Challenges of Kinematic Measurements

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FIG Working Week

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Structure

- Motivation
- Definitions
- Multi-Sensor-Systems
- Current Challenges
  - Machine guidance and total stations
  - Modeling of vehicle movements
  - Automated low-cost GNSS monitoring system
- Summary and Outlook

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Motivation

Standard Surveying / Geodesy

- static and descriptive

New Challenges in Surveying / Geodesy

- moving objects or moving sensors
- consideration of time
- consideration of forces / causes

WG 5.4 „Kinematic Measurements“

within FIG Commission 5

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Motivation

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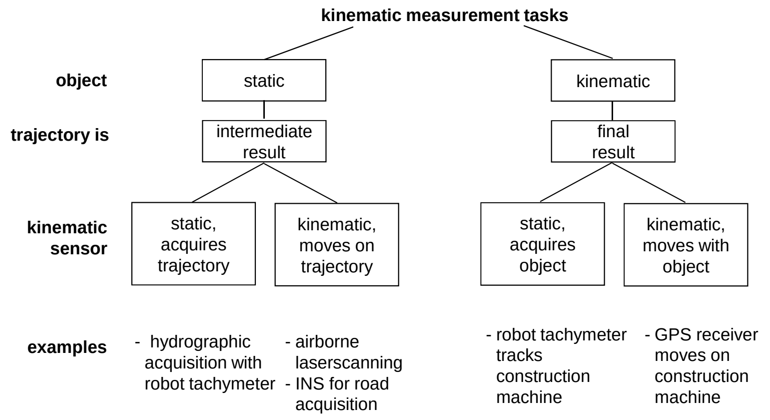
Definitions

Classification of kinematic measurement tasks



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Definitions

Classification of kinematic evaluation and modeling

- Identity Model / Congruency Model
  Geometric changes among minimum two points of time are investigated. The point movements are assumed to be zero. Time and acting forces are not considered. An example is the well-known statistical analysis of deformations.
  Static Model
  Static states of an object are investigated with respect to the different acting forces. Time is not considered. As an example a load experiment of a bridge may serve.
- Kinematic Model
  Time-related movements are described without consideration of acting forces. For the modelling more than two points of time are required. The model for the circle movement of a vehicle is an example.
- Dynamic Model
  Here the time-dependent movements are regarded as reactions of the object on the time-dependent acting forces. This is the most realistic picture of reality. A good example is to use the same model then in the kinematic case but introducing the steering angle as acting force.

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Definitions

Kinematic and static tasks

Kinematic Problems

Measurement Technique

Kinematic
e.g. navigation,
machine guidance

Static
e.g. landslide,
recent crustal movements

Evaluation Technique

Kinematic
Kinematic or Dynamic Models
e.g. circle movement of a car;
deformation of an object due to temperature

Static
Congruence Model or Static Model
e.g. congruence model of
deformation analyses;
load experiment on a bridge

Static Problems

Multi-Sensor-Systems are required !

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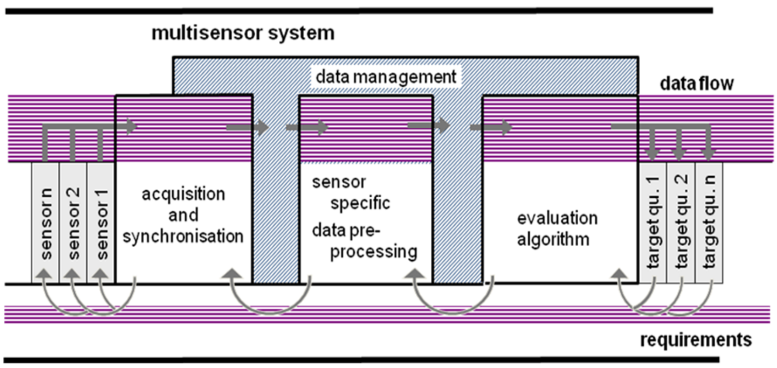
Multi-Sensor-Systems

Components of a multi-sensor-system



operation phase: data flow from left to right
design phase: requirement flow from right to left

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Multi-Sensor-Systems

Classification of multi-sensor-systems

• Space-distributed systems
In this case similar sensors are installed at different measurement sites.This is an typical example e.g. for monitoring surveys by measuring time-varying coordinates of a landslide by GNSS or total station.

• Redundant systems
For this system different sensors acquire the same measurement quantity. In this way the possibility to control the measurements and to find errors within the acquired data is given. A good example is the determination of the position using a GNSS receiver and a total station.

• Complementary systems
Here different sensors acquire different measurement quantities that are required to determine a target quantity. Typical examples are the determination of a horizontal angle and a horizontal distance to estimate the 2D-coordinates or the measurement of the yaw rate and the acceleration to realize dead reckoning for moving vehicles.

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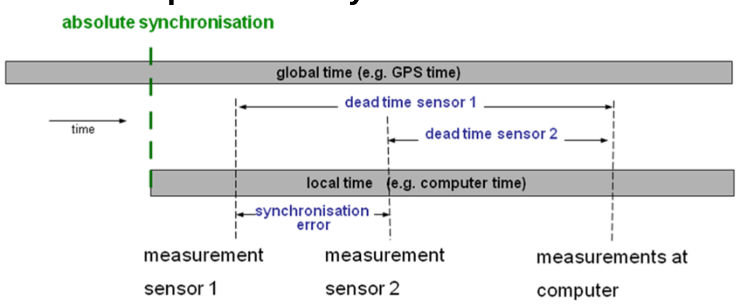
Machine guidance and total stations

Total station = complementary multi-sensor-system

Time-related problems: synchronisation and dead time



Dead time is of importance for realtime applications only, especially for control and guidance applications.

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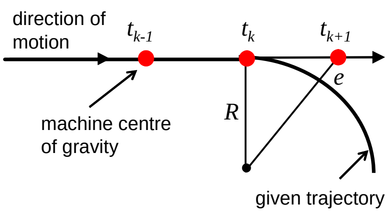
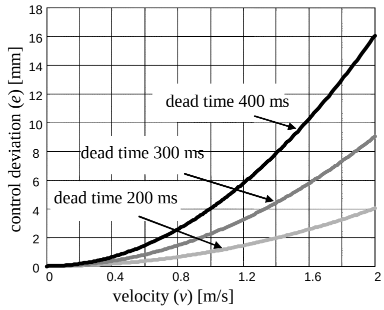
Machine guidance and total stations



Influence of dead time of total station on controlled curve drive



Influence of dead time on control deviation in dependence of velocity

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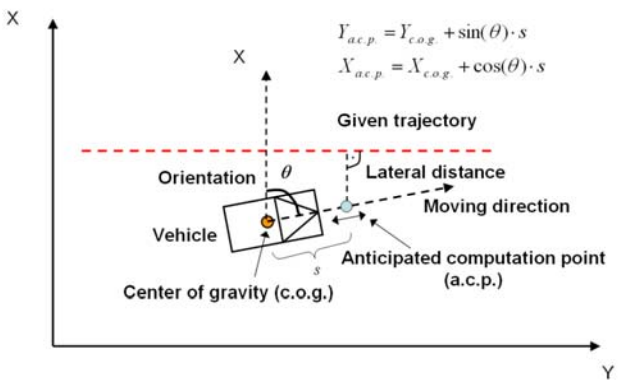
Machine guidance and total stations

Solution: Anticipated computation point



Control quality better than 2 mm (in laboratory) !

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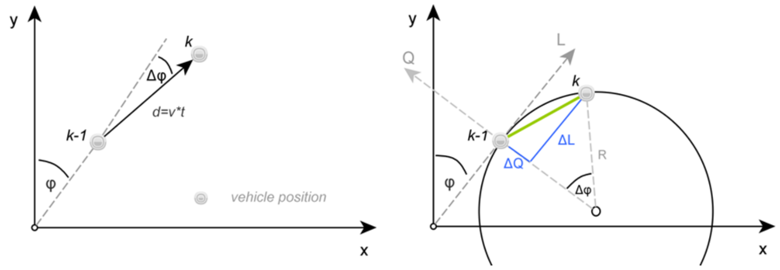
Modeling of vehicle movements

Redundant and complementary multi-sensor-system



Straight line or circle as dynamic model !

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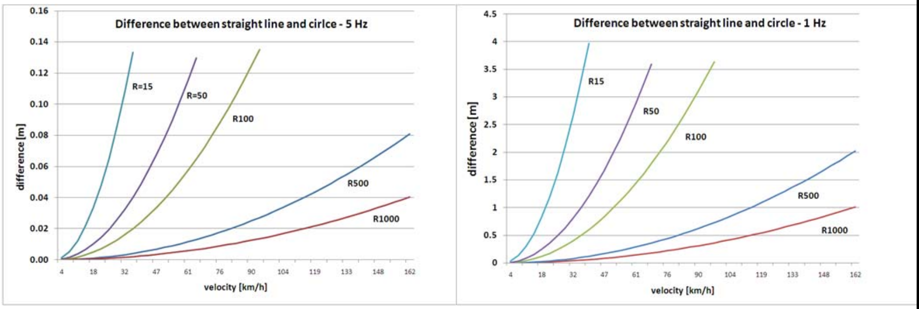
Modeling of vehicle movements



- **Straight line sufficient for most of the applications**
- **Precise applications (cm-level) require circle model**
- **Low data rate shows a need for circle model**

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Automated low-cost GNSS monitoring system

GNSS receivers = space-distributed multi-sensor-system

CabLynx router including
u-blox Lea-6T receiver,
ANN-MS antenna and shielding,
WLAN antenna,
solar pannel,
charge controller and battery.

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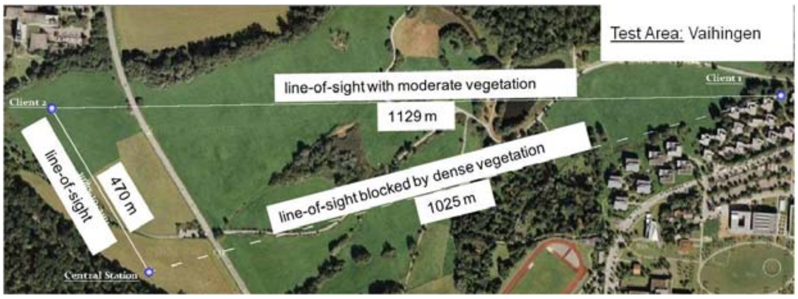
Automated low-cost GNSS monitoring system

First test measurements using three receivers



- **Dynamic routing of mesh topology is working**
- **Standarddeviation < 1 cm**
- **Deviations to given coordinates < 2 cm**

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Summary

- Kinematic measurements are an important field for surveying
- Multi-Sensor-Systems are widely excepted
- Space-distributed, redundant and complementary systems exist
- Time-relations, modelling and efficiency are possible working and research fields
- FIG Commission 5 „Positioning and Measurements“ offers the possibilty to work within these topics in WG 5.4 „Kinematic Measurements“

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Thank you very much for your attention!

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