

Challenges in Shared-Environment Human-Robot Collaboration

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Bi-directional Intention Recognition

Humans consistently convey internal state and planning information

- Informs co-workers' predictive models of their behavior

Implicit communication improves performance

- Under temporal constraints
- With team fluency through co-worker anticipation

Communicating intent at the subtask level

- Broadcasts intended motion paths
- Informs teammates of one's goals
- Leads to fewer instances of turn-taking behaviors during collaboration
- Is a dynamically calibrating process

Enabling Multi-channel Communication



How can robots generate non-verbal cues for known skills or learn to recognize such cues from others?



How can robots overcome physical disparities to leverage communication channels humans understand?



How can a robot identify human intent, and better use this information for action selection?

Role Selection With Human Teammates

Humans can decompose tasks into multi-role, multi-collaborator endeavors

- Leverages contextual knowledge
- Ambiguities are resolved by shared experience and environmental reasoning

Role assignment is not a static activity

- Pre-activity role assignment sets initial expectations
- Roles and responsibilities may overlap or be traded

Role selection through social modeling of co-workers

- Can be achieved with adaptive planning systems
- Improves fluency of action selection

Task decompositions must be comprehensible to both humans and robots

- Learned from low repetitions of skill sequences
- Parallelization of subtasks must often be inferred

Dynamic And Adaptive Role Assignment



How can a robot synchronize its computed task decompositions with its human teammates?



Given a set of roles and associated actions within a task decomposition, how does a robot know which role(s) to assume while minimizing conflict with team preferences?



How can a robot effectively communicate its understanding of roles within a task to its teammates?

Performance vs. Preference Optimization

Some subtasks can be better suited for either robot or human execution

- Minimizing the disruption of existing team roles when introducing co-robots requires careful design
- Violating worker preferences of process or role selection can be costly

Established teams can be reluctant to accept new members

- Robots bear the burden of instilling trust in co-workers, particularly within potentially dangerous tasks
- Demonstrations may be too complex or too costly to use as a means of proving readiness

Task performance criteria is complex

- Varies by team and task
- Incorporates elements that are difficult to quantify

Robot co-workers must balance multiple factors



Modeling And Acting On Co-worker Subtask Proficiency



When and how should a robot leverage information about which agents are best suited for particular subtasks?



How can a robot adapt its role selection to optimally integrate with existing human teams?



How can co-worker preferences be quantified, and when should a robot object to an observed role distribution?

Live Self-evaluation In Team Contexts

Evaluating oneself as a team member requires

- A shared mental model of the task
- Knowledge of co-workers' roles and responsibilities
- Accurate estimates of expected task progress at various times

Contingency detection and planning

- Measures the impact one's actions have on co-workers
- Helps model teammates' personal or workspace boundaries

Self-evaluation as a "Team member" provides heuristics for

- Reinforcing role selections
- Refining skill execution choices
- Evaluating novel task decompositions

Success can have situationally-dependent definitions

- Self-improvement within subtask execution
- Reduction of team idle times
- Encouraging and building team cohesion

Using Teamwork Metrics To Drive Self-assessment



How can a robot determine if it is performing in line with teammate expectations?



What actions should a robot take if it detects it is underperforming within the context of a team?



When is it appropriate for a robot to ask for help, if it means interrupting a teammate?