A Stochastic Self-reconfigurable Modular Robot with Mobility Control

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Recently, a variety of robotic systems have been studied under the umbrella term of modular reconfigurable robotics [7,6]. Unlike conventional fixed-morphology robots, whose performance is usually confined by the operating environment and their own size, modular reconfigurable robots have the potential advantage of being able to change their morphology by rearranging the connectivity of their modular units [3]. This project investigates the development and improvement of a self-reconfigurable modular robot designed in previous work to study the emergence of robotic life-forms in a controllable physical environment [4]. The system contains 7 cm x 7 cm square robot units. Each unit is externally propelled and moves stochastically on an air table [2,1]. Each unit can establish, and break, up to four physical connections with other units by means of swiveling permanent magnets [4,1]. Connected units can communicate using infra-red transceivers.

A newly-designed air table and two novel prototype units were built (see Fig. 1). Three air ventilators and eight boundary air blowers ensure that the units float freely and randomly on the table. The air blowers can be computer controlled or manually operated (both azimuth and speed). An elastic rubber band boundary was fixed around the table to reduce a unit's energy loss after collision. The unit's base structure was redesigned with a weight of 8 g, which is 6 g lighter than the previous design [5]. The connection/disconnection mechanism was improved as the new base structure provides a tighter magnetic coupling between the units. The most important contribution is a novel jack mechanism that allows for mobility control of the units, which otherwise move passively. The operating principle is to use a retractable anchor by which the unit establishes physical contact with the surface of the air table and thus immediately loses its mobility. This can be triggered, for example, in response to a nearby light or heat source detectable by an upward-facing infra-red sensor. Therefore, through mobility control, units could choose to stay in regions offering high solar energy (this is to be exploited by future prototypes).

A series of systematic experiments were conducted in order to evaluate the unit and air table design. The experiments included a single unit mobility test, an inter-unit connection/disconnection test, a connected units mobility test, a communication test, and a jack mechanism test. The system achieved a satisfactory performance. The jack mechanism turned out to be particularly effective:

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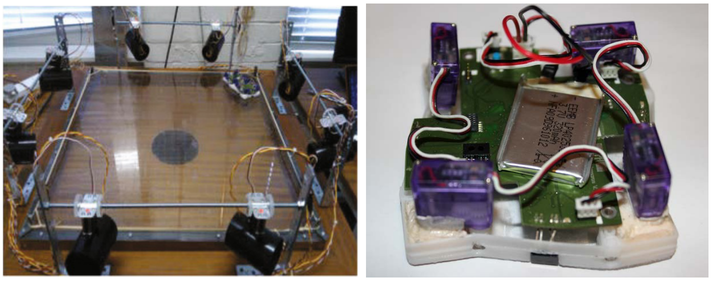

Fig. 1. Left: Two connected robot units floating on the newly designed controllable air table system. Right: A single robot unit capable of self-assembly, inter-robot communication, light sensing, and mobility control. Its total weight (including the battery) is 45 g.

when underneath a light bulb, a unit could immobilize not only itself, but also another unit it was connected with. Future work will investigate the interplay of a greater number of units. Video recordings showing the working system are available on-line.[1]

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References

1. Bishop, J., Burden, S., Klavins, E., Kreisberg, R., Malone, W., Napp, N., Nguyen, T.: Programmable parts: A demonstration of the grammatical approach to self-organization. In: Proc. of the 2005 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, pp. 3684–3691. IEEE Computer Society Press, Los Alamitos (2005)
2. Griffith, S., Goldwater, D., Jacobson, J.M.: Self-replication from random parts. Nature 437(7059), 636 (2005)
3. Groß, R., Dorigo, M.: Self-assembly at the macroscopic scale. Proceedings of the IEEE 96(9), 1490–1508 (2008)
4. Groß, R., Magnenat, S., Küchler, L., Massaras, V., Bonani, M., Mondada, F.: Towards an Autonomous Evolution of Non-biological Physical Organisms. In: Kampis, G., Karsai, I., Szathmáry, E. (eds.) ECAL 2009, Part I. LNCS, vol. 5777, pp. 173–180. Springer, Heidelberg (2011)
5. Massaras, V.: Experimental study on evolvable robotic organisms. Master's thesis, EPFL, Lausanne, Switzerland (2009)
6. Støy, K., Brandt, D., Christensen, D.J.: Self-Reconfigurable Robots: An Introduction. MIT Press, Cambridge (2010)
7. Yim, M., Shen, W.M., Salemi, B., Rus, D., Moll, M., Lipson, H., Klavins, E., Chirikjian, G.S.: Modular self-reconfigurable robot systems. IEEE Robot. Autom. Mag. 14(1), 43–52 (2007)

[1] `http://naturalrobotics.group.shef.ac.uk/supp/2012-002`