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
  -- SENSORCOMPLETE: 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 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