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MANUFACTURING METROLOGY TEAM

Methodology for the development of in-line surface measuring instruments (with a case study)

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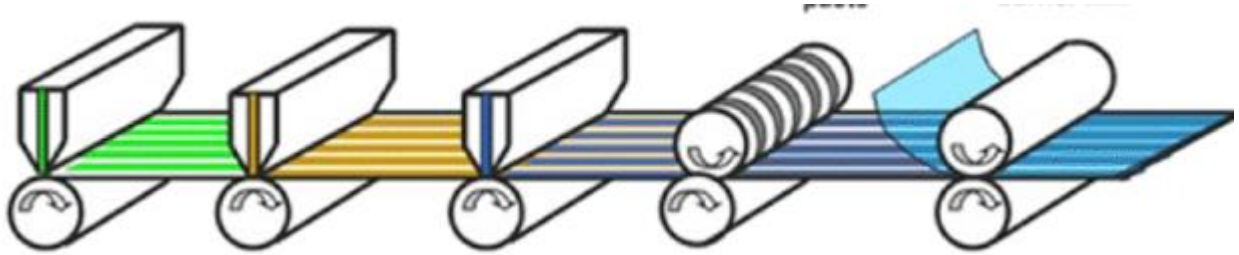
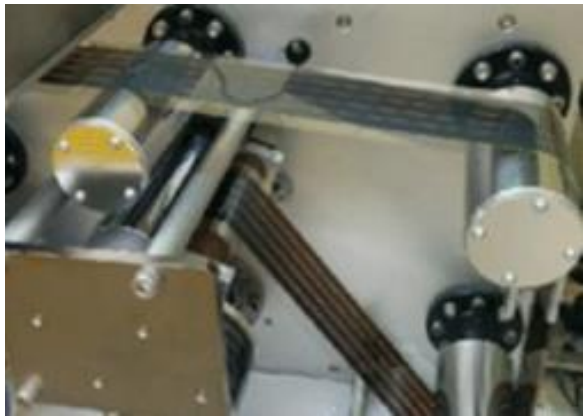
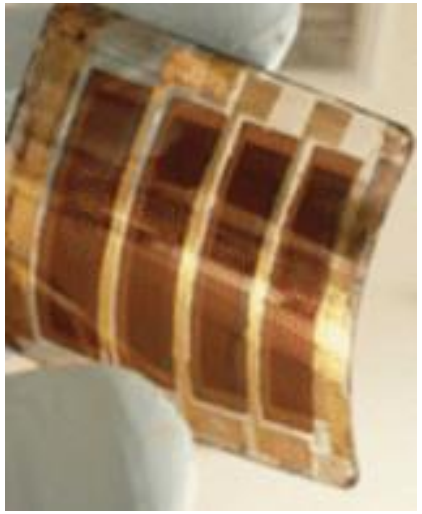
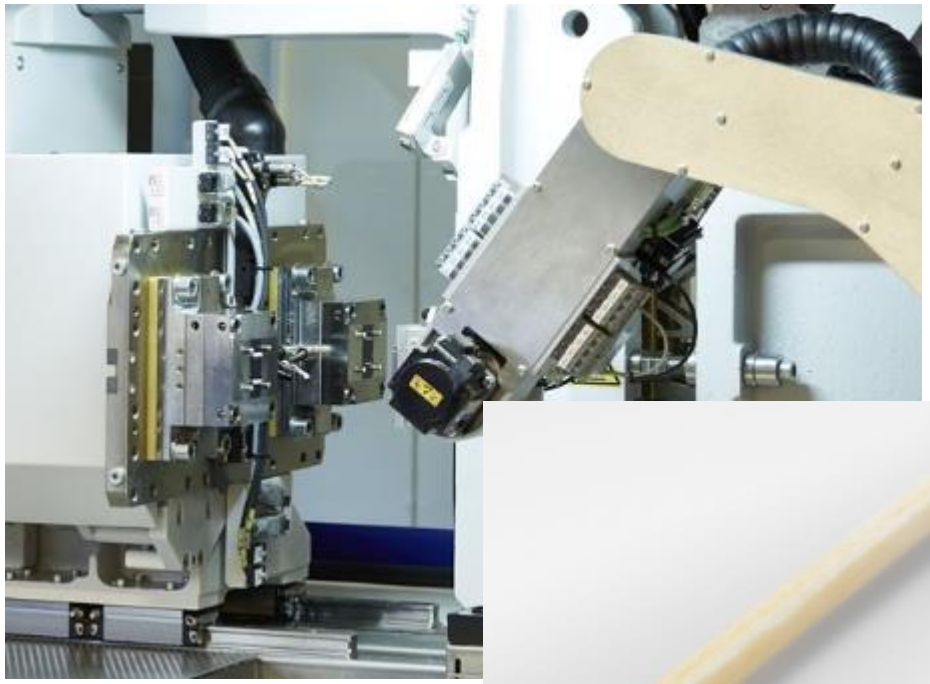
Motivation

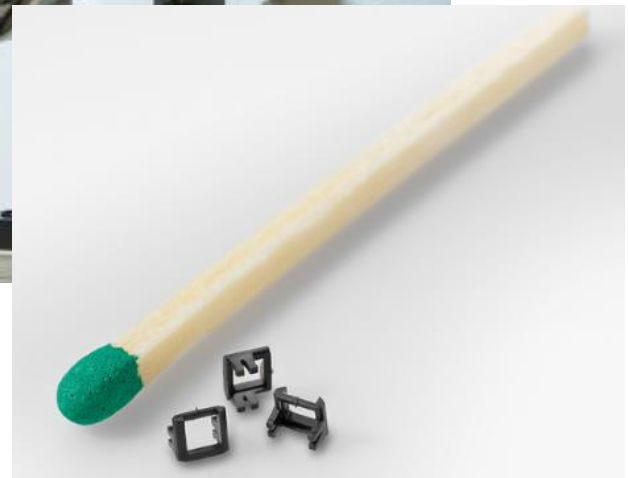
- Fast and accurate optical in-line measurements for **mass-production** manufacturing processes at millimetre- to micrometre-scale











Challenges

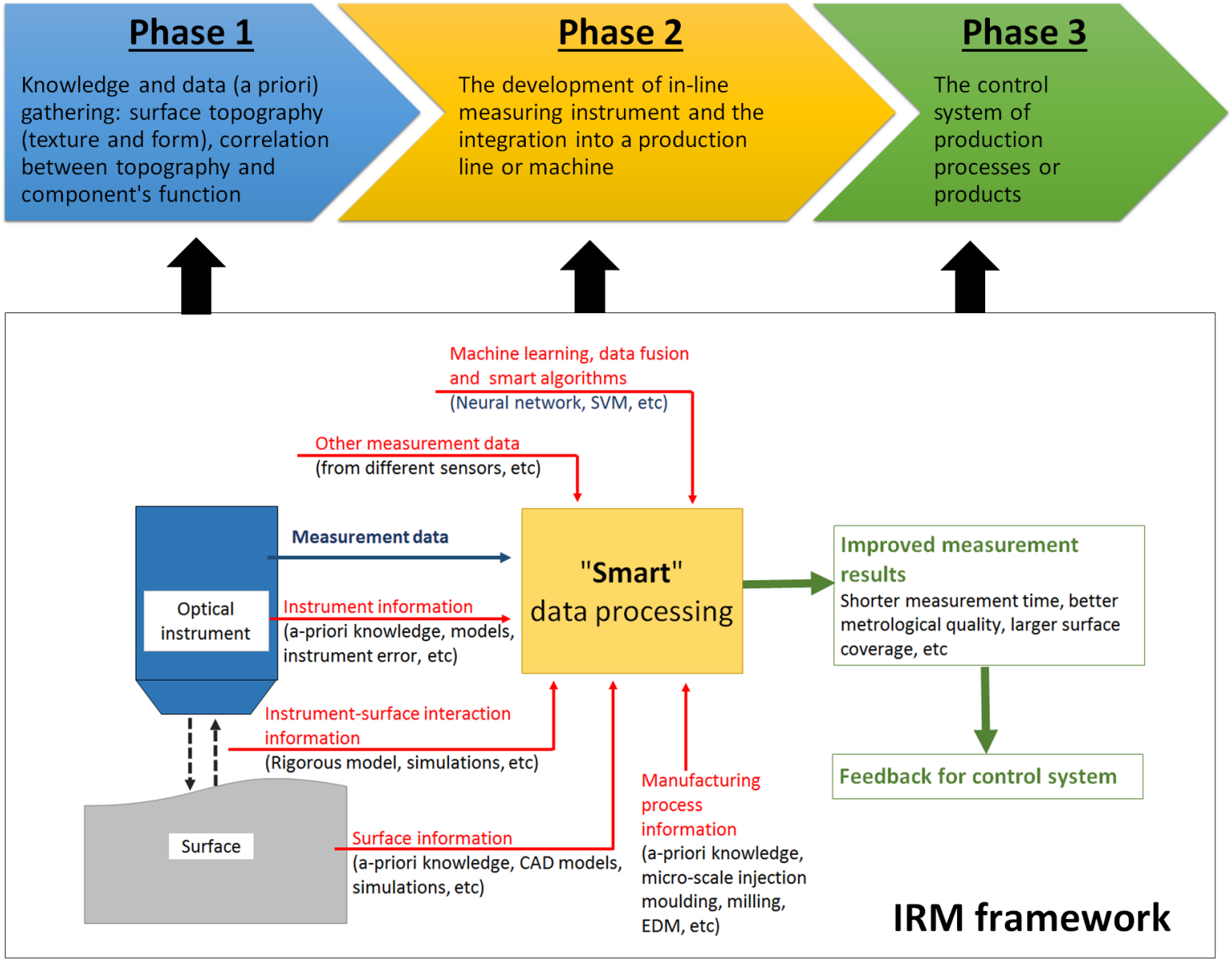
Many challenges for the realisation of fast and accurate optical in-line measuring instruments:

1. Methods
2. Speed
3. System integration and control
4. Traceability
5. Intelligence

NOTE:
Not all challenges need to be addressed for a given case

Proposed methodology

Proposed by Richard Leach



Case study: additive surface finishing

Rough surface:

ADDITIVE MANUFACTURING TECHNOLOGIES

PostPro3D machine

Smooth surface:

Goal: a fast in-process surface condition detection for close-loop control

Approach

Phase 1

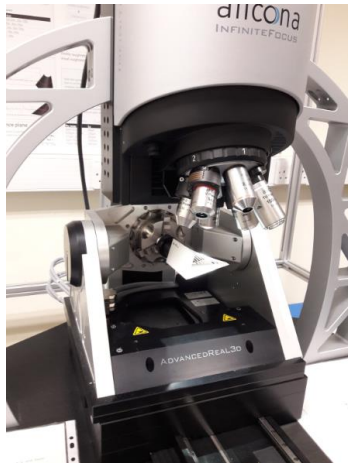
Knowledge and data (a priori) gathering: surface topography (texture and form), correlation between topography and component's function

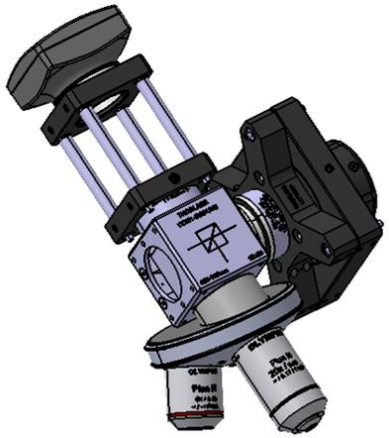
Phase 2

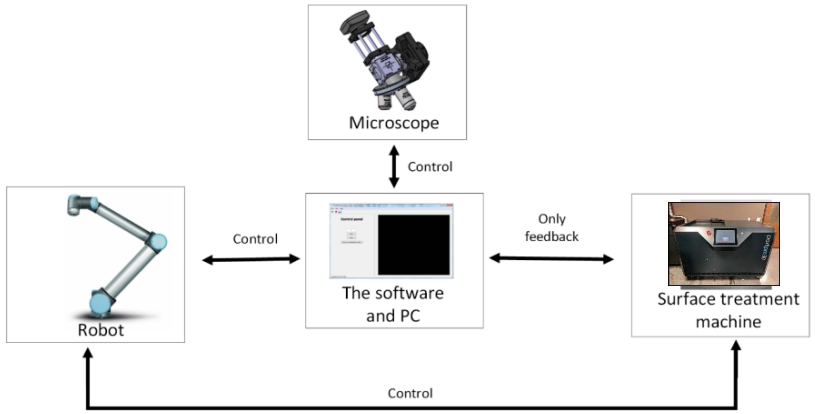
The development of in-line measuring instrument and the integration into a production line or machine

Phase 3

The control system of production processes or products

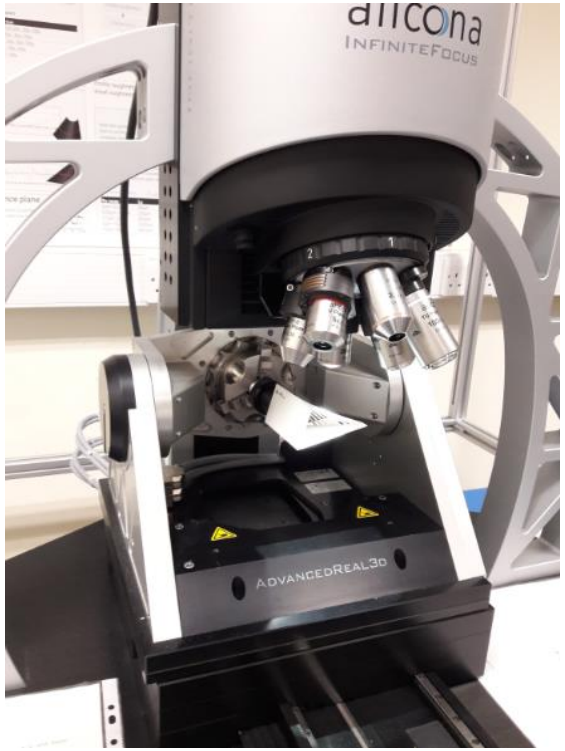


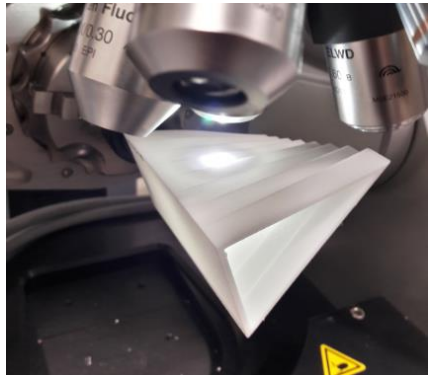




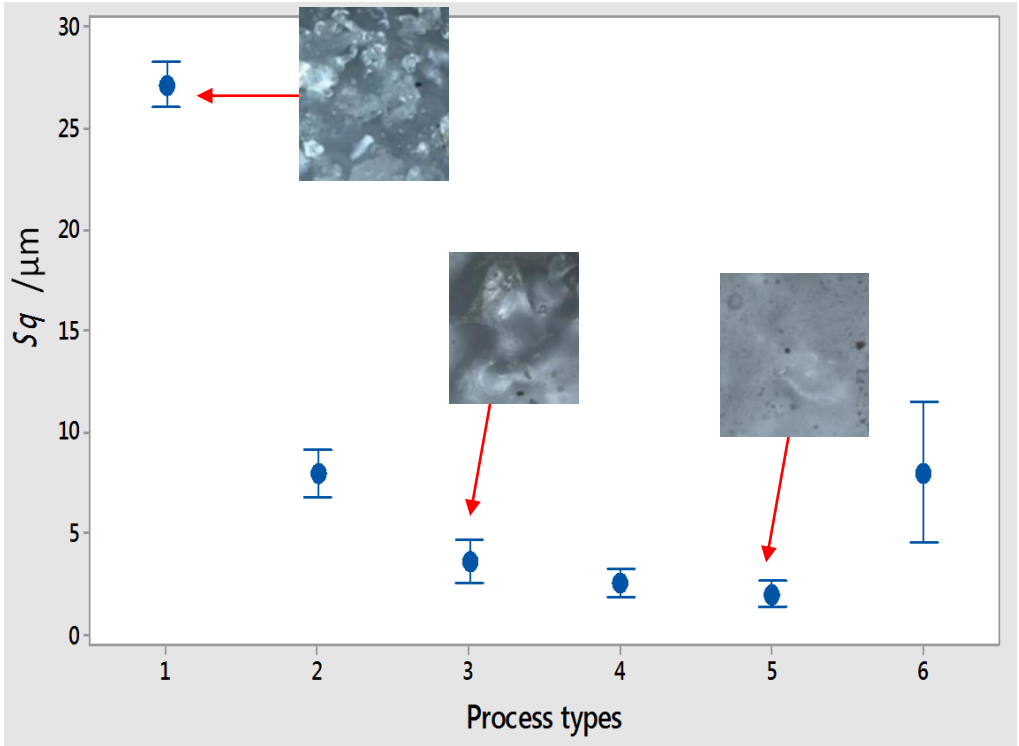
Phase 1: Knowledge and data gathering

- A lot of measurements with high resolution focus variation microscopy
- Different polymers measurements
- Understanding surface evolutions during different post processing





1 = 0 %
2 = 25 %
3 = 50 %
4 = 75 %
5 = 100 %
6 = Over process



Phase 2: Instrument and software development

Requirements:

- Small and compact measuring instrument
- Software to control the instrument
- Fast detection of surface condition < 30 s (preferably < 15 s)
- Low cost
- Flexible and portable
- Easy to integrate
- Time limit: a 6 month project

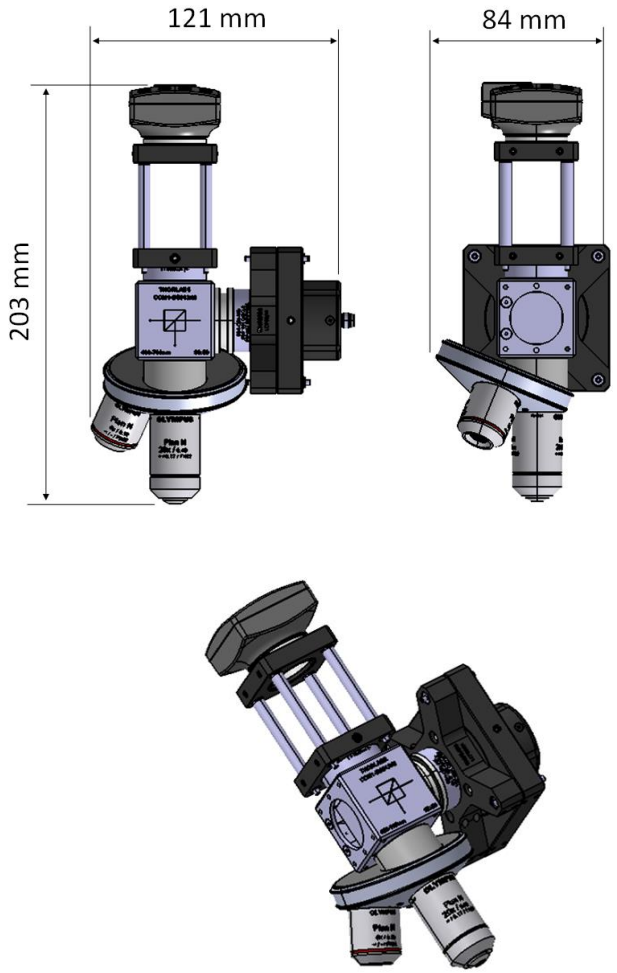
Solution:

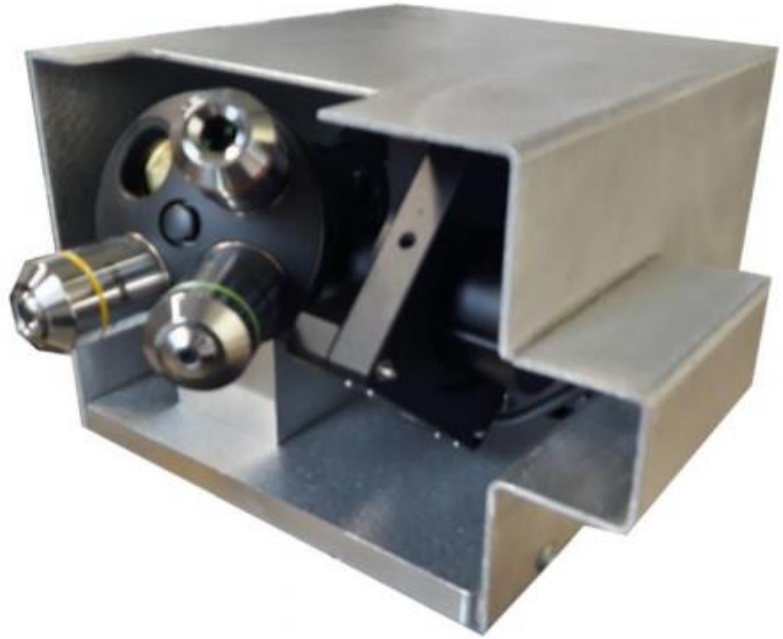
- 3D surface reconstruction (at this moment) is not a solution
  - With current technologies, measurements take time = 1 min. (scanning, data processing, etc)
  - High-cost for precision stage (most 3D measuring instruments involve a scanning a surface through its focused position).
  - Longer development time

- 2D image analysis solution is selected
  - Low-cost
  - With machine learning, image analysis is significantly enhanced
  - Absolute surface measurements are not required

Phase 2: Instrument and software development

Instrument development:

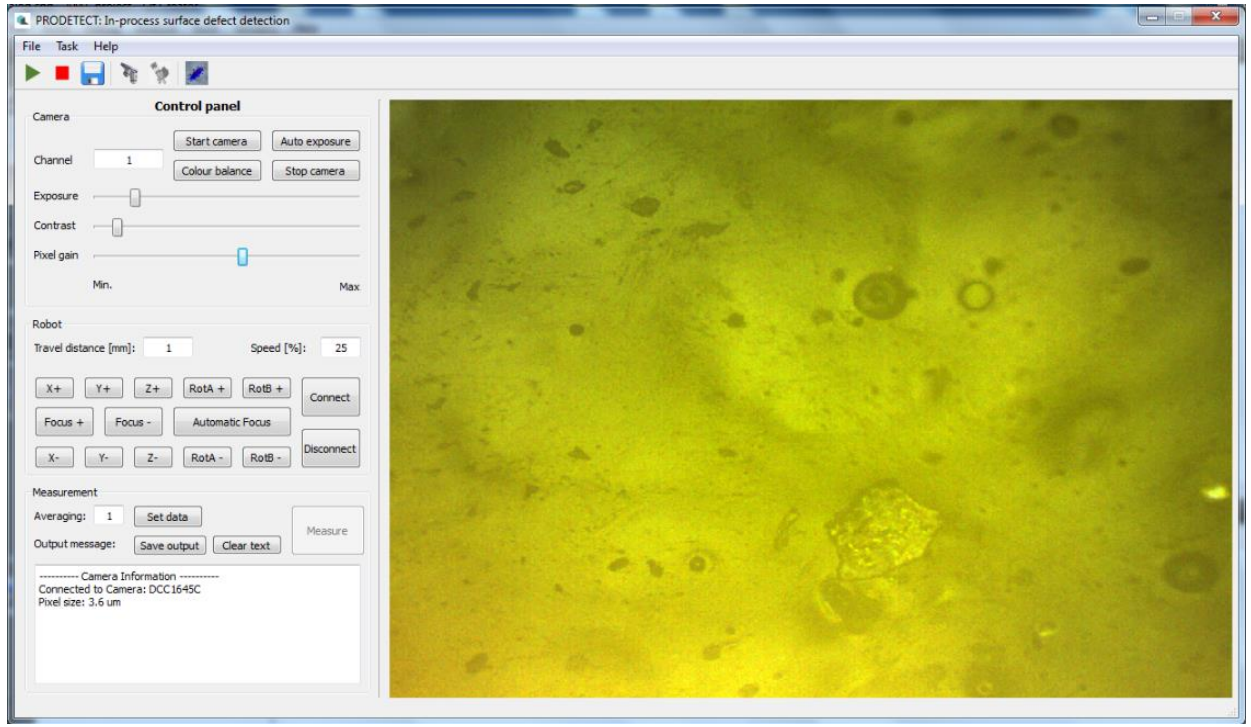




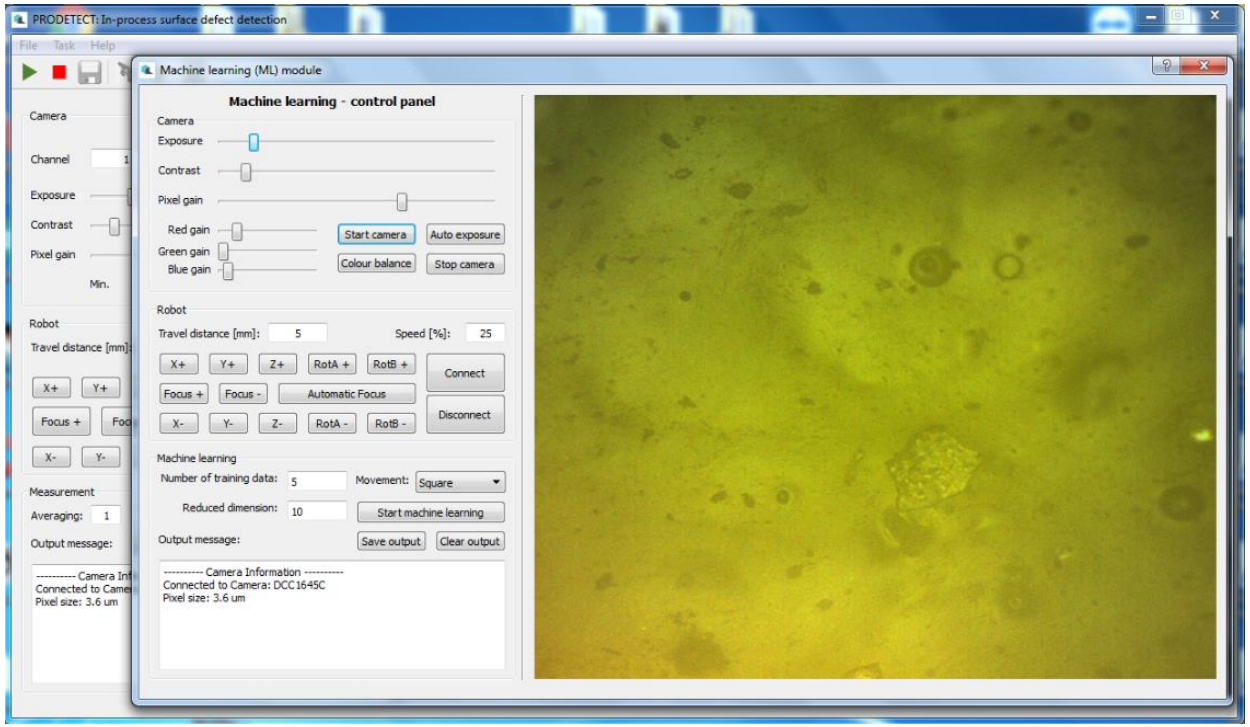
Phase 2: Instrument and software development

Software development:

Measurement module



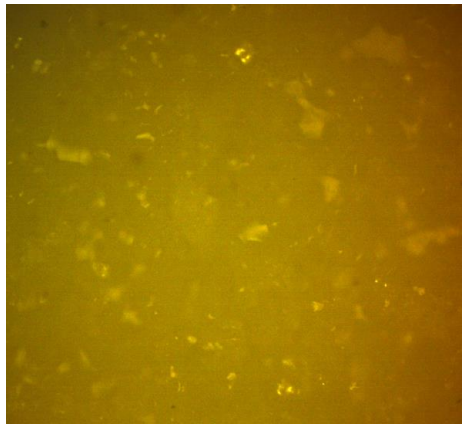
Machine learning module



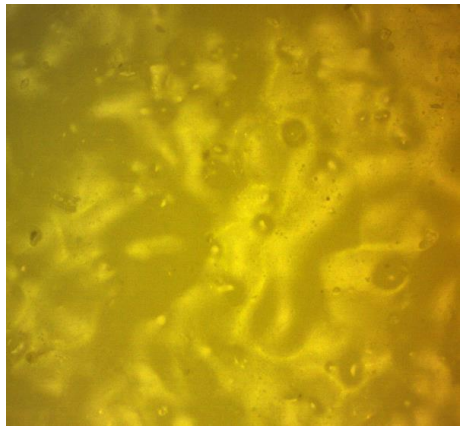
Phase 2: Instrument and software development

Instrument and software testing: TPU samples

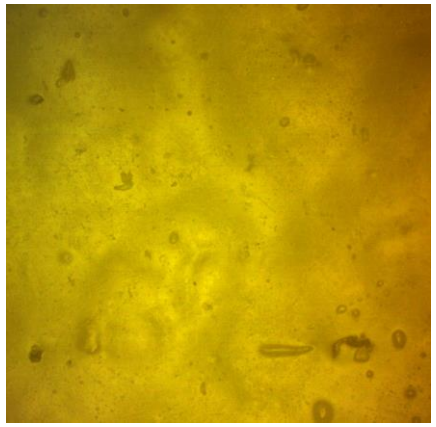
Type 1 – 0 %



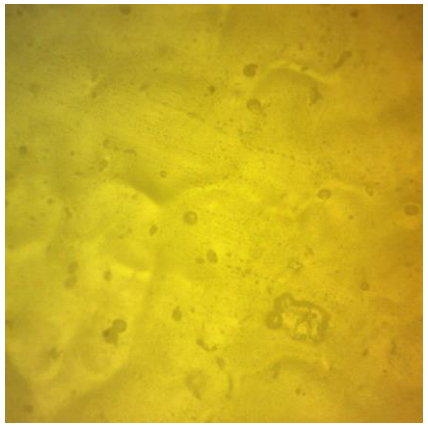
Type 2 – 25 %



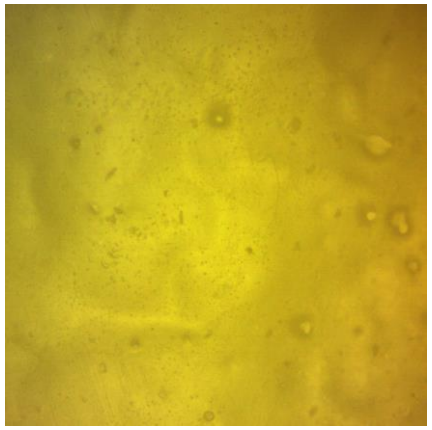
Type 3 – 50 %

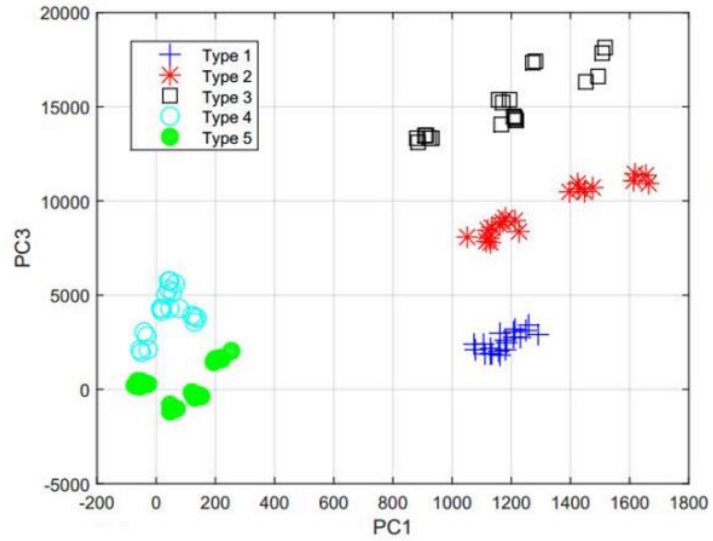


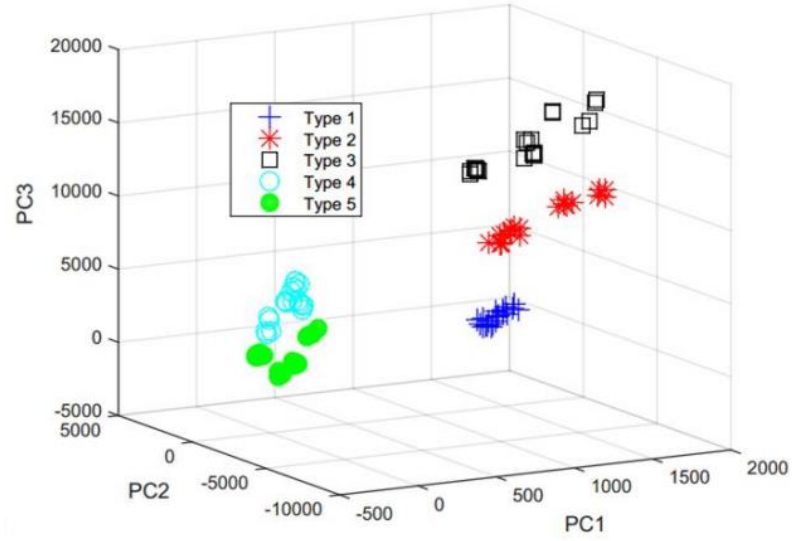
Type 4 – 75 %



Type 5 – 100 %

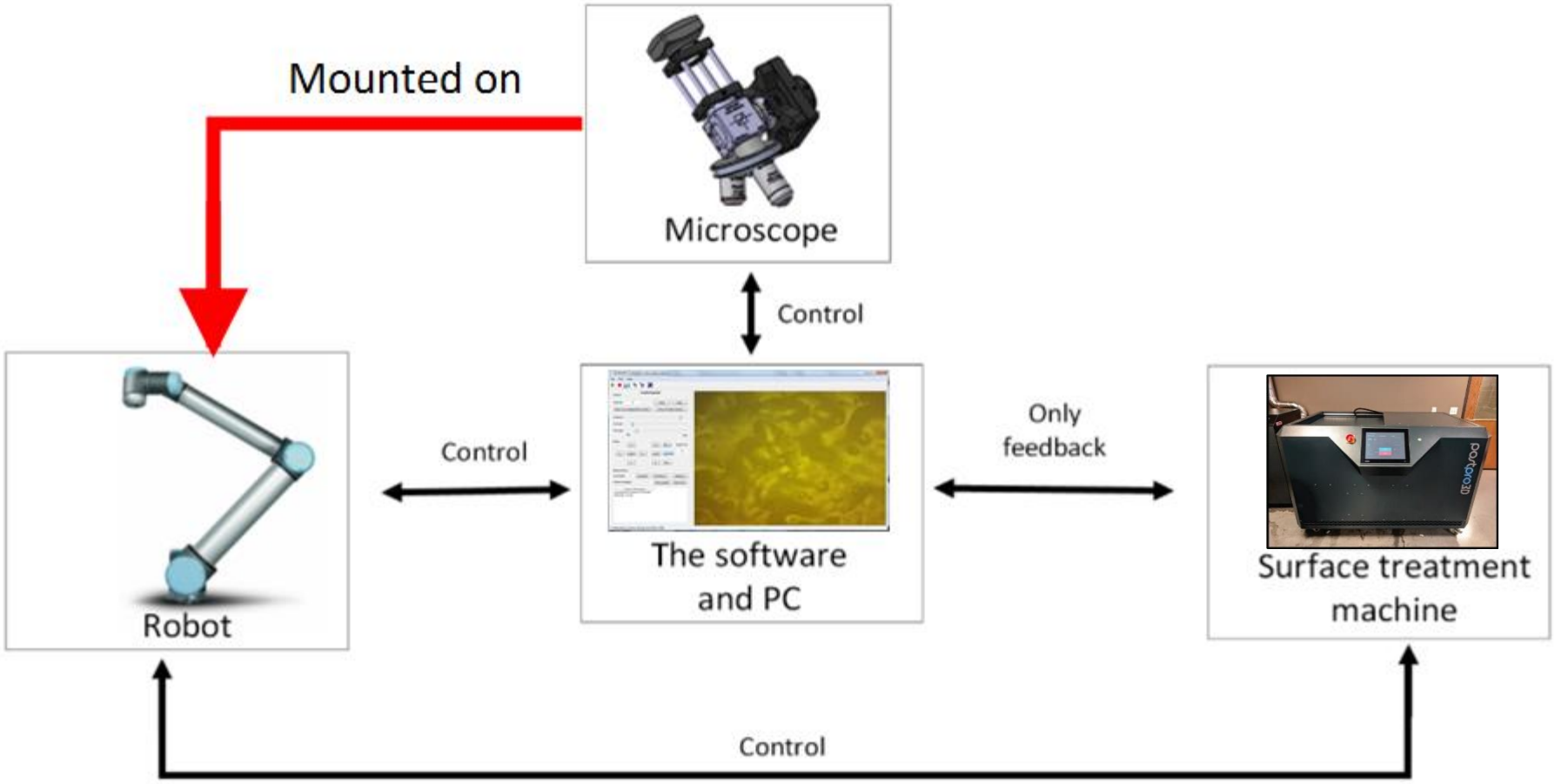




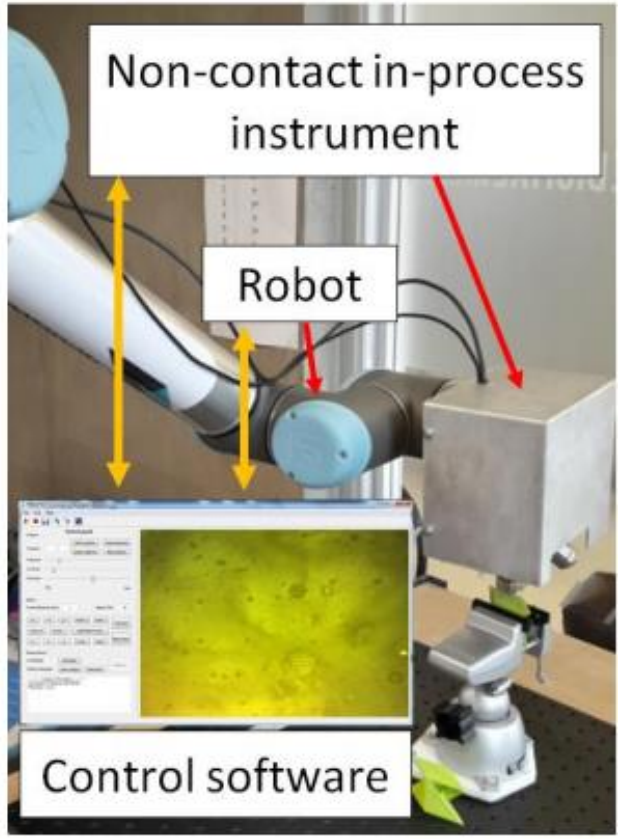


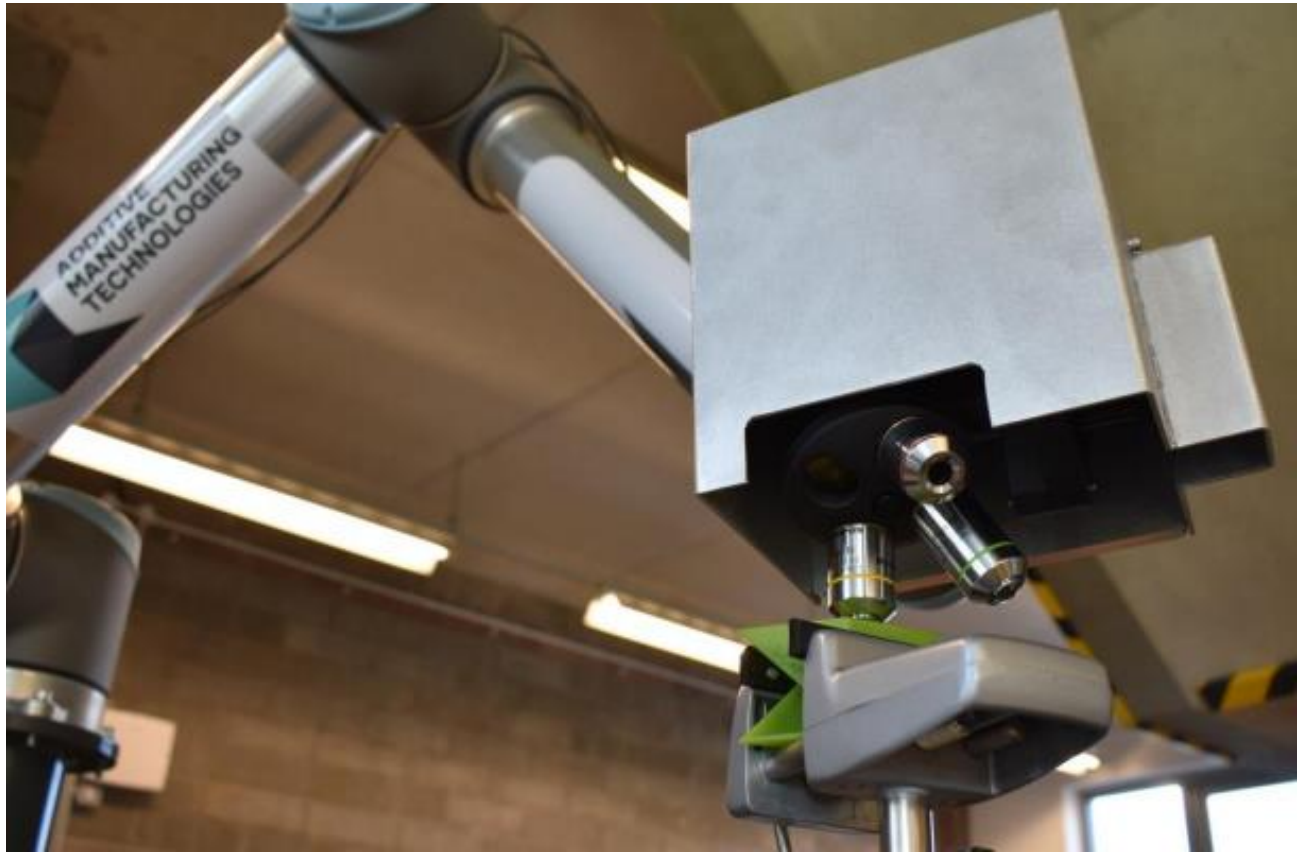
Phase 3: Control system based on in-line feedback

- Instrument placement: in-line
- After the process, but still inside the process cycle



Phase 3: Control system based on in-line feedback





Future works

- Fundamental research to address the challenges for in-line measurements at millimetre- to micrometre-scale
- Exploitation of various state-of-the-art machine learning methods for improved measurement performance
- Implementation of the methodology for absolute in-line measurements, for example: diameter measurement, length, *Sa*, *Sq*, etc

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Manufacturing Metrology Team at Nottingham

Thank you!

Horizon 2020

EPSRC Centre for Doctoral Training in Ultra Precision Engineering

EPSRC Engineering and Physical Sciences Research Council

EPSRC Centre for Doctoral Training in Additive Manufacturing

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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States