FIG WORKING WEEK 2023
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Protecting Our World, Conquering New Frontiers

Review of international standard ISO 17123-4:2012 for electro-optical distance meters

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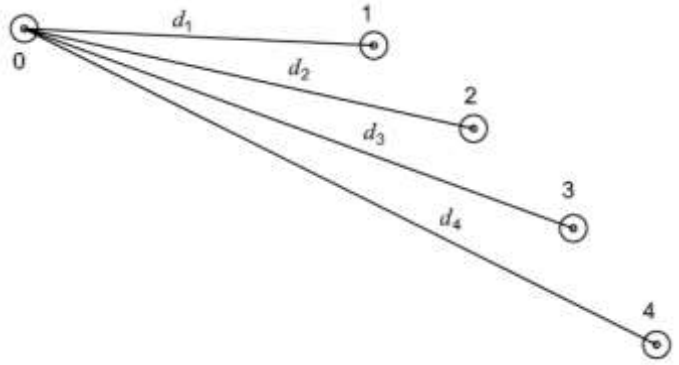
ISO standard 17123-4:2012

- Specifies procedures for determining the level of uncertainty in distance measurements.
- Instrument manufacturers quote the standard in their specs.
- Example from a contemporary total station (1 sigma):
  - 1 mm + 2 part per million. At 200 m, uncertainty of ±1.4 mm.

Test procedures

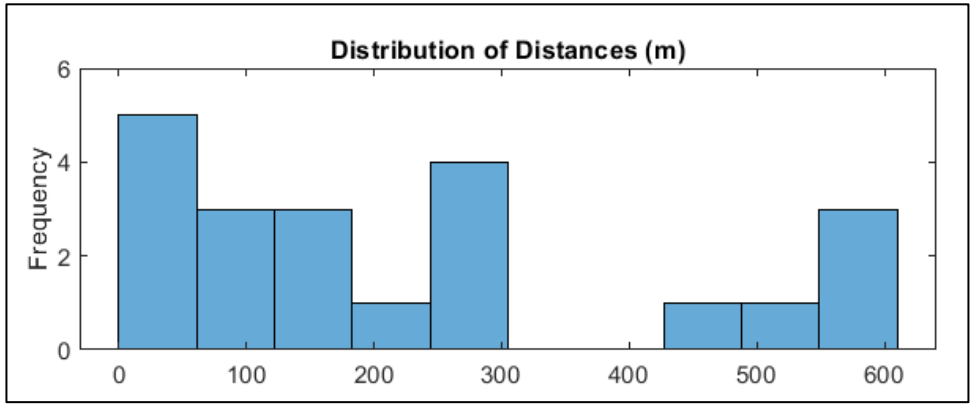


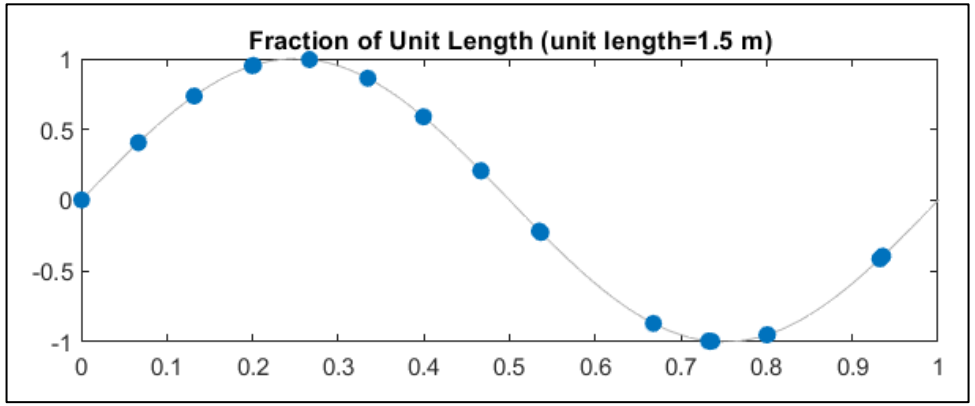
- Simplified test
  - Check if the instrument is within spec: yes or no.
  - Does not enable statistical analysis.

- Full test
  - Determine the standard uncertainty of distance measurements.
  - Determine the correction for the "zero-point" systematic bias.
  - Field tested with a Leica TS60 total station.

Full test procedure

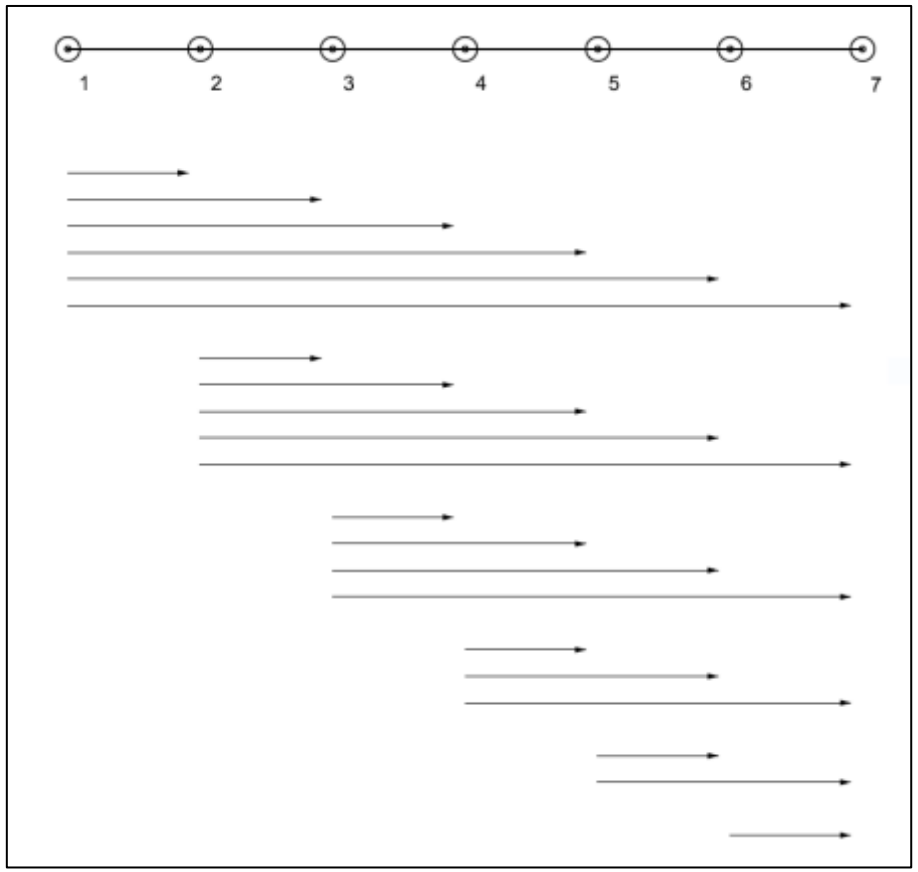
- Layout a test line with 7 points. 21 unique distances.





Measurements

- Measuring mode is left to the user.
  - Number of readings, 1 face vs. 2 face.
- Systematic effects should be corrected.
  - Atmospheric refraction.
  - Reduction of slope distances to horizontal.
- Occupy all marks and measure each pair.

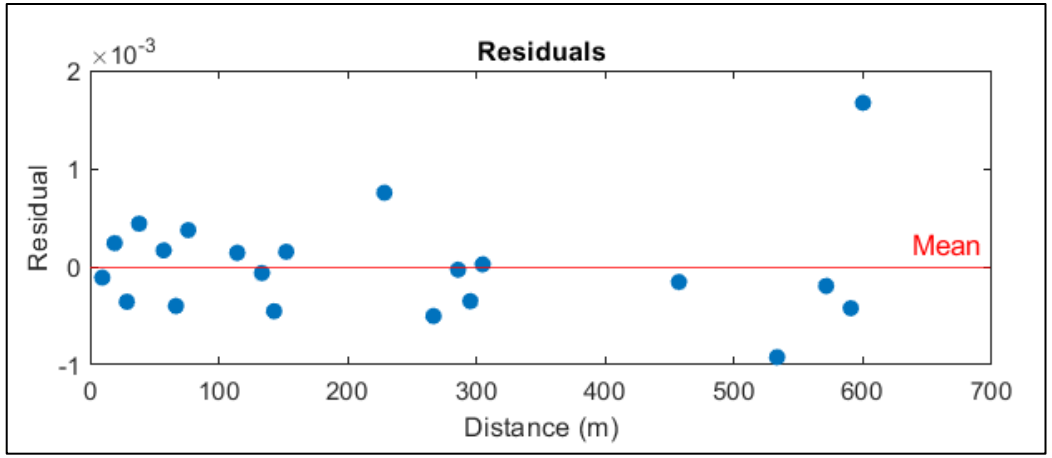


Calculation

- Use least squares to estimate the distances and zero-point correction.

$$r = Ay - x\,, \qquad \hat{y} = (A^T A)^{-1} A^T x\,, \qquad s = \sqrt{r^T r \,/\, v}$$

$$\hat{y} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \\ d_5 \\ d_6 \\ \delta \end{bmatrix} = \begin{bmatrix} 9.5011 \\ 19.0983 \\ 38.0992 \\ 76.2002 \\ 152.3019 \\ 304.8012 \\ -0.00045 \end{bmatrix} meters$$



Results

- Use statistical tests to evaluate the significance of the results.

$$\boldsymbol{s} = 0.6\,mm\,, \qquad \boldsymbol{\delta} = -0.5\,mm\,, \qquad \boldsymbol{s_\delta} = 0.3\,mm$$

  - A: Does the experimental standard deviation meet the desired precision (0.6 mm)?
    - Yes.
  - B: Do two different samples agree with each other?
    - Different measurement modes agreed.
  - C: Is the zero-point correction statistically equal to zero (at 95% confidence)?
    - Yes.

Discussion

- s represents the expected uncertainty of a single distance measurement at the 1-sigma, 68% confidence level.

- δ represents the zero-point correction, reflecting a constant bias.

- "Instrument" includes ancillary equipment and observing techniques.

Discussion

- The full test procedure whenever the instrument's inherent level of random error needs to be established.
- Solved parameters may be used as *a prior* values for subsequent work.
- Can evaluate the influence of different observing techniques to evaluate suitability for a particular task.
- Simplified test provides a less stringent option.

Discussion

- Distance-dependent uncertainty is not adequately modeled by a single value. Instrument specifications also have a scale uncertainty.

- ISO 17123-4 mentions using a frequency meter.

Conclusion

- ISO 17123-4 is widely used as a measure of achievable precision for EDM instruments.
- Facilitates consistency among all parties. Flexible in implementation.
- In this study, a test line was established and all distances measured.
- Resulting standard uncertainty was 0.6 mm, comparable to the spec.

Future research

- Measure scale with a frequency meter.
- Investigate alternate methods for determining scale uncertainty.
- Evaluate the necessary number of points. Is less than 7 suitable?
- Investigate other standards in the ISO 17123 series.

Thank you.