Mblocks Stigmergic Tags and Algorithims

John W. Romanishin, John Mamish, and Daniela Rus

***Abstract*— This paper presents distributed algorithms which utilize a novel type of magnetic barcode and mesh wireless networks to guide the reconfiguration of 3D M-Blocks modular robotic modules. The 3D Mblocks modular robots, original described in [1] and [1] have been outfitted with a novel type of magnetic tag and reader circuitry on each face, so that modules can accurately read ID information for other modules, or messages encoded in specially signified tags in the environment. This ability allows for a scalable, reliable, inexpensive, and simple way to identify their location information.**

I. Introduction

Modular self-reconfigurable robots have been proposed as one method to create general purpose robots or of arbitrary complexity in an autonomous way. These robots generally can be though of consisting of individual **modules**, which connect to other elements, either powered modules or passive structural elements, through a standardized **connector** to create a specific **configurations** in order to accomplish a designated task. The connectors themselves have several general requirements, to provide 1. some level of mechanical connection, 2. location and orientation information, 3. provide communication, or 4. provide additional connections (e.g. electrical, fluid, etc...). Many different systems have been proposed, and each system has tacked each of these connection variables in different ways, if at all. This paper focuses on the second point, looks at an overview of how location and identity information is encoded in connectors, and proposes a new method which the authors belive compares favorably with the existing state of the art.

The remainder of the paper is organized as follows: Section II gives an overview of related work that pertains to modular robots, and specifically to identifying and encoding physical location information in modular connectors. system. Section **??** presents a quick overview of the 3D Mblock modules, and then gives a detailed description of the new magnetic tag hardware and electronics.

Next, Section IV presents data characterizing the hardware and the results of experiments with the system.

Finally, Section **??** concludes with a short discussion and ideas for future work.

II. Related Work

Modular self-reconfigurable robots are often characterized by their system topology: lattice, chain, or hybrid [2]. Most of the systems currently under development including U-Bots [3], Roombots [4], and SMORES [2] utilize a hybrid architecture. The fundamental distinction between hybrid or chain modules and strict lattice systems is that hybrid or chain modules have either fewer connector faces than lattice faces, or these connector faces are located in off-lattice positions. Chain and hybrid systems are typically designed to self-reconfigure using complicated implementations which approximate simpler models, such as the sliding cube model [5] or the pivoting cube model [1].

To the best of our knowledge, the 3D M-Blocks are the only self-reconfigurable robots capable of implementing a simple movement model in three dimensions that allows for both independent and lattice-based locomotion.

J. W. Romanishin, D. Rus are with the Computer Science and Artificial Intelligence Lab, MIT, Cambridge, MA, 02139 {johnrom|rus}@csail.mit.edu.

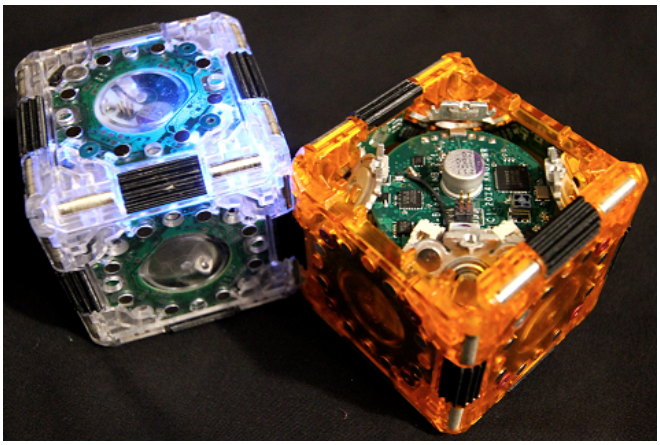

Fig. 1: M-Bocks modular robots with connections illuminated with onboard LEDs

III. Hardware

A. M-Blocks hardware overview

This work utalizas a fleet of modular robots previously described in [] and [], called the 3d M-Blocks. Characteristics of the M-Blocks at a glance can be seen in Table **??**

TABLE I: Basic info of the m-Blocks modular robots

Actuation Directions	6
Mass	150 g
Characterist Dimension	50 mm
Total Parts	216
Actuated Moving Parts	10
Est. Cost	$130

B. Magnetic Barcodes Overview

Several different Tag technologies are shown in Table **??**.

IV. Algorithims

This section describes two different algorhtims... These algorithims are similar to those described in...

TABLE II: Comparison of tagging technologies

	Passive	Size
RFID Tags	0	0
QR Code	-1	-50
IR Light	0	0
Electrical Contacts	0	0
BLE Beaconds	0	0

V. Experiments

A. Tag Characterization Experiments

We did some stuff, wrote it down here...

B. Crystalization Experiments

We did some stuff, wrote it down here...

VI. Introduction

We did things... Things are good. Bye!

Acknowledgments

This work is supported by the NSF through grants 1240383 and 1138967.

Supplementary Material

`http://youtu.be/y27gUFO6mTA`

References

[1] J. W. Romanishin, K. Gilpin, and D. Rus, "M-blocks: Momentum-driven, magnetic modular robots," in *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*. IEEE, 2013, pp. 4288–4295.

[2] M. Yim, W. Shen, B. Salemi, D. Rus, M. Moll, H. Lipson, E. Klavins, and G. S. Chirikjian, "Modular Self-Reconfigurable Robot Systems: Challenges and Opportunities for the Future," *Robotics and Automation Magazine*, vol. 14, no. 1, pp. 43–52, 2007.

[3] Y. Zhu, J. Zhao, X. Cui, X. Wang, S. Tang, X. Zhang, and J. Yin, "Design and implementation of ubot: A modular self-reconfigurable robot," in *Mechatronics and Automation (ICMA), 2013 IEEE International Conference on*. IEEE, 2013, pp. 1217–1222.

[4] M. Vespignani, E. Senft, S. Bonardi, R. Moeckel, and A. J. Ijspeert, "An experimental study on the role of compliant elements on the locomotion of the self-reconfigurable modular robots roombots," in *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*. Ieee, 2013, pp. 4308–4313.

[5] R. Fitch, Z. Butler, and D. Rus, "Reconfiguration planning for heterogenous self-reconfiguring robots," in *Intelligent Robots and Systems*, 2003, pp. 2460–2467.