

Robot Teams: From Diversity to Polymorphism

Chapter 2 Taxonomies of Multirobot Task and Reward

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Task impacts multirobot performance

- Purpose of taxonomies of task
 - Effectiveness of design strategy of multirobot system depends on task
 - Example: Might need cooperation or not
- Assumption: task defined by performance metric
 - Taxonomy of tasks based on difference between performance metrics
- Studied from reinforcement learning perspective
 - Reinforcement learning: rewards and/or punishments are used to alter numeric values in a controller to encourage/discourage robot's behavior
- Taxonomy provides framework for investigating impact of differences in performance metric and rewards on system performance

Difference between task and reward

- Performance maximized when reward parallels performance metric
- Might be difficult to reward strictly according to performance
 - Examples:
 1. No enough information from sensors to evaluate performance
 2. Great delay in receiving reward
 3. Performance depends on other agents
- Performance metric (task) and reward function are different and should be treated separately
- Taxonomy of rewards enable to study which features enhance or hinder performance

A Taxonomy of Multirobot Task

- Time
 - TIME_LIM: Fixed time task
Example: collect as many objects as possible in 10 minutes
 - TIME_MIN: Minimum time task
Example: HW3 – find 90 percent of targets
 - TIME_UNLIM: Unlimited time task
Example: patrol the building for burglars
 - SYNC: Synchronization required
- Subject of action
 - OBJECT_BASED: movement/placement of **objects** is important
Example: robot soccer
 - ROBOT_BASED: movement/placement of **robots** is important
Example: robot formation keeping

A Taxonomy of Multirobot Task (cont.)

- Resource limits
 - RESOURCE_LIM: limited external resources
Example: foraging
 - ENERGY_MIN: minimum energy task
 - COMP_INT: competition between team members for resources
Example: foraging
 - COMP_EXT: team competes with external agencies
Example: robot soccer
- Group movement
 - CONVERGENCE: multiple robots converge
Example: HW2
 - COVERAGE: multiple agents spread apart
Example: search, grazing and cleaning
 - MOVEMENT_TO: movement to a position
 - MOVEMENT_WHILE: movement while maintaining position
Example: HW4

A Taxonomy of Multirobot Task (cont.)

- Platform capabilities
 - SINGLE_AGENT: a single agent can perform task
 - MULTI_AGENT: multiple agents are required
 - DISPERSED: agents must be dispersed
 - SENSOR_COMPLETE: can sense all relevant features
 - SENSOR_LIM: world is partially observable
 - COMM: communication required

Two examples of task classification

- Foraging: maximize the number of objects collected and delivered to homebase in 10 minutes
 - TIME_LIM: performance measured over fixed period
 - OBJECT_BASED: performance based on location of objects
 - RESOURCE_LIM: collection of objects reduces availability of attractors
 - COMP_INT: robots on a team compete among themselves
 - SINGLE_AGENT: an individual robot can perform task
- Formation maintenance: minimize total position error for four robots in a diamond formation in 10 minutes
 - TIME_LIM: task carried out over 10 minutes
 - ROBOT_BASED: performance depends on location of robots
 - CONVERGENCE: robots maintain close to each other
 - MOVEMENT_WHILE: convergence maintained while robots move
 - MULTI_AGENT: required four robots

A taxonomy of multirobot reward

- Source of reward
 - INTERNAL_SOURCE: reward is internal based on sensor values
 - EXTERNAL_SOURCE: reward is generated by external agent
 - Example: dog trained by master; “reward” and “punish” button for robots
 - COMB_SOURCE: combined internal and external reward
- Relation to performance
 - PERFORMANCE: reward is tied directly to performance
 - PERFORMANCE-based reward might be delayed
 - Example: foraging
 - HEURISTIC: reward based on intuition of state value
 - can provide more immediate feedback
- Example of comparison of PERFORMANCE-based and HEURISTIC reward
 - robot soccer

A taxonomy of multirobot reward (cont.)

- Time
 - IMMEDIATE: immediate rewards are provided
 - DELAYED: reward is delayed
- Continuity
 - DISCRETE: reward takes on several discrete values
 - CONTINUOUS: reward drawn from continuous interval
- Locality
 - LOCAL: individual agents receive unique rewards
 - GLOBAL: all agents receive identical reward signal
 - Comparison Example: robot soccer
 - * GLOBAL: might require expensive communication
 - * GLOBAL: possible weak correlation between agent action and value of global signal
 - * LOCAL: might not be able to optimize overall system performance
 - COMBINED_LOCALITY: combination of global and local

Summary and Conclusions

- Taxonomies provide framework for investigating how different types of reward impact task performance
- Taxonomy of reward functions provide framework for robot system design
- This work is a starting point – to expand to learn more about multiagent robotic systems