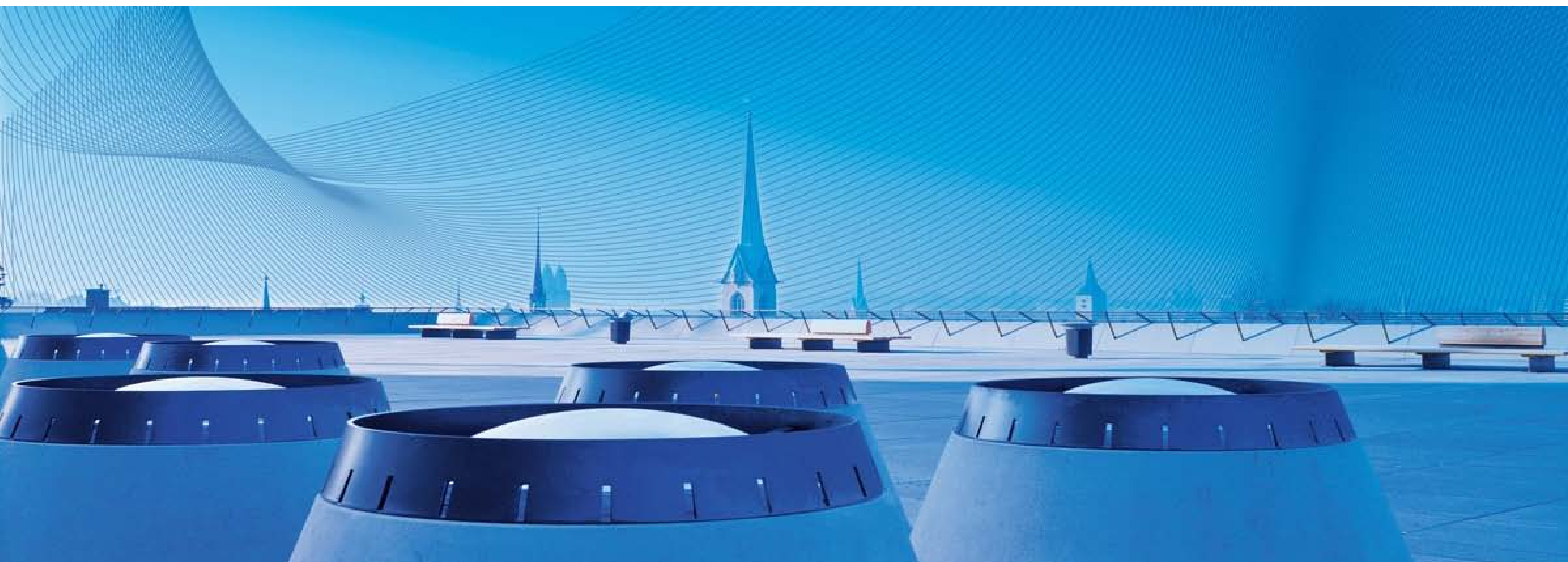
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

DBAUG
Department of Civil,
Environmental and
Geomatic Engineering

DEVELOPMENT OF A NEW LASER-BASED, OPTICAL INDOOR POSITIONING SYSTEM

S. Tilch & R. Mautz

Institute of Geodesy and Photogrammetry, ETH Zurich



Outline

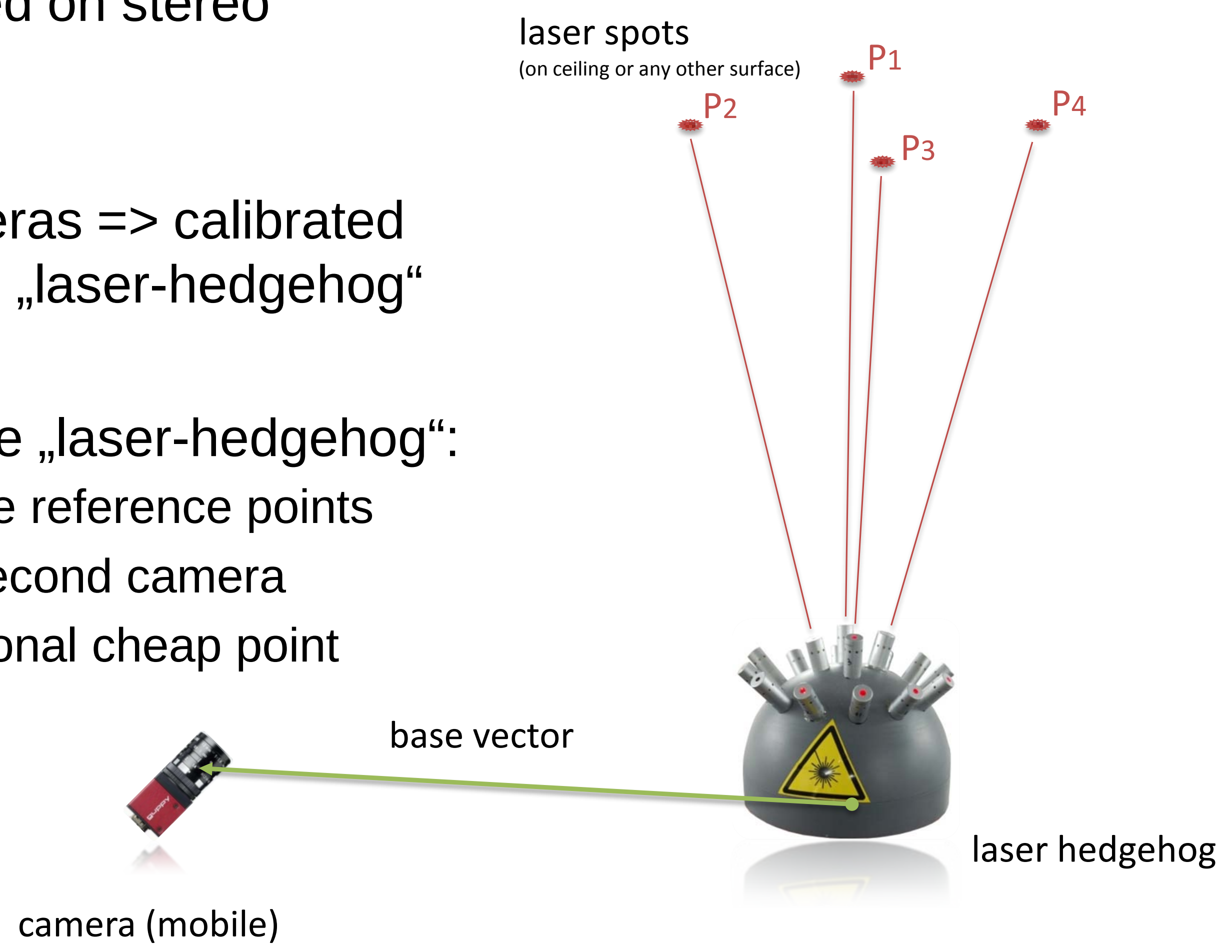
- Introduction
- Architecture
- Challenges
- Relative Camera Orientation
- Assessment of the Prototype
- Conclusion and Outlook

Introduction

- Optical indoor positioning system
- CLIPS – Camera and Laser-based Indoor Positioning System
- Objectives:
  - No need for a deployed reference field
  - Inexpensive
  - Automatic precise pose estimation (continuous sub-mm) of a mobile camera
  - Realtime

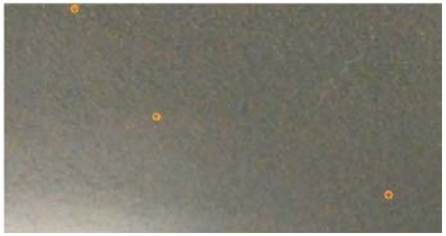
Architecture of CLIPS

- Central idea is based on stereo photogrammetry
- Instead of two cameras => calibrated camera + calibrated „laser-hedgehog“
- Main functions of the „laser-hedgehog“:
  - Projection of flexible reference points
  - Simulation of the second camera
  - Use of a computational cheap point detection

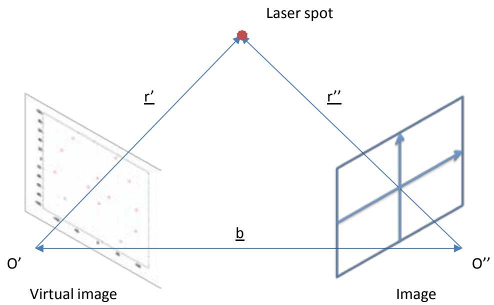


Challenges of CLIPS

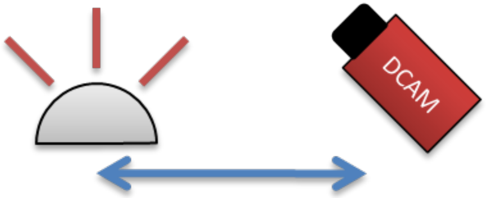
- Point detection and identification



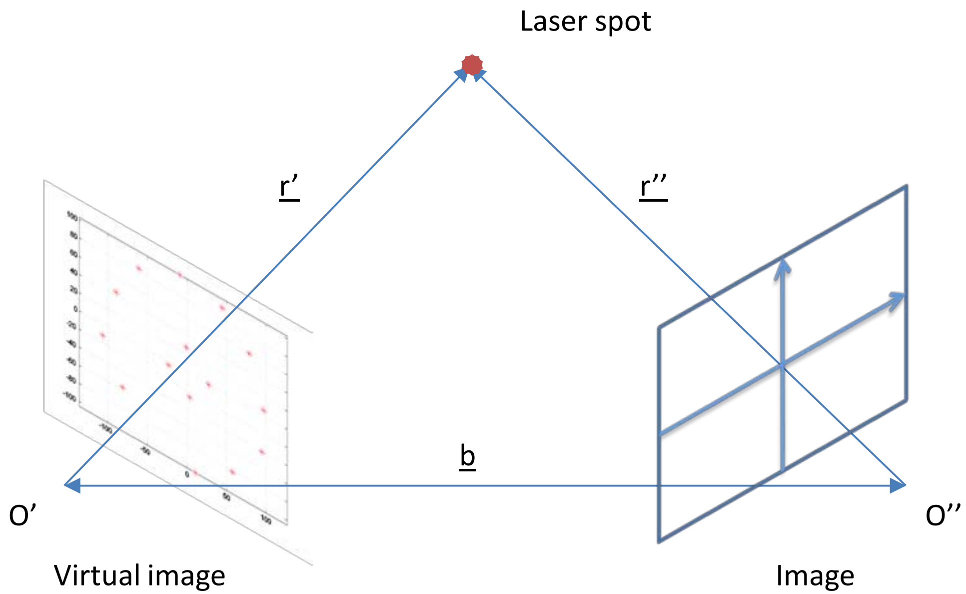
- Determination of the camera's relative orientation



- Introduction of the system scale



Relative Camera Orientation



Goal:

Determination of translation and rotation of the camera with respect to the laser-hedgehog

6 parameters of the exterior orientation

base vector b: bx, by, bz

rotation of camera: ω, φ, κ

Relative Camera Orientation

- **Criteria for the algorithm**
  - Must perform without approximate values
  - Correct, unique and robust determination of the relative orientation
  - Minimum number of corresponding points
  - No restrictions to the geometry

Relative Camera Orientation

- **5-Point Algorithm by Stewenius and Nister**
  - Requires five corresponding points
  - Requires the interior orientation of the camera
  - Yields the camera pose in form of the essential matrix E

$$E = R'^{T} \; B \; R''$$

  - Direct solution by solving Gröbner bases
  - Up to ten solutions => Embedding in a RANSAC Framework

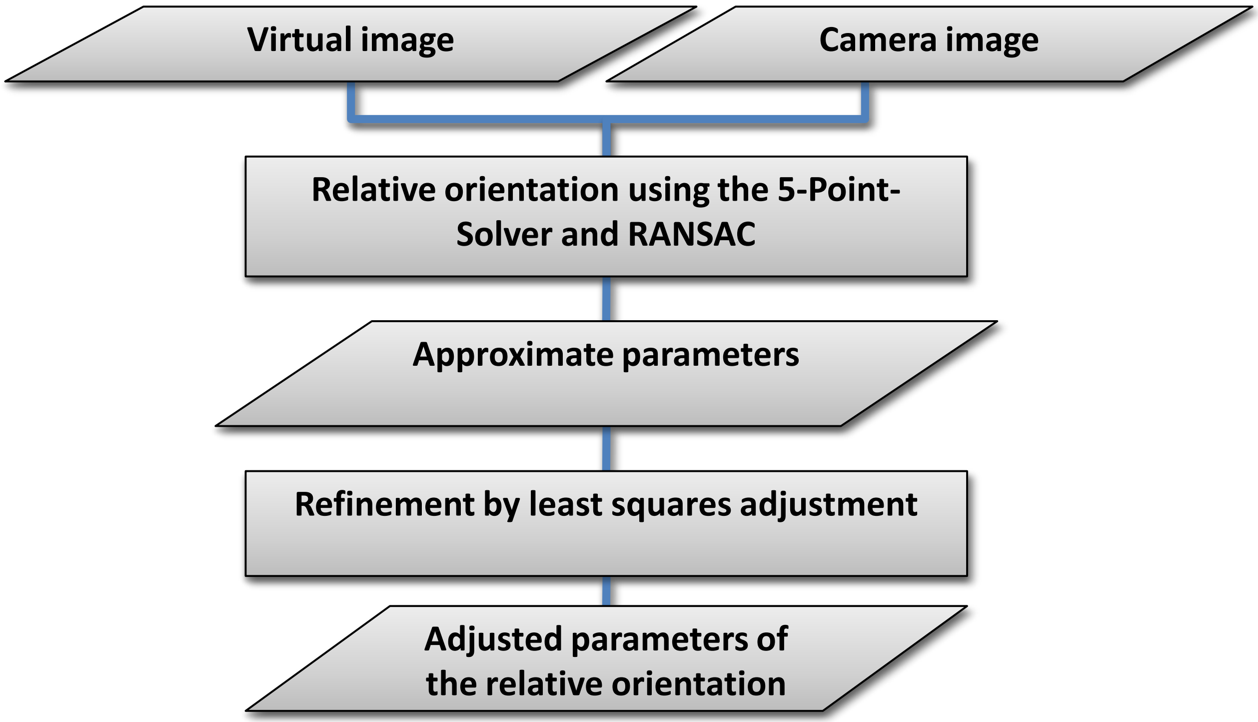
Relative Camera Orientation

- **Least-Squares adjustment exploiting the coplanarity constraint**
  - Observation equations are based on the coplanarity constraint

$$\Delta = \underline{r}'^{T}(\underline{b} \times \underline{r}'') = \begin{vmatrix} 1 & x' & r_x'' \\ b_y^* & y' & r_y'' \\ b_z^* & z' & r_z'' \end{vmatrix} = 0$$

  - Requires at least five corresponding points
  - Requires good initial approximate values for the base vector **b** and the rotation matrix **R**
  - Iteration until improvement is insignificant

Relative Camera Orientation



Assessment of the Prototype

- Determination of the 3D laser spot coordinates via a totalstation and CLIPS

- **Accuracy:** Comparision of both point clouds via similarity transformation

Measure	Value
scale m	0.9981
Standard deviation σ_0 [mm]	0.6

- **Precision:** Repetitive CLIPS measurements for each camera position

σ_x [mm]	σ_y [mm]	σ_z [mm]
0.16	0.16	0.35

Conclusion and Outlook

Conclusions

- The relative orientation of the camera could be determined
- Potential to achieve a positioning accuracy in the magnitude of millimetres and better
- The system is not completely operational yet

Outlook

- Increasing the number of projected laser points
- Improvement of laser point detection and identification
- Find a practicable solution for the determination of the system scale

Thank you for your attention!