Innovations in Surveying and Geometrical Quality

Acquisition on Solid Ground

Innovative terrestrial data acquisition technologies: Mobile Mapping, Close Range Photogrammetry and Panoramic Images. How do these technologies work and how can they be used?

Acquisition on Solid Ground

- Panoramic images
  - Distortion, intersection,…
- Positioning
  - GNSS, Inertial Navigation,…
- Mobile scanning
- Automation

Mobile Mapping @ Fugro

Mobile Mapping @ Fugro

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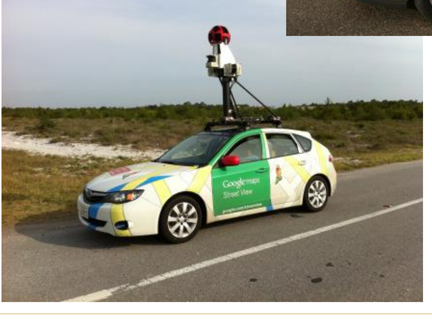
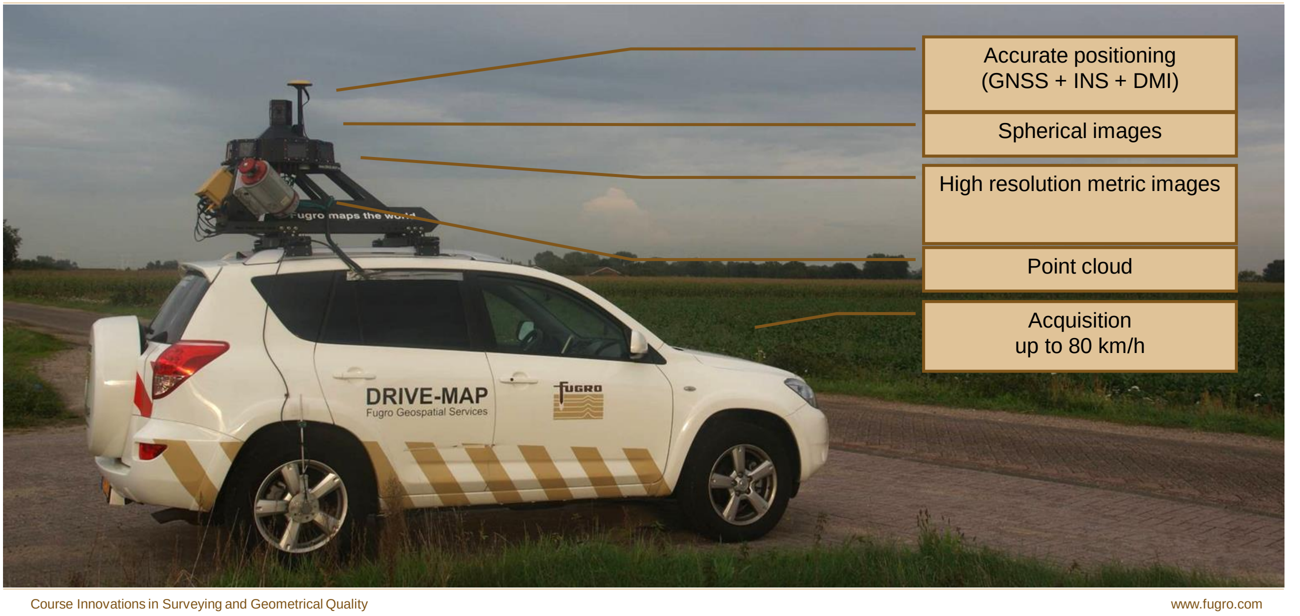
Mobile Mapping @ Fugro

Mobile Mapping in The Netherlands



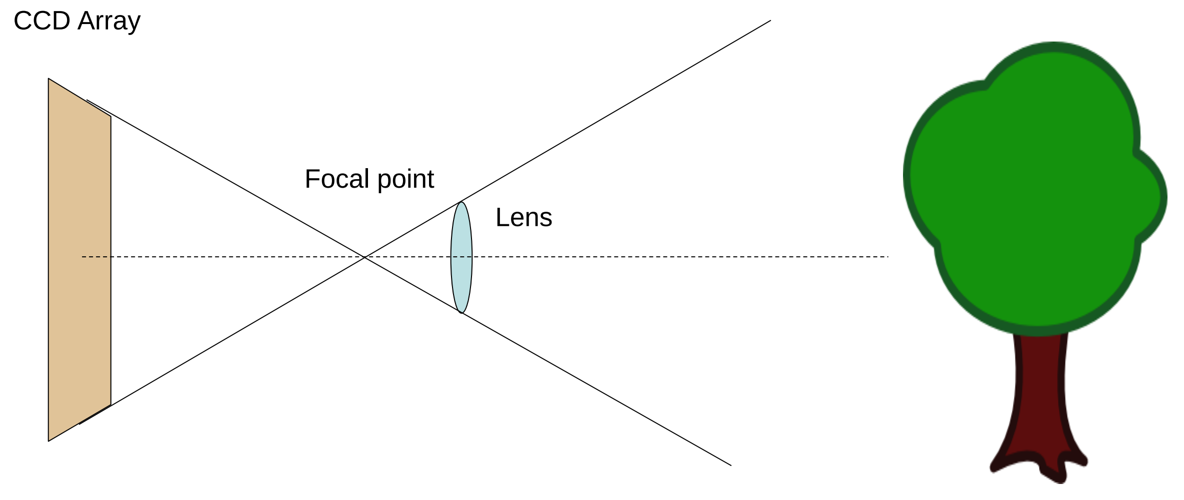
Mobile Mapping Concepts



Panoramic Images

- 360 degree images acquired from a car, boat, bicycle, …
- Introduced in 1995 in The Netherlands by Cyclomedia

Camera model



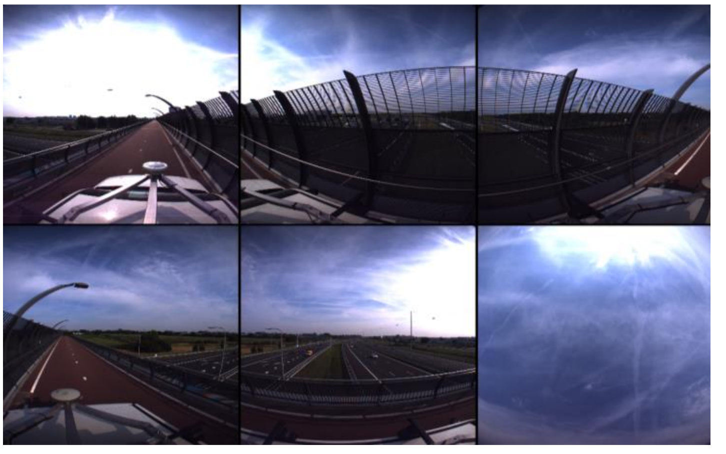
Imaging method: Fish-Eye

- Opening angle of 180˚ x 360˚
- Combination of two fish-eye images gives a full panoramic image.
- Application of two images in opposite direction with focal point on the same location.
- Advantage: can be calibrated accurately, no seem lines or blending areas in the image.
- Disadvantage: limited resolution

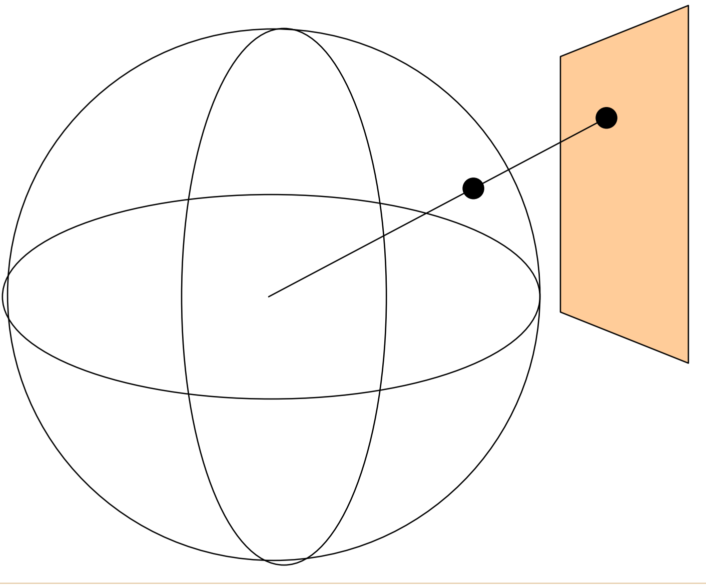

Image CC yuan2003

Imageing method: image stitching

- Multiple images can be combined to one panoramic image.
- Reprojection of separate images onto a sphere
- Advantage: high resolution, better colour balancing.
- Disadvantage: stitch lines can be visible in the image



Projection of images on a sphere



Distortion in panorama projection

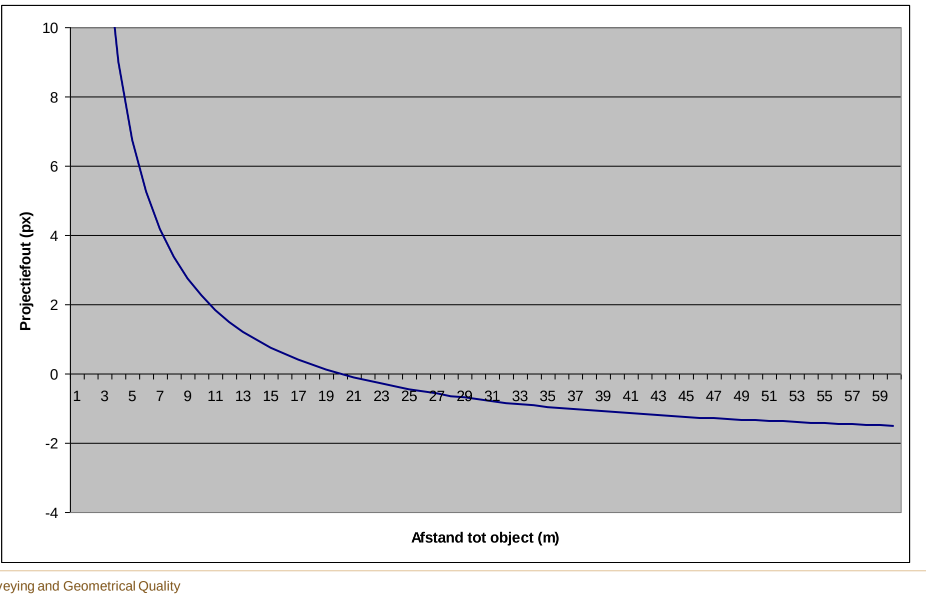
0 pixel blending

20 pixel blending

100 pixel blending

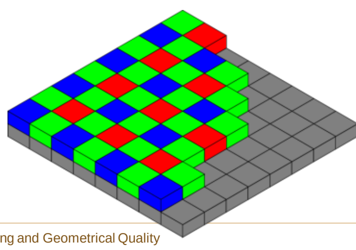
Image by Point Grey

Distortion in panorama projection



Digital imaging of colours

- Most cameras work with one sensor
- The Bayer filter determines for each pixel which colour it is sensitive to: red, green or blue.
- In post-processing three colour bands are computed by means of interpolation.



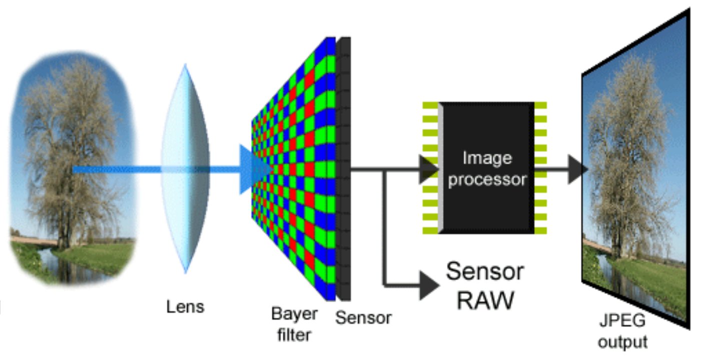
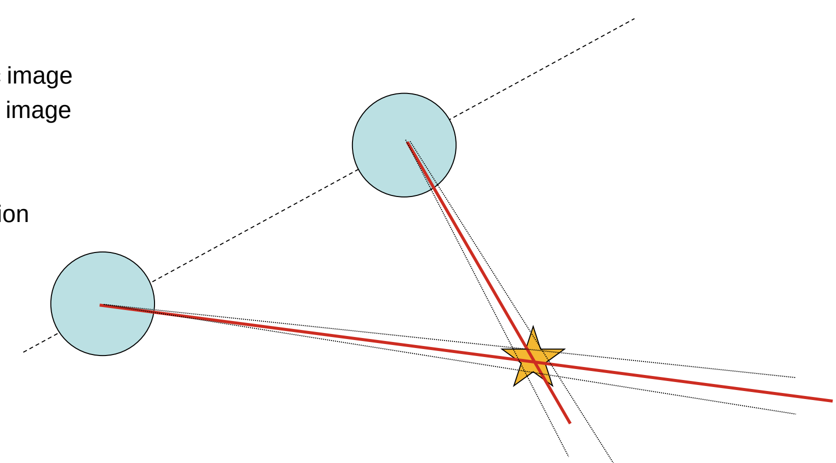


Image by Trusted Reviews

Measuring in panoramic images

- Point positioning by forward intersection
- Accuracy depends on:
  - Resolution of the panoramic image
  - Distance of the object to the image
  - Angle of intersection
  - Accuracy of the image position
- Relative: 2 – 5 cm can be achieved
- Idealisation?



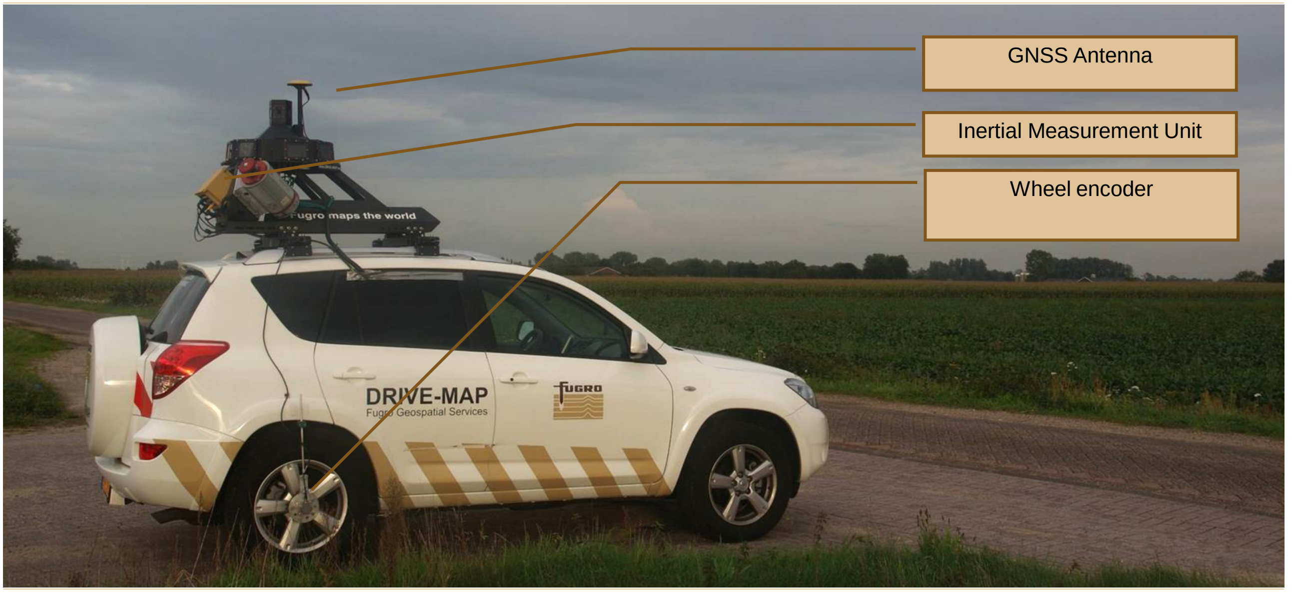
Effect of distance on precision

- Panoramic image is 8000 px x 4000 px
- Therefore: 1 pixel = 360 / 8000 = 0.045˚
  = 0.000785 rad
- Assume: measurement precision in the image is 1 pixel
- Approximate estimation of distance effect: multiply angular resolution with distance
- For this camera approximately: 8mm / 10m

Mobile positioning

- Positioning of the vehicle “platform” is essential for panoramic imagery and laser scanning.
- Depends on GNSS, inertial navigation and incremental rotation encoders.
- Comparible with airborne positioning, but with additional limitations due to:
  - Bridges and tunnels
  - Urban canyons

Components for positioning

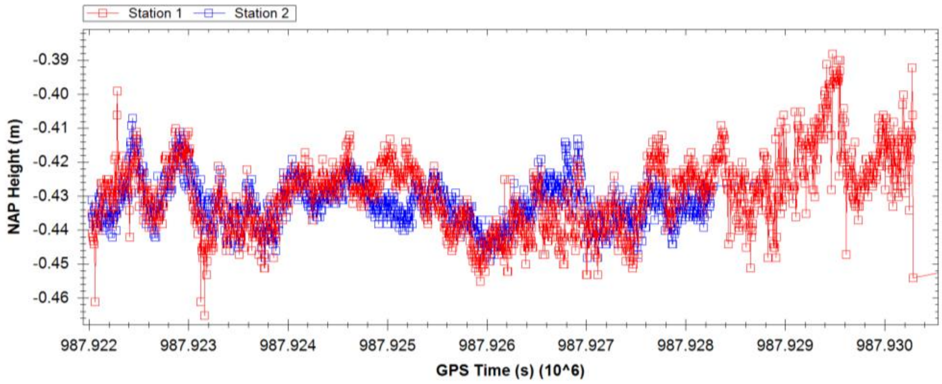


GNSS Positioning

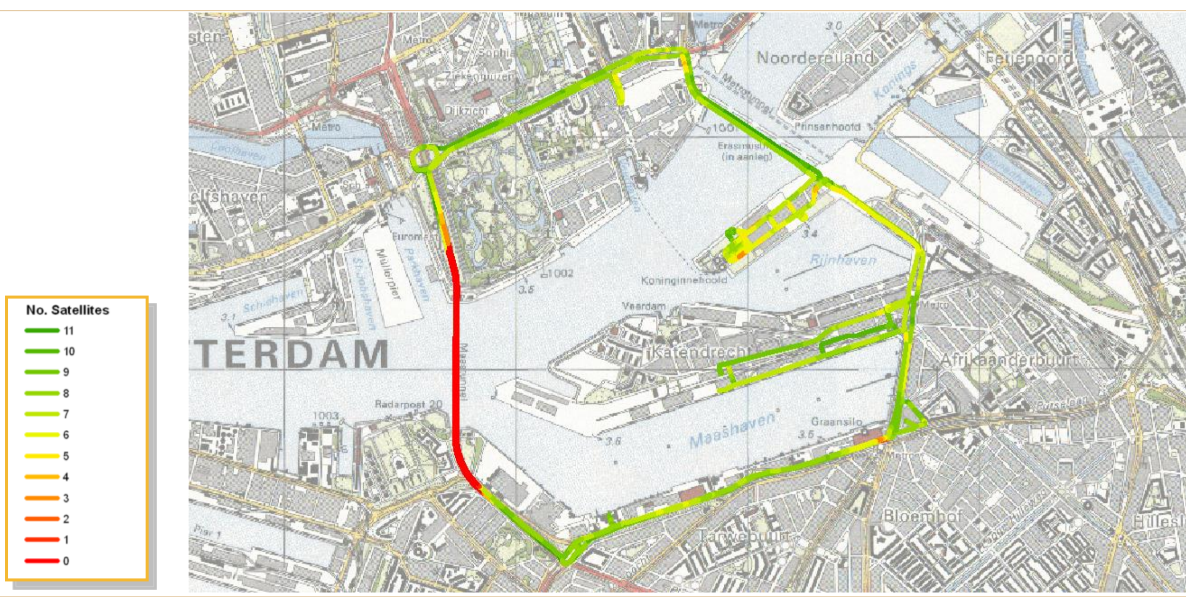
- The quality of the GNSS positioning is the prime component of the total error budget of the end result.
- Usually positioning based on PRP (Precise Relative Positioning), which is RTK in post processing.
- By applying Virtual Reference Stations, processing with very short base lines can be achieved. Effects of the Ionosphere and Troposphere can be compensated in this way.
- Two important measures for GNSS quality:
  - Number of satellites
  - PDOP (Position Dilution of Precision)

GNSS Systematic errors (RTK)

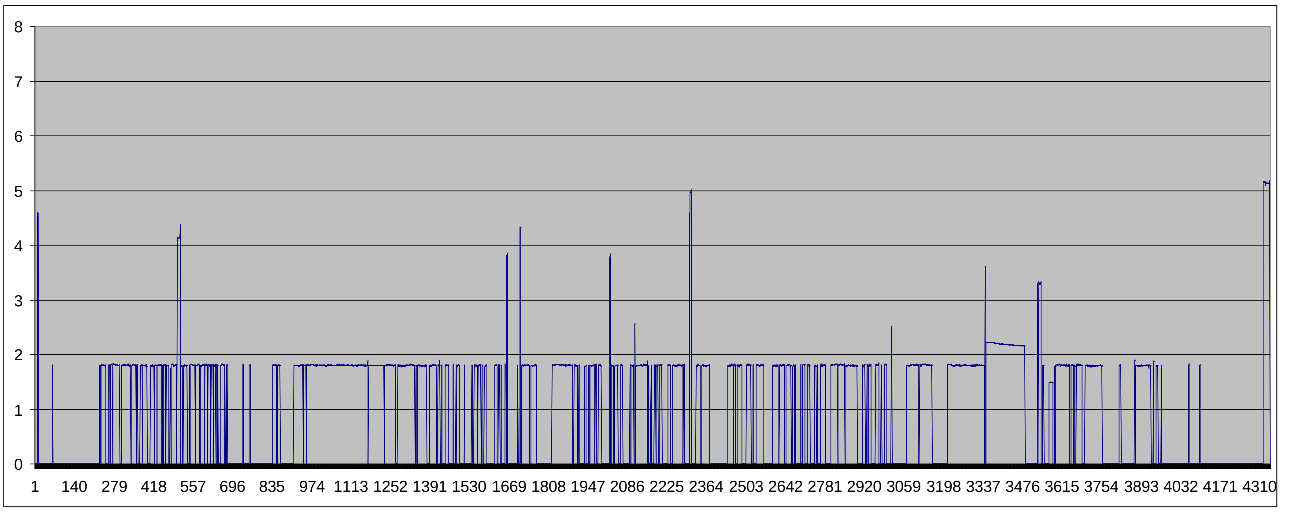
- Base line: 5 km with high end receivers
- Systematic “waves” of 15mm – 20mm



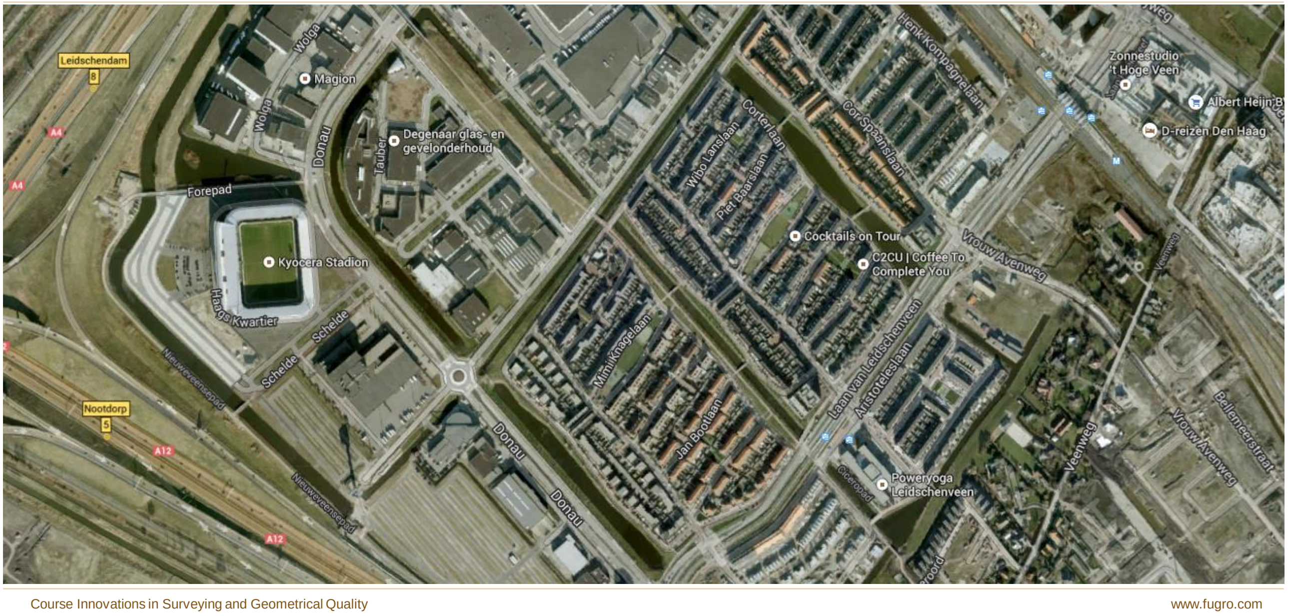
Number of satellites



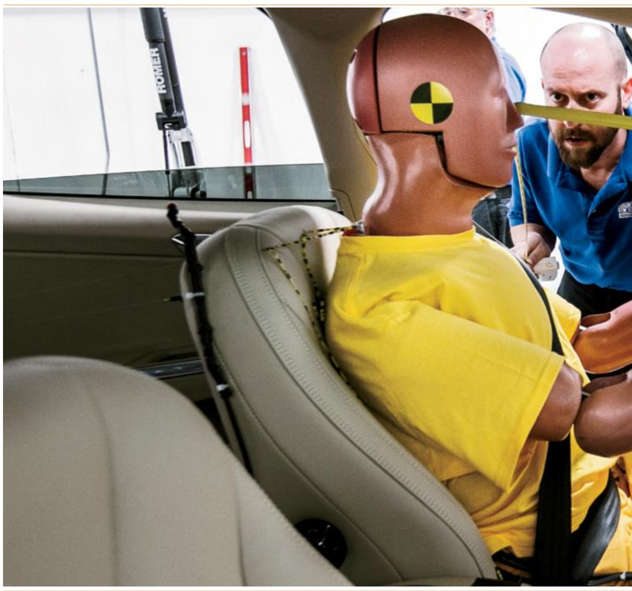
GNSS Effects during a survey



How hard can it be?



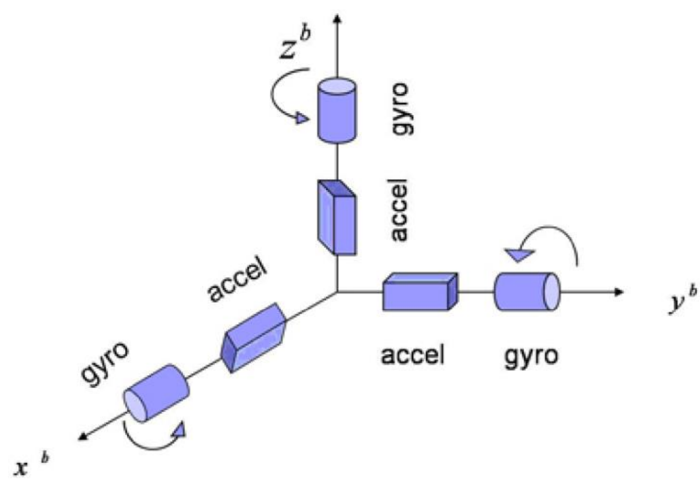
Additional measurements: intertial navigation



- Just GNSS observations is not sufficient
  - Recording frequency is 1 Hz
    This equates to interpolation distances between 10 en 20 m
  - GNSS suffers from outages of the solution contains errors.
  - Besides position, we also need to know attitude and direction
- Intertial Navigation:
  - Measurement of accelerations
  - Measurement of angular velocity

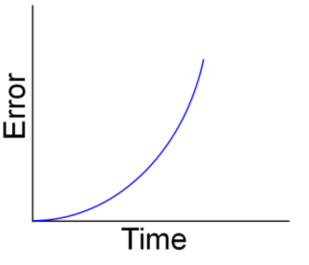
Inertial Navigation

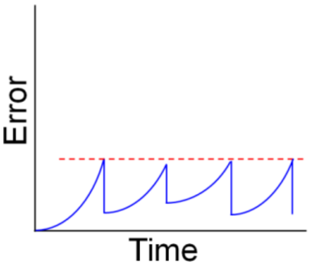
- Inertial Navigation System (INS) comporises:
  - Inertial Measurement Unit (IMU)
  - Software: Kalman Filtering
- An IMU has an internal axis system
- Along every axis the IMU measures:
  - Acceleration (m/s2)
  - Angular velocity (rad/s)
- Typically 100 Hz up to 1000 Hz



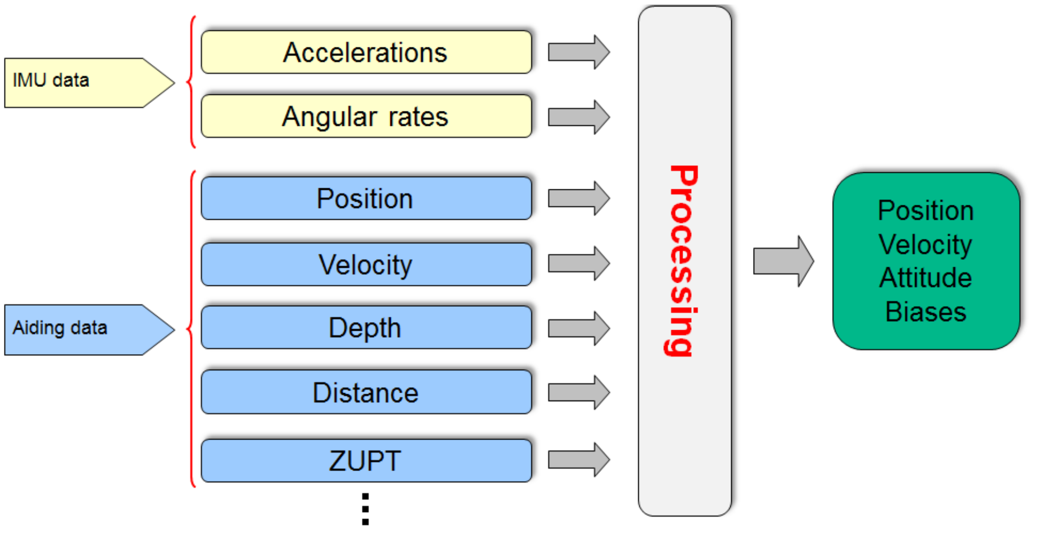
Processing INS data

- Data from an INS cannot be used stand alone
- Combination with GNSS gives a stable result. “GNSS Aiding”
- Maximum “GNSS Gap” depends on the type of IMU. For most applications 30 seconds is the maximum allowed GNSS gap.



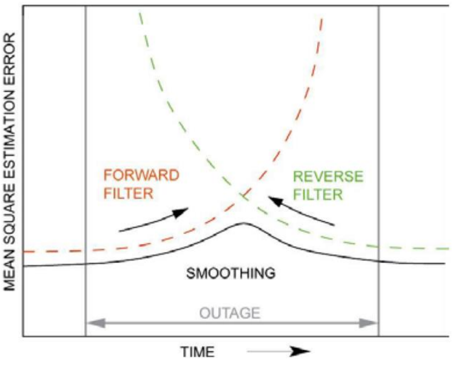


Kalman filtering



Kalman filtering

- Extra smoothing by forward and backward computation.
- Functions of the kalman filter
  - Integration of all observations
  - Statistical tests on these observations. (outlier detection, w-test, F-test)
  - Internal QC on these observations



	Traditional	Mobile Mapping
Geodetic network	Adjustment (Move3)	Kalman filtering
Detail measurement	Direction + distance	Panoramic images, Scanning

In addition to kalman filtering

- Further quality improvement can be obtained by:
  - Relative matching
    Detect objects that were surveyed multiple times and correct such that these objects get the same coordinate.
  - Ground Control Points
    Measure the location of known points and use these to improve the end result. Theoretically, this can be a step in the kalman filtering, but it I usually done afterwards.
    With sufficient ground control an absolute accuracy of 1 cm is feasible.

Survey procedure

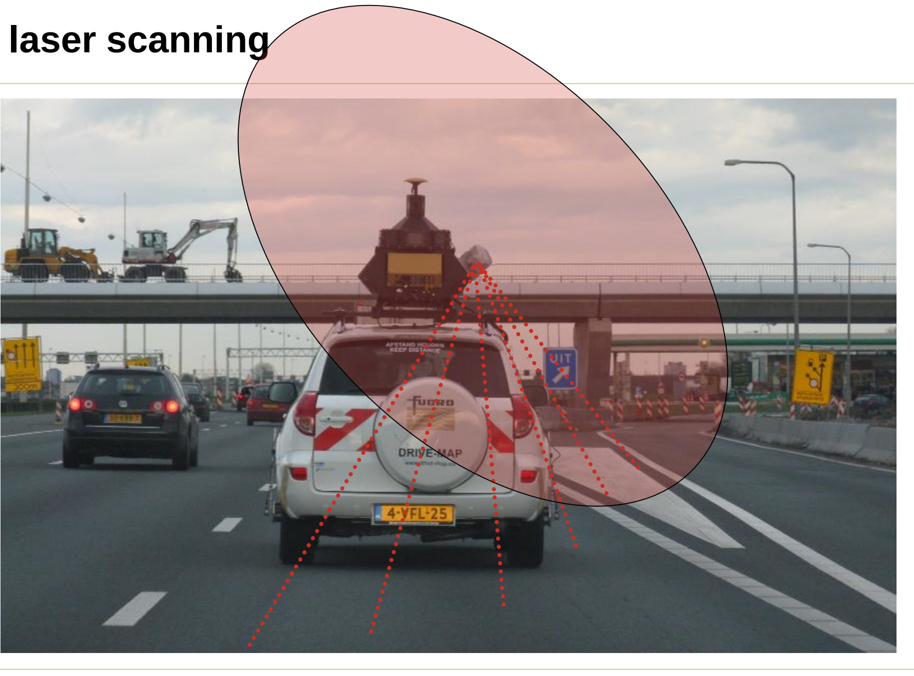
- Static initialisation under good GNSS conditions
- Dynamic initialisation to calibrate the IMU
- Survey
- Static closure under good GNSS conditions

Insight into kalman filtering

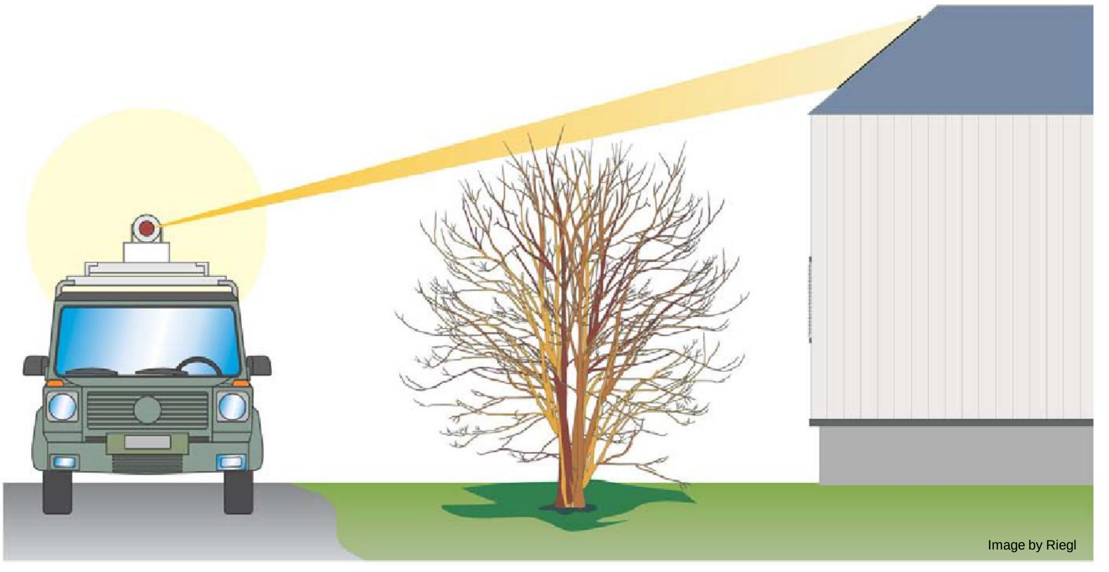
Quality requirements for end results

- Typical requirements
  - Panoramic images: absolute accuracy: 10 cm standard deviation
  - Scanning: absolute accuracy: 3 cm standard deviation

Mobile laser scanning



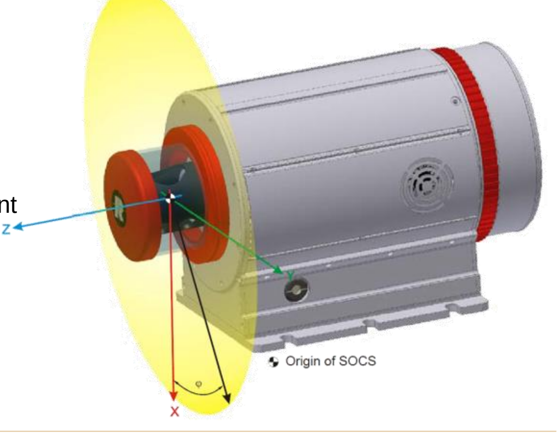
Mobile laser scanning



Mobile scanners

Maximum distance:	100 m (but max 30 m is recommended)
Range accuracy:	< 1 cm
Point measurement rate:	300 000 – 500 000 points / second

- Most systems
  - Eye safe (Class I scanners)
  - 1 or 2 scanners
  - Inclined mounting to reduce shadow
  - Observe both ranges and intensity
  - Combination with images gives RGB values for each point



Building a point cloud

- During a survey all sensors are synchornised by time
  - Time stamp per laser pulse
  - Time stamp per GNSS epoch
  - Time stamp per IMU observation etc.

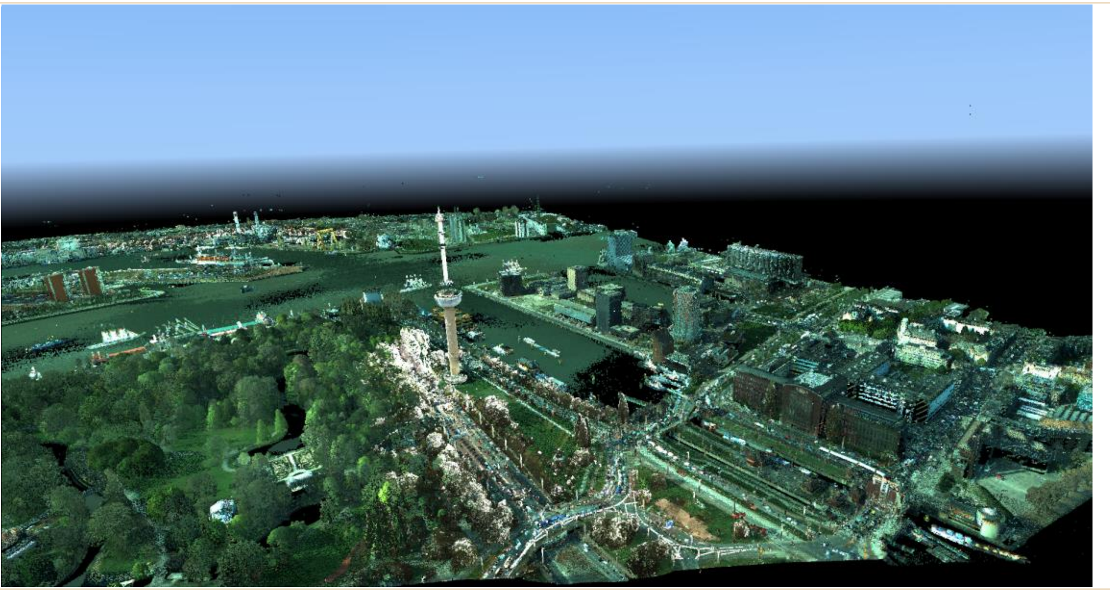
  - Question: what timing accuracy is needed?

- The position of the scanner with respect to the IMU is calibrated (translation and rotation)

- For each reflected pulse
  - Compute the vehicle position and attitude at that time
  - Apply the pulse distance and direction

Point cloud

Integration of airborne and mobile



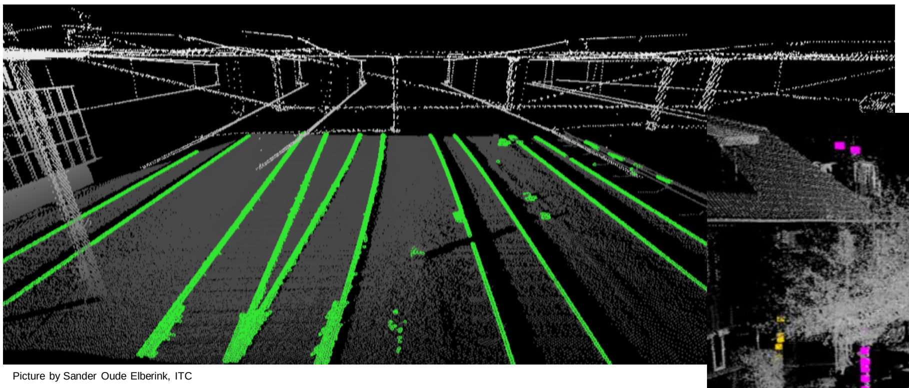
Applications of point cloud

- Visualisation
- Local map updating (Flaim)
- Height clearance measurements
- DTM for infrastructural design
- Large scale mapping

Mapping the Dutch Rail Network

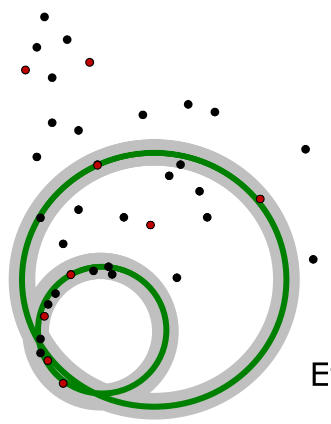
- Mapping the entire rail network of The Netherlands, including all side tracks.
- Strict requirement: 15 mm standard deviation for each point.
- Combination of Rila, RAIL-MAP and FLI-MAP
- Application of novel point cloud matching method
- Delivery of asset database to client
- Billions of points collected

Automatic recognition and modelling



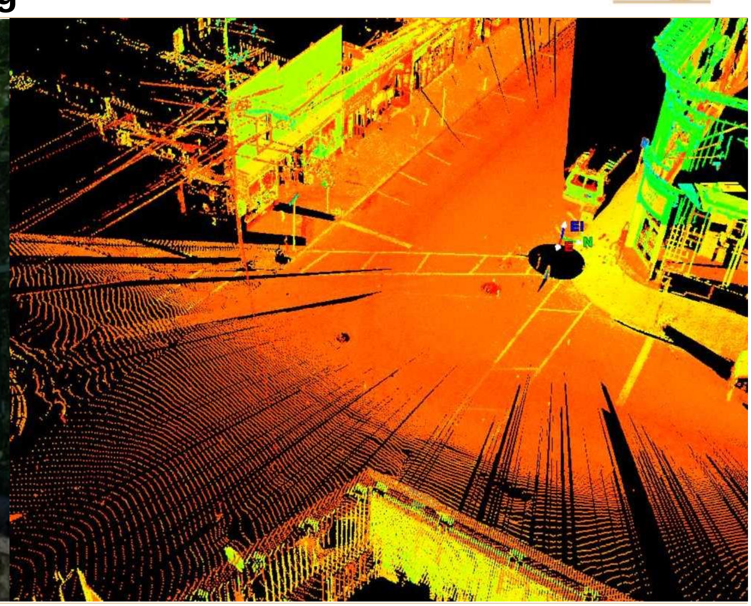
Picture by Sander Oude Elberink, ITC

Cylindrical object detection with Ransac



Etc…..

Terrestrial Laser Scanning



Terrestrial Laser Scanning: application

- Terrestrial Laser Scanning at Petro-Chemical Sites and plants
- Accurate representation of piping network
- Used for clash detection, pipe system inspection, asset management.
- Individual scans integrated into one large point cloud (registration)
  - Partly automatic (Iterative Closest Points)
  - Partly manual

Summary

- Panoramic images are made with fish-eye lens or stitching
- Panoramic images have distortions
- Within a panoriamic images, points up to a distance of 40 m can be pointed with a precision of 5 cm. Measurements from multiple panoramic images have an accuracy of approximately 10 cm.
- The accuracy of the end result is mostly determined by the quality of GNSS positioning.
- Integration of GNSS and INS is the fundament for further processing
- Ground Control and relative matching can be applied to improve the final result
- Mobile Scanning can be used to collect a 3D point cloud. The accuracy is mostly a function of the positional accuracy.

Thank You

http://goo.gl/FZaL7X