DESIGN AND PROTOTYPE IMPLEMENTATION OF CIRCULAR-RAIL ROBOT SYSTEM FOR EXTRA-VEHICULAR ACTIVITIES

Yongquan Chen[1], Chengjiang Wang[1], Wenfu Xu[2], Meng Chen[3], Yangsheng Xu[1]

[1]Department of Mechanical and Automation Engineering, The Chinese University of Hong Kong, Hong Kong SAR, China

[2]School of Mechanical Engineering and Automation, Harbin Institute of Technology Shenzhen Graduate School, Shenzhen 518055, China

[3]National Key Laboratory of Space Structure and Mechanism Technology, Institute of Aerospace System Engineering Shanghai, Shanghai 201109, China

yqchen@mae.cuhk.edu.hk, cjwang@mae.cuhk.edu.hk, wfxu@hit.edu.cn, workmailcm@126.com, ysxu@mae.cuhk.edu.hk

Abstract

Space station exploration is a global hot research topic. The space stations are usually large in scale so that they have to be fabricated and assembled in space, which involves a large number of Extra-Vehicular Activities (EVAs) by astronauts and robots. There are two main problems of EVA mission. (1) Current space robots such as Canadarm1, SSRMS and JEMRS, have workspace limitations and cannot reach the whole exterior of a space station, making it challenging to carry out inspection and servicing. (2) Large vibration and low accuracy at the tip of the manipulator. Current space robots are usually designed with a long manipulator to increase their workspace. Such long manipulators often suffer from vibration due to the flexibility in the link and joint. It is hard to balance vibration and accuracy in these robot designs.

A novel Circular-Rail Robot System (CRRS) was proposed in this paper. The CRRS provides full coverage of the space station workspace, as it is a mobile robot that drives on a circular rail system around the space station. The proposed novel CRRS consists of three subsystems, the circular rail, mobile robot and rail switch. Firstly, the CRRS' circular rail system is an important component that allows full coverage of the space station. The rail curve is arranged to extend the robot's workspace so that it surrounds the space station. Secondly, the mobile robot was made of a mobile base and a short manipulator. A shorter manipulator, such as 5 m long, will still offer a full coverage workspace. Finally, an electrically driven subsystem, the rail switch, is used for rail exchange between different space modules. The rail switch is rotatable on the exterior of the space station and is a temporary payload bay for mobile robot parking. A mobile robot on one space module will drive into this temporary payload bay. The rail switch will rotate to the rail of another space module. The mobile robot will drive out of the temporary payload bay and travel on the new space module's rail.

Taking the launch cost into consideration, it is necessary to optimize the length and layout arrangement of circular rail but keep large workspace performance. A cost function is defined and optimized under the multi-objective optimization method. The mobile platform, driving force and turning radius of CRRS are carefully designed and analyzed. A prototype of the CRRS mobile platform is implemented for concept verification. This system is the first design of robotic system with circular-rail in space and also has the smallest turning radius (R=0.5m).

Some sensors, electronic and subsystem was developed for autonomy control of proposed robot system. Whole-body path planning algorithm was proposed for typical EVA missions.

Some experiments have been conducted on the tested under 1g gravity environment for performance evaluation. The vibration performance is also address by simulation and experiments. The results show that proposed method could address the workspace problem and reduce vibration of the manipulator.

The proposed concept, hardware prototype and experiments of Circular-Rail Robot System were shown in Figure 1, Figure 2 and Figure 3.

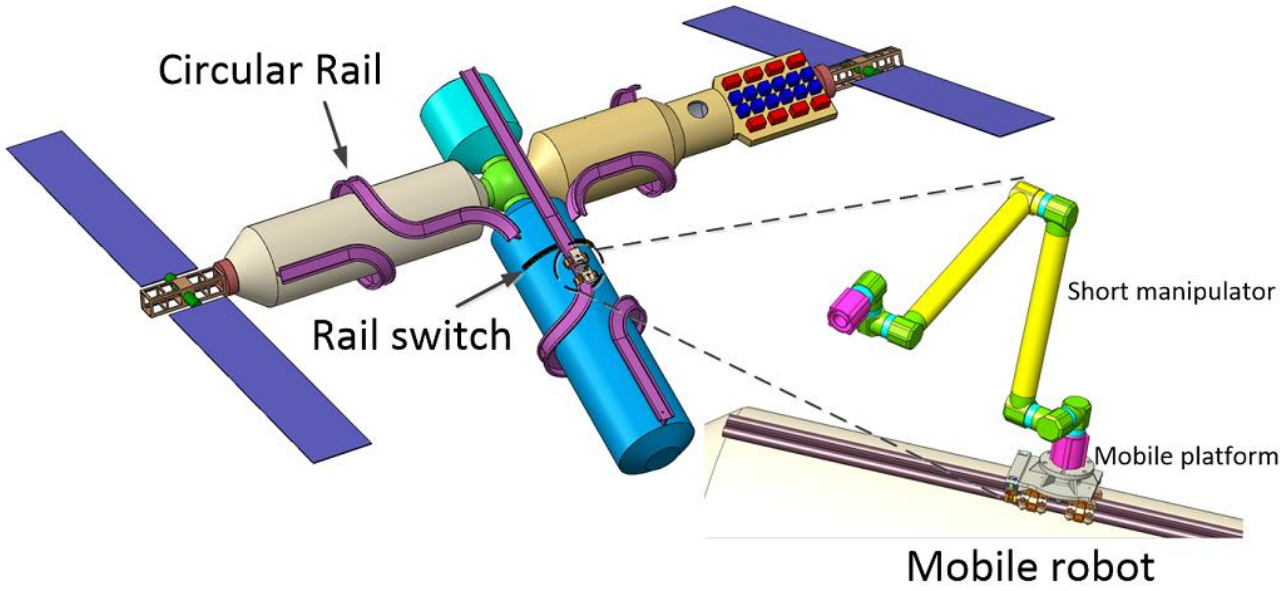

Fig. 1 Proposed Concept of Circular-Rail Robot System (CRRS)

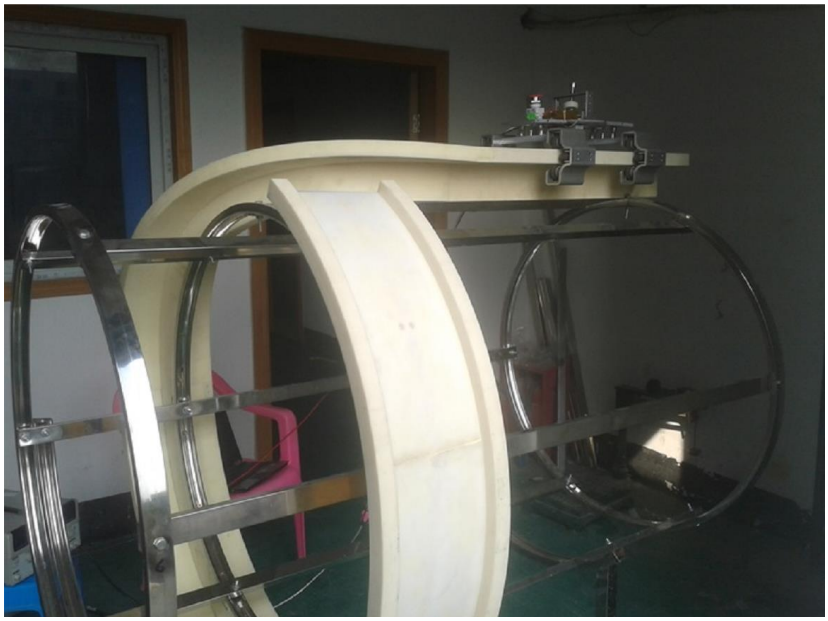

Fig. 2 Prototype of Circular-Rail Robot System (CRRS)

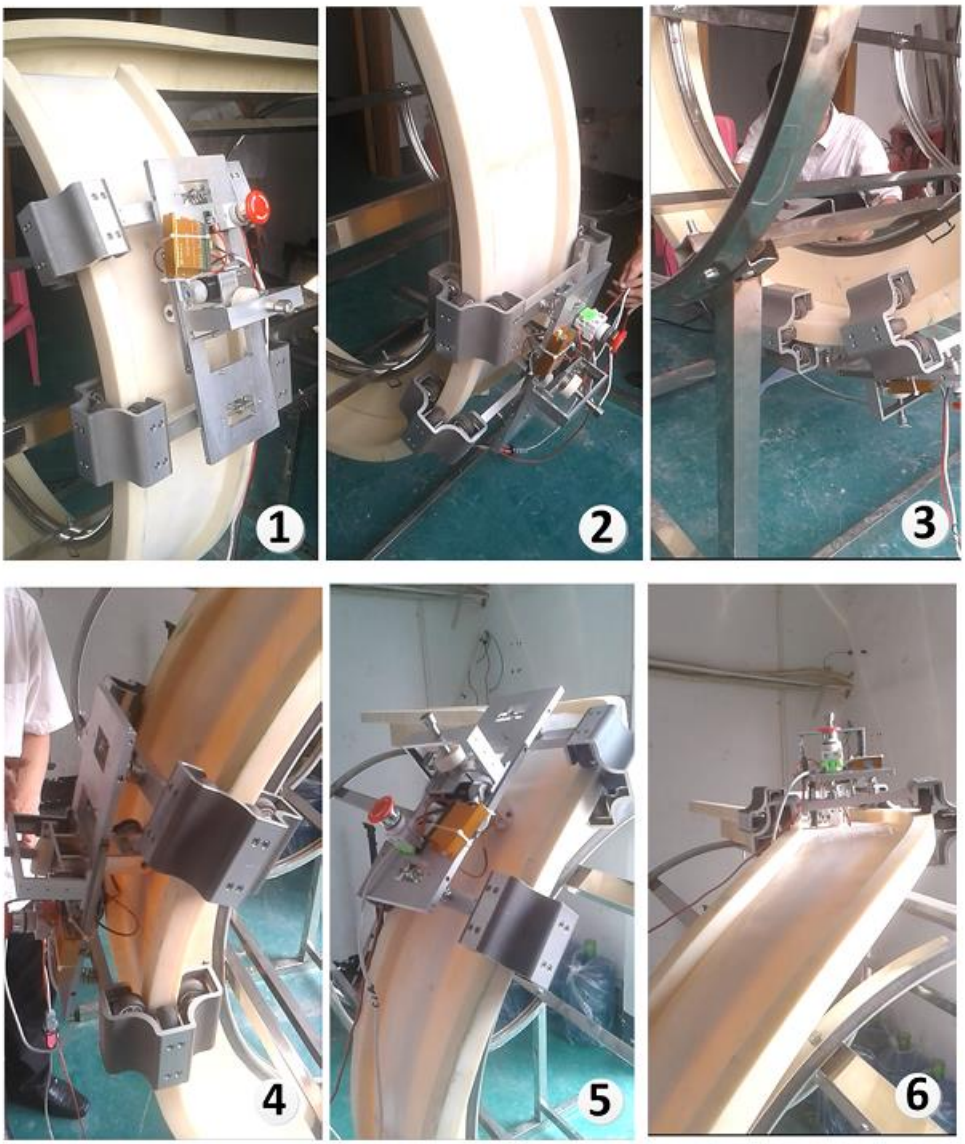

Fig. 3 Experiments on Circular-Rail Robot System (CRRS)