Principled Synthesis for large-scale multi-robot systems

Task Sequencing

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Robot swarms are multi-robot systems with many simple interacting robots that perform tasks collectively.

Such systems may exhibit rich behavior.
The problem:
Programming robot swarms is more of an art than a science.

Challenge:
Synthesis is an instance of the local-to-global problem requiring multiple levels of description be reconciled.

Proposed solution:
Enable system design at the macroscopic level by combining processes with formally characterizable macroscopic behavior.
Design space has dimensions that are difficult to characterize.

Multiple suitable controllers.
No suitable controllers

Characterization of collective behavior

Controller behavior is sensitive to small changes in the design space
Characterization of collective behavior

Real-time performance, uncertainty, etc.

Levels of Detail

Macroscopic

Microscopic
Levels of Detail

Macroscopic Description

Microscopic Details

Physical Robots
Simulation
Modeling

Levels of Detail

Macroscopic Description

Processes:  +  =

Processes:  +  =

Physical Robots
Simulation
Modeling
Levels of Detail

Macroscopic Description

Processes

Modeling Individual Processes

Microscopic view
Complete description of each robot's state.

Analysis and modeling of individual processes

Macroscopic view
Low-dimension description that collapses equivalence classes of state.
Elevating Synthesis

\{(\text{\ding{59}}, \text{\ding{51}}), (\text{\ding{51}}, \text{\ding{52}}), (\text{\ding{51}}, \text{\ding{53}}), \ldots \}\}

Examples

- Symmetry-breaking
  - Task sequencing
- Collective strategy selection

- Smoothing
  - Task-allocation/Division of labor