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Non-Contact Ultrasonic-based Bayesian Mapping for Robotic Structural Inspection

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The state-of-the-art robotic ultrasonic inspection of large structural assets such as oil and gas storage tanks is carried out on a point-by-point scheme, where an ultrasonic probe with a mobile platform is scanned over every point on the component. Point-by-point inspection, which generates a huge amount of data, is time-consuming for inspecting large structural and industrial assets. One way to achieve a more efficient inspection of large structures is to take advantage of ultrasonic guided waves (UGW) suitable for mid-range inspection. Unlike the point-by-point scheme, guided waves can also be used to inspect and detect defects such as corrosions in inaccessible regions (e.g., corrosion under pipe supports).

In this ongoing research project, we are working towards simultaneous localisation and mapping (SLAM) of thick structures (~10mm) under inspection using ultrasonic guided waves, in particular shear horizontal (SH) wave modes generated using electromagnetic acoustic transducers (EMATs). In other words, we use guided waves to simultaneously localise the robot and map the geometrical features such as defects and boundaries.

We present results on the sensitivity of different guided wave modes for weld detection. We then demonstrate the application of guided wave robotic occupancy grid mapping (GW-OGM) to map internal defects and the unknown structure’s edges/boundaries. Both pseudo-pulse-echo and pitch-catch measurement setups are used for this purpose, in which one transducer acts as a transmitter and the other one as a receiver. The former mode is used to localise welded joints, which can be eventually exploited for robot localisation. The latter mode is used for defect identification and characterisation.

Defect information such as the depth of defect can be used for predicting the remaining useful life of the component. Furthermore, to create a rich ultrasonic mapping of structures by characterising defects on the fly as the robot navigates the structural assets, we have taken advantage of a machine learning approach to estimate the depth of the corrosion-like defects. Phase-based handcrafted features are extracted and fed into the Gaussian process regression model to estimate the defects’ depths using the calibrated simulated data set.