Automated maintenance feasibility testing on the EU DEMO Automated Inspection and Maintenance Test Unit (AIM-TU)
Jimenez, Samuel; Bookless, Darren; Nath, Radhika; Leong, Wei; Kotaniemi, Jarkko; Tikka, Petri

Published: 21/09/2020

Document Version
Publisher's final version

Please cite the original version:
1. Background

For commercial viability fusion reactors must minimise maintenance shutdown durations. However, as reactor complexity and radiation levels increase so do the number of maintenance tasks that must be performed remotely. The remote maintenance systems of the future must therefore perform more tasks in less time. This requires a step change in task parallelisation and speed. Existing teleoperation approaches are inherently limited in these aspects so cannot scale to meet the challenge. Automation emerges as a potential solution, having demonstrated revolutionary productivity gains in the global manufacturing industry. The EU DEMO programme is exploring four key research questions about Automated Maintenance:

- Is it feasible in the fusion environment?
- Can it improve plant availability?
- Can it be robust and safe enough?
- How does it change reactor designs?

The programme will explore the feasibility of automating representative maintenance tasks under fusion conditions, excepting radiation. The proposed development roadmap shows representative maintenance tasks and the underlying automated capabilities required.

The first two major capabilities to be studied are anomaly detection (both for maintenance planning and validation of task execution) and component manipulation (for installation and removal).

2. IMP version of the EU DEMO Automated Inspection and Maintenance Test Unit (AIM-TU)

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3. Automated reactor tile replacement

Replacement of reactor tiles is the most common maintenance task performed on JET. The task was successfully automated using two robots handling tile replicas. One robot secures the tile with its gripper while the other uses a JET boltrunner to release the tile bolt. The tile is then transferred to a storage location and exchanged for a new one, which is returned to the installation location and bolted in.

The detection and location of tiles and installation/storage positions is achieved using robot's wrist cameras.

4. Contactless detection of tile anomalies

Detection of anomalies is essential for maintenance. The automation of this capability has been applied to detection of gross surface anomalies in replica JET tiles. The robot wrist cameras take images of tiles and computer vision algorithms are applied to automatically detect anomalies. The first approach trialled relies on comparing images against annotated, anomaly-free ground truth images, which does not require the large data sets necessary for machine-learning-based training.

The test was carried out with multiple positions, algorithms and surface anomaly types. The criteria for successful anomaly detection was based on the intersection over union (IoU) overlap of the test image anomalies with the ground truth image. Under ideal conditions detection accuracy was highest for adaptive gaussian (100%) and Otsu thresholding algorithms (97%). However, when including disturbances (noise, image offset, discoloration), binary and zero thresholding demonstrated the best accuracy (75%). The results show that under realistic imaging conditions the approach is not sufficiently robust for a reactor setting. Hence future work will explore a combination of deep learning techniques along with structural similarity algorithms to improve accuracy and robustness to disturbances.