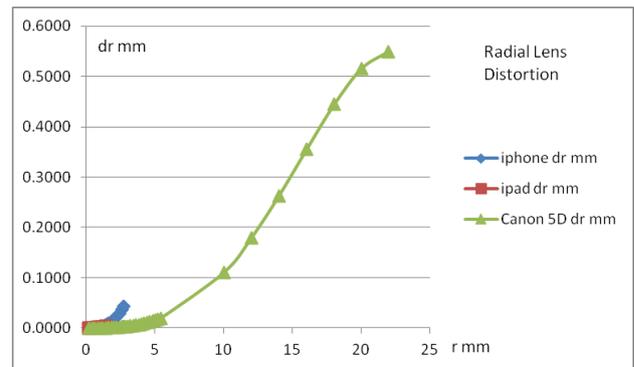


Figure 4. Radial lens distortion over the maximum radial distance of the Canon

**3.1.2 Camera calibration analysis of results**

Tables 2, 3 and 4 and the associated image measurement precisions form the basis for the analysis. They clearly show the differences in geometric characteristics. The geometric parameters of the iPhone and iPad are significantly smaller than similar parameters of the Canon. It should be noted that the Canon is not typical of many digital single lens reflex cameras as it has what is often termed a ‘full frame sensor’ where the sensor format is comparable with the traditional 35mm negative (24x36mm). The image measurement precision in terms of pixels shows the Canon with the smallest overall RMS followed by the iPhone then the iPad.

Figure 3 shows graphically the radial lens distortion for the three cameras over the range of the iPhone sensor and clearly shows the significantly smaller radial lens distortion in the Canon. The iPad radial distortion is a little larger than the Canon over its small radial distance. Figure 4 gives the radial distortion over the maximum radial distance for the Canon.

Having calibrated the camera it could be argued that these values can be applied regardless of their magnitude however, rapid changes in distortion do increase their sensitivity to the quality of the measured radial distance (image coordinates).

### 3.2 3D model building

#### 3.2.1 Test site - image capture

Images from the cameras were taken all round the NGB. The geometry of the cameras created a similar field of view for each camera as can be seen from the building to camera position distance in figures 5, 6, 7 and coverage in figures 8, 9 and 10.

Figures 8, 9 and 10 show a similar image of the building taken with the three cameras so that you can see a comparison of images format, coverage and quality. It should be noted that the front of the building was the main focussing plane, so the inserts may not be fully in focus. However, the difference in image quality can be clearly seen from the inserts.

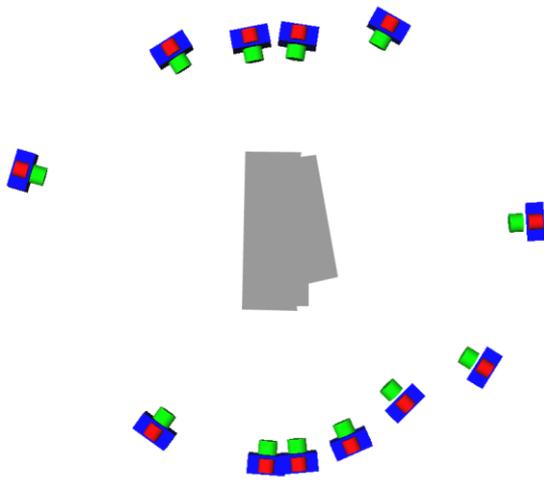


Figure 5. Canon EOS 5D Mk II network of images for 3D building modelling

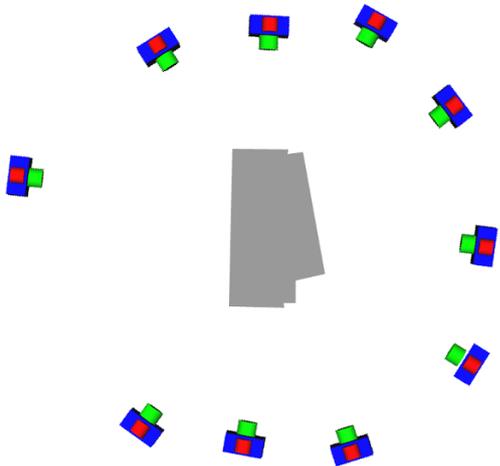


Figure 6. iPhone 4G network of images used for 3D building modelling

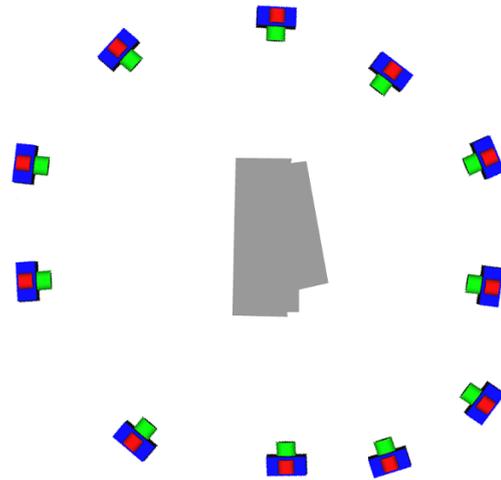


Figure 7. iPad 2 network of images used for 3D building modelling



Figure 8. Building facade and image quality from the Canon EOS 5D Mk II



Figure 9. Building facade and image quality from the iPhone 4G



Figure 10. Building facade and image quality from the iPad 2

### 3.2.2 Creating the 3D model of the building

The generation of the 3D building models from the three different camera sensors was performed using PhotoModeler software. The close range photogrammetric process involved the manual measurement of tie points between the network of overlapping images as shown in figure 11 in order to solve the bundle block adjustment.

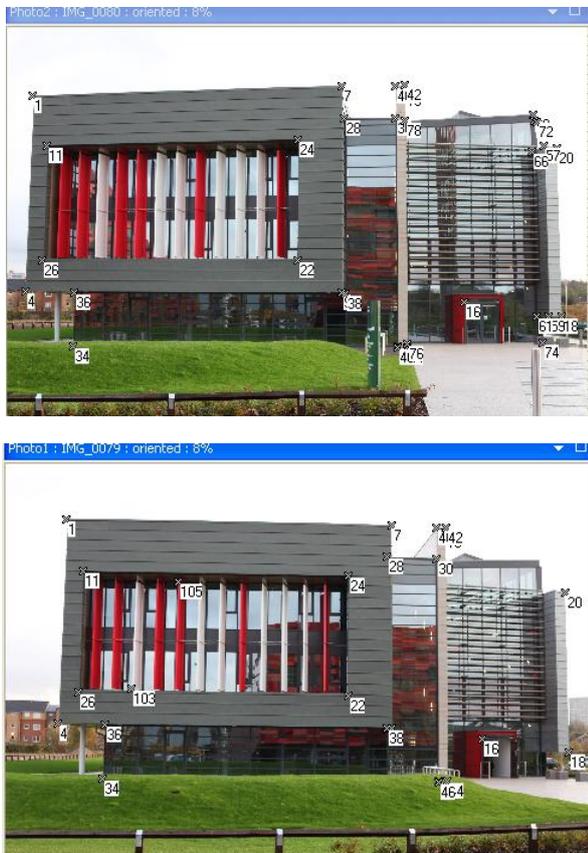


Figure 11. Two overlapping images from Canon EOS 5D Mk II with tie points measured in PhotoModeler

With the bundle block adjustment performed the 3D building model is built by identifying points on the images that represent

corners of 3D planes. Each plane is formed by at least 4 3D corner points as shown in figure 12. Figure 13 shows the 3D building model created from the Canon images.



Figure 12. Creating 3D planes of the facades given the corner points



Figure 13. Two perspective views of the 3d building model created from the Canon EOS 5D Mk II images

The quality of the position of the points forming the 3D planes of the model was affected by the radiometric quality and resolution of the imagery. Images from Canon were the easiest to work with given the high resolution and exceptional radiometric quality. Identifying and measuring 3D points from the iPhone imagery was slightly more difficult and the iPad images were the most challenging as the quality and resolution of the photos was significantly less.

### 3.2.3 Comparison of the 3D building models

The comparison of the 3D models created was undertaken using Geomagic Studio by performing a 3D volumetric comparison between a reference and a test model. The 3D building model from the Canon was considered the most appropriate to be used

as a reference and 5 control points were chosen to perform a 3D transformation to fit the iPhone and iPad models to it. Figure 14 shows the 3D difference map between the Canon and the iPhone building models. The deviation between the models was calculated as:

Maximum difference: +0.030m

Minimum difference: -0.024m

Average: 0.003m

Standard deviation: 0.004m

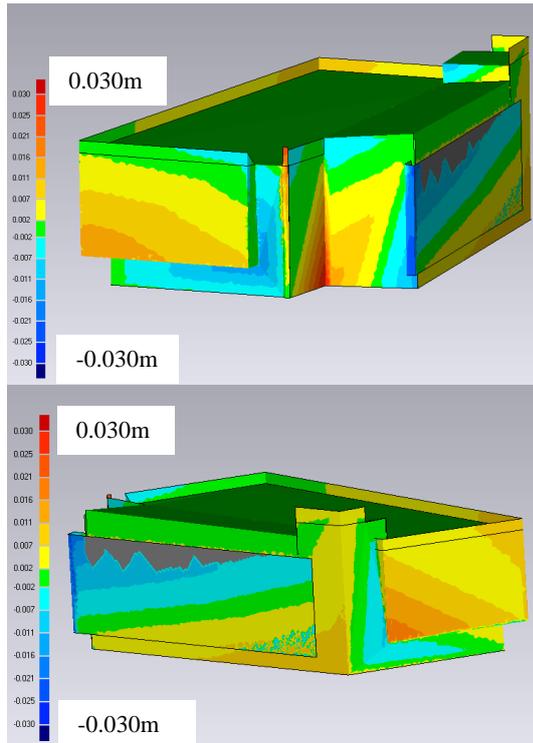


Figure 14. 3D difference map of the front (top) and the back (bottom) facade between the Canon and the iPhone 3D model

The comparison indicates the presence of relatively small differences with the maximum being only 3 cm. This is mainly caused by small differences in the 3D coordinates of corner points that form the 3D planes. Some systematic patterns can be seen.

Figure 15 shows the 3D difference map between the Canon and the iPad building models. The deviation between the models was calculated as:

Maximum difference: +0.080m

Minimum difference: -0.057m

Average: 0.015m

Standard deviation: 0.017m

The building model from the iPad 2 presents larger deviations than the iPhone model with a maximum of 8cm. The reduced quality of the imagery has clearly contributed in the increased differences observed on the front and back facade of the building. Some systematic patterns can be seen.

#### 4. CONCLUSIONS AND FUTURE ACTIVITIES

The results above have shown that even with the small lens and sensors the iPhone and iPad have photogrammetric potential.

The calibration of the cameras has shown that over the format of the iPad and iPhone sensor the Canon EOS 5D Mk II has significantly smaller radial lens distortion. Over the small format of the iPad the iPhone has slightly greater radial lens distortion.

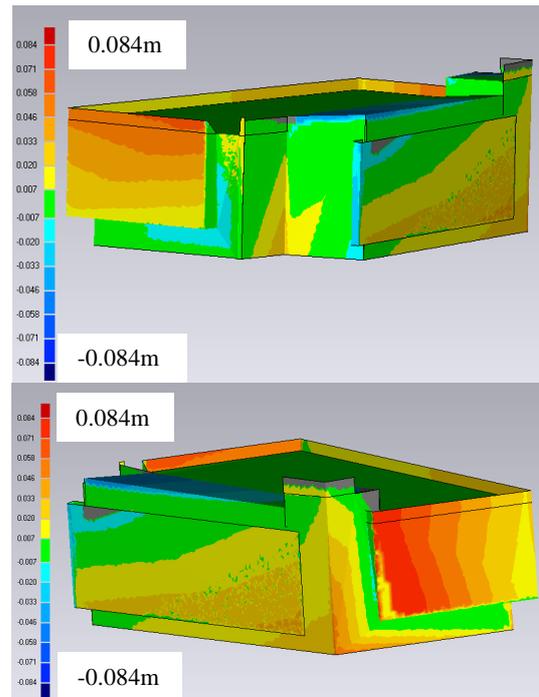


Figure 15. 3D difference map of the front (top) and the back (bottom) facade between the Canon and the iPad 3D model

Both the iPhone and the iPad have produced good quality 3D building models when compared with the Canon model. The iPhone with its larger image format and higher resolution enables better measurements to be made than on the iPad images. Further investigations into the systematic patterns and a wider number of applications will be undertaken.

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