On the Potential of Geodetic Techniques for the Navigation of Construction Processes

by

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Agenda

- Construction and Surveying
- Typical Applications
- Requirements for Geodetic Participation in Construction Process
- Modern Instrumental Developments
- Data processing and Communication
- Construction Process as Dynamic System

Construction and Surveying

Situation now : Services from Surveying

Phases of construction		Surveying delivers :
• Idea/ Feasibility	<=	Maps, GIS
• General Planning	<=	Detailed GIS
• Design	<=	Coordinate references
• Real Construction	<=	Setting out, quality control
• Utilisation Phase	<=	As-built documentation
Reconstructions		+ Monitoring
• Demolition		

Ideal situation : Real Integration

Real Integration of Surveying in Construction Process

Design phase	<=>	*3D-coordinates (virtual model)*
		‖ V
Real construction phase	<=>	*All geometrical aspects by surveying engineering*

Typical Applications

- Tunneling : Steering of Tunnel Drilling Maschines (TDM)
  with total stations and electronic laser systems
- Roads : Steering of pavement machines
  with total stations
- Earth work : Steering of dozers and graders
  by rotating levels and/or GPS
- Structural engineering : Basic setting out
  + checking of pre-fabricated concrete elements
  + quality control for setting out
- Bridges : Basic setting out
  + monitoring the behaviour of the structure during
  critical phases of the construction

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Requirements for stronger integration of surveying in construction processes :

- *Measuring techniques to determine geometry of arbitrary forms and structures without targets*
- *Processing techniques to compute geometry and derivation from design model in real time*
- *Communication and data structure for interaction with information systems used in construction*

Modern Measuring Techniques

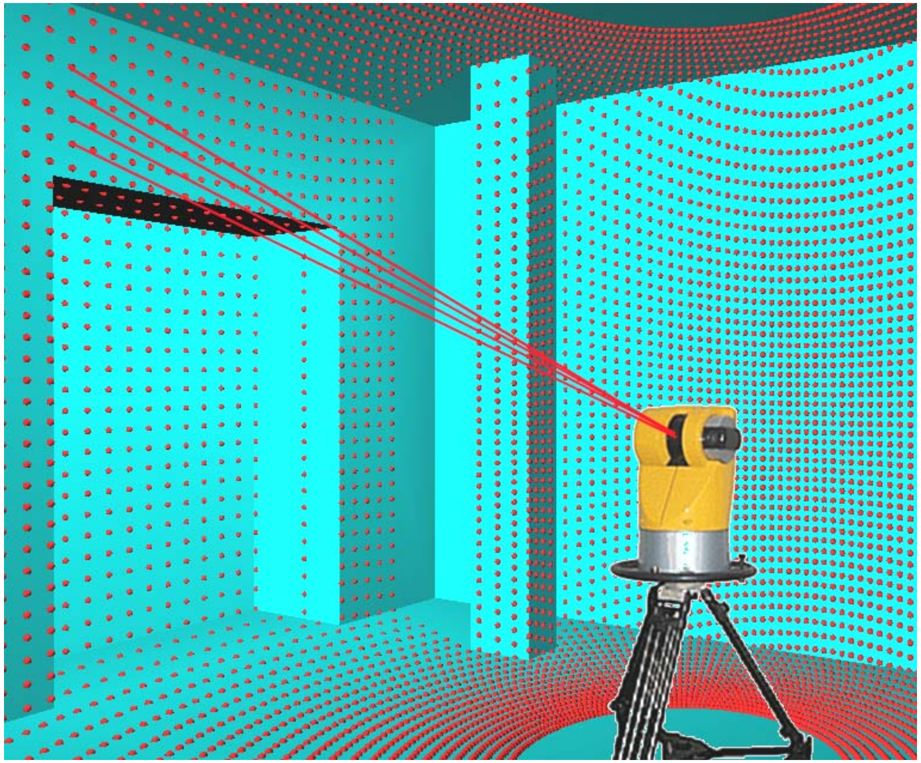
Requirements :

- Geometry of arbitrary forms and structures
- Without targets
- Flexible : Fast and from arbitrary position
- Sufficient accuracy

Instruments :

- Laserscanner
- Lasertracker
- GPS (?)
- Automatic Total Stations (?)

Applications : „Continuous in Space"

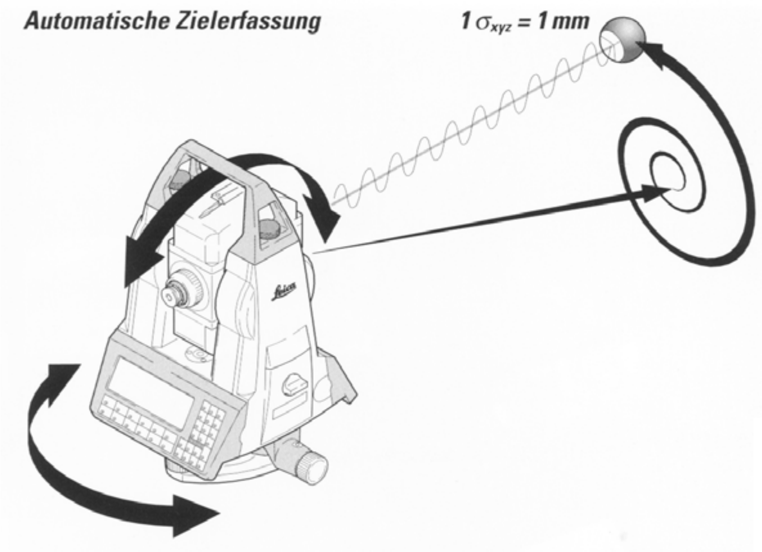


Scanning Systems : Remote capture of the geometry of a surface by a raster of predefined points without specific targets

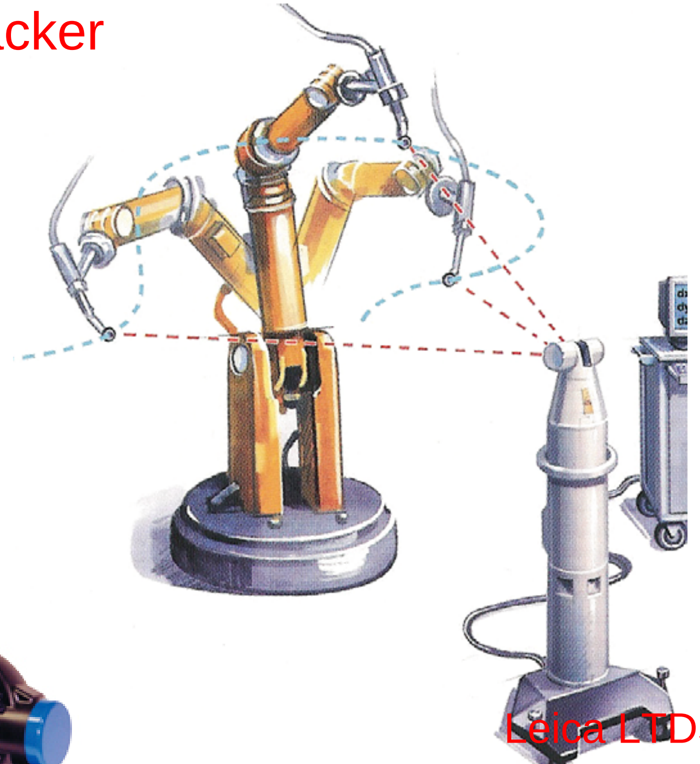
Tracking Systems : Follow up a specific reflector which is „in touch" with the surface of an object

Applications „Continuous in Time“ (Tracking Systems)

Automated Total Stations



Lasertracker



Leica LTD500

FARO

Different Laserscanners

Leica Cyrax 2500	Callidus Callidus Precision Systems	Imager 5003 Zoller + Fröhlich

(Schwarz 2003)

Characteristics of some commercial lasersanners

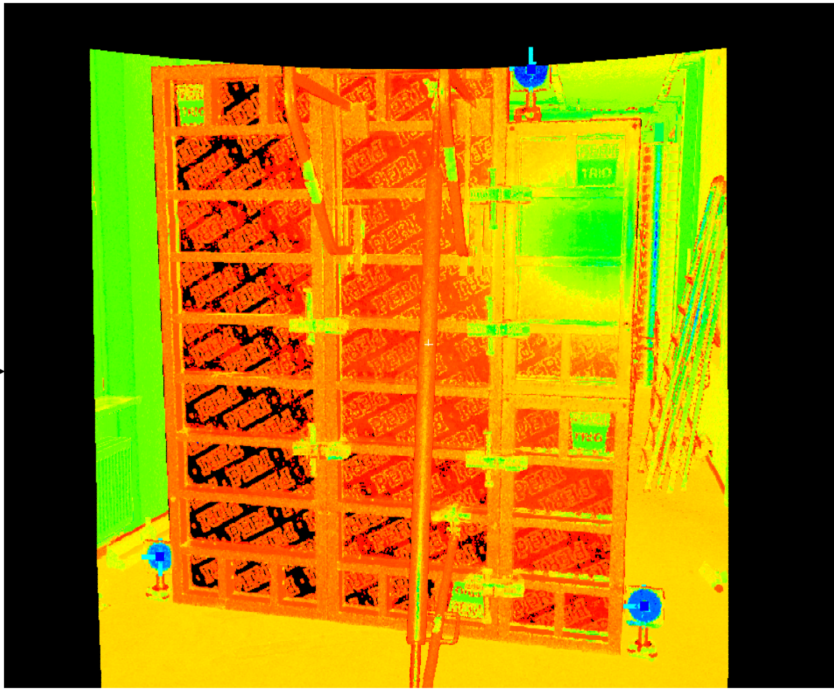
	CYRAX 2500	***Callidus V1.1***	***Zoller+Fröhlich***
Measurement technique	*Time of flight*	*Time of flight*	*Phase shift*
Position accuracy	*6mm*	*5 mm*	*3 mm*
Field of view (H&V)	*40º x 40º*	*360º x 150º*	*360º x 310º*
Scanning rate	*1 000 point/ s*	*28 000 point/ s*	*625 000 point/ s*

Potential of 3D-Laserscanning

To determine

- arbitrary objects,
- 3-dimensional,
- with correct scale,
- in a few minutes,
- complete

Back view of 2
form elements
from PERI



„Cloud of Points“ with about
1 Million 3D-points.
The colors indicate remission values

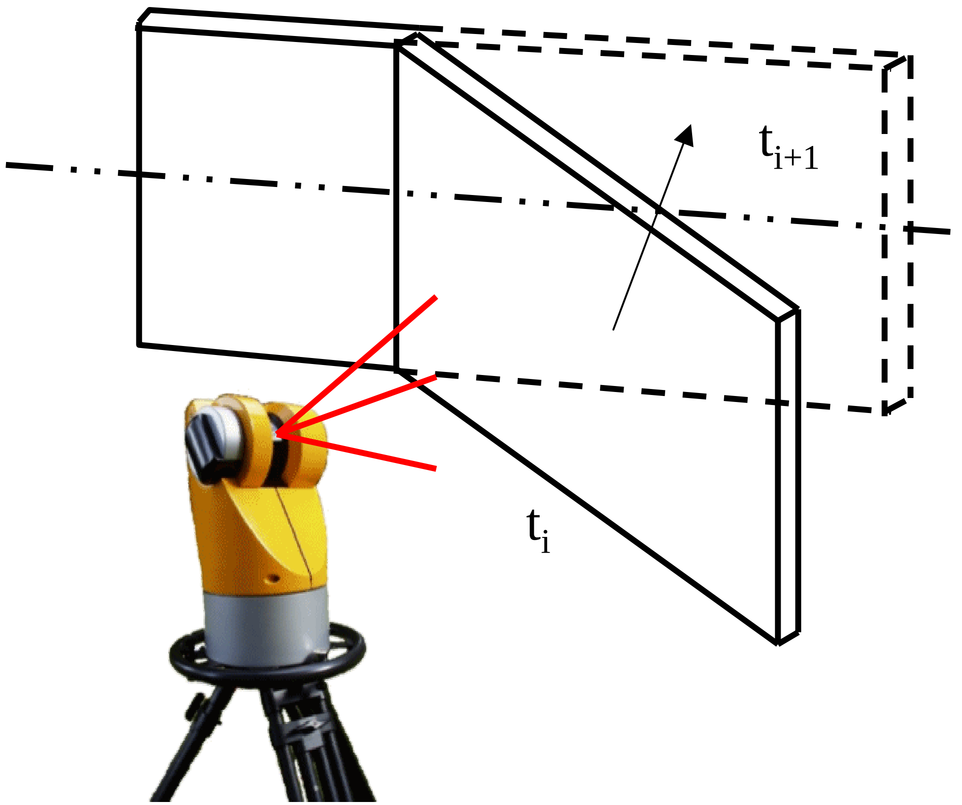
Application of 3D-Laserscanning to control a form

To control :

- position in reference coordinate system

- angles between different forms

- flatness within form



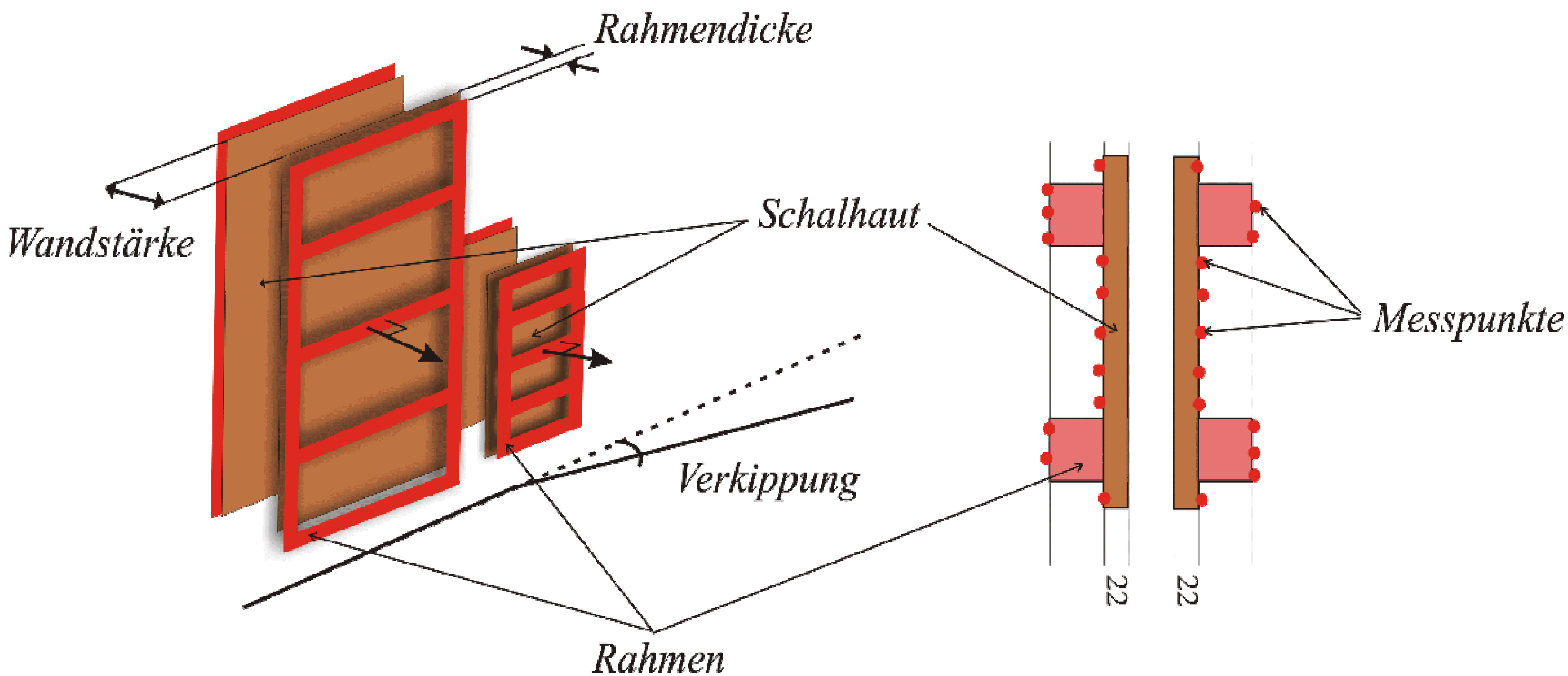
Requirements :

- without interrupting the construction process

- partial visibility has to be sufficient

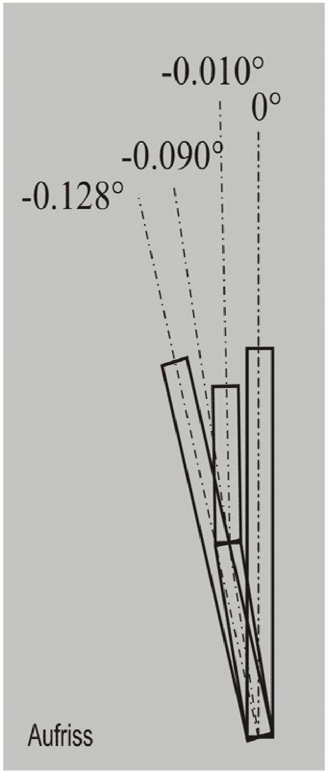
Procedure to determine a form :

Objective : Geometrie of the inner surface (skin)



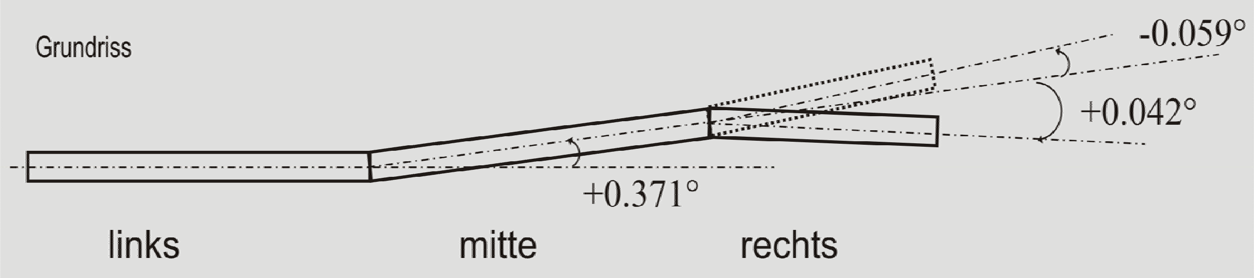
The inner surface is not observable directly. By optical scanning the outer surface has to be determined (Fig. On the right). Knowing the internal geometry of the form, the inner skin can be computed.

Results



Tilting of the 2 form elements :

1. Tilt in vertical direction (cross section)
2. Tilt in horizontal direction (ground plan)



Further aspects :

- Internal flatness of elements
- Absolute position of form elements
- ...

Real Time Processing

„Real Time“ : Time intervall until this information is required for next step

=> In construction : minutes, hours, days

Geodetic processing techniques have to be optimized to deliver in real time :

- geometry of arbitrary structures (not of a few points)
- derivation from design model

(including an evaluation of the significance of the differences)

=> Intelligent, automated processing algorithms

Example : 3D-Steering of a Dozer using GPS

- Fully automated height-control of the blade
- Continuous comparison bewteen model and reality
- Accuracy

  2-3 cm (Height)

Different Measuring Systems and Applications

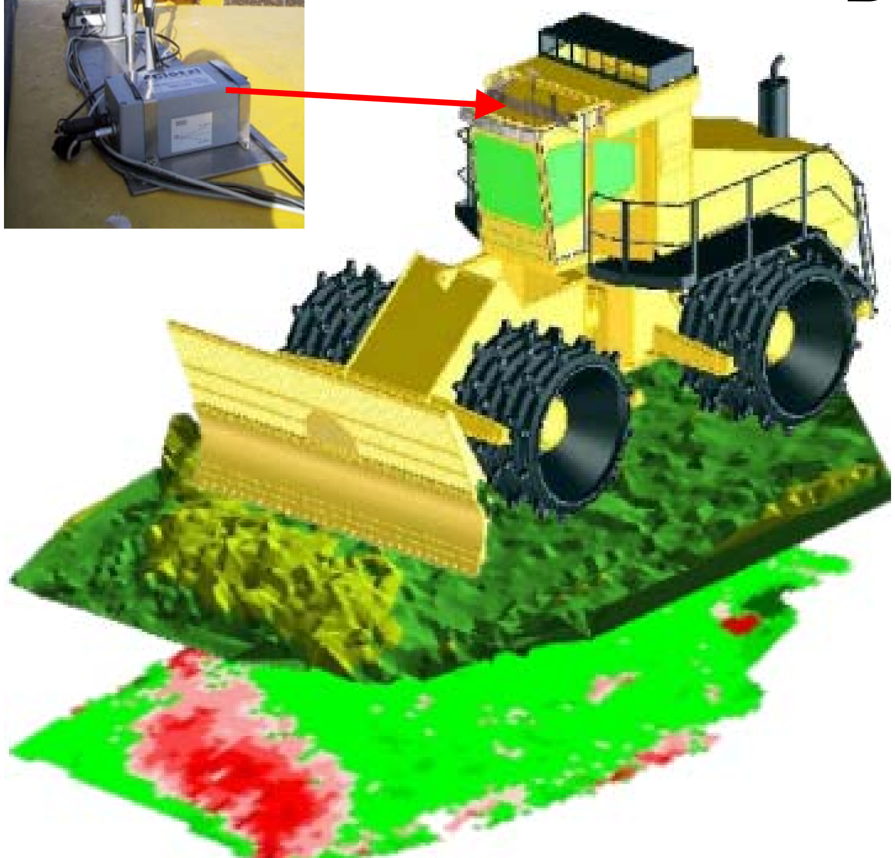
	Dozer	Grader	Road paving machine	Slipform paving machine
Major application field	Bulk eartworks and earthmoving	Fine grading, sideslop work	Asphalt surface for highways, concrete surface for runways	Concrete surface for highways, high speed railways, runways
Precision requirements	up to ± 2 cm	up to ± 5 mm	up to ± 5 mm in plane ± 3 mm in height	up to ± 5 mm in plane ± 2 mm in height
Guidance systeme	3-D systems: GPS or total station	Laser systems 3-D systems: total station	String lines or stakes Laser systems 3-D systems: total station	String lines or stakes Laser systems 3-D systems: total station

Tab. 1: Comparison of differnt types of construction machines

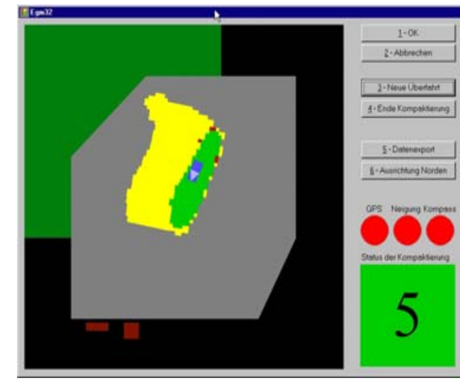
(Retcher, 2002)

Advanced Compaction Control System (ACCS)

Sensoren



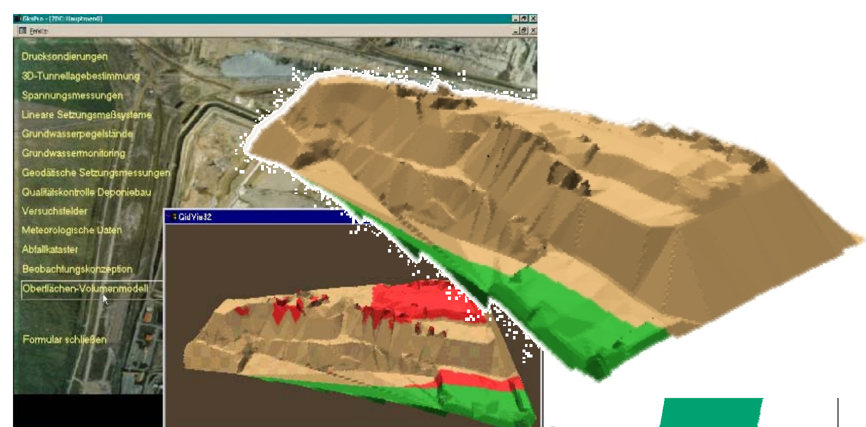
EGM32-Software



Data management

Visualisation

Dokumentation
and analyses

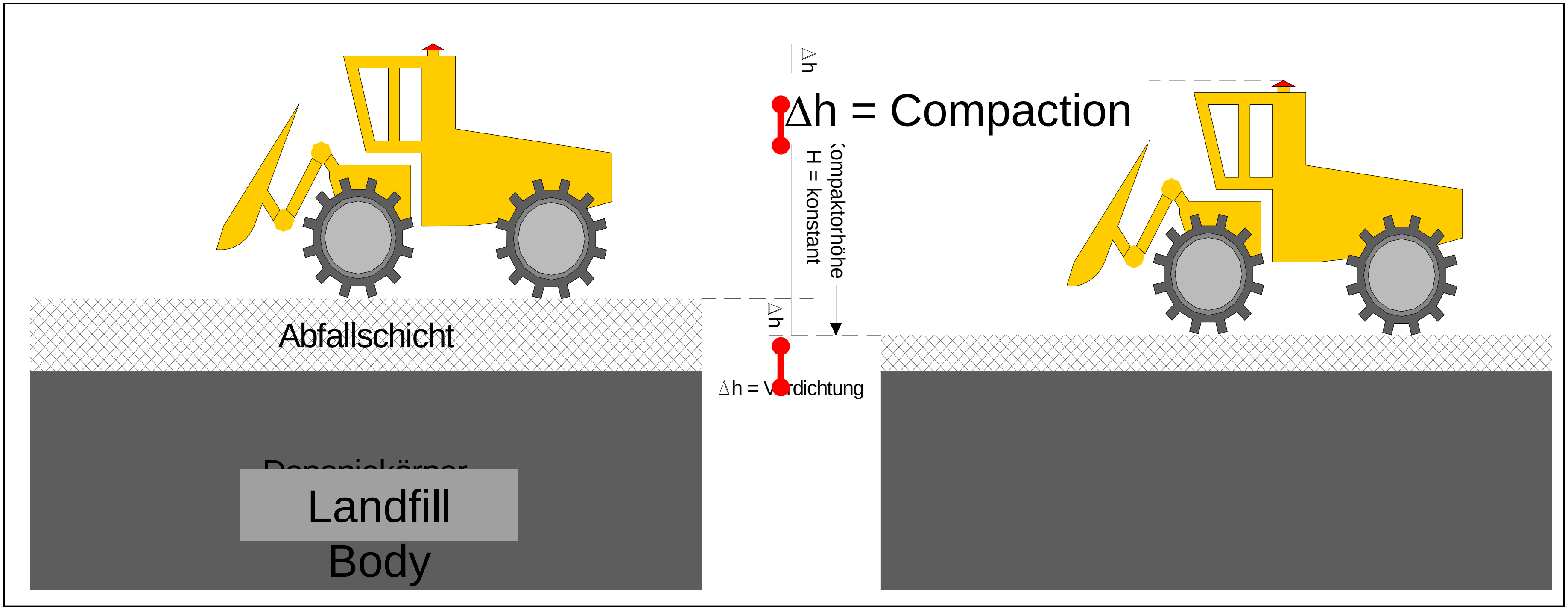


Project Objectives

- Volume Accounting
  - yearly, monthly and daily Accounting
- Control of the Emplacement Progress
  - Determination of the backfilled Dump Volume
  - Indication of the residual Remaining Volume
- Optimization of the Emplacement Technologie
  - Availability of Control Information
  - → Increase of the efficiency

→ Development of a Measuring System for continuous recording of Surface and Surface Changes

Geometrical derivation of surface changes



- Determination of the Compactor Position with Real-Time-Kinematik GPS
- Determination of the Compaction in case of High-Differences of individual Crossings

Systemconfiguration

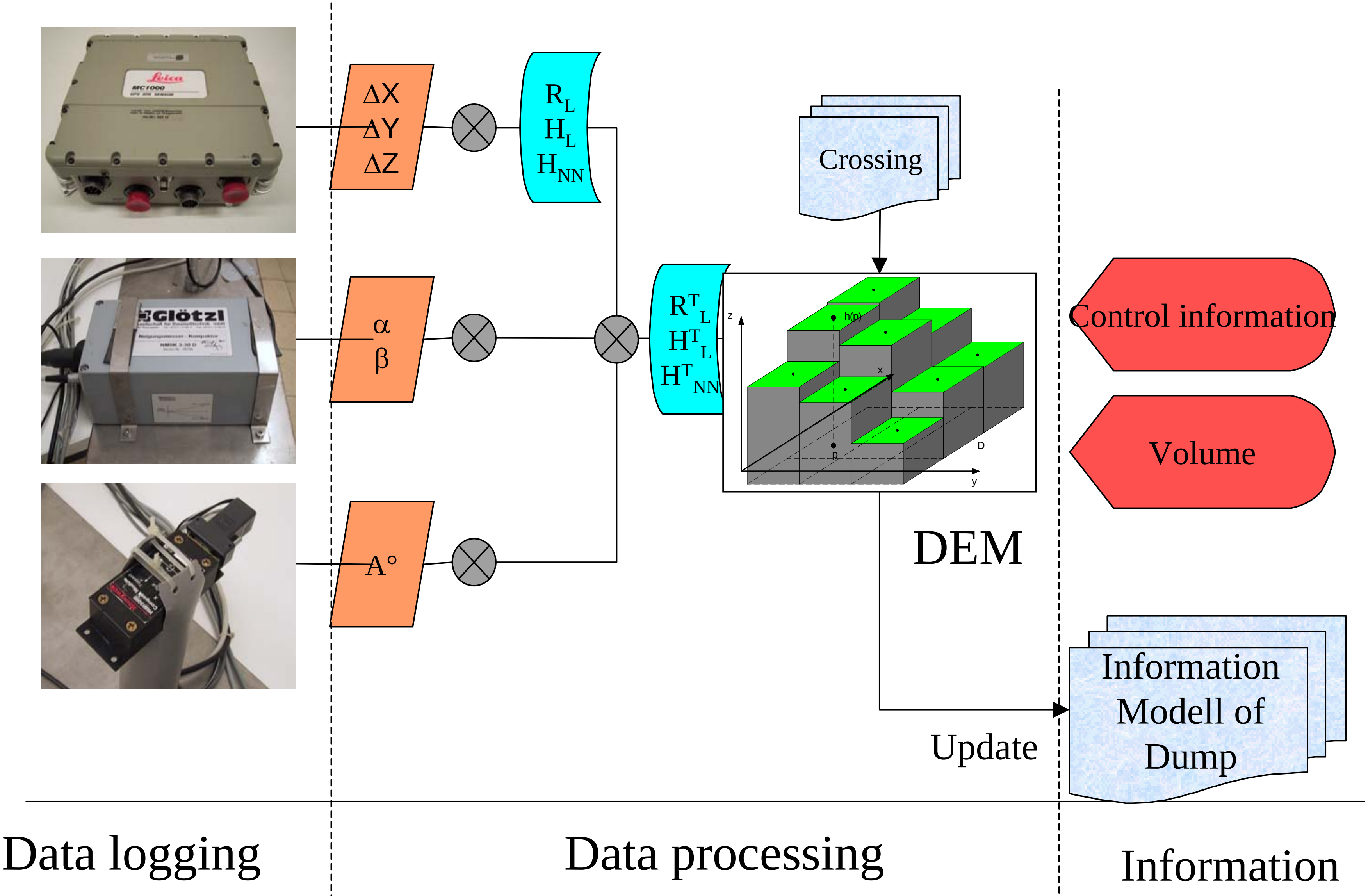
- GPS-Antenna
  + Radio Link

- Azimuth Sensor
  - HMR 3000 (Honeywell)
  - Accuracy: 0,5°

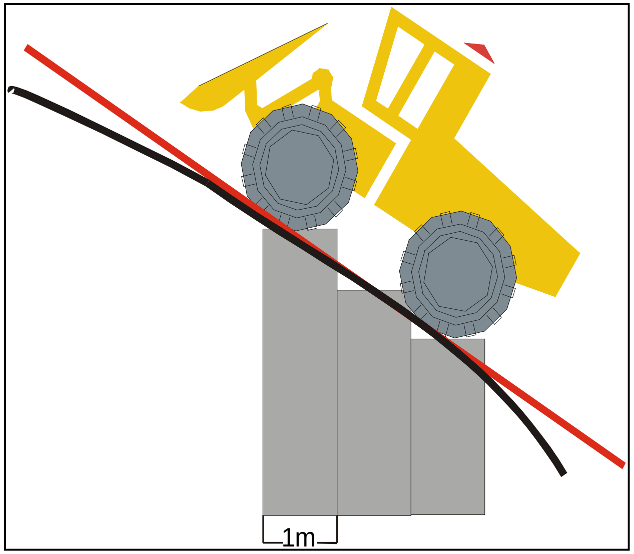
- GPS-System
  - MC 1000 (Leica)
  - Accuracy 1-2 cm (3D-Position)

- Inclination Sensor
  - NMSK 3-30D (Glötzl)
  - Accuracy: 0,01°
  - Permissible Inclination Field 45°

Management of measuring data

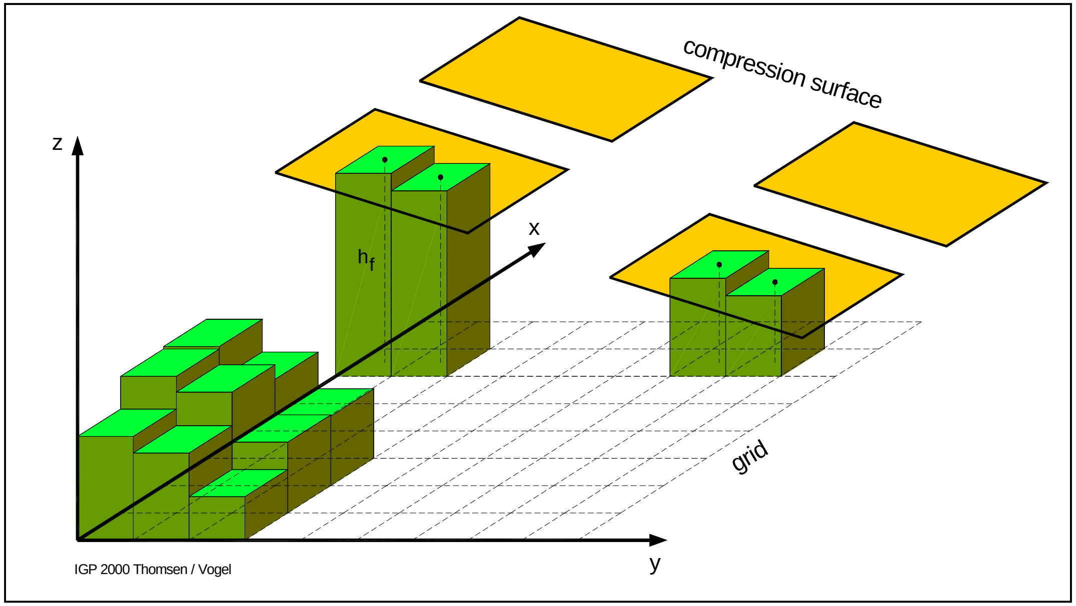


Determination of Surfaces

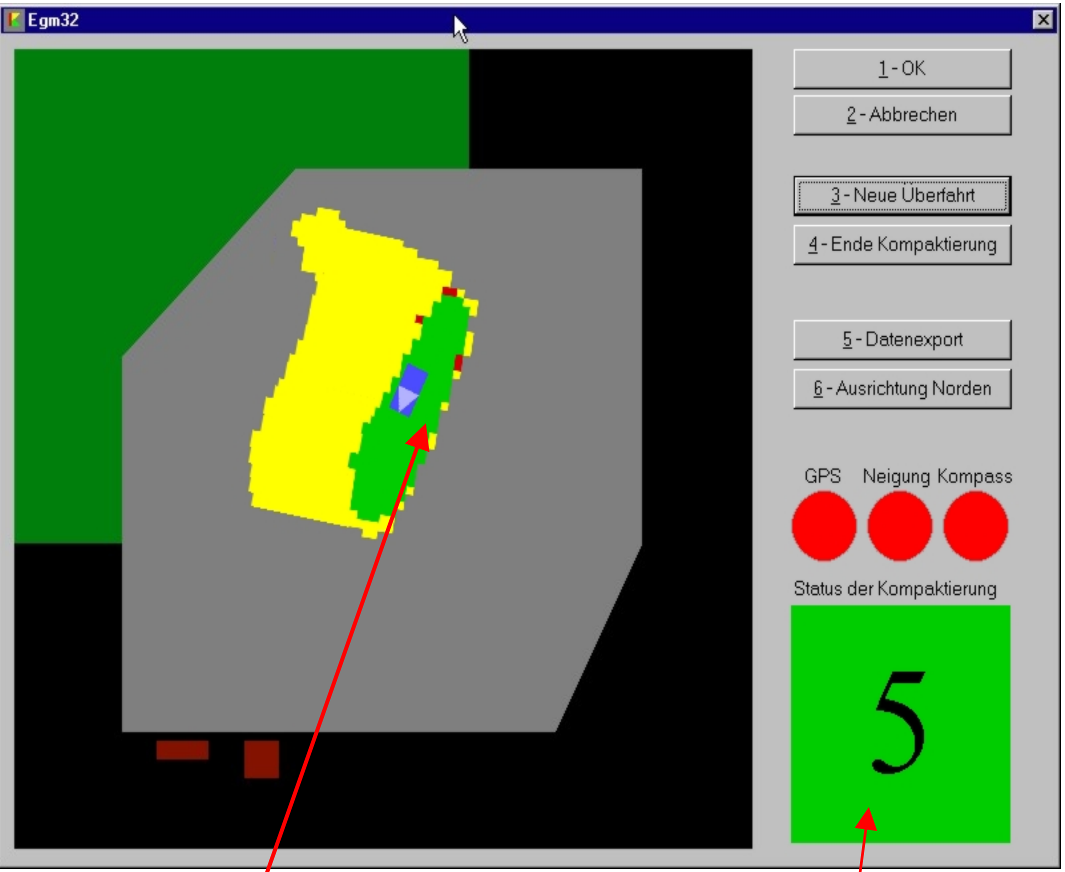


- estimation of mean height of every grid element
- compression surfaces representing the effect of the compactor

- surface approximation (here 1x1m)



Steering Information for Driver



Actual Position of Compactor

Number of crossings

Functions

- Navigation
- Number of crossings
- Status of achieved density(compression)
- Definition of new crossings
- Storage of a digital elevation model
- Interface to information system

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Communication Links

- *Common data base and data structure for design model and results of surveying*
  => Information system for each construction
- *Intelligent and continuous communication links between structural and surveying engineer*
- *Presentation of results in attractive graphical form : no lists with coordinates or displacements, no raw drawings !!*

Existing Standard for Presentation of Geometry

Responsible :

International Alliance for Interoperability (IAI)

www.iai-international.org

www.iai-ev.de

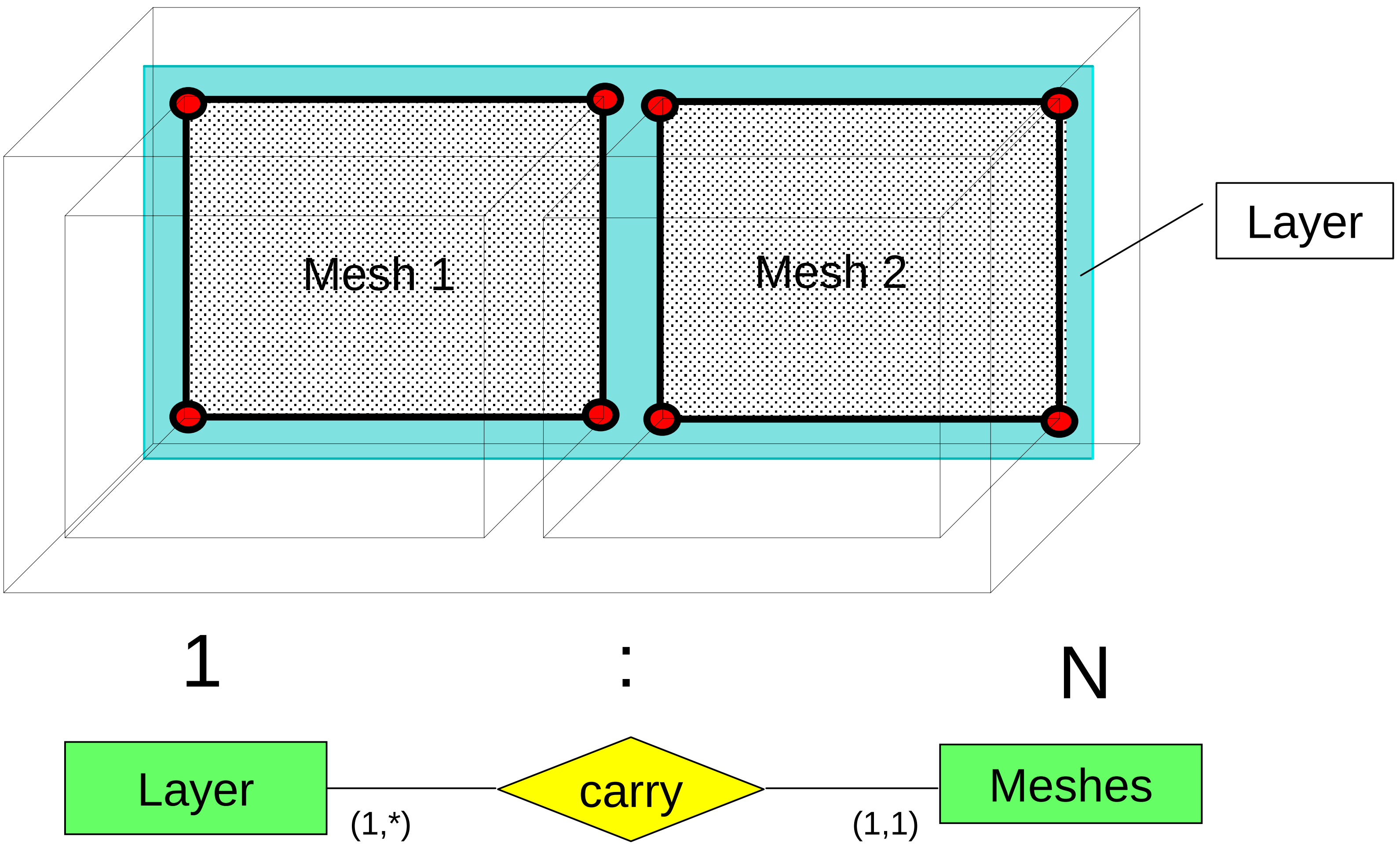
Industry Foundation Classes IFC

- Standard for Exchange of Information of Building
- Dokumented in XML and Express

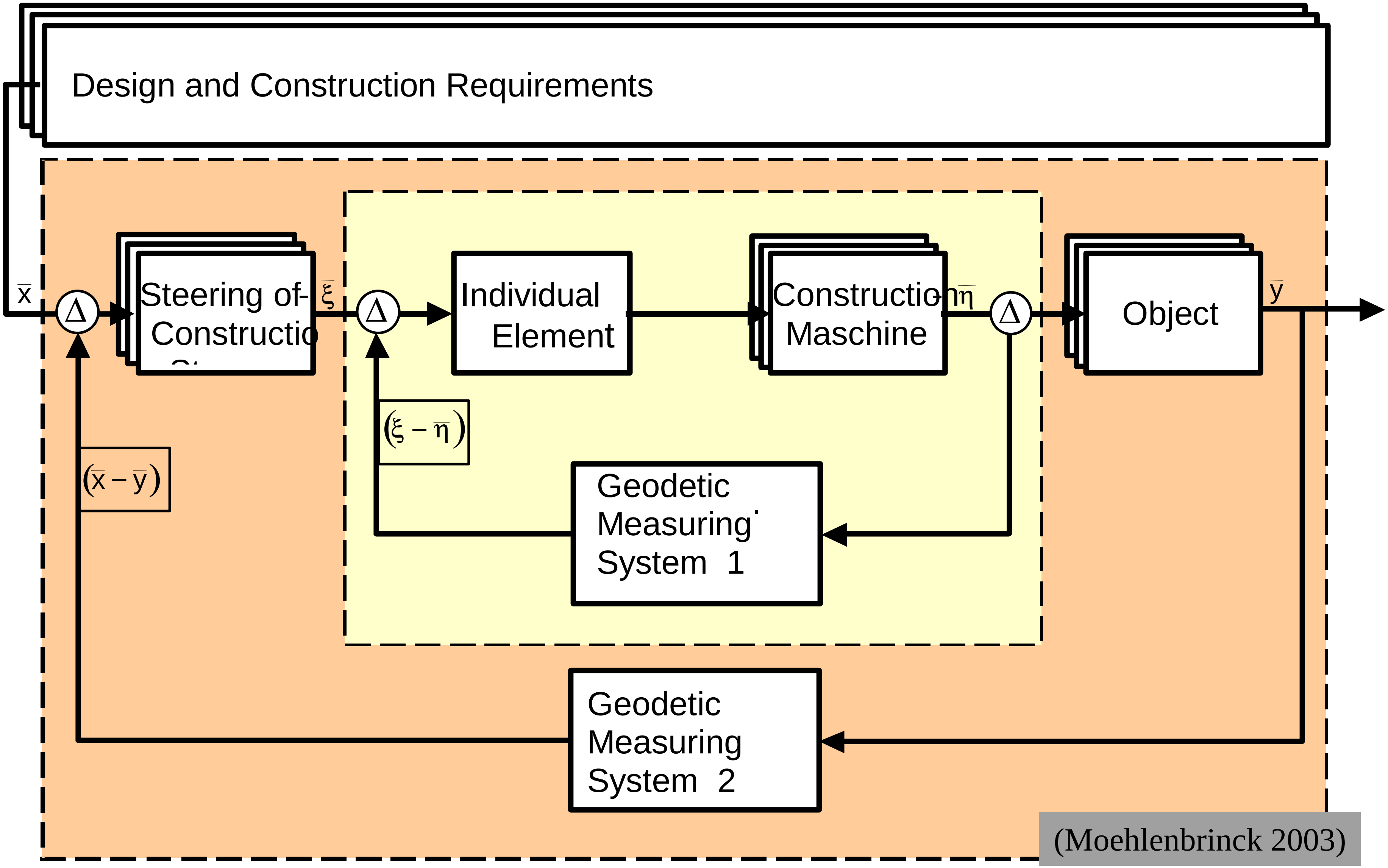
IFC-Standard

- Uniformity
- Parametrisation in all dimensions
- Topology
- n : m – Relations between geometry and topology
- Axis in time
- Stochastic information
- Storage of observations
- Ability to use in real-time

Geometry and Topology



Construction Process as Dynamic System



(Moehlenbrinck 2003)

Conclusion

- *Construction process as dynamic system :*
  Geometry is important part for steering process
- *Surveying has to become an integral part of this process*
  => „Expert for Geometry“ AND „Part of the Team“
- *Developments necessary in direction :*
  - flexible, universal instruments
  - real-time processing algorithms
  - interoperability in communication and data formats

IAG Commission 4 „Positioning & Application“
President : Chris Rizos

Within the 5 Subcommissions (SC) :

SC 4.2 „Application of Geodesy to Engineering“

Within the 4 Working Groups (WG) of SC 4.2 :

WG 4.2.1 Measurement Systems for the Navigation of Construction Processes

WG 4.2.1 : Measuring Systems for the Navigation of Construction Processes

Chair : Wolfgang Niemeier
Co-Chair : Guenther Retscher

To promote research and stimulate new ideas and innovation for integrating geodetic measuring systems and concepts into the navigation and steering of construction processes.

This area of research includes

- *a better understanding of geometrical requirements of construction processes,*
- *the further development of adequate sensor systems,*
- *the development of algorithms for real-time applications,*
- *the interaction between geometrical information and the navigation/steering process and*
- *the definition of interfaces.*