SIS100 Inspection robot – lane keeping and curved pipes

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Current status and steering capability

In previous work we presented a basic robot concept for visual inspection of the SIS100 vacuum system [1,2]. A 3D printed robot prototype was built and it was shown that the robot is able to traverse simple obstacles inside the beamline vacuum system like single steps and gaps. The general robot concept follows a modular design, consisting e.g. of joints between the modules to lift or lower specific parts of the robot. Each module has two driven wheels and all wheels are controlled synchronously. As a result, the robot would only be able to move in a straight direction which has two significant disadvantages.

On the one hand, the robot could leave the center of the beam pipe if initially it is not placed precisely straight or if there are any inaccuracies in the control or manufacturing of the motors. Without steering capabilities the robot would run onto the curved sides of a pipe and would get stuck if the pipe has an elliptical shape, and in cylindrical pipes it could tilt over, which is even worse. On the other hand, the SIS100 is a ring accelerator with curved pipe sections. A robot that moves exclusively straightforward cannot be used here, obviously. Thus, additional joints between the modules must be provided to enable the robot to bend in the horizontal plane.

Description of the new prototype

The problem of steering capabilities and climbing skills can be considered separately. In a first step the joints for vertical movement are neglected. Instead, solely small robot smart actuators are inserted between the modules as it is shown in Fig. 1 for a robot configuration with four modules. The size of these joints is very important because their axles are arranged vertically, and with respect to the dimensions of the SIS100 dipole vacuum chambers the total height of the robot is limited to 5 cm.

According to [3], the velocity of each module must now be controlled separately. To keep the amount of wires manageable, port expanders are placed next to the first and the third joint, respectively. An additional benefit is that only two pins of the microcontroller are needed for an I²C communication with the port expanders instead of 16 to directly control the stepper motors. The servos are interconnected and merely require one control pin. A half duplex asynchronous serial communication enables both write and read instructions. Each servo possesses a unique identification address and can be operated with an angle resolution of 0.29°.

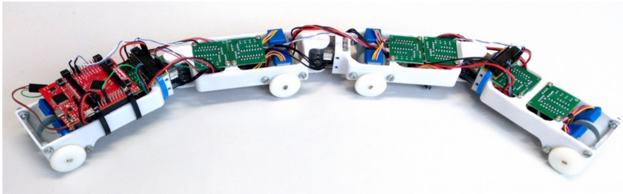

Figure 1: Prototype with four modules and three servos as steering joints.

Further development

Next, the prototype has to be tested and its dynamical parameters must be identified to derive a suitable model which can be used for concurrent simulations and to calculate the steering angles as well as the individual module velocities. With the help of an inertial measurement unit curved pipes or deviations of the robot from the pipe center will be detected and corrected by a dedicated controller.

Currently, a third prototype is under development which combines climbing and steering capabilities in one robot. This is achieved by a series connection of the two different joints between two modules.

Furthermore, the stepper motors will be replaced by robot smart servos, obviating the need for external motor drivers and saving space on the modules, e.g. for essential sensors or batteries. The servos can be set to wheel mode for endless turn. Additionally, the microcontroller board will be substituted with a more sophisticated controller board with smaller dimensions, therefore better fitting into a module.

A major modification will be done for the control concept. To use the same implemented programs as in the robot simulator Gazebo, the robot has to be operated within the Robot Operating System (ROS) framework. For this purpose, the robot will be equipped with a WiFi module to be able to communicate with an external control computer.

References

[1] N. Schweizer and I. Pongrac, IPAC'17, pp. 4528-4530.

[2] N. Schweizer and I. Pongrac, GSI Scientific Report 2016, September 2017.

[3] B. Murugendran et al., IROS'09, pp. 3643-3650.

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