ITS Applications: Precision Asset Positioning and Monitoring in Degraded GNSS Signal Environments

Aiden Morrison, Nadia Sokolova (SINTEF), Trond Arve Haakonsen (NTNU)

Reference frames, Positioning and Navigation Seminar

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Outline

SMITS – GNSS

- About SINTEF
- Project Background and Structure

SMITS – GNSS: High Accuracy Object Positioning

- Objectives and Challenges
- Project Scope (systems considered, methodology, etc.)
- Sample Results and Conclusions

The SINTEF Group

Scientific

Commercial

SINTEF Foundation

- SINTEF Building and Infrastructure
- SINTEF ICT
- SINTEF Materials and Chemistry
- SINTEF Technology and Society

Limited companies

- SINTEF Energy Research
- SINTEF Fisheries and Aquaculture
- SINTEF Petroleum
- MARINTEK

SINTEF Holding AS
(Sinvent AS, SINTEF Raufoss Manufacturing AS, SINTEF NBL AS, SINTEF Business Development AS, Molab AS)

SINTEF ICT

Applied mathematics
Cooperative and trusted systems
Software engineering, Safety and security
Acoustics

Communication systems

Applied cybernetics
Microsystems and nanotechnology
Optical measurement systems and data analysis
Instrumentation

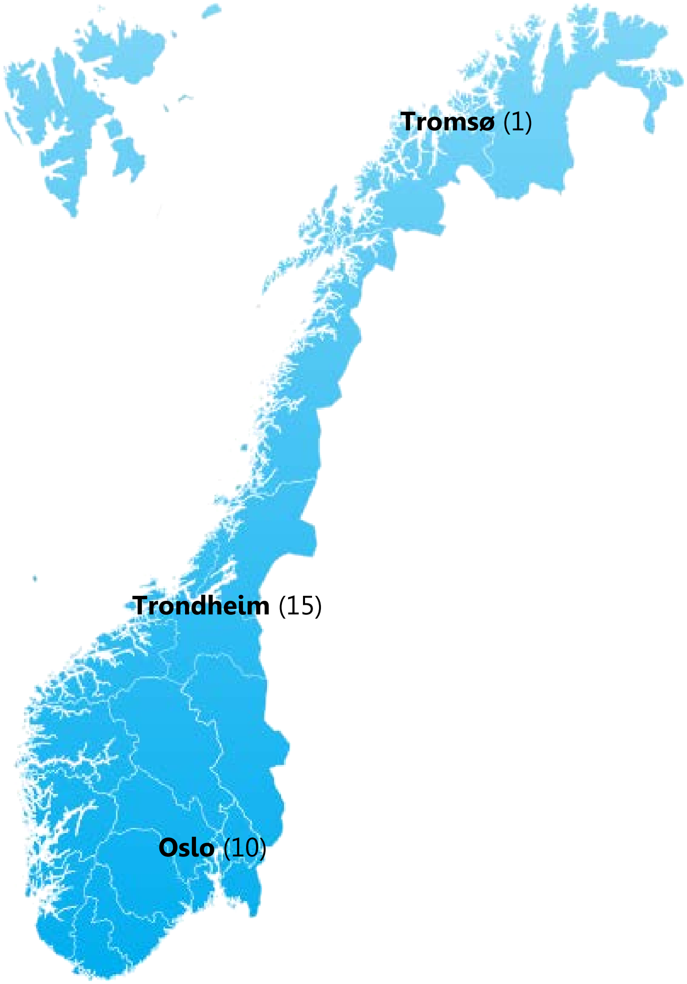
Communication systems

Our research is focused on developing systems facilitating fast, reliable and energy-efficient data communication using electromagnetic or acoustic signals via all types of channel.

We frequently develop hardware prototypes in order to test and verify our researched concepts.

Personnel

- **26 scientists** (50% PhD)
  - 2 chief scientists
  - 8 senior scientists
  - 16 research scientists

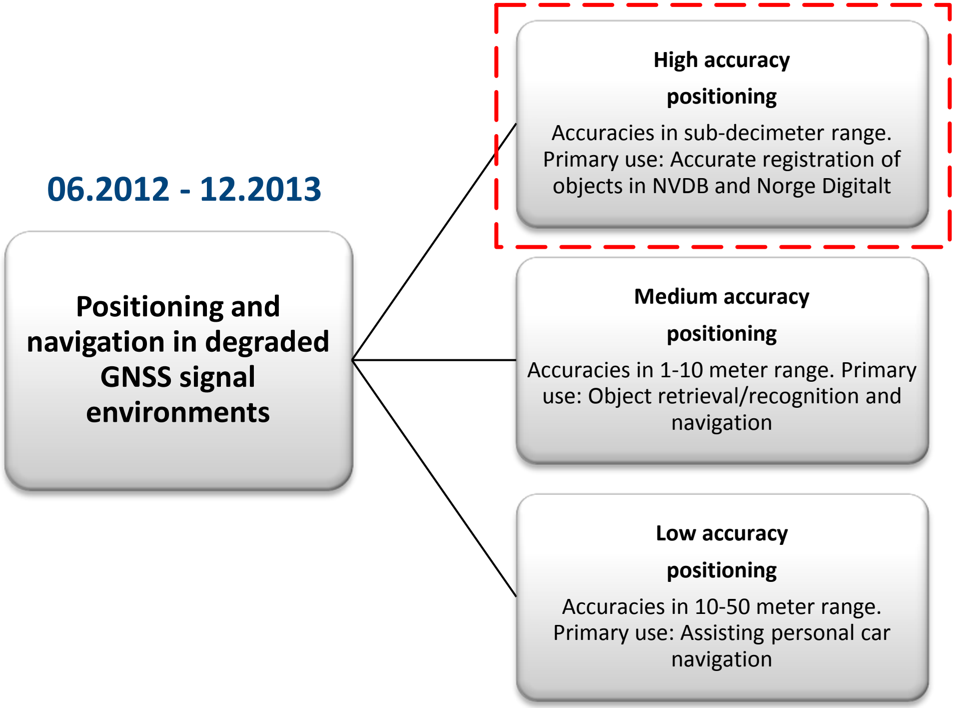


Project Background and Structure (1/2)

- GNSS in degraded signal environments - one of several projects within SMITS program
- **SM**arter Road Traffic with **ITS** (SMITS) **-** program directed by the Norwegian Public Roads Administration

SMITS objectives: increased use of smart technology solutions, intelligent transportation systems and services (i.e. more efficient use of existing transport infrastructure, innovation and increased efficiency of internal processes etc.).

06.2012 - 12.2013



Partners Involved:

- NPRA (project owner)
- SINTEF ICT
- NTNU, Road Transport & Geomatics

SINTEF and the NTNU were asked to evaluate the use of new systems for suitability and performance

Project Background and Structure (2/2)

- The existing method of positioning assets used relative measurements:
  - 1) Use reference points at the start of road segments
  - 2) Along each 'segment' of road measure distance along track using odometry
  - 3) For each asset on the road, measure out from the centre line

- This approach works but suffers from a few accuracy limitations
  - 1) Odometry drifts when a reference is not available
    - Changes in tire temperature (weather), road quality, etc. can affect measurements

  - 2) Changes to the road itself require re-measuring moved assets, and recalculating positions of all other assets further down that 'segment'

  - 3) Approach does not work well on roundabouts or other short/irregular city roads
    - Measuring distance from the centre-line for every asset is time consuming

- Therefore the NPRA sought a more accurate and less labour intensive method:
  - Use absolute coordinates rather than relative
  - Partially automate the process

High Accuracy Positioning - Objectives and Challenges (1/2)

Objectives: accurate and efficient positioning of assets/objects connected to the road infrastructure (traffic signs, storm drains, railings, etc.) for registration in NVDB (National Road Databank) .

- Produce an accurate unique 3-dimensional position for every asset, in any environment.
- Images for later reference desirable

Challenges: a large part of the road infrastructure is located in the areas where GNSS signals are strongly attenuated or not available at all (e.g. dense urban areas, tunnels).

- Systems/equipment used today cannot provide seamless operation.

  Different systems used in different environments

  - Open-sky - GNSS-based systems
  - Tunnels - traditional surveying equipment (total stations)

High Accuracy Positioning - Objectives and Challenges(2/2)

Accuracy Requirements

- Stringent positioning accuracy requirements for object registration in NVDB (in most cases <10 cm)
- Specifications for a limited number of objects are available. In the case of missing requirements FKB-B Class 1 standard is used.

FKB-STANDARD		Nøyaktighetsklasse Klasse 1 Svært veldefinerte detaljer	Klasse 2 Veldefinerte detaljer	Klasse 3 Uskarpe detaljer	Klasse 4 Diffuse naturlige detaljer
FKB-A	Grunnriss	0.15 m	0.20 m	0.35 m	0.55 m
	Høyde	0.15 m	0.20 m	0.25 m	0.35 m
FKB-B	Grunnriss	0.20 m	0.25 m	0.35 m	0.55 m
	Høyde	0.20 m	0.25 m	0.35 m	0.40 m
FKB-C (fotogrammetri)	Grunnriss	0.40 m	0.45 m	0.50 m	1.00 m
	Høyde	0.40 m	0.60 m	0.70 m	0.90 m
FKB-C (digitalisering)	Grunnriss	2 m (1)	2 m (1)	2 m (1)	2 m (1)
	Høyde	2 m (1)	2 m (1)	2 m (1)	2 m (1)
FKB-D	Grunnriss	10-50 m (2)	10-50 m (2)	10-50 m (2)	10-50 m (2)
	Høyde	10-50 m (2)	10-50 m (2)	10-50 m (2)	10-50 m (2)

General FKB accuracy requirements (in terms of std) for object positioning based on the standard and the visibility level class [1].

- **Traditional Survey not desirable**
- Tunnels must be shut down to have a survey crew present
- Surveying every sign and road marker would be very expensive

Degraded GNSS Signal Overview

<u>How accurate are GNSS signals?</u>
Multiple error sources (approximate):

- Satellite orbit errors ~1m
- Satellite clock errors ~1m
- Ionosphere effects ~10m
- Troposphere effects ~1m
- Multipath 0m-20m

<u>How are they made accurate enough for positioning?</u>

- Troposphere error is 'easily' modelled
- Multipath can be mitigated
  - carrier smoothing of the code
  - choke ring antennas
- Dual frequency measurements remove the range bias from the ionosphere
- Satellite orbit and clock errors are highly correlated over km level distances - **<u>differential corrections remove these</u>**

GNSS signals are extremely weak:

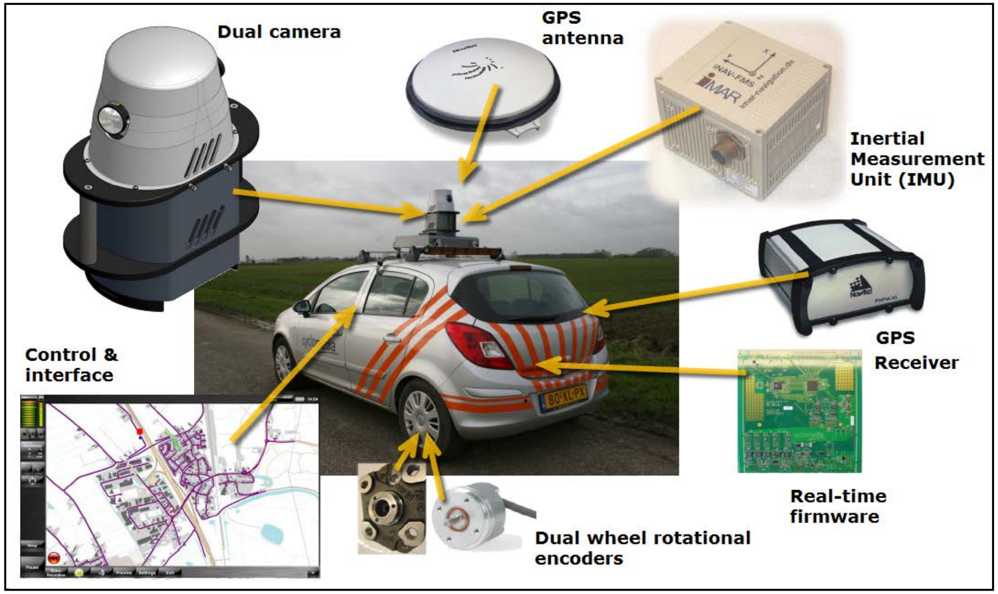
- They do not pierce concrete
- They do not pierce tunnels
- Signals can be significantly degraded by tree foliage
- **<u>Other sensors are needed.</u>**

High Accuracy Positioning – Scope of the Activity

Scope: Comparison testing of available state-of-the-art technologies

Do the systems support the NVDB accuracy requirements in degraded GNSS signal environments?

Mobile mapping system from CycloMedia (RTK GNSS, IMU, DMI, **dual camera solution - 360° images**)



[2]

Lynx Mobile Mapper from TerraTec (RTK GNSS, IMU, DMI, **dual high rate laser scanner solution**). Dual camera solution – not used for object positioning in the project.

[3]

System Comparison

- Nearly identical navigation platforms
- Performance level inside tunnels with no external aiding source expected to be similar

	iMar FSAS IMU (Cyclomedia) after 60 seconds without GPS (Predictions from NovAtel PP)	POSLV420 (TerraTec) after 1km of travel or 60 seconds without GPS (Predictions from Applanix PP)
Horizontal accuracy	13 cm RMS	12 cm RMS
Vertical accuracy	5 cm RMS	10 cm RMS
Heading	0.016 degrees RMS	0.02 degrees RMS

Stereo cameras

- Images.
- Object positioning requires 2 + images
- Spatial separation

Laser imager

- Measures distance between the sensor and the object + scanning angle
- Object positioning requires 1 measurement

High Accuracy Positioning Assessment – Methodology

Data collection:

- Trajectory passing through 2 consecutive tunnels selected (Ilsvik and Skansen)
- A set of 209 reference objects selected inside the tunnels and their position surveyed to be used as reference. Surveying performed by Nidaros Oppmåling AS
- Mapped image data was already available through a demo project conducted by the NPRA, data collection performed by the Norwegian CycloMedia system operator - Blom Geomatics AS
- Lynx Mobile Mapper: data collection performed by TerraTec

Data analysis in terms of:

- Success rate
- Accuracy
  (bias and noise)

High Accuracy Positioning – Target objects/assets

Object types: lamps, manholes, storm drains, reflector marks, etc.

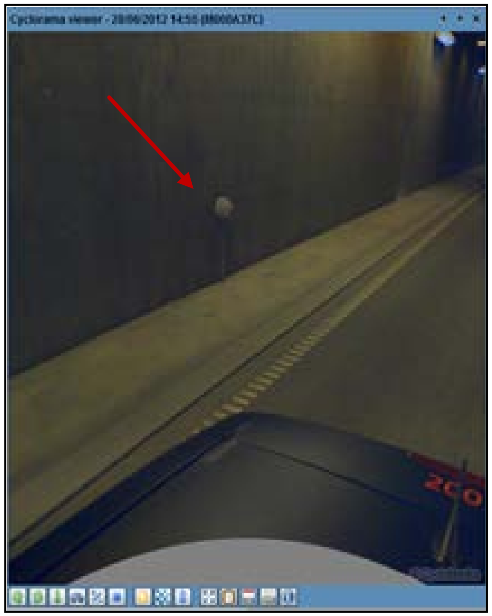
Data processing/object identification and positioning (post-mission):

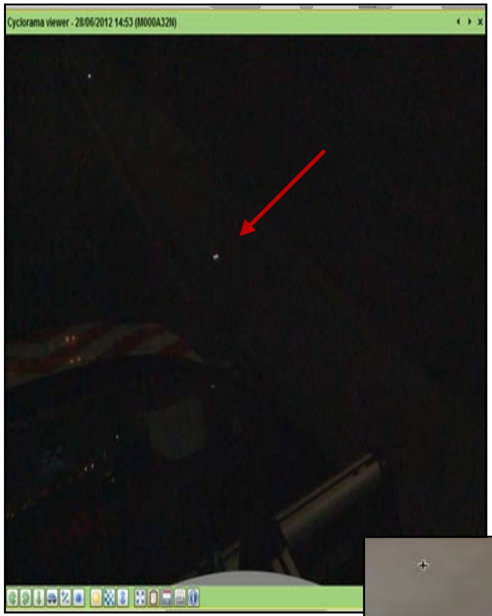
- Cyclomedia images: GlobeSpotter software
- TerraTec point cloud data: Microstation with TerraSolid software application

Success Rate

Accuracy is critical, but missed objects will require sending out a survey team anyway

- Cyclomedia - lighting conditions are critical for the image quality
- TerraTec- road surface reflectors - <u>invisible to IR laser</u>





Coordinate Matching – Not implemented by Cyclomedia

- Correcting the orientation and location of laser points from different drive passes by matching to points pre-surveyed by an independent and accurate positioning system.

  to limit error growth in the data set as the vehicle passes through the tunnel or other region without GPS aiding.

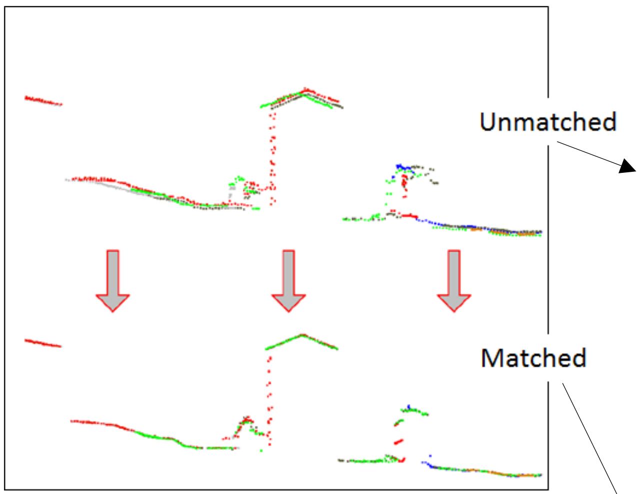
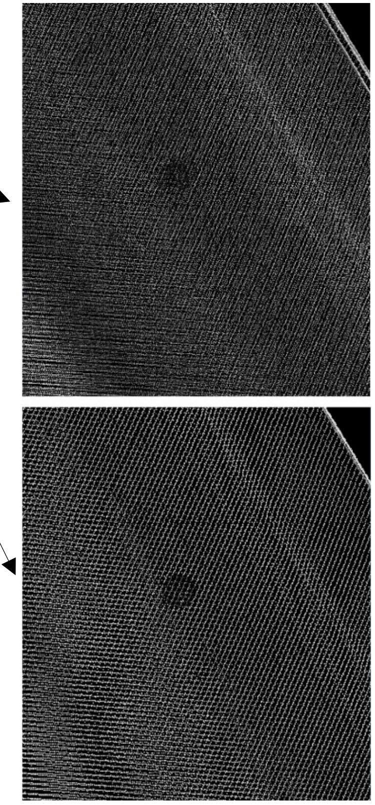


Illustration of the data matching effect [4].

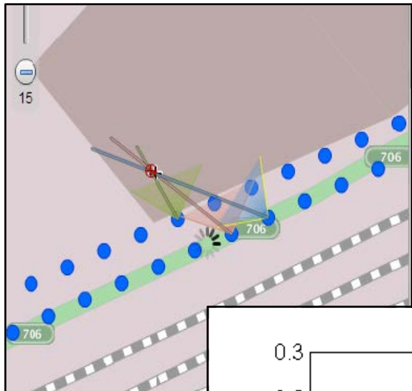


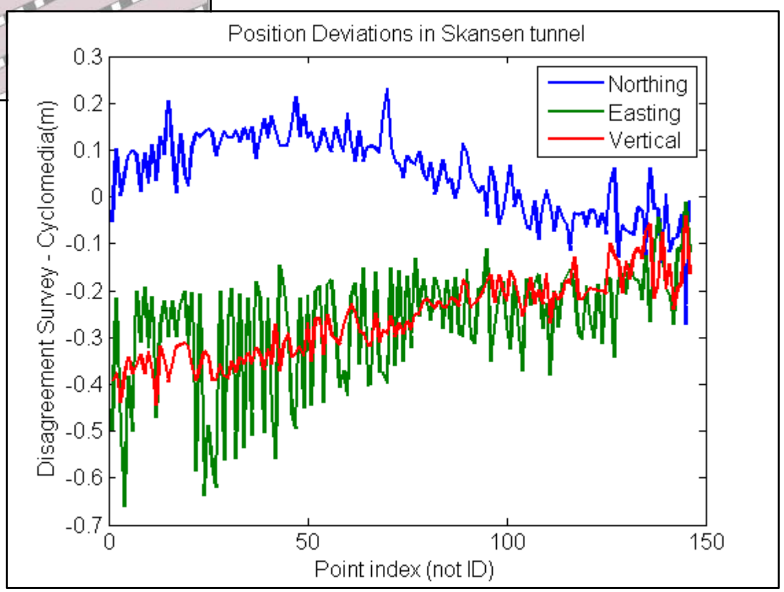
- In both cases inertial systems show drift when operating in tunnels.
- Matching capability only available for the TerraTec solution.
- 10 points surveyed to be used for matching the TerraTec point cloud data.

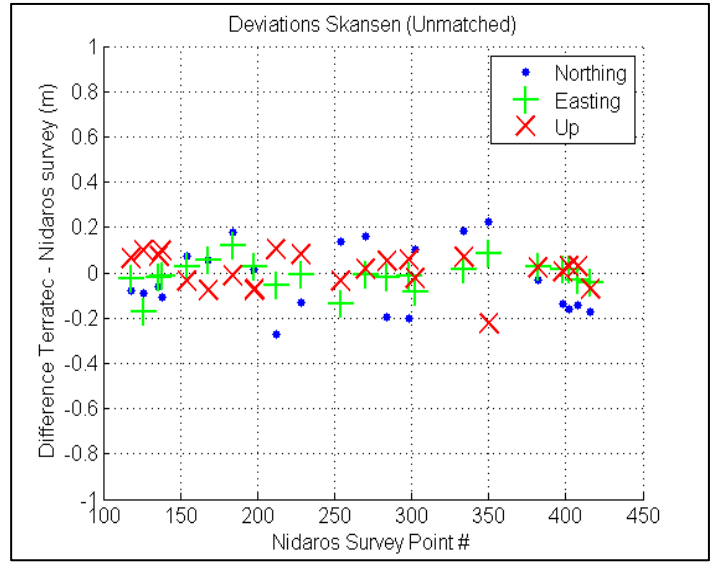
Performance Analysis (1/3)

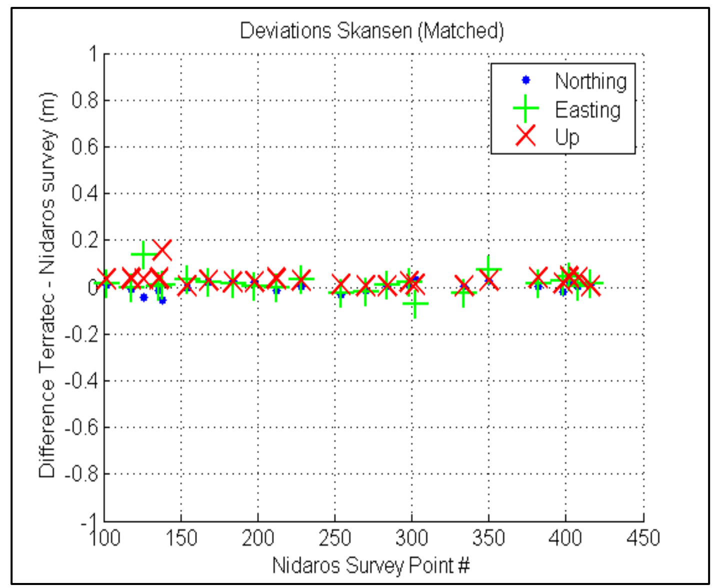
Skansen Tunnel:

Cyclomedia system result was dependent on trajectory used due to inertial drift







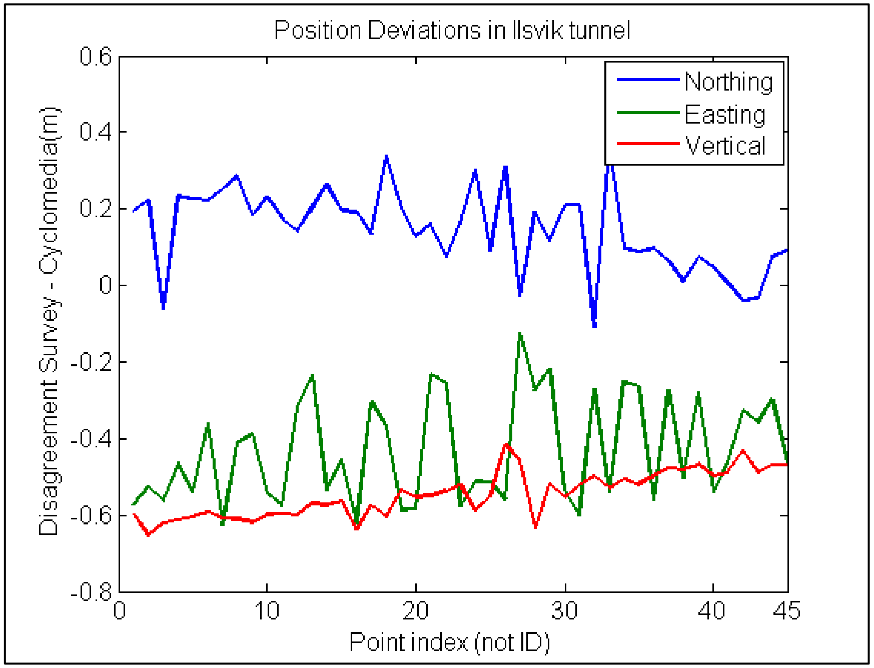


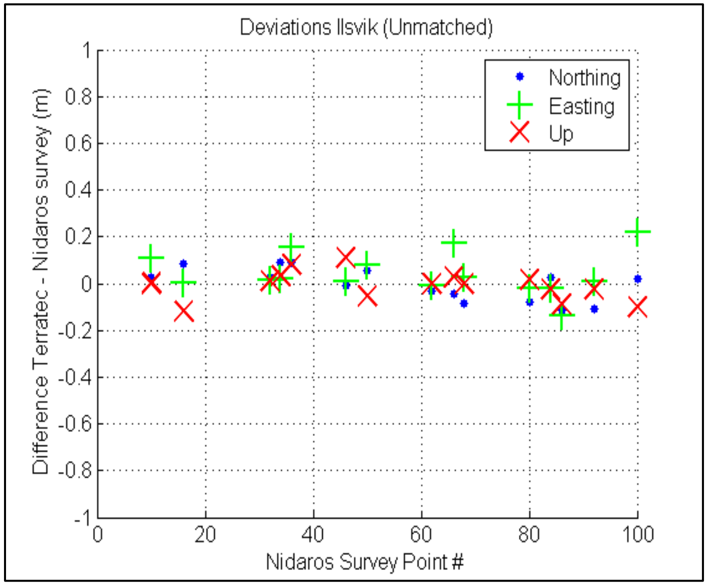
Performance Analysis (1/3)

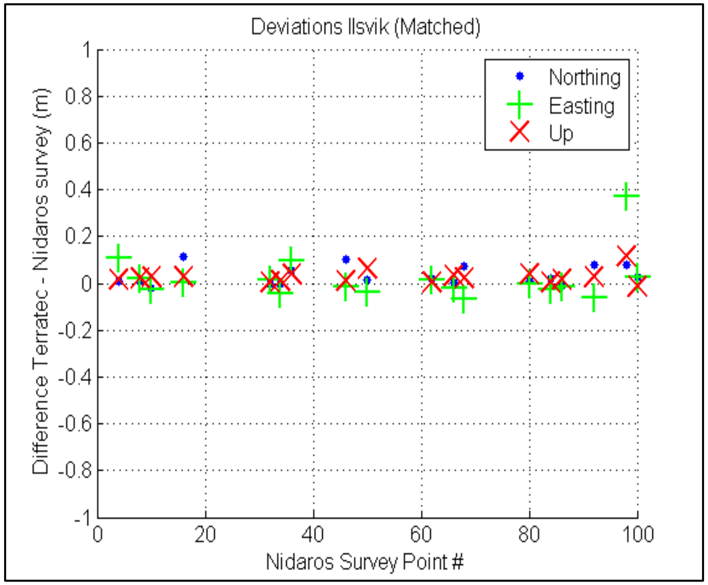
IlsvikTunnel:

TerraTec system produces excellent results in terms of systemic coordinate bias

- Slightly lower noise level compared to Cyclomedia

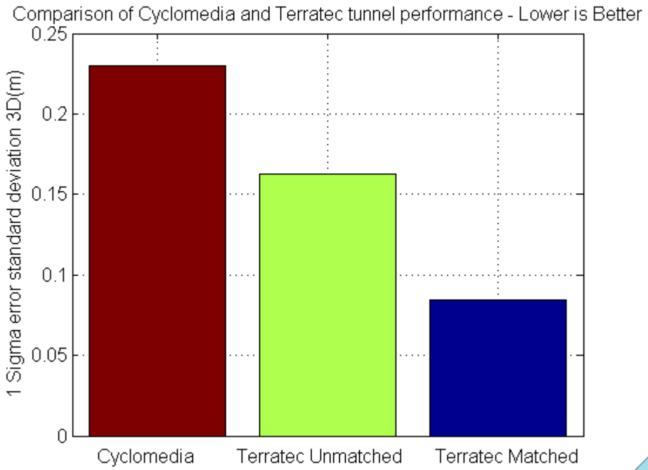




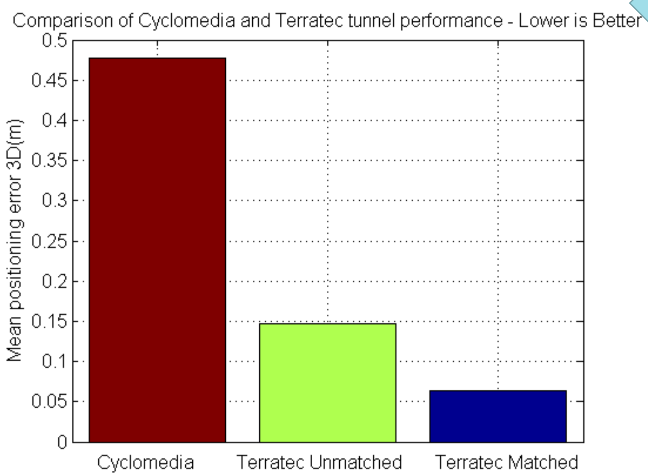


Performance Analysis (3/3)

Accuracy



Noise

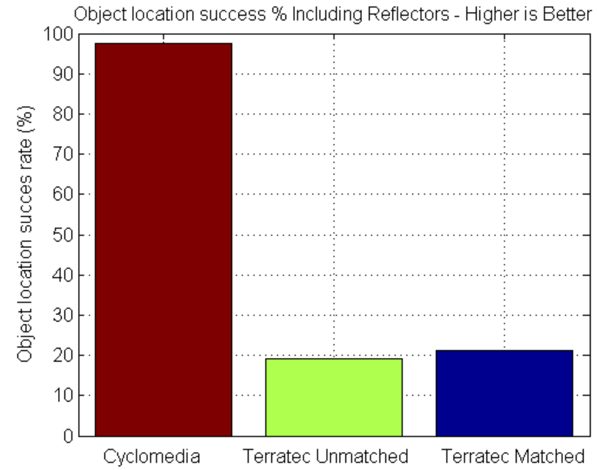


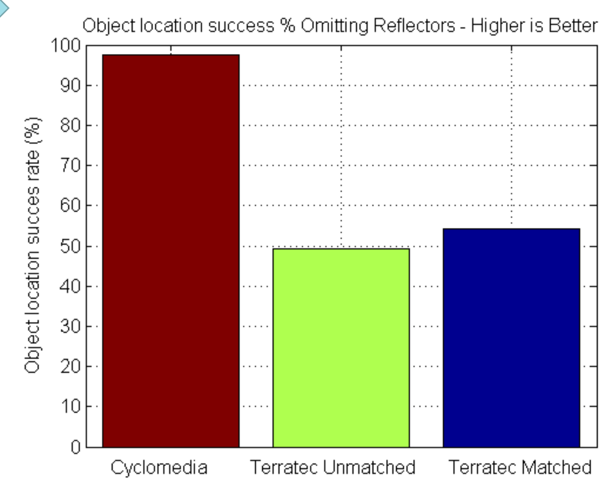
Bias

Lower = Better

Higher = Better

Success Rate





- Best solution would be Cyclomedia + coordinate matching

Conclusions

- Neither system can achieve the most stringent NVDB classifications
- Both systems vulnerable to blockage of objects to be positioned
  - E.g. snow, mud, passing vehicles
- Cyclomedia system has much higher bias levels
  - Can be removed by measuring a known reference point (coordinate matching)
- Cyclomedia system has slightly higher random noise levels
  - Might require multiple observations of the same points
- TerraTec system has very low success rates
  - Abysmal on some types of assets – e.g. reflectors with a ~0% success rate
    - IR light used by the laser does not pass through glass well – not reflected by the glass mirrors inside, nor through the casing.
- Cyclomedia software generally easier to use
- In our opinion it is easier to upgrade the performance of the Cyclomedia system
  - Better IMU, and **add coordinate matching** support in software

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Contact Information

Statens Vegvesen

Erik Olsen erik_olsen@vegvesen.no

Åsmund Hansen aasmund.hansen@vegvesen.no

SINTEF

Nadia Sokolova nadia.sokolova@sintef.no

Aiden Morrison aiden.morrison@sintef.no

NTNU

Trond Arve Haakonsen trond.arve.haakonsen@ntnu.no