Online preventive non-destructive evaluation in automated fibre placement

Ir. Rik Tonnaer, Dr. Sonell Shroff and Dr. Roger Groves

1st 3DMC Conference

22nd – 24th November 2016

Delft University of Technology

- One of 3 TU`s
- 21.000 students (2015)
- 15% intl. in BSc.
- 30% intl. in MSc.

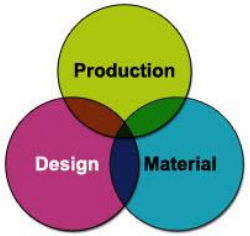
- 4700 staff (2015)
- 30% intl.

Aero NDT

TU Delft

Aerospace Engineering

Structural Integrity and Composites



Aerospace NDT

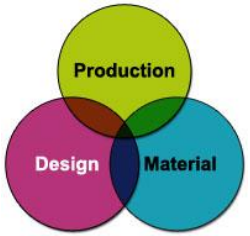
- Optical Metrology
- Spectral Imaging
- Fibre Optic Sensing
- Ultrasonics

Manufacturing

- Automated fibre placement
- Filament winding
- Thermoplastic welding
- Process simulations

Aerospace Engineering

Structural Integrity and Composites



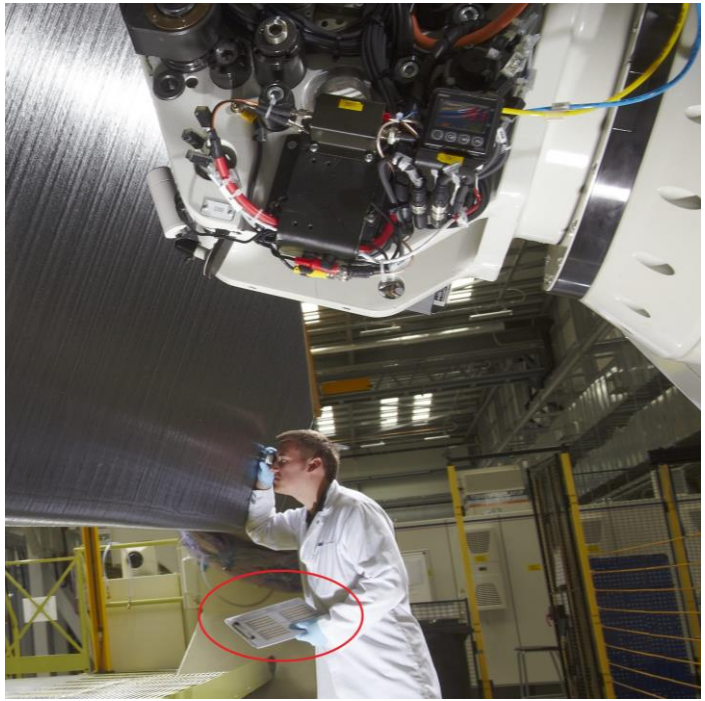
Aerospace NDT

- Optical Metrology
- Spectral Imaging
- Fibre Optic Sensing
- Ultrasonics

Manufacturing

- Automated fibre placement
- Filament winding
- Process simulations
- Manufacturing based design

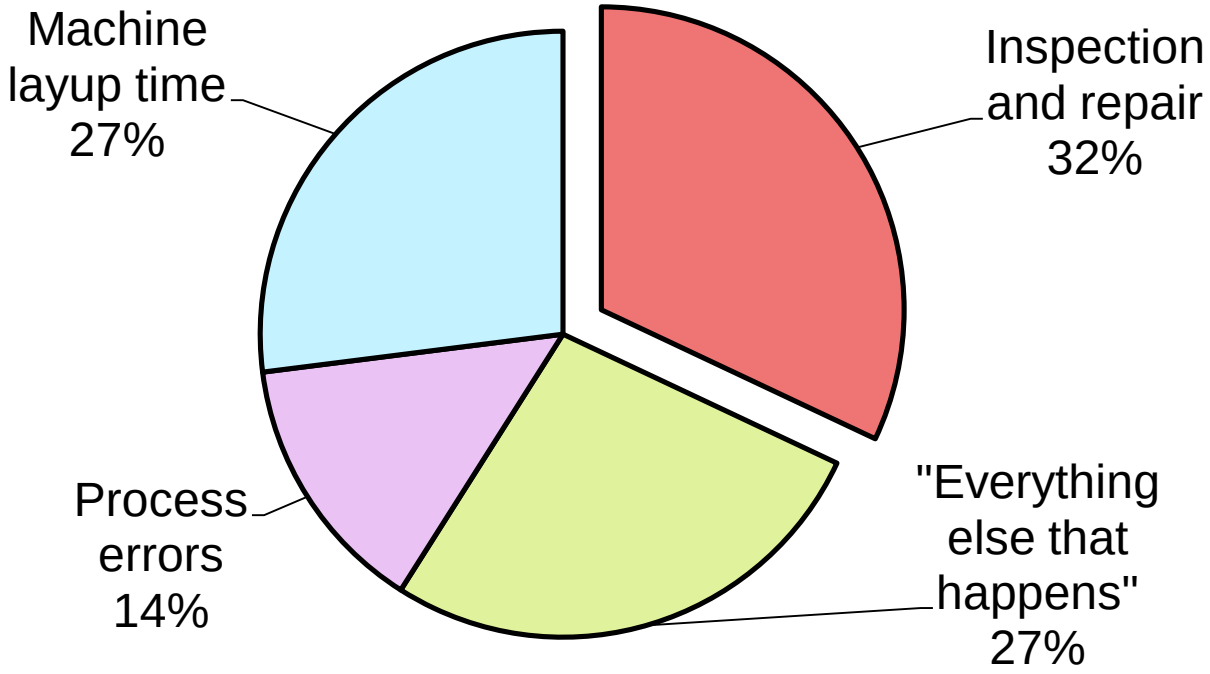
Motivation



Source: GKN Aerospace

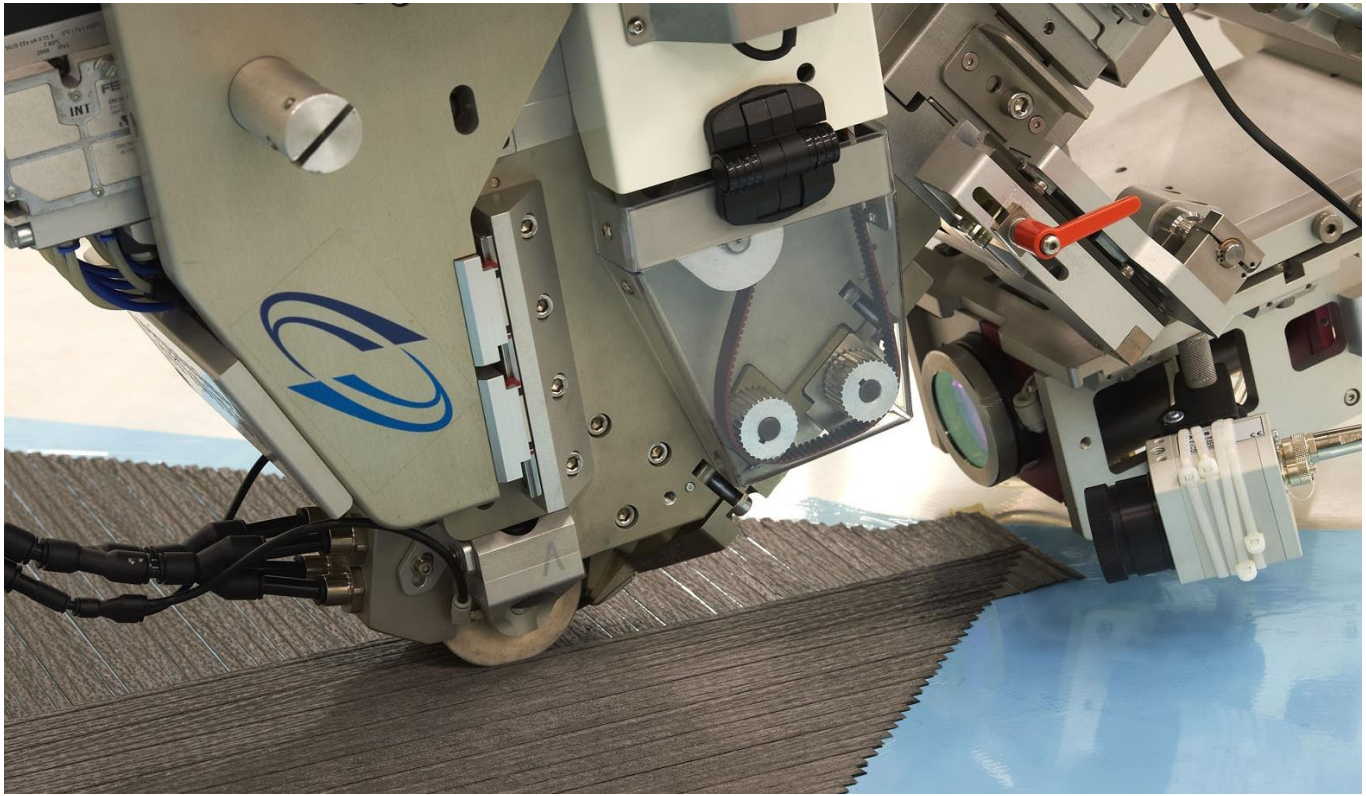
- High requirements lead to:
  Strict quality control
- Quality control mostly a *manual* process
- Consequence:
  Main cost driver

Time distribution during part build



Source: Rudberg et al.

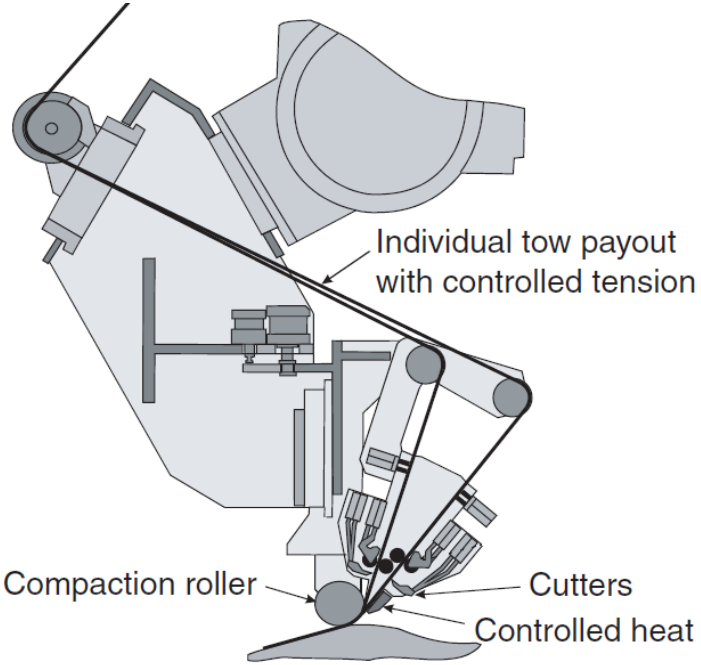
Automated fibre placement (AFP)



Source: Coriolis Composites

Automated fibre placement (AFP)

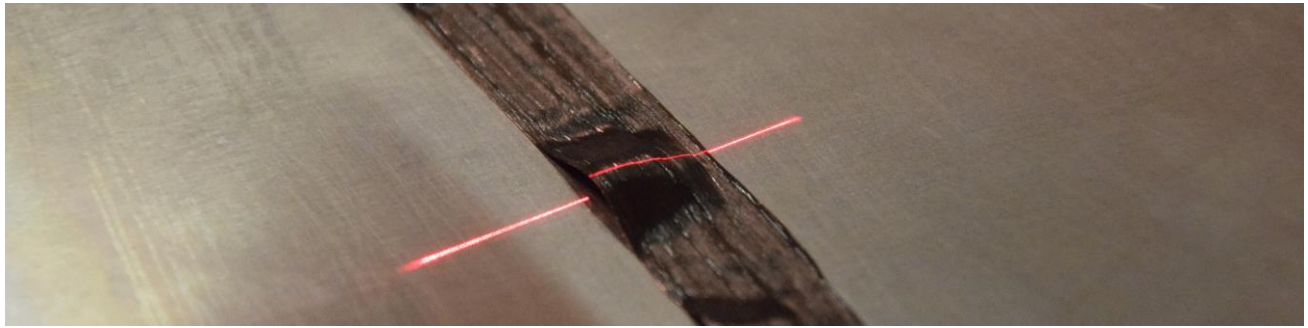
- Method of producing composite laminates
- Full control over placement of composite tapes
- Process not perfect



Source: Miracle (2001)

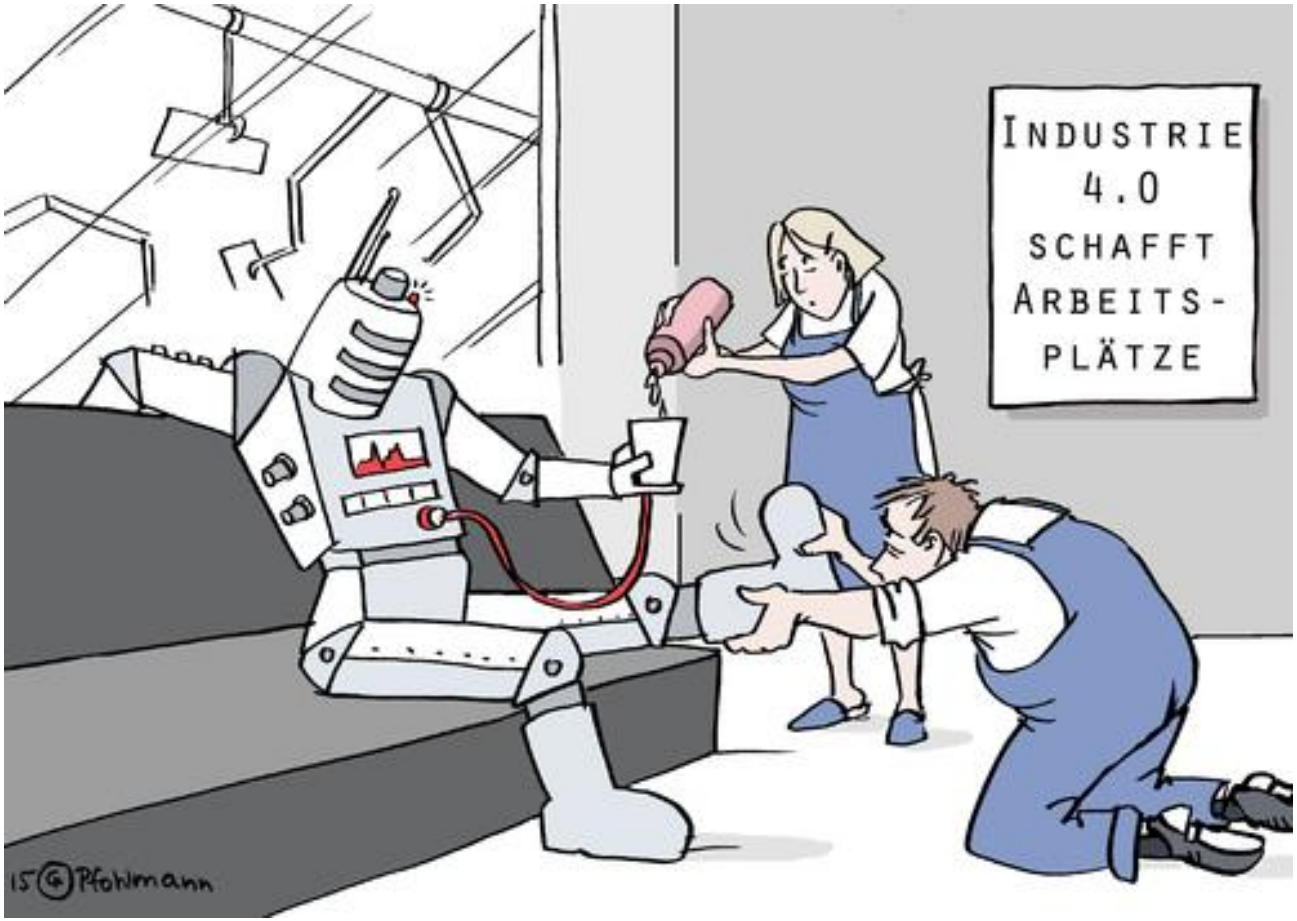
Defects in AFP

- Gaps or overlaps between two tapes
- Foreign objects (e.g. fuzz, backing foil)
- Wrong fibre path/wrong curvature of path
- Local buckling due to fibre steering.



Preventative non-destructive evaluation

- Philosophy: In process assessment of production quality to prevent defects in final product
- Main focus of our Aero NDT lab for smart manufacturing
- Intelligent integration of sensors and data analysis into the production process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SCHAFFT
ARBEITS-
PLÄTZE
15 © Pfohlmann

Research approach

1. Fusion of data from robot and sensor
2. Real-time gathering and processing of data
3. Online determination of fibre geometry

Experimental setup

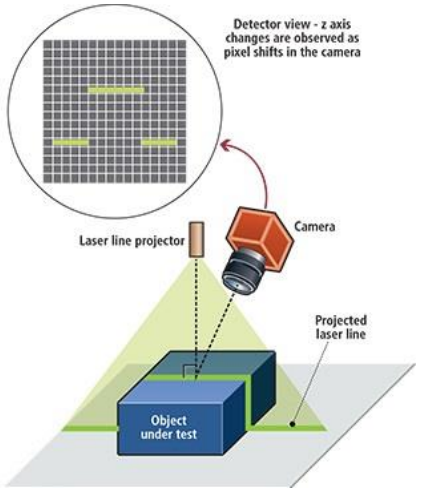
- Kuka KR210R2700 extra
- Micro epsilon scanCONTROL sensor
- Data fusion using Robot Operating System (ROS)

- Data analysis based on OpenCV image processing


KUKA

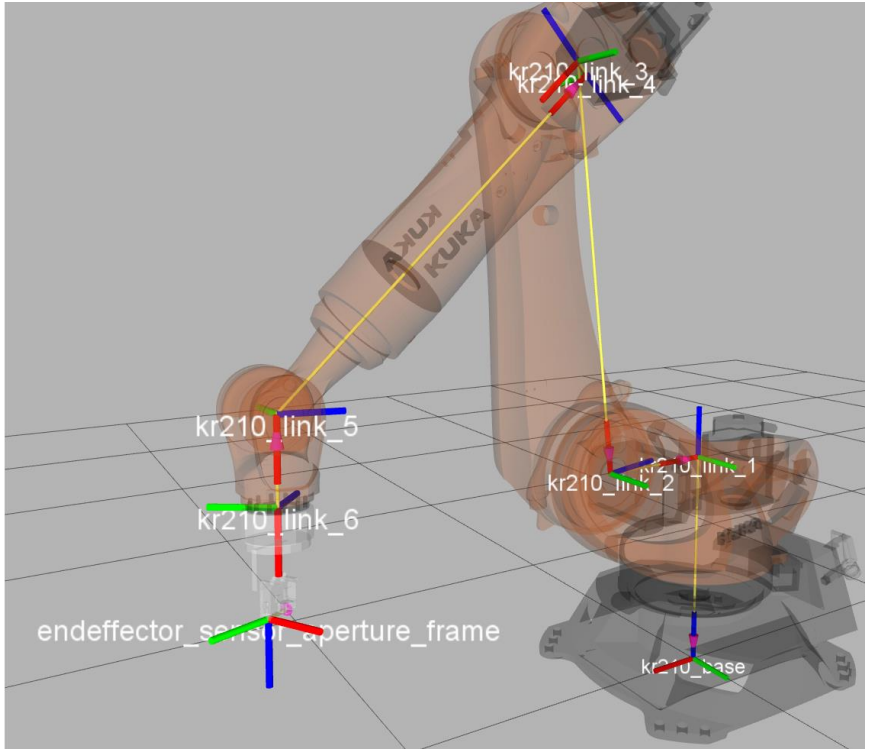
Laser Displacement Sensing

- Laser triangulation
- Height profile along a laser line
- Micro Epsilon scanCONTROL
  - Up to 2000 Hz
  - Up to 1280 points per line
  - Height resolution: up to 2 µm

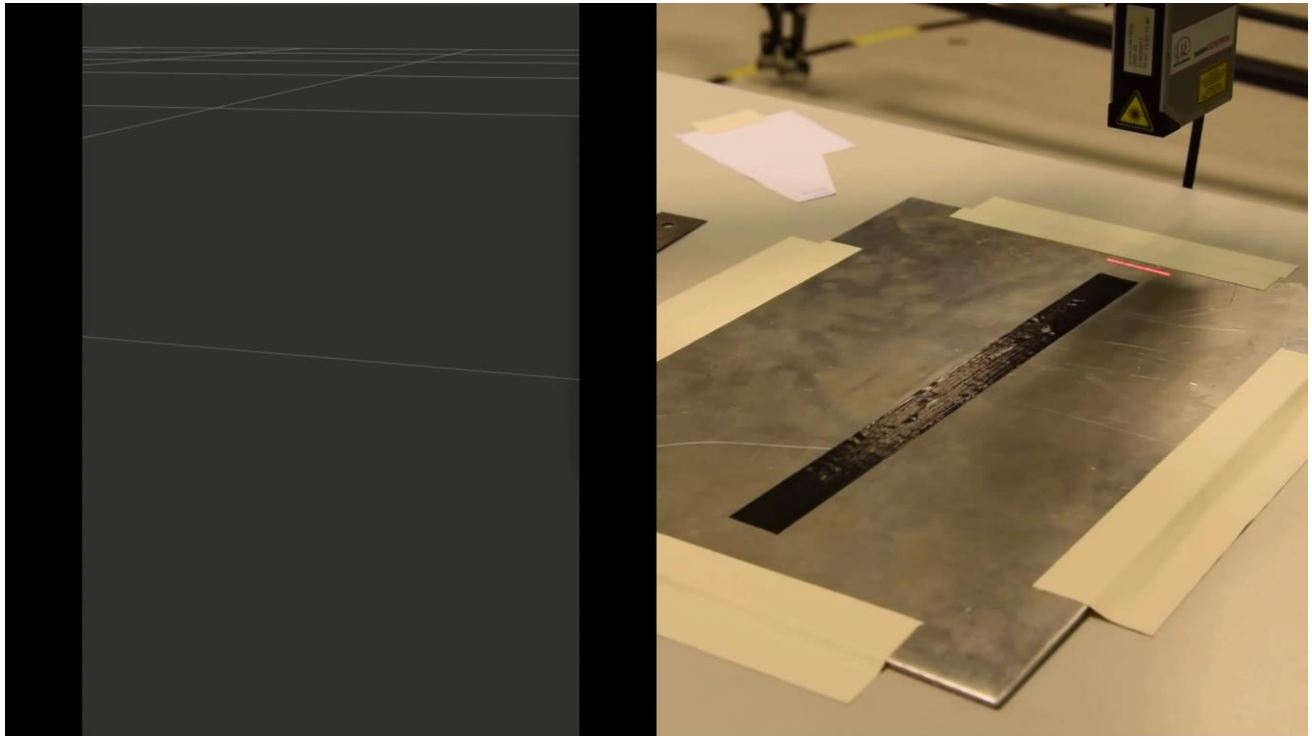


Data acquisition

- Data from sensor is transformed to robot coordinate frame (ROS)
- Fusion of robot and sensor data yields point cloud
- Point cloud converted to image

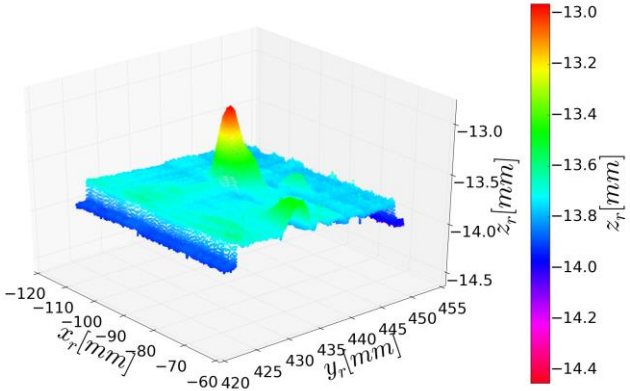


In action…

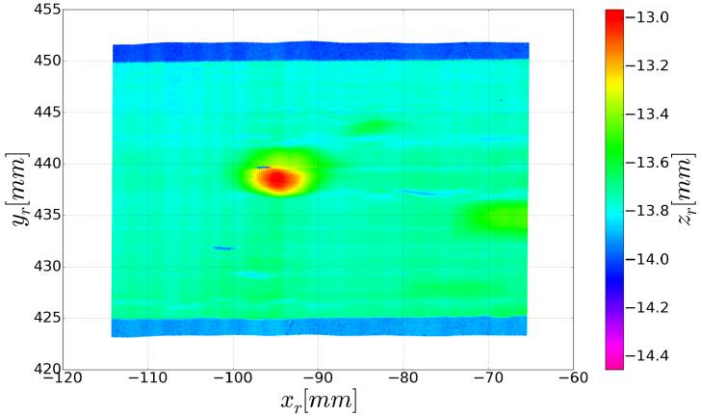


Section of data

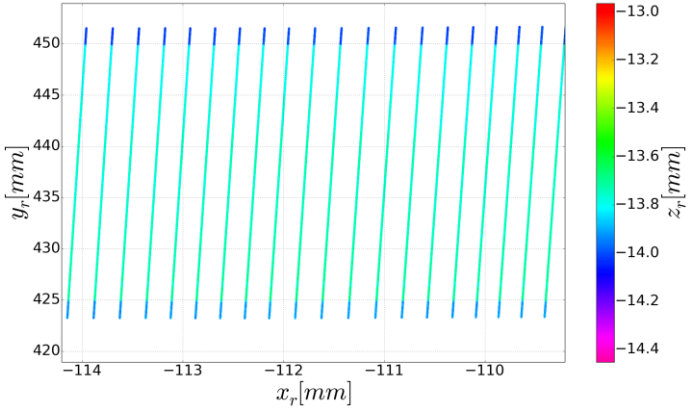
- Point cloud of 250.000 points
- 196 profiles in 2 seconds
- X,Y,Z coordinates



3D view



Top view



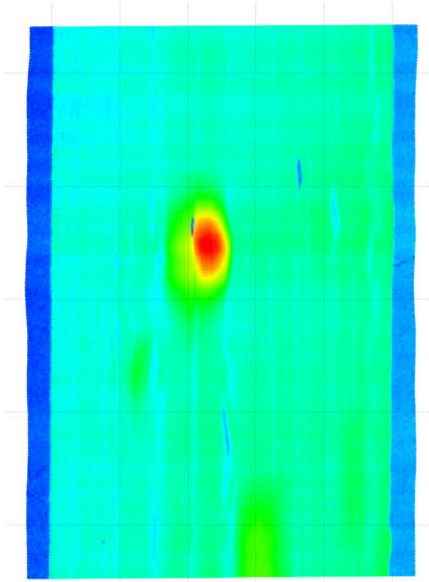
Top view - Close

Conversion to an image

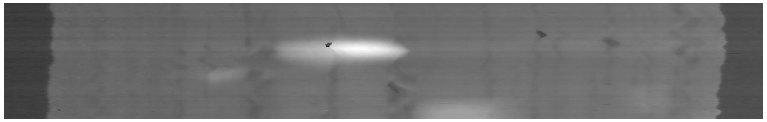
- To use OpenCV:
  - Conversion to image format
- Extraction of:
  - Thickness,
  - Width and
  - Edge location
- Normalization:

$$P_i = (z_i - z_{max})\frac{(P_{max} - P_{min})}{(z_{max} - z_{min})} + P_{min}$$

- In this case:
  - $P_{max} = 255, P_{min} = 0$



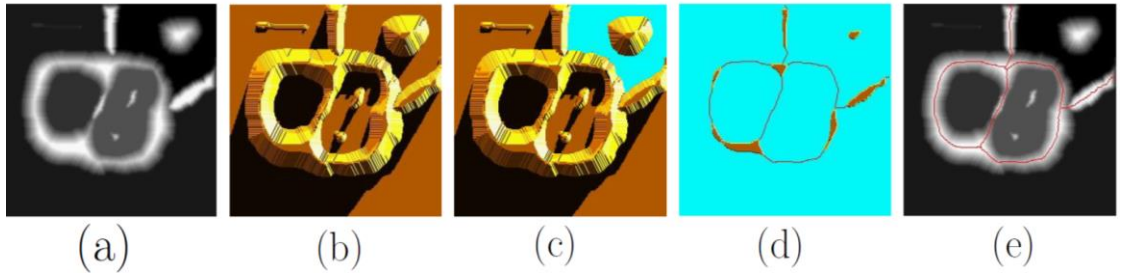
Point cloud



8-Bit Greyscale Image

Segmentation using OpenCV

- Many approaches possible (e.g. Canny)
- Finding discontinuities in pixel intensity
- Segmentation using Meyer`s flooding algorithm



Source: Centre for Mathematical Morphology

Advantages vs disadvantages

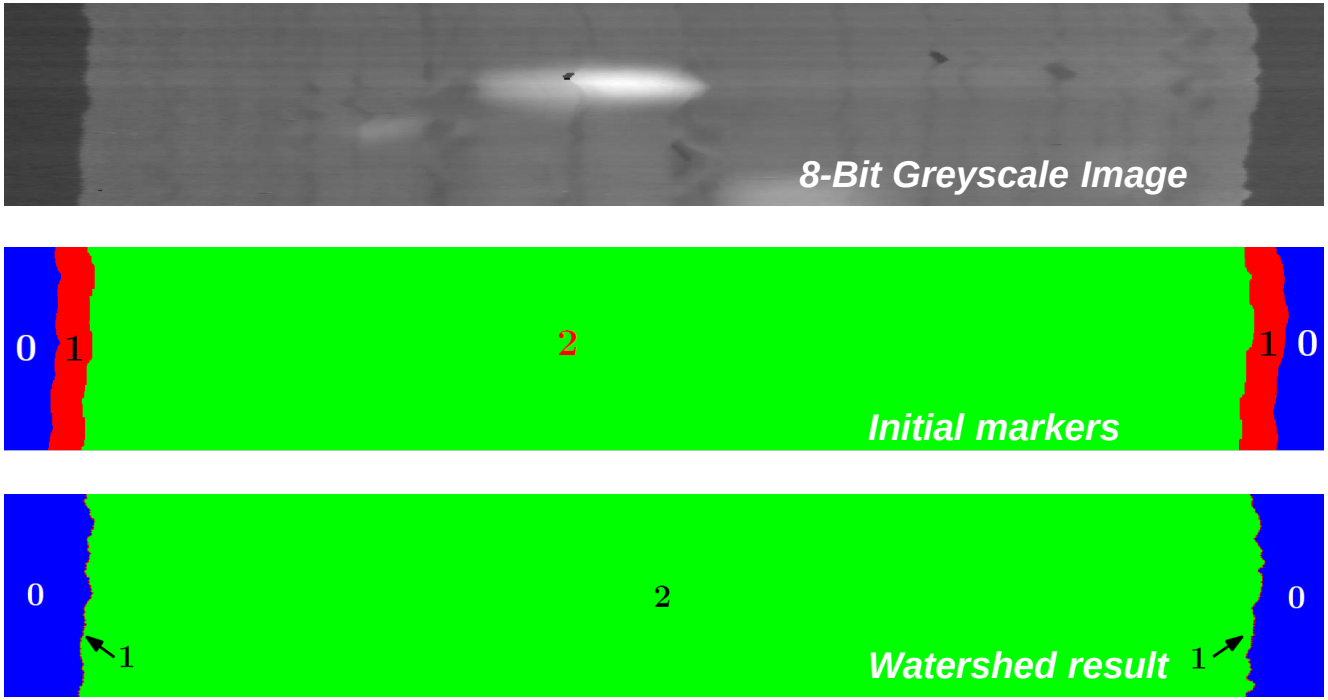
Advantages:

- Fast implementation (C++)
- Provides closed contours by design
- General method, widely applicable
- Ability to segment touching regions of same “height”

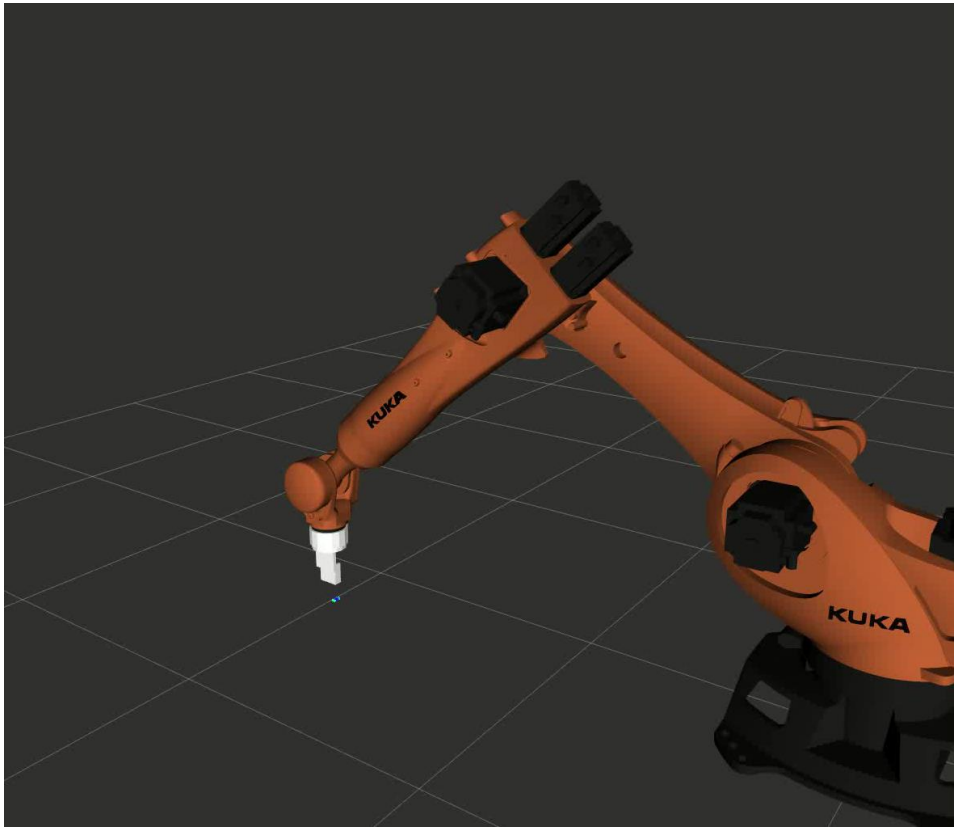
Disadvantages:

- Over segmentation
- Need for pre-processing (i.e. provide a-priori info)
- Current pre-processing sensitive to local height spots
- Loss of “resolution” in conversion from point cloud to image

Results in images



Results in point clouds



Future work

- Expansion of defect detection
- Application of more sophisticated algorithms
- Use results to validate our simulations of the fibre placement process

Thank you!