Digital Levelling Technique Applied in Water Crossing

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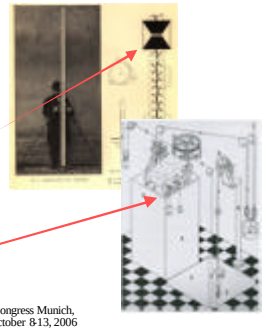
Height Determination in Water Crossing

Objects
Unbridged rivers, fjords, straits, seas, valleys

Methods
- Levelling with special targets
- Theodolite with vertical angels and *later* with slope distances
- Hydrostatic levelling with water tubes
- Tide gauge method with mareograph recordings



Precision Levelling in Water Crossing

Most popular

Also in Finland

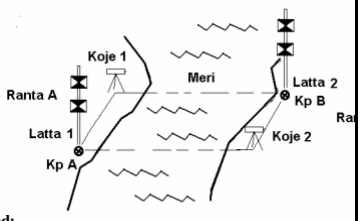
Valley crossing equipment Zeiss Ni2

Precision Levelling in Water Crossing

Parallellogram method

Reciprocal and symmetrical observations cancels

- **Earth curvature**
- **Refraction**
- **Collimation**



Accuracy achieved in Finland:

$\pm(0.44 + 1.98\ s^2)$ mm , s = [km],
i.e. ±2.42 mm/km

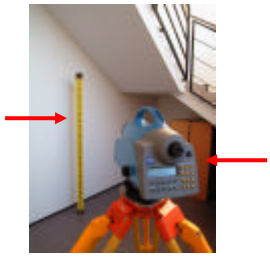
Vesiylitysvaaitus: Suunnikastekniikka

Digital Levelling System Zeiss DiNi12

Consists of two elements

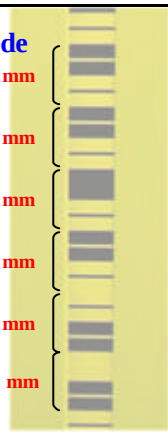
Bar code rod

Digital level
- level
- CCD - camera

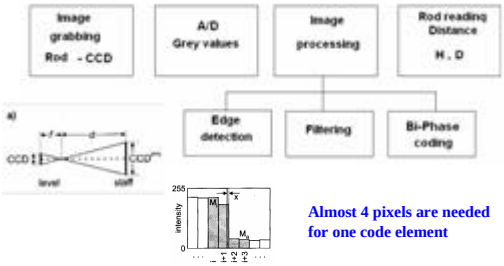


Bar code rod with Dini-code

- **Prinzip der Einzelintervall Messung**
- **Pseudo -stokastical distribution of the code in rod**
- **Code element = 20 mm**
- **Code word = 8 code elements**

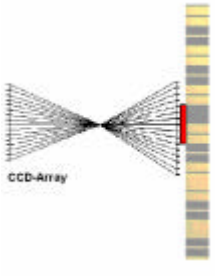


Processing Rod Readings

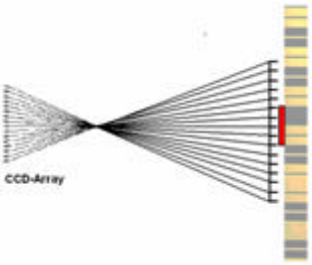


Almost 4 pixels are needed for one code element

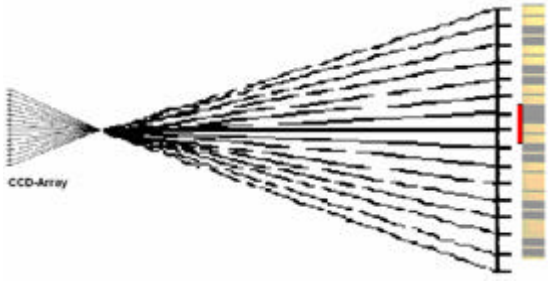
Problem is the sighting distance (s)
If s = 60 m there are only 7 pixels per element



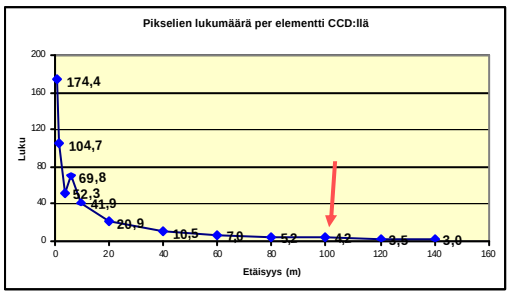
If s = 90 m there are only 4.5 pixels per element



If s = 140 m there are only 3 pixels per element => System can not process



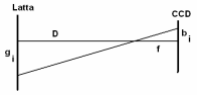
Number of pixels per element



How can we use digital levelling system in water crossing, where is needed longer sightings than 100 m ?

Solution

$$n \cdot g\, f^{3} \quad n \cdot D_{max}\, p\, OV$$



where

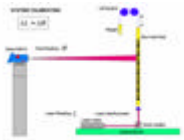
g = code element (20mm)
f = focal length
D_{max} = distance, 100 m
p = size of pixel (0.014mm)
OV= pixel per element > 4

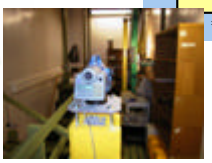
Magnification of code element

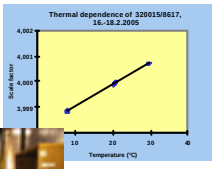
- **4x Magnified Bar Code Rod**
  - Black and white tape
  - Sharp edged knife
  - Measuring steel pieces

System calibration of Zeiss DiNi12 level and 4xmagnified rod

- At three different temperatures
- Accuracy 5 ppm







Scale Factors

Scale factors of the 4x magnified bar code rods

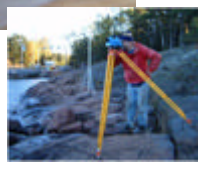
Instrument	Rod	Scale factor
320015	8617	3.99990 + 21.6 x 10-6 (t-20°)
320015	8618	3.99982 + 22.2 x 10-6 (t-20°)

Otsolahti Test Field

- In the city of Espoo
- Established 2003 – 2004
- Three bench marks in bedrock;
  The circumference of the loop T1-T2-T3-T1 is 1035 m
- T1-T3, length 405 m
- T1-T4, length 730 m, is for trigonometric water crossing,

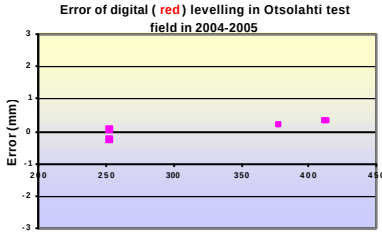
leasurement with Digital Level

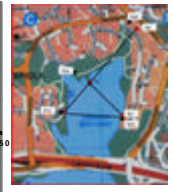
- Reference
  - In 2004-2005
  - Along coastal paths
  - Precision ±0.18 mm/√km
- Water crossing tests
  - A pair of 4xmagnified scale,
  - Three Zeiss Dini12,
  - Two observers
  - Unsymmetrical observations
  - Loop T1-T2-T3-T1
  - Zero point, collimation, refraction
  - Height difference = Scalefactor x Observed height difference



Error of Digital Level in Otsolahti Water Crossing tests

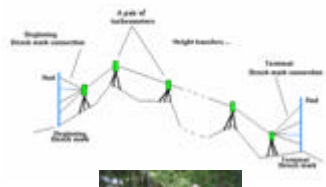
Error = "True" – Observed value





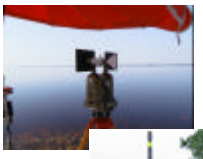
Trigonometric levelling (Trigo)

- Second method
- Two theodolites+EDM
- Method
  - Bench mark connection
  - Height transfer
- Procedure
  - Reciprocally
  - Zenith distance
  - Slope distance
- Accuracy
  - ±1.5 mm√km when sightings are 200-300m



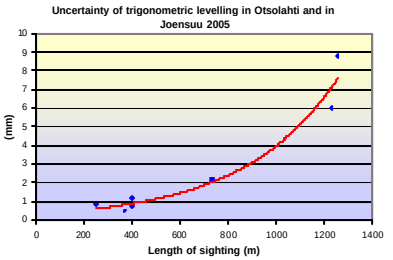
Trigonometric in water crossing levelling

- Enlarged signal target
- Additional observations
- Preliminary measurements in Joensuu, maximum sighting 1.3 km
- In Otsolahti
  - Interval T1 – T4, length 730 m
  - Loop T1-T2-T3-T1



Trigonometric levelling

Error in Otsolahti and Estimated in Joensuu



All results and Closing Errors in Otsolahti

Measurement	T1-T3 (mm)	T3-T2 (mm)	T2-T1 (mm)	T1-T4 (mm)	T1-T3- T2-T1 (mm)
Precise levelling 2004	+175,76	+114,86	-290,62	_	_
Precise levelling 2005	+175,60	+114,87	-290,47	+3829,73	_
Digital crossing 2004	+175,1	+114,5	-290,1	_	-0,5
Digital crossing 2005	+175,0	+114,5	-290,6	_	-1,1
Trigonometrical crossing 2005	+175,6	+116,7	-291,2	+3830± 4 DD =+0.3mm	+1,1

Achieved accuracies

- Digital water crossing
  ±1.0 mm/ km
- Trigonometric water crossing
  ±5.0 mm/ km

Conclusions

- **The digital levelling system Zeiss DiNi12** is a good tool in the water crossing until to 400 m and theoretically very promising for longer distances
- The reflection of the sun beams from the sea surface sensitively disturbes the working of Zeiss DiNi12
- In the future will be magnified the bar code 8-10 times in order to measure even one km water crossing
- **The trigonometric levelling** in water crossing was satisfactory, but not expected. Therefore, more test are needed

Thank You for Your Attention

Tan alegre el marinero

Tan triste, amante, el minero
Tan azul el marinero
Tan negro, amante, el minero
(La Amante)