A COMPACT METHOD FOR SMART-PHONE CAMERA CALIBRATION

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ABSTRACT

This paper adopts a new camera calibration method to calibrate smartphone camera. The chessboard image is used as a control plane and the corners are defined as control points. This camera calibration method is compact and fast without any professional instruments. It could be implemented by non-professional users. The experiment result demonstrates that the average error is less than 0.1 mm. Therefore, it is possible to use smartphone camera in some applications which need not high accuracy.

INTRODUCTION

What is camera calibration?

The process of finding the camera parameters when imaging.

It stands for the relationship between the 3-D geometric coordinates of a point and its corresponding coordinates in image.

Calibration methods

According to the used calibration object, the methods for camera calibration are sorted as [1]:

1 stereo calibration method

2 plane calibration method

3 line calibration method

4 self-calibration method

1、 Stereo calibration method

Observe a calibration object whose geometry in 3-D space is known with very good precision.[2]

Advantages:

(1) Adaptive to any camera model

(2) High precision

Disadvantage:

(3) Specific calibration apparatus.

(4) Complex.

2、 Plane calibration method

Require to observe a planar pattern shown at a few different orientations.[3]

Advantage:

(1) Flexible and robust.

(2) Less cost.

Disadvantage:

(1) Not conducive to automated calibration.

3、 Line calibration method

Observe objects consisting of three or more colinear points with known relative positioning.[4]

Advantage:

Could calibrate the multiple cameras.

Disadvantage:

The fixed point should be seen by all cameras.

4、 Self-calibration method

Calibrate camera by image point correspondence.[5]

Advantage:

(1)No need reference objects.

(2)Adaptive to condition when intrinsic parameters are not fixed

Disadvantage:

(1)Less precision.

(2)Complex.

Smartphone camera

Nowadays, smartphone camera could also have good performance on imaging.

Following is the comparison on camera of several smartphones.

						
	三星Note8	iPhone 8 Plus	华为Mate 10 Pro	小米Note 3	OPPO R11s	vivo X20Plus
	前置:8MP F/1.7光圈	前置:7MP F/2.2光圈	前置:8MP F/2.0光圈	前置:16MP F/2.2光圈	前置:20MP F/2.0光圈	前置:12MP (24MP感光单元) F/2.0光圈
	后置:12MP+12MP 广角(F/1.7)+长焦(F/2.4) 1.4μm单位像素(广角) 双OIS光学防抖 2倍无损变焦 全像素双核对焦	后置:12MP+12MP 广角(F/1.8)+长焦(F/2.8) 1.22μm单位像素(广角) OIS光学防抖(广角) 2倍无损变焦 双核对焦	后置:12MP+20MP 彩色(F/1.6)+黑白(F/1.6) 1.25μm单位像素(彩色) OIS光学防抖(彩色) 2倍双摄变焦 4合1混合对焦	后置:12MP+12MP 广角(F/1.8)+长焦(F/2.6) 1.25μm单位像素(广角) OIS光学防抖(广角) 2倍无损变焦 PDAF 相位对焦	后置:16MP+20MP 广角(F/1.7)+广角(F/1.7) 2.0μm单位像素(高感聚合) 没OIS光学防抖 没无损变焦 双核对焦	后置:12MP+5MP 主摄(F/1.8)+景深辅助 1.28μm单位像素(主摄) OIS光学防抖(主摄) 没无损变焦 全像素双核对焦

METHODOLOGY

- We adopt the plane calibration method to calibrate smartphone camera.
- We apply bundle adjustment by additional parameters to calculate interior parameters and exterior parameters.

- We assume that except the interior and exterior parameters, there are tangent distortion in x and y direction. We use five parameters to express this distortion.
- $dx = x(k_1 r^2 + k_2 r^4 + k_3 r^6) + p_1(r^2 + 2x^2) + p_2 xy$
- $dy = y(k_1 r^2 + k_2 r^4 + k_3 r^6) + p_2(r^2 + 2y^2) + p_1 xy$

Where $x = x' - x_0,\ y = y' - y_0$

x' and y' *are measure coordinates*

$r^2 = x^2 + y^2$

k_1, k_2, k_3 are parameters.

p_1, p_2 are parameters.

- The relationship between three-dimension location of a point and its corresponding image coordinates can be defined as:

$$\begin{bmatrix} x' - x_0 \\ y' - y_0 \\ 1 \end{bmatrix} = A[R|T] \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} + \begin{bmatrix} dx \\ dy \\ 0 \end{bmatrix}$$

- Where A is the interior parameters matrix

  $[R|T]$ is the exterior parameters matrix

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There are totally 14 parameters including 3 interior parameters, 6 exterior parameters, 5 distortion coefficients.

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- Take image point coordinates as observed value.
- Take interior, exterior parameters, object coordinates and distortion coefficients as unknown parameters, then use the adjustment method to iterate and calculate them.
- $\begin{bmatrix} V_{i,x} \\ V_{i,y} \end{bmatrix} = \begin{bmatrix} a_{i,11} & a_{i,12} & a_{i,13} & a_{i,14} & a_{i,15} & a_{i,16} \\ a_{i,21} & a_{i,22} & a_{i,23} & a_{i,24} & a_{i,25} & a_{i,26} \end{bmatrix} X_1 + \begin{bmatrix} a_{i,17,} & a_{i,18} & a_{i,19} \\ a_{i,11} & a_{i,11} & a_{i,11} \end{bmatrix} X_2 +$
- Where means adjusted exterior parameters

$\begin{bmatrix} c_{i,11} & c_{i,12} & c_{i,13} \\ c_{i,21} & c_{i,22} & c_{i,23} \end{bmatrix} X_3 + \begin{bmatrix} b_{i,11} & b_{i,12} & b_{i,13} & b_{i,14} & b_{i,15} \\ b_{i,21} & b_{i,22} & b_{i,23} & b_{i,24} & b_{i,25} \end{bmatrix} X_4 + \begin{bmatrix} x_i - (x_i) \\ y_i - (y_i) \end{bmatrix}$

means adjusted object coordinates

means adjusted interior parameters

- Where X_1 means adjusted exterior parameters

means adjusted distortion parameters

X_2 means adjusted object coordinates

(means predicted image point coordinates

X_3 means adjusted interior parameters

X_4 means adjusted distortion parameters

$(x_i)(y_i)$ means predicted image point coordinates

- Before adjustment, we set corners coordinates detected by interest operators as the initial value of (x, y) so that the iteration could convergence quickly.
- After adjustment, we could get the interior, exterior, tangent distortion parameters.

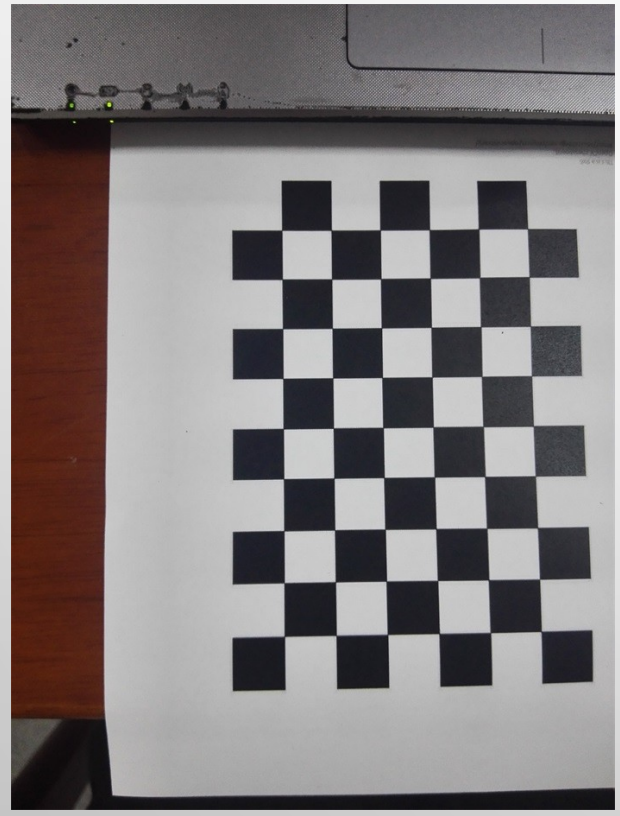
EXPERIMENT AND RESULT

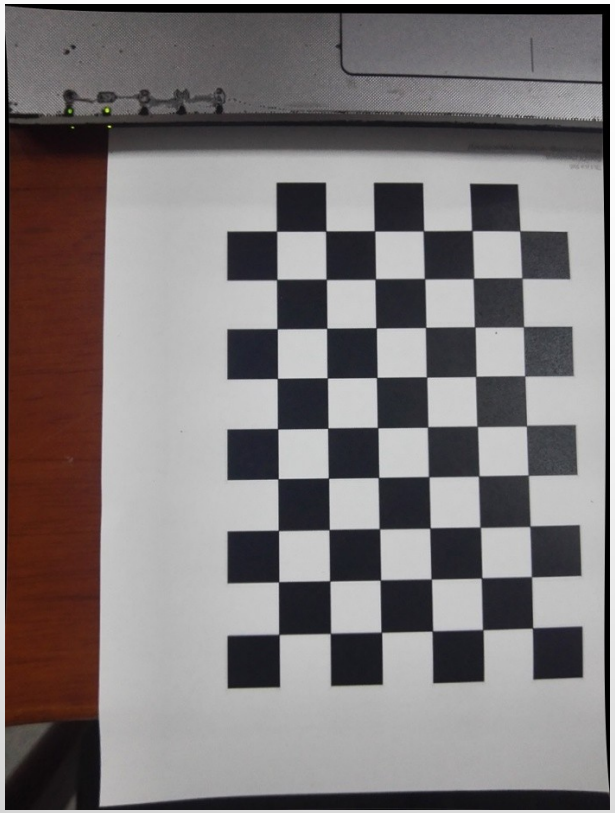
- We use the smartphone to take six photos from different viewpoints. These images have affine transformation relationship.
- Experiment details:

(1)The chessboard gridwidth = gridheight=14mm

(2)Smartphone : HUAWEI Honor 6 plus

Image 1 Result





rotation matrix:

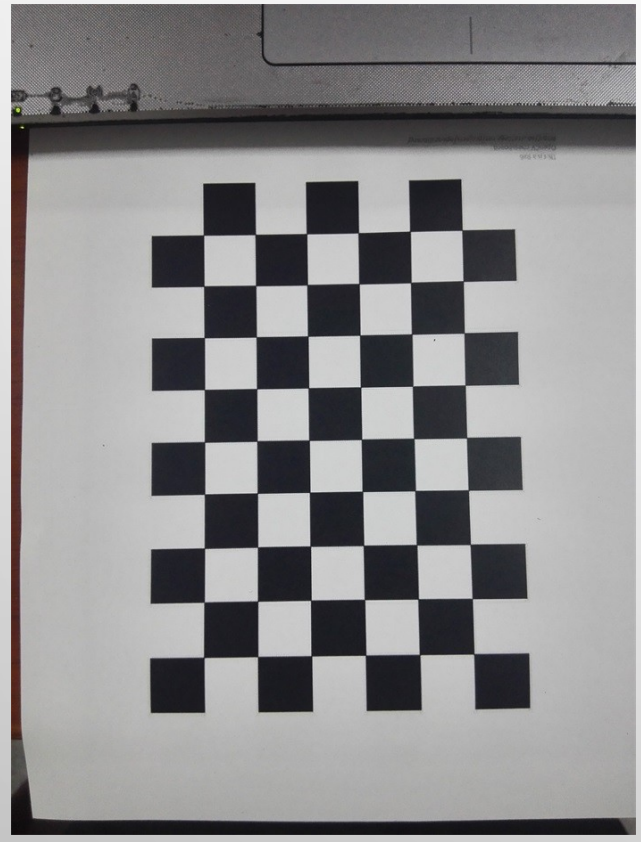
$$\begin{bmatrix} -0.01424409141313877 & 0.9984956667547877 & -0.05294817590556479 \\ -0.9950731824499772 & -0.008959421769902963 & 0.09873748189225749 \\ 0.09811456277581342 & 0.05409373562124802 & 0.9937038796028979 \end{bmatrix}$$

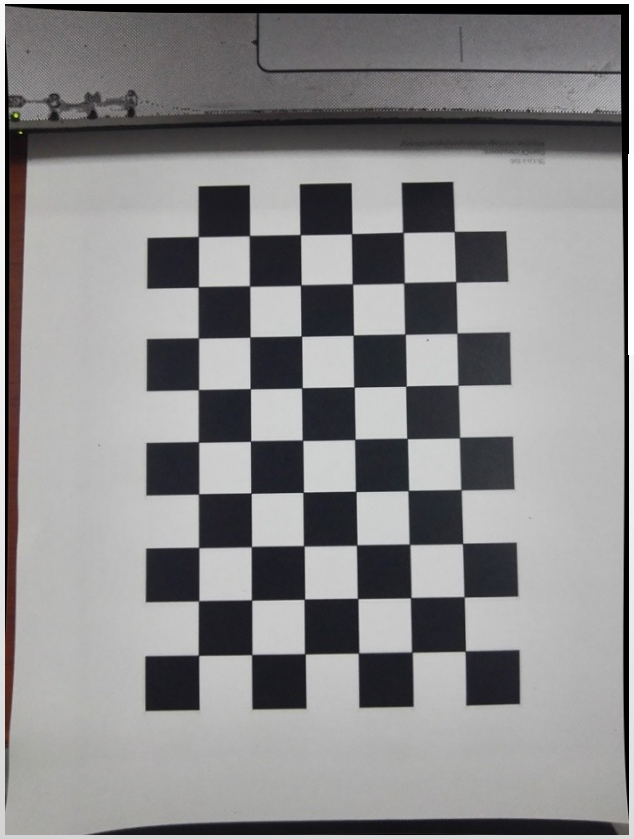
translation vector:

$$\begin{bmatrix} -20.93597361565055 & 75.3824452219564 & 265.024671152226 \end{bmatrix}$$

average error is 0.0739896mm

Image 2 Result





rotation matrix:

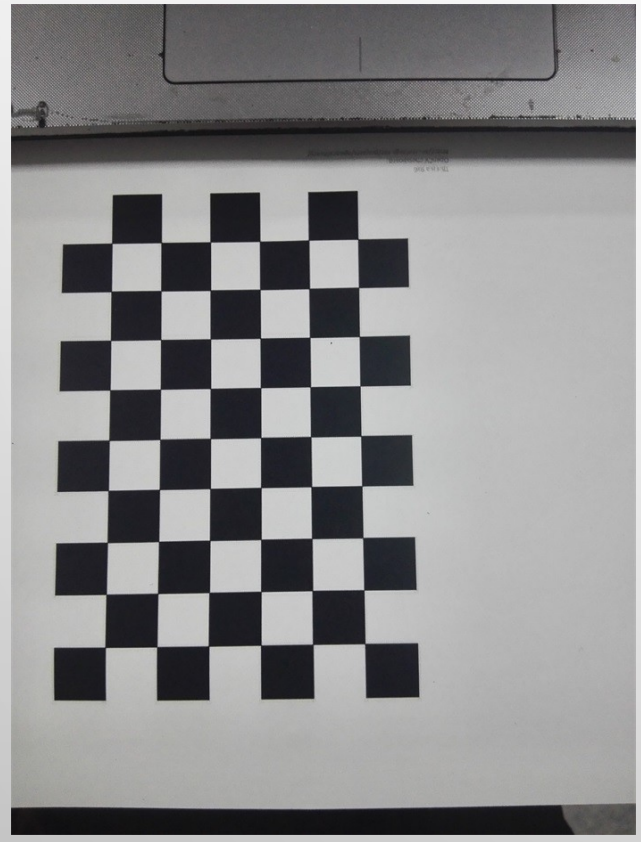
$$\begin{bmatrix} -0.016827696328283 61 & 0.999722584652835 & 0.016479756410151 66 \\ -0.9957556839253747 & -0.018247955802353 74 & 0.090208813534733 98 \\ 0.090484510092015 93 & -0.014891804594816 89 & 0.995786517075481 2 \end{bmatrix}$$

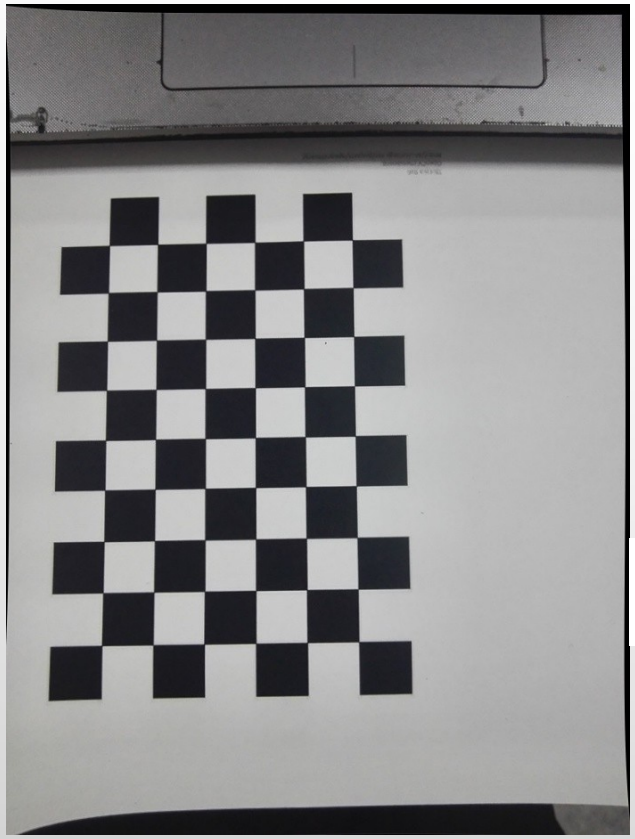
translation vector:

$$\begin{bmatrix} -44.175435945018 52 & 75.323772956314 86 & 263.928481699315 9 \end{bmatrix}$$

average error is 0.0643934mm

Image 3 Result





rotation matrix:

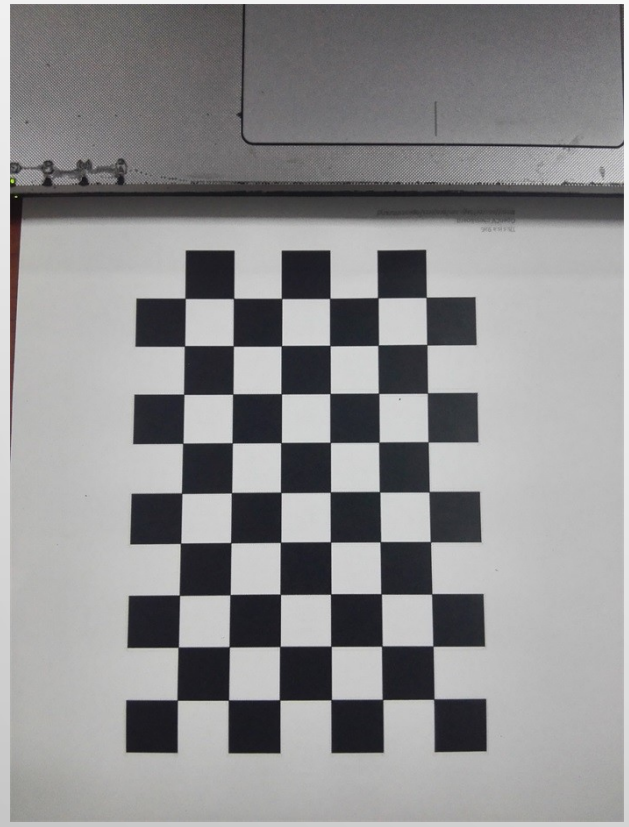
$$\begin{bmatrix} -0.01659855639653864 & 0.99946730655913 & 0.028099662720202 52 \\ -0.991699229982707 & -0.02004033183894913 & 0.1270079617641774 \\ 0.1275034320214827 & -0.0257582650662465 & 0.9915035988858135 \end{bmatrix}$$

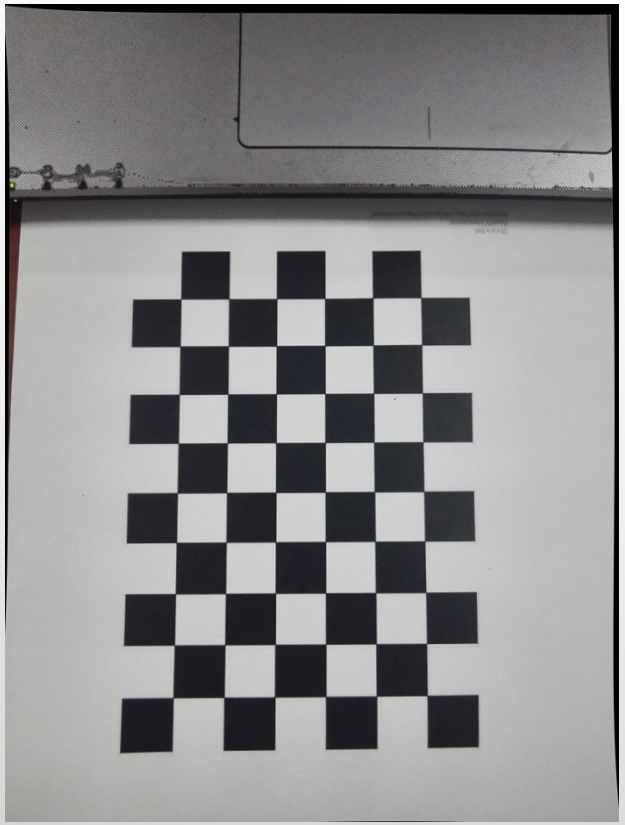
translation vector:

$$\begin{bmatrix} -72.424686754960 56 & 75.51339090707 11 & 274.0008494696808 \end{bmatrix}$$

average error is 0.0649147

Image 4 Result





rotation matrix:

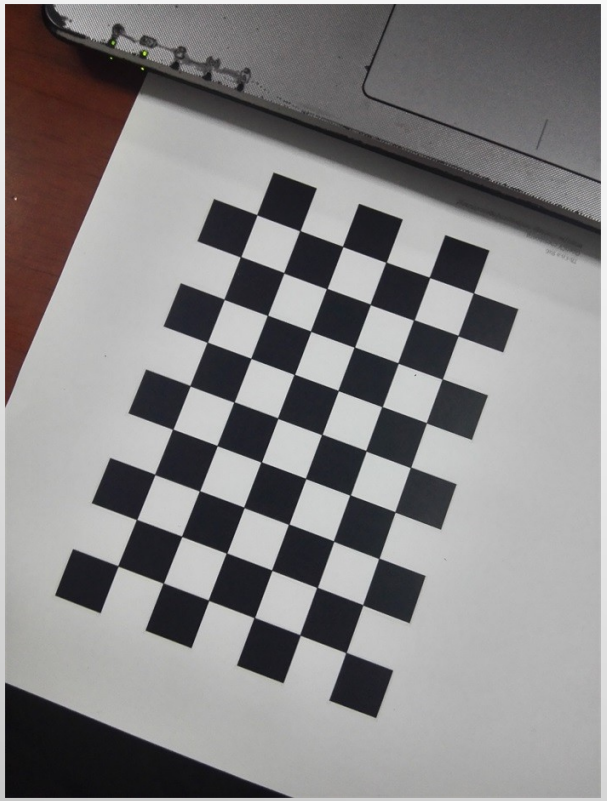
$$\begin{bmatrix} -0.006406513638521912 & 0.9999789549196663 & 0.0010228884453536 01 \\ -0.9911431700290032 & -0.006485583817083835 & 0.1326391861683796 \\ 0.1326430287947991 & -0.0001640741411236407 & 0.9911638613225455 \end{bmatrix}$$

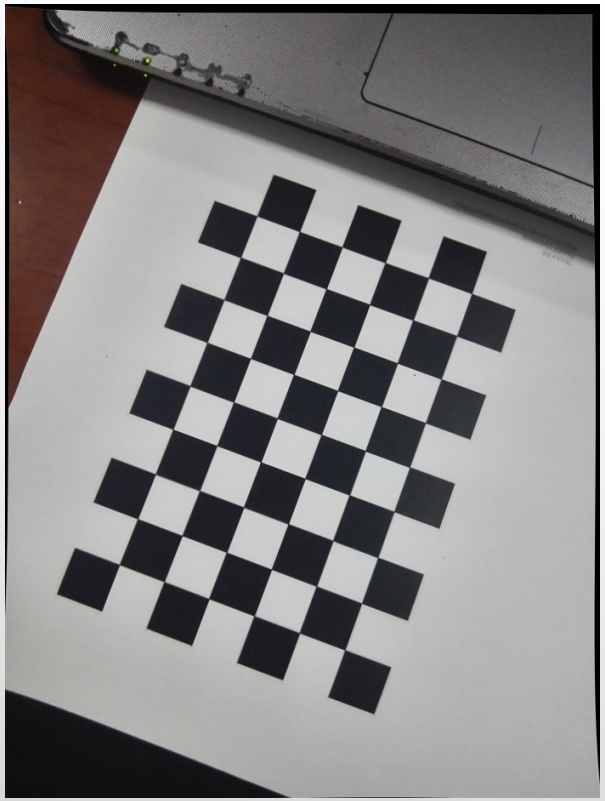
translation vector:

$$\begin{bmatrix} -51.740370489883 84 & 92.31772109621689 & 272.65353146004 74 \end{bmatrix}$$

average error is 0.070202mm

Image 5 Result





rotation matrix:

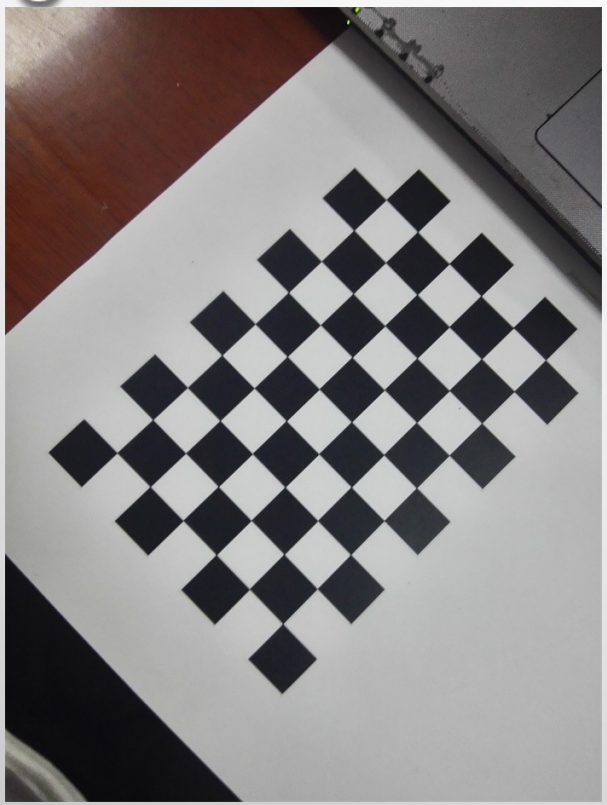
$$\begin{bmatrix} 0.3452842074517707 & 0.9384274745112067 & -0.0115191652007067 \\ -0.9283803507141268 & 0.3433334615417091 & 0.1422394410622547 \\ 0.1374363143143667 & -0.03841886604659739 & 0.9897652500665883 \end{bmatrix}$$

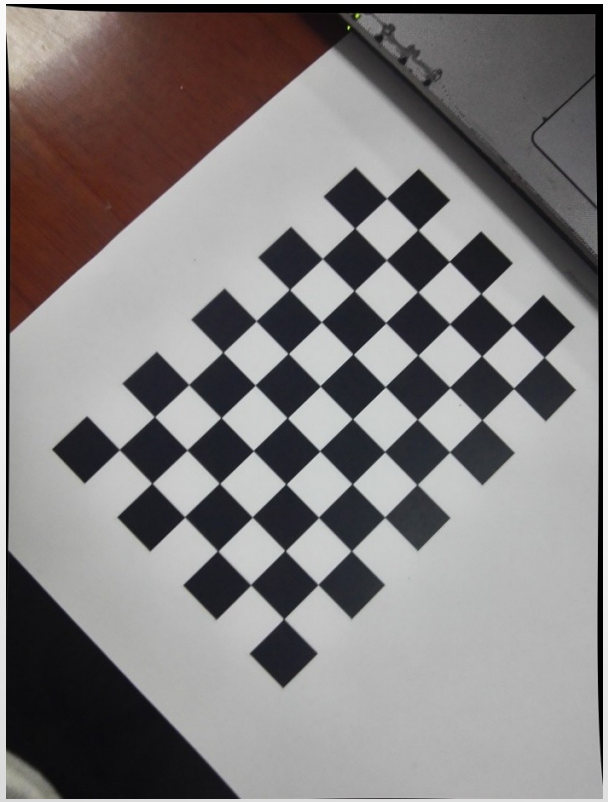
translation vector:

$$\begin{bmatrix} -67.26801305322964 & 61.90157078285434 & 279.5275795798518 \end{bmatrix}$$

average error is 0.0543511mm

Image 6 Result





rotation matrix:

$$\begin{bmatrix} 0.7121681823430801 & 0.6994751760371264 & -0.059589916646898 07 \\ -0.6902572942910749 & 0.7131858493803456 & 0.1221098354826485 \\ 0.1279114839884121 & -0.04583036495017174 & 0.9907261124611666 \end{bmatrix}$$

translation vector:

$$[-69.11347731864105 \quad 28.65156429967218 \quad 286.0734206797922]$$

average error is 0.114672mm

- intrinsic matrix:

$$\begin{bmatrix} 1125.666283464561 & 0 & 406.2741514614974 \\ 0 & 1124.497048211875 & 410.2640567705536 \\ 0 & 0 & 1 \end{bmatrix}$$

- distortion coefficients

$$\begin{bmatrix} 0.2159752978274336 \\ -0.2855261273079563 \\ -0.007948170451493868 \\ 0.007390336311180357 \\ -2.107860849961472 \end{bmatrix}$$

CONCLUSION

- This paper adopt a plane calibration method to calibrate smartphone camera.
- this method has following advantages:
- (1) calibration with high accuracy.
- (2) flexibility and robust.
- (3) with less cost.

REFERENCE

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