TOPCON

Operation Manual
Camera Calibration Software

PI-Calib

Table of Contents

Table of Contents i

1. Introduction 1

1-1. Preface 1
1-2. Outline 2

2. Quick Operation Guide 3

Step0 Outline 3
2-0-1.Outline 3
Step1.Preparation 5
2-1-1.Print Out 5
2-1-2.How to attach the Calibration Sheet 6
2-1-3.Camera Setting 8
Step2 Taking Images 9
2-2-1.Take image from Front 9
2-2-2.Take image from Left side 10
2-2-3.Take image from Right side 12
2-2-4.Take image with Look-down angle 14
2-2-5.Take image in Look-up angle 16
Step3 Process 17
2-3-1.Importing images 17
2-3-2.Detecting center of marked Points 18
2-3-3.Calculation 21

3. Trouble Shooting 23

3-1. Focus distances can not be read from Exif file of Image data 23
3-2.Image can not be captured in good quality 24
3-3.Examples of bad images 25
3-4.In case Judgment is NG 27
3-5.Enter Image Resolution Manually 28
3-6.Image Contrast Adjustment 29
3-7 Create image corrected lens distortion 30

1. Introduction

1-1. Preface

Thank you for purchasing TOPCON Camera Calibration Software. To get the best use of the instrument, read carefully the On-line Instruction Manual of this software.

Contents of this manual are prepared with thorough care. However, your information about incomprehensibilities and errors, if any, would be highly appreciated.

Disclaimer

TOPCON shall not take any responsibility for damage due to fire, earthquakes, actions by third persons, intension or fault of the user, misuse and use under unusual conditions.

TOPCON shall not take any responsibility for damage due to inability to use this instrument, including change/loss of data, loss of business profit and suspension of business.

TOPCON shall not take any responsibility for damage caused by operations other than those described in this Instruction Manual.

TOPCON shall not take any responsibility for damage caused by malfunctions due to combination with other instruments.

1-2. Outline

This software is designed to get calibration data of digital camera used to capture images that will be used for 3D measurement on 3D Image Survey Station, PI-3000 and DI-3000 software module.

In order to get precise 3D measurement result from taken images on the PI-3000 and DI-3000 software module, it is necessary to get own parameters (Camera Data) of such digital camera, by performing calibration procedure under the same settings applied when taking the images for measurements.

With this software, following 7 parameters will be obtained.

1) Focal Length of lenses : f

2) Distortion of lenses (Radial direction) : K1, K2

3) Distortion of lenses (Tangential direction) : P1, P2

4) Location of Principle point of camera sensor) : Xp, Yp

To perform calibration procedure, please print out the exclusive Calibration Sheet (with an exclusive pattern) through any Printer or Plotter, then take images by a Digital Camera from several direction.

Feed those images into the software to get above 7 parameters.

The obtained 7 parameters are stored with file name as "**Project Name.cmr**".

Furthermore, image which corrected distortion of lenses (Calibrated image) is created used 7 parameters. For detail see "3-7 Create Image Corrected Lens Distortion "

2. Quick Operation Guide

Step0 Outline

2-0-1.Outline

Preparation should be done as in following procedures.

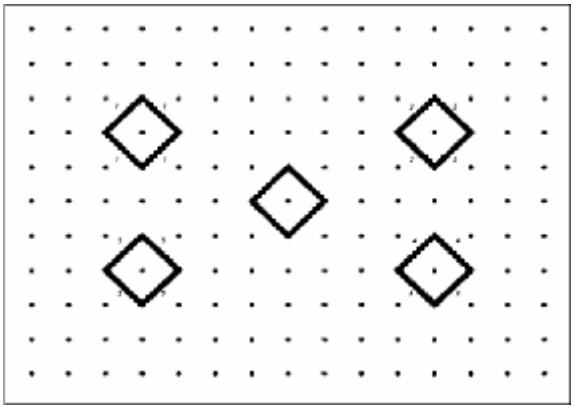
Step1 Preparation

Print out the exclusive pattern sheet.

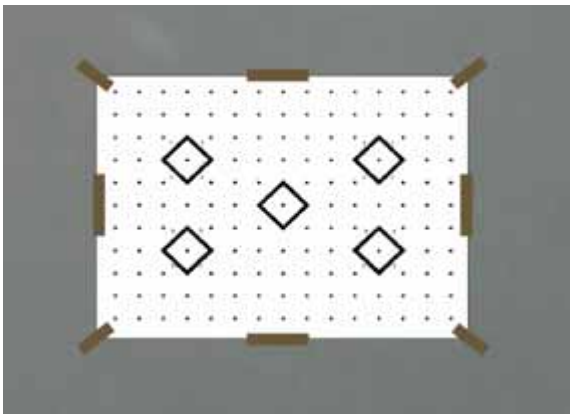
The following pattern data is contained in the software CD with the file name of **"2Dchart.dxf"** in DXF format. This file will be read automatically by the Camera Calibration Software.

For this, please locate this 2Dcahrt.dxf at the same folder which includes the execution file (**PICalib.exe)** of the Camera Calibration Software.

Note: Do not change the file name.



Attach the Printed Calibration Sheet on a flat surface (on a wall).



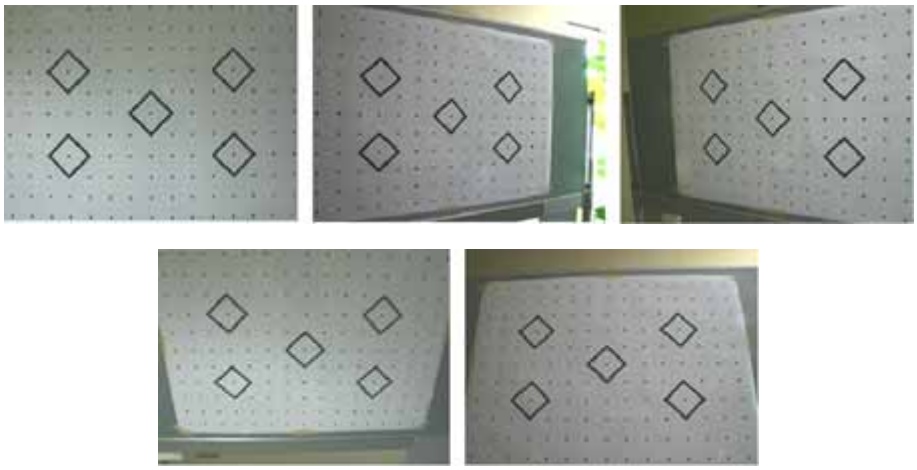
Choose setting of the digital camera

On the digital camera, choose same setting as those should be used when taking images for 3D measurements.

Step2 Taking Images

Take image of the pattern sheet.

Take images of the calibration sheet, attached to the wall, from 5 different angles (from direct front, Upper location, Lower location, Left side and Right side) and get images as in following examples.



It is recommended to use a camera tripod when taking image by a digital camera as much as possible in order to get a better quality images and also to more easily adjust the shooting angle and height.

If no tripod is available, adjust the height using step or in stooping position.

Step 3 Process

Importing images

Import those images of the calibration sheet into Camera Calibration Software and store them.

Detecting center of marked Points.

Let the software to detect center of marked points of the pattern.

Calculation

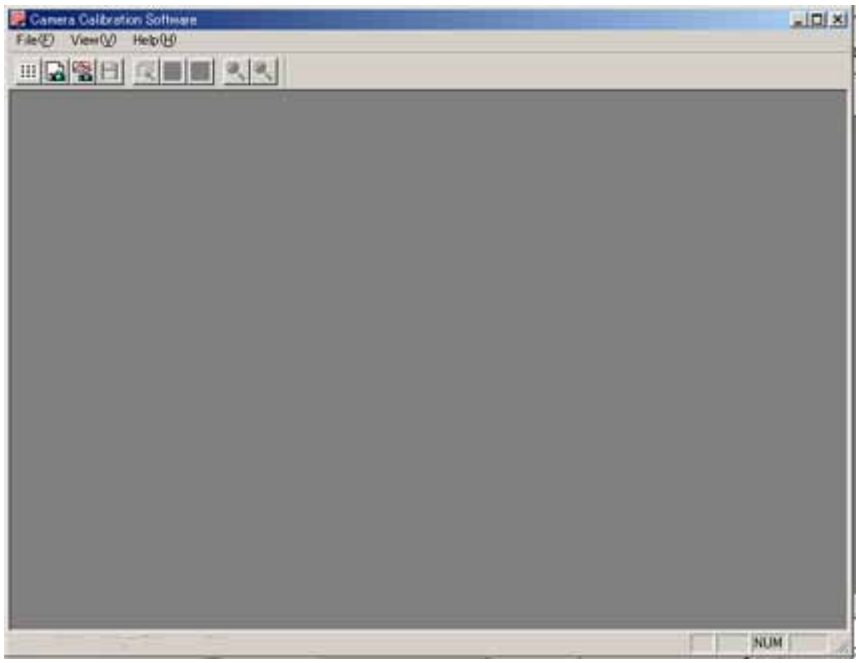
Let the software to make calibration calculation.

Refer to the following descriptions for details of each step.

Step1.Preparation

2-1-1.Print Out

1. By double clicking "PICalib.exe", the application software will start up and the following initial screen appear.



2. At menu bar, select menus **[File] - [Print Calibration sheet]**. A dialog box "Select Sheet Size" will appear and select desired size of the Calibration Sheet and click "OK".

   It is recommended to choose a possible maximum size to print or plot out by owner's printer or plotter.

   In case, however, of using a Telescopic lenses on digital camera to be used, then choose A4 size.

3. The calibration sheet will be shown on the screen in the selected size, and a dialog box for print out will appear.

   On the dialog box or through the property button, choose the paper size at the same size as the one specified in the above step 2 execute print out.

   (Operation in dialog box for print out or use of property button may slightly differ depends on Windows version or type of printer or plotter used. Please refer to the related manuals for details)

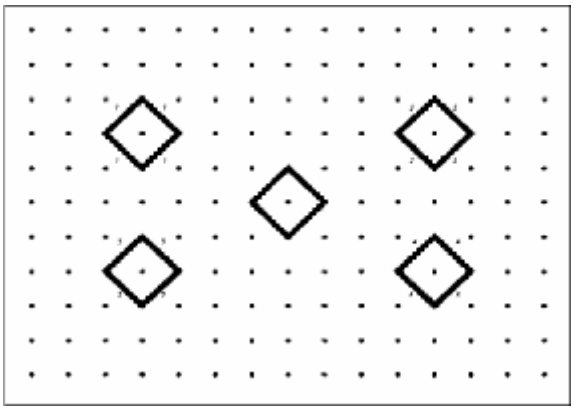
Note:

It is recommended to make print out the Calibration Sheet pattern just before actually taking images since the paper may shrink, expand or fold when it is left for a long time.

If intended to use the Calibration Sheet once printed at the later time again, please keep and store them carefully by rolling it up.

2-1-2.How to attach the Calibration Sheet

The printed Calibration Sheet contains, as in following figure, totally 145 black dots and 5 square patterns.



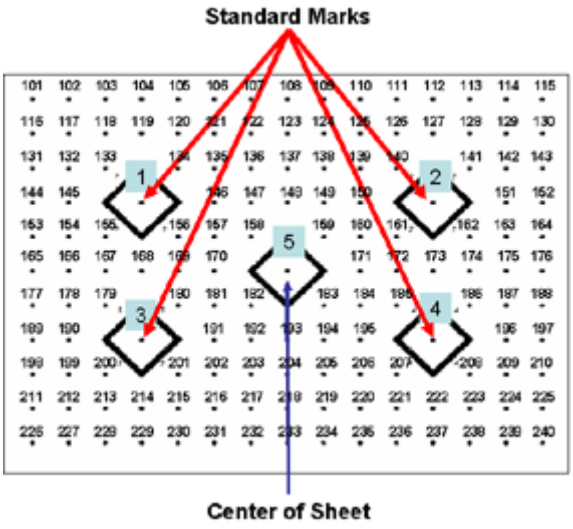
The black dot points in 4 peripheral squares (except the central one) are regarded as standard mark and are numbered as Standard mark # 1, #2, #3 and #4 (Up Left, Up Right, Lower Left and Lower Right)

The dot point in the central square is located in the centre of the sheet and is #5.

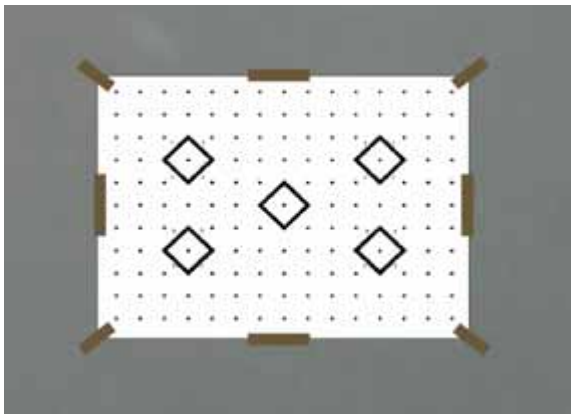
(This may be referred to find center of the sheet when image is taken)

Including these 5 standard marks, there are totally 145 dot points and are identified in the software with identification number from #101 through #240 (not numbered on the sheet).

During the camera calibration calculation, center of these 145 dot points are detected and used for the calculation.



As been illustrated in the figure below, attach and fix the printed Calibration Sheet on a flat wall surface in such way that the calibration sheet is naturally stretched and is not slacken, using some scotch or mending tape at 4 corners and each side line.

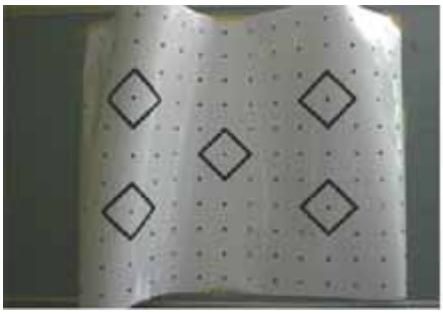


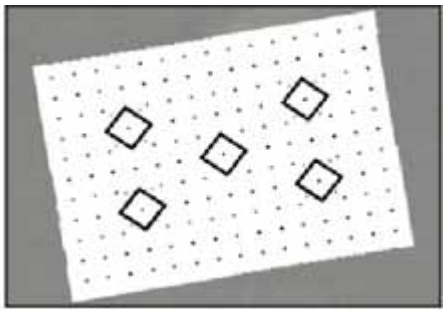
Note:

Please attach the sheet on a flat wall and choose location at where not much reflection of lighting appears in the image. In case of taking image outside, select a place not to take images against the sun light.

Taking image will be easier if the calibration sheet is attached at a height so that Standard square marks #1 and #2 are at user's eye height.

Followings images are bad examples to avoid when attaching the sheet on to the wall.





2-1-3.Camera Setting

Adjust and set the digital camera to be used.

- When capturing images Focal Length (Zooming position, if provided), Focusing distance, Image quality and Image size to be same as ones that will be used for taking capturing images for 3D measurements.
- Focusing should be selected as Manual Focus.

Notes:

1. Focal Length

When using Zoom lenses, use only either at the most wide position or the most Telescopic position.

If desired to use at intermediate zoom position, fix the zoom position used during the calibration, for example by some mending tape so that the same position can be used for

Later capturing for 3D measurements.

Also, in this case, always set Auto focus function OFF.

Due to above reason requiring a fixed focus position, a compact digital camera which has self storing type lens system can not be used for this camera calibration purpose.

2. Focusing adjustment

Always set the Auto focus function Off and use in manual focus mode.

It is recommended to adjust the focusing distance to infinity side.

If desired to use at some intermediate focusing position, that particular position should be kept (by fixing focusing ring with some mending tape) in order to keep the same focusing condition when it is used later for image capturing for 3D measuring purposes.

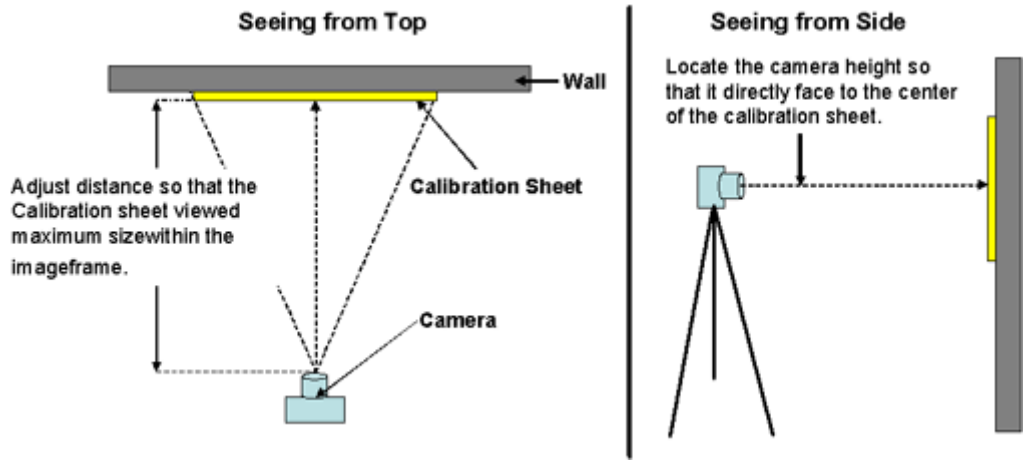
3. Image Quality, Image Size

No restriction for these settings, however, accuracy may be diluted if smaller size and high compress ratio are chosen. Therefore, recommended to set the maximum image size and the lowest compression ratio of JPEG to get the optimal result.

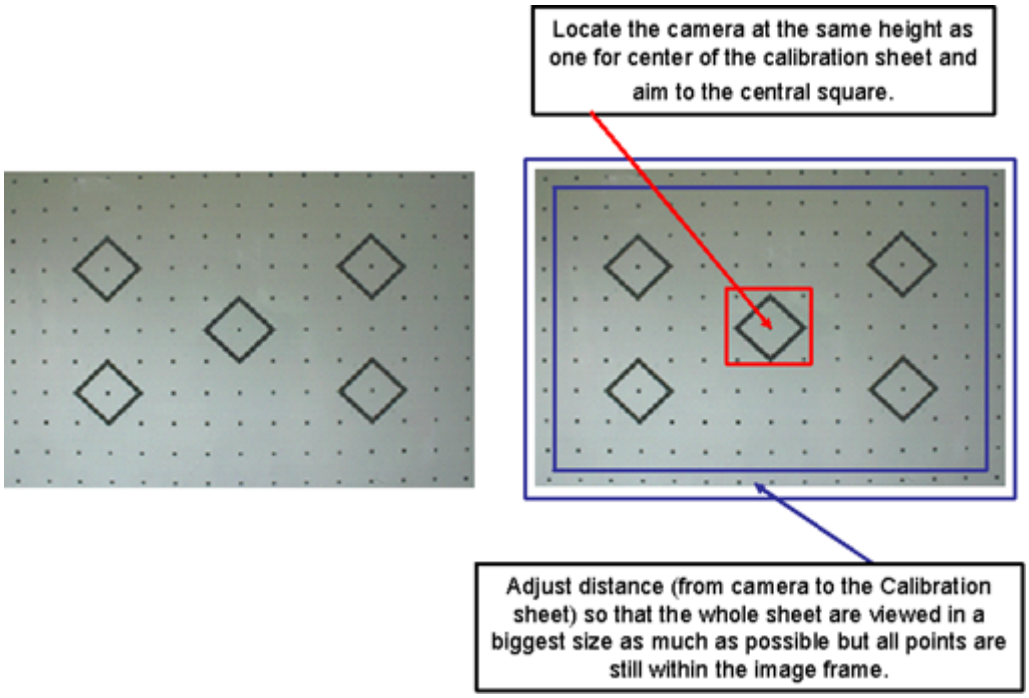
Step2 Taking Images

2-2-1.Take image from Front

1.Camera Position



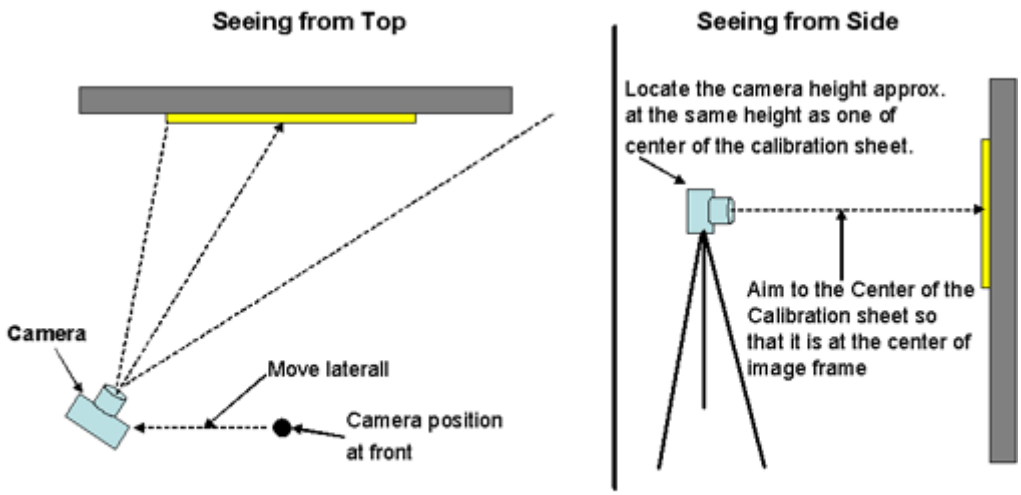
2.Good Example



Please refer to the "Examples of Bad Image"

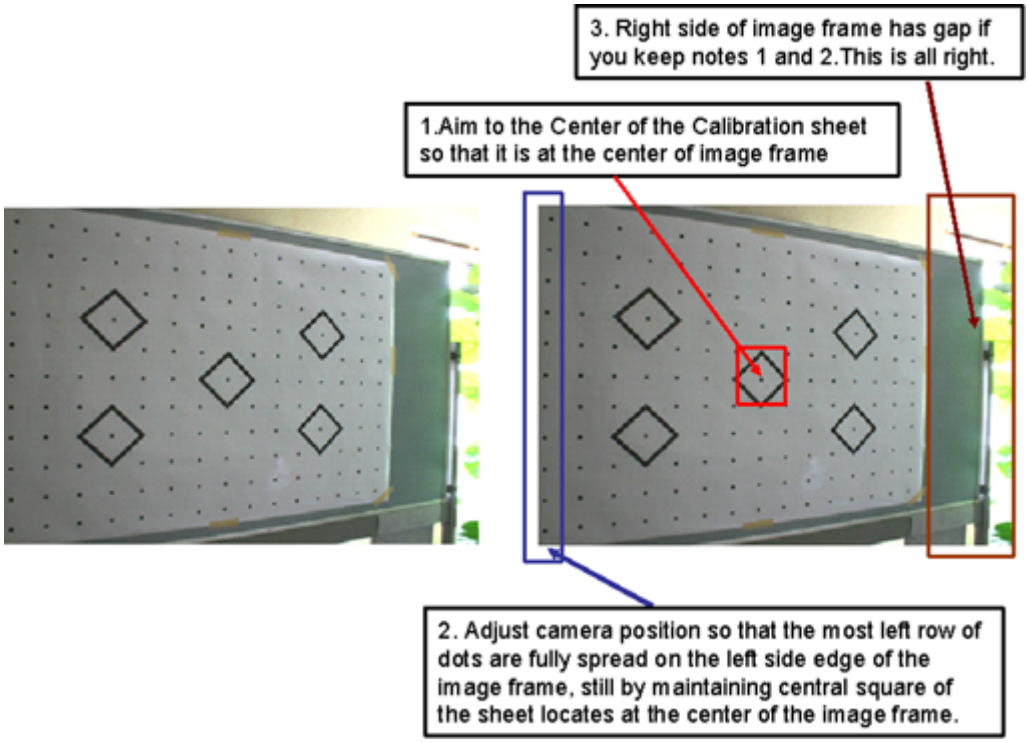
2-2-2.Take image from Left side

1.Camera Position



Note: The best camera position may differ depends on the used camera, therefore, adjust the position to get better image satisfying the point noted in the example.

2.Good Example



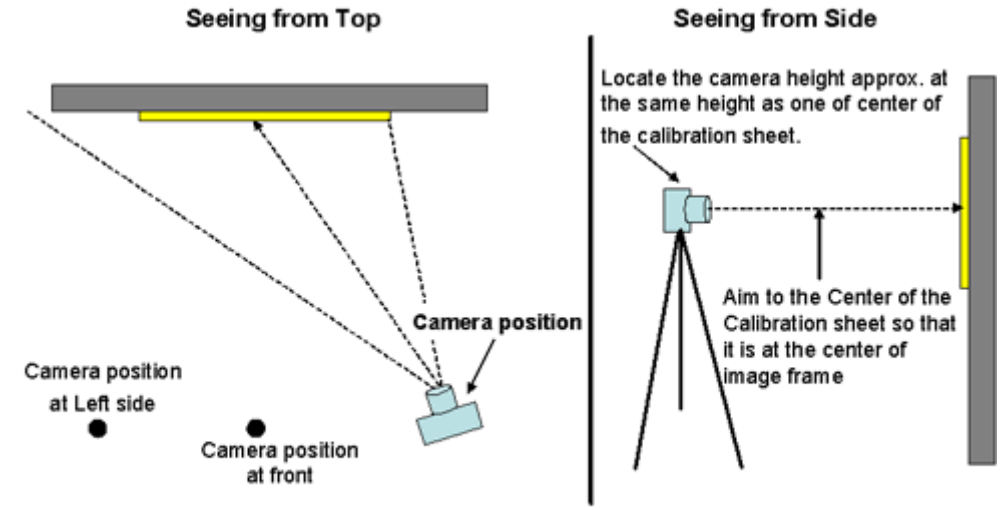
Please refer also to the "Examples of Bad Image"

By keeping alignment to the central square at the center of image frame, find camera position so that the most left row of the dots are spread fully on the left side edge of the image frame, by changing aiming angle.

If this is done, the right end of calibration sheet does not reach to the right end of image frame due to perspective effect. This gap is all right and does not affect to the calibration result.

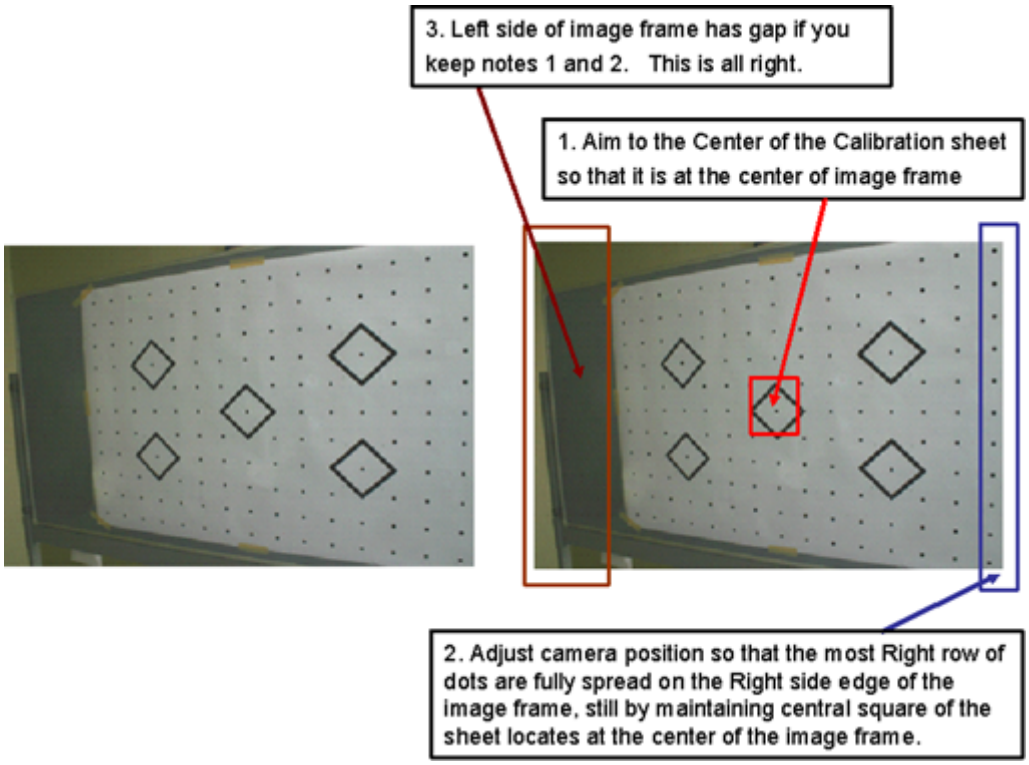
2-2-3.Take image from Right side

1.Camera Position



Note: The best camera position may differ depends on the used camera, therefore, adjust the position to get better image satisfying the point noted in the example.

2.Good Example



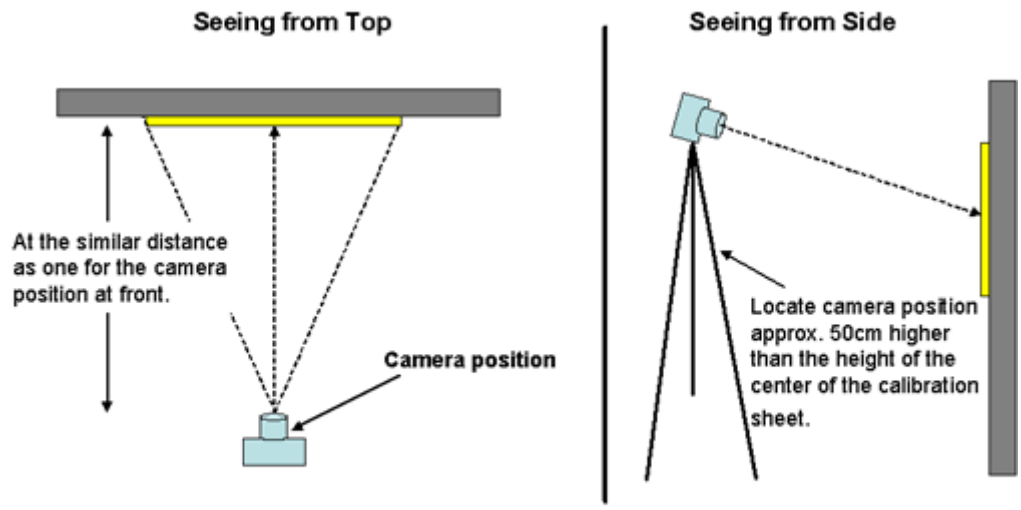
By keeping alignment to the central square at the center of image frame, find camera position so that the most right row of the dots are spread fully on the right side edge of the image frame, by changing aiming angle.

If this is done, the right end of calibration sheet does not reach to the right end of image frame due to perspective effect. This gap is all right and does not affect to the calibration result.

Please refer also to the "Examples of Bad Image"

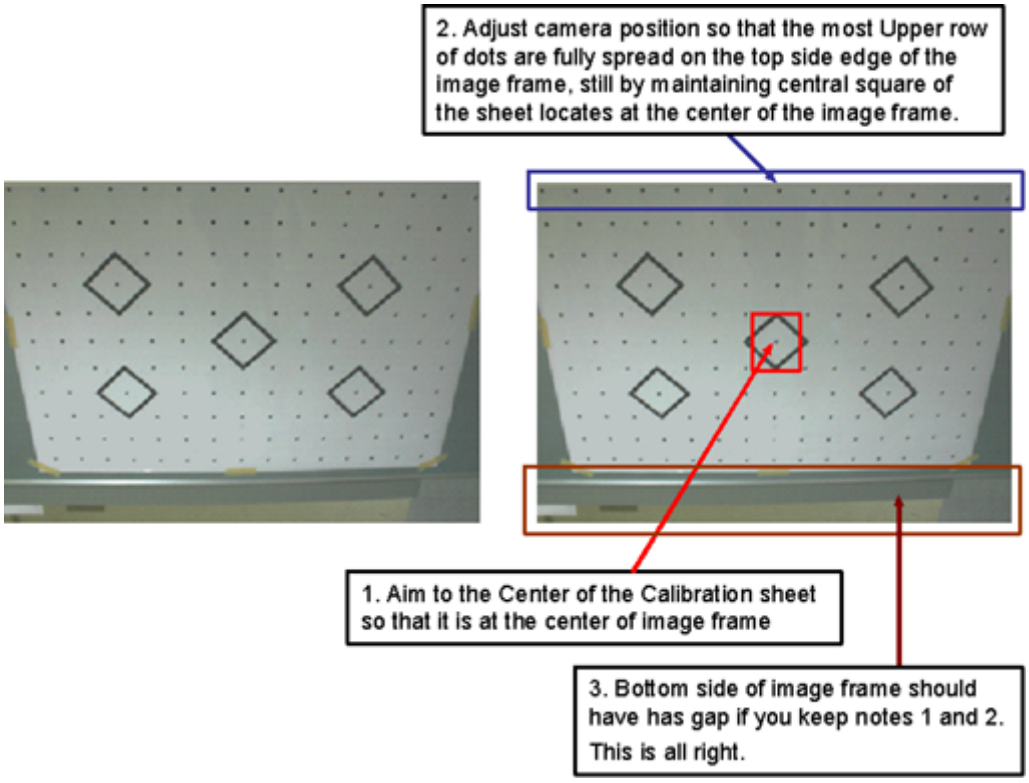
2-2-4.Take image with Look-down angle

1.Camera Position



Note: The best camera position may differ depends on the used camera, therefore, adjust the position to get better image satisfying the point noted in the example.

2.Good Example



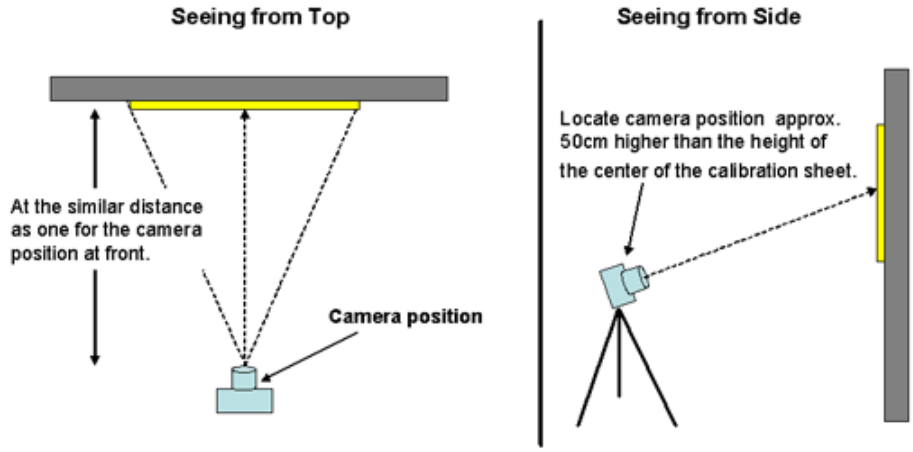
By keeping alignment to the central square at the center of image frame, find camera position so that the most top row of the dots are spread fully on the top side edge of the image frame, by adjusting aiming angle.

If this is done, the bottom end of calibration sheet does not reach to the bottom end of image frame due to perspective effect. This gap is all right and does not affect to the calibration result.

Please refer also to the "Examples of Bad Image"

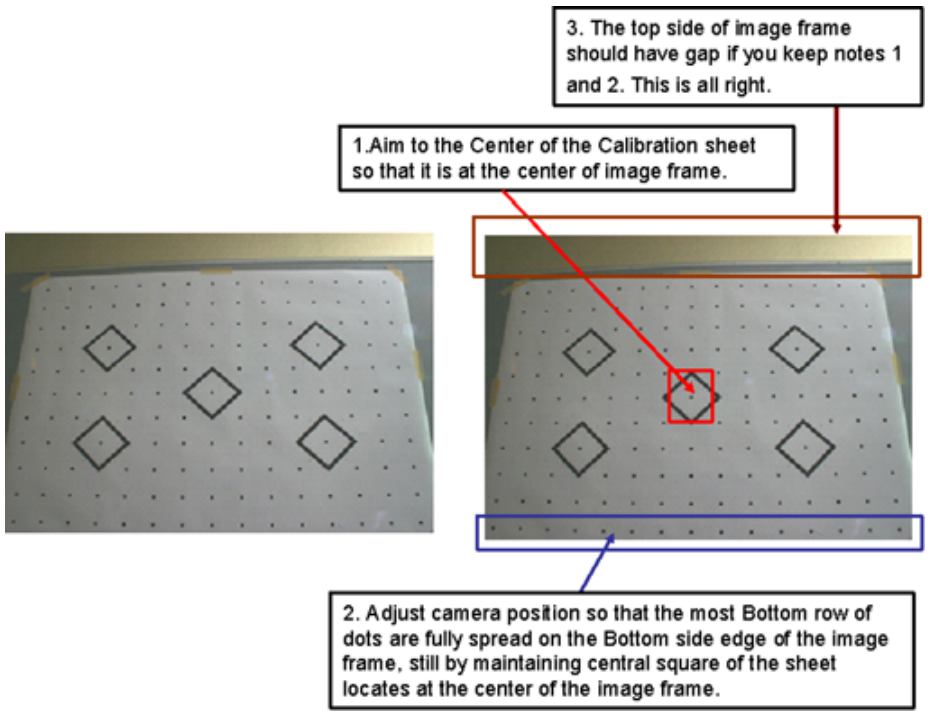
2-2-5.Take image in Look-up angle

1.Camera Position



Note: The best camera position may differ depends on the used camera, therefore, adjust the position to get better image satisfying the point noted in the example.

2.Good Example



By keeping alignment to the central square at the center of image frame, find camera position so that the most Bottom row of the dots are spread fully on the Bottom side edge of the image frame, by adjusting aiming angle.

If this is done, the Top end of calibration sheet does not reach to the Top end of image frame due to perspective effect. This gap is all right and does not affect to the calibration result.

Please refer also to the "Examples of Bad Image"

Step3 Process

2-3-1.Importing images

1. Start up the Calibration Software by double clicking "PICalib.exe".

   The main screen will appear.

2. Select menus, **[File] - [New Project]**

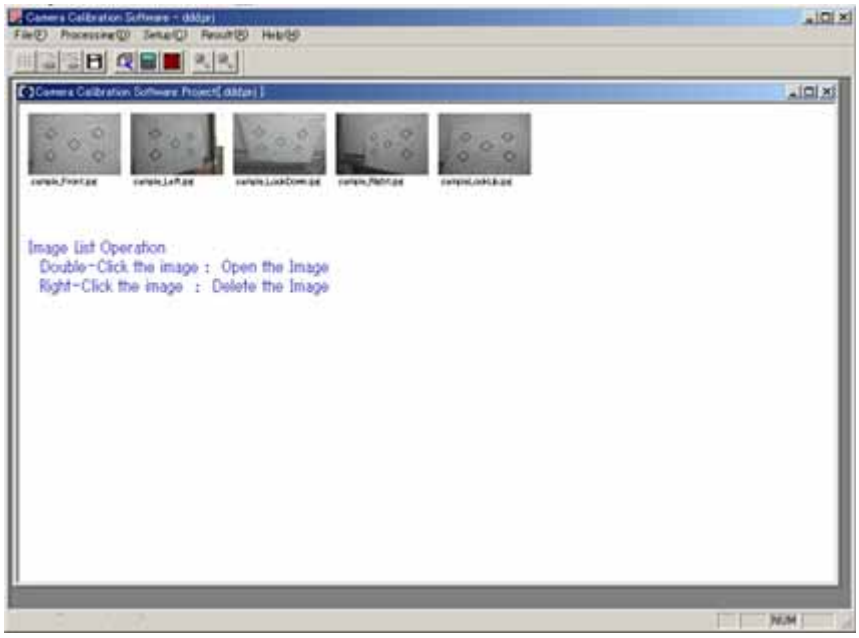
3. Dialog box "New Project" will appear and enter the Project Name, then, click "OK" button.

4. Dialog box "Select Sheet Size" will appear. Select size of the used Calibration Sheet and click. "OK".

5. Dialog box "Open" will appear. Select 5 images (taken from 5 different angles) and click "Open" button.

6. Dialog box "Confirmation of Initial Focal Length" will appear. Confirm focal length and Enter the focal length value (which is set when the image is taken) if wrong, then click "OK" button.

7. Images will be registered and thumb-nail images are shown as in following screen.



In case an error message **"Focal Length data could not be read from Exif file of Image data"** appears, please refer to the related Chapter **"3. Trouble Shooting "**.

2-3-2.Detecting center of marked Points

In order to perform calibration calculation, it is necessary to detect precise center coordinates (x , y) of the dot marks spread on the Calibration Sheet and pictured on the registered images.

On this Calibration Software, the center coordinates of all dot marks (including Standard Marks in squares) are measured semi-automatically following the steps as follows. However diameter of all dot marks are needed to be composed more than 5 pixels or more on the taken images in order to detect center of dot marks correctly.

1. Plotting Standard Marks

On the pattern of the Calibration Sheet, there are 5 squares. Center dot mark of 4 peripheral squares, except for central square to be detected. (4 points each on 5 different images, totally 20 points)

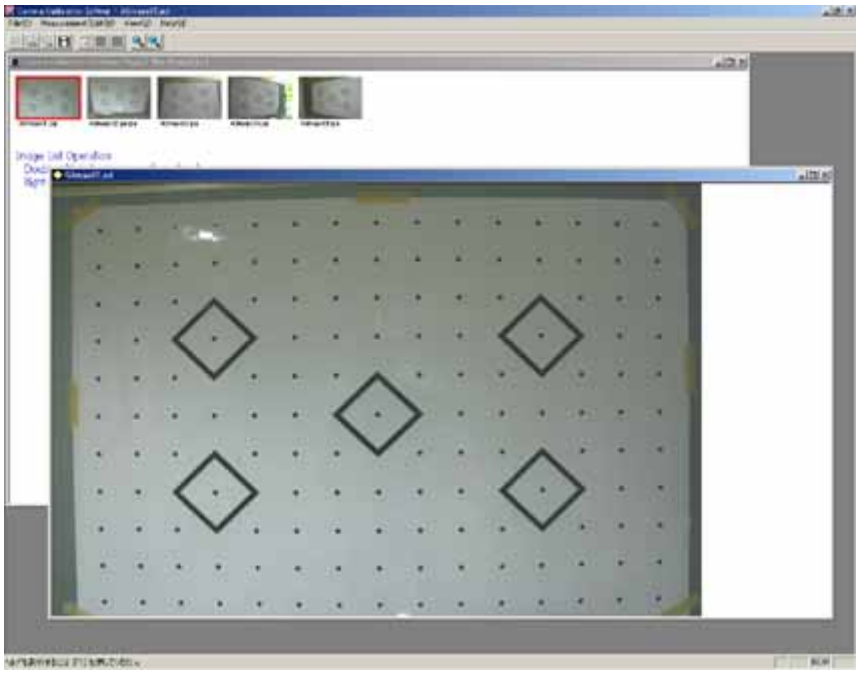
1) Confirm 5 Images are registered in a Project as in section 2-3-1. Importing Images**.**

2) Select menus, **[Process] - [Measure Standard Marks of All Images] - [Measure Standard Marks of All Images]**

3) A dialog box **"Measure 4 Standard Marks of All Images"** will appear. Press **"OK"** button.

2. On the separate screen, the first image will be displayed.

If necessary, Zoom-In or Out (click menus, **[View] - [Zoom In / Zoom Out]**) and adjust the **"Brightness"**.



3. Measure those 4 Standard marks (the dot mark in each square) by pointing with the cursor and clicking, in clock-wise order starting from left-up standard mark, Left-up (#1) ->Right-up (#2)->Left-bottom(#3)->Right-bottom(#4).

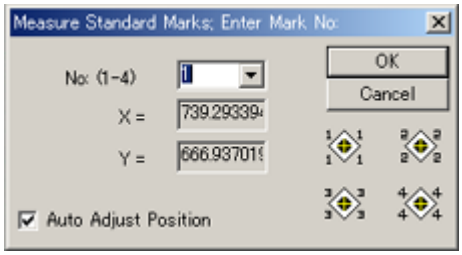
   When measuring each standard mark, the cursor need to be pointed rather precisely within the dot,

   then, click the mouse. The center of the dot will be automatically and very precisely detected.

   For this cursor pointing, use Zoom-up function of the image.

   A dialog box **"Measure Standard Mark: Enter Mark No."** will appear.

   Confirm if number indicated at the Standard Mark Number is correct, and click **"OK"** button.



   If the center of dot is detected, then yellow cross mark will be displayed.

   If clicking is made without pointing the cursor within the dot, click **"Cancel"** button for retry measurement.

   If the detecting center of dot was unsuccessful, a message,

   "Center Detection was not Successful. Re-try Measurement." will appear and a red cross mark will be displayed at the pointed location.

   Re-try to measure again.

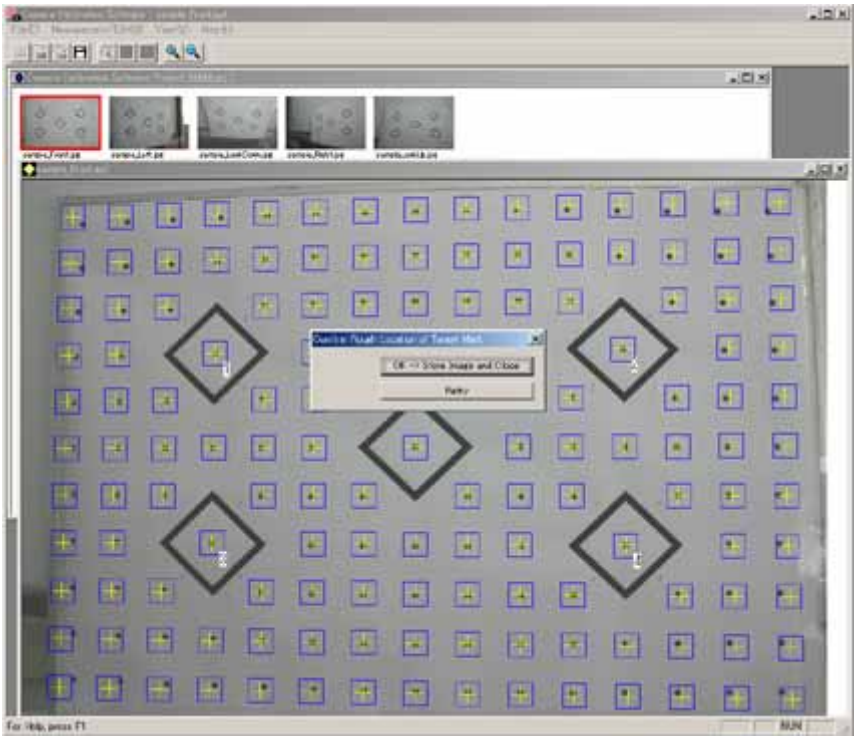
   If center detection can not be successful even after several times of re-measurement, the image

   itself may be containing some problem (insufficient clearness, contrast, etc).

   Check with the Trouble Shooting section, **"Examples of Bad Image "** and if judged the image is bad, then, please re-capture the image.

   Repeat the above procedure on all 4 Standard Marks.

4. After when measurement of all 4 Standard Marks are completed, following screen will appear. Zoom ratio will be reset and whole sheet will be shown.

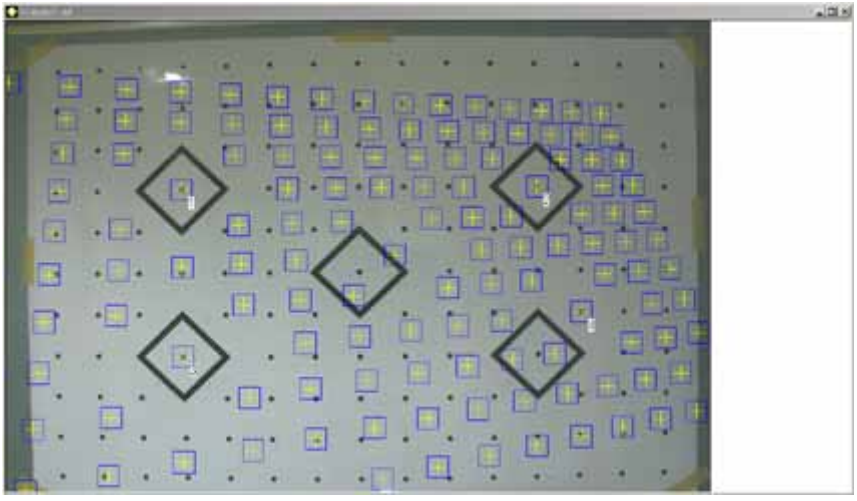


Soon after, small blue square marks will be displayed around the all dot marks, including those Standard Marks in the black squares.

Check if almost all dots are within the blue squares (several exceptions are acceptable), click **"OK ➔ Store Image and Close"** button at the dialog box, **"Confirm Rough Location of Target Mark".**

If the result shows, as in the following example, many dots are out of blue square, click **"Retry"** button to go back to the step 3 and re-start measurements.

Such result may be caused if the measurements of the 4 Standard Marks were not properly done.



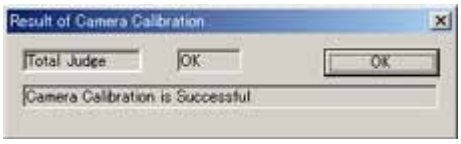
5. The next image will be shown, therefore, repeat the procedure step 3 and 4.

   In the same way, repeat the procedure for the rest 4 images.

2-3-3.Calculation

1. After the measurements of Standard Marks and all dot marks on all 5 images are completed successfully, calculation will be automatically started.

2. Dialog box **"Result of Camera Calibration"** will appear.



   Confirm if Judgment is indicated OK, then click **"OK"** button.

   If the Judgment is "NG", the calibration calculation could not be completed.

   Please try to follow the procedure 2-3-1 and 2-3-2, maybe some steps were passed without properly completed.

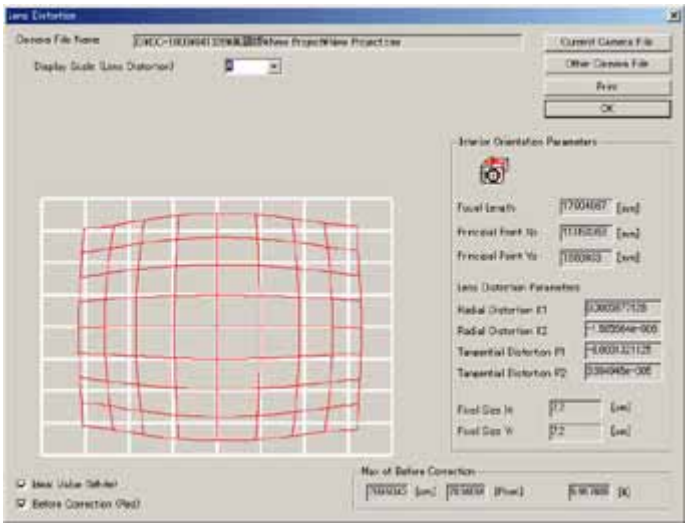
   In case "NG" judgment does not change even after a couple of re-trying 2-3-1 and 2-3-2 procedures, there can be other possible causes for "NG".

   Please refer to the section "Trouble Shooting", "In case Judgment is NG" and check the items described there.

   In case still the judgment indicates **"NG"**, the used images may contain some problem.

   Try to re-capture the images.

3. The result of the calculation will be shown as following screen.



4. This result of the Calculation will be stored as an file automatically named **"Project Name.cmr"** and in the Project file created in the **"2-3-1 Importing Images "**.

   When 3D measurement is performed on the 3D Image Survey Station, PI-3000, using the images taken by this calibrated camera, use this file as an camera data.

Judgment Criteria

Criteria to obtain the **"OK"** judgment is to get standard deviation of image coordinate residuals for all dot points is within 1 pixel.

Since there are several possible reasons to get **"NG"** judgment, please refer to the Chapter **"3.Trouble Shooting", "In case Judgment is NG "**

3. Trouble Shooting

3-1. Focus distances can not be read from Exif file of Image data

This Calibration Software automatically read the focal distance information, which is contained in Exif file attached to the image data of digital camera, when the image data is imported as a file, and use the focal distance information in the calculation.

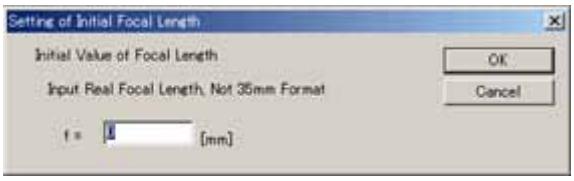
However, some digital camera and/or the image data taken by such camera is not complied with Exif file format.

In such case, it is necessary to manually obtain and enter the focal distance information follow the steps below.

1. When the message **"Focal Length data could not be read from Exif file of Image data"** appeared, click **"OK"** button.

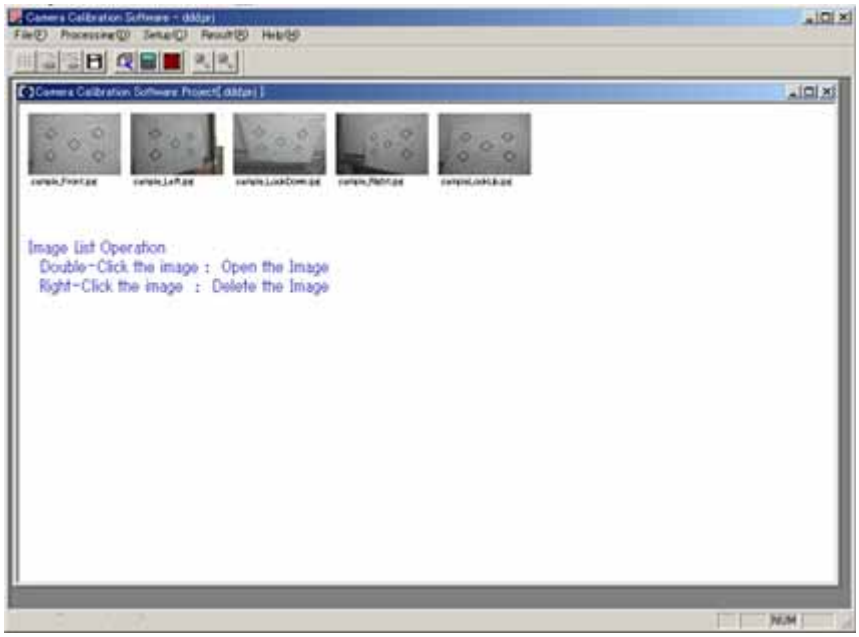
2. Dialog box "Setting of Initial Focal Length" will appear.

   Enter the focal length value (which is set when the image is taken) and click "OK" button.



3. Images can be registered and following screen will be shown.

   Proceed to the measurement of Standard Marks.



3-2.Image can not be captured in good quality

1. Image is unfocussed

   Maybe shuttering speed of the camera too slow.

   Recommended to set shutter speed to faster than 1/250 when camera is hold in hands.

2. Too strong flash light disturbs clearness of patterns.

   When distance from the camera to the Calibration Sheet is too close, strong flash light may affect image and some part of dot pattern may be not clearly pictured.

   On such images, automatic detection of the center of dot mark may be not successful.

   Even if automatic center detection is failed on a few points in a image, this may not affect to get calculation be completed. However, those 4 Standard Marks has to be clearly imaged and detected.

   Take the bigger size of the Calibration Sheet and capture image from longer distance.

3. Too dark image

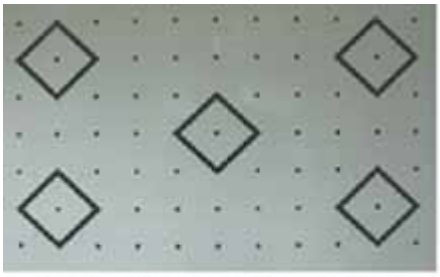
   Take one of following 3 counter measures.

   1) Use contrast adjustment function

   2) Use a flash light

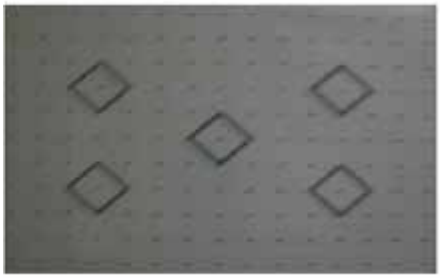
   3) Take slower shuttering speed (use tripod in this case)

3-3.Examples of bad images



Not all dots are in the image

Too small image in the image frame



Unfocussed image

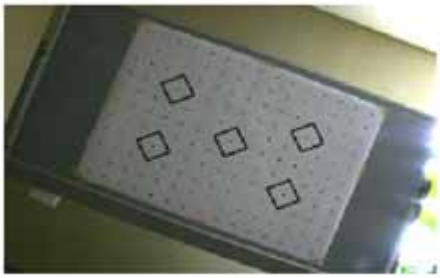


Image is too much inclined

Image is too much bright

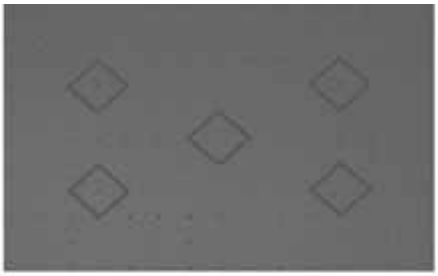
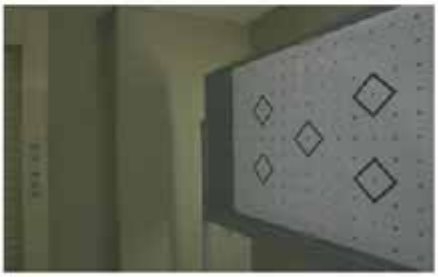


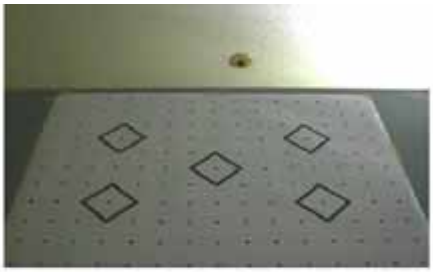
Image is too much dark

The most right raw of dots to be located more right end of image frame



The Center square mark should be at the center of the image frame

The bottom raw of dots to be located more bottom end of image frame



The center square mark should be at the center of the image frame

3-4.In case Judgment is NG

Following situation may cause NG judgment.

1. Detecting the center of dots were not properly performed.

   There are totally 145 dot marks in the Calibration Sheet.

   Detecting the center of each dot on approximately 75% of these 145 points on an image is necessary in order to get the calculation successful.

   Also, failing detection of center on more than 40 dot points totally over 5 images may cause unsuccessful calculation.

   Try to repeat the procedure in 2-3-2 Detecting Center of Standard Marks/Dot Marks

   If still NG judgment is indicated even after repeating the procedure for Detection of center,

   image quality may be insufficient. Please re-start from capturing images.

2. Focal Length information is not available.

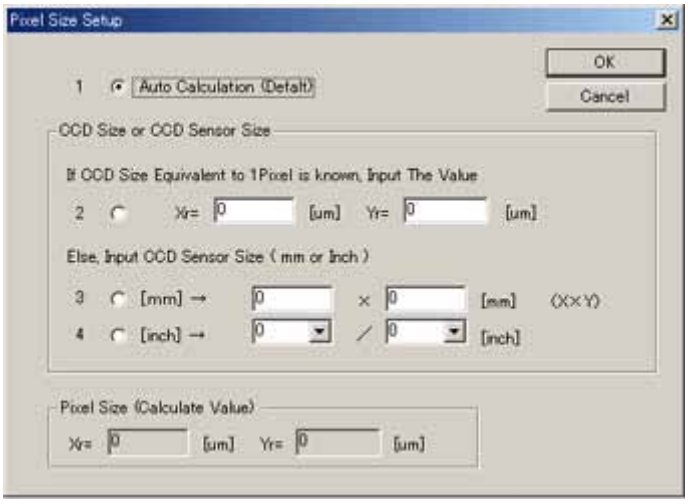
   This software normally detect the used camera"s Focal Length information from Exif file automatically. Some digital cameras on the market are not using the Exif file format.

   In such case an error message is indicated during importing image data and user need to enter manually the focal length of used camera at the time image is taken, through menus, [Setup] - [Focal Length Setup]

3-5.Enter Image Resolution Manually

After importing and registering images in Project is completed (see 2-3-1 Importing Images), select menus, **[Setup] - [Pixel Size Setup]**

Following dialog box will appear.



Select mode how to Image Resolution factor.

1 --- Normally choose by put check at check button of, "1 - Use Image Resolution obtained by automatic measurement"

If "NG" judgment is given for the calibration calculation result, however, entering the image resolution factor manually and performing re-calculation may solve the problem to get the "OK" judgment.

To enter Image Resolution factor manually, choose the way to enter among following 3 ways.

Please refer to the specification in operation manual published by manufacturer of used camera and check which factor is available. of the used digital camera and take the available factors.

2 --- Choose when pixel size of used camera is known. Enter pixel size in Xr and Yr.

3 --- Choose when Image sensor size is known in mm scale. (Enter Horizontal x Vertical size)

4 --- Choose when Image sensor size is known in inch scale. (example: 1/ 1.7 inch)

After selecting and entering the factor, click "OK" button.

The image sensor size may not be described in the user's manual of some digital cameras.

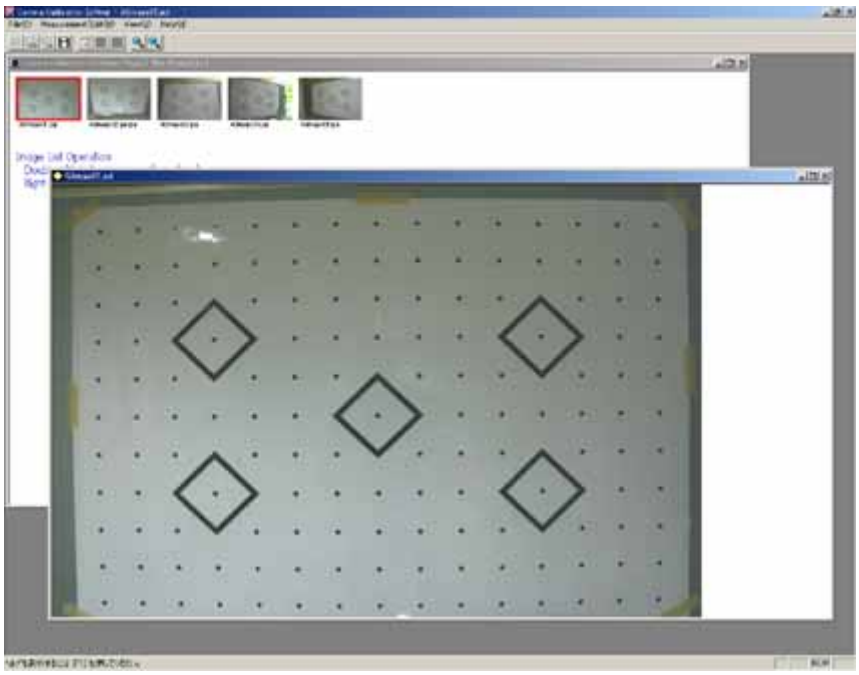
3-6.Image Contrast Adjustment

When the used image is too bright or too dark, the automatic center detection of the dot mark may be not successfully done.

In such case, contrast of the image can be adjusted in the following manner.

1. Select the image to be adjusted and open it.

   Select menus, **[View] - [Contrast Adjustment]**



2. Dialog box "Contrast Adjustment" will appear.

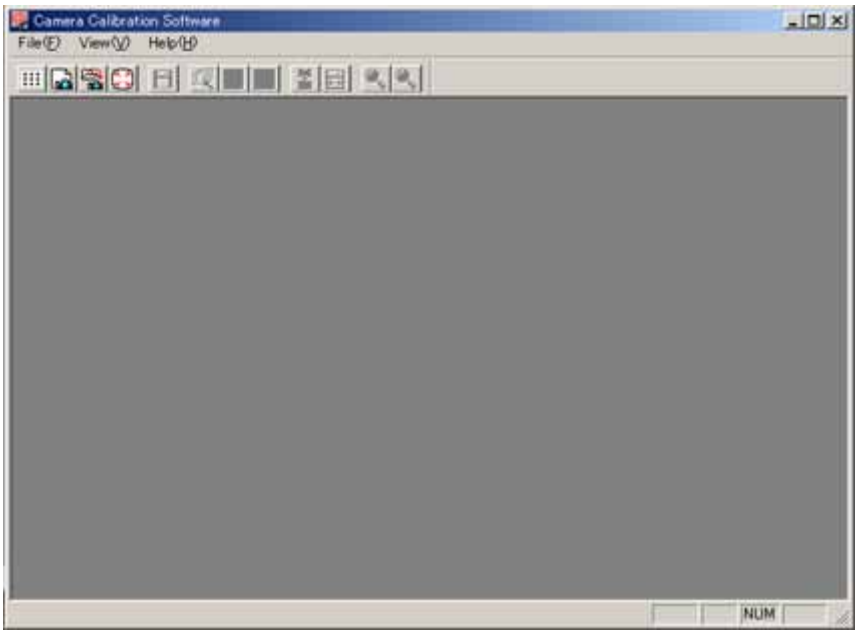
   Adjust contrast level with it"s scroll bar and click "Set" button.

   The contrast will be changed according to the set level.

   Please note that this change of contrast is reflected on the displayed image only and not on the original image, therefore, once the adjusted image is closed and open the original image again the contrast level will be the original one and not the changed one.

3-7 Create image corrected lens distortion

1. By double clicking "PICalib.exe", the application software will start up and the following initial screen will appear.



2. At menu bar, select menus **[File] - [Image Calibration Mode]**. A dialog box "Open" will appear and select image and click "OK".

3. A dialog box "Open" will be displayed again. Select camera file(.cmr) and click "OK". The 7 registered parameters will be shown on the dialog box "Lens Distortion".

4. At menu bar, select menus **[Process] - [Image Calibration]**. Message box "Make Calibrated Image Data" will appear, then click "OK".

5. Image corrected distortion of lenses will be displayed. At menu bar, select menus **[File] - [Save Image Data]**. Dialog box "Save as" will appear and save image if you want to save.

Operation Manual
Camera Calibration Software

PI-Calib

TOPCON POSITIONING SYSTEMS, INC.
7400 National Drive, Livermore, CA 94551, U.S.A.
Phone: 925-245-8300 Fax: 925-245-8599 www.topcon.com

TOPCON CALIFORNIA
3380 Industrial Blvd, Suite 105, West Sacramento, CA 95691, U.S.A.
Phone: 916-374-8575 Fax: 916-374-8329

TOPCON EUROPE POSITIONING B.V.
Essebaan 11, 2908 LJ Capelle a/d Ussel, The Netherlands.
Phone: 010-458-5077 Fax: 010-284-4949 www.topconeurope.com

IRELAND OFFICE
Unit 69 Western Parkway Business Center
Lower Ballymount Road, Dublin 12, Ireland
Phone: 01460-0021 Fax: 01460-0129

TOPCON DEUTSCHLAND G.m.b.H.
Giesserallee 31, 47877 Willich, GERMANY
Phone: 02154-885-100 Fax: 02154-885-111 info@topcon.de
www.topcon.de

TOPCON S.A.R.L.
89, Rue de Paris, 92585 Clichy, Cedex, France.
Phone: 33-1-41069490 Fax: 33-1-47390251 topcon@topcon.fr

TOPCON ESPA,A S.A.
Frederic Mompou 5, ED. Euro 3, 08960, Sant Just Desvern, Barcelona, Spain.
Phone: 93-473-4057 Fax: 93-473-3982 www.topconesp.com

TOPCON SCANDINAVIA A. B.
Neongatan 2 S-43151 Mölndal, SWEDEN
Phone: 031-7109200 Fax: 031-7109249

TOPCON (GREAT BRITAIN)LTD.
Topcon House Kennet Side, Bone Lane, Newbury, Berkshire RG14 5PX U.K.
Phone: 44-1635-551120 Fax: 44-1635-551170
survey.sales@topcon.co.uk laser.sales@topcon.co.uk

TOPCON SOUTH ASIA PTE. LTD.
Blk 192 Pandan Loop, #07-01 Pantech Industrial Complex, Singapore 128381
Phone: 62780222 Fax: 62733540 www.topcon.com.sg

TOPCON AUSTRALIA PTY. LTD.
Unit 18, 4 Avenue of Americas Newington NSW 2127, Australia
Phone: 02-8748-8777 Fax: 02-9647-2926 www.topcon.com.au

TOPCON INSTRUMENTS (THAILAND) CO., LTD.
77/162 Sinn Sathorn Tower, 37th Fl.,
Krungdhonburi Rd., Klongtonsai, Klongsarn, Bangkok 10600 Thailand.
Phone: 02-440-1152~7 Fax: 02-440-1158

TOPCON INSTRUMENTS (MALAYSIA) SDN. BHD.
Excella Business Park Block C, Ground & 1st Floor, Jalan Ampang Putra,
Taman Ampang Hilir, 55100 Kuala Lumpur, MALAYSIA
Phone: 03-42701068 Fax: 03-42704508

TOPCON KOREA CORPORATION
2F Yooseoung Bldg., 1595-3, Seocho-Dong, Seocho-gu, Seoul, 137-876, Korea.
Phone: 82-2-2055-0321 Fax: 82-2-2055-0319 www.topcon.co.kr

TOPCON OPTICAL (H.K.) LIMITED
2-4/F Meeco Industrial Bldg., No. 53-55 Au Pui Wan Street, Fo Tan Road,
Shatin, N.T., Hong Kong
Phone: 2690-1328 Fax: 2690-2221 www.topcon.com.hk

TOPCON CORPORATION BEIJING OFFICE
Building A No.9, Kangding Street
Beijing Economic Technological Development Area, Beijing, China 100176
Phone: 10-6780-2799 Fax: 10-6780-2790

TOPCON CORPORATION BEIRUT OFFICE
P. O. BOX 70-1002 Antelias, BEIRUT-LEBANON.
Phone: 961-4-523525/961-4-523526 Fax: 961-4-521119

TOPCON CORPORATION DUBAI OFFICE
C/O Atlas Medical FZCO., P. O. Box 54304, C-25, Dubai Airport Free Zone,UAE
Phone: 971-4-2995900 Fax: 971-4-2995901

TOPCON CORPORATION
75-1 Hasunuma-cho, Itabashi-ku, Tokyo 174-8580, Japan
Phone: 3-3558-2520 Fax: 3-3960-4214 www.topcon.co.jp

0507(2B)