Camera Calibration Methods Evaluation Procedure for Images Rectification and 3D Reconstruction

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Outline

- Introduction
- Evaluated Camera Calibration methods
- Evaluation Procedure
- Experimental Results
- Conclusions

- **Introduction**
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Introduction

- **Purpose**
  - An accurate and handy camera calibration methods evaluation and comparison procedure.

- **State of the art**
  - Calibration result depends on the calibration method, number of images, pattern and its position in the image(s) [Zollner et al. 2004], [Isern-González et al. 2005].
  - Based on 2D or 3D evaluation pattern accuracy measures.
  - Pattern position must be known [J. Salvi et al. 2002].

Evaluated Camera Calibration methods

- Introduction
- **Evaluated Camera Calibration methods**
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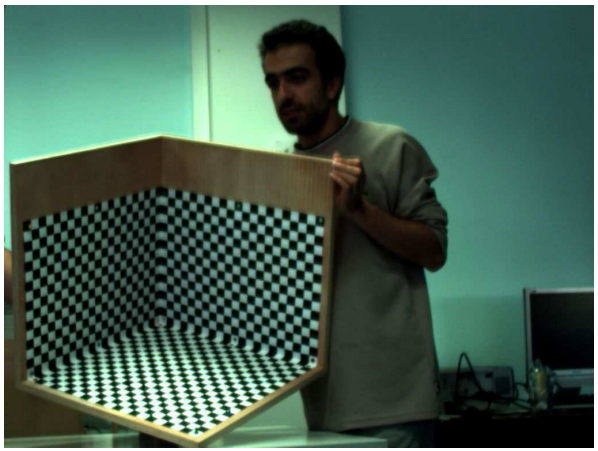
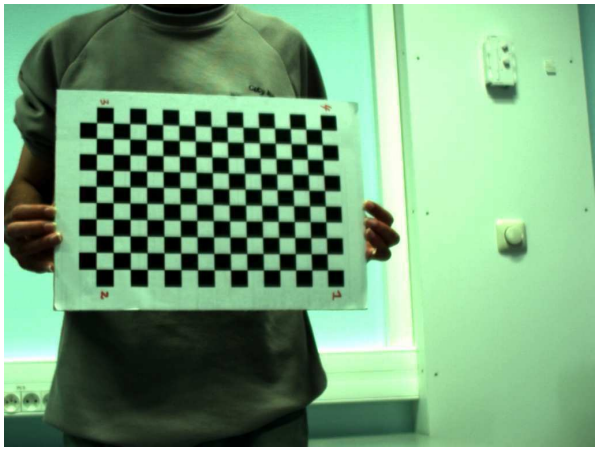
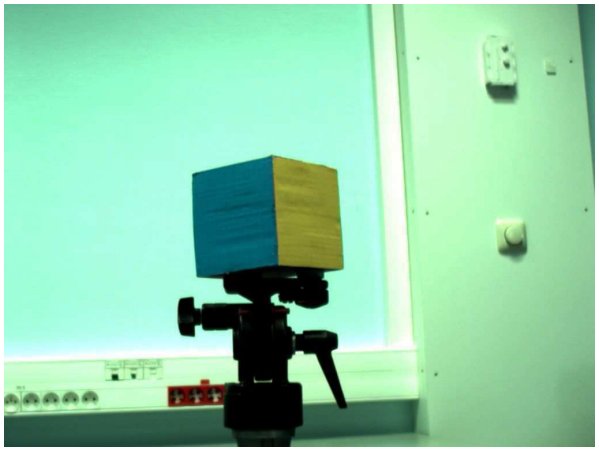
Faugeras-Toscani (1987)	Zhang (2000)	Robust Calibration (2006)
• 3D pattern • Single image • Linear and non linear optimization	• 2D pattern • 2 images at least • Non linear optimization	• 3D pattern • Single or multiple images • Robust optimization
		

Evaluation Procedure Principle

- Introduction
- Evaluated Camera Calibration methods
- **Evaluation Procedure**
- Experimental Results
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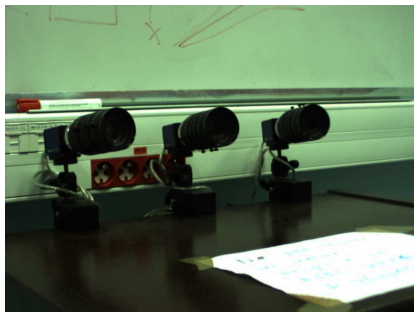
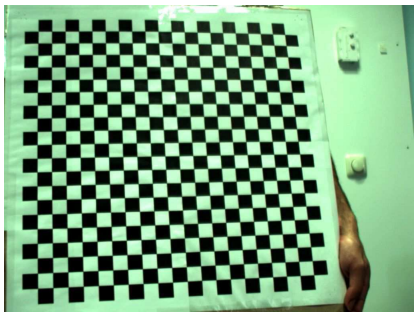
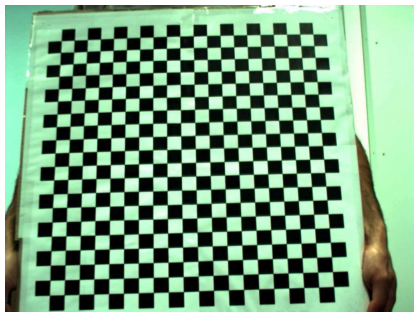
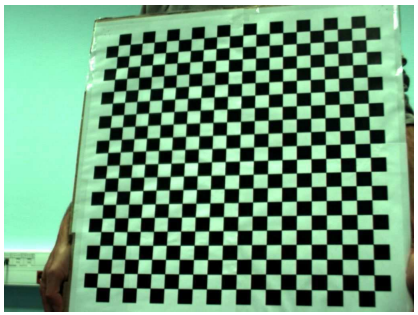
- *Stereo system (2 cameras or more),*
- *Rectification and 3D reconstruction of a set of coplanar points,*
- *Unknown position of the pattern in the world reference space,*
- *The dimensions of the pattern are known.*

			
Stereo system 3 Cameras	Image 1	Image 2	Image 3
	Known size of the black and white squares		

Evaluation Procedure
Rectification

- Introduction
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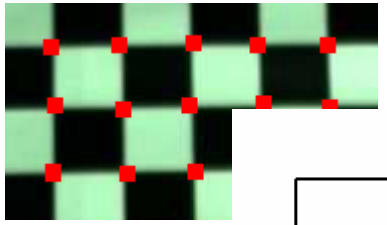
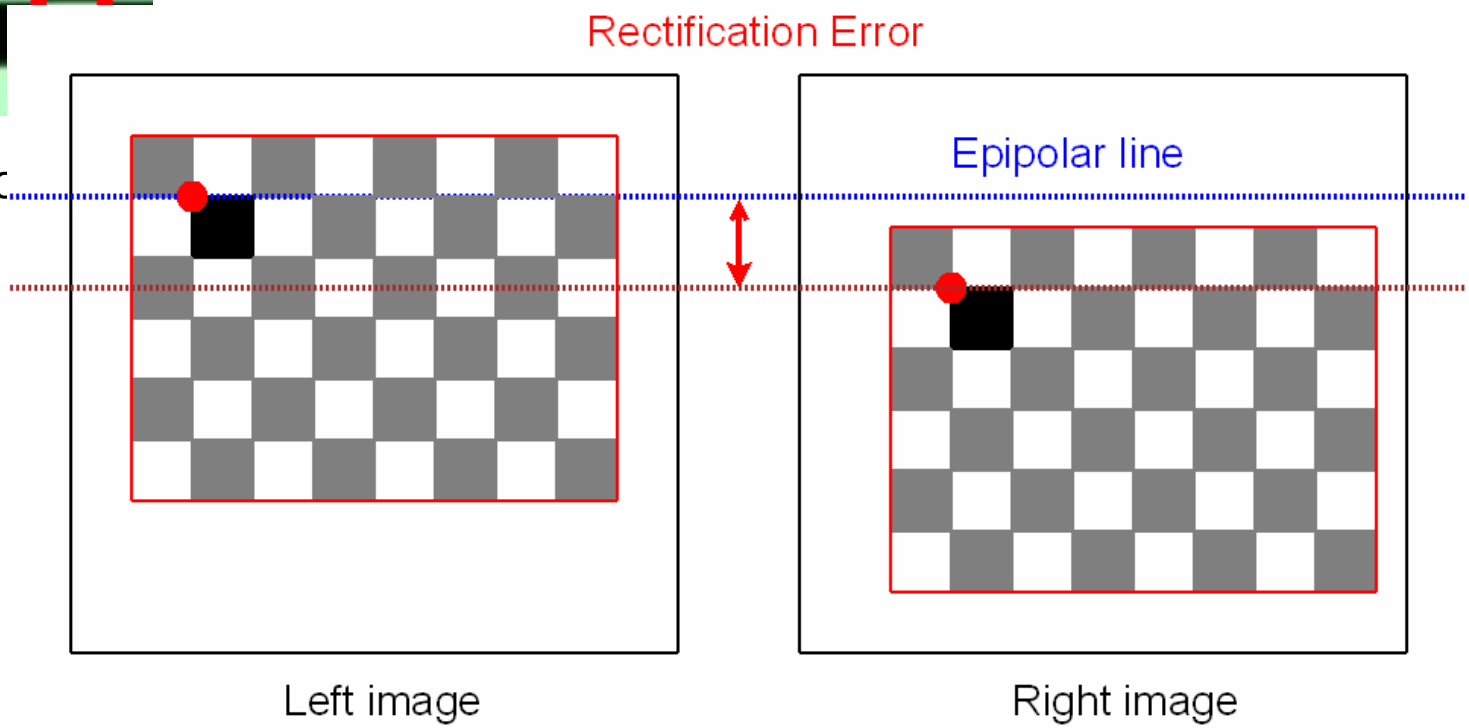
- Rectification of each stereo images of the planar pattern [A. Fusiello *et al. 2000].*



Automatic detectic



Quantification of the rectification errors (all the points, 3 stereo pairs)

Evaluation Procedure
3D reconstruction

- Introduction
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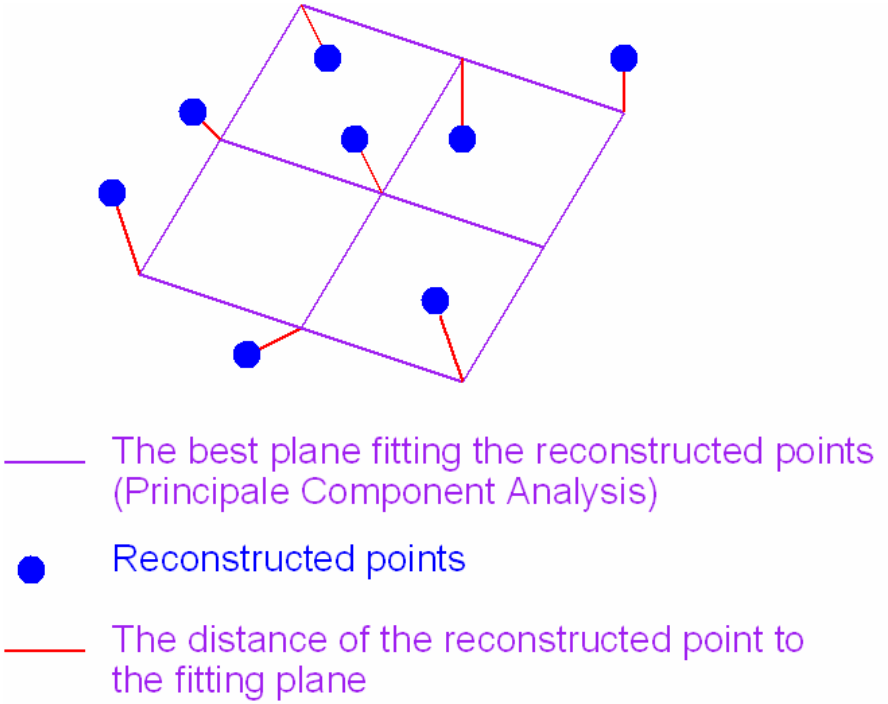
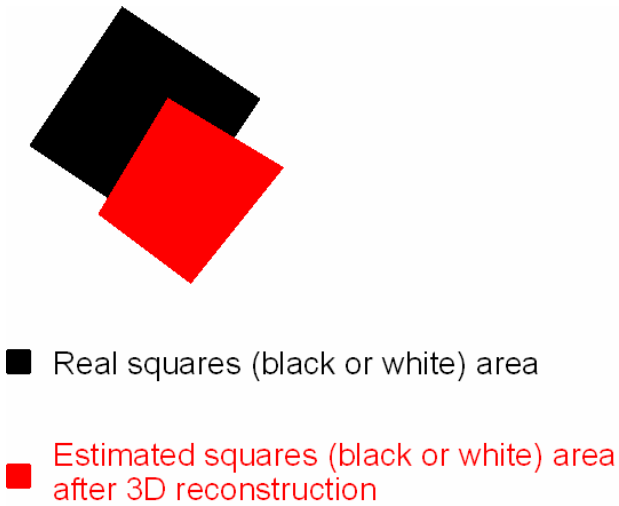
- 3D reconstruction of the points from stereo triangulation



Safeguard of the planarity of the points (**mdp**: **M**ean of the **D**istances of reconstructed points to the **P**lane).



Safeguard of the dimensions of the black and white squares (mds: Mean Difference between real and reconstructed Square).

Experimental results
Rectification errors (1)

- Introduction
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Method	Number of calibration images per camera	Mean error over all the system
Zhang	10 30	**16.71** **5.01**
Faugeras-Toscani	1	**3.74**
Robust calibration	1 9	**2.69** **7.94**

Rectification errors in pixels (image height 768)

Surprising results: multi-images calibration → improve the accuracy of calibration → reduce the rectification errors

Errors remain high (Zhang Method)

Unexpected results appear in the case of multi-images calibration

Experimental results
Rectification errors (2)

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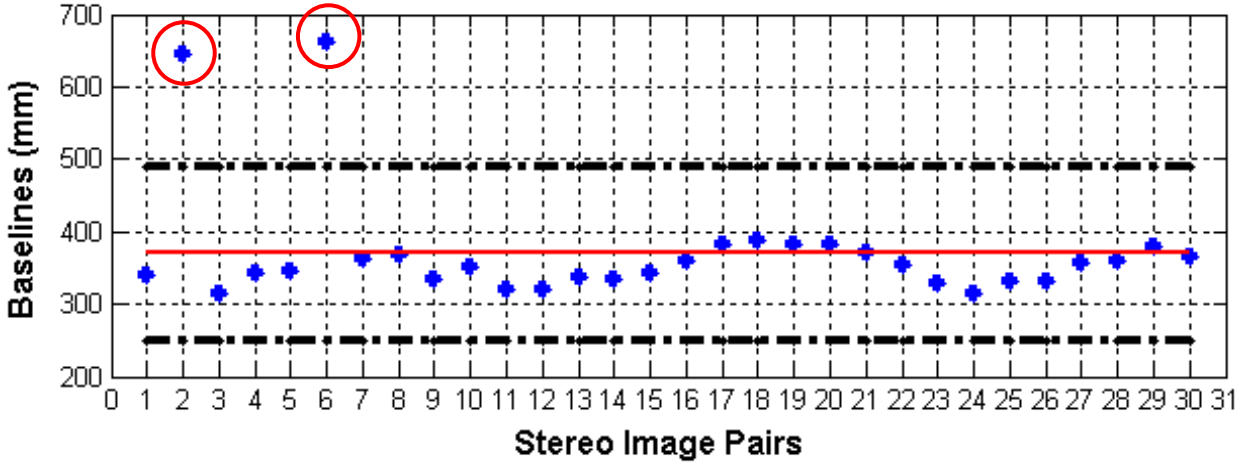
Explication: aberrant images for which the estimation of the projection matrices failed.

How to find and remove those images:

1- Compute the baseline for all the calibration image pairs.

2- Detect outlier values of the baseline estimates



- *Plot of the baseline $B_{1,2}$*
- *Zhang method*
- *30 image*
- *points: baseline values;*
- *continuous line: the baseline mean*
- ***discontinuous lines**: mean ±1.5 standard deviation*
- *2 outlier values pairs 2 and 6.*

Experimental results
Rectification errors (3)

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3- Suppression of the corresponding calibration image pairs
4- Recalibrate the cameras
5- Repeat the steps 1,2,3,4 until no image pair is removed

Method	Number of calibration images per camera Before --- After	Mean error over all the system **Before Aberrant Images Removal**	Mean error over all the system **After Aberrant Images removal**
Zhang	10 10 30 28	**16.71** **5.01**	**2.88** **2.54**
Faugeras-Toscani	1 1	**3.74**	**3.74**
Robust calibration	1 1 9 7	**2.69** **7.94**	**2.69** **2.48**

Rectification errors in pixels (image height 768)

- Low rectification errors. Zhang and Robust methods are more accurate.

Experimental results
3D reconstruction errors

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Methods	Faugeras-Toscani	Zhang	Robust calibration
mdp: Safeguard of the planarity of the points (mm)	**2.96**	**2.39**	**2.49**
mds: Safeguard of the dimensions of the black and white squares ($mm^{2)}$	**28.94**	**21.18**	**21.26**

mdp : similar accuracy of the three methods

mds : Zhang and robust methods are more accurate

Conclusions

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- Accurate and handy criterion to compare and evaluate camera calibration methods
- Useful for other methods, distortions estimation can be introduced.
- An accurate procedure to remove outlier images in the case of multi-images calibration

Thank you for listening

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