MODULAR SELF-RECONFIGURABLE ROBOT FOR EFFICIENT MANEUVERING IN A CLUTTERED ENVIRONMENT

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ABSTRACT

Modular robots consists of a basic module that can function independently, while a number of these modules, connected with each other, form a more versatile robotic structure with wide array of transformation capabilities and modes of motion. This paper presents one such modular design for a robot that can reconfigure itself in 3D space . A cubic robotic module is designed wherein each module is able to change its dimensions and foot print with two degrees of freedom. The proposed robot can navigate through obstacles by dynamically adapting its shape, reach a point in 3D space by changing its height and width according to the task in hand. A prototype was developed using readily available components such as servo motors and a microcontrollers based control unit.

***Key words*:** Module, locomotion, transformations

1.INTRODUCTION

Modular robots are part of an area of robotics that has seen an increasing interest in recent years [1] [2] [3]. The goal in modular robotics is to produce a set of small modules that are able to function both individually and as a group with other modules to achieve their objectives, such as step climbing, other outdoor terrains, and avoiding obstacles. This is generally achieved through moving individual modules around while connected in a group, thus changing the dimensions of the combined robot structure in the process. Their ability to move modules around also makes it possible for modular robots to split a large task into many smaller ones. For example if the task at hand were to nark the lines on a tennis court then multiple robot modules with inter-module communication would be able to complete the task much faster than otherwise. One of the many reasons why reconfigurable robots have enjoyed so much interest in recent years is that since modules can combine together as needed, they are not restricted to performing only one task.

Modular Robots have a long history behind them. Since the first reconfigurable robot called CEBOT was built in 1988 by T. Fukuda and S. Nagawaka [4] (mentioned in [1]), many others have improved on this idea. Such research includes the M-TRAN modular system [6], the Superbot[6] and the Sambot[7]. When many modules are linked together they are usually called a ‘swarm’ and these are sometimes referred to as swarm robots[7].

This paper presents a modular robot design for a robot that was designed in order to transform itself into different shapes while collecting information from the surrounding.The robot is able to reconfigure itself within a 3 dimensional space. It is able to move around thanks to its many transformations as opposed to traditional wheeled robots. The scope of the project was limited out so that the robot would only move in flat surfaces while avoiding obstacles. With this in mind, the robot was designed in a manner where weight and power was optimized, as it needs to be able quick movements.

The paper is organized as follows: Section 2discusses the core module design; its degrees of freedom and how it can move around, and the algorithm used for obstacle avoiding. Section 3looks at the possible transformations that are available with 2 modules that have been linked, and the options for connecting together the 2 modules while Section 4 gives concluding remarks.

2. HARDWARE AND DESIGN CONSIDERATIONS

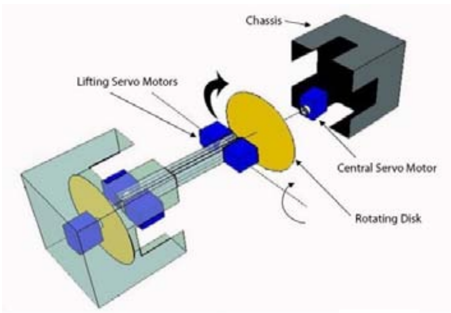
Since our design needed to be able to move around and change its shape even without combining with other modules, the approach we took was similar to the Superbot[1] and M-TRAN[6] robots. Each module contains 2 cubes, each of which can move in the XZ and YZ planes relative to each other. Increasing the number of modules linked to each other exponentially increases the number of possible transformations.

2.1 Mechanical Design

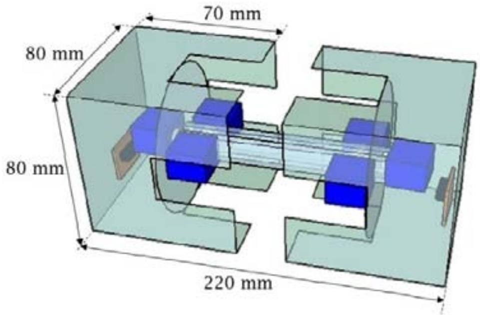
One module consists of 2 boxes, as illustrated in figure 1(a), where each box is connected to the other by the use of a rod. The module is controlled by a single microcontroller (PIC16F84A), where it controls all the other components.

The main driving components of the robot are the servo motors. Each module has 6 servo motors, wherein each chassis contains 3 servo motors. Two lifting servo motors, ML1 and ML2 are fixed onto a circular platform, where it carries out the function of rotating the connecting rod, which brings about the most importa5nt movement in the robot. The third central servo motor, MC carries out the function of rotating the circular platform.

While making the modules, one of the most important factors to consider was the dimensions of the module. If the modules were too big, it meant that there would be a large load on the servo motors, while making a module too small would mean that all the necessary components such as servo motors and the microcontroller wouldn't be able to fit inside a single module. Figure 1 (b) presents the final dimensions for each module.



(a)



(b)

Figure 1: Actuators (a) and Dimensions (b) of a single module

For each module the outer box and connecting rod is made out of acrylic, as is the disc onto which ML1 and ML2 are placed. To hold the servo motors in place metallic contacts are used. The above materials were chosen in order to minimize the weight while upholding the overall strength of the bot.

As each module would be using servo motors as its actuators several different makes of servo motors as given in table 1, were considered for the task. The servo motor would have to be small in size, yet be able to provide high enough torque to support the weight that would be imposed on it.

The Tower Pro SG-90 servo motor was chosen as the most suitable to our task given that it provided a good torque without increasing the weight too much. Its specifications are listed below in Table 1.

Make	Tower Pro
Model	SG-90
Modulation	Analog
Weight	9.0g
Torque	4.8V : 1.8kg-cm
Speed	4.8V : 0.10 sec/60o
Dimensions(LxWxH)	23.1x12.2x29.0mm
Motor Type	3-pole

Table 1: Specifications of servo motors used

When using only one module, only a few different transformations are possible. However each chassis offers 2 degrees of freedom as illustrated in Figure 2. The central rod is thereby able to move along a horizontal axis and a vertical axis. It is important to note these 2 degrees of freedom in each chassis is what allows us to realize so many transformations when modules are connected together.

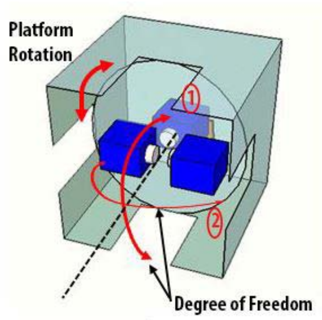


Figure 2: Degrees of freedom available to one chassis

To accomplish its goal, understanding the environment around it is a vital task. As illustrated by Figure 3(a), sonar sensors are used to obtain the useful information. With the information from the sonar sensors the bot is capable of understanding and realizing its current position.

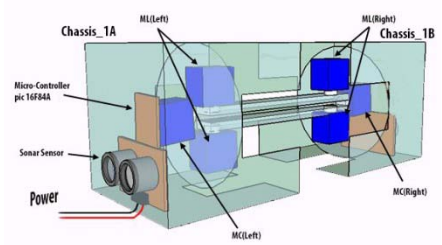


Figure 3: Components of the individual modules

2.2 System Design

The limitation of the project being the fact that the robot could only traverse in flat surfaces, gives it the ability to perform different functions. Thus it all depends on the task that it needs to achieve; it might be to avoid an obstacle or go over it or even push it. A general
algorithm was laid down as shown in figure 6, where the bot would refer to its sensors and command the actuators to move accordingly depending on what it needs to do. Below is a flow chart showing the basic data flow within the system.

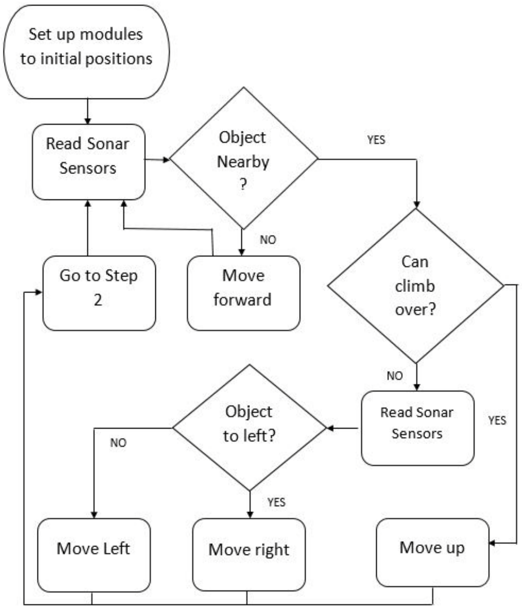


Figure 4 : Program Flowchart Showing Overview of Robot Operations

For the robot to achieve the above tasks, each function should be coded in so that it will be able to manipulate itself in order to move to the desired place.

3.RECONFIGURATION AND LOCOMOTION

To achieve the bots main target, where it should be able to navigate through a cluttered environment, it is essential that it should have greater degree of flexibility. A single module has two degrees of freedom giving it the capability of reconfiguring itself to make up different shapes. By the increment of the number of modules the possible shapes that could achieved by the bot increases exponentially. Thus the way it could move could be changed significantly.

3.1 Reconfiguration

Due to the limitation of the number of modules used, the following different configurations could be achieved with them, the diagram below illustrates the possible configurations .

The possible configuration could be expanded depending on the surface in which the bot is travelling; this again is possible due to the flexibility of the bot.

As represented by figure 4, many different transformations are possible with even 2 modules when they are linked together. Also the possible configurationscould be expanded depending on the surface in which the bot is travelling; this again is possible due to theflexibility of the bot. While adding more modules will mean that more transformations are possible and the creation of more complex designs and structures becomes possible.

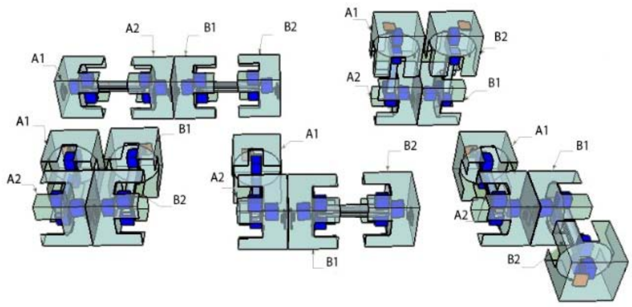


Figure 5: Different transformations available with 2 modules

Modules are interconnected by the use of permanent magnets, where four are used to link the two modules together. This brings about the required strength for the modules to be attached while movement, also giving it the ability of being detached when required. As serial communication is required between the microcontrollers, wired connections are used to link the two microcontrollers together. So the permanent magnets are also used as a base to which an electrical link could be established between the two bots. This method saves both power and space thus optimizing the energy considerations of the bot.

3.2 Locomotion

To fulfill the requirement of analyzing the surrounding and moving, sonar sensors are added to the front and the back. With this the bot would be able to move and recognize objects and take decisions as to whether it would move around or even climb it.

A single bot could move forward by rotating the cubes to angles of 45 and back to 90, in reference to module A, the cube A1 and A2 would being at their initial positions of 90 degrees. Afterwards by moving the cube A1 to an angle of 45 followed by the cube A2 taken to the same position, the module would move forward. To bring it back to its rest position, first cube A2 is move back to initial position (90 degrees), and then Cube A1 is moved to its rest position. With such coordination the bot could be made to move forward, by reversing the actions the bot could be made to move backwards. Also the bot could be moved left or right by use of the rotating servos, doing so the cubes could flip over and change its present direction. This type of locomotion is demonstrated in Figure 6

When the modules are interconnected, only one cube of each module is free to move. So all movement is done using the rear cube and the front most cube, both of these cubes would have sonars connected onto them thus they are used as the information gatherers

4.RESULTS AND DISCUSSION

This paper presents an idea for a robot that uses a feedback loop with input from sonar sensors and servo motors as actuators. It is able to change its dimensions based on its task and this allows it to be used for various purposes. In order to develop this idea the robot could be fitted in with a camera input rather than a sonar sensor. Also if we could allow for a temporary link between modules rather than a permanent one, and a wireless link between modules then it would be a good improvement.

With proper developments on self-reconfigurable robots they can be used for applications such as space exploration, as it is difficult to predetermine what kind of challenges a robot will face. However with self-reconfigurable robots this problem doesn't arise as they are able to change their shape and form to fit a given task/terrain.

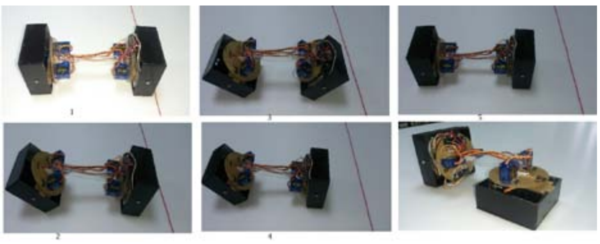


Figure 6: Demonstrating locomotion using one module

REFERENCES

1. Yanhe Zhu, Jie Zhao, Xindan Cui, Xialou Wang, Shufeng Tang, Xueyuan Zhang, Jingchun Ying, *"Design and implementation of UBot: A modular Self-Reconfigurable Robot"*, Proceedings of IEEE 2013, Conference on Mechatronics and Automation.
2. GuifangQuiao, Guangming Song, Jun Zhang, Hongtao Sun, Weiguo Wang Aiguo Song, *"Design of Transmote: A Modular Self-Reconfigurable Robot with versatileTransformation Capabilities"*, Proceedings of the 2012 IEEE, Conference on Robotics and Biomimetrics.
3. Michael D. M. Kutzer, Matthew S. Moses, Christopher Y.Brown, David H.Scheidt, Gregory S.Chirikjian, Mehran Armand, *"Design of a new Independantly-Mobile Reconfigurable Modular Robot"*, 2010 IEEE International Conference on Robotics and Automation.
4. T. Fugawaka, S. Nakagawa, "*Dynamically Reconfigurable Robotic System*", IEEE International Conference on Robotics and Automation, Vol 3, pp. 1581-1586, 198
5. Satoshi Murata,member, IEEE,Eiichi Yoshida, Member, IEEE, AkiyaKamimura, HaruhisaKurokawa, Kojhi Tomita, Member, IEEE,ShigeruKokaji, Member, IEEE, "*M-TRAN: Self Reconfigurable Modular Robotic System*", IEEE/ASME Transactions on Mechatronics, Vol. 7, No. 4, December 2002
6. Behnam Salemi, Mark Moll, Wei-Min Sheh, *"Superbot: A Deployable,multi-functional and modular Self-Reconfigurable robotic system"*, University of South Carolina
7. Hongxing Wei, *Member*, IEEE, YinpengCai, Haiyuan Li, Dezhong Li, Tianmao Wang, *"Sambot: A Self Assembly Modular Robot for Swarm Robot"*, 2010 IEEE International Conference on Robotics and Automation.