DESIGN AND DEVELOPMENT OF A DEPLOYABLE MOBILE ROBOT MANIPULATOR TO BE UTILIZED FOR EXTRATERRESTRIAL OPERATIONS

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Abstract

Thanks to the technological advances in current literature, utilization of robot manipulators in extraterrestrial operations has increased rapidly. Most of these manipulators have been designed as mobile systems that can be controlled both autonomously and. Due to the fact that they have been specifically designed with respect to the give remotely constraints prior to the missions, it is not possible for their structures to be altered throughout the operation if necessity arises. Although mentioned disadvantage can be tolerated for extraterrestrial explorations on vast spaces, in case of their future use in sustainable extraterrestrial settlements, adaptability gains importance. In light of this, in order to get rid of this disadvantage by implementing adaptability, current study proposes spatial six degrees of freedom mobile robot manipulator for indoor extraterrestrial settlements. Proposed manipulator can be disassembled into multiple three degrees of freedom planar mobile robot manipulators. This way it can be deployed for various different tasks as efficient as possible.

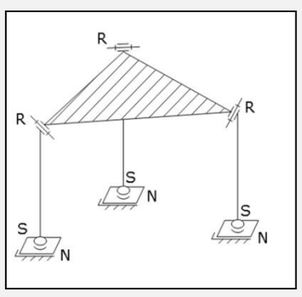
1. Introduction

Unmanned robotic platforms are used for situations that may endanger human life and have extreme conditions [1]. Such rover platforms are most prominently made for extraterrestrial exploration applications [2]. Thanks to the increasing technological developments, robotics have started to take an important place in space. Human species have become more interested in extraterrestrial locations. In this direction, various mobile robots were sent to outer planets for investigation and surveilance purposes [3]. Modern space robotics represents a thriving multidisciplinary field that builds on and contributes to aerospace engineering. Robotics opens opportunities for human beings in terms of exploring new frontiers. Providing access beyond human limitations in harsh environments space robots also support operations that expand the capabilities of astronauts. Autonomous systems have also the ability to reduce cognitive loads [4].

As seen in brief literature, the world's increasing interest in space robotics is clearly visible. Throughout the literature, many examples of autonomous or remote controlled robot manipulators have been encountered. Instead of sending humans into space for extraterrestrial exploration, mobile robots have been charged without endangering human life. On the other hand most of the mobile robots sent to space in this vision are generally sent to operate in large outer environments, and none of them have been proposed for extraterrestrial indoor spaces so far. In light of this, current project proposes a 6 DoF deployable parallel mobile platform to adapt various task conditions in extraterrestrial indoor spaces. Proposed manipulator includes three 3 DoF mobile robots with omniwheels carrying the parallel platform. The main purpose here is to pose the platform by the individual motions of mobile robots. Each of the mobile robots can be charged for various tasks individualy or in groups by forming a desired platform manipulator structure.

2. Structural Design

Kinematic representation and mobility calculation of the prposed mobile parallel manipulator can be seen below.



$$M = \sum f_i - \sum \lambda - j_p \quad \textbf{(1)}$$

$\sum f_i$: the total DoF of all kinematic pairs in the system, $\sum \lambda$: the total subspace of the, independent loops of system, *M:* Mobility [5]

$\sum f_i$ =21, $\sum \lambda$ =12, j_p=3, $M = 6$

Figure 1: Kinematic Representation and Mobility Calculations

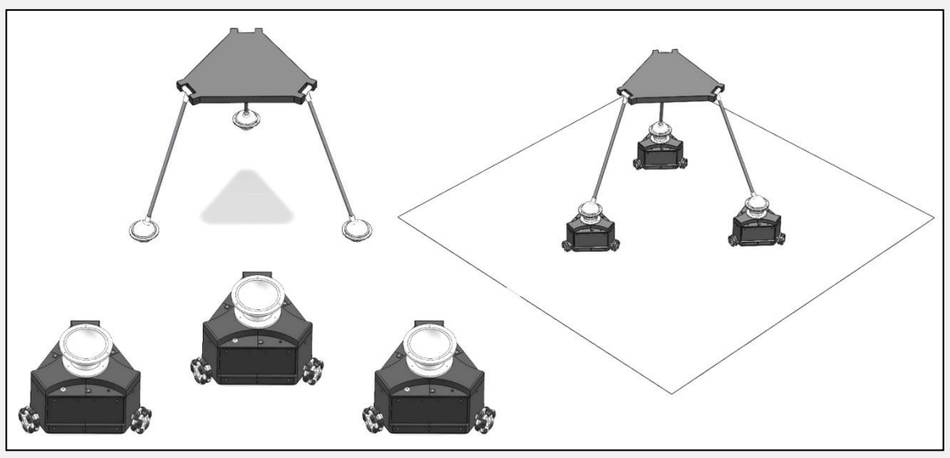
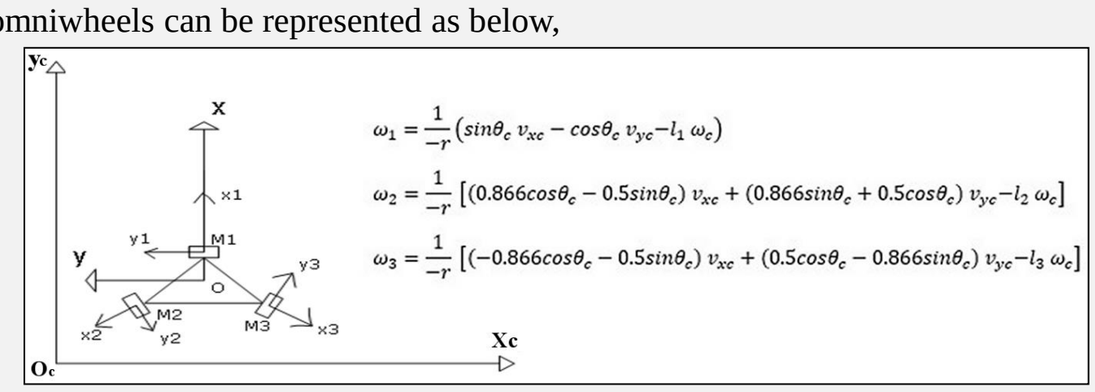


Figure 2: Mobile Robots and Their Assembly State to Form 3RSN

Figure 3: Demonstrations of Indoor Utilizations

3. Theoretical Calculations

For a given desired mobile manipulator velocities, angular velocities of individual omniwheels can be represented as below,



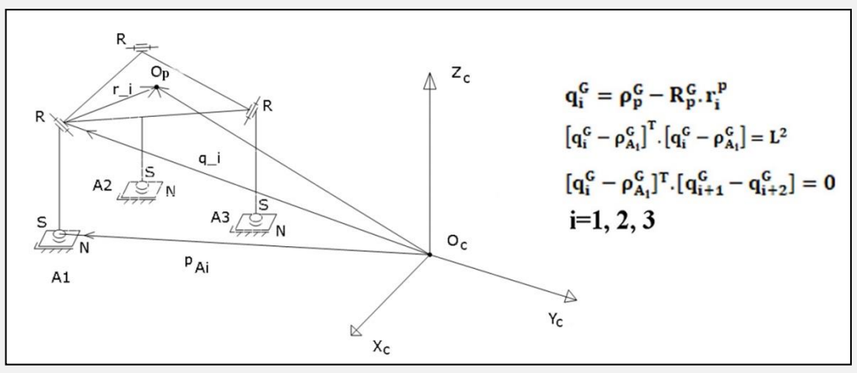
$$\omega_1 = \frac{1}{-r}\left(sin\theta_c\, v_{xc} - cos\theta_c\, v_{yc} - l_1\, \omega_c\right)$$

$$\omega_2 = \frac{1}{-r}\left[(0.866cos\theta_c - 0.5sin\theta_c)\, v_{xc} + (0.866sin\theta_c + 0.5cos\theta_c)\, v_{yc} - l_2\, \omega_c\right]$$

$$\omega_3 = \frac{1}{-r}\left[(-0.866cos\theta_c - 0.5sin\theta_c)\, v_{xc} + (0.5cos\theta_c - 0.866sin\theta_c)\, v_{yc} - l_3\, \omega_c\right]$$

Figure 4: Inverse Task of Mobile Platforms

Each of the omniwheels can be represented as M1, M2 and M3 at their own coordinate frames as x_{1i}, y_{1i} , i=1,2,3. These coordinates can also be represented by means of the mobile (x, y) or global (x_c, y_c) coordinate frames.



$$\mathbf{q_i^G = \rho_p^G - R_p^G . r_i^p}$$

$$\mathbf{[q_i^G - \rho_{A_i}^G]^T . [q_i^G - \rho_{A_i}^G] = L^2}$$

$$\mathbf{[q_i^G - \rho_{A_i}^G]^T . [q_{i+1}^G - q_{i+2}^G] = 0}$$

$$\mathbf{i=1,\ 2,\ 3}$$

Figure 5: Inverse Task of 3RSN Parallel Platform

Inverse task of assembled parallel manipulator can also be easily calculated by writing down loop closure equation and existing constraint of the dyads being perpendicular to the non adjacent side of the platform.

4. Prototyping

Early prototypes of the mobile platforms were constructed by utilizing rapid prototyping. Each mobile platform are actuated via three DC actuator equipped with a gearbox and an encoder. Desired angular velocities are sent to the ArduinoMega microcontroller via wireless bluetooth connection. Simple PI controller is utilized for actuator velocity controls between Arduino Mega and actuator drivers.

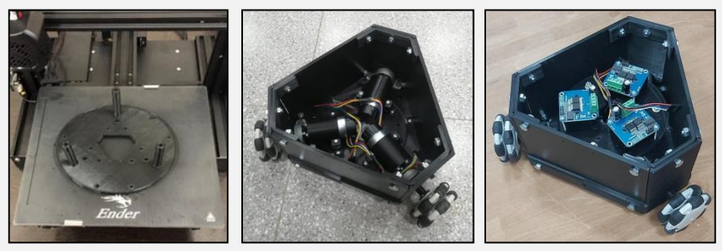


Figure 6: Early Prototype of the Mobile Manipulator

5. Conclusions

Throughout the study 6 DoF parallel mobile platform manipulator that can also be deployed with individual mobile manipulators was proposed for extraterrestrial indoor space utilization. Kinematic analysis of both omniwheel mobile manipulators and 3RSN parallel manipulator were carried out. With respect to the designed CAD models, prototype of the system was constructed. Promising results were achieved during hardware verification steps.

References

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