

EVALUATION OF STRETCHED WIRE MEASUREMENT BASED ON PHOTOGRAMMETRY IN THE CONTEXT OF CERN

IWAA 2016 – ESRF – Grenoble – France

A. Behrens, D. Mergelkuhl, CERN, Geneva, Switzerland
C. Vendeuvre, INSA, Strasbourg, France



ENGINEERING
DEPARTMENT

Table of content

- Ecartometry for accelerator alignment
- Photogrammetry for wire measurement?
- Test bench
- Real scale mock-up
- Alternative approach
- Conclusion

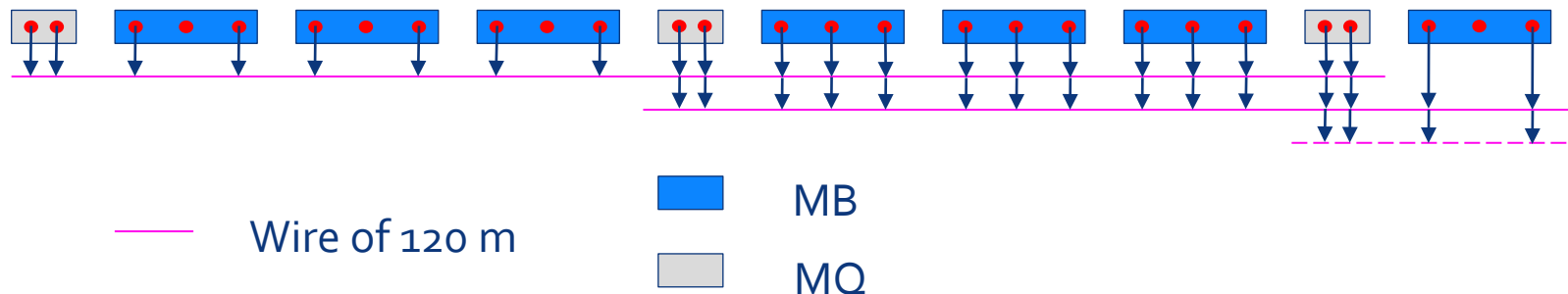
Ecartometry for accelerator alignment

- Radial offsets with respect to stretched wire
- Precision 0.05 mm within sliding window of 150 m
- Team of 2 persons: 500 m accelerator per day

– Time consuming, cost intensive

– Personnel in radioactive area

➔ How can radial alignment be automated?



Could photogrammetry be a solution?

Magnet fiducials can be signalized and measured,
but a stretched wire?

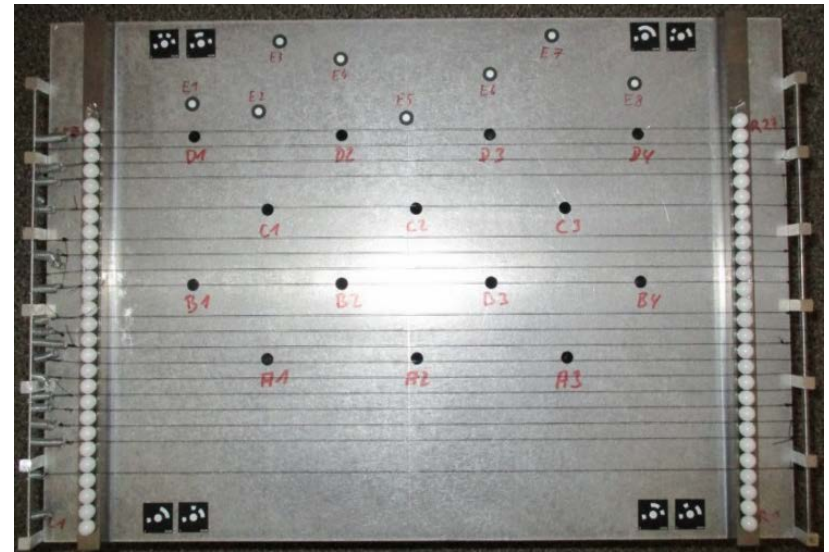
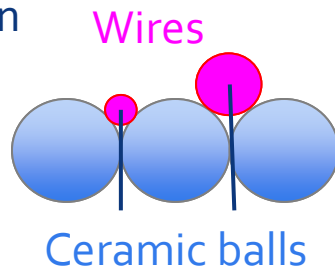
Recent developments

- Hardware: High resolution cameras
 - also thin wires become visible
 - 0.3 mm diameter at 1-2 m distance
- Software: AICON DPA / 3D Studio
 - Module feature measurement – Curved line measurement
 - No homologous points but multiple epipolar geometry

Test bench

- Test bench used to define different parameters
- Afterwards precision and accuracy for wire measurement has been evaluated

- Steel grooves at each side
- 26 precise ceramic balls in contact
- ➔ Up to 25 wires stretched between balls
- Photogrammetric sticker targets
- Metrology with precision of 2 μm
- Knowledge of wire position in horizontal,
NOT in vertical direction



Tested parameters ...

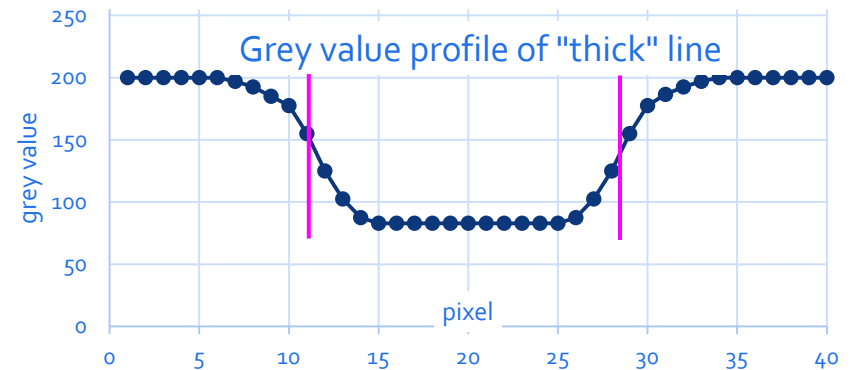
Wire

- Non-reflective
 - Dark for good contrast
 - Monofilament
 - Non-metallic
 - Of adapted size, wire should correspond to 1-2 pixel in image
- ➔ black, monofilament fishing wire of 0.3 mm diameter

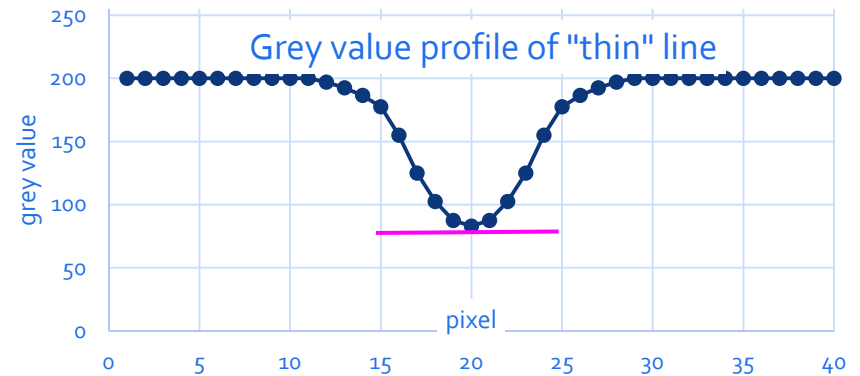
Software

- Edge method
- Spacing 0.25 mm – 2.0 mm
- Contrast values 20-40

«Edge» method



«Centreline» method



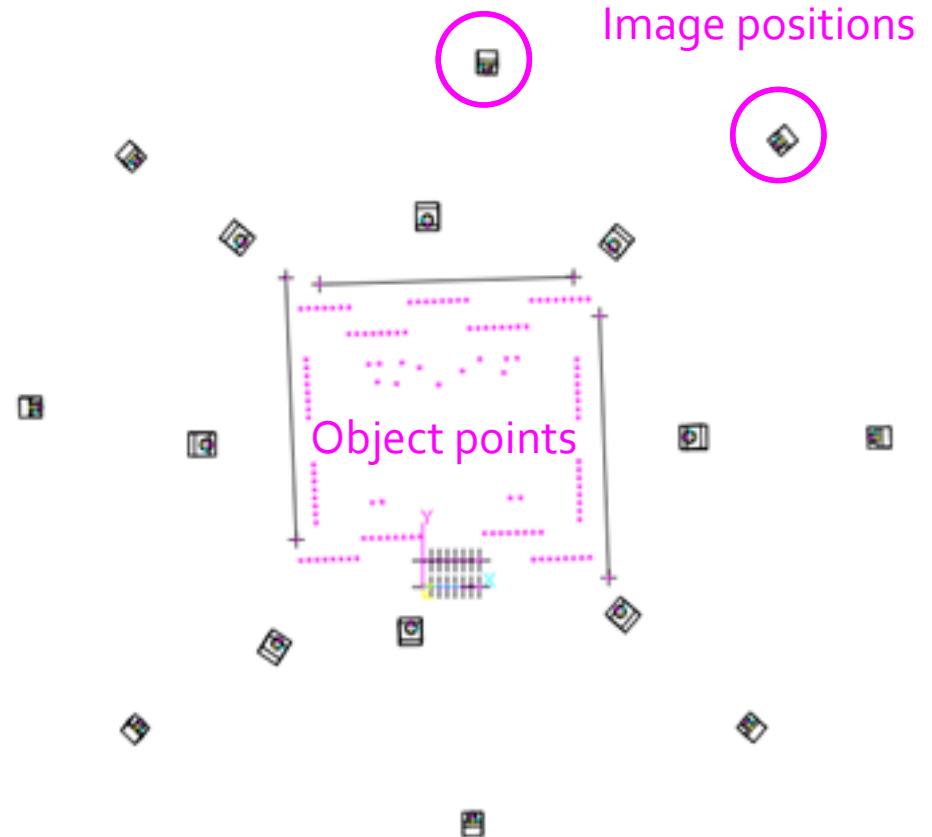
... tested parameters

Camera

- Nikon D3x with 24 Megapixel
- AICON «metric» 28 mm lens
- ISO 100-600
- Exposure time 1/125 – 1/250 sec.
- Aperture 11 or 16
- Top mounted flash

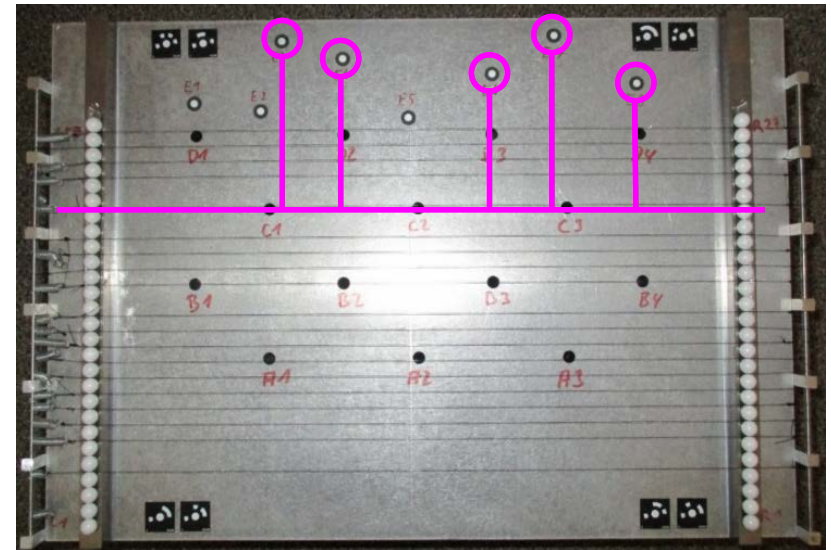
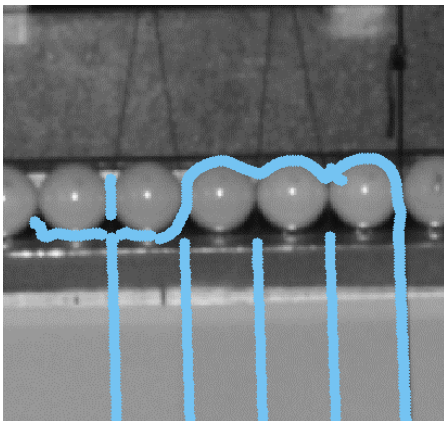
Configuration

- 16 images at distance of ~1.4 m
- Intersection angles above 90 degree



How to analyze the measurement ?

- 10 wires measured 10 times
- Horizontal 2D distances between 5 sticker targets and 10 wires
- ➔ 500 measurements for analysis
- Least squares fitted mean line of measured points
- Problems:
 - Shadow
 - Lines do not end
- ➔ Iterative error detection

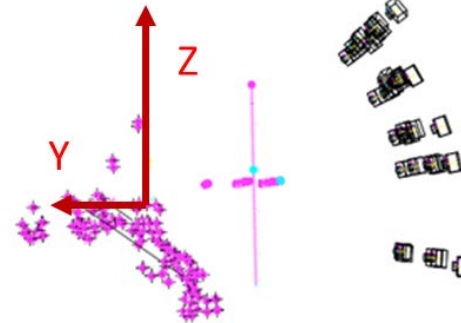
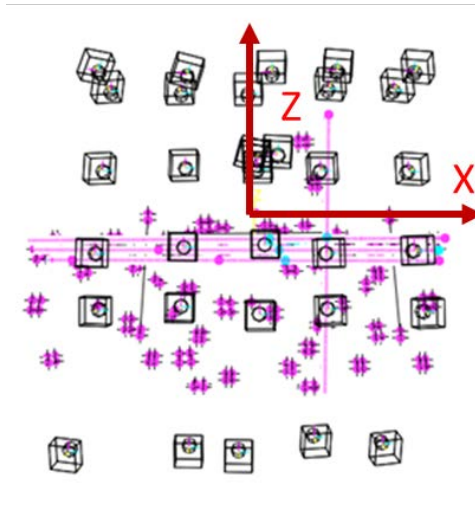
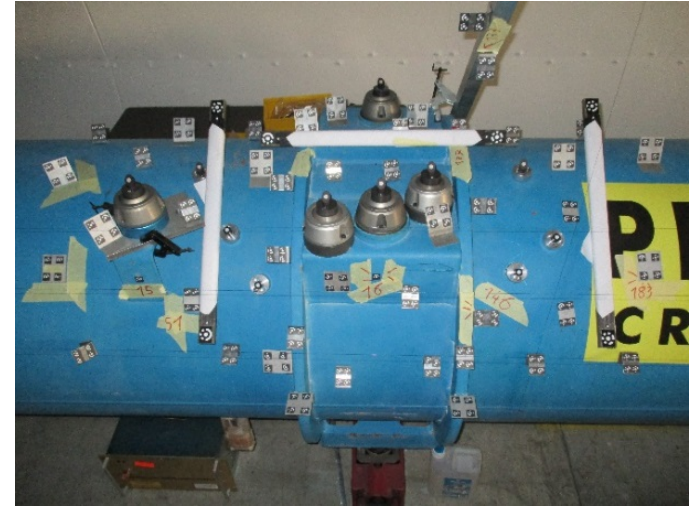




ENGINEERING
DEPARTMENT

Real scale test

- LHC dipole mock-up in wooden tunnel
- 165 magnet fiducials and additional targets
- 3 wires
- Plumb line as 4th wire for definition of vertical
- 10 photogrammetric measurements



Real scale test - Results

- 3D coordinates of 165 targets

Sigma of points	X (μm)	Y (μm)	Z (μm)
Precision AICON	4.2	7.7	4.2
Repeatability	4.0	7.0	4.3

Depth

- 2D horizontal distances between 10 targets and 3 wires

	σ (μm)	min (μm)	max (μm)
Wire 1 nylon	8.0	-29.4	28.9
Wire 2 vectran	6.3	-20.8	22.0
Wire 3 nylon	7.9	-24.4	26.3

Comparison to Wild T3000

- Comparison to theodolite measurement
- 3D coordinates by intersection
- Precision 10-20 μm
- Differences for 3D coordinates

	σ (μm)	min (μm)	max (μm)
Quadratic mean	8.1	15.2	13.3

- Wire by multiple plane intersection
- Differences for 2D distances

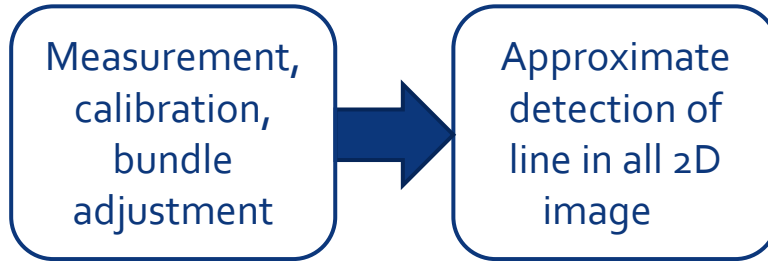
	Wire 1 nylon	Wire 2 vectran	Wire 3 nylon
Quadratic mean	19.9	34.2	15.0

Alternative Approach

Measurement,
calibration,
bundle
adjustment

- Existing AICON Move Inspect for collimator train

Alternative Approach



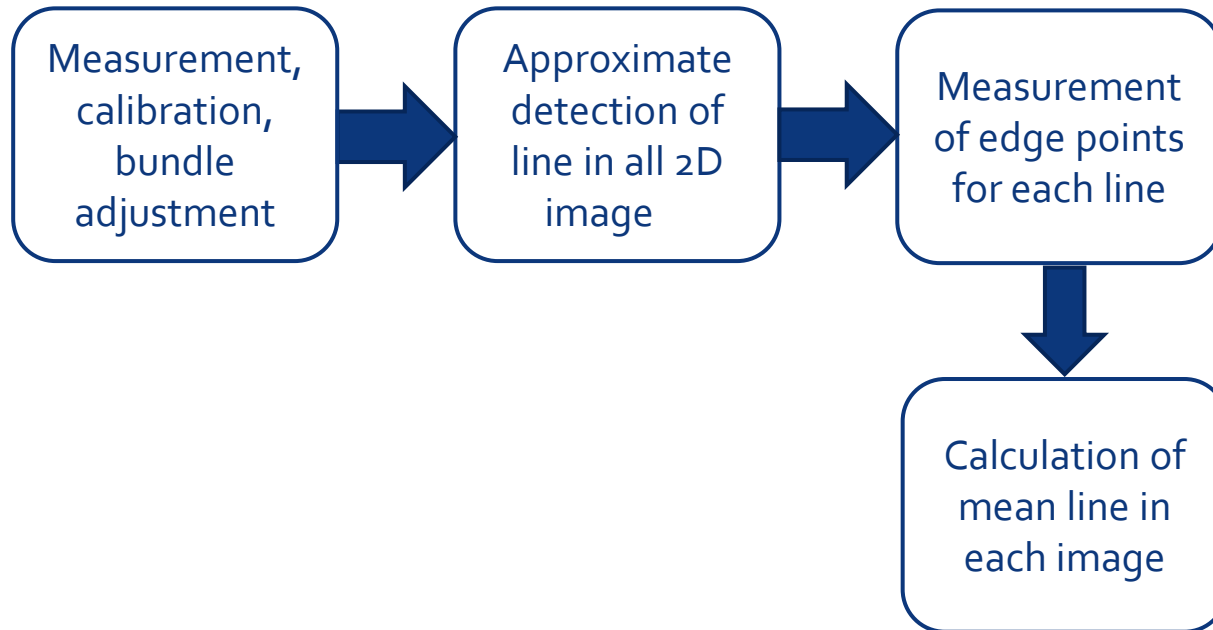
- RANSAC (random sample consensus)
- Additional Knowledge
 - Line is horizontal
 - Two edges close to each other
 - Wire passes through entire image
 - Colour can be chosen

Alternative Approach



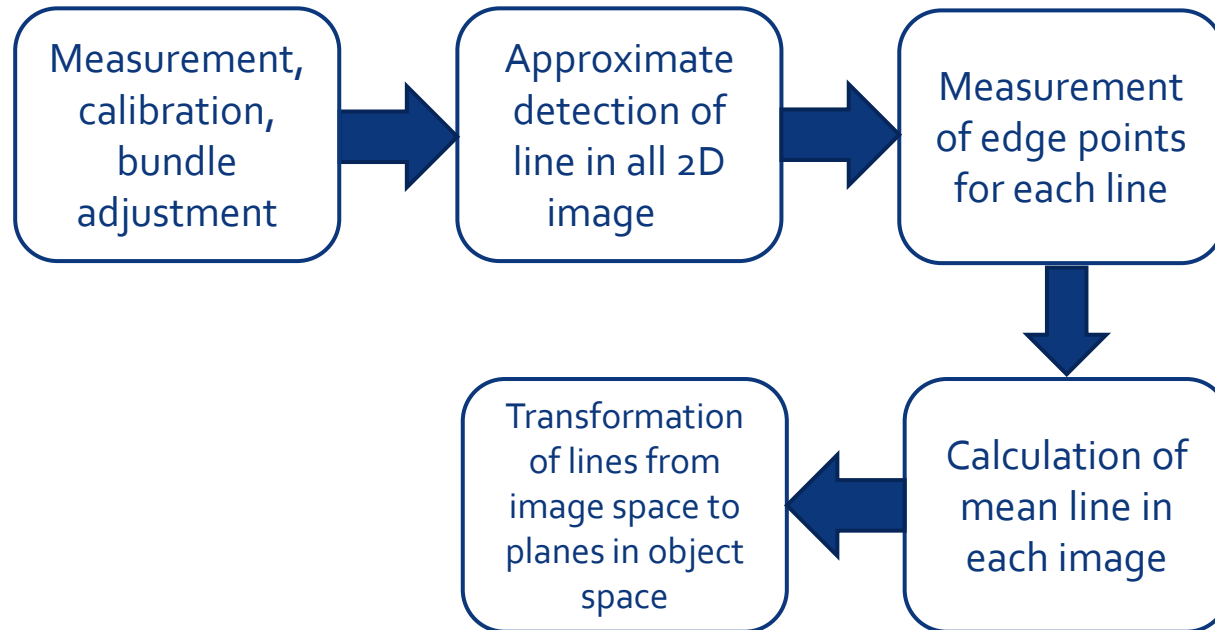
- Sub pixel edge detector Trujillo-Pino
- Iterative correction of distortion
- Edge points separated for both edges

Alternative Approach



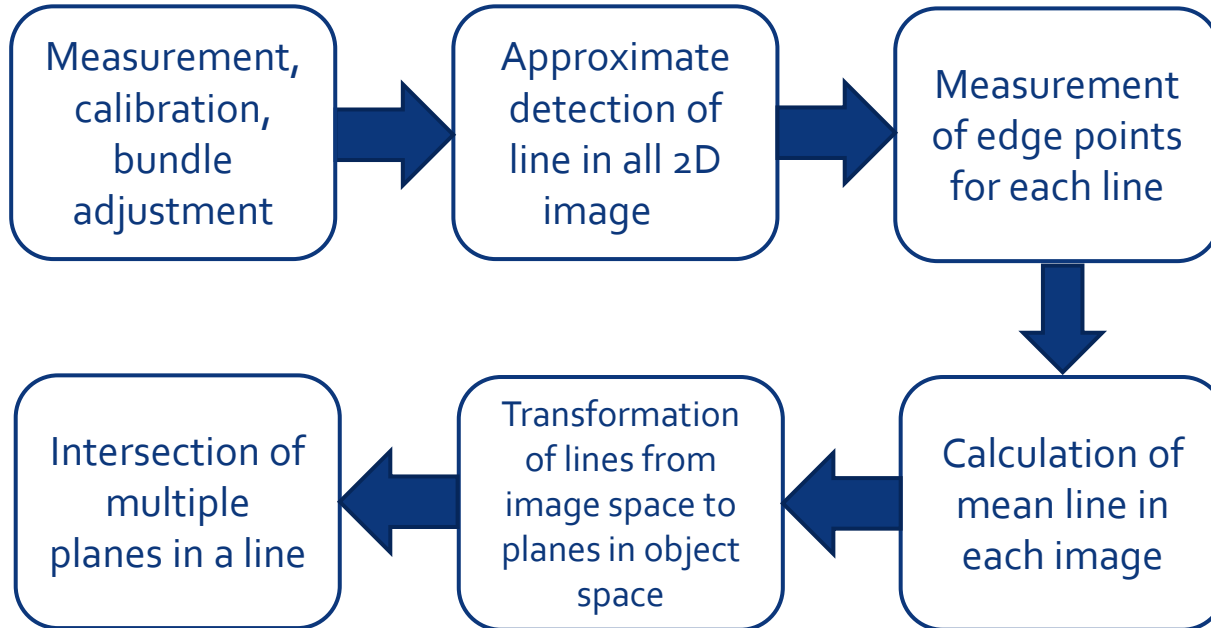
- Mean line by linear regression for each edge
- Angle bisector corresponds to wire measurement in image

Alternative Approach



- Intersection points of line with image borders projected in object space by collinearity equations

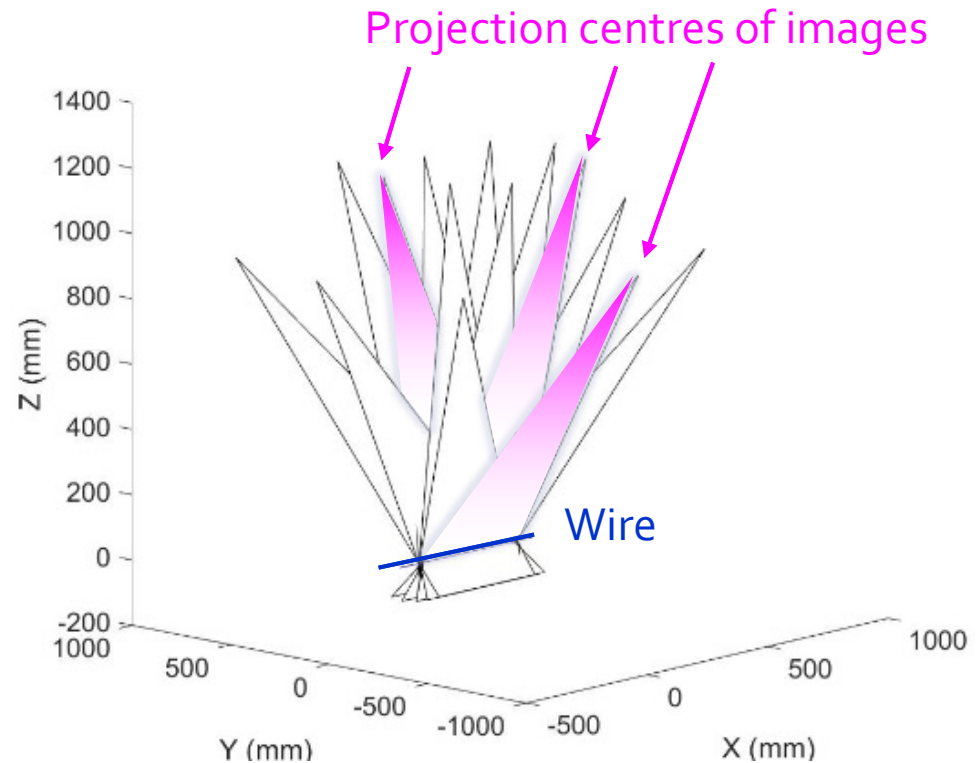
Alternative Approach



- Line calculated by individual adjustment or within bundle adjustment

Alternative approach - Results

- Set of images from standard project
- Plane calculation with alternative approach
- Multiple plane intersections
- Offset of planes to wire
- Comparison to AICON measurement
- ➔ Sigma of differences < 8 μm



Conclusion and outlook

- Photogrammetry is possible tool for ecartometry
- Precision of distances between points and wire less than 10 μm

What comes next?

- Real scale comparison with Micro-triangulation as developed in the PACMAN project (*see talk from V. Vlachakis Friday morning*)
- Definition of scale
- Introduction of the vertical
- Measurement of complete wire / complete sector in manual mode

- Interesting approach during detector fiducialisation, for example wire chambers
- To be studied...

Thank you!

Merci!