Machine Learning for Slow but Steady Interplanetary Construction

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Problem Statement

• Can a set of construction robots build useful structures on other planets given a long period of time

• Large number of robots (dozens)
• Robots are small
• Construction time up to 20 years
• Simple structures:
  – Landing pads
  – Pyramid type buildings
Challenges

- Robots need to coordinate
- Robots need to cooperate
  - Not large enough to operate entirely in parallel
- Robot precision is low
- Raw material is poor
- Robots need to overcome failure
- Robots need to be autonomous
Multiagent Learning System

- Allows for coordination of multiple agents
- Assumes agents are imperfect and low precision
- Adapts to agent failures
- Handles uncertain environments
- Learns instead of being told what to do
- (Can be slow)
Agent Learning

Agent Controller

Choose Action

Simulator or Environment

Modify Policy

Reward Computation

Observe Results
Temporal Credit Assignment

Temporal Credit Assignment Problem
(RL)
Structural Credit Assignment
Both Credit Assignment Problems

• Can be difficult to assign credit through time and to the right agent.
• Convergence possible through “team games” but very slow.
• Reward shaping can improve prospects
  – Want shaped reward to improve “signal.”
  – Want shaped reward to promote coordination.
Rover observes points of interest and navigate using local sensing. Rover chooses function to perform mapping from sensor inputs to control action. Rover updates its population of mapping functions based on evaluation. Shaped evaluation is used to take "noise" out of global evaluation.

\[ D_\eta \equiv G(z) - G(z_{-\eta} + c_\eta) \]

Rover is evaluated based on contribution to global evaluation.
Sector With Possible Congestion
Will it Work for Planetary Construction?

- Is enough coordination possible?
- Can learning be independent of operators?
- Will small rovers have enough capabilities?
Tensegrity Robots
In Action
Tensegrity Control Learning
Tensegrity Construction
Will it Work?

- Collapsible and light weight
- Scalable
- Can be highly redundant
- (Learning can be difficult)
Thank You