Robotic Self-Replication in Structured and Adaptable Environments

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- Future Directions
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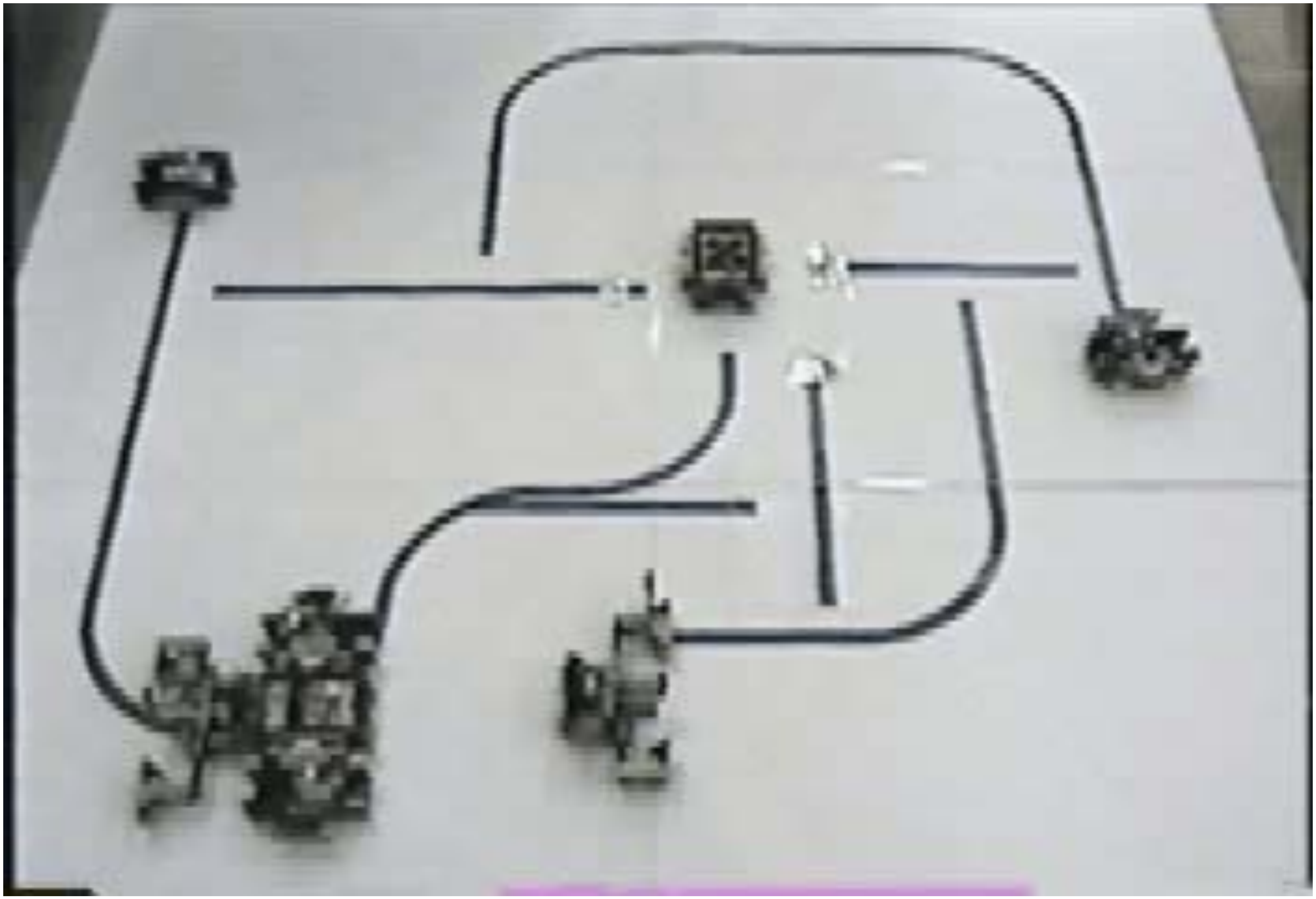
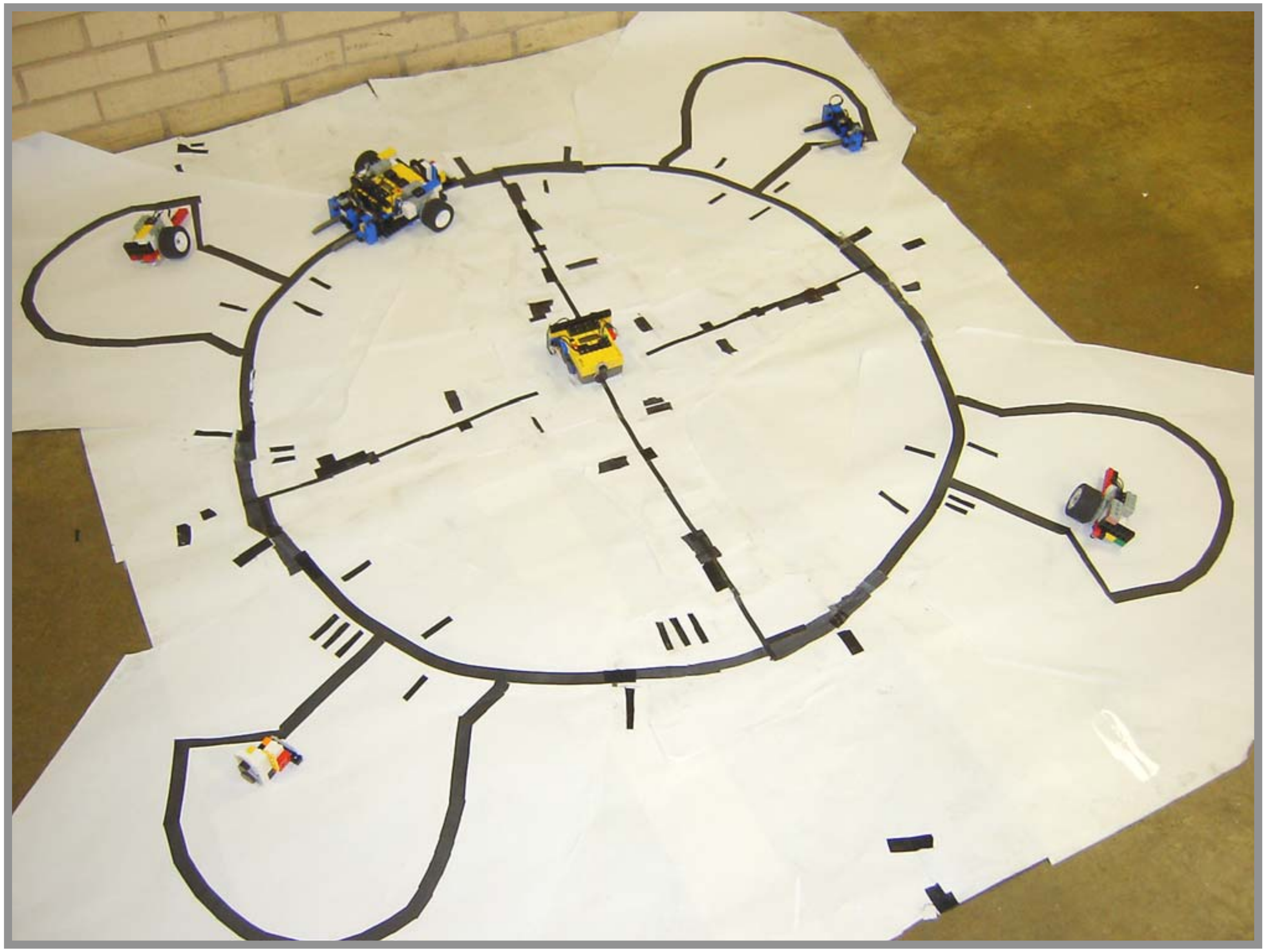
  - Robotic Self-Replication by Mitosis

A Remote Controlled Design

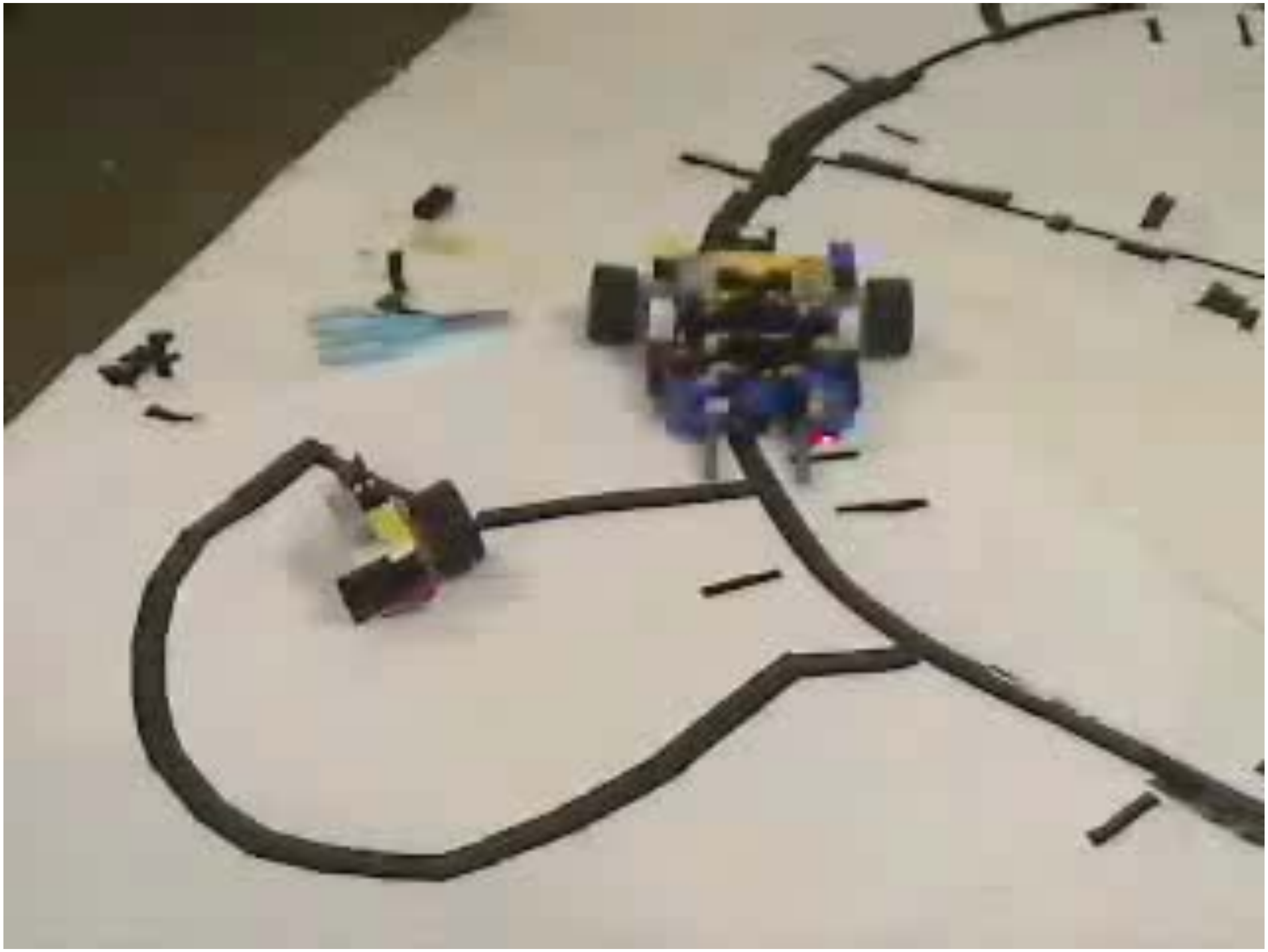
A Fully Autonomous SRR



Robotic Self-Repair in a Semi-Structured Environment



Robotic Self-Repair in a Semi-Structured Environment

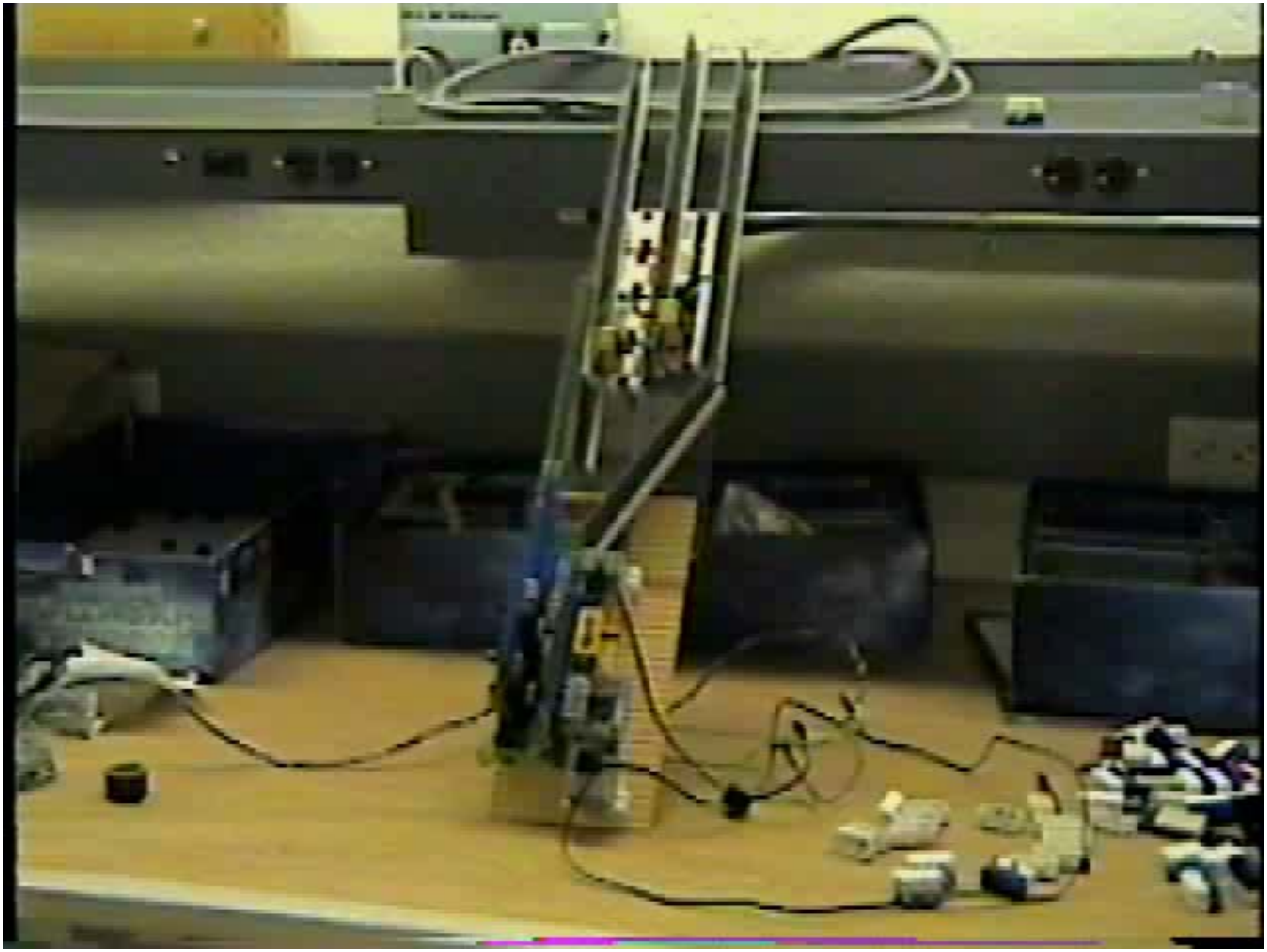


Computers that Copy Themselves

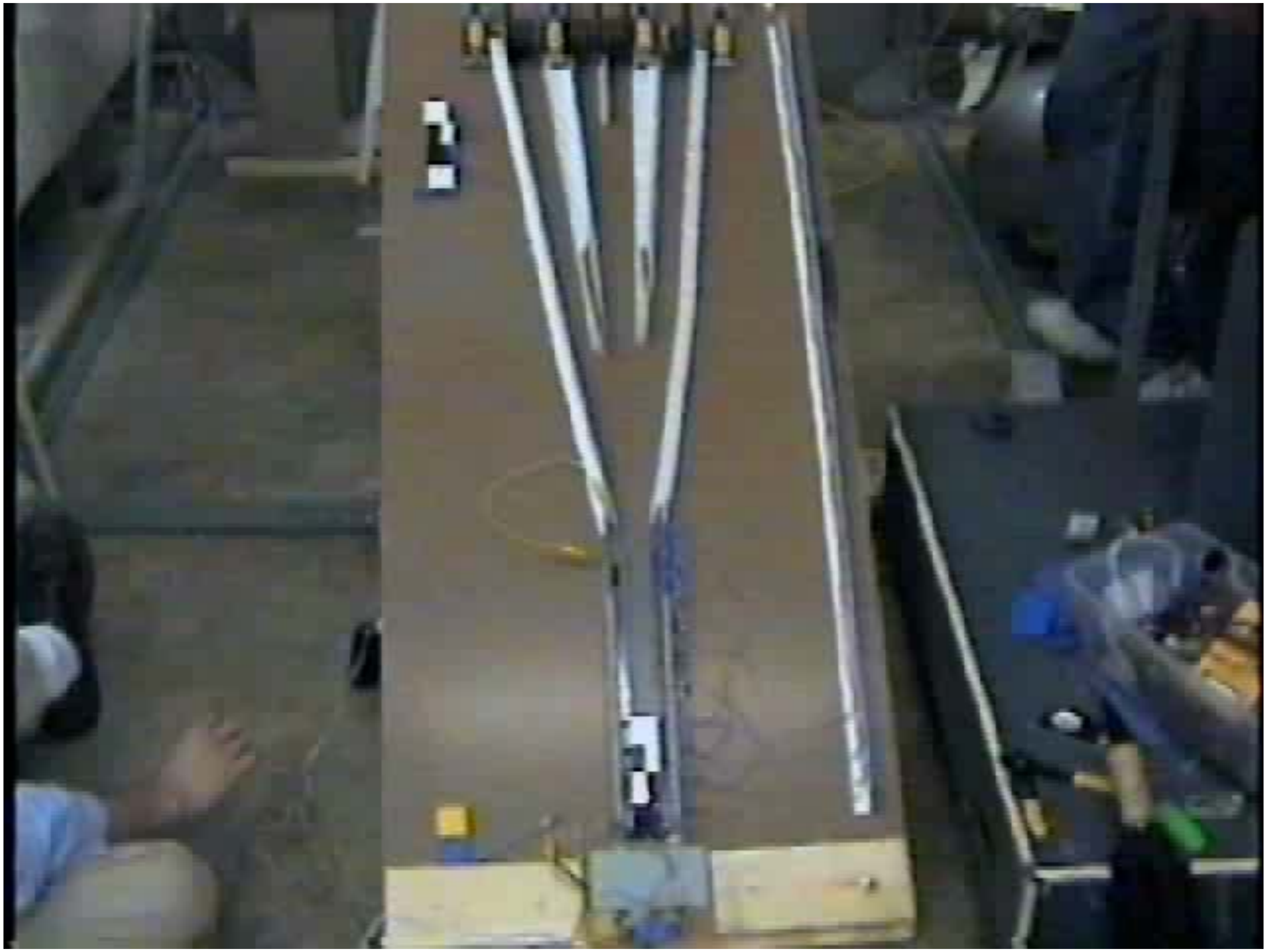
To make computers from logic elements using a von Neumann Universal Constructor would require a very complicated code.

An alternative is Laing's paradigm of self-replication by self-inspection. We developed three prototypes to demonstrate this idea physically for the first time.

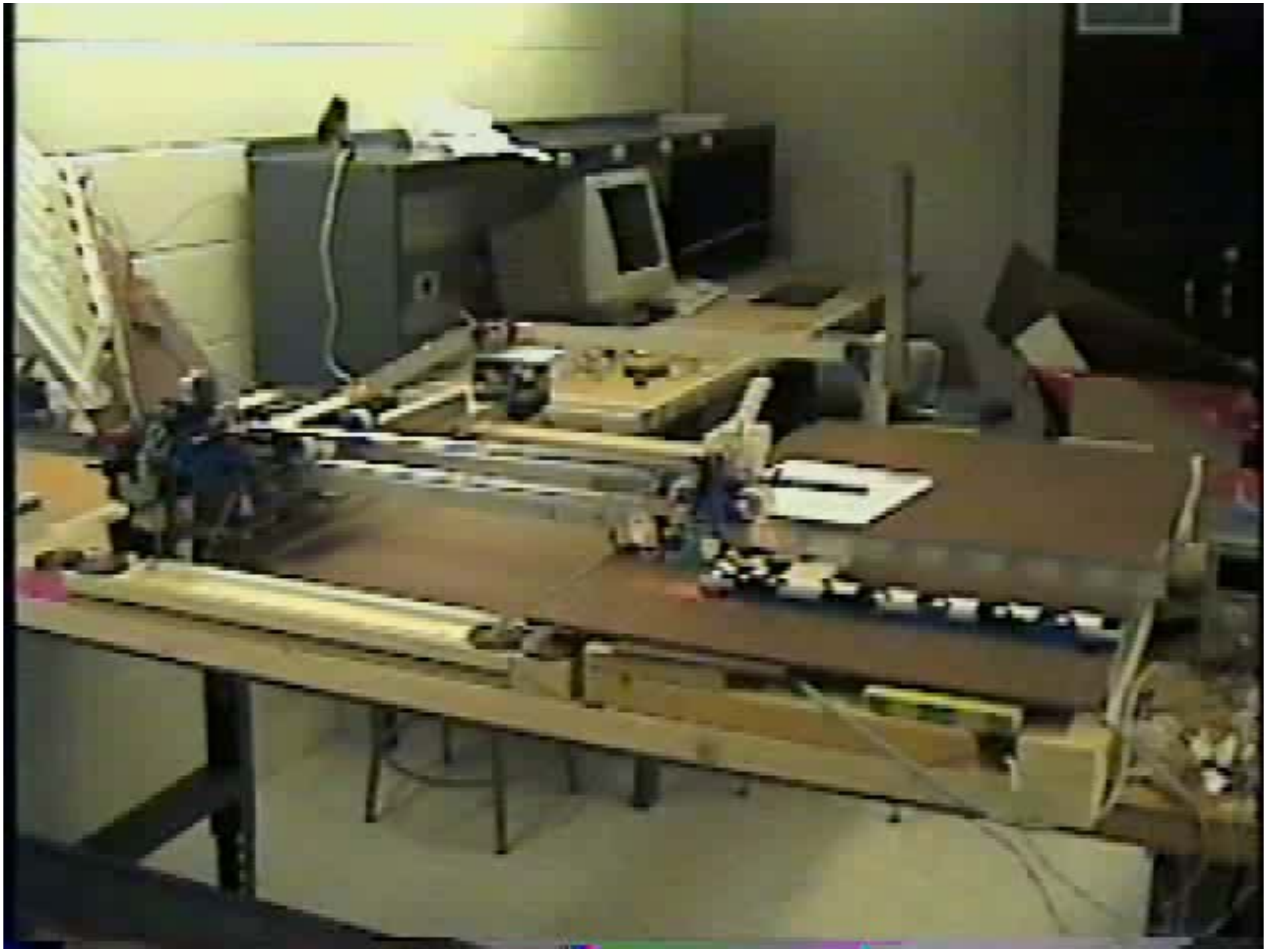
Self-Replication by Self-Inspection 1



Self-Replication by Self-Inspection 2



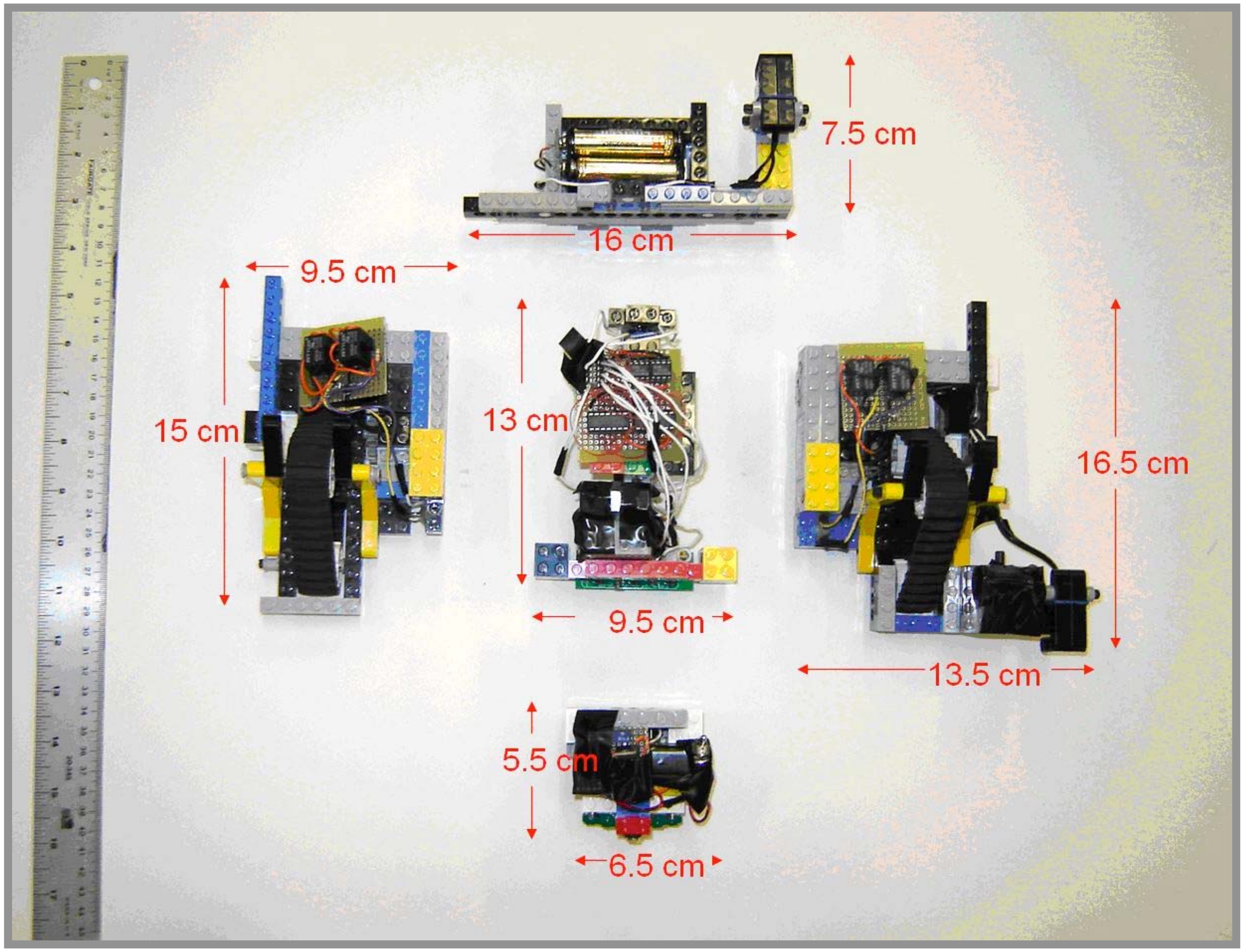
Self-Replication by Self-Inspection 3



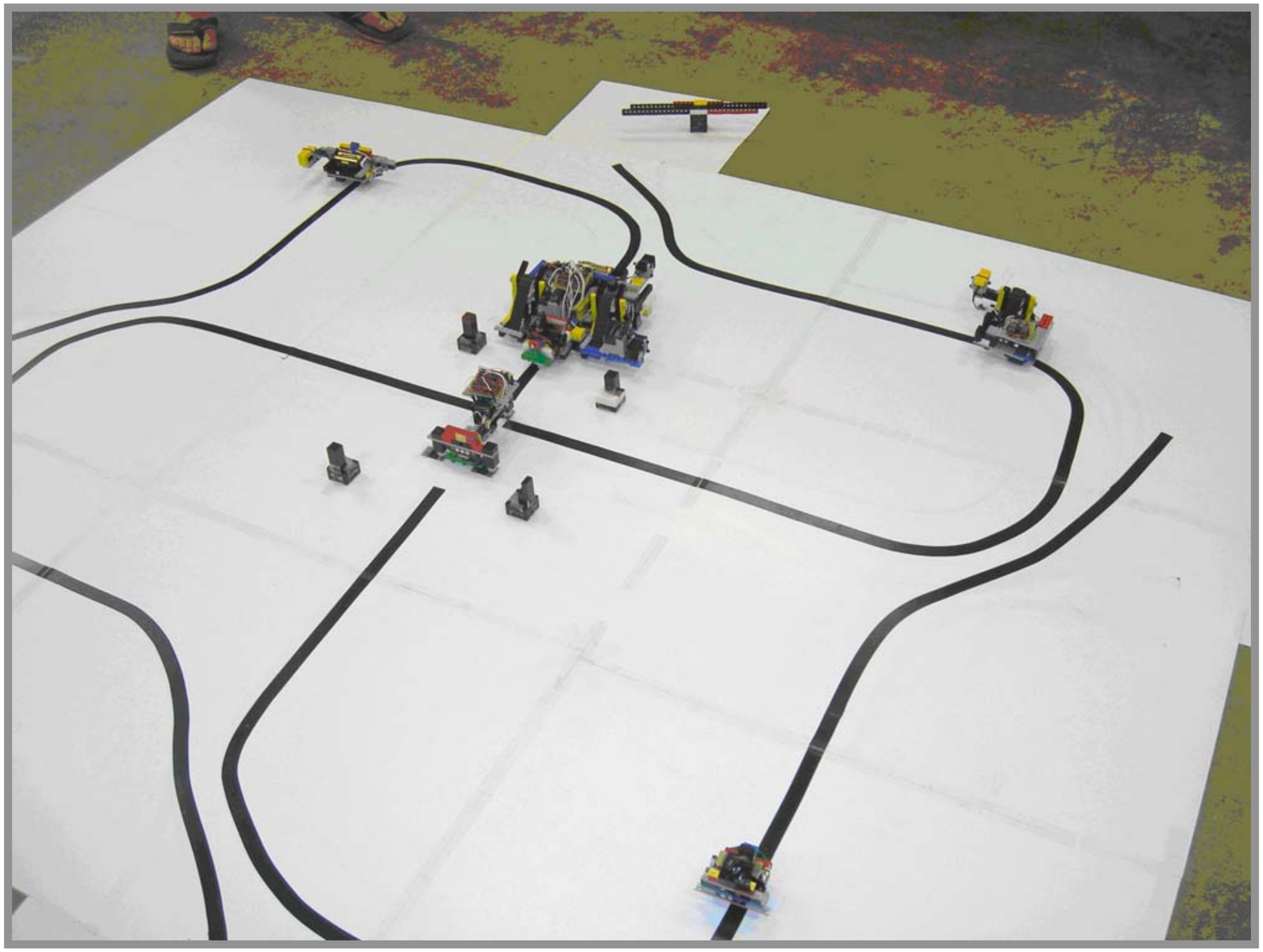
Combining Previous Concepts:

Self-Replicating Robots with Distributed Computing Elements

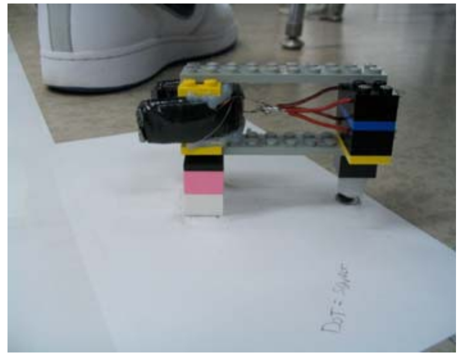
SRR with Distributed Circuits

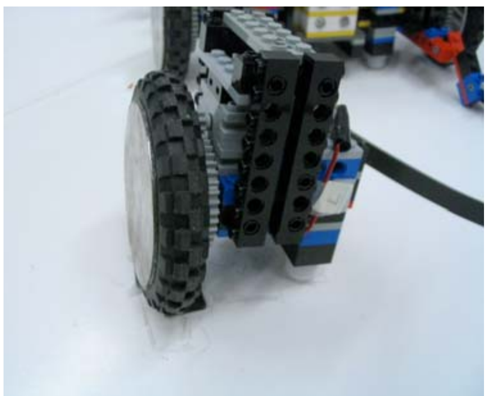


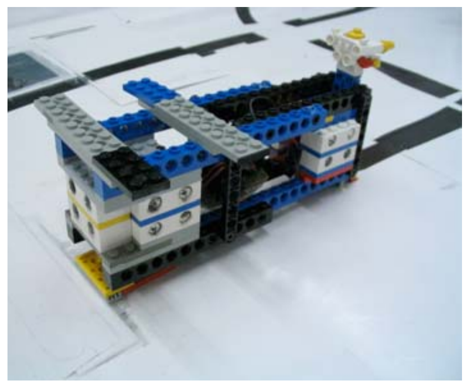
SRR with Distributed Circuits

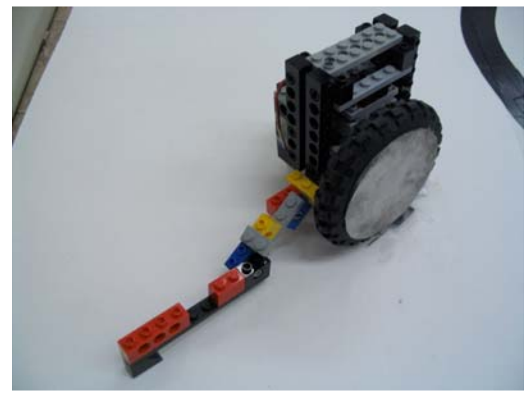


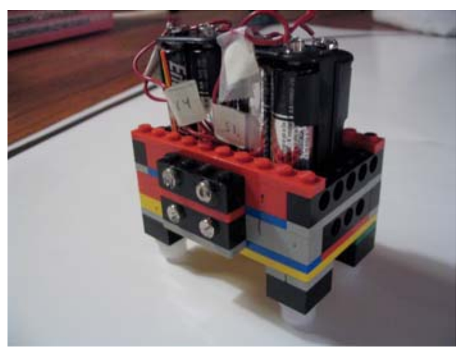
SRR in Adaptable Environment



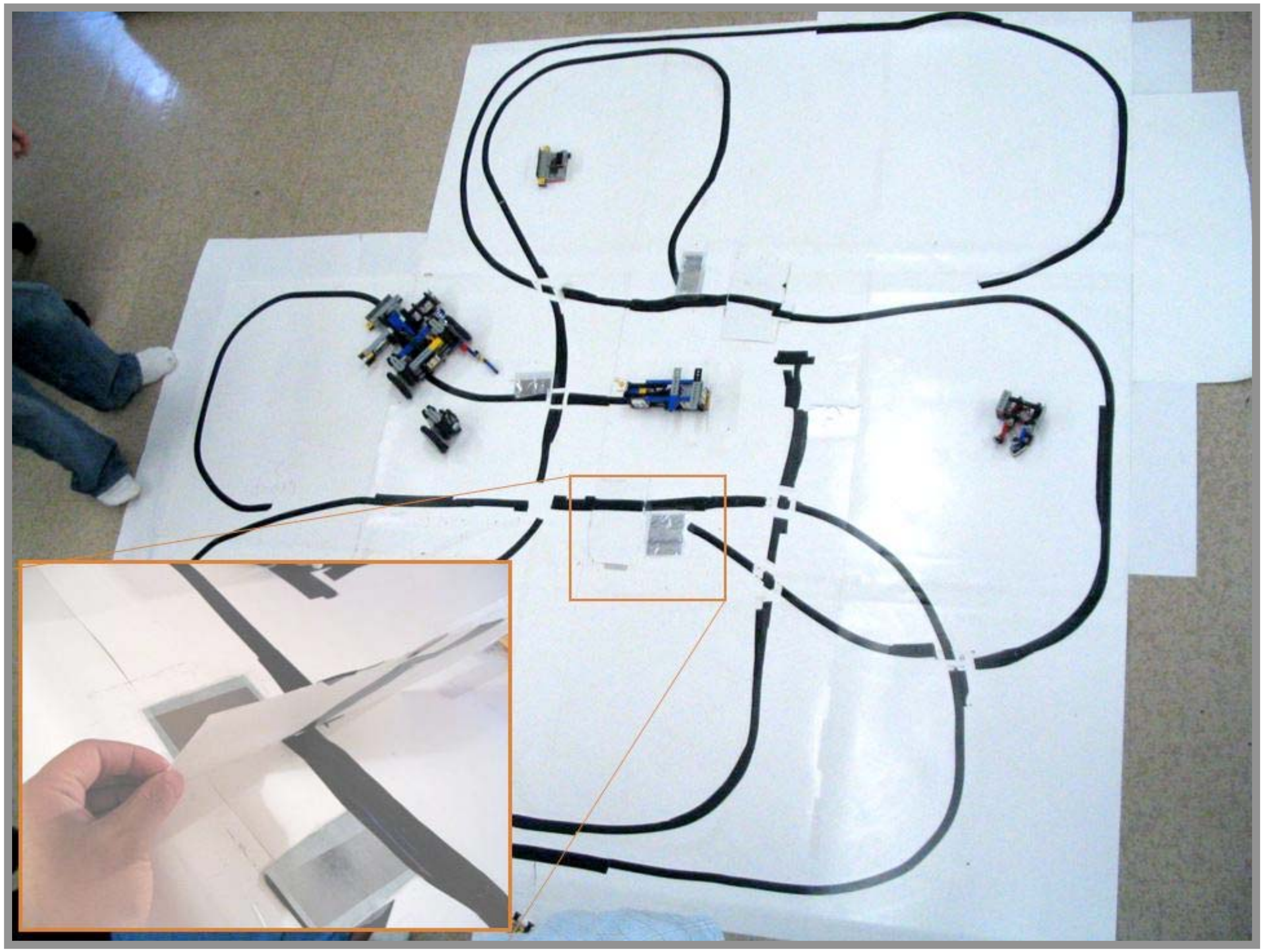








SRR in Adaptable Environment



Remainder of the Talk

- **Principles of Robotic Self-Replication (RSR)**
  - Universality, High Relative Complexity, Robustness, and Efficiency
  - Entropy/Information

Principles

- Universality
  - What can it become?
  - What can it produce?
  - What functions can it perform?
- High Relative Complexity
  - Complexity of the Robot vs. Complexity of the Individual Parts
- Robustness
  - Error tolerance in sensing and manipulation
- Efficiency
  - How efficiently can it reproduce?

Entropy

- Entropy is:
  - A potential useful tool to describe the sophistication of tasks in robotic self-replication;
  - A measure useful when the environment can be defined by any element of an ensemble of different configurations;
  - A property of the collection of all environmental objects over all of their possible arrangements.

Entropy

Discrete Entropy: $$H_x = -\sum_{\mathbf{x}_i} f(\mathbf{x}_i)\log f(\mathbf{x}_i)$$

Continuous Entropy: $$S_x = -\int_{\mathbf{x}} f_x(\mathbf{x})\log f_x(\mathbf{x})d\mathbf{x}$$

Covariance: $$\Sigma = \int_{\mathbf{x}} (\mathbf{x}-\langle\mathbf{x}\rangle)(\mathbf{x}-\langle\mathbf{x}\rangle)^T f(\mathbf{x})d\mathbf{x}$$

Upper Bound of Continuous Entropy: $$S_x \le \log\{(2\pi e)^{n/2}|\Sigma|^{1/2}\}$$

Pose Entropy

Full pose entropy of a collection of rigid bodies:

$$S_g = -\int_G \cdots \int_G f'(g_1, g_2, \cdots, g_n) \log f'(g_1, g_2, \cdots, g_n) dg_1 \cdots dg_n$$

Assuming that each body can move independently:

$$f(g_1, \cdots, g_n) = \prod_{i=1}^{n} f_i(g_i)$$

An estimated overlap of rigid bodies *i* and *j* :

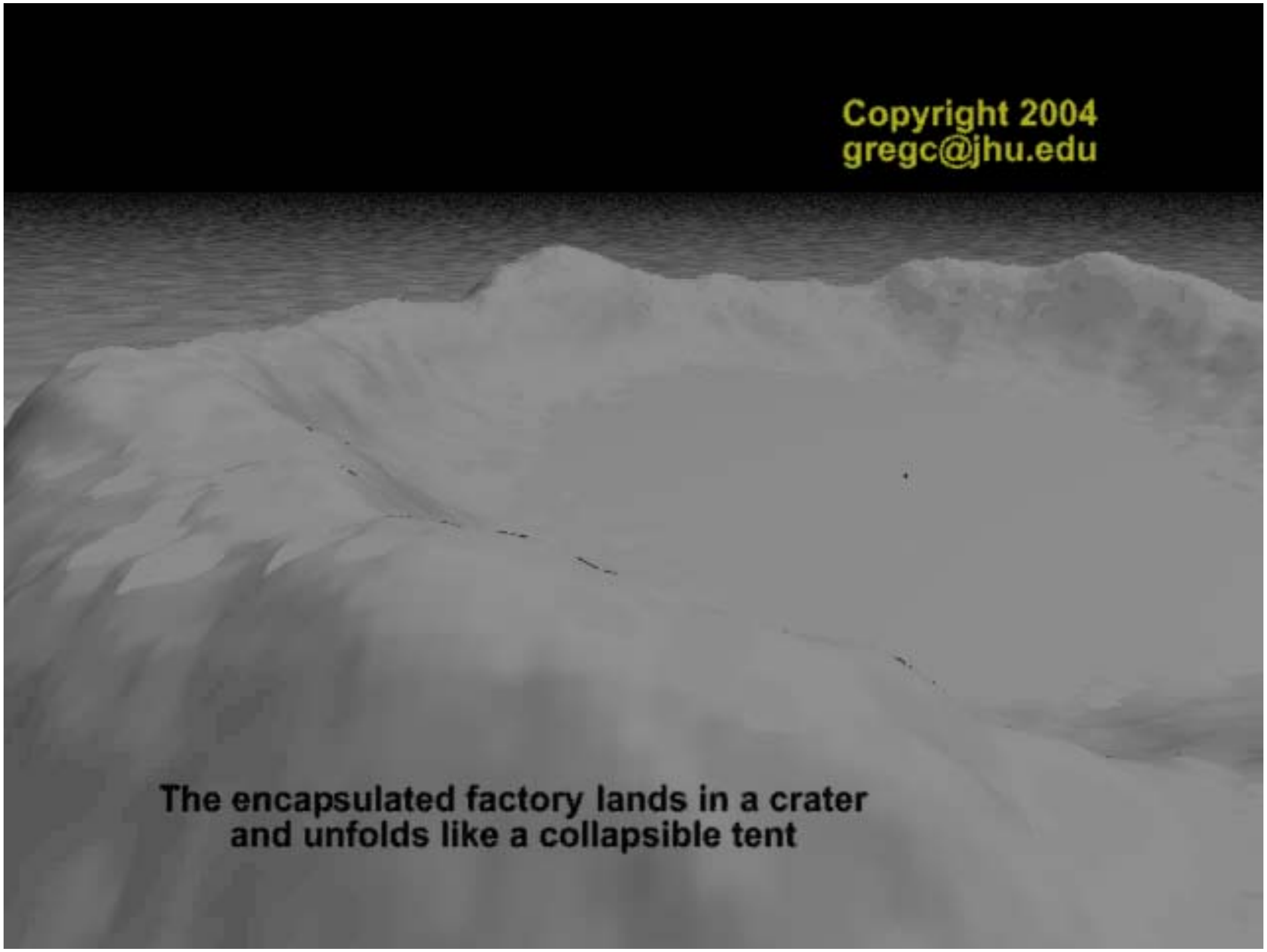
$$w_{ij}(g_i, g_j) = \int_{\Re^3} d_i^{'}(g_i^{-1} \circ \mathbf{x}) d_j^{'}(g_j^{-1} \circ \mathbf{x}) d\mathbf{x}$$

$$w_{ij}(g_i, g_j) = w_{ij}(e, g_i^{-1} \circ g_j) = w_{ij}(g_j^{-1} \circ g_i, e)$$

Then we have,

$$f'(g_1, \cdots, g_n) = Cf(g_1, \cdots, g_n) \prod_{i<j}^{n} (1 - W_{ij}(g_i^{-1} \circ g_j))$$

Future: A Self-Replicating Lunar Factory System



Selected References

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For more:
http://custer.me.jhu.edu/publication/self_replicating.html