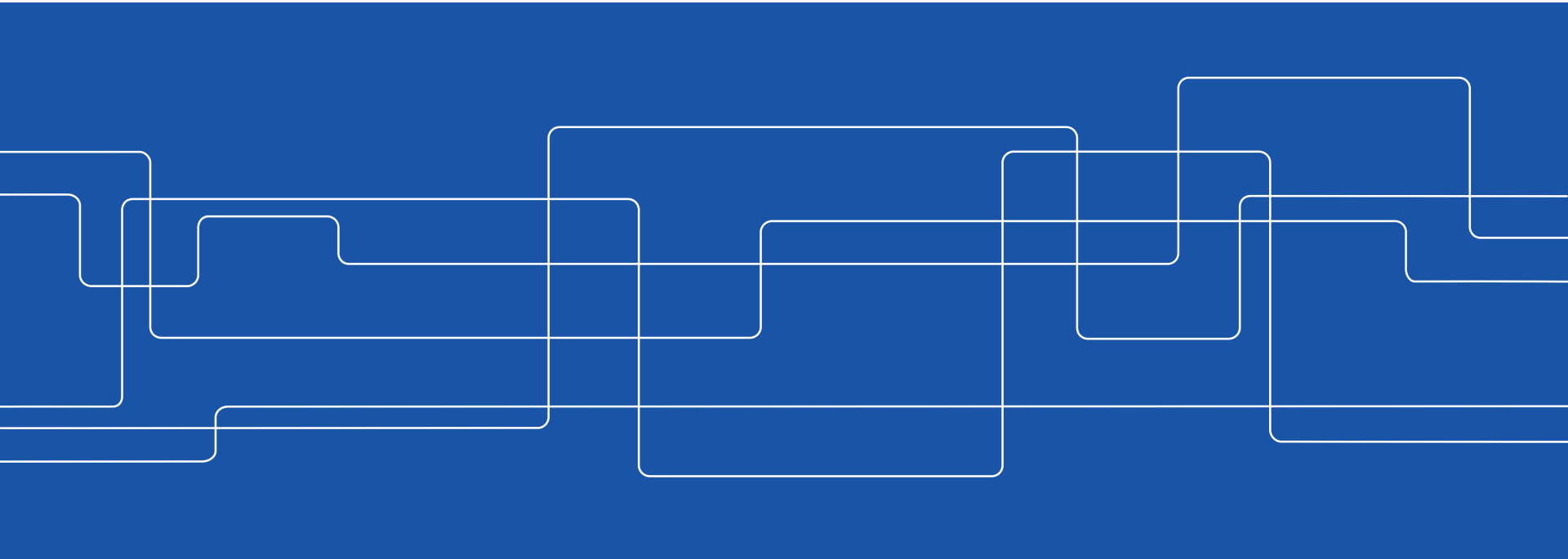




# Research, Development and Education in the Field of PNT at KTH

Milan Horemuz

Division of Geodesy and Satellite Positioning, KTH





# KTH Royal Institute of Technology

Sweden's largest technical university,  
located in Stockholm

Teaching and research in science  
and technology since 1827

Today approx. 15000 students and  
4000 employees

5 schools



PNT – related activities

- School of Electrical Engineering and Computer Science
- School of Architecture and the Built Environment



## PNT related research at the Division of Information Science and Engineering

- Lead by Peter Händel
- GNSS for smartphone-based insurance telematics
- Using GNSS combined with IMU in smartphones for driver behaviour analyses focusing on e.g. eco-driving and speeding
- Life-saving shoes – inertial positioning in shoes for emergency responders
  
- J. Wahlström *et al.*, "Fusion of OBD and GNSS Measurements of Speed," *IEEE Transactions on Instrumentation and Measurement*, vol. 67, no. 7, s. 1659-1667, 2018.
  
- I. Skog och P. Händel, "Time Synchronization Errors in Loosely Coupled GPS-Aided Inertial Navigation Systems," *IEEE transactions on intelligent transportation systems (Print)*, vol. 12, no. 4, s. 1014-1023, 2011.



# Division of Geodesy and Satellite Positioning

Research and teaching in the field of geodesy including e.g. geoid modelling, geodynamics, high accuracy GNSS positioning and navigation, land surveying, and laser scanning

Geodesy has been a research area at KTH since 1911. GNSS has been part of the research in geodesy since the late 1980'ies

7 PhD dissertations and 6 licentiate theses (1998 – 2017) related to PNT

Currently only one active PhD student in PNT



# PhD dissertations related to PNT

- Alizadeh Khameneh, Mohammad Amin (2017). Optimal Design in Geodetic GNSS-based Networks
- Yueming Zhao (2013). Key Technologies in Low-cost Integrated Vehicle Navigation Systems
- Massoud Shirazian (2013). Quality description in GPS precise point positioning
- Johan Andersson (2008). A Complete Model for Displacement Monitoring Based on Undifferenced GPS Observations.
- S-G Mårtensson (2001). Height Determination by GPS - A Practical Experiment in Central Sweden
- Patric Jansson (1998). Precise Kinematic GPS Positioning with Kalman Filtering and Smoothing- Theory and Applications
- Kjell Almgren (1998). A New Method for GPS Ambiguity Resolution on-the-fly at Short Baselines

# Biases in multi-GNSS positioning

For high accuracy GNSS based positioning (and for probing of the atmosphere) code and phase biases between different signals and systems must be estimated for multi-GNSS precise point positioning



Industrial Ph.D. student assigned to investigate GNSS biases which are relevant for the SWEPOS network and services

- Method for estimation of between-receiver and between-signal biases, analysis of satellite dependency of GNSS biases
- Precise positioning with mobile phones, consideration of inter-system and inter-frequency biases
- Ionospheric tomography using GNSS observations

# Accuracy verification of positioning modules

Development of methods for accuracy verification of positioning modules in mobile mapping systems incl. GNSS, INS, vision and laser scanning:

- Direct method using independent observations (land survey techniques)
- Indirect method using known coordinates for objects observed by the system

Work carried out by M. Horemuz and P. Jansson KTH, in cooperation with WSP and Swedish Transport Administration





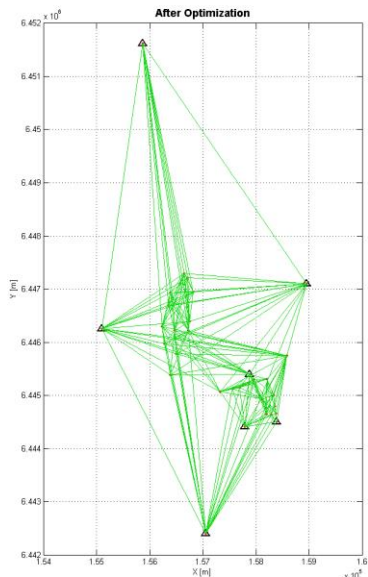
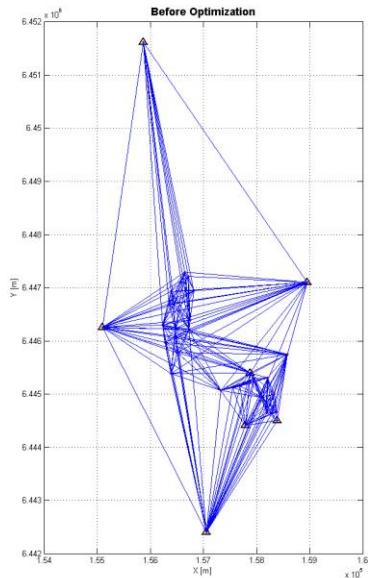


# Optimization of GNSS monitoring networks

Networks of points observed with GNSS often provide the basis for deformation monitoring and detection

At KTH a method for optimization of such networks was developed and tested with good results, using the Lilla Edet land slide area as a case

Work carried out by M. A. Alizadeh, M. Eshagh and L. Sjöberg, KTH, funded by Formas research foundation





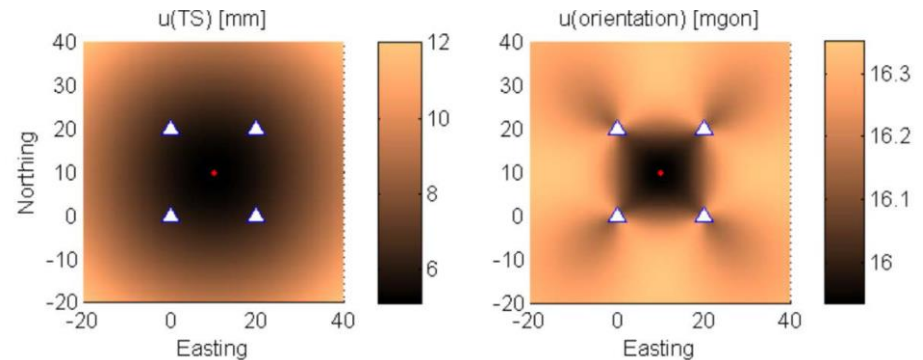
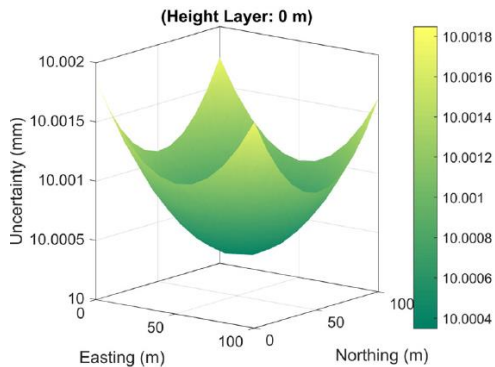


# Combination of total station and GNSS observations

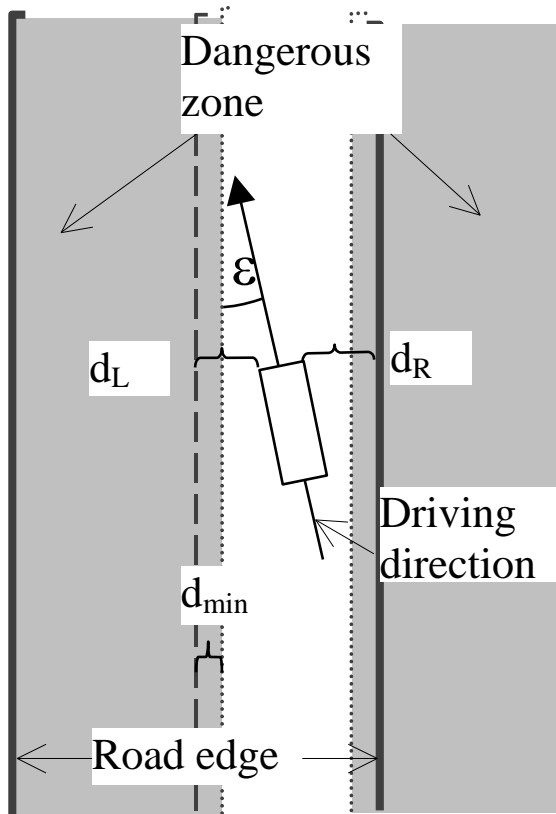
Analysis of precision of total station establishment using GNSS RTK

Determination of optimum geometry of GNSS points with respect to horizontal and vertical precision and reliability

Vertical Uncertainties of TS Establishment (mm)



# Car collision warning system based on RTK GNSS



Use of high accuracy RTK GNSS positioning as sensors in a car collision warning system

Tests carried out using RTK correction data from SWEPOS

Number of false alarms reduced with both float and fixed RTK positions compared to using autonomous GNSS

Work carried out by M. Horemuz and L. Sjöbjerg, KTH, in cooperation with the Swedish Transport Administration



# Education

Currently only the division of Geodesy and Satellite Positioning offers PNT related courses on bachelor, advanced and research level