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AN ACOUSTIC-CENTRIC METHOD FOR THE SPACE INFRASTRUCTURE TUBULAR INSPECTION

Abstract

Large scale, complexity and sophistication are trends in the design of space infrastructure. This has led to a rapid growth in demand for autonomous inspection robotic clusters. Piping systems composed of certain materials, such as metal or carbon fiber, can block electromagnetic wave and optical signal, leading to a limited communication environment for the multi-robot collaboration. Meanwhile, optic sensors equipped by tubular robots is vulnerable in tubular environment since their lens can be easily smudged. To address these problems, we propose an acoustic-centric approach for the inspection of space station tubular system by robot clusters. Our approach combines passive and active acoustic methods to enhance the performance of robotic clusters performing fault detection, positioning, and structural integrity assessment in tubular environments. In realizing of passive perception, we design a fault diagnosis system based on acoustic emission (AE) signal emitted by tubular environment and a sound source positioning algorithm. We present a deep learning model based on the convolutional neural network (CNN) to exploit the statistical changes in the AE signal due to the defects in the tubular or cabin structure in order to detect and locate tubular breakages. In terms of active perception, we propose a multi-robot structural inspection approach. The approach consists of 1) an audio coding method that can robustly propagate information through structures, 2) an audio coding method that detects structural integrity, and 3) a pattern to place robots that transmit or receive sound sequences. This approach will first specify the position of each robot and their transmitter/receiver roles. Once all robots are in position, the transmitter robots will emit coded sound wave for receiver robot to sample. The captured acoustic signals are then classified in real-time, with a CNN analyzing their propagation behavior and assessing the health status of the tubular structure. In summary, this paper offers a highly integrated and efficient solution for autonomous inspection of confined space in large-scale space infrastructure and can serve as a solution for both communication and positioning.