Preliminary Investigation on Modular Self-Reconfigurable Robot Architecture

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ABSTRACT – Modular Self-Reconfigurable (MSR) robot is a robotic system which involves a group of identical robotic modules that are connecting together and form a structure. Such robotic system allows reconfiguration of the robots to adapt to the specific tasks. However, the use of this robot is very limited. This robot is at the early stage of development. This paper is written to analyze self-reconfigurable modular robot that has been till today. Improvements made for each developed MSR robot but still a lot of lacking. However, it still has the potential to be widely applied in future and this paper provide information for our future plan that is to establish control system for the MSR robot.

1. INTRODUCTION

MSR robots is a new approach in robotic technologies which provide viable solution for several applications such as space exploration [1] and management of large facilities [2]. In term of robotics. A "module" of robot has the ability to perform robot tasks that able to interact with other "modules" [3]. For being "modular", it must able to have an unrestricted number or a specific small set of identical modules for structure of MSR system. One MSR robot module might not be able to locomote by itself, but the behavior for combination of several modules can make itself move and achieve many different locomotion gaits [4]. Majority of the module developed is based on available resource at specific time which sometimes restricted MSR capabilities due to limited technology advancements. The various current proposed MSR robots architecture implicit challenges to researchers while identify the pros/cons for their approach in MSR robot technologies. This study is intended to perform a preliminary study from researcher's perspective and obtaining necessary information employed for the next phase of the modular robot research.

2. MODULAR ROBOT ARCHITECTURE

2.1 Hardware

MSR prototype robot was developed by each researcher related [6][9] and the research was directed for development of different MSR robot structure which mimic the biological organism such as snake [5]. The accepted classification of MSR robot is based on how frequent of attaching locations. This is based on the moving methods between locations or according to the possible formations when the MSR robots bind together which one of the mechanism using Soft Magnetic Alloy (SMA). The accepted configurations or architectures for current MSR robotics system are Chain, Lattice, Mobile, and Hybrid. MSR robots also categorized as Stochastic, Trusses and Free-form system.

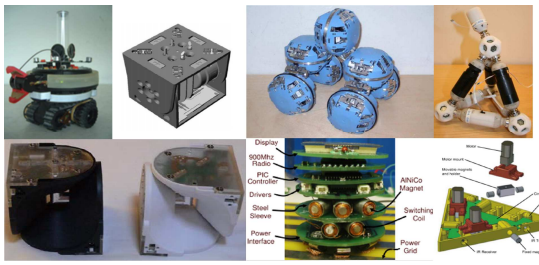

Figure 1. Some of the reviewed MSR robot hardware architecture which are mobile, chain, lattice, trusses, hybrid, Free-form and Stochastic (Left to right)

2.2 Control

The idea of MSR robot is for the system to work together and perform a specific task. Controlling a multiple MSR robot is a complex process as it is not the same as control one MSR robot in which theoretically it should be simpler. The establishment of control architecture depends on the communication system built for specific MSR robot such as neighbor-to-neighbor communication by using infrared (IR). Wireless communication is also possible, for example YaMoR MSR robot that uses Bluetooth as the sole means of inter-module wireless communication [6].

3. RESULTS

Based on our studies, researchers that developed MSR robot architecture face several challenges in term of hardware design. It is found that, even though MSR robotic system has high adaptability, generally it is unsuitable for manufacturing processes [7] but can be used in the manufacturing field for facilities management [2]. Besides that, according to Yim et al. [8], the self-reconfigurable robot also face a challenge in term of control and planning. As self-reconfigurable modular robot system involves multiple modules, high level-planning is needed to overcome realistic

constraint. Table 1 shows the information extracted for the MSR robot hardware and control architecture.

Table 1 Information on current MSR robot architecture

MSR Robot	Hardware Architecture	Type of Control (Centralized/Decentralized)	Docking Mechanism
ATRON	Lattice	D	Mech.
CONRO	Chain	D	Mech., SMA
Cebot	Mobile	D	SMA
Cross-Ball	Lattice	D	Mech., Permnt.Magnet
Crystalline	Lattice	D	Mech.
EM-Cube	Lattice	C	Permnt.Magnet
Lucian Mobile Climbing Robot	Mobile	D	
M-TRAN	Hybrid	D	Mech., SMA
Metamorphic	Lattice	C	Mech.
Molecule	Lattice	D	Mech.
Odin	Trusses	D	Mech.
PolyBot	Chain	D	Mech., SMA
Programmable Parts	Stochastic	D	Permnt.Magnet
Sambot	Hybrid	D	Mech.
SuperBot	Hybrid	D	Switch.Permnt.Magnet
Smores	Hybrid	C	(EP) Magnet
S-Bot	Hybrid	D	Mech.
Ubot	Hybrid	D	Mech.
Yamor	Chain	C	Mech.

4. DISCUSSION

Several researchers have put focus to rescale the modules to millimetre or micrometre scale [9]. The MSR robot is needed to be designed so that the modules are able to have maximum contact surfaces with stability and coordinated structures. However, there are some inescapable aspects of MSR which create limitations and challenges for the researchers. At this point, the robot controlled must have its multiple configurations externally. But, the capability to change configuration is limited to hardware constraints (mechanically) besides some configurations are difficult to be achieved. For the robot is not being controlled externally, multiple sensors have to be implemented so that the robot can perceive the environment condition in real-time and able to make decision on their own in term of choosing their configurations. Docking mechanism of the MSR robot is based on magnets, hooks and lock-key mechanism. Basically, the architecture of MSR robot developed as male-female, active and passive interface. Those information will helps in term of providing a better approach to establish better and more versatile MSR robot.

5. CONCLUSION

This technology is being developed for various possible future applications. Review from researchers in this field has address several challenges in term of hardware design, planning and control. Some improvements made but there is still a lot of lacking due to limited technology advancements. In term of manufacturing applications, as the fast technology advancement nowadays such as Industrial Revolution 4.0, it will be possible to see the implementation of MSR robot in manufacturing applications in near future.

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