Online geocoding and evaluation of large scale imagery without GPS

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

Thanks to Prof. A. Grimm

Online geocoding and evaluation without GPS?

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

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

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Outline

1. Georeferencing of imagery
2. Evaluation of imagery

Context:
- no external sensor
- large scale imagery
  - small footprint (< 100 x 100 m²)
  - 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)

THE TOPOGRAPHY OF MARS
BY THE MARS ORBITER LASER ALTIMETER (MOLA)

Block - orbits 266, 279, 292

Height differences to MOLA-DTM before and after processing
Drachenfels LIDAR-DSM with sub-patch

per image patch: 15 matched points
On-Line use of DSM for improving INS

Runnals/Grooves 2005

\[ p(x|y) \]

Evaluation

1. Orientation
   - Video-sequence \( \rightarrow \) Kalman filter
   - Key-frames (1/10) \( \rightarrow \) bundle adjustment

2. Surface reconstruction

\( \rightarrow \) Videos 1 and 2

Flying height: appr. 30 m
848 x 480 pel
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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
    \((X_0, q, v, \omega)\)
  - Up to 1000 static 3D-points (inverse depth)
    \((X, Y, 1/Z)\)

- observation model
  Collinearity constraint (Gauß-Helmert-Model)
  \(x'Z^* - cX^* = 0\) \quad \(y'Z^* - cY^* = 0\)
  Accuracy: \(\sigma_x = 0.5\) pel
Orientation (1/2)

Position: Bundle adjustment $\leftrightarrow$ Kalman filter

Orientation (2/2)

Rotation: bundle adjustment $\leftrightarrow$ Kalman filter

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Point clouds from BA

video 1

video 2

Point cloud from Match-T

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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 $\sigma_Z = 5$ cm

$\Rightarrow \text{rmse}(xy) = 3$ cm, $\text{rmse}(z) = 7$ 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)

- **Georeferencing**
  - 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

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