Visvesvaraya National Institute of Technology, Nagpur, India

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(COSMOS): Compliant Omnidirectional Spherical Modular Snake Robot

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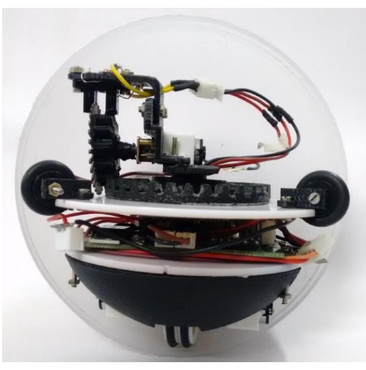
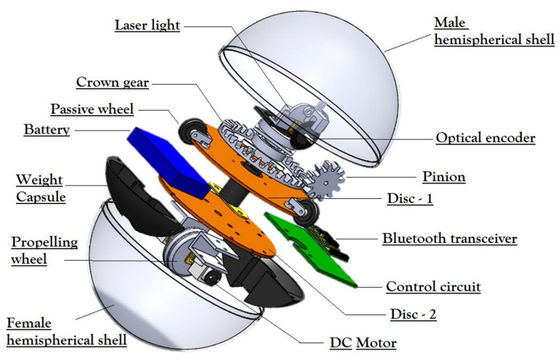
1. Introduction:

- Control, state estimation and motion planning of highly articulated snake robots [1] have been challenging tasks for researchers.
- This paper presents a novel design of a Compliant Omni-directional snake robot (COSMOS) consisting of mechanically and software linked spherical robot modules.

2. Design of Spherical Modules:

- Omni-directional design of, a spherical robot inspired from BHQ-3 [2] and is based on the principle of barycenter offset. Controlling the motion of the center of gravity to deviate from its static position, to produce a gravity moment.





- The Spherical robot consist of two units: IDU (Internal Driving Unit) which propels the robot forward and Steering Unit which controls the orientation of robot.

3. Complaint Link Design:

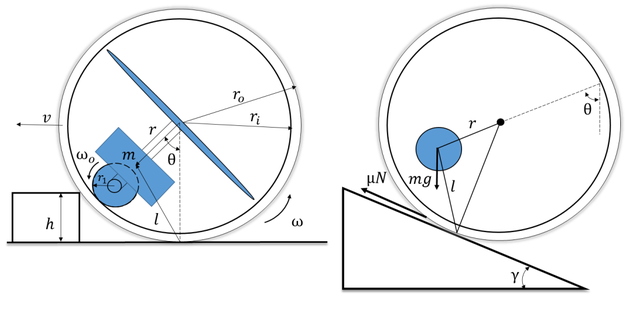
- In order to mechanically connect spherical modules without hampering their holonomic nature, a novel design of floating link is used.
- However, the updated design[3] focuses on introducing a compliant joint at the end of each passive rod near to the central spherical module as shown in Fig

4. Gait Design and Experimentation

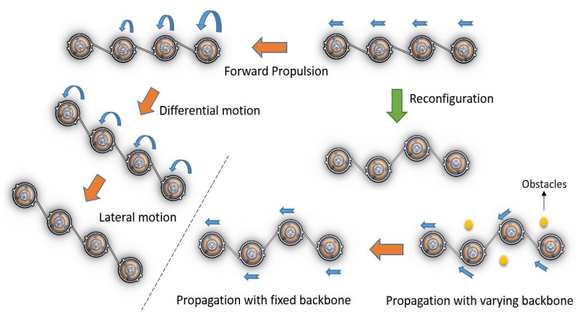
- The spherical modules are capable to roll uphill in certain inclination as shown in figure. The kinematic maximum hill inclination γ and height *h* of obstacle that can be surmounted is given by:

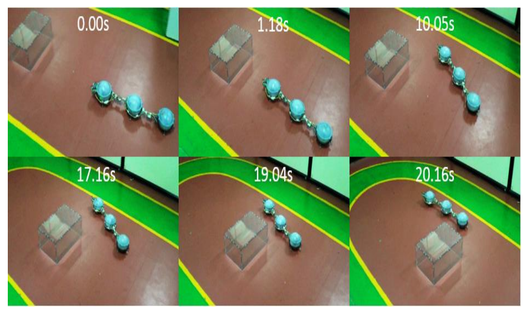
$$\gamma_{max} \leq \sin^{-1}\left(\frac{r}{r_0} - \frac{\mu}{r_0} - \frac{\mu\ M_{ball}}{m\ r_0}\right)$$

$$h_{max} = r_0 - \sqrt{{r_0}^2 - \left(\frac{m\ r}{m + M_{ball}}\right)^2}$$



5. Omni-directional Gait:

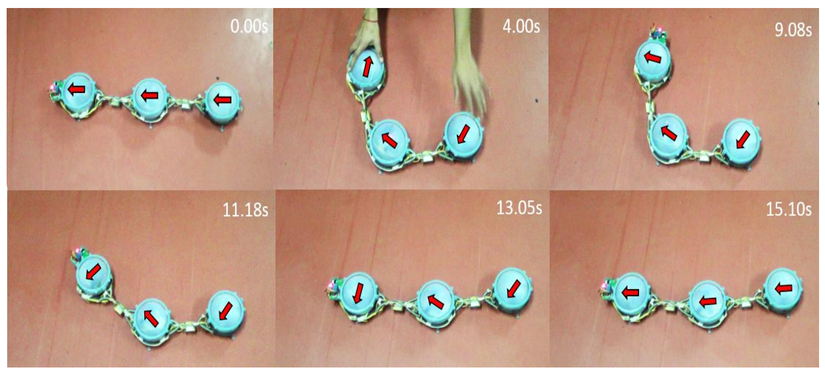




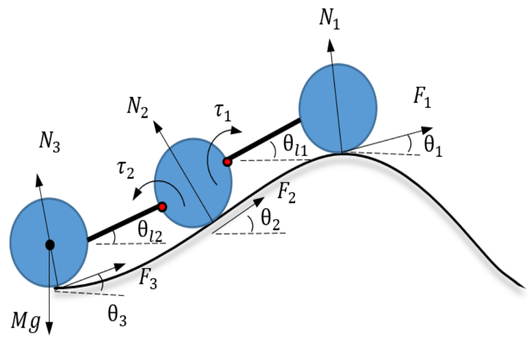
- In this gait, COSMOS is controlled in any direction while keeping the body shape unchanged. To achieve this motion, the orientation of all spherical modules is modified synchronously to a specific value and then propelled in attained direction.

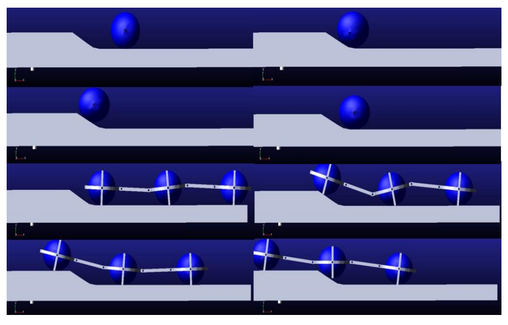
6. Rejuvenator Gait:

- This gait is performed by COSMOS in order to recover from a distorted body shape caused due to collision with obstacle or interaction with external forces during locomotion, to the original robot shape and locomotion direction.



7. Analysis of slope climbing:





- The spring stiffness value of the complaint links in the robot are calculated by doing a quasi static analysis of the robot in different configurations and solving optimization problem for spring value

8. Conclusion and Future Work:

- We presented a novel design of omnidirectional snake robot that is capable of traversing a given planar trajectory and overcoming obstacles. Various gaits of snake robots like circular motion, rejuvenation.
- Future work will focus on the control and motion planning in cluttered environments with varying backbone.

9. References:

[1] P. Liljeback, K. Y. Pettersen, Ø. Stavdahl and J. T. Gravdahl, "Snake Robot Locomotion in Environments With Obstacles," in IEEE/ASME Transactions on Mechatronics, vol. 17, no. 6, pp. 1158-1169, Dec. 2012.

[2] Qiang Zhan, Yao Cai and Caixia Yan, "Design, analysis and experiments of an omni-directional spherical robot," Robotics and Automation (ICRA), 2011 IEEE International Conference on, Shanghai, 2011, pp. 4921-4926.

[3] A. Singh, A. Paigwar, S. T. Manchukanti, M. Saroya, M. Maurya and S. Chiddarwar, "Design and implementation of Omni-directional spherical modular snake robot (OSMOS)," *2017 IEEE International Conference on Mechatronics (ICM)*