Industrial Metrology

Defintions of Metrology

- **Metrology**
  - …is the knowledge about measurement
- **Legal metrology**
  - …is concerned with the accuracy of measurements where they have influence on the transparency of transactions, health and safety
- **Scientific metrology**
  - …develops the scientific basis for metrology, measurement standards, and procedures.
- **Industrial Metrology**
  - …has to secure the adequate functioning of measurement instruments in industry as well as in production and testing processes
- **Fundamental metrology**
  - …is scientific metrology plus those parts of legal and industrial metrology that require scientific metrology plus maintenance of national standards.

Current Issues Metrology

- **Traceabiility**
  - To internationally recognised standards
  - Preferably to the Système International d'Unités, SI
- **Uncertainties**
  - Measurement results must be accompanies by unceertainties
  - Uncertainties are based on the whole measurement process
- **Inter-Laboratory intercomparisons**
  - Traceability and uncertainty are verified through inter-laboratory comparisons

Example:

In connection with the introduction of a new district heating meter, DFM used advanced mathematical methods to compute the necessarily sampling sizes and periods for the control of the performance of the installed meters

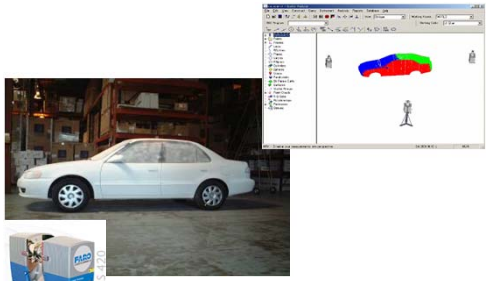
Application Areas

- Aircrafts/ Vehicles/ Ships Machines, Engines, ……
- Robot Calibration
- Machine Constructions
- Onsite inspections
- Experimental Facilities (Radio telescope, Accelerators, Laser plants)
- Power stations (Turbines, Generators)

Technologies and Trends in Industrial Metrology

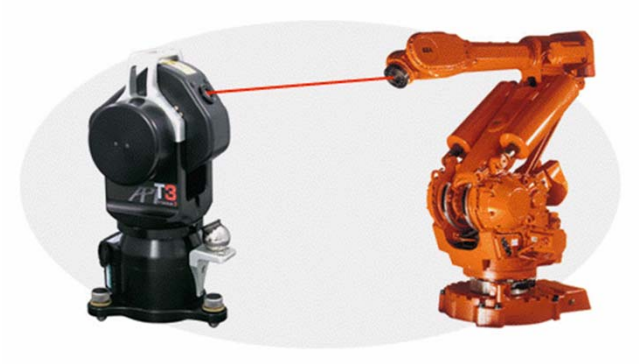
- Optical tooling
- Gaugeless tooling vs. master models
- Reverse engineering
- Online inspection systems
- Real time systems

Reverse Engineering



Turning reality into a virtual representation. From modeling ancient buildings, production plants, crime scenes and football stadiums to design concepts for cars and for replacement parts which have no design data, reverse engineering is a broad field allowing us to create virtually anything we can touch. Laser Trackers;Arms and Scanners can be used to reverse engineer geometric objects whilst more complex shapes are better captured using a non contact devices

Robot Calibration



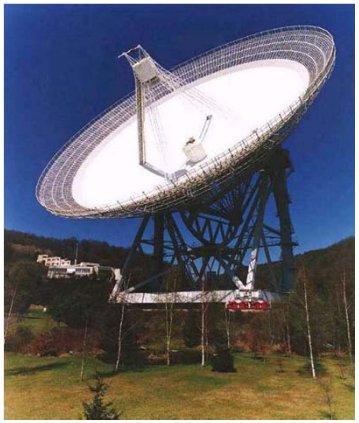
Aus: http://www.p-cmm.com/images/industry_robot_calibration_1.gif&imgrefurl

Aircraft Metrology

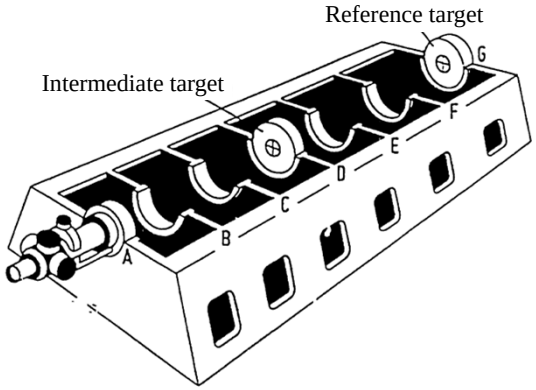
Wing to Body Assembly

- Production plant for the wing to body assembly of Boeing 737
- Fixed location points for the body
- Moveable location points for the wing

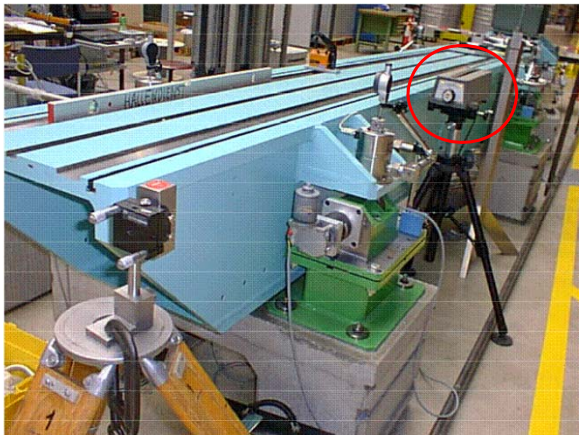
Parabolic Mirrors and Radiotelescopes



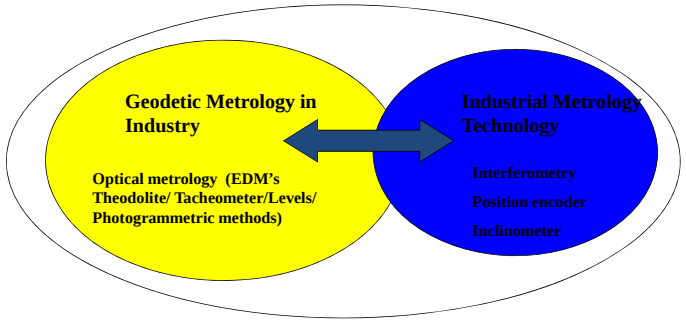
Optical Alignment (Ship Engines)



Alignment of Components using Interferometry



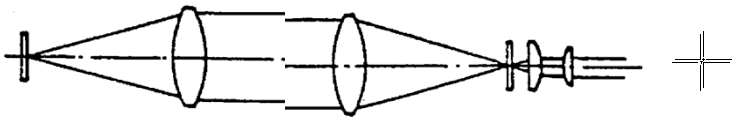
Metrology in Industry



$0{,}0001[\text{mm}] < \sigma < 0{,}1\ [\text{mm}]$ for Object size up to 150 m

Optical Tooling

Optical Direction Measurement (Collimation, Autocollimation)



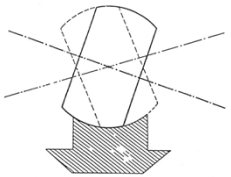
Telescope 1 Telescope 2

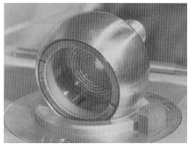
In optics collimation is the process of paralleling directions.

Collimation stands for the alignment of two telescopes with parallel rays. Infinitely focused telescopes are called collimators. This technique is used in IMT and for calibration of optical instruments and direction transfer.

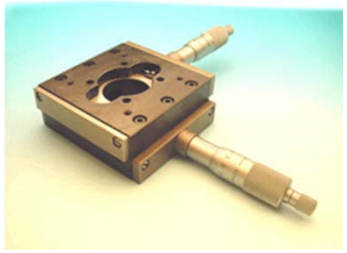
Centering and Tools

Taylor-Hobson Spherical Centering



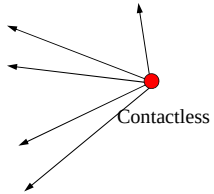


Cross Slide with Micrometer Screw



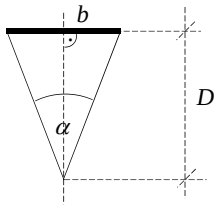
High Precision Distance Metrology

Distance Finding Methods in Industry

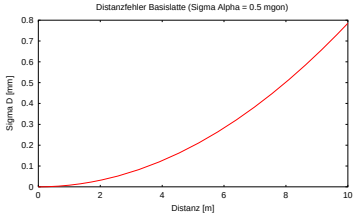


Subtense Bar

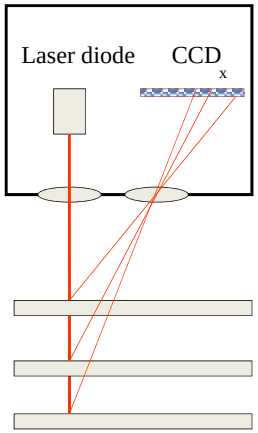
$$D = \frac{b}{2} \cdot \cot\frac{\alpha}{2}$$



$$\sigma_D = \left(\frac{D^2}{b} + \frac{b}{4}\right) \cdot \sigma_\alpha$$



Triangulation based Range Finder



D=F(x)

A triangulation sensor emits a laser beam, which returns in a different angle of reflection dependent on the distance from the test object. The reflected beam is projected by an optic to a CCD or PSD sensor.

Distance range

Direct Distance Measuring using EDM

larger measurement range, based on used method

higher accuracy

METHOD						
MODULATION	Light Frequency	Frequency Modulation "Chirp"	Synthetic Frequencies	Polarisation Modulation	Amplitude Modulation	Pulse Measurement Technique
DETECTION	Interferometry	Frequency Interference	Interferometry	Phase-Shift Differential Comparison	Phase Measurement	Time of Flight Measurement
Accuracy						
Range w. Refl.	**50 m 0.005 mm**	**0 - 60 m 0.005 mm**	2 - 10 m 0.02 - 0.1 mm	**1 - 50 m 0.025 mm**	1 - 50 m < 0.05 mm	100 - 500 m 2 - 5 mm
Range w/o Refl.		**0 - 60 m 0.01 mm**	2 - 10 m 0.02 - 0.1 mm		0.5 - 5 m < 0.1 mm	100 - 500 m 2 - 5 mm
Leica Systems	**LTD (IFM)**	**LR200**		**LTD (ADM)**		

focused beam is necessary to measure without reflectors - detectable signal is essential

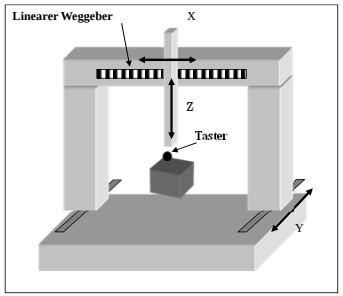
Loser, 2001

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Coordinate and Geometry Determination

Coordinate measuring machine
Laser scanners
Theodolite based systems
Real-Time Photogrammetry
Polar measurement systems
Arms
High Precision Total Stations
Laser tracker

Industrial Metrology: 3-D Coordinate Measuring Machine (CMM)



3D Coordinate measuring machines are big and stationary. They have a three dimensional, freely movable probe, which samples the test object. The movement of the probe is measured in x-, y-, and z-direction of a machine coordinate system (interferometric or with optical linear transducers) and stored.

Coordinate Measuring Machine

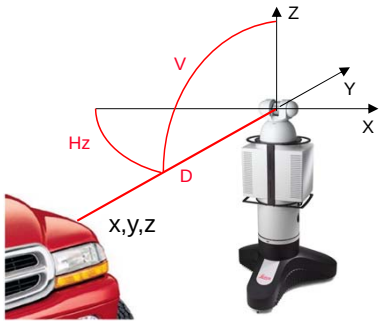
PICT0015.MOV

High-Precision Laser Scanners

Industrial „Scanner“: Metricvision

http://www.metricvision.com

Laser Radar



Frequency Modulated Coherent Laser Radar (FM CLR) is a non-contact ranging technology similar in accuracy to a laser interferometer (a few microns).

The MV200 Products are used as

1) ultra-large volume Coordinate Measurement Machines (CMM)
2) ultra-large volume precision scanners for engineering and reverse engineering tasks
3) precision layout tool for marking and other tool and fabrication purposes

The Laser Radar is programmable, and fully automate-able, from CAD file input to report output and filing

geomETH

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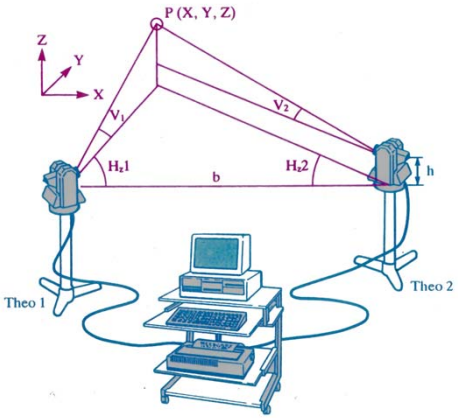
Theodolite based Triangulation Systems

Theodolite based Metrology (TMS)



Principle of spatial intersection:

The basis b and the horizontal respectively vertical angle to the object point P is measured. Therefore the coordinates of P are determinable.

The measurement of two zenith angles results in a redundancy for the z coordinate of the object point. This enables to find a potential error in pointing.

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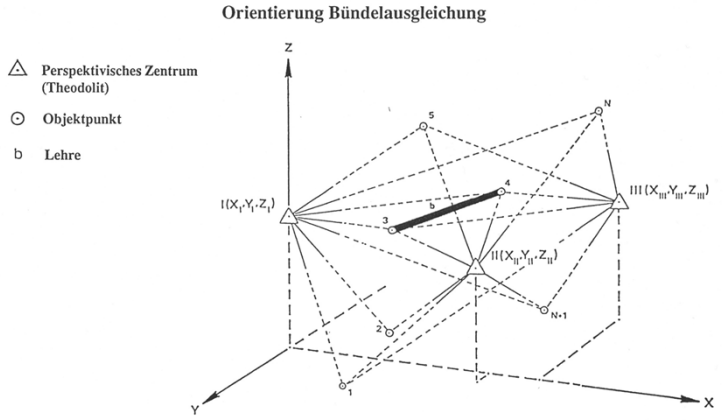
Bundling



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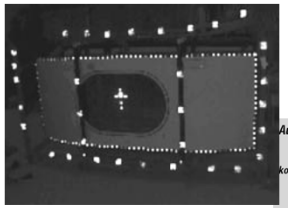
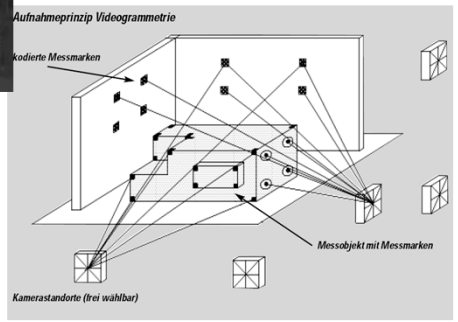
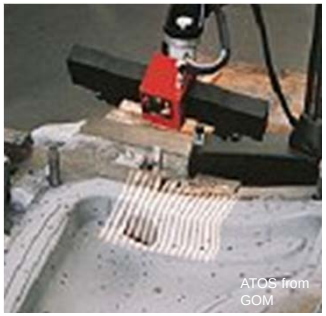
Hidden Point Measurement Device

Real-Time Photogrammetry in Industry





Photogrammetry: Structured light



Structured light systems project patches of structure light on surface. Thus, one intensity per patch which is difficult when surface has different characteristics.

Manufacturer: GOM, Cognitens, Metris, etc.)

White Light Scanning Systems

Vector Methods

High Precision Theodolites and Total Stations

With high-precision alignment telescope and auto collimation ocular

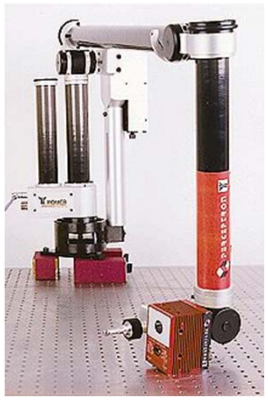
Leica TM6100A

Leica TDRA6000

Reflectors and Accuracy

Reflectors	1 Sigma
Reflex foil	0.5mm / 0.02in
High precision prism 65mm ø	0.3mm / 0.01in
360°-Prism, up to	2mm / 0.08in
Corner cube-reflector CCR1.5" (triple prism)	0.2mm / 0.008in
Surface reflector	0.2mm / 0.008in

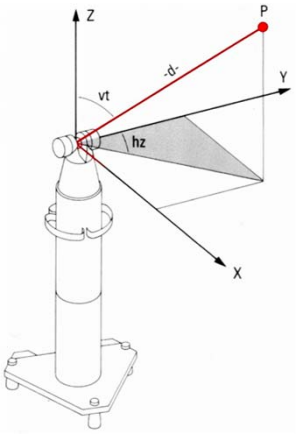
Faro and Romer Measurement Arms (Traversing Method)

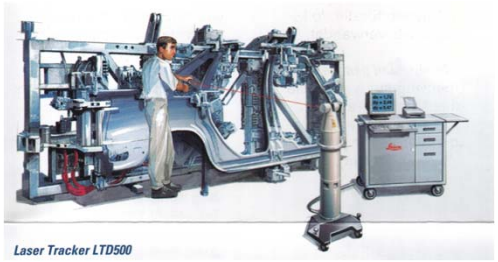


Laser Tracker

Laser Tracker

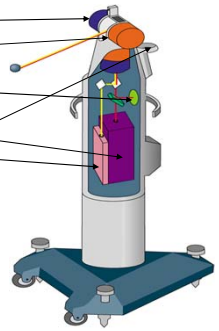

Laser Tracker





Laser Tracker LTD500

Leica Laser Tracker

- Encoders
- Motors
- Position detector
- Interferometer
- Absolute distance meter
- Target lost indicator
- Birdbath
- Cable connection
- Base plate with rollers



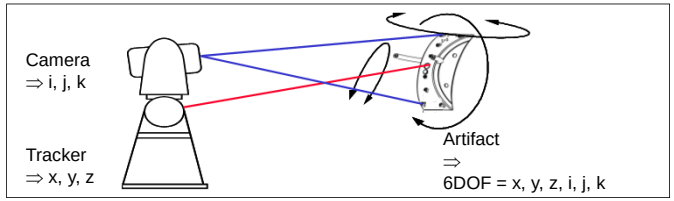

12/10/2003

Leica

Merging Tracker Technology with Photogrammetry

Laser Tracker and Camera for T-Probe tracking
- Tracker measures position (X,Y,Z)
- Camera measures roll, pitch and yaw (i, j, k)
- Artifact is equipped with reflector and LED
  - E.g. T-Probe, T-Scan and whatever makes sense

Tracking performance
- 6 Degree of Freedom (6DOF) data frequency: >100Hz
- Tracking speed: 2 m/sec
- Tracking acceleration: 2 g



Laser Tracker with T-Probe Head

END