The SLAC Comparator for the Calibration of Digital Leveling Equipment

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Overview

- System Calibration
- Rod Calibration
- Factors influencing the accuracy:
  - Scale factor
  - Critical distances and focusing
  - End section of the staff
  - Illumination
- Equipment tested:
  - Leica DNA03
  - Trimble (formerly Zeiss) DiNi 12
  - NEDO precision invar rods
  - NEDO self illuminating rod
System Calibration
Rod Calibration

• Camera System
  – CCD camera (Sony XCD-SX900)
  – Telephoto lens (Schneider Kreuznach Componon S 5.6/100, f=128mm)
  – Inclinometer (Leica Nivel 20)
  – Interferometer (Agilent 5517B)
• Camera Tilt
  – Invar band not 2D
  – $\Delta d < 1\text{mm}; \Delta h_{\text{CCD}} = 0.15\mu\text{m}$

• Camera Leveling
  – Leveled laser beams
  – Two different distances
  – Cross-correlation of the laser point position
Edge Detection

- Edge detection

Postprocessing:
  - Least Squares Adjustment
    - Scale Factor of Image
    - Rotation of Image
    - Perspective Distortion
    - Position of the Edge
Slightly different results. The system calibration includes a systematic pattern which is caused by the level (including its software).

Scale factor: 0.1 ppm

Scale factor: 2.4 ppm
Critical Distances – Leica

- 1 code element (Leica: 2.025mm) is projected onto exactly 1 pixel, or integer multiples
- Leica NA3000 critical distance at 14.92 m (causes up to 0.4 mm misreading)
- Leica DNA03 critical distance at 26.70 m
- Trimble Dini12: 251 critical distances between 1.5 m and 15 m

e. g. Leica: DNA03:
• Leica DNA03 and Trimble DiNi12: critical distances do not cause deviations > 30 μm
• Defocused measurements increase these values
End Section of the Rod

- Measurements when only part of the rod is visible
  - Smaller section of the scale is available to compute the height in the digital level
  - Inaccurate measurements are the consequence
• Measurements in dimly lit environments require additional illumination

• Illumination at a steep angle causes biased measurements of up to 100 μm (only correct for the instruments tested)

• Prototype of a self illuminating rod
To link all height readings together the scale offset between the rods has to be determined.

Step 1: determination of 1 ½ in ball center
Offset Determination (2)

Step 2: transfer of short rod offset to regular rods with 1 ½ inch ball
Summary

• Both system and rod calibration performed at SLAC
• Regular calibration and testing of equipment
• Test of new equipment
• Test of field procedures
• Determination of rod offsets