On the Robotization of Precise Levelling Measurements

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On the Robotization of Precise Levelling Measurements

- Precise levelling is an arduous and time-consuming method
- Repetitive: Work stages are repeated in every setup
- Robotized levelling = motorized levelling + robots
- Equipment: Levelling instruments & robots
- How to Simplify a Complex Task (robotiq.com)

STEP 1: Document your current process

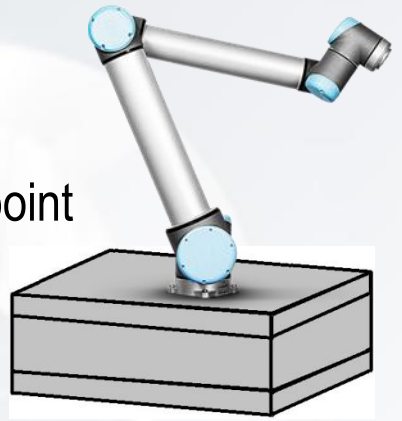
STEP 2: Sketch out the automated process you have in mind

STEP 3: Identify the challenges for automation

Precise levelling instrument Sokkia SDL1X

- It has an autofocus property
- Remotely controlled wireless operations (Bluetooth modem)
- Protection class of IP54
- Weight with battery 3.7kg
- BIS30A rods (3 m) weight 5.5 kg

Collaborative robots (Cobots)

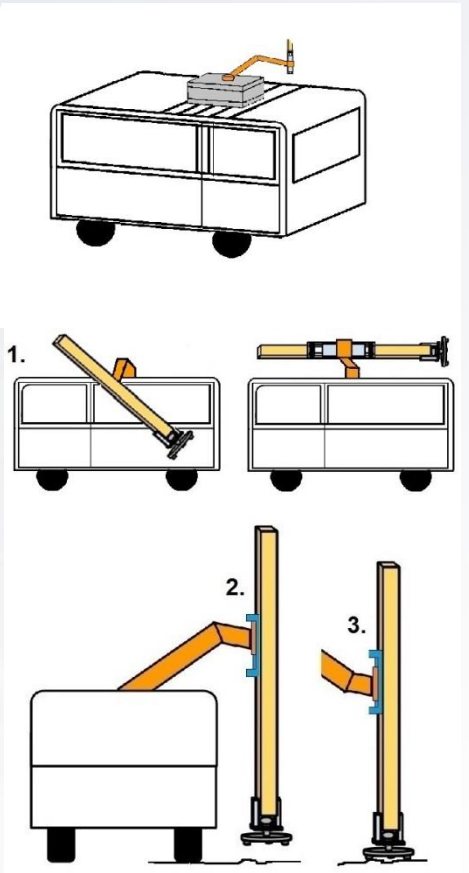


- Can work safely alongside humans (collision detection system)
- Trajectory planning by hand-guiding the robot (moving from point A to point B and avoiding collisions)
- Light weight (possible to fix on top of a roof-rack)
- Grippers (end-of-arm-tooling) are installed on the wrist of the robot arm
- Good repeatability (0.1 mm or better)
- Robots in Table have a protection class of IP54
- Prices vary strongly (€35 000 -)

Robot	Payload	Reach	Weight
KUKA LBR iiwa 7 R800 KUKA LBR iiwa 14 R820	7 kg 14 kg	800 mm 820 mm	23.9 kg 29.9 kg
Mabi Speedy 12	12 kg	1250 mm	35 kg
Universal Robots UR10	10 kg	1300 mm	28.9 kg
Yaskawa Motoman HC10	10 kg	1200 mm	45 kg

Rods in the robotized levelling

- ❑ Robotic arms are fixed on top of a roof-rack
- ❑ Transporting positions (1.) are used when rod cars are moving between setups (distance < 200m)
- ❑ Hand-guide programming (1.->2.) can be done in minutes
- ❑ The robot would always use the same path between the positions
- ❑ Determination of rod trajectories
- ➢ Predetermined paths between positions (1.) and (2.)
- ➢ Rods are rotated to vertical positions (at position 2.).
- ➢ The movement to the observing position (3.)



Rods to the observing positions

- Problem: Road surface is not flat
- First solution is based on the load or contact sensors. The weight of the carried load is known.

Position (2.):

Load: Rod + slide + rails + steel plate, weight > 5 kg

Observing position(3.). Rod is on the ground.

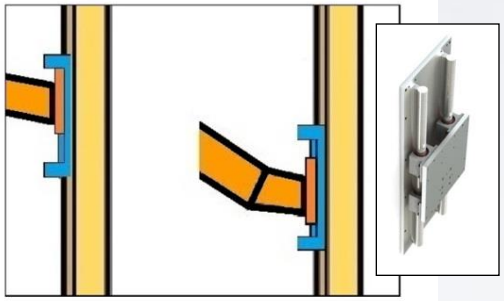
Load: Slide, weight < 1 kg

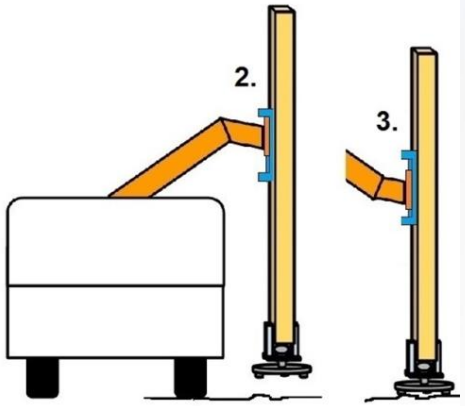
- Second solution. Without any sensors.

Rails are 20 cm longer than slides.

At position (2.), rods are 10 cm above the ground

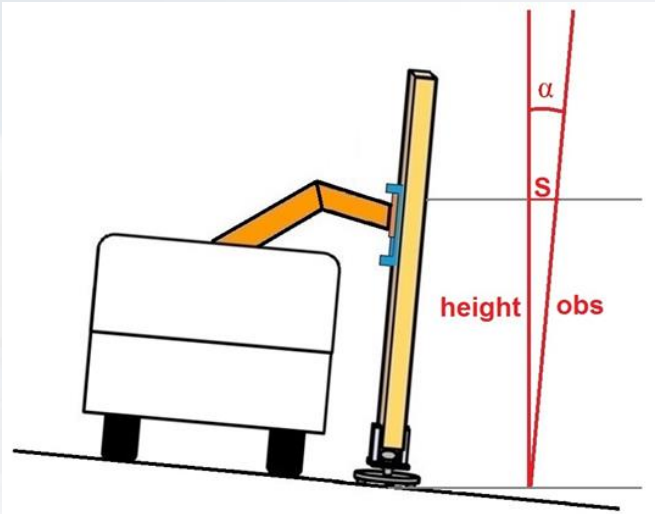
Rods are moved 20 cm down in z-direction

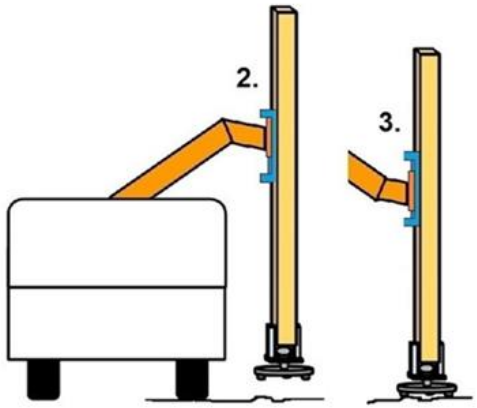




Measurements on sloped roads

- Without tilt corrections: Rod's verticality is relative to the rod car
- The slope of a car = The difference from true vertical (plumb line)
- Rod readings from tilted rods > true rod readings
- This error is easy to compute (Pythagorean theorem)
- Tilt sensors are needed
- Rods have to correct to vertical positions before observations (in position 2.)



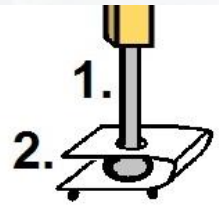


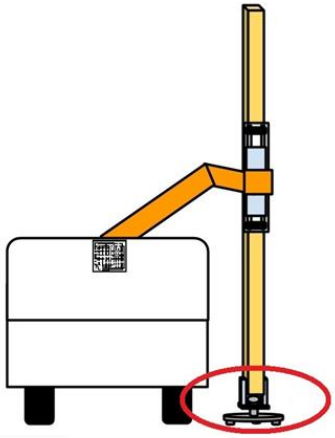
Rods are on steel plates

- During observations rods are on the ground on steel plates
- Fore rods are rotated after setups so that steel plates are without motion
- Steel plates are carried with rods
- A rod support construction consists of two parts

Part 1. Fixed to the bottom of a rod

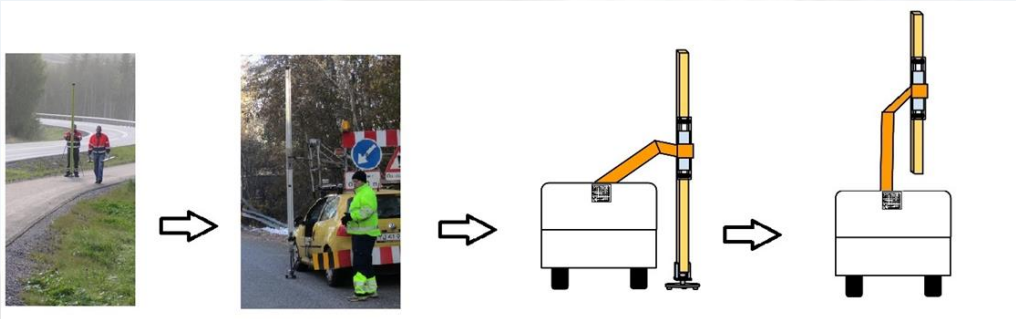
Part 2. Stable ”Steel plate”





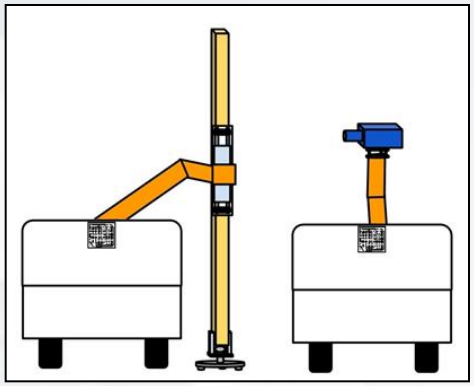
Idea: Rods are above the surface of the ground (during observations)?

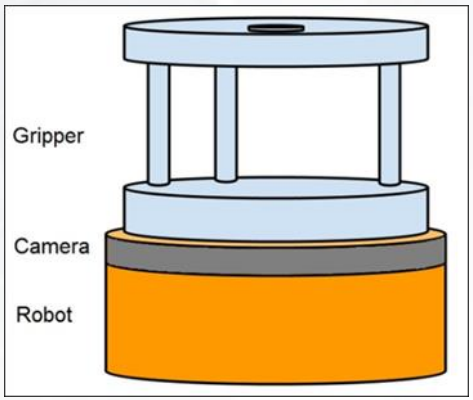
- For the 2nd order levelling (?)
- Rods would be on the ground only in benchmark connections
- Good repeatability properties (~0.1mm), no (significant) height changes when rods are rotated towards rods
- More safe in urban areas
- After movements rods would be quickly ready to observations



Recording of observations

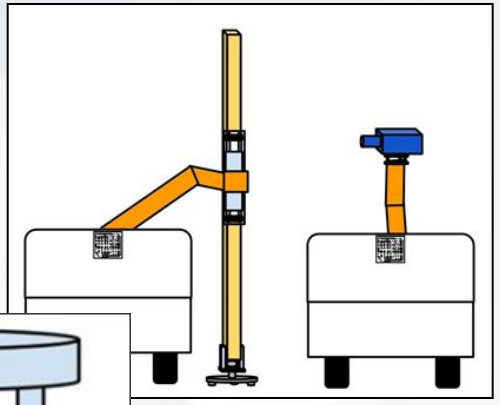
- Typically four rod readings are recorded.
  - For example: BFFB (B = back rod and F= fore rod)
- Work stage: Level the instrument
  - Robot + tilt sensor
- Work stage: Sighting of a rod
  - Robot guidance is done using camera solutions
  - Camera and instrument are oriented similarly (calibrated positions)
  - In difficult situations rods are selected manually from images
  - Cheap cameras can be good enough for the operation
- Work stages: Focusing of the instrument and recording rod readings
  - Levelling instrument with an autofocus property and remote observations

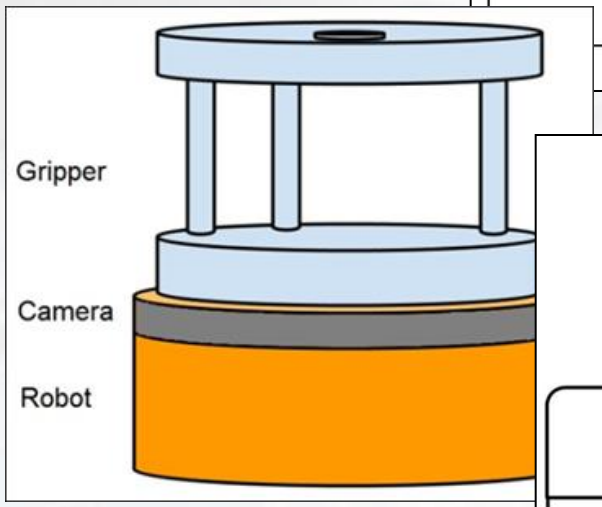


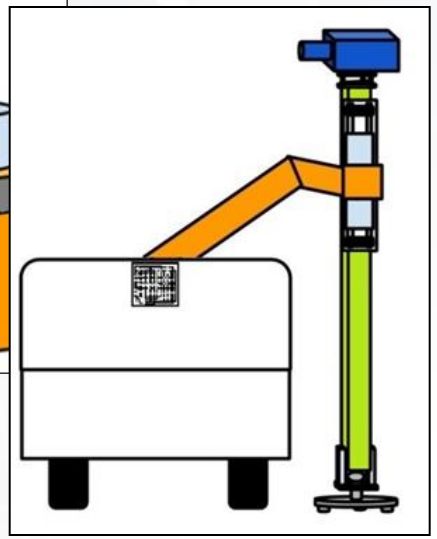


Instrument's support

- Traditionally instruments are mounted on tripods
- Two solutions:
  - Instruments are mounted on grippers (robots)
  - Instrument is on a pole which has a similar gripper to the rod solution
- In the gripper solution
  - The gripper is rotated by a robot
- In the pole solution
  - The pole is rotated
  - Good vertical stability
  - No need to develop second gripper solution

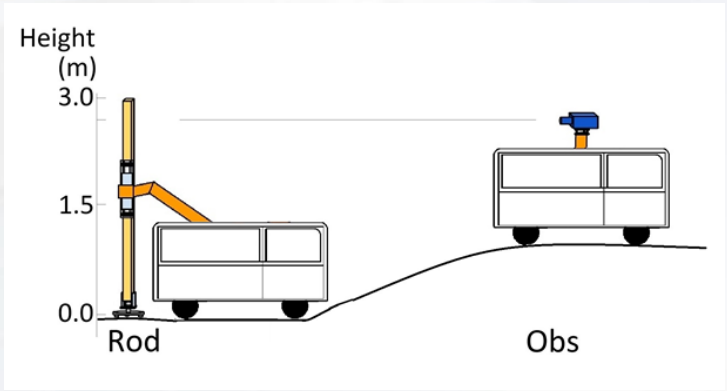


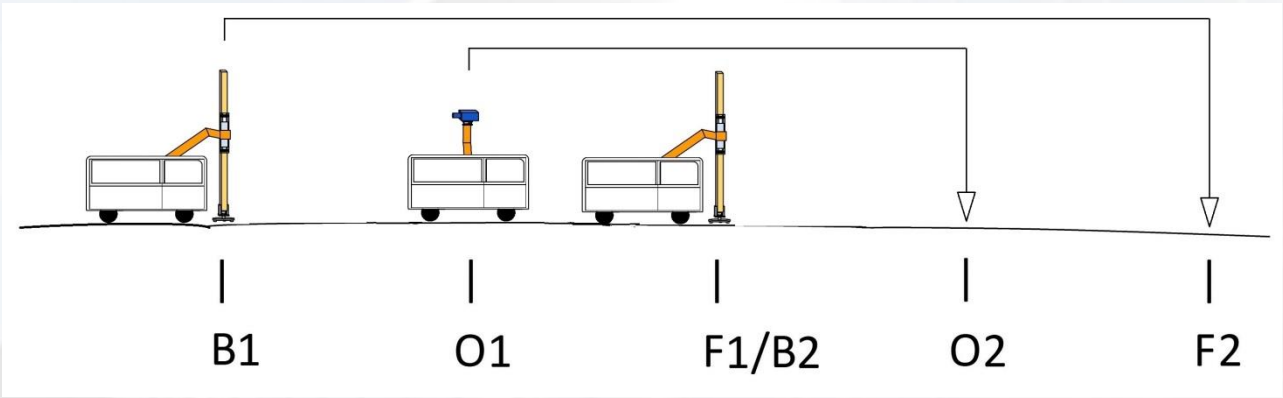




Work stages: sight distances and the movement of expeditions

- dist(B1,O1) = dist(O1,F1) < 50 m
- After setup: Observer O1->O2, Rod B1 -> F2. The fore rod at F1/B2 does not move
- Distances are determined when cars are moving
- Several solutions for the sight distance determination (GNSS, odometer, camera & markers,…)





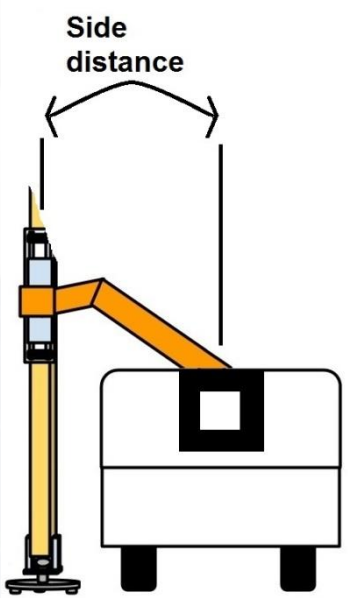
Cameras & markers and real time positioning

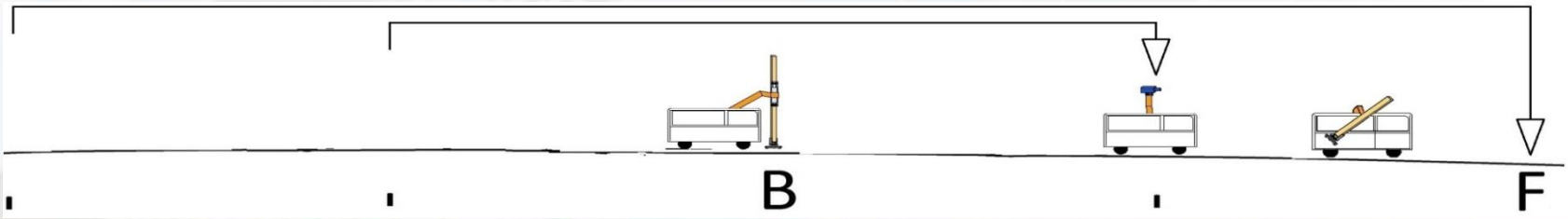
The determination of sight distances when the rod cars are moving. This method is performed when the observer is waiting for the fore rod.

- Using Template Matching techniques the sizes (distances) and orientations of markers are computed
- The accuracy of sight distances should be better than 0.5 m

Tracking rod's approximate position during the movement

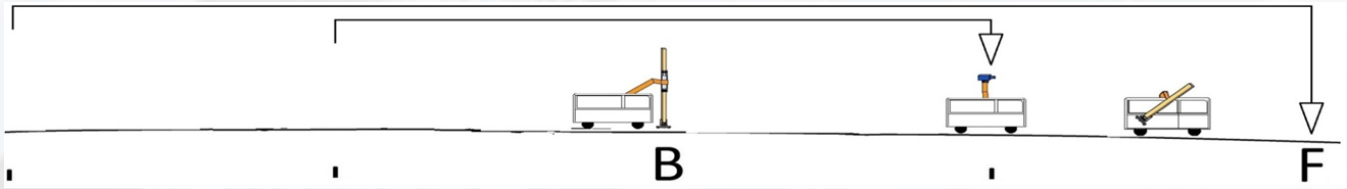
- Side distance = The distance between the marker and the rod (during observations)
- The sighting can be performed quickly after the movement





Productivity

- Sight distance is 35 m (distance between the instrument and rods)
- Average speed of cars is 25 km/hr
- After movements rods and instruments are ready to observations in 5 sec
- Recording time 2,5 sec / rod reading
- Instruments are rotated between rods in 2 sec
- One setup in 36 sec; 20 setups (1,4 km) in 12 min, 40 km/day



Conclusion

- ❑ Rod operations are easy to robotize
- ❑ Tilt sensors are needed (levelling on sloped roads)
- ❑ Robotized observations require camera solutions
- ❑ Instrument's instabity during observations
- ➢ Use a support pole with a rod gripper
- ➢ Observations without robots; use only rod robots
- ❑ Robot technology is developing all the time
- ❑ New manufacturers and low-cost robots are coming to markets

Thank you!