Online geocoding and evaluation of large scale imagery without GPS

Wolfgang Förstner, Richard Steffen
Department of Photogrammetry
Institute for Geodesy and Geoinformation
University of Bonn
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Motivation

- **Cooperation with company:**
  Photogrammetric analysis of image sequences
  – Driver assistance (observation of traffic)
  – Monitoring the car interior (airbag)
  →
  – Investigation into configurations
  – Development of real time solutions

- **IGI at Photogrammetric Week 2005**
  – Demo of drone from Microdrones

- **Interest in simultaneous localisation and mapping (SLAM) = Photogrammetry**

Drone MD 4-200 from Microdrones ©

Video camera:
Panasonic Lumix
848 x 480 pel
→ *video*

Thanks to Prof. A. Grimm

Goal

Provide tools
- Georeferencing
- 3D-mensuration
- 3D-object description

for everybody (non-specialists)
- Geoscience
- Agriculture
- Police
- Architecture
- Archeology
- ...

Motivation (4/4)

- **small photogrammetric projects (<< 1 qkm)**
  - Single buildings
  - Archeological sites
- **flying on demand**
  - Traffic accidents
  - Rural area after thunderstorm
- **light and cheap platform**
  - No aeroplane
  - No helicopter
- **navigation by user**

... historical examples

Figure 7. Nadar obtaining photography from a balloon.

1893: the first U.S. patent for aerial photography was issued to Cornele B. Adams of Augusta, Ga. (No. 510,758)

1906: Earthquake, San Fransisco, 18. 4. 1906 from kite

... today

Topic of presentation

- **Large scale imagery:**
  Low altitude: (< 300 m h_g)
- **Online:**
  In time, up to real time (30 Hz)
- **Geocoding:**
  Absolute referencing
- **Evaluation**
  Mensuration, 3D-reconstruction

- **Why without GPS/INS?**
  may be not available
  GPS: down town, indoor
  INS: cost

Outline

1. **Georeferencing of imagery**

2. **Evaluation of imagery**

Context:

no external sensor

large scale imagery

small footprint (< 100 x 100 m^2)

arbitrary orientation (ω, ϕ, κ)

Georeferencing

Only supporting automatic procedures

- **Control points**

  Image patches (e. g. Rauhala 1995)

  – need to be similar (correlation, mutual information)

  – simple test with Google images *failed*

- **Control features**

  lines, regions, ...

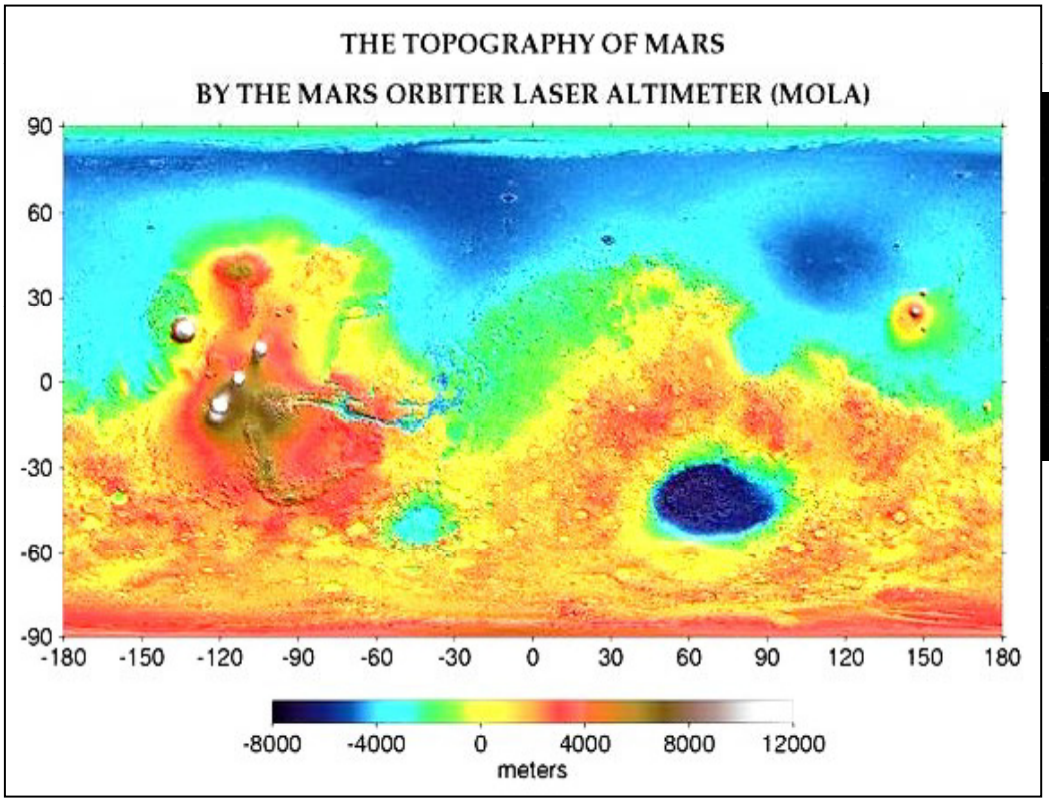
same problems to be expected

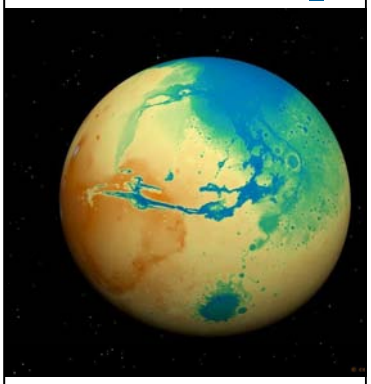
→Digital surface model

(Strunz/Ebner 1988)

Cf. Matching of LIDAR-strips (Pfeiffer)

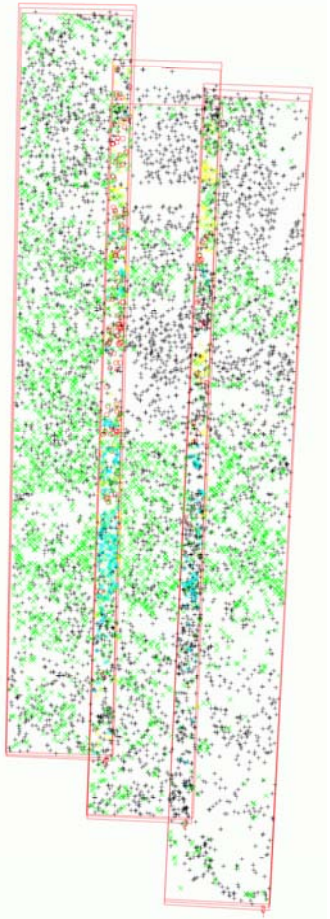
DSM as Control: MGS-MOLA DTM (1998)

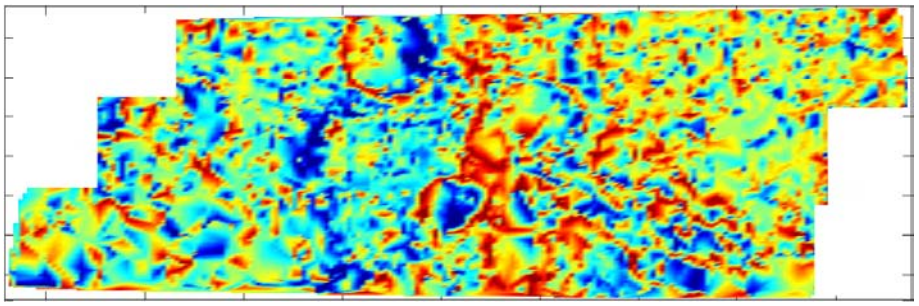




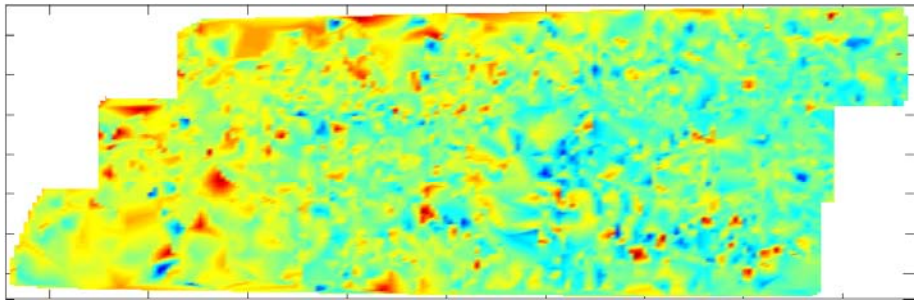
C. Heipke

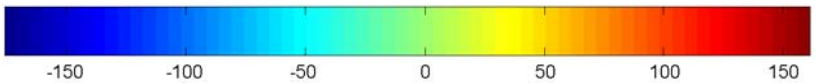
Block - orbits 266, 279, 292





Height differences to MOLA-DTM before and after processing

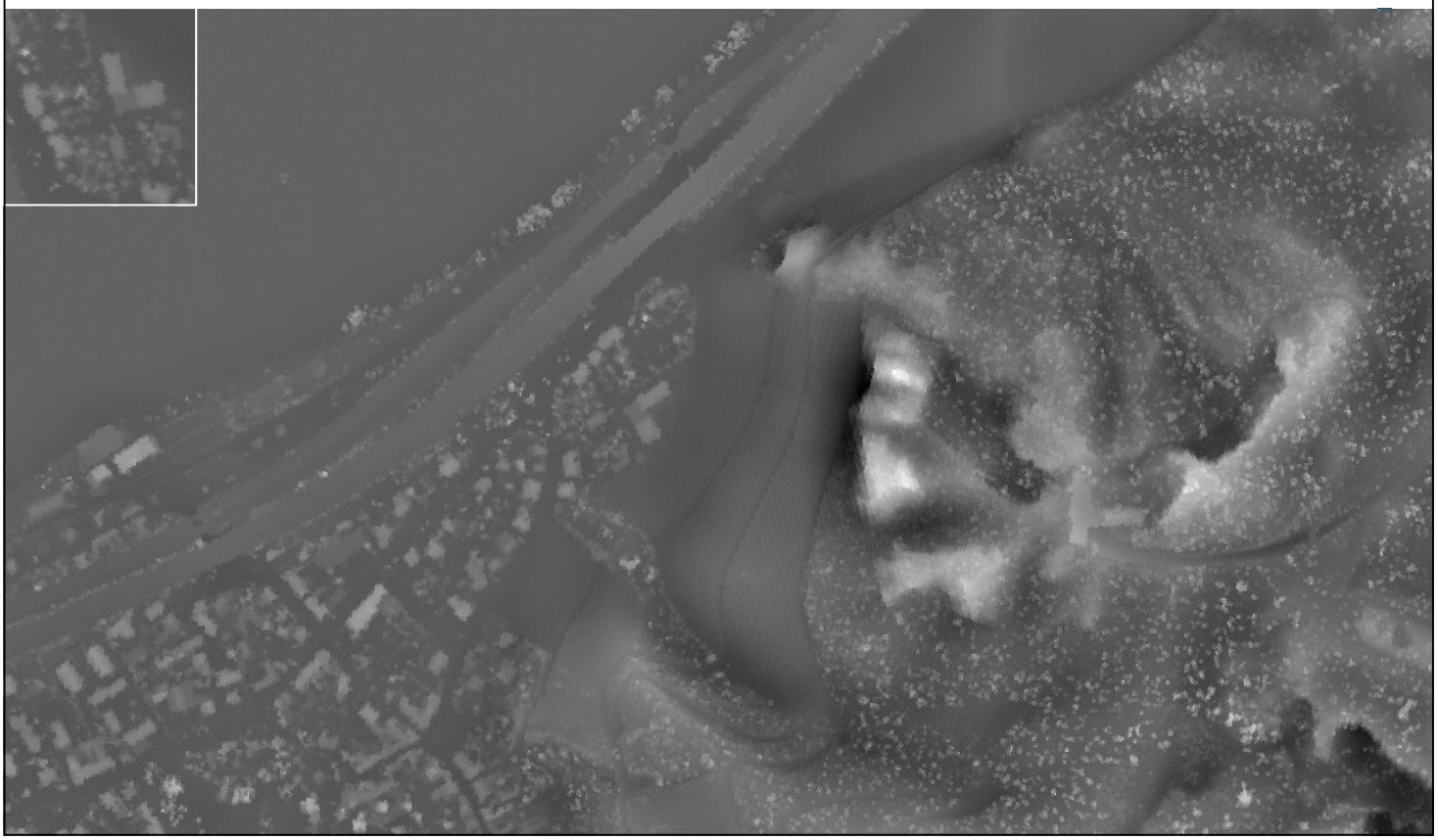




C. Heipke

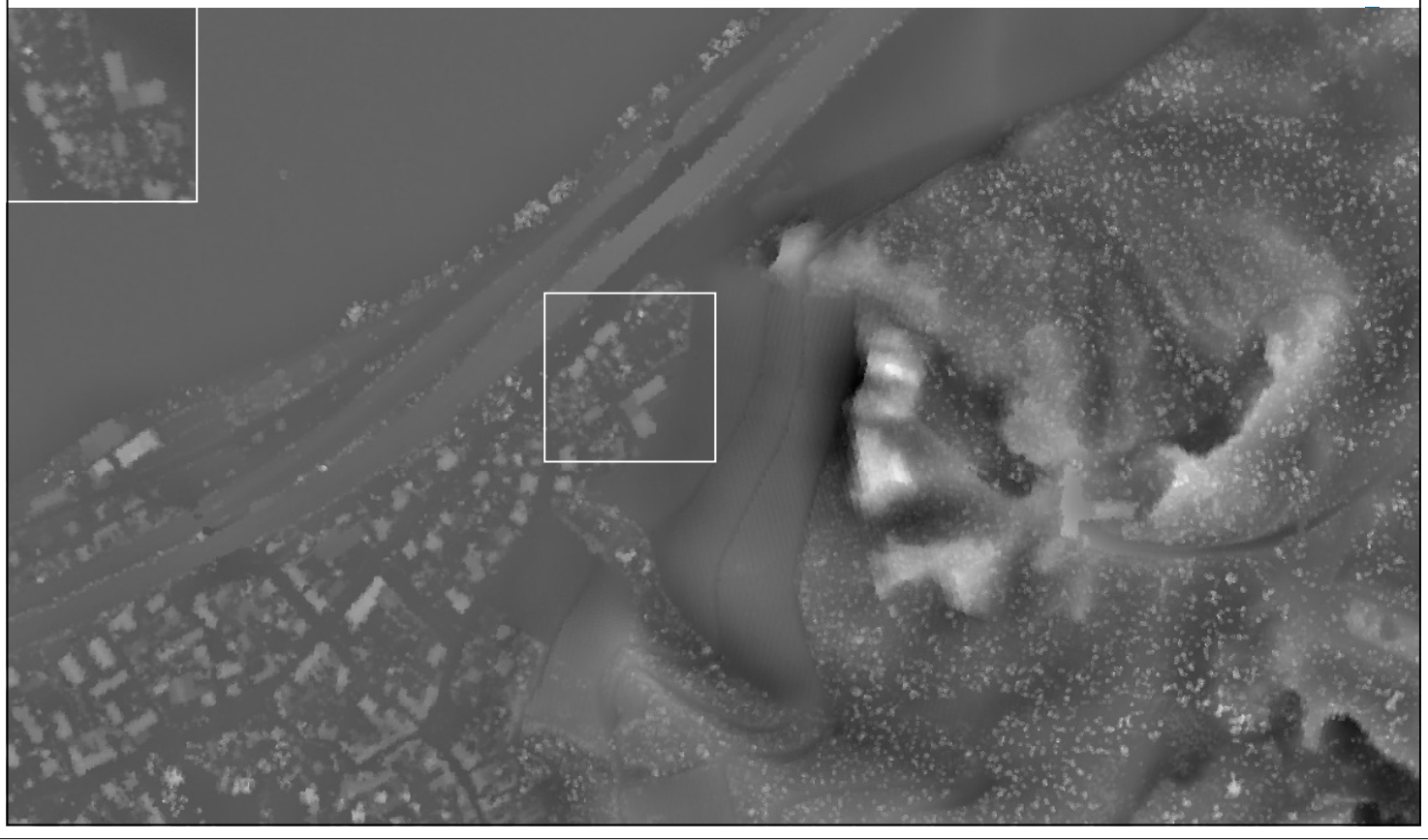
Matching with Lowe-Features of DSM

Drachenfels LIDAR-DSM with sub-patch



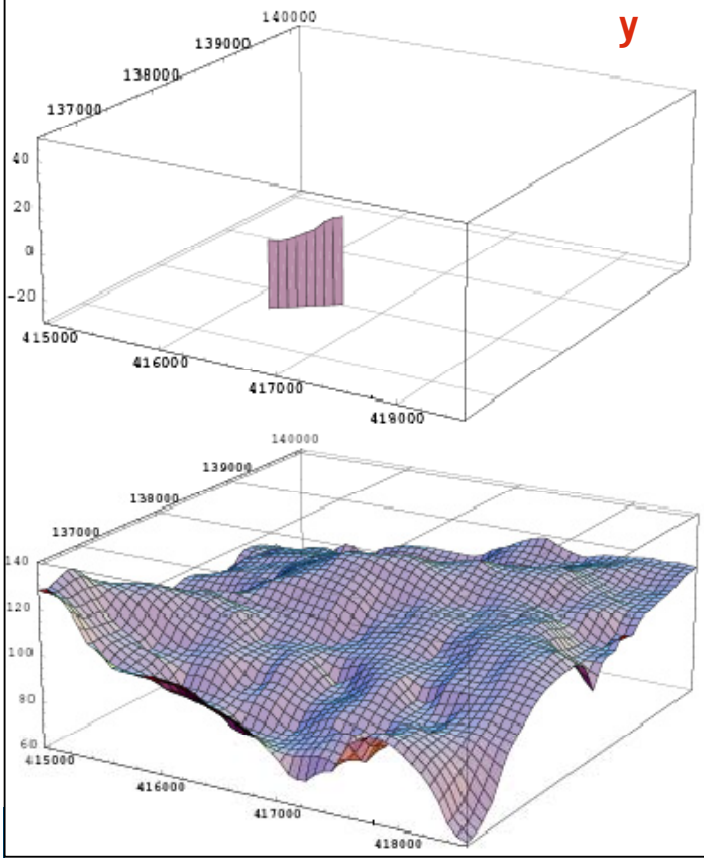
Matching with Lowe-Features of DSM

per image patch: 15 matched points

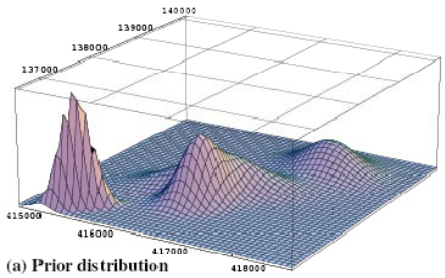


On-Line use of DSM for improving INS

Runnals/Grooves 2005

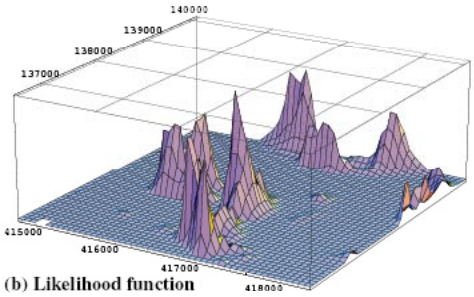


p(x)



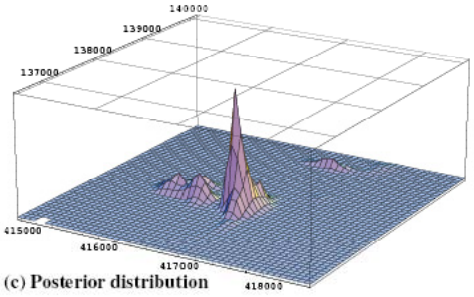
(a) Prior distribution

p(y | x)



(b) Likelihood function

p(x | y)



(c) Posterior distribution

15

PS?

Evaluation

1. Orientation

- Video-sequence → Kalman filter
- Key-frames (1/10) → bundle adjustment

2. Surface reconstruction

→ **Videos 1 and 2**

Flying height: appr. 30 m

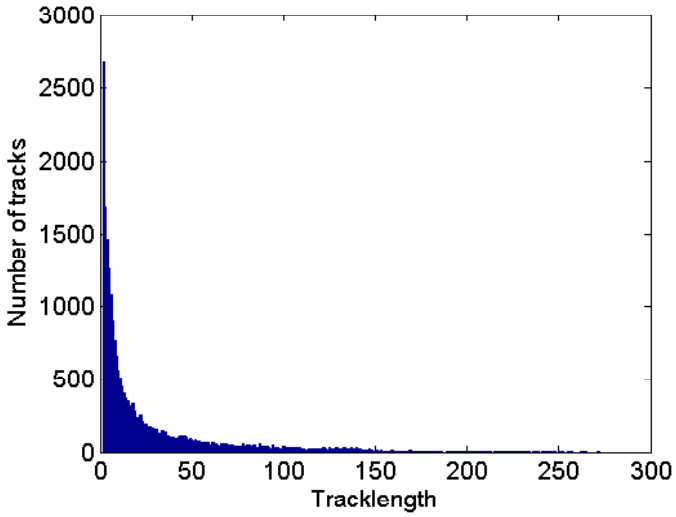
848 x 480 pel

16

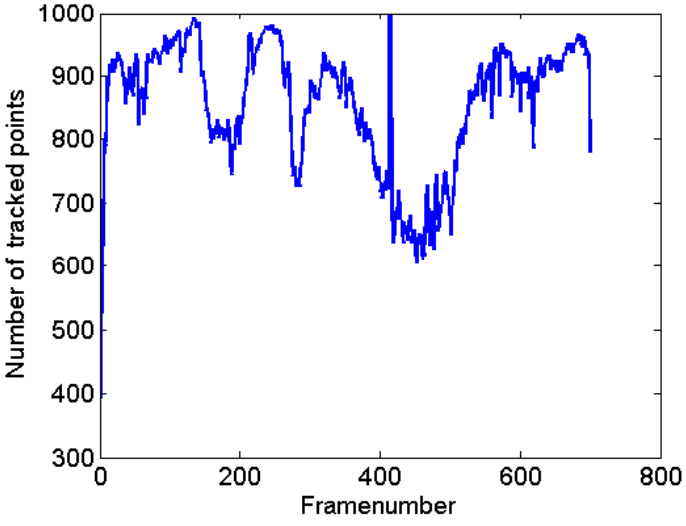
First-, middle- and last image

Tracks

track / tracklength



of tracks per image



Automatic bundle adjustment

(Förstner/Läbe 2005)

- **Fully automatic**
- **Lowe features**
- **Relative orientation of pairs and triplets**
- **Blunder detection**
- **Free block adjustment**

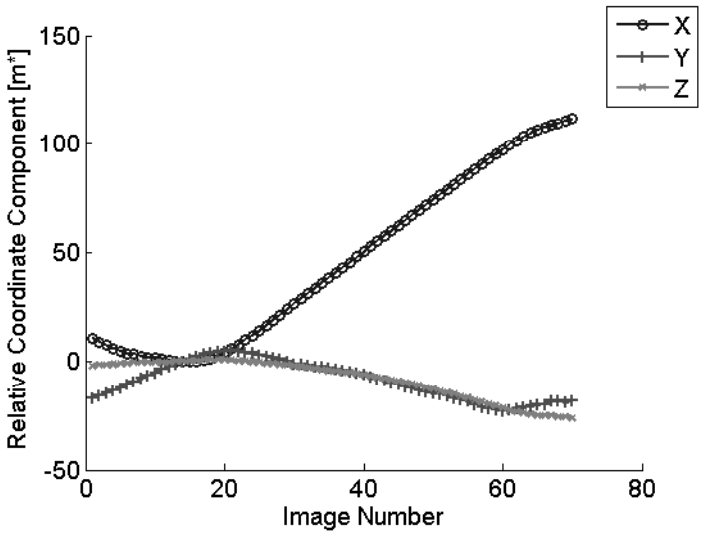
Kalman Filter

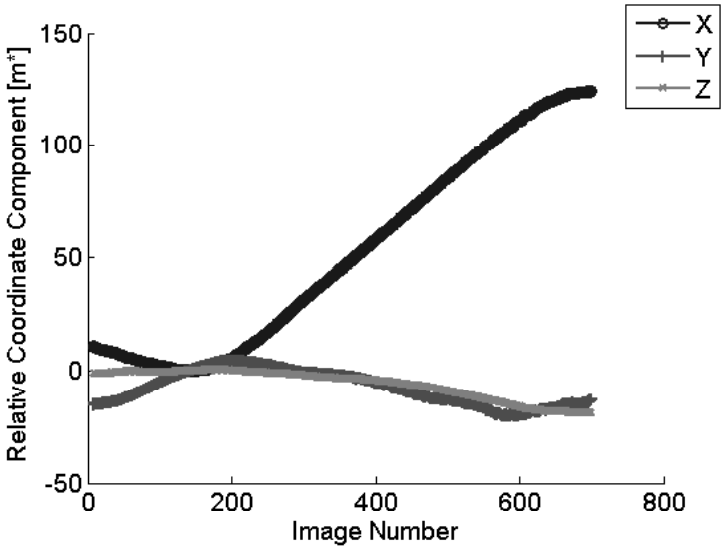
- **system model, state vector ca. 3000 elements**
  - constant translation and rotation velocity
    13 parameters for orientation and its velocity
    $(X_0, \mathbf{q}, v, \omega)$
  - Up to 1000 static 3D-points (inverse depth)
    $(X, Y, 1/Z)$

- **observation model**
  Collinearity constraint (Gauß-Helmert-Model)
  $x' Z^* - c X^* = 0 \qquad y' Z^* - c Y^* = 0$
  Accuracy: $\sigma_x = 0.5$ pel

Orientation (1/2)

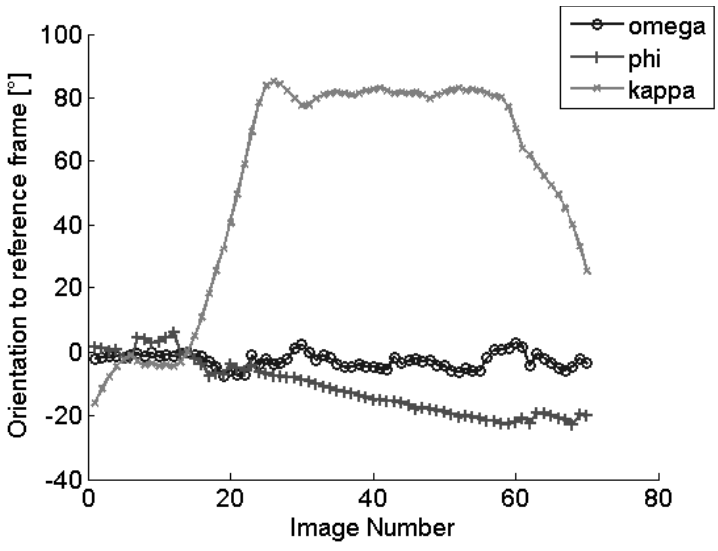
Position: Bundle adjustment ← → Kalmanfilter

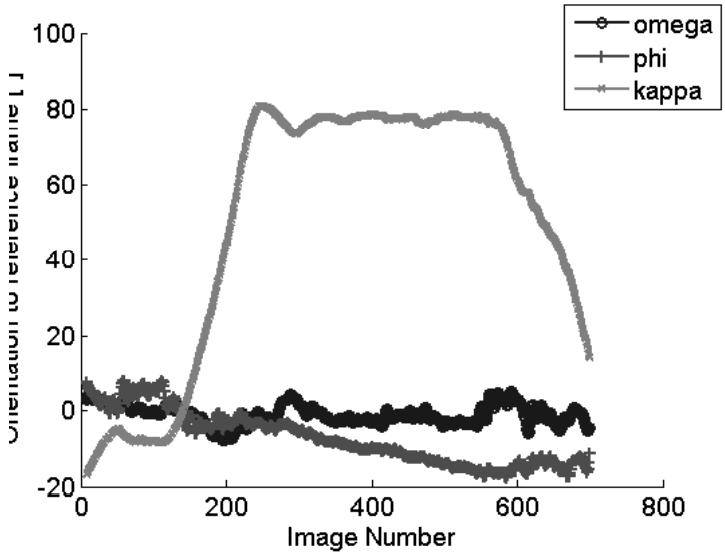




Orientation (2/2)

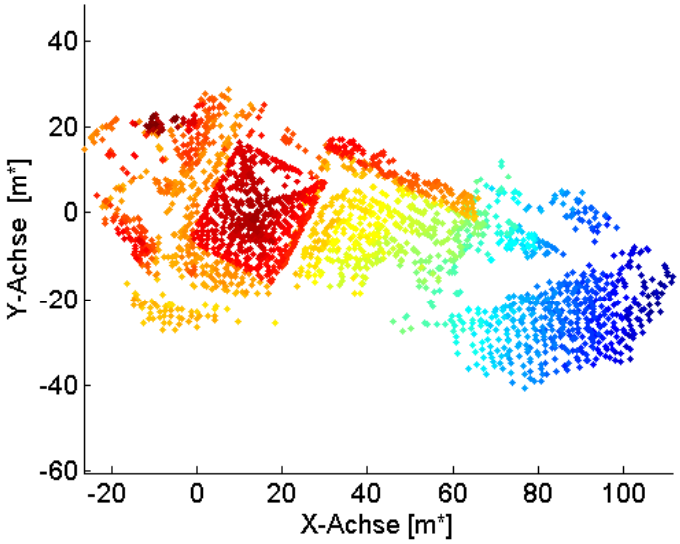
Rotation: bundle adjustment ← → Kalman filter



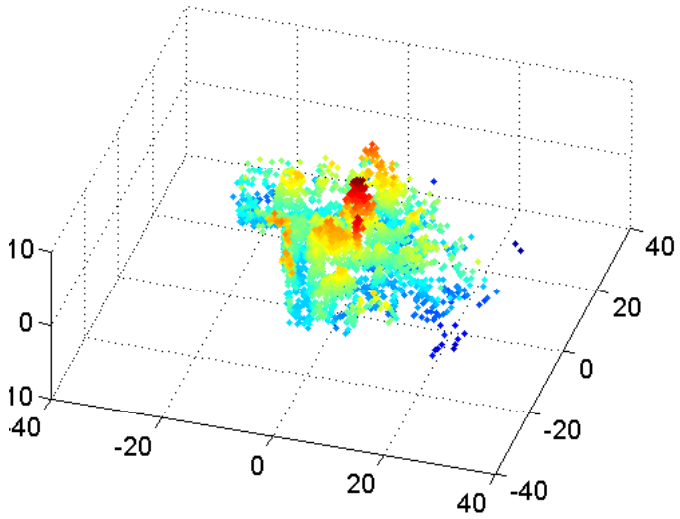


Point clouds from BA

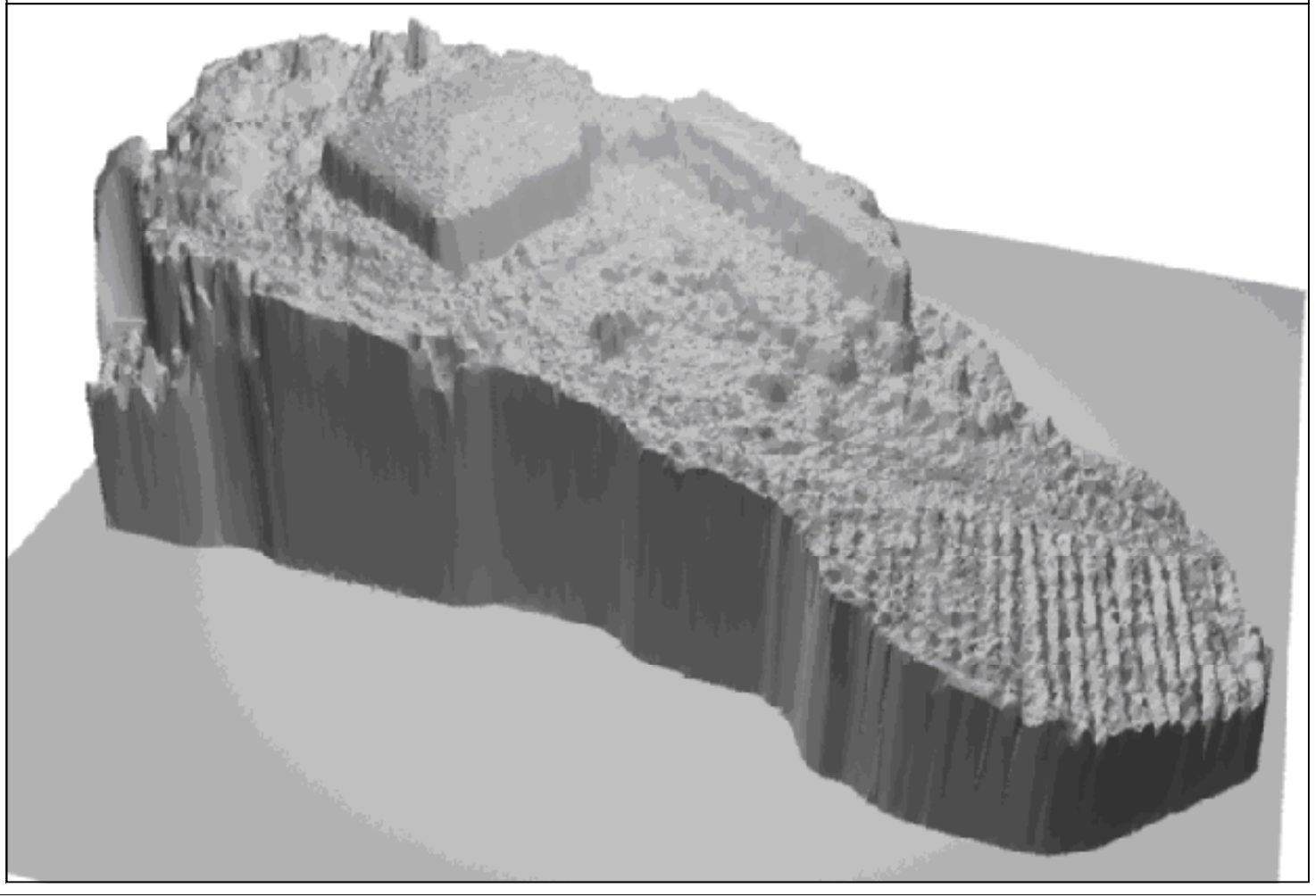
video 1



video 2

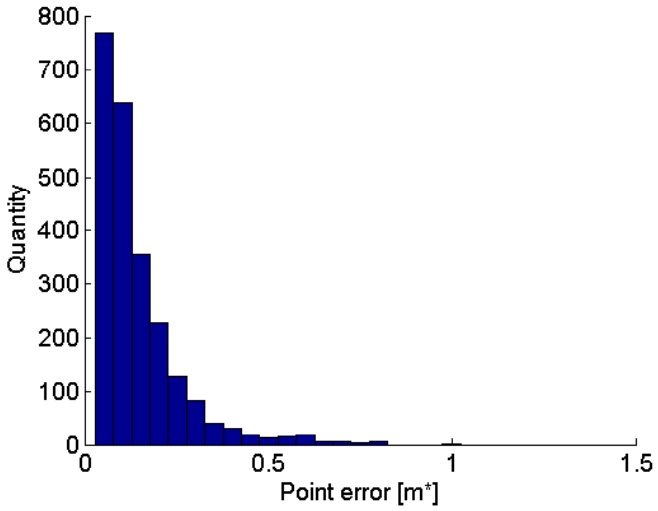


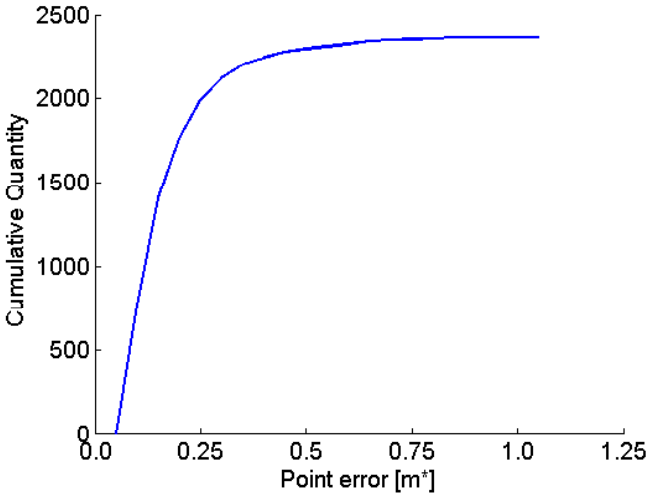
Point cloud from Match-T



Theoretical accuracy after BA

68 % point errors < 18 cm





First controlled test: Rheinaue Bonn

(Zug 2007)

- flying height 20 m
- 1 strip, 12 images
- pre-calibration (< 4 pel correction)
- 34 check points (total station, 2 cm)
- 5 cm GSD

- bundle adjustment
- expected σ_Z = 5 cm

→ rmse(xy) = 3 cm, rmse(z) = 7 cm

CPU-time

- **First own implementation in C++: 5 Hz**
  Including up to 1000 points in state vector
- **Implementation of Schlaile et al. 2006: 28 Hz**
  Reduced number of points (ca. 50)

Conclusions (1/2)

- **Georefenrencing**
  - Use GPS if available
  - If GPS is not available and terrain not flat, use DSM
  - Use INS if available
  - If INS not available, use image sequence (if textured)

Conclusions (2/2)

- **Real-time**
  - RT AT feasible
  - Exploitation of GHM in KF
  - RT DSM (rough) feasible (byproduct of KF)
  - RT orthophoto feasible
  - RT orthophoto (full resolution) in near future

- **Open**
  - Robustify algorithms
  - INS ←→ image sequence
  - Image sequences ←→ HR key frames
  - Tackle truly 3D-point cloud → visualization