Self-Reconfiguring Modular Robotics

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JAMES DYSON FOUNDATION PROJECT SUMMARY

Self-reconfiguring modular robotic systems consist of a large number of small, relatively simple robots. The systems can adapt their configuration to address a wide range of physical challenges. The first of such systems were developed in the 1980s. They have the potential to offer several advantages over conventional robotics, as they can be extremely versatile, so a single set of modules can perform the same tasks as many separate specialised machines. This can bring savings in weight and cost, and makes them especially suited to environments with unpredictable challenges, such as disaster zones, or where it is impractical to transport a large number of different machines, such as in space travel.

In this project I designed, made and tested modular robots, spread across four design phases. In phase one, I generated ten concept designs. In phase two, I developed four of these into simple prototypes. I developed one concept in much more depth in phase three, producing a fully functional robotic prototype. I then manufactured five identical prototypes in phase four in order to test the functionality of the modules as a system. This process allowed me to investigate the challenges associated with the design of self-reconfiguring modular robots and explore some possible avenues for development within the field.

The prototypes are made primarily of 3D printed PLA and laser-cut acrylic components. The joints are operated by small geared DC motors and position feedback is implemented with rotary encoders. Modules connect together with mechanically operated grippers. Each module is controlled using an Arduino microcontroller on a custom printed circuit board and powered from a single rechargeable battery. The system is controlled from the operator's laptop via Bluetooth using a custom designed byte-wise communications protocol.

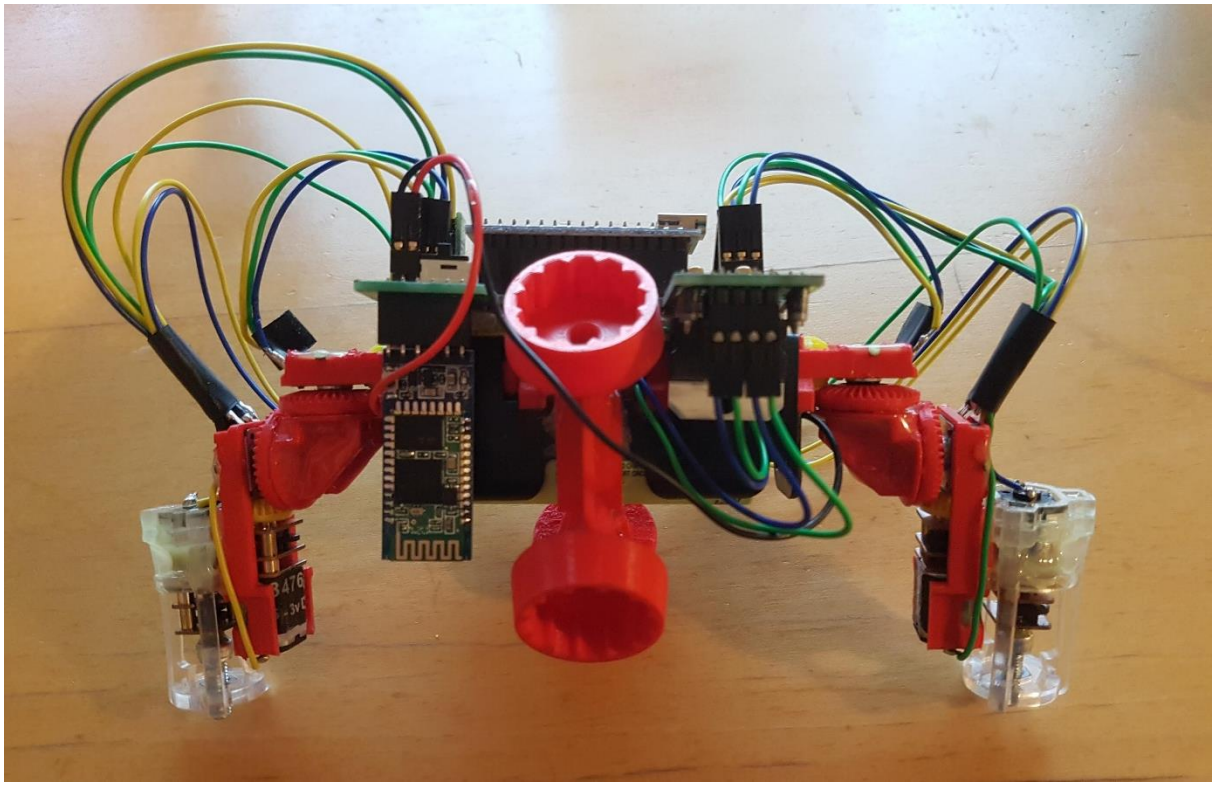
The final system of five prototypes was able to:

- Locomote at 2 cm/s
- Form structures 37 cm high
- Operate for 3 hours of typical use on battery power

The main disadvantage of the design is that the robots are not very robust. After ten hours of testing, three of the modules had suffered mechanical failure at the joints. The main advantage of the design is the cost. The total bill of materials cost for each module is £89, so systems are affordable and could be widely adopted.

To further develop the design, the motor torque and angular precision at each joint need to be increased, as at present the positional control is insufficiently accurate to reliably self-reconfigure, and larger configurations struggle to locomote due to their self-weight.

The project achieved its aim as, by developing the robots, I investigated many of the design challenges for self-reconfiguring modular robotics and was able to draw useful conclusions. Based on my experiences, I have found that advancements in the field are likely to result from improvements in miniature actuator technology and positional sensing. This may involve moving from conventional actuators to smart materials such as shape memory alloys, as these are more readily miniaturisable. These advancements could allow engineers to develop systems with a much larger number of modules and bring the field closer to widespread commercial application.



One of the final prototype modules