Monitoring in Geo-Applications

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Geotechnik Hydrogeologie Monitoring

Content

- *Introduction „Monitoring“*
- *Terms and definitions*
- *Concept of Uncertainty of Measurements GUM*
- *Data Acquisition and Monitoring Methods*
- *Challenges on data acquisition*
- *Conclusion and future prospects*

Introduction

Monitoring

systematic acquisition of information/data to observe a situation for any changes which may occur over time, using a measuring device of some sort.

Measurement

is the process or the result of determining the magnitude of a quantity (e.g. length, mass), relative to a unit of measurements (e.g. m, kg)

The science of measurement is also called the field of metrology

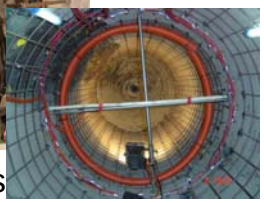
Introduction

Measurements

- *various quantities*
- *different environment (Lab, In-Situ)*
- *various methods with a wide range of different devices*
- *limitation in in degree of perfection*
- *confidence in results, reliability of source of information*

„Das Messbare messen,
das nicht Messbare messbar machen.“ *Galileo Galilei*

Examples

Tunnel und Caverns


Deep Excavations


Landslides and Rock falls

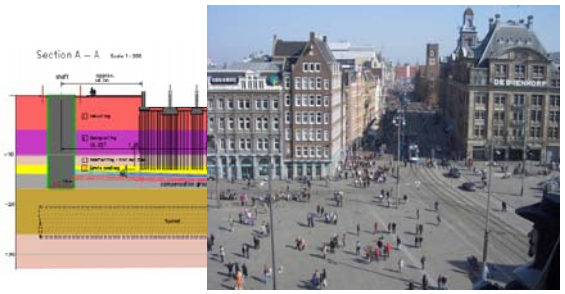

Dams and Retaining walls

Examples



Structural Monitoring

Foundations



Settlements for Compensation Grouting

Examples

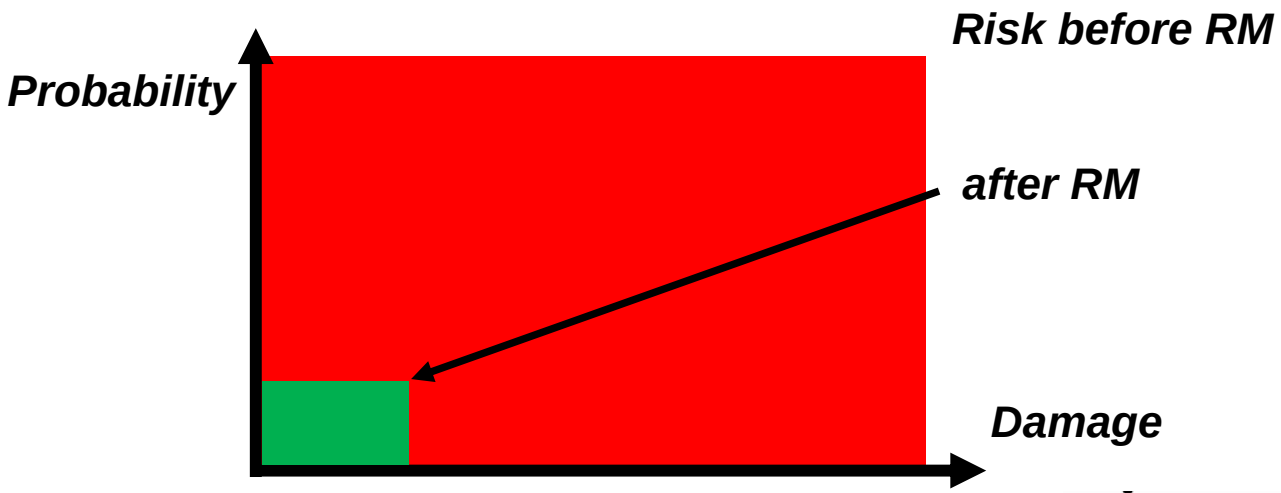
Hydrogeological Testing

Underground Laboratories

Ground Water

Risk Management

Damage x Probability = Risk



Risk Management – Systematic Approach to Planning

What are the problems to be solved

Physical quantities

Measuring principle

Type of instrument selected

Measuring programm

How are data processed

Form of contractural organisation

Interpretation of results

Problem solution

Instrumentation

Geo-Applications

Risks from natural or anthropogen processes managed by cross-area and cross function teams

role of Geomatic Engineers:

allrounder in applications

processes, vocabulary, requirements, display of results

specialist in monitoring

to master devices, methods, limitations, proof of results

Specialist in Monitoring - Expectations

- *Understanding the tasks and their requirements*
- *Knowing the devices (physical principal, properties of the sensors, sensitivity to environmental influences)*
- *Applying the methods in a proper manner*
- *Carrying out installations and measurements carefully*
- *Analyzing raw data reliable*
- *Validating results and presenting them clearly*

Terms

Calibration

Resolution

Uncertainty of measurements

Tolerance

Standard Deviation

GUM

Accuracy

Precision

Error Propagation

Variance

Error

Reliability

Concept of Uncertainty of Measurements

„Wenn Einigung erzielt ist, wie der Begriff der Sache lautet, die erörtert werden soll, ist zu erklären, was mit diesem Begriff gemeint ist. Erst dann darf man in das Gespräch eintreten.“

Cicero, de re publica 1,38-41: Die Staatsdefinition

Concept of Uncertainty of Measurements

- *Guide to the Expression of Uncertainty of Measurement*
- *1993 published from ISO/BIPM, Revision 2008*
- *Procedure to estimate the uncertainty of measurements in order to make results comparable*
- *Extended model of Gaussian error propagation for systematic error*
- *Calculation of variances from repeated measurements (Typ A) and from other information sources (Typ B)*
- ***Uncertainty of Measurement (Messunsicherheit)**: non-negative parameter characterizing the dispersion of the quantity values*
- *Result: quantitative value to describe the quality of measurements*

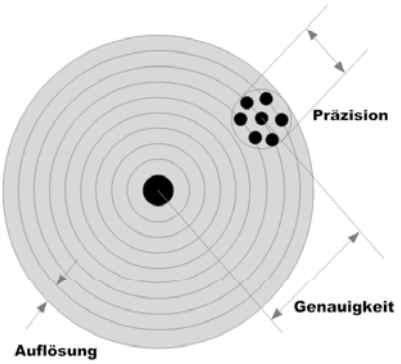
➔ *Estimation of reliability of measurement results*

Terms and Definitions

Qualitativ Expressions

- *Accuracy: closeness of agreement between a measured quantity value and a true quantity value*

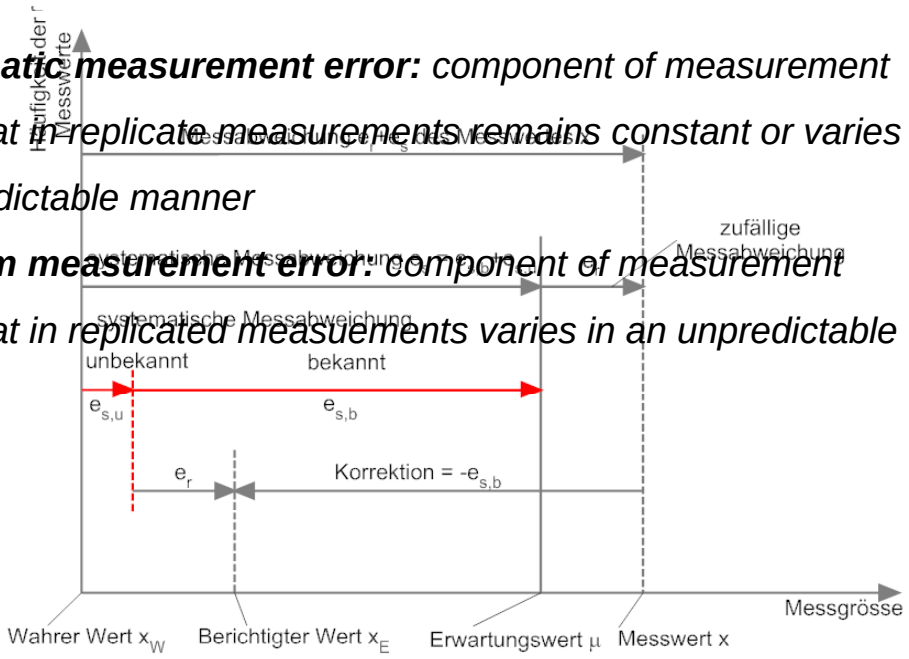
- *Precision: closeness of agreement between measured quantity values obtained by replicate measurements (…) under specified conditions*



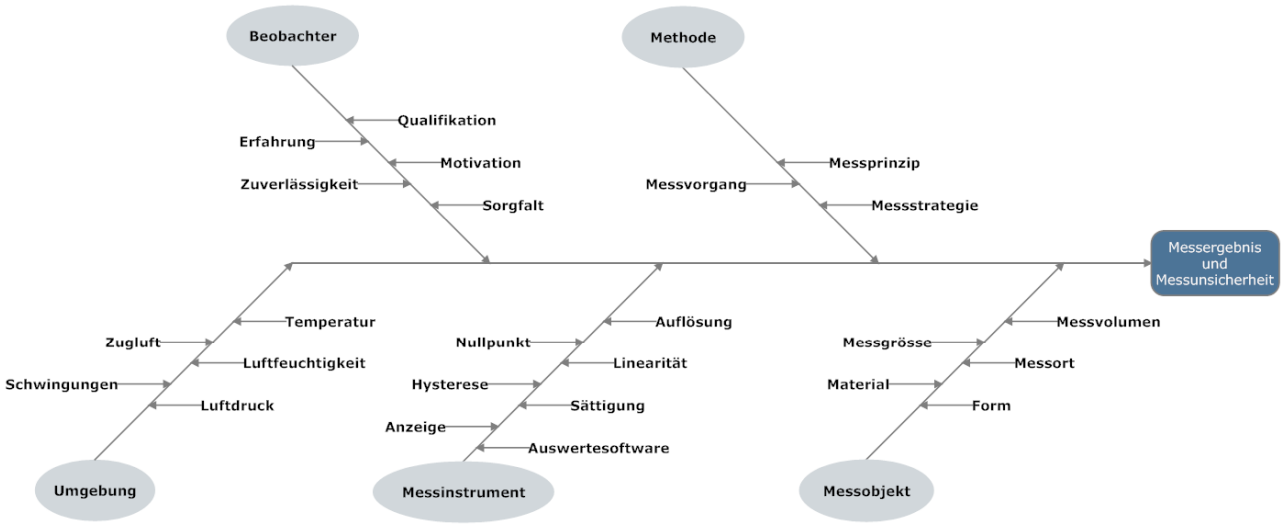
Terms and Definitions

Systematic measurement error: *component of measurement error that in replicate measurements remains constant or varies in a predictable manner*

Random measurement error: *component of measurement error that in replicated measuements varies in an unpredictable manner*

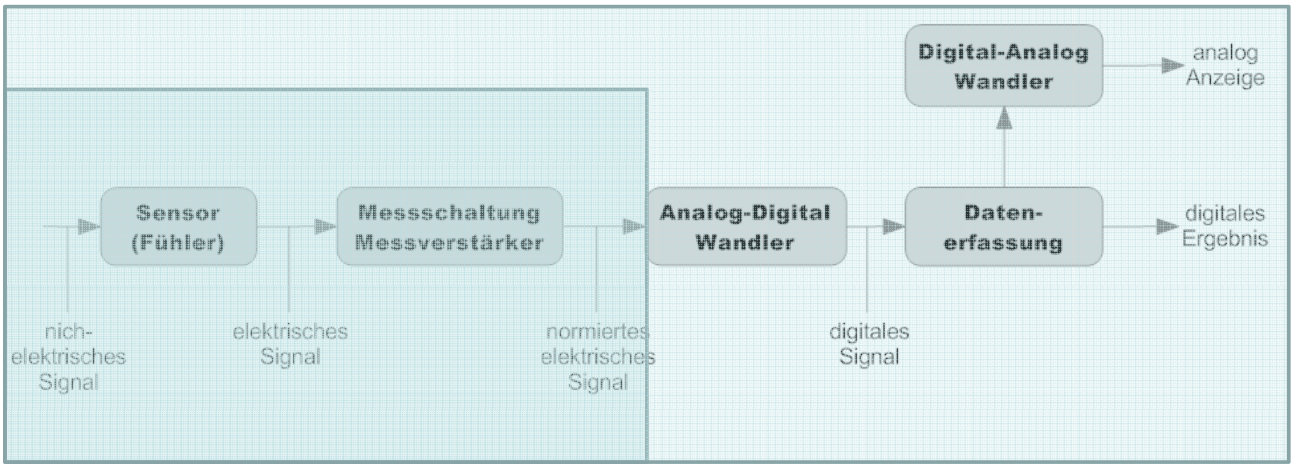


Cause and Effect diagramm (Ishikawa)



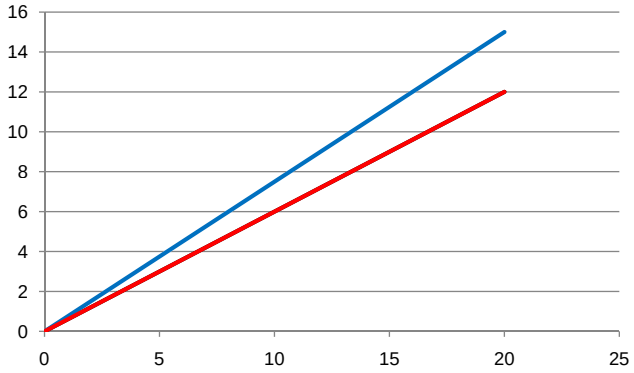
Data acquisition and monitoring methods

Measuring Chain – Device/Sensor Challenges



Device-specific effects

- *Linearität/Linearity*



Korrektion: Multiplikation mit konstantem Faktor

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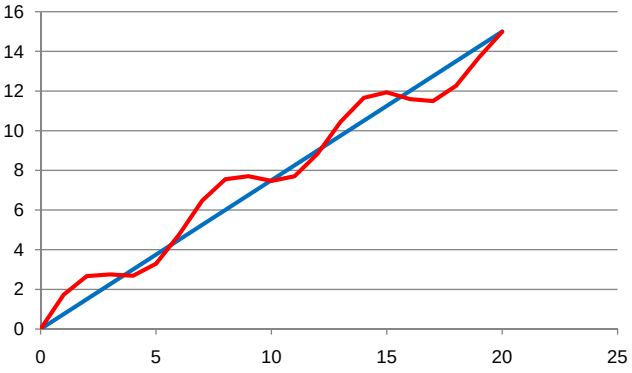
Device-specific effects

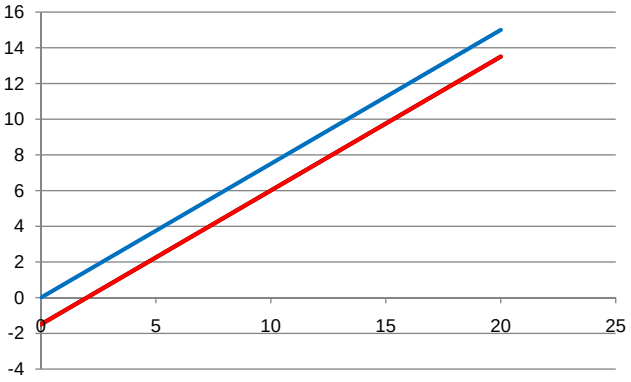
- *Linearitätsabweichung/Error of linearity*



Korrektion: reproduzierbare Abweichung durch Korrekturpolynom oder punktweise Korrektur (Look-Up Table) annähern

Device-specific effects

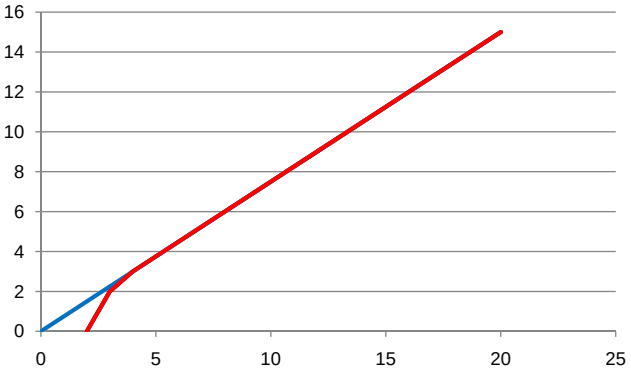
- *Nullpunkt /Offset*



Korrektion: Addition eines Korrekturwertes

Device-specific effects

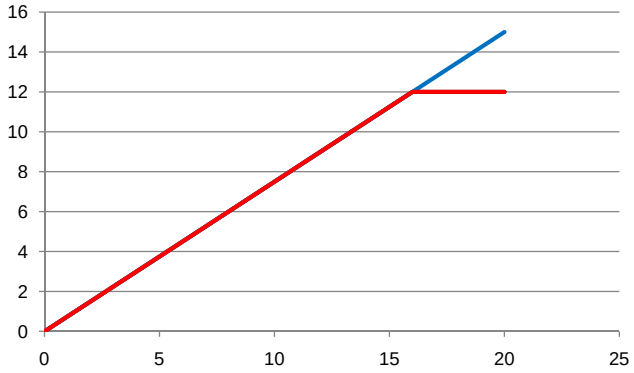
- *Ansprechempfindlichkeit/ Response sensitivity*



Massnahme: Messbereich auf linearen Bereich beschränken

Messgerätespezifische Einflüsse

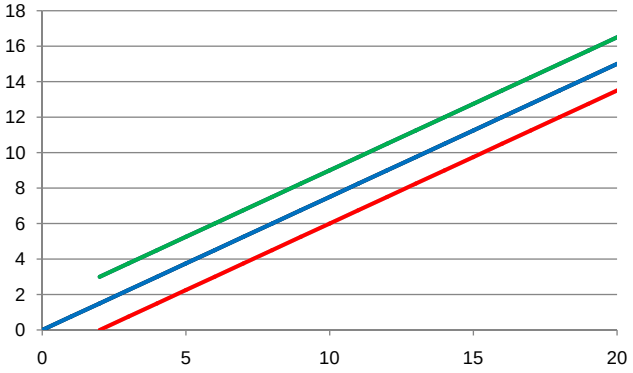
- *Sättigung/Saturation*



Massnahme: Messbereich auf linearen Bereich beschränken

Device-specific effects

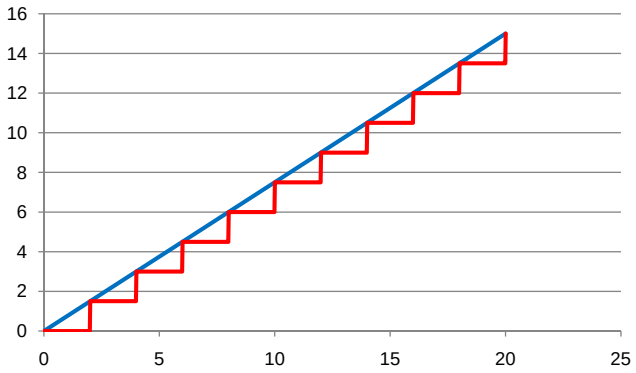
- *Hysterese/Hysteresis*



Massnahme: Konvention über gleichbleibende Messrichtung oder Korrektur über funktionale Beschreibung

Device-specific effects

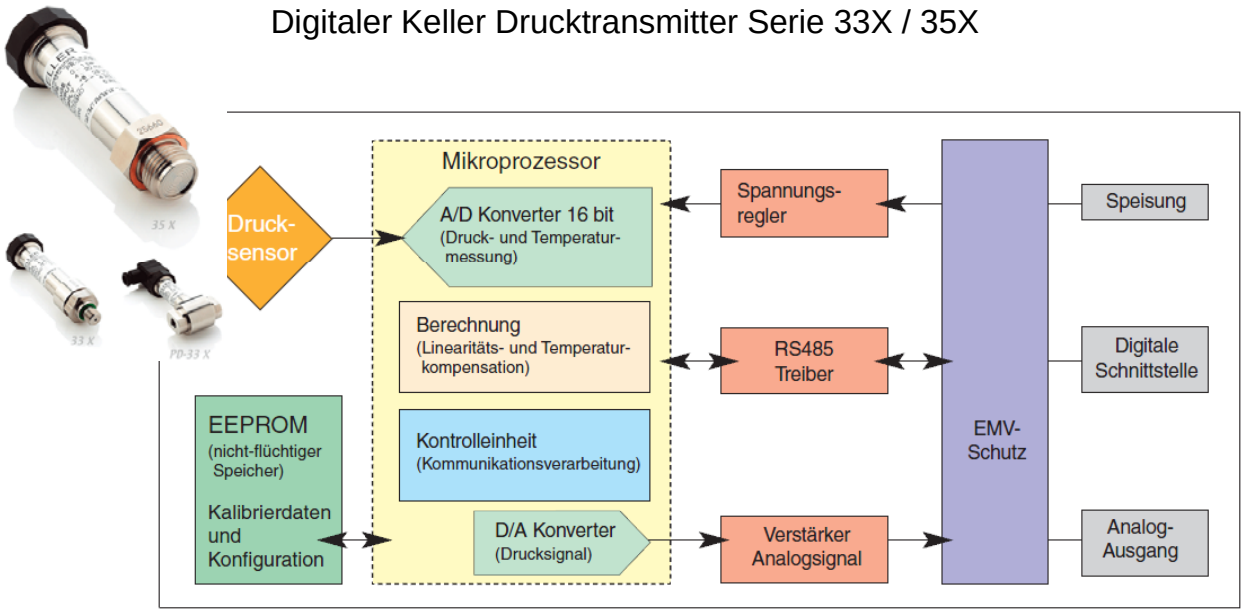
- *Auflösung /Resolution*



Massnahme: Erhöhung der Anzahl Digitalisierungsschritte

Exsample: Pressure Transducer

Digitaler Keller Drucktransmitter Serie 33X / 35X



aus: Fachbeitrag Serie 33X / 35X, www.keller-druck.com

Data Acquisition Systems

GeoMonitor II

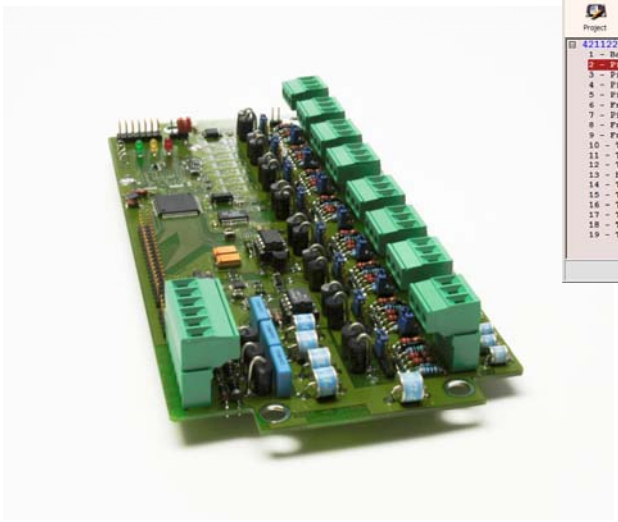
Data Acquisition and Control Software

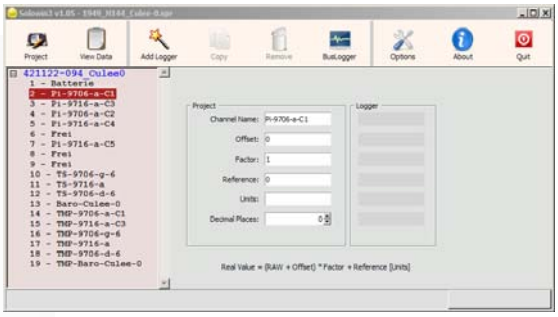
The leading choice for automatic data acquisition, monitoring and control

- Flexible, robust, powerful
- Wide range of devices, loggers and sensor types
- Sophisticated alarms
- Real-time calculations
- Single cable connections
- Remote control
- Automatic transfer to WebDAVIS

Solexperts Data Logger with GPRS

For tiny data acquisition projects





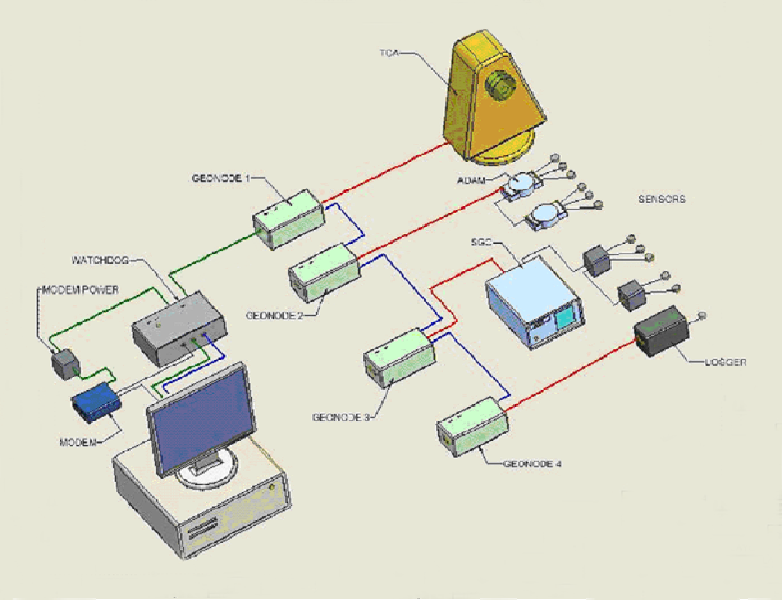
- Easy to use
- Battery powered
- 8 Channels @16 bit, various signal types
- Remote sensor configuration
- Automatic transfer to WebDAVIS

GeoMonitor II

GeoMonitor hardware offers many advantages:

- **Industrial PC**
- **Watchdog**
- **Interfaces/GeoNodes**
- **Single cable connections**
- **Sensors: Analog, Vibrating wire, Digital**
- **Devices: Total stations Digital levels, others**

System Overview



GeoMonitor II

Hardware

Industrial PC

Watchdog

GeoNode

Industrial PC:
- **Rugged, field proven**
- **Fanless, dust proof**
- **Small size, low power**

***Watchdog*:**
- **Monitors system for additional security**
- **Electrical isolation (lightening protection)**
- **Signal conversion**
- **Internal & remote reset**

GeoNode/Interfaces:
- **Simultaneous measurements, faster scans**
- **Alarm switches (available in the office and field)**
- **Universal translator connecting a wide range of devices / loggers / sensors**

Datenerfassungssysteme

GeoMonitor II

GeoMonitor II

Loggers

Devices

Sensors

Hardware

- ***Loggers:***
  - **Solexperts systems**
  - **Adams 4000/5000**
  - **Campbell Scientific**

** Many others available*

- ***Devices:***
  - **Robotic Total Stations**
  - **Digital Optical Levels**
  - **Laser Distance Meter**

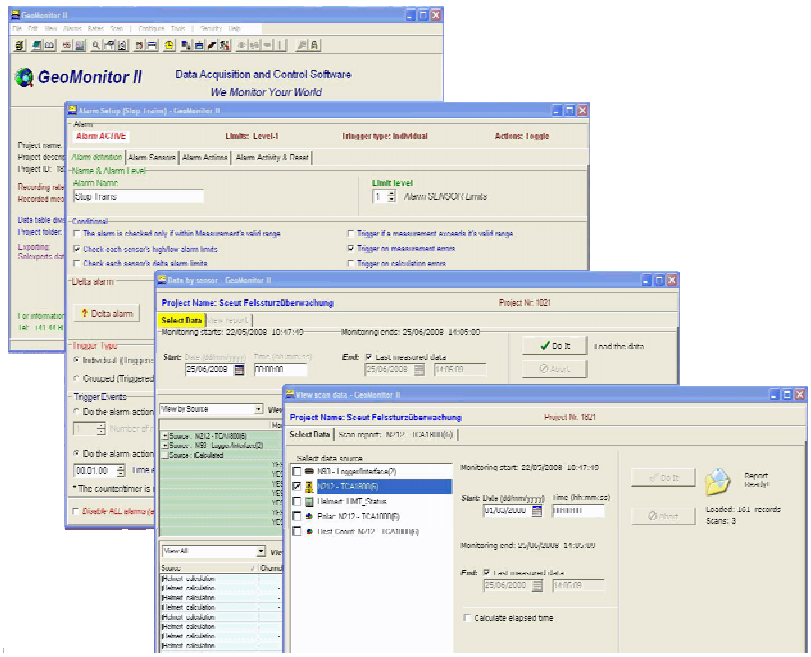
- ***Sensors:***
  - **Pressure, Temperature, Load, Strain, Movement, Tilt, etc**
  - **Various analog Signals (mA, Volt, mV/V)**
  - **Vibrating wire**

GeoMonitor II

Software

Benefits:

- **Flexible, powerful, robust**
- **Simple to operate, made to be used in the field.**
- **Sophisticated alarms**
- **Real-time calculations, graphics and reports**
- **Remote control**
- **Automatic exports, reports and transfer to Internet**



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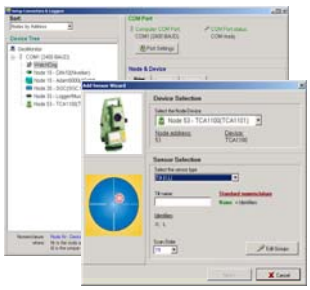
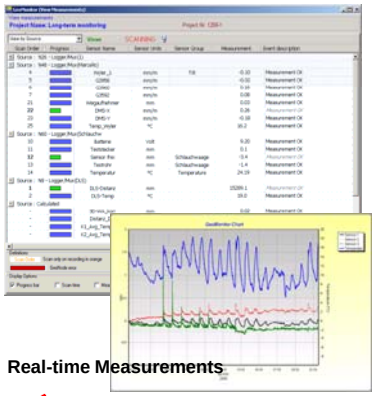
GeoMonitor II

Software



Sensor seutp



Real-time Measurements

Flexible:

- **Modify recording rates while scanning.**
- **Add, modify alarms while scanning.**
- **Easily add loggers, devices, sensors.**

Powerful:

- **Simultaneous sensor scanning**
- **Real-time calculations (equations, statistics, Helmert, polar, etc.)**
- **Group alarms, multiple triggers, multiple: low, hi, deltas limits**
- **ODBC database, ASCII, Excel, Automatic Internet upload**
- **Measurement meta data (errors, alarm status, valid range, etc)**
- **System and user action event logging**
- **Secure login, multiple access levels**
- **Automatic restart**

Robust:

- **Tested, field proven software**
- **Used by clients <u>and</u> Solexperts**

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SOLEXPERTS

Data Acquisition – Hardware Challenges

- *Components (reliability, compatability)*
- *Housing (water, dust proof IP-Class)*
- *Powering, Power failure*
- *Data bus topology (length, number of participants)*
- *Connection (Cable, Radios) and Connectors*
- *Addressing and Communication (Protocol)*
- *Protection against weather and vandalism*

Data Elaboration and Processing – Software Challenges

- *Impact from „human being“:*
  Input error, assignment, labelling, mix-up
- *Numerical operations, rounding, data types*
- *Extrapolation of calibration data*
- *Synchronisation of measurements*
- *Measuring Frequency, Anti-Aliasing*
- *Recording rules, data storage, back-up*
- *Outlier detection*
- *Alarming, avoiding false alarms*

Beispiel: Mathematische Operation

- *Berechnung der Varianz aus dem Mittelwert*

$$s^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

Abspaltung des Mittelwertes, Aufsummieren der Differenzen

- *Berechnung der Varianz aus fortlaufenden Messungen*

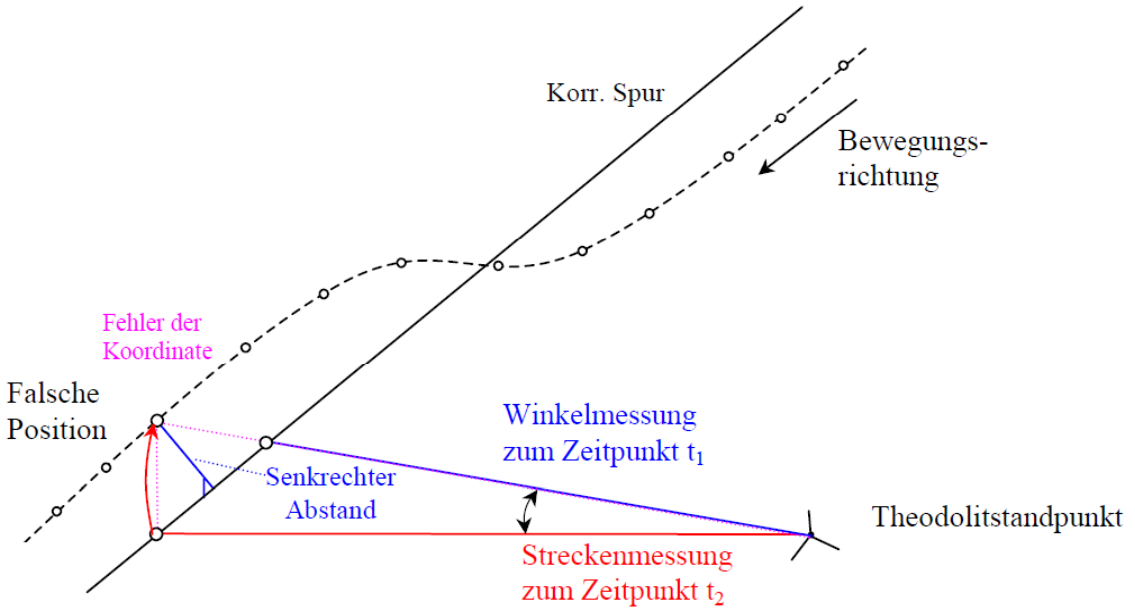
$$s^2 = \frac{1}{n}\left(\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2\right)$$

Vorsicht: Werte werden quadriert!

Nach IEEE 754 Datentyp:

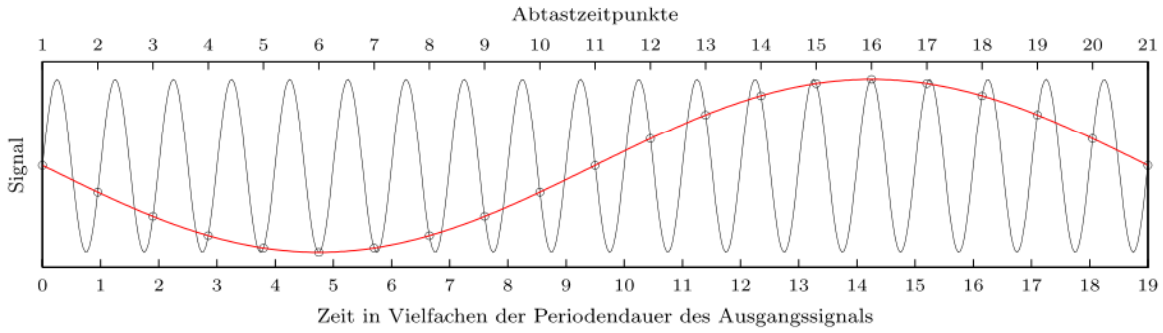
32 bit (Single) 7-8 Dezimalstellen, 64 bit (Double): 15-16 Stellen

Beispiel: Mangelnde Sychronisation



Aus: Stempfhuber, W. (1998), Kinematische Vermessung mit dem zielverfolgenden Tachymeter

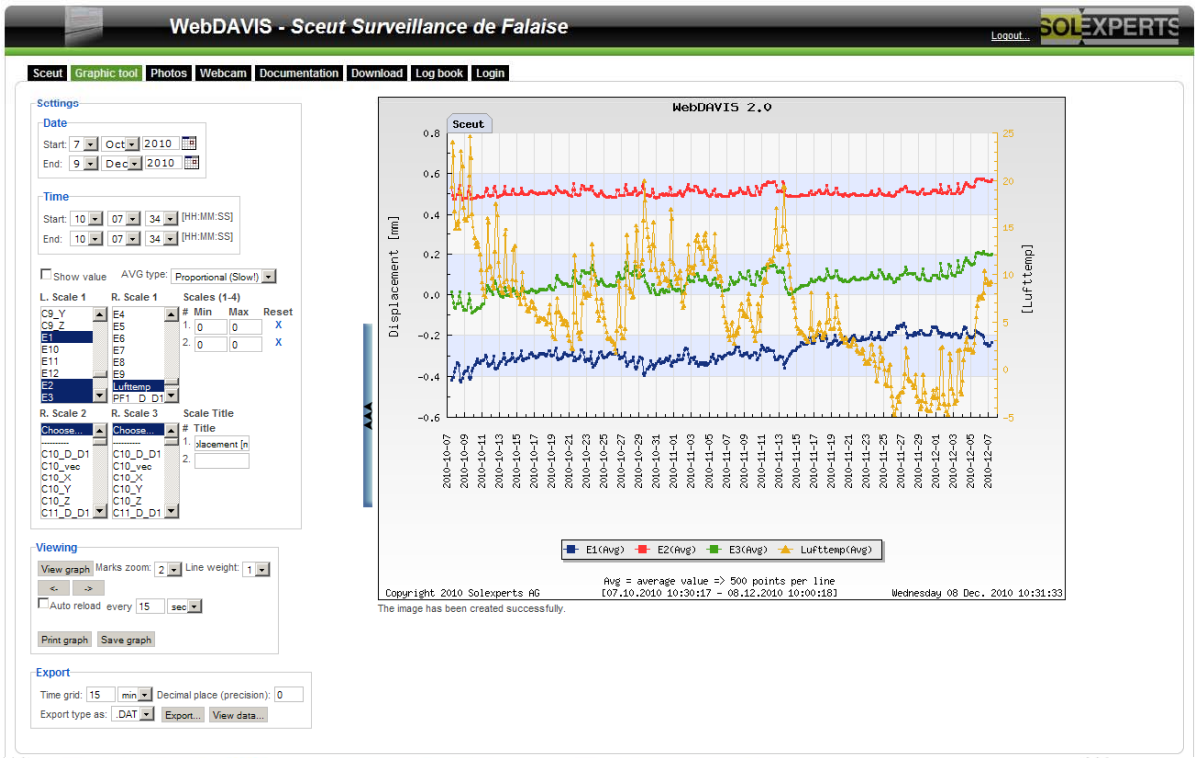
Beispiel: Anti-Aliasing



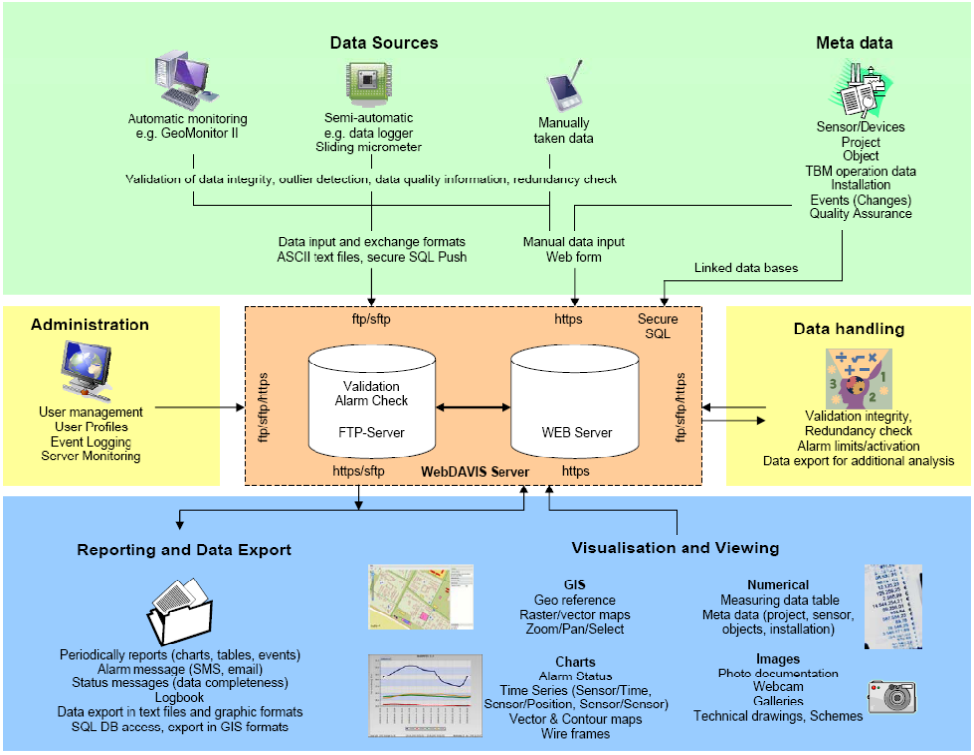
Abtastung mit: $f_{Abtast} > 2 * f_{max}$ (Nyquist-Shannon-Abtasttheorem)

Massnahme: f_{max} ermitteln, Tiefpassfilterung

WebDAVIS – Data Visualisation



WebDAVIS - Concept



Conclusion and future prospects

- *See monitoring as a comprehensive process*
- *Understanding the measuring principles from devices and sensors*
- *Deal with systematic effects of black boxes*
- *System check to ensure full functionality*
- *Uncertainty of measurements as a quality expression*
- *Tools for data acquisition and data management*
- *Work honestly and censoriously*

Thank you for your attention!