Simulation Study of DTTO Modular Robots with 2 DOF to Propagate Multiple Configurations

M. Haziq Hasbulah[1], Fairul Azni Jafar[1], Mohd. Hisham Nordin[1], Kazutaka Yokota[2]

[1]Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2]Research Div. of Design and Eng. For Sustainability, Graduate School of Engineering, Utsunomiya University, 7-1-2 Yoto, Utsunomiya-shi, 321-8585, Japan

*Corresponding e-mail: muhammadhaziqbinhasbulah@gmail.com

Keywords: DTTO robot; simulation; configuration

ABSTRACT – Most of the Modular Self-reconfigurable (MSR) robot is being developed in order to have the capability of achieving different locomotion gaits. In this study, a 3D-printed MSR robot called DTTO was used to study the achievable propagation that can be made based on three of DTTO robot module. As DTTO robot is developed based on Modular Transformer (M-TRAN), DTTO robot has number of Degree of Freedom (DOF) same as M-TRAN which is 2 DOF. The robot propagation was simulated in Virtual Robot Experimentation Platform (V-REP) software. The result of the simulation shows that the DTTO MSR robot can propagate multiple configuration and it is suitable for the purpose of further research on MSR robot architecture.

1. INTRODUCTION

The DTTO modular robot is developed based on M-TRAN robot which is developed by Murata et al. [1]. The module consists of two semi-cylindrical parts that can be rotated about its axis and with a link. It possess 2 DOF, which resemble M-TRAN robot module ability [2]. With only 2 DOF, it might not have many movement ability to propagate multiple configurations. It is believe that it also might be limited in movement if there is only one robot module, but the collective behaviour of modular robot could establish more movements or propagate multiple configurations of different locomotion gaits [3]. Basically, most of the MSR robot that has been developed able to propagate snake-like motion. It is known as Serpentinoid curve which discovered in 1976 by Hirose for application of biomechanics of snake to robot construction [4][5]. M-TRAN robot is Hybrid type MSR robot which is in the form of Chain and Lattice, same goes with DTTO robot. We believe that the main configuration for the robot propagation is Snake-like motion. The other configuration possible with limited DOF is studied and all configurations are simulated by V-REP software.

This study is done to ensure the DTTO robot with 2 DOF is able to propagate multiple configurations with multiple robot modules. The simulation results are illustrated and discussed in this study.

2. METHODOLOGY

The robot control is established by interfacing with Python as we want to provide external control to the DTTO robot in simulation environment for each configuration. This communication is maintained via a while loop and the configuration of the robot changed based on the input where the robot configuration is predetermined with one of it is based on the snake-like motion equation [4][5], so the robot can propelled forward by sending Sine and Cosine value. The following flowchart (Figure 1) is the establishment of Python to V-REP communication so that the robot propagate multiple configurations. V-REP is integrated simulation environment where each object can be controlled individually by remote Application Program Interface (API) client.

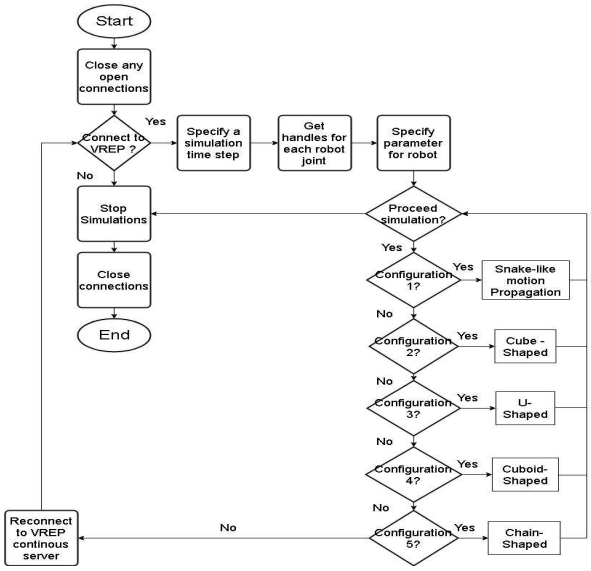

Figure 1 Flowchart for Python coding to propagate multiple configurations for DTTO robot

3. RESULTS AND DISCUSSION

The approach discussed in section 2 (Figure 1) is needed to show that the robot is able to propagate multiple configurations with 3 modules of DTTO robot where one module only have 2 DOF. Figure 2 (on the right) shows that to have 3 axis configuration (X, Y, and Z), one or more of the robot have to be in different positions compare to in Figure 2 (on the left) whereas all the robots in same position attachment are having only 2 axis configuration (X and Z). By having an ability to propagate configuration by 3 axis, it gives more possible configuration for the robot to propagate.

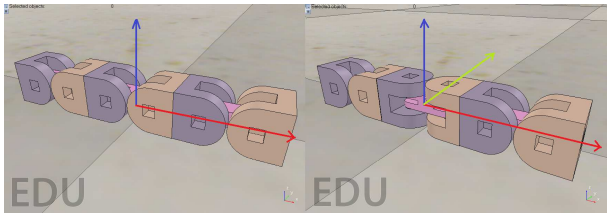

Figure 2 Uniform attachment position (Left) and irregular attachment position of robot (Right)

The first configuration being studied for DTTO modular robot is the ability to propagate a snake-like motion. It is not necessary for the robot to propagate snake-like motion first but, we decided to have one propagation for robot mobility. The snake-like motion was studied first because it is complicated compared to other predetermined configurations we decided. We decided for snake-like motion because it has similarity with normal snake robot (modular with redundant segment). At first, the robot is studied as the robot has the same position attachment which have 2 axis configuration. The robot orientation will be as Figure 3 which at are Z and X axis (Left) and Y and X axis (Right). Figure 3 shows the motion created for the robot.

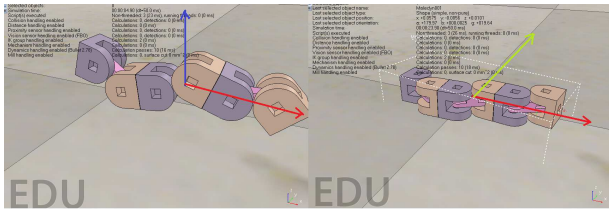

Figure 3 Robot X-Z axis orientation (Left) and X-Y axis orientation (Right)

From Figure 3, the modular robot at X-Z axis orientation create a caterpillar type motion. This configuration create a propelled motion that move the 3 robot modules of DTTO as one. For the modular robot at X-Y axis orientation, it create a snake-like motion by sending a value of Sine and Cosine to the robot. The motion known as a Serpentinoid curve based on values of angles. However, for the modular robot at X-Y axis orientation, the motion of the robot for X axis is forward and reverse in Serpentinoid motion without propagate forward or backward. The motion for Y axis is to left and right in Serpentinoid motion without propagate to left or right. Hence, this orientation is unsuitable because we need at least one configuration that provides locomotion to the robot. However, even though the configuration as Figure 3 (Left) give a movement ability to the robot, it only propagates by 2 axis of configuration which limited the number of configuration it able to be made. That is why we choose to have the robot in attachment position as Figure 2 (Right) so that the snake-like motion can be achieved with 3 axis configuration of the robot. The first configuration simulated is the snake-like motion with the configuration as in Figure 2 (Right). As the robot is simulated, the robot motion created is as in Figure 4.

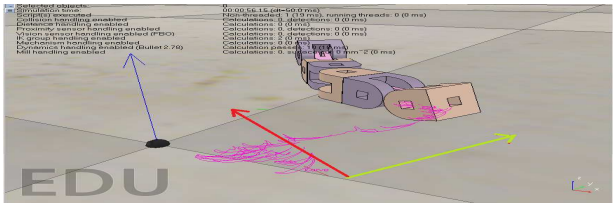

Figure 4 Robot propagation for 3 axis configuration

Based on Figure 4, it can be seen that the robot is able to move towards right direction (Y-axis) and propagate backwards (X-axis) simultaneously which provide locomotion to the robot. Besides that, the other 4 predetermined configurations are able to be simulated which shows that DTTO modular robot is able to propagate multiple configurations as shown in Figure 5.

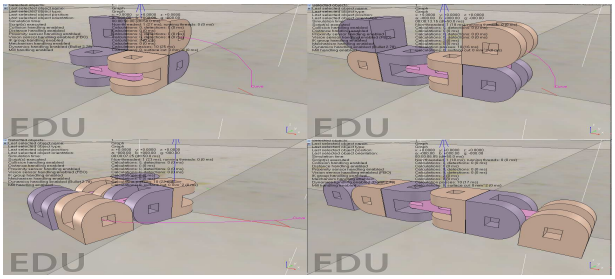

Figure 5 Multiple configuration propagated

4. CONCLUSION

The DTTO modular is able to propagate multiple configurations. Due to robot limitation, it is necessary to establish position attachment, and 3 axis configuration is able to propagate more different configuration and provide locomotion that same goes with 2 axis configuration. Hence, this idea will provide significant information for future research work.

REFERENCES

[1] S. Murata, E. Yoshida, A. Kamimura, H. Kurokawa, K. Tomita, and S. Kokaji, "M-TRAN : Self-Reconfigurable Modular," *IEEE/ASME Trans. Mechatronics*, vol. 7, no. 4, pp. 431–441, 2002.

[2] Alberto, "Dtto - Explorer Modular Robot," *Hackaday*, 2016. [Online]. Available: https://hackaday.io/project/9976-dtto-explorer-modular-robot. [Accessed: 04-Jul-2017].

[3] M. Yim, "New locomotion gaits," in *Proceedings of the 1994 IEEE International Conference on Robotics and Automation*, 1994, pp. 2508–2514.

[4] S. Hirose, *Biologically inspired robots: snake-like locomotors and manipulators*, Illustrate. Oxford University Press, 1993, 1993.

[5] W. Nan, P. Bo, and Z. Sha-Sha, "Simulation study of snake-like robot's serpentine locomotion based on recurdyn," *Res. J. Appl. Sci. Eng. Technol.*, vol. 7, no. 1, pp. 37–41, 2014.