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.

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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.

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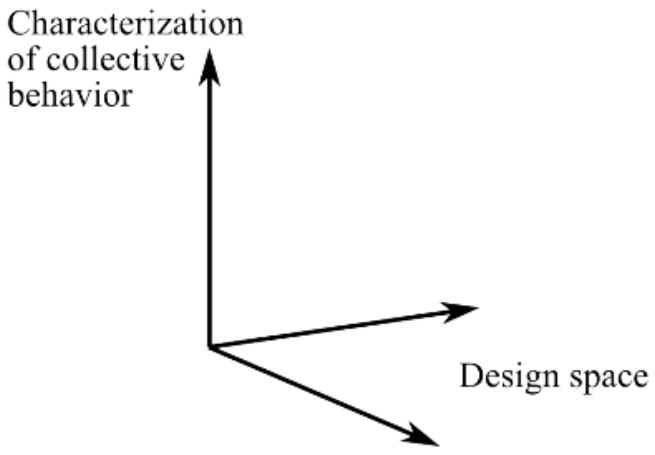
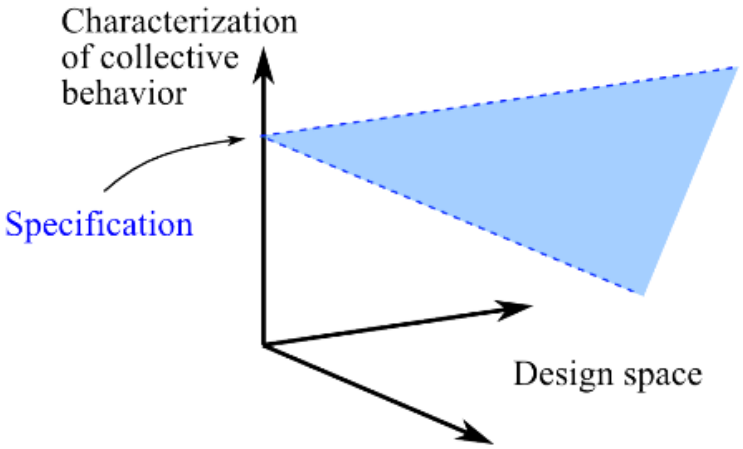
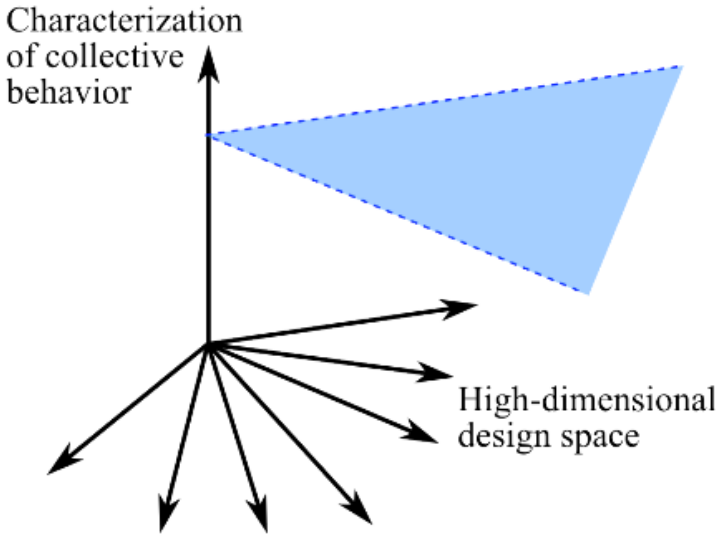
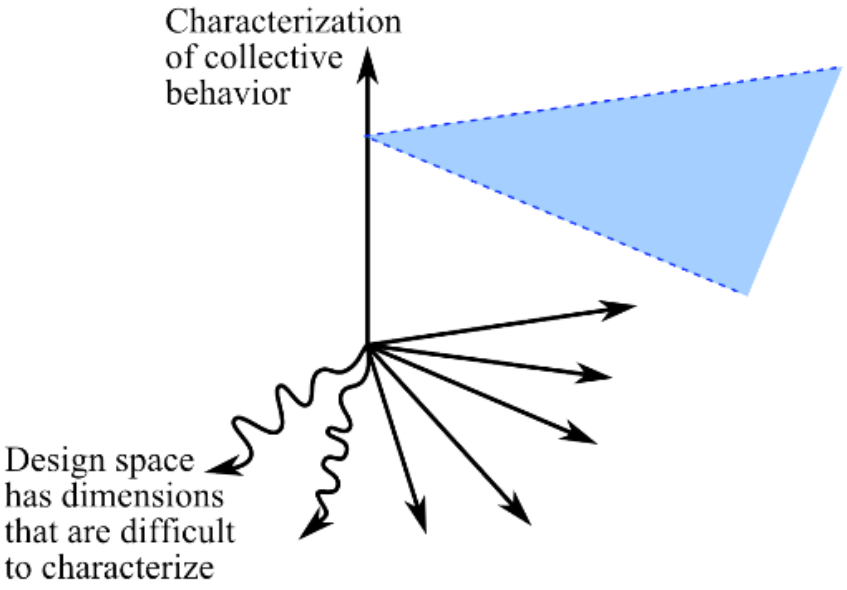
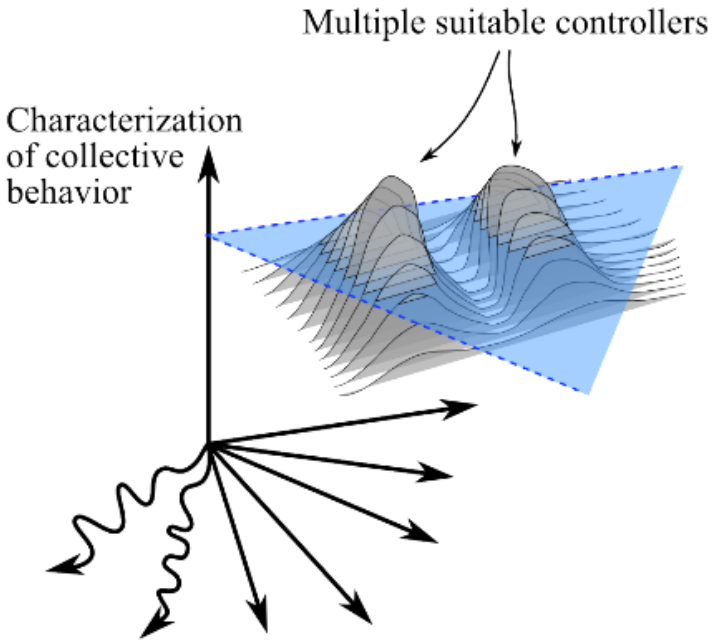
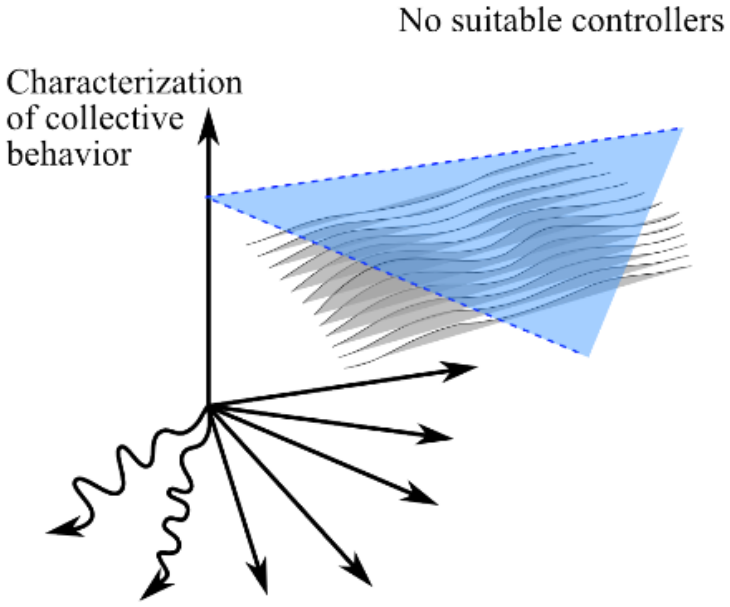


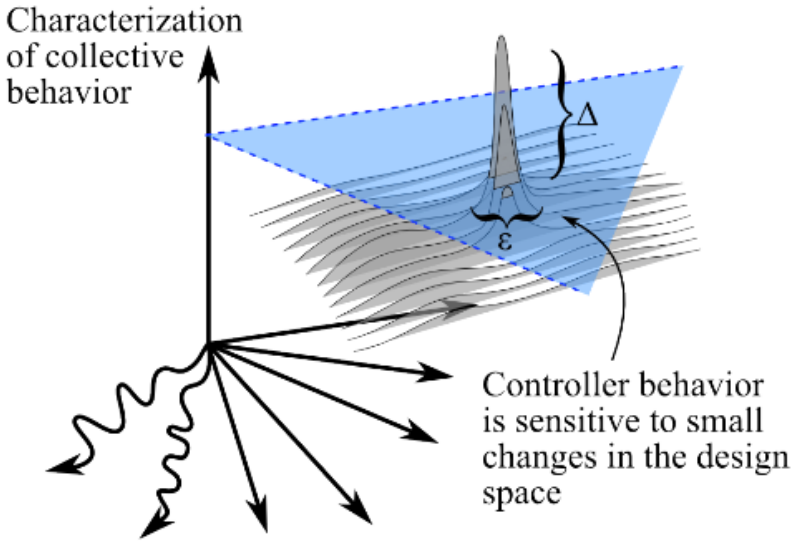

Characterization
of collective
behavior
Specification
Design space

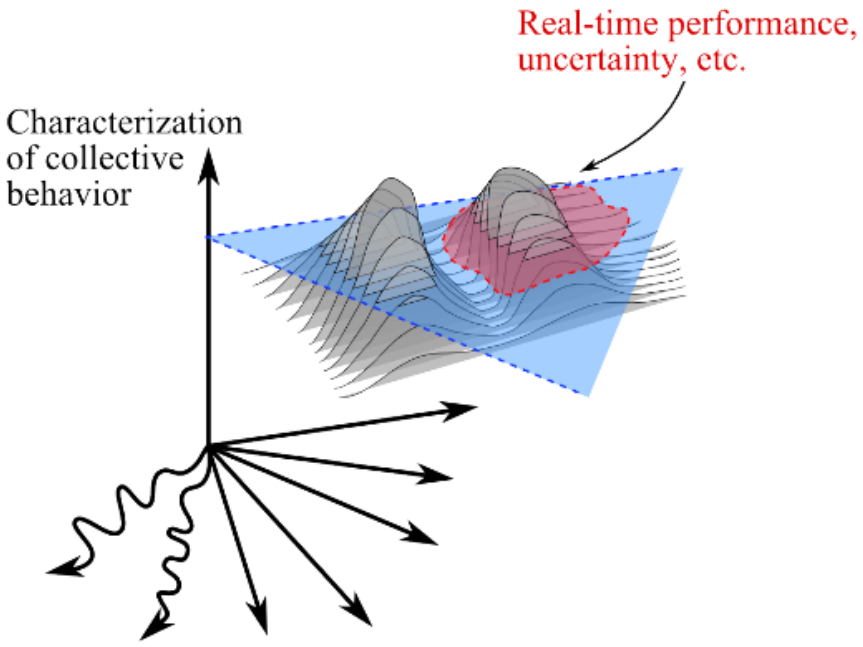

Characterization
of collective
behavior
High-dimensional
design space

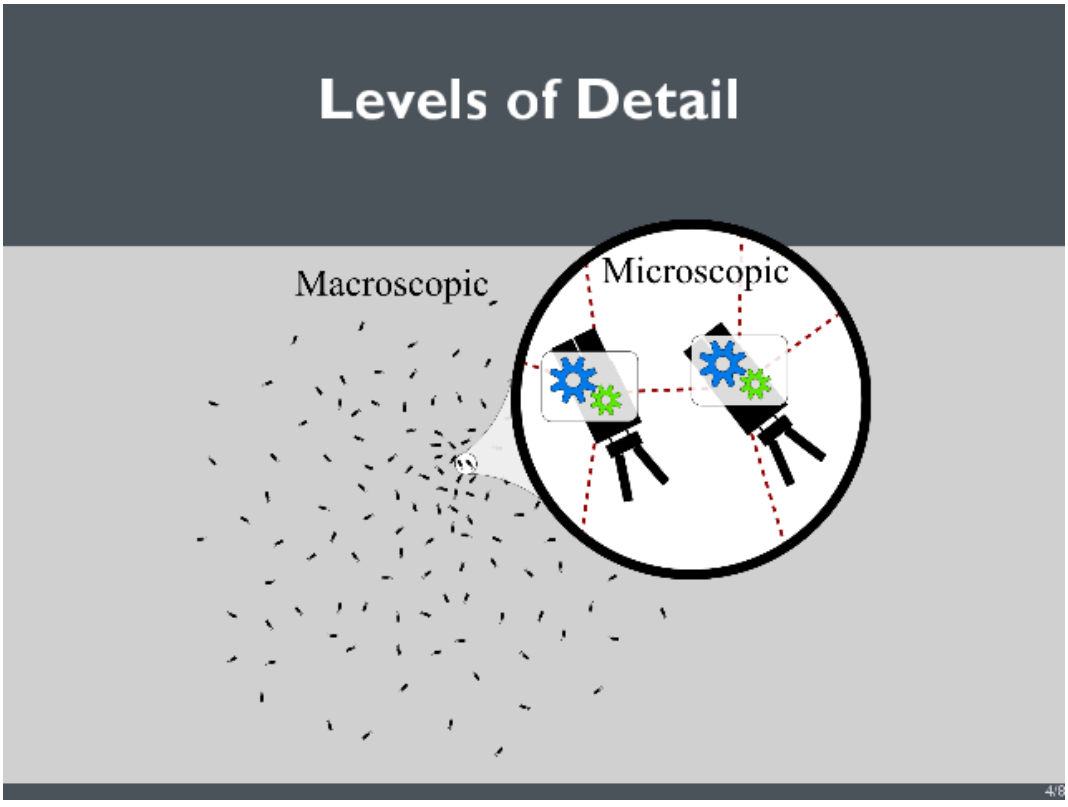

Characterization
of collective
behavior
Design space
has dimensions
that are difficult
to characterize


Multiple suitable controllers
Characterization
of collective
behavior


No suitable controllers
Characterization of collective behavior

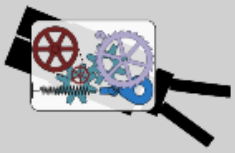

Characterization of collective behavior
Δ
ε
Controller behavior is sensitive to small changes in the design space


Real-time performance,
uncertainty, etc.
Characterization
of collective
behavior


Levels of Detail
Macroscopic
Microscopic

Levels of Detail

Macroscopic Description



Microscopic Details

Physical Robots

Simulation

Modeling

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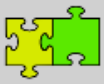
Levels of Detail

Macroscopic Description



Processes

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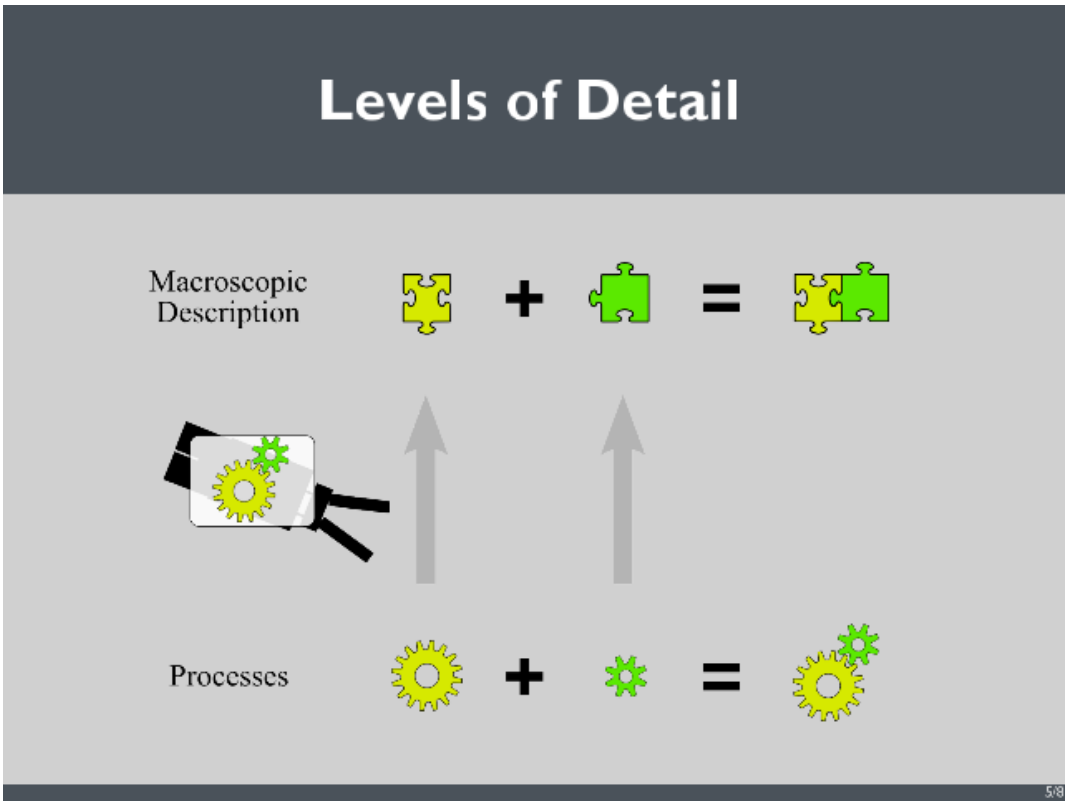
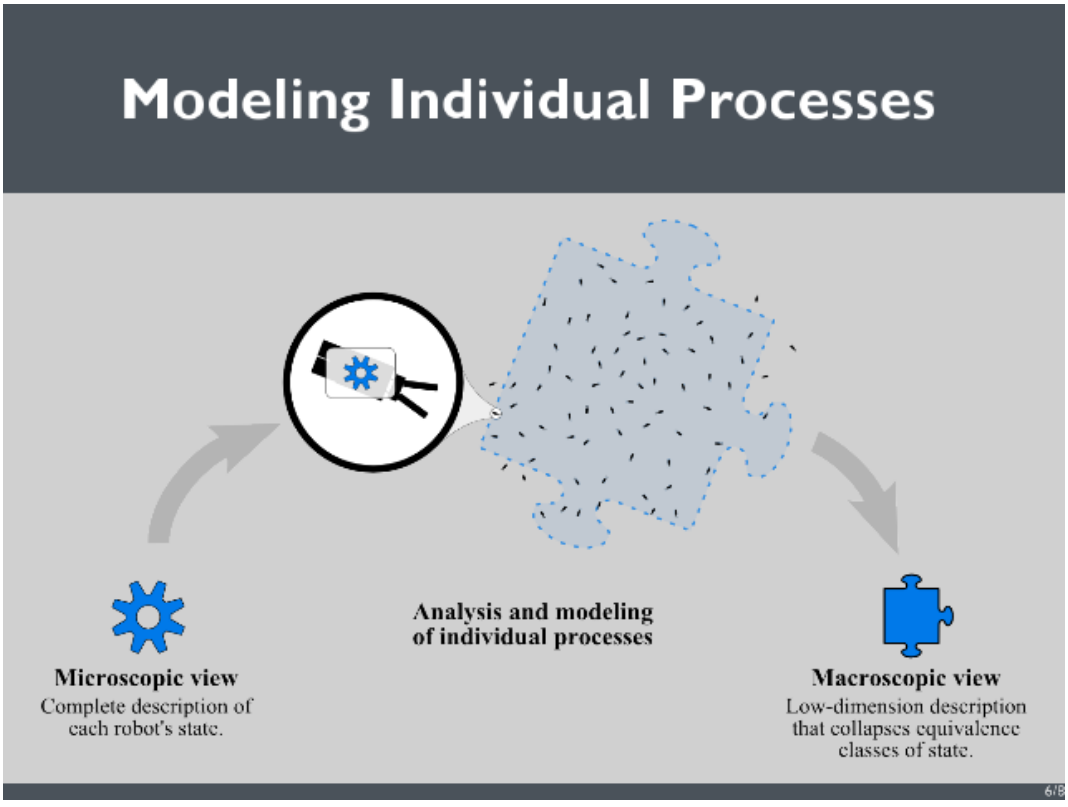

Levels of Detail
Macroscopic Description
Processes
5/8


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.
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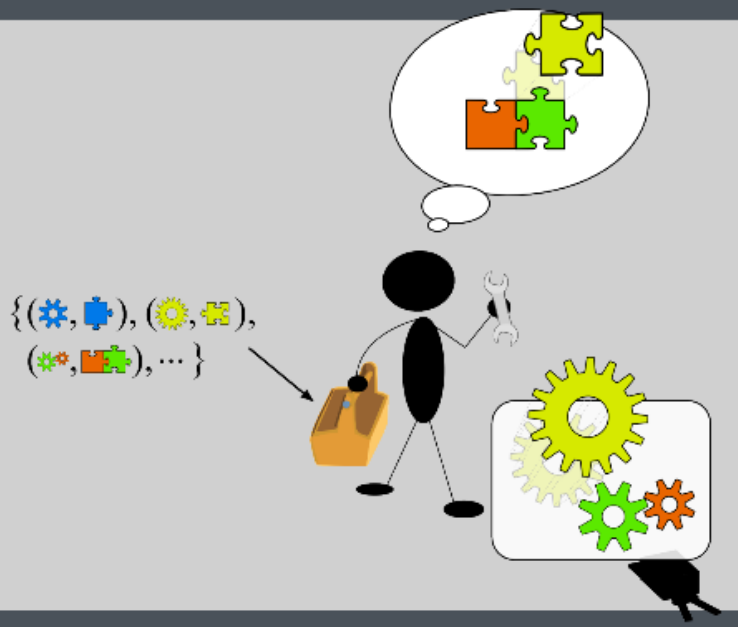
Elevating Synthesis



Examples

- Symmetry-breaking
  - Task sequencing
  - Collective strategy selection
- Smoothing
  - Task-allocation/Division of labor