Challenges in Modular Spatial Robots

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Introduction
Over the past five years, I have been designing and developing modular reconfigurable robots and interactive media experiences for use at an architectural scale. While developing robot materials and interface interaction logic, I have identified a number of key challenges and opportunities that will affect the future of robots in architecture. This paper gives an overview of these topics.

Modular Reconfigurable Robots
After studying the landscape of modular robotic projects including the Self-Replication Module by Cornell Computational Synthesis Lab [1], M-Tran 1-3 by Distributed System Design Research Group at AIST [2], Claytronics by the Claytronics Team at Carnegie Mellon [3] and many others, I have developed my own robotic architecture system, which is called Nano Meta-morphic Space [4].

This project consists of the design and development of a palette of small-scale self-similar robotic modules

that have the ability to dynamically move and attach to other modules to create different configurations in real-time. Each module contains various hardware (sensors, accelerometers, computation and kinetics) and computational logic to enable it to interpret and physically respond to different local and global inputs. Inhabitants can use hundreds of thousands of these modules to create and recreate dynamic real-time formations. This project included the design of the overall geometry, logic and behavior of the modules as well as the creation and development of fully working prototypes.

Through the lens of architecture and user interface design, a number of key technical and sociological challenges can be identified that affect the future of using modular reconfigurable robots in the context of architectural space. These challenges also apply to the broader field of architectural robotics. It is important to understand an overview of all the topics when approaching the future of modular reconfigurable robot design. These challenges include:

Technical Challenges

- Developing fail-safe robotic systems that can maintain their structural capabilities without power
- Integrating robotic modules with the external and natural landscape
- Building and enabling the movement of small-scale modules
- Integrating multiple scales of robotic modules within the same architectural system
- Building and integrating information display within a single robotic system

Sociological Challenges

- Approaching design from the users perspective
- Identifying and understanding single-user and multiple-user goals
- Understanding that different control technologies (touch, gesture and cognitive control) are appropriate at different scales
- Using multiple interaction scales simultaneously
- Balancing physical local user response with global response

Opportunities

Modular reconfigurable robotic systems offer entirely new possibilities for the built environment and more importantly can address the dynamic demands of users on a single system. Right now, many of the individual technical and sociological challenges that affect modular reconfigurable robotic systems are currently being developed in various fields (researchers and designers are addressing specific challenges pertaining to their fields). It will be up to future robot designers to understand the challenges and apply this knowledge to their robotic designs.

Example Citations

[1] Lipson, Hod. Self Replication Robots. http://ccsl.mae.cornell.edu/self_replication

[2] Mtran 1, 2 and 3 Robot. http://unit.aist.go.jp/is/dsysd/mtran/top.htm

[3] Claytronics. http://www.cs.cmu.edu/~claytronics/

[4] Kemp, Miles. Nano Meta-morphic Space. http://www.seriesdesignbuild.com/nano/main2.htm.