Laser Tracking System for Coordinate Measurement

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Position measurement (1)

- Automobile
  - Building
- Airplane
  - Mirror
  - Laser
Position measurement (2)

- Machining center
  - Stepper
- Industrial robot
  - Mirror
  - Laser
CMM

X scale

Z scale

Y scale

X scale
Calibration of CMM

If the CMM is deformed, the measurement point shifts against the scales.

CMM does not conform Abbe’s principle.

Measurement point itself should be measured directly.
Current laser tracker

- Polar coordination
  - One length, two angles
- Low accuracy (10ppm)
- Expensive
- Bulky
- Accuracy is degraded when the target is far due to limited resolution of the rotary encoder.
Biggest error source

- Two axes of the scanning mirror should cross perpendicularly and coincide perfectly.
Articulating system

- The center of the mirror never moves.
- Two axes cross 90° and coincide.

The hemispherical mirror is sitting on the three small balls.

X-Y stage

Accuracy depends of the sphericity of the hemisphere. 50 nm sphericity bearing balls are commercially available.
Trilateration (three length)

- Arrangement of the base points
- Distances: each base point - the target

- - - > Determine the position of the target

(Four lasers are used for the self-calibration.)
Trilateration

- Only length measurement by laser
- Angle is not measured.
- Accurate, traceable to the length standard
- Conforms Abbe’s principle
- Most accurate in principle
Self-calibration

- Unknown system parameters: 9
- Each measurement points: 3 unknowns but 4 measurement results, i.e. 1 redundancy
- After 9 measurements, system parameters can be calculated analytically.

- We don’t have to measure the arrangement of the trackers or the initial lengths of the interferometers.
- The trackers can be placed at arbitrary positions.
Laser tracking system

At the beginning of the measurement, all lasers are locked to the target.

After that, all trackers automatically chase the target.
Design: Laser tracker
Photos: Laser tracker (1)
Photos: Laser tracker (2)
Photos: Laser tracker (3)
Performance

- Error of length measurement of the tracker: $\geq 0.3 \, \mu m$.

- Error of coordinate measurement of the system: $\geq 1 \sim 2 \, \mu m$ (almost same as our CMM).

- Accurate enough for almost all applications even for the calibration of CMMs.
Conclusion

- Laser tracking system will be the next standard of coordinate.
- Thank you for giving me the opportunity to make this presentation.
- Thank you for your attention.