Journal of Thi-Qar University number1 Vol.7 December/2011

FEASIBILITY STUDY OF USING MOBILE PHONE CAMERA IN DIGITAL CLOSE RANGE PHOTOGRAMMETRY

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2010

Abstract

The mobile industry has seen, in recent years, rapid developments which contain digital cameras with good resolution, this research study the possibility of use these cameras in a close range photogrammetry, which is widely used today in many engineering and scientific applications.

This research has used two types of mobile phone with built-in digital cameras, the first type was NOKIA N82 and the second was CoolPAD 288. Stereo pair of digital photos have been picked up to the test field, which installed on it twenty four targets carefully, 3D- coordinates were observed by using Total Station instrument, type TOPCON-GPT7501. Because of non availability of External and Internal orientation elements of the camera, it used mathematical method known as *Direct Linear Transformation DLT*. The results obtained from using mobile phone camera in digital close range photogrammetry, were compared with field data, have showed that the Root Mean Square Error (RMSE), indicates promising results.

دراسة جدوى استخدام كاميرا الهاتف المحمول في المسح التصويري الرقمي ذو المدى القريب

الخلاصة

لقد شهدت صناعة الأجهزة النقالة في السنوات الأخيرة تطورات سريعة منها احتوائها على كاميرات رقمية ذات قدرة تمييز جيدة، هذا البحث يدرس أمكانية استخدام هذه الكاميرات في المسح التصويري ذو المدى القريب والذي بات يستخدم بشكل واسع في يومنا هذا في العديد من التطبيقات الهندسية والعلمية. في هذا البحث تم استخدام نوعين من أجهزة الهاتف المحمول مزود بكاميرا رقمية، النوع الأول هوNOKIA N82 والثاني CoolPAD 288. وقد تم التقاط زوج مجسم من الصور الرقمية إلى منطقة الدراسة والتي ُثبت عليها أربع وعشرون هدفا بعناية، تم رصد الإحداثيات الثلاثية الأبعاد لها باستخدام جهاز المحطة المتكاملة نوع Topcon-GPT7501. لعدم توفر عناصر التوجيه الخارجية والداخلية للكاميرا موضوع البحث تم استخدام الطريقة الحسابية المعروفة باسم (التحويل الخطي المباشر) . آن النتائج المستحصلة من استخدام كاميرا الهاتف المحمول في المسح التصويري الرقمي ذو المدى القريب تم مقارنتها مع بيانات الرصد الحقلي فكان جذر مربع معدل الخطأ RMSE يشير إلى نتائج واعدة.

Introduction

Digital Close range photogrammetry is an important branch of the science of Photogrammetry that utilized digital technology to make digital images of subjects. With the revolution of digital technology, digital cameras are nowadays being used as a new communication tool. This new tool is enhanced by the production of mobile phones with built-in digital cameras. This product gives us the opportunity to take photographs of any object we may face at anytime instantaneously. Just get your phone from your pocket and take the photos. This new facility in the mobile phone generation could enable us to use it in the digital photogrammetric field. To use this tool, first we must find out its accuracy [1].

Two different types of mobile phones with cameras were applied in study. The first was NOKIA N82 with 5.0 megapixel digital camera, and the other phone CoolPAD-288 with a camera of 2.0 megapixel. The mobile phones as shown in Fig.1, and the technical specifications of the cameras given in Table 1.

(a) (b)

Fig.1: Mobile phones used in the study: (a) NOKIA N82, (b) CoolPAD

Table 1: Technical specifications for Mobile phones cameras used in the study

Properties	NOKIA N82	CoolPAD 288
camera model	N82	PAD 288
Image dimensions	2592x1944	1600x1200
	5.0 megapixel	2.0 megapixel
Horizontal resolution	300 dpi	96 dpi
Vertical resolution	300 dpi	96 dpi
Focal length	5.6 mm	5.2 mm
Optical zoom	5X	4X
Output format	JPEG Image	JPEG Image
Flash used	yes	No

Test Field

The test field was a wall fixed on it white board and cooling duct, twenty four targets installed carefully on the test field in different planes (Fig.2), the targets arranged as (4 rows x 6 columns), and the targets points were precisely measured by using Topcon total station instrument, GPT7501. The chosen base line was of 3 meters with two end stations, A and B, the 3D coordinates of station A assumed locally as follow (100 m, 100 m, 10 m), then the total station has been mounted on A and back-sight on B, the 3D coordinates of the 24 targets points have been measured directly by using the characteristic of *laser reflector-less* which exists in Topcon total station instrument GPT7501, these coordinates listed in table 2.

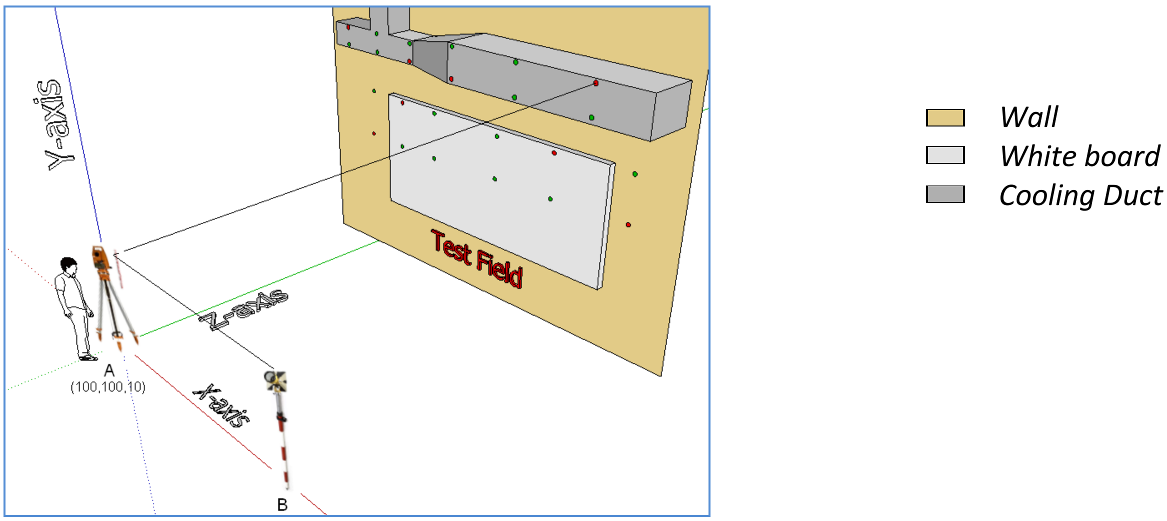


Fig. 2: Test Field, including twenty four targets installed carefully

Table 2: 3D Coordinates for twenty four targets points at Test field

P	X(m.)	Y(m.)	Z(m.)	P	X(m.)	Y(m.)	Z(m.)
1	100.619	102.692	14.496	**13**	102.229	102.785	14.377
2	100.616	102.423	14.507	**14**	102.235	102.415	14.402
3	100.61	101.873	14.858	**15**	102.213	101.887	14.735
4	100.607	101.295	14.865	**16**	102.215	101.302	14.747
5	101.195	102.694	14.493	**17**	102.936	102.786	14.377
6	101.196	102.425	14.506	**18**	102.933	102.415	14.397
7	101.193	101.899	14.745	**19**	102.933	101.868	14.745
8	101.219	101.313	14.752	**20**	102.94	101.292	14.751
9	101.68	102.694	14.49	**21**	103.525	102.782	14.376
10	101.685	102.423	14.504	**22**	103.522	102.414	14.394
11	101.699	101.896	14.739	**23**	103.523	101.874	14.851
12	101.706	101.317	14.752	**24**	103.54	101.248	14.857

Determination of photo coordinates

The photos generated by mobile phone camera which picked up a stereo pair of photos to the targets on the Test field (Fig.3), and handled as digital files by the computer. 2D measurements of digital files are mainly performed on a computer display. Today's measurement technologies allow that the determination of photo coordinates as pixel indices [2].

Fig.3 : Stereo pair of digital photos picking up by mobile phone Camera

Mathematical formulation

The mathematical relationship between the relative spatial positions of the photo points in the two-dimensional photograph and their corresponding positions in the three-dimensional object space, that is applicable for close range photogrammetry depends on the photo type, if it is source from metric or non-metric camera. For metric camera (External and Internal orientation elements are available) a general solution can be obtained by applying terrestrial collinearity condition equations. Another solution for non-metric camera (Orientation elements are non-available) was provided by (ABDEL-AZIZ and KARARA), a direct connection was established between the photo coordinates of object points specified in a machine coordinate system and the coordinates of the object side. They noted the method as Direct Linear Transformation and is generally referred to as DLT. [3] The DLT method is based on the following equations:

$$x = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1} \qquad \text{.............................. (1)}$$

$$y = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

where:
x, y :Photo coordinates in a machine system.
X,Y,Z :The object space coordinates system.
L1,L2,…,L11: The DLT transformation coefficients.

If photos are taken of more than six points of known coordinates in a photo and their photo coordinates are measured, then the DLT eleven parameters referring to this photo can be calculated by using the least squares method. And if these parameters are known in at least

two photos, then by measuring the photo coordinates of an unknown new point in these photos object-side coordinates can be calculated. [2]

If the errors due to the optical and de-centering distortion add to DLT equations they become :

$$x + \Delta x = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1}$$
$$y + \Delta y = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1} \qquad \text{..............................} (2)$$

where:

$$\Delta x = x\left(L_{12} r^2 + L_{13} r^4 + L_{14} r^6\right) + L_{15}\left(r^2 + 2x^2\right) + 2L_{16} yx$$
$$\Delta y = y\left(L_{12} r^2 + L_{13} r^4 + L_{14} r^6\right) + 2L_{15} xy + L_{16}\left(r^2 + 2y^2\right)$$
$$r^2 = x^2 + y^2$$

-14 : The coefficients of the optical distortion.
: The coefficients of the de-centering distortion. [5]

By substituting the values of $\Delta x \; and, \Delta y$ to DLT equations and by simplified, and Rearrange these equations to obtain the following observation equations form [3]:-

$$x = L_1 X + L_2 Y + L_3 Z + L_4 - xL_9 X - xL_{10} Y - xL_{11} Z - xL_{12} r^2 R$$
$$- xL_{13} r^4 R - xL_{14} r^6 R - \left(L_{15}\left(r^2 + 2x^2\right)\right)R - 2L_{16} yxR \qquad \text{..............................} (3)$$
$$y = L_5 X + L_6 Y + L_7 Z + L_8 - yL_9 X - yL_{10} Y - yL_{11} Z - yL_{12} r^2 R$$
$$- yL_{13} r^4 R - yL_{14} r^6 R - 2L_{15} xyR - L_{16}\left(r^2 + 2y^2\right)R$$

Where $R = L_9 X + L_{10} Y + L_{11} Z + 1$

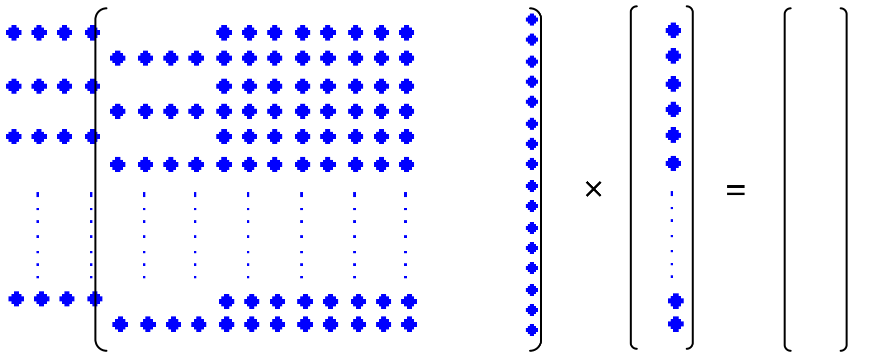
In this study, to obtain the sixteen DLT parameters of each photo captured by mobile phone camera using the least square method, it should be taken in consideration, solving the normal equation, that can be derived from the observation equation as in form bellow:-

$A.X = L$ **where A: Coefficients matrix (2n x 16)**

$X = \left(A^T.A\right)^{-1}.A^T.L$ **X: DLT parameters matrix (16 x 1)**

L: photo coord. Matrix (2n x 1)
n: No. of Control points

Structural matrix of the normal equation can be represented as follows:-



A=(2n x 16) **X**=(16 x 1) **L**=(2n x 1)

After the 16-DLT parameters of each stereo pair of photos become available, it can be computed the object space coordinate (X, Y, Z) of any points appear in each photos of stereo pair, by applying the DLT equations with additional parameters (Equ.2). By rearranging these equations it can be represented in matrices forms (for two photos) as shown bellow. [5]:-

$$\begin{bmatrix} L_1-\xi\, L_9 & L_2-\xi\, L_{10} & L_3-\xi\, L_{11} \\ L_5-\eta\, L_9 & L_6-\eta\, L_{10} & L_7-\eta\, L_{11} \\ L_1-\xi\, L_9 & L_2-\xi\, L_{10} & L_3-\xi\, L_{11} \\ L_5-\eta\, L_9 & L_6-\eta\, L_{10} & L_7-\eta\, L_{11} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \xi & -L_4 \\ \eta & -L_8 \\ \xi & -L_4 \\ \eta & -L_8 \end{bmatrix}$$

where:

$$\xi = x + \Delta x$$
$$\eta = y + \Delta y$$

Results

In this study, applied the DLT Mathematical formulation to compute the object space coordinate for eight check points by using Matlab programming language (Fig.4). The root mean square error (RMSE) computed by the Comparison between the calculated value and the measured value of the object space coordinate.

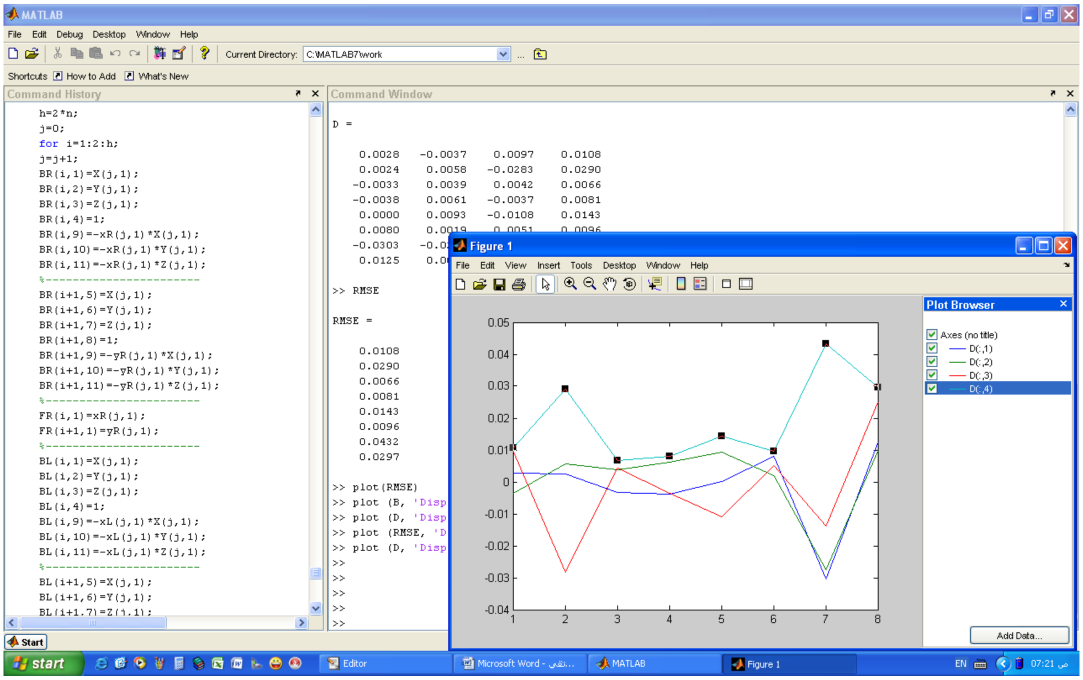


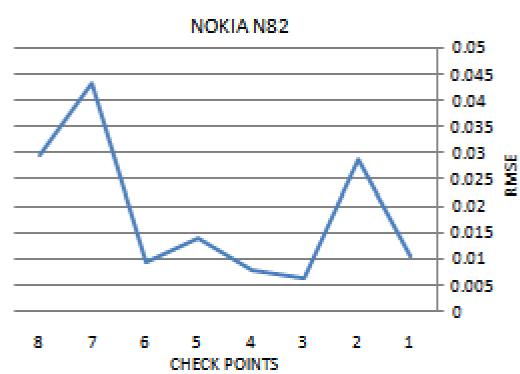
Fig.4 : Processing by using Matlab programming language

Results of these study can be arranged as the following steps:

1- **By using photos of mobile phone camera type NOKIA N82, the RMSE of check points as listed in table 3.**

Table 3: RMSE using NOKIA N82

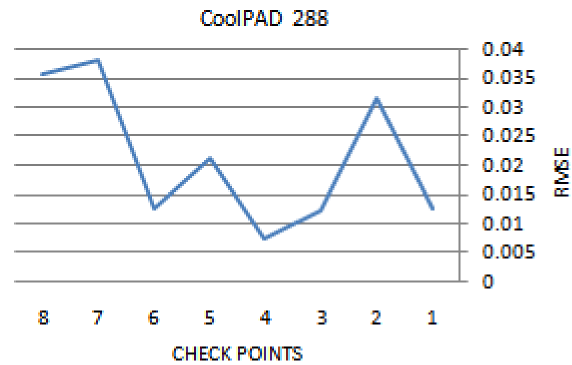
No.	(m)	(m)	(m)	SE(m)
	028	)037	097	108
	024	058	)283	290
	)033	039	042	066
	)038	061	)037	081
	000	093	)108	143
	080	019	051	096
	)303	)275	)137	432
	125	097	251	297
			Total RMSE	242



2- **By using photos of mobile phone camera type CoolPAD 288, the RMSE of check points as listed in table 4.**

Table 4: RMSE using CoolPAD 288

No.	(m)	(m)	(m)	SE(m)
	031	056	107	125
	071	04	304	315
	023	069	095	120
	029	049	044	072
	125	098	136	209
	104	021	061	122
	298	197	125	378
	111	126	313	355
		otal RMSE		257



3- It have been compared between results of RMSE from using photo of mobile phone camera NOKIA N82 and CoolPAD 288, as illustrated in Fig.5 .

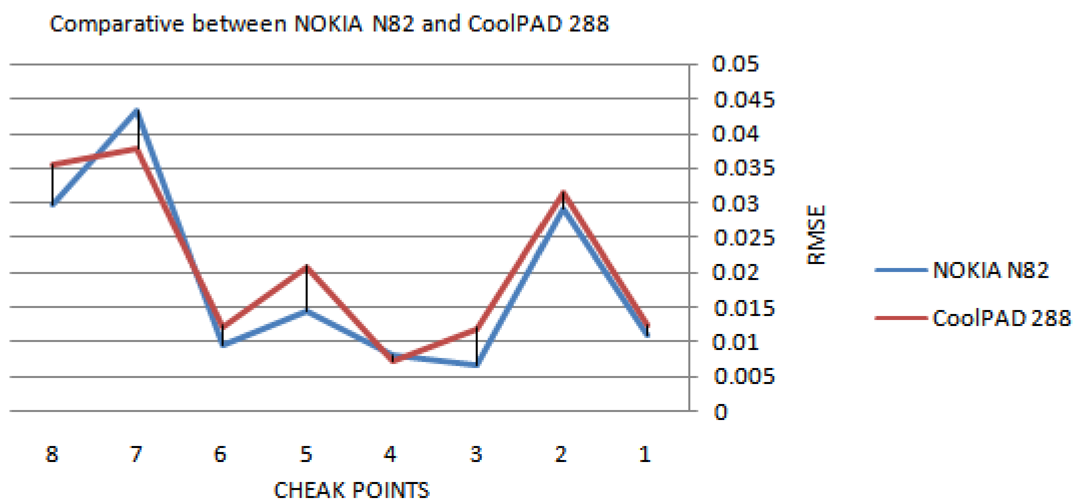


Fig.5 : Results, as comparing between Nokia N82 and CoolPAD 288

Test capabilities results

Capabilities results that obtained from using mobile phone camera have been tested in comparison with the results from high resolution CCD Camera, as in the following steps:

- **Picking up a stereo pair of digital photos to the targets on the test field using high resolution CCD Camera. Camera type, and technical specifications for its photo as shown in Fig.6.**

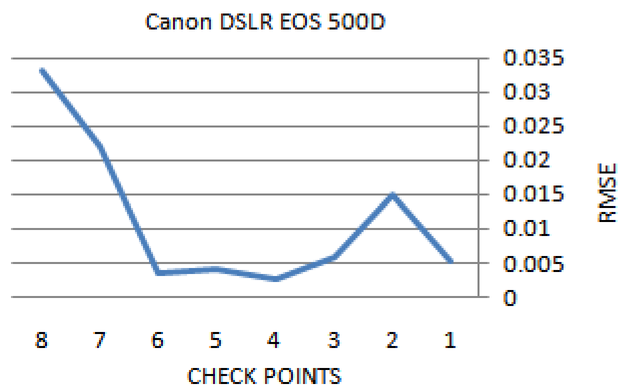
Camera model	Canon DSLR EOS 500D
Image dimensions	4752 x 3168 15 megapixel
Horizontal resolution	72 dpi
Vertical resolution	72 dpi

Fig.6 : High resolution CCD Camera/ Canon DSLR EOS 500D

- **Computing the object space coordinates for the same eight check points, by using the same mathematical model that applied in camera phone mobile. The results of RMSE as listed in table 5.**

Table 5: RMSE using Canon DSLR EOS 500D

No.	(m)	(m)	(m)	SE(m)
	)017	027	040	051
	019	)041	143	150
	041	022	)035	058
	023	006	005	025
	)012	033	)019	039
	)032	)012	001	034
	)131	)077	)159	220
	)203	)047	258	332
		'otal RMSE		165



- **The results compare, that obtained from using high resolution CCD camera, with results of both types of mobile phones cameras, as illustrated in Fig.7.**

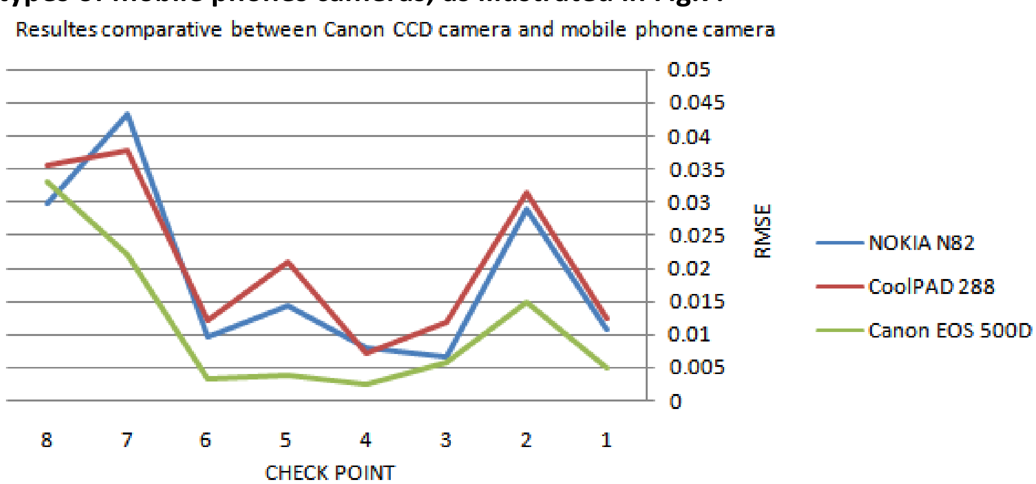


Fig.7 : The results Compare, between Canon CCD camera and mobile phone camera

Results analysis

- **The Total RMSE from using camera of NOKIA N82 less than Total RMSE of CoolPAD 288, in amount of 1.5 mm.**
- **When used high resolution CCD camera, the Total RMSE become less than results of both types of mobile phones cameras, in amount of 9 mm.**

Conclusions

From the preceding results, appear the mobile phone camera can be used in some applications of digital close range photogrammetry, for easy to use, and give good results in comparison with high resolution camera, and whenever camera resolution increases, the RMSE dwindle.

Recommendations

- **Using mobile phone camera has high resolution, more than Nokia N82 (5 mega pixel).**
- **Applying terrestrial collinearity condition equations with self calibration to compute the object space coordinates.**
- **Using another test filed has multi different planes, such as the front of building.**

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