University of Stuttgart
Institute of Engineering Geodesy (IIGS)

Image-based Target Detection and Tracking Using Image-assisted Robotic Total Stations

Volker Schwieger, Otto Lerke, Gabriel Kerekes

Institut für Ingenieurgeodäsie

Motivation

- Total station / tachymeter is a standard instrument in geodesy
- Robotic total stations are used for target recognition and tracking
  requirement: reflector mounted on the object
- Installation of reflector time-consuming or impossible!

- New instrument class

  Image-assisted Robotic Total Station (IATS) / Videotachymeter

- New Possibilities:
  - target recognition and
  - target tracking without reflector, based on camera images

Structure

Basics

- Image Processing for Feature Extraction
- Object Recognition and Matching
- Kinematic Object Tracking

Examples and Control

- Static Object Recognition and Positioning
- Kinematic Object Tracking
- Quality Control by Laser Tracker
- Conclusions and Outlook

Trimble S7 IATS

Leica TS16I IATS

Image Processing for Feature Extraction

- Detection may be edge-based, corner-based (= point-based) or feature-based (= template-based)
- Feature-based (and point-based) detection is distinctive and robust towards:
  - noise
  - rigid body movements
  - illumination
  - geometric deformations
  - photogrammetric distortions
- Using of image pyramids:
  - series of images
  - the following image is reduced in resolution and size by factor *n* and smoothed
- Result invariant to scale

Image Processing for Feature Extraction

To the right: smoothing

To the left: decrease of resolution and size

Image Processing for Feature Extraction

SIFT (Scale Invariant Feature Transform) Algorithm

- <u>Detector</u>: two convolutions with the Gaussian kernel and a subsequent Gaussian difference filter to approximate the Laplacian of Gaussian in order to detect curvatures
- <u>Descriptor</u>:
  Gradient magnitudes (green) and orientations (yellow);
  dimension n = 16 x 8 = 128
  (8 angle sectors)

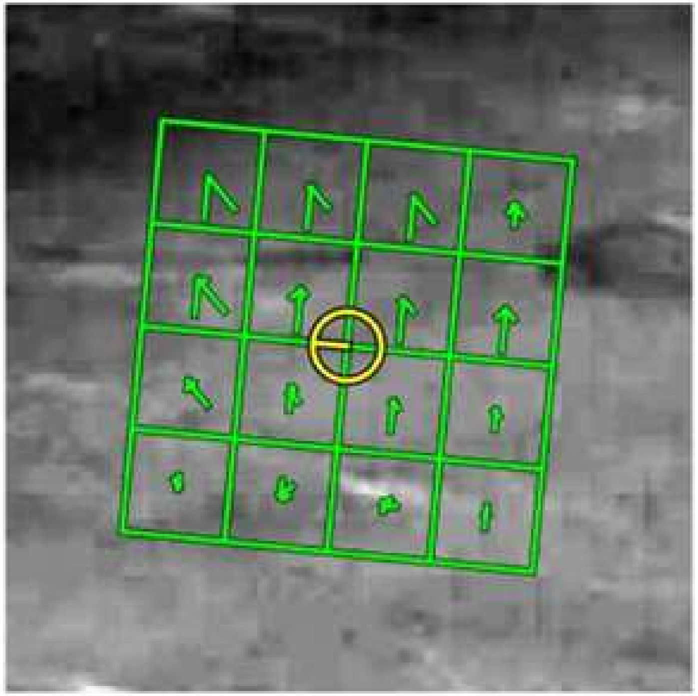


Image Processing for Feature Extraction

SURF (Speeded-Up Robust Feature) Algorithm

- Detector:
  Determinant of the Hessian matrix and Blob-filter responses resulting in a map representing the image scale space, implemented by image pyramids.
- Descriptor:
  1st order responses of the Haar-Wavelet in x and y direction,
  intensity values characterize the features;
  dimension n = 16 x 4 = 64
  (4 sums over 5x5-grid)

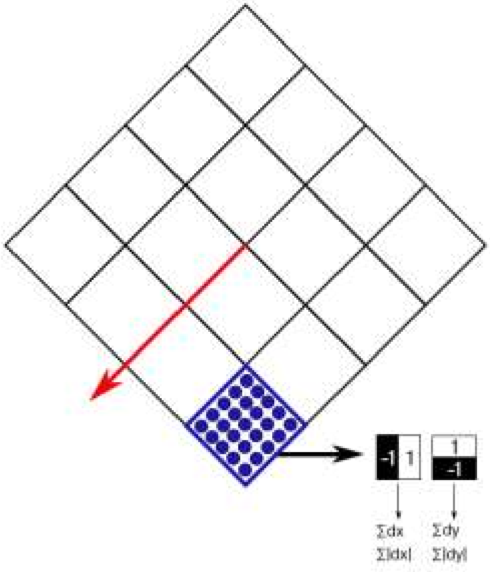


Image Processing for Feature Extraction

Comparison of the two Algorithms

	SIFT	SURF
Algorithm input	Greyscale images	Intensity images
Used filter	Original filter	Approximated filter
Structure of the scale space pyramid	Different resolutions of the image	Different resolutions of the filter
Base of the descriptor	Gradients	Haar-wavelet filter response
Descriptor dimension	128-dimensional	64-dimensional
General property	More reliable	Faster

Object Recognition and Matching

- extracted points in two images are compared with each other
- next neighbors between the two feature vectors
  (created by SIFT or SURF, dimension 64 or 128)
- Use Best-Bin-First algorithm to identify point pairs in two images
- Affine transformation
  - filtering by the MSAC (M-estimator Sample Consensus) algorithm
  - avoid gross errors / increase the robustness
  - determination of the transformation parameters
    (and transformation of one image on the other)

Object Point Determination

- Distance: reflectorless measured (need for recognition not for tracking)
- horizontal and vertical telescope angles from images

  - relation between pixel and angle $i = \frac{p}{\alpha}$

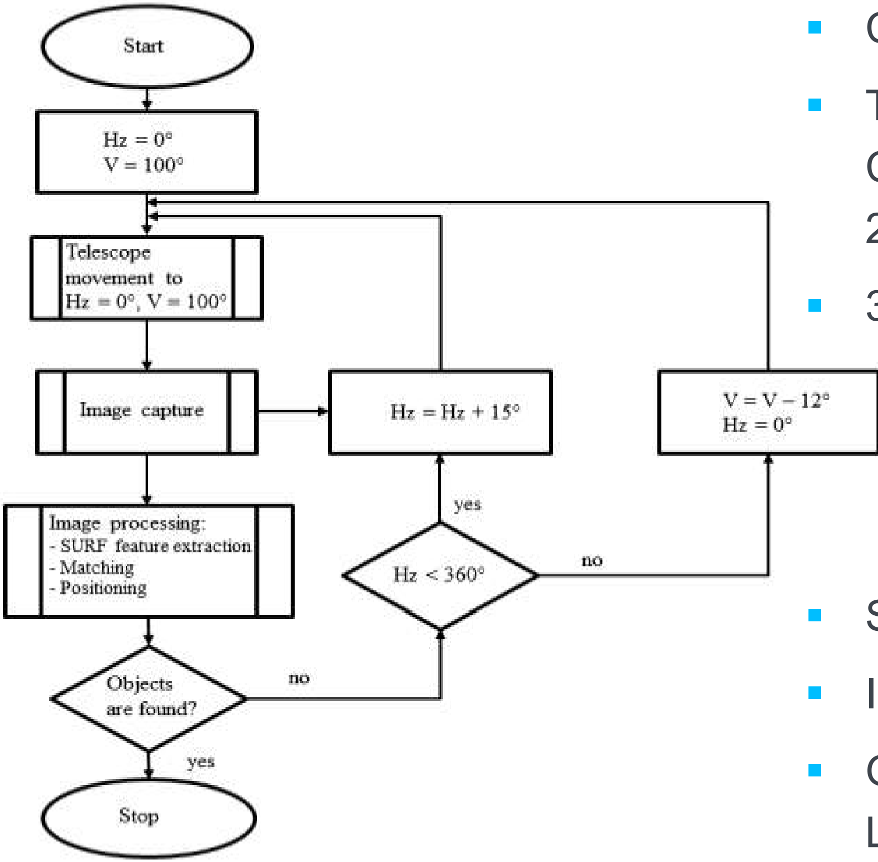
  - correction terms for eccentric camera-telescope

$$\Delta Hz = i \cdot \left(hpix_g - (hpix_m + k_h)\right)$$

$$\Delta V = i \cdot \left(vpix_g - (vpix_m + k_v)\right)$$

$hpix_g, vpix_g$:	pixel coordinates (row and column) of the measured object in the image,
$hpix_m, vpix_m$:	pixel coordinates (row and column) of the image center,
Hz:	horizontal telescope angle,
V:	vertical telescope angle,
k_h:	horizontal correction term (valid for eccentric layout only),
k_v:	vertical correction term (valid for eccentric layout only).

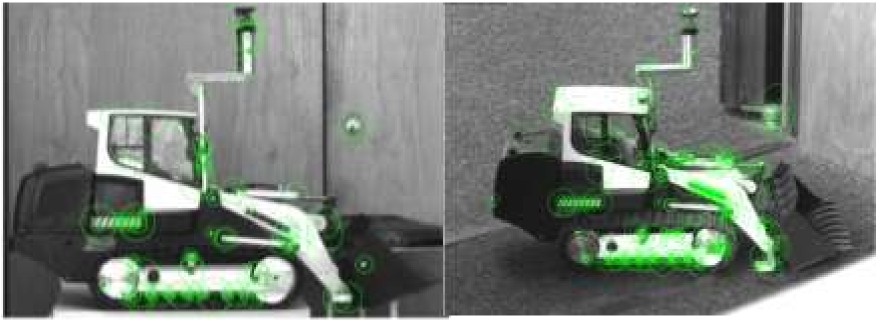
Static Object Recognition and Positioning



- Caterpillar as object
- Trimble S7 as total station with Camera with 20.3° x 15.2° F

- 3.15 MPixel
- Steering of total station with C#
- Image processing by Matlab
- General steering programm: LabView
- SURF Algorithm used

Static Object Recognition and Positioning



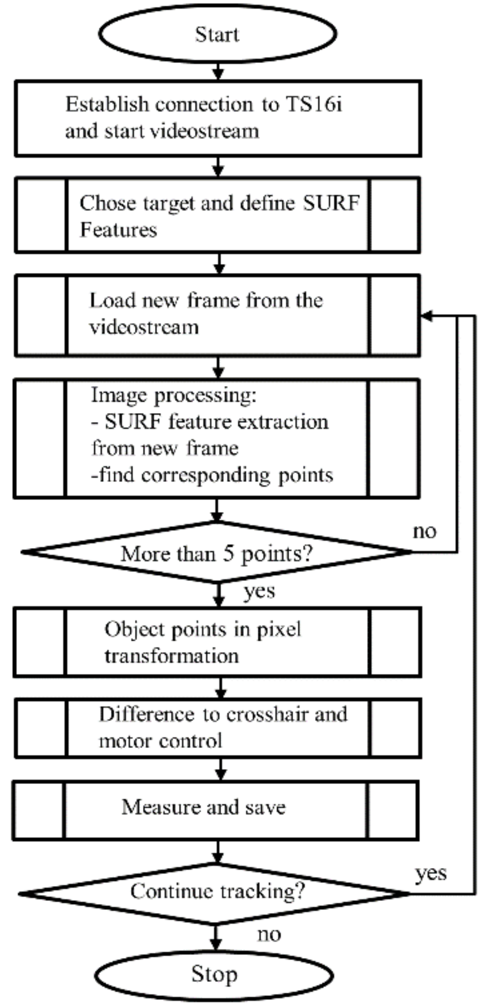
Non-identical features in both images after SURF

Correct matches after MSAC algorithm

Object identified, postion determined using pixel coordinates and reflectoless distance measurement

Kinematic Object Tracking

- IIGS-Logo as object
- Leica TS 16i IATS as total station
  with 5 MPixel Camera
  with 15.5° x 11.7° field of view
  0.5 Hz tracking rate (currently)
- Interface: GeoCom wia WLAN
- Image processing by
  Matlab
- General steering
  programm: Matlab
- SURF Algorithm used



Kinematic Object Tracking

Identified feature points in the left figure

Object identified,
tracking by movement of the telescope in two directions,
position determination possible (if needed)

Quality Control by Laser Tracker

RMS angle: 0.2 mgon

RMS relative distance: 10 μm or 5 ppm

RMS absolute distance: 10 ppm

- Distance accuracy: 250-times better than IATS
- Angle accuracy: 1.5-times better than IATS

Quality Control by Laser Tracker

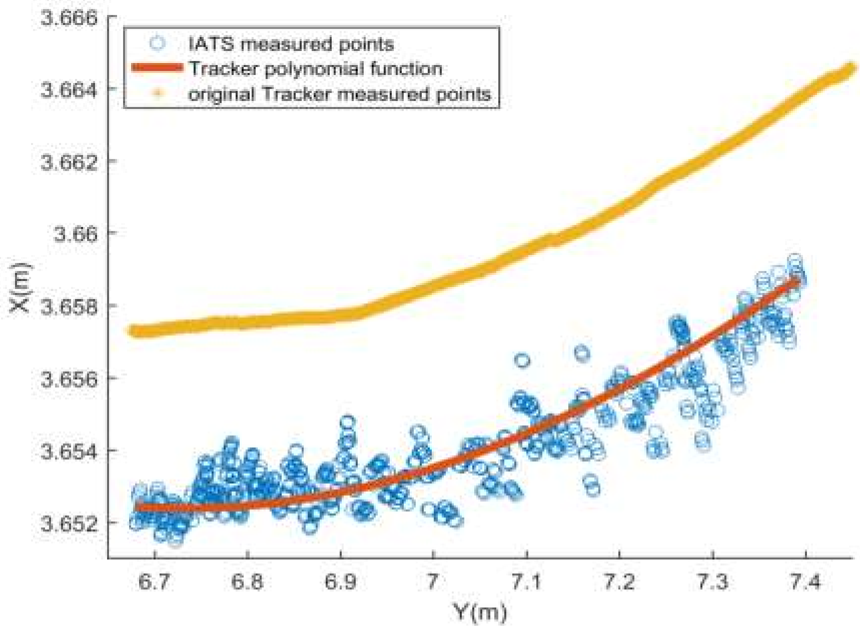
- Moving of a trolley in defined steps
- Tracking of target by image-based methods with the Leica TS 16i and of the SMR (Sperical Mounted Reflector) by the Laser Tracker (reference)
- Instrument located in aprox. 2.5 m distance normal to the rail
- Comparison of the measure positions

SMP on trolley

target with feature points on trolley

Quality Control by Laser Tracker

Comparison of IATS and laser tracker measurements



- Systematic offset of ca. 5 mm
- 0.6 mm mean deviation after correction of systematic effect

Conclusion and Outlook

- Use of camera from IATS for positioning tasks presented
- Target recognition and positioning using Trimble S7
- Traget tracking using Leica TS 16I
- Both tasks solved using SURF algorithm
- Low update rate for tracking of 0.5 Hz
- High accuracy (below mm!?)

- Improvement of update rate important
- Recognition and tracking of non-marked objects e.g. on construction sites
- Integration into Cluster of Excellence (German Research Foundation) for „Integrative Compuational Design and Construction for Architecture“

Thank you!

Volker Schwieger

e-mail volker.schwieger@iigs.uni-stuttgart.de
phone +49 (0) 711 685-84040
www.iigs.uni-stuttgart.de

University of Stuttgart
Institute of Engineering Geodesy (IIGS)

Geschwister-Scholl-Str. 24D
70174 Stuttgart
Germany