A Unified Digital Twin Framework for Enhanced Robotic NDT Processes and Visualisation

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NDE 4.0 has seen its growth in the recent years, encompassing the integration of artificial intelligence, robotics and Internet of Things (IOT) into traditional nondestructive testing (NDT). While automated delivery of NDT has become common, the interconnectivity aspect of an automated NDT is still in its early stages. This study introduces a digital twin framework that seamlessly integrates various components of an automated NDT process into a unified platform. It leverages the power of Unity, a versatile 3D rendering engine, and Robot Operating System (ROS), a flexible middleware for robot control. This not only streamlines the orchestration of robotic NDT hardware, but also provides a robust environment for data communication and manipulation. A use-case of using a Sonus Evo, a modular electromagnetic acoustic transducer (EMAT) system by Sonobotics Ltd., mounted on a Universal Robot's UR10, to provide a C-scan of a carbon steel pipe section is considered. A graphical user interface has been developed in Unity, which presents the operator with the inspection scene and allows for the scan area and parameters to be selected. These parameters are then processed to generate a 3D C-scan mesh overlaying the inspected area. The computed waypoints are imported into ROS for trajectory generation and robot control. The UR10 subsequently scans the pipe section upon operators' confirmation, while the Sonus Evo acquires the pipe thickness at each scan increment. The sensed thickness value is then used to construct the 3D C-scan in real time. Beyond real-time visualisation and control, another key contribution is the immersive 3D C-scan. Unlike traditional C-scan that only provides a 2D representation regardless of the test sample shape, this work generates a 3D mesh based on the surface of the inspection area as the C-scan, which is overlaid on the test sample. This allows operators to inspect from any angle and provide more intuition for data analysis, which is only made possible with the seamless sensor integration, e.g., the robot encoder and NDT transducer. The proposed framework is a unique development, retrofitting current automated NDT process into collaborative entities, enabling a more streamlined integration across the manufacturing supply chain.