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Modeling and Control of an Omnidirectional Spherical Robot *Omnicron*

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Abstract—**to improve the unstable performance, a controller is installed in the Omnidirectional Spherical Robot. Then the performance is experimentally evaluated. The controller is proved to be effective to improve the locomotion.**

I. Introduction

The robot *Omnicron* shown in Fig. 1 is one of the very few spherical robots which can perform omnidirectional locomotion [1]. It has neat three-to-three mapping from three omnidirectional wheels' motion to the planar three degree-of-freedom robot motion. It also has good dustproof and waterproof characteristics. Previously, the motion of the robot is simply designed based on open-loop trajectory mapping which assumes the main body inside the spherical shell remains horizontally. Empirically, the main body oscillates frequently owing to its pendulum-like configuration which results in the unstable robot locomotion. Here, we report on design and implementation of a model-based linear-quadratic regulator (LQR) which stabilizes the robot locomotion.

II. Methods and Results

The model adopted in this work is a simplified 2-dimentional spherical robot model which is previously developed in the lab [2]. It was developed for this robot's processor, *OmniQue*. The dynamic model links the torque input to the state of the robot, including outer shell angular velocity and main body pitch and angular velocity. Though the configuration of *OmniCron* is different from that of *OmniQue*, the same dynamic model can still be applied to describe the dynamic relations of *OmniCron* among the torque and the body states. Together with selected operation points, the linearized state-space equations for LQR can be constructed.

To ease the development process, performance of the controller was firstly evaluated in the simulation environment (i.e. MATLAB), in which the input command was further transformed into the voltage input command used in real robot. The simulation provides the overall view of the system dynamics which is useful in determining the right parameter settings.

The control strategy was implemented on the robot and evaluated experimentally. Information from three sensors are utilized for feedback, including an inclinometer for body pitch, a gyro for pitch rate, and encoder for odometry. The robot is equipped with a real-time embedded system (sbRIO-9642, National Instruments) and is programmed by LabVIEW. The experiments of the robot moving forward with five different speeds were tested, where the body pitch and robot forward speed were measured for analysis.

In general, performance of the robot with LQR control is significantly improved in comparison to that with open-loop trajectory setting. The achievable stable moving speed increases from 0.5 m/s to 1.8 m/s, close to four times increase. The motion is more stable owing to suppression of the main body vibration. In addition, motion trajectory is straighter than before as well.

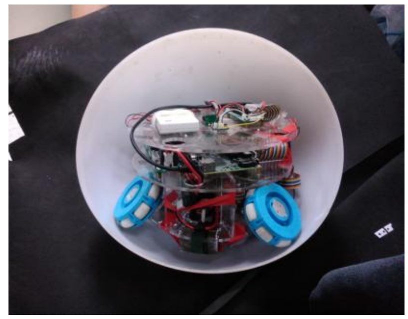

Fig. 1. Photo of the robot *Omnicron*.

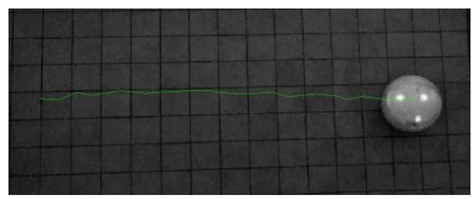

Fig. 2. Motion trajectory of the robot in one of the experimental runs. The three LEDs mounted on the main body are utilized to determine the robot center of mass.

III. Conclusion

The point-contact characteristic of the spherical robot easily excites the robot's oscillating motion during its locomotion. This instability in nature makes the robot motion controlled by simple open-loop strategy not feasible, similar to the situation of a two-wheeled robot. By installing the LQR feedback controller, smooth and accurate locomotion is achieved. We are in the process of implementing more complicate planar trajectories and possibly the locomotion on rough terrain to extend the application domains for practical use.

References

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