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INHERENT SENSING METHOD OF INCHWORM-INSPIRED SOFT ROBOT FOR SPACE STATION TUBULAR INSPECTION

Abstract

The construction of large-scale space infrastructure is a promising point in space exploration, with an increasingly prominent demand arising for the maintenance of space station cabins. The confined space and intricate tubing assemblies necessitate an urgent demand for an efficient and safe tubular inspection solution. Echoing to such requirement, this paper presents an inherent sensing method for pneumatic inchworm-inspired tubular soft robot, which consisting of two actuators, with a total diameter of 20mm, a length of 200mm, and a weight of 20g. Under the pressure of an external air source, two actuators can sequentially anchor and elongate, facilitating the robot to perform inchworm-like locomotion in tube. The robot is capable of 1) moving forward or backward in tube regardless of its orientation or whether it contains liquid, 2) adapting to tube with inside diameter from 20mm to 45mm, and 3) resisting damage from sharp edges. In order to resolve its perception problem, a tailored learning-based inherent sensing method inspired by natural mechanoreceptor is proposed. Through an analysis of the Pacinian corpuscle structure, we design a neural network model utilizing the variation in pressure-time curves generated by actuators elongating in tubes with varying inside diameters, inner shapes, and inner wall softness. The model takes the pressure-time curve of actuator sampled by pressure sensor in the external air source as input and produce inside diameter, inner shape, and inner wall softness of the tube as output. The model comprises three classifiers and a set of fitters. These classifiers are respectively used to classify the internal shape, inner wall softness, and inner diameter range of tube. Each fitter corresponds to a specific range category, once the inner diameter range is determined, the model invokes the corresponding fitter to estimate the tube's accurate inner diameter. The approach utilizes the actuator itself as a sensor, minimizing the cost of robot manufacturing and its space transportation. The robot neither generates electromagnetic interference nor affected by it, thanks to the absence of electronic sensor. The sensorless design also allows the robot to sustain extra inertial forces during space launch. In summary, the framework of this paper provides an effective solution for tubular inspection of space infrastructures, including space station and moon base in the future. This can also be extended to tubular inspection in other application scenarios with minor modifications.