Spinal Robot Composed of Cooperative Tendon-Driven Modules

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1. Introduction

The spine plays various roles such as body support, securing the range of motion, and protecting the central nervous system. The development of robots with spine has been reported(1). However, these studies have focused on mimicking animals, and the engineering design of spine can be improved for further investigation. In our study, we aim to develop a modularized spinal robot that incorporates spine properties.

2. Tendon-Driven Module

In order to artificially reproduce the spinal structure, the necessary elements were defined as the skeleton, intervertebral disc, muscles, and nerves, which were replaced by ABS resin, pull springs, tendon drives, and CAN bus lines, respectively. In designing the robot, the skeleton, intervertebral discs, and muscles of one joint were designed as a single module, and the aim was to reproduce a variety of vertebrae by connecting and separating single modules with built-in measurement, drive, and control functions. The tendon driven module is shown in the Fig. 1.

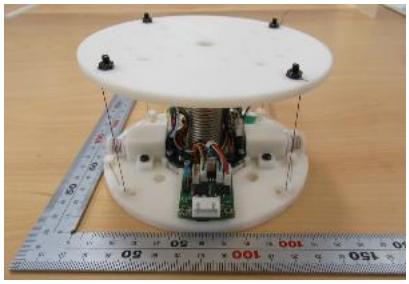


Fig. 1. Tendon-driven module

3. Mechanical Verification

Two types of experiments were conducted to verify the operation of the fabricated modules. One was a range-of-motion test of the pitch and yaw axes, and the other was an posture control test. Fig. 2 shows the results of the pitch and yaw range of motion test. In this test, the robot was able to move up to about 60[deg] in both pitch and yaw. Fig. 3 shows the results of the posture control test. The orange graph shows the time variation of the angle, and the blue graph shows the command value output by the module during posture control. Without posture control, the entire robot tilts, so both the pitch and yaw axes tilt up to a maximum of about 30[deg]. However, when posture control is applied, the command values are determined in the direction that cancels the tilt according to the tilt direction, and the tilt is suppressed to less than 10[deg] as a result of posture control.

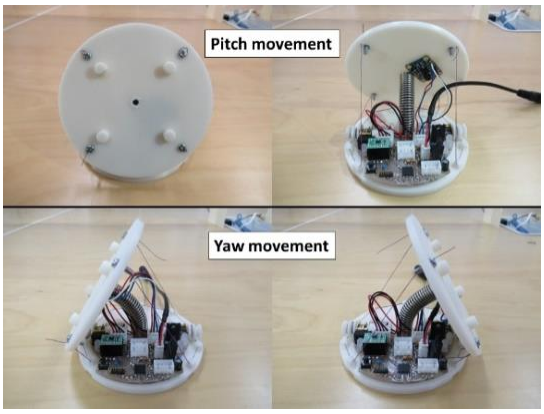


Fig. 2. Range of motions

4. Posture Control

An experiment was conducted to determine the attitude angle during module operation using two types of sensors: an encoder and a proximity sensor. In the experiment, the measured value of the IMU was used as the true value to correct each sensor, and angle control was performed based on the correction results. Fig. 4 shows the results of the correction of the angle estimates by each sensor. Angle control experiments were conducted using the corrected sensor values. Fig. 5 shows the control results. Only the encoder and proximity sensor were used for control, and the IMU values are shown for comparison. The IMU value results show that the encoder control is accurate, but there is a deviation due to the initial value obtained by the proximity sensor.

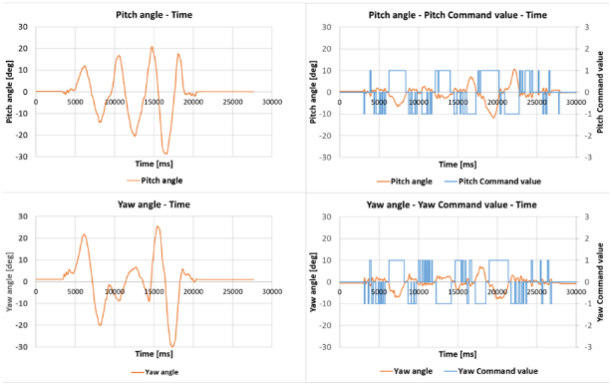


Fig. 3. Result of posture control test

5. Conclusion

In this paper, an artificial reproduction of the spinal structure was proposed. The experiment results showed that the robot realized a wide range of motion and successful posture control. In the future, we intend to improve the hardware and software of the modules to achieve more advanced control using both encoders and proximity sensors. We also plan to develop systems to support the communication among a large number of modules to allow distributed and cooperative control.

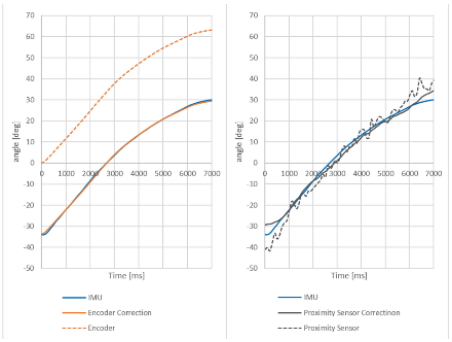


Fig. 4. Correction results of encoder and proximity sensor

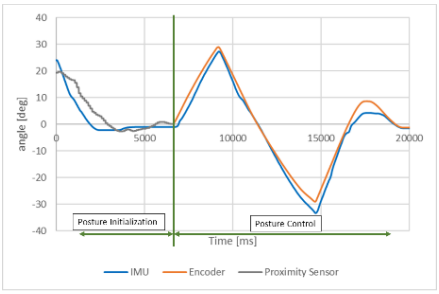
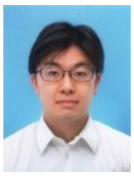


Fig. 5. Posture control by proximity sensor and encoder

Reference

(1) Tomislav H, et al., "Inverse kinematics and reflex based controller for body-limb coordination of a salamander-like robot walking on uneven terrain," IEEE International Workshop on Intelligent Robots and Systems (IROS), 195-201, 2015.

Biography



Riku Sudou is a master course student at Kanagawa Institute of Technology. His research interest includes microcomputers and the applications



Ryo Saegusa is an associate professor at Kanagawa Institute of Technology. His research interest includes symbiotic interaction between human and machines towards coevolution.