Sensor technology for robotic welding of wind turbine substructures

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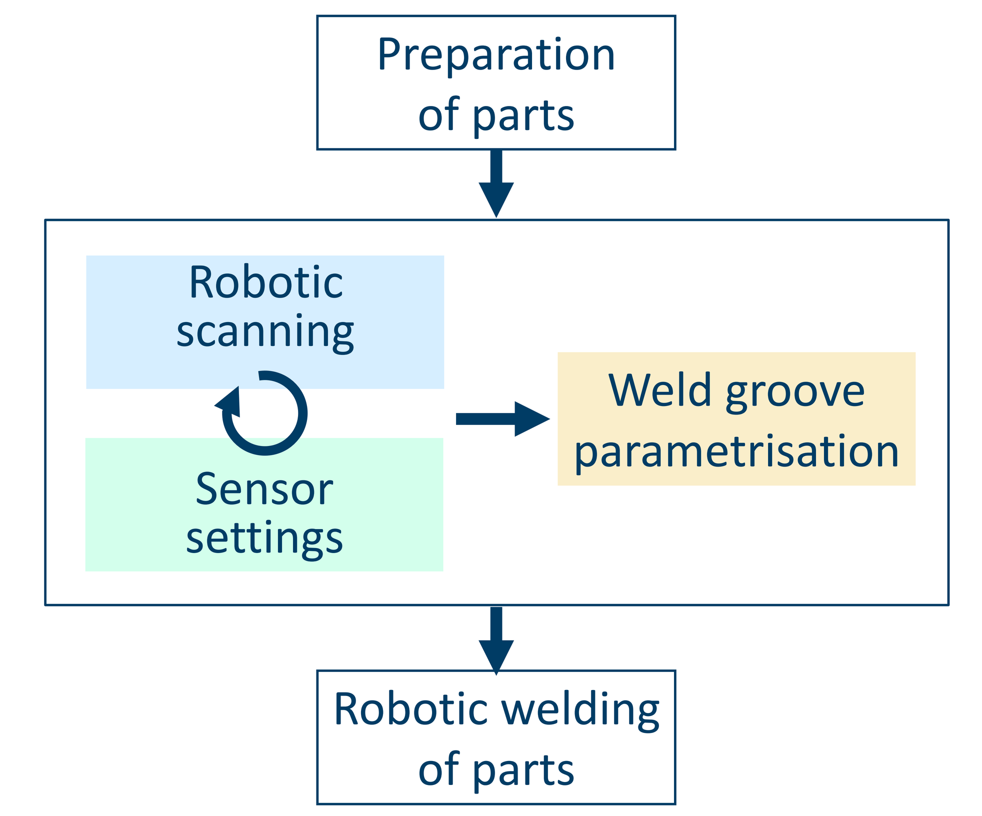
Motivation

Robotic welding is a well-established technology for the mass production of standardised products. In the case of large structures with significant geometric tolerances and large multi-pass, **conventional robotic welding can require unpractically long rigging and programming time**. Jackets used for bottom-fixed offshore installations of wind turbines comprise many tubular elements of large dimensions and require a lot of welding in the assembly phase. Robotic welding, in this case, is still a labour-demanding process. The main challenge is that manual robot path adjustments are needed to accommodate the **geometrical variations and** given **welds with up to over a hundred passes**, the process efficiency is significantly reduced.

In this poster, we present **sensor and data processing technology** that allows for **automated robot path generation** based on actual workpiece geometry. The described procedures and algorithms for geometric data collection and processing have three main steps: **automated geometry scanning, sensor parameter setting and parametrisation of geometric data**. Such parametrised data represents the as-is geometry and can directly be used for robotic welding path planning. The demonstrated algorithms allow for the **minimising of human input and the reduction of production time**. Faster and more cost-efficient production of offshore wind turbine jackets is another important step towards meeting the demand for green wind energy.



Fields of application

- Substructures for wind turbines and HVDC platforms
- Offshore aquaculture structures
- Substructures for oil and gas

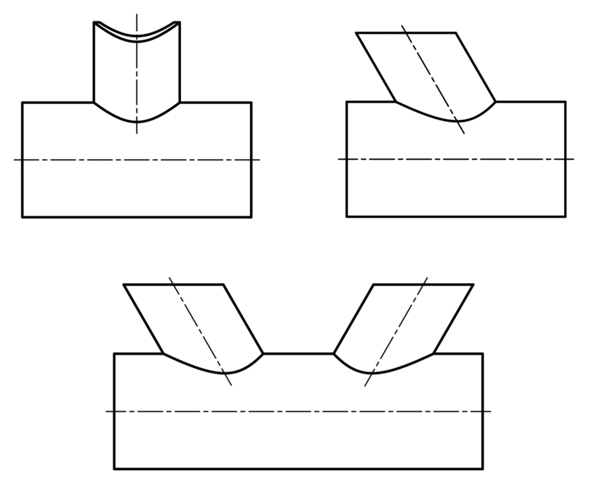


Figure 1: Tubular T-, Y- and K-joint

Figure 2: Substructures of wind turbines (Source: Aker Solutions)

Data noise reduction by adapting the sensor settings

- Several parameters are changed per individual parameter combination
- Using the Taguchi orthogonal arrays[3] for reducing data sampling and evaluation time
- Evaluated at different locations along the weld groove with uncleaned welding slag dispositions, both rusty and grinded shiny surfaces

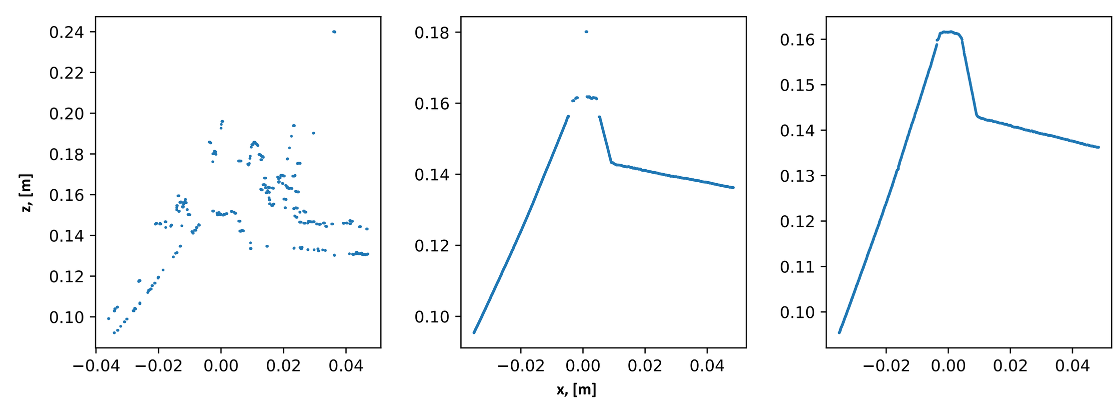


Figure 5: Three different parameter combinations at the same location along the weld groove

Robotic scanning

2D profile scanning

- Laser triangulation principle for 2D profile detection
- Laser beam is formed to a known laser pattern and its reflected light is projected onto a camera sensor array
- Sensor output: Measurements in a 2D sensor coordinate system

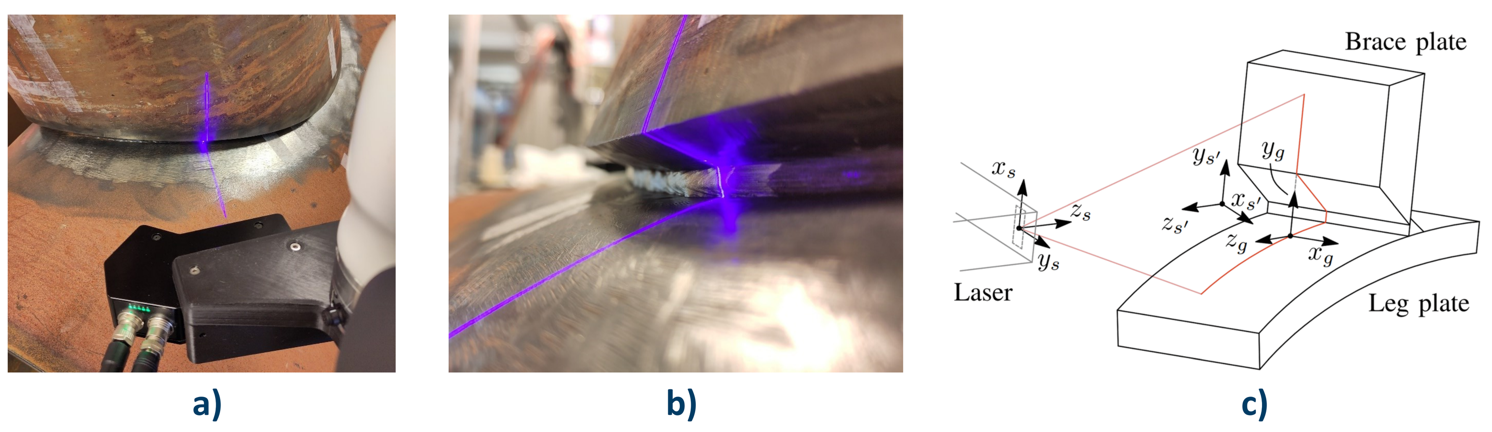


*Figure 3: **a)** Experimental setup. **b)** Laser line beam on a T-joint weld groove. **c)** Sensor alignment and orientation with respect to the weld groove[1]*

3D point cloud scanning

- Stereoscopic camera setup with structured light projector
- Projection of structured light patterns onto the object, and the pattern pixels are then detected in the camera 2D image
- Sensor output: 3D point cloud of the object surface, in the sensor coordinate system

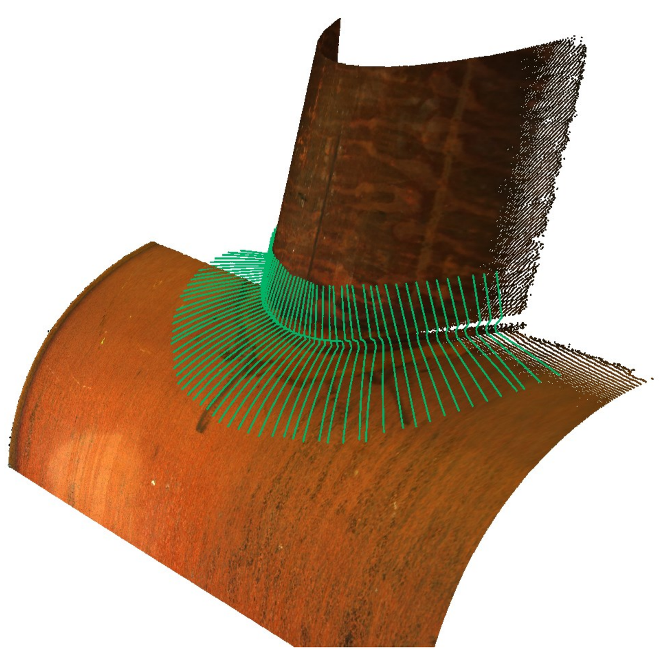


Figure 4: 3D point cloud of the T-joint stub and profile scans of the weld groove

Weld groove parameterisation

- Identification of the geometric parameters of the weld groove shape that varies along the circumference of tubular T-joints (Fig. 6a)
- Algorithmic detection of the weld groove segments and corner coordinates[4]
  1. Sequential RANSAC procedure
  2. Detection of groove corners
  3. Noise detection
  4. Iterative corner coordinate correction procedure
- Alternative CNN-based feature extraction procedure results in five times shorter execution time, while achieving similar precision[2]

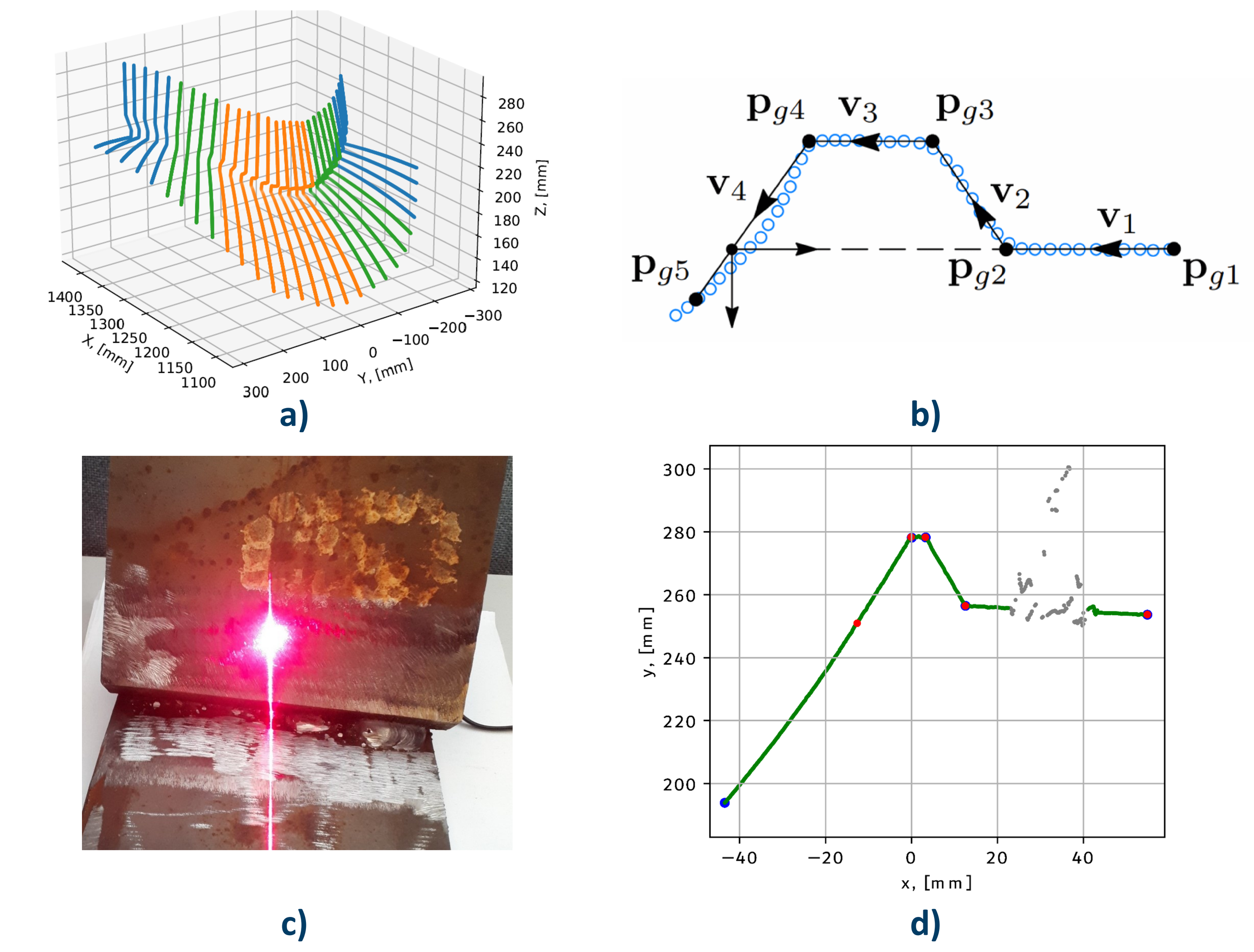


*Figure 6: **a)** Varying groove geometry along the circumference, indicated by different colors[2]. **b)** Parametrisation of a weld groove of a T-joint[1]. **c)** Reflection from laser projection onto a shiny metal surface[4]. **d)** Parametrisation result with groove corner points from noisy data[4]*

References

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