Thinking Together: Active Collaborative Planning in Human-Robot Teams

Luke Burks
Graduate Research Assistant

Cooperative Human-Robot Intelligence (COHRINT) Laboratory
Ann and H.J. Smead Aerospace Engineering Sciences
University of Colorado at Boulder
Motivation

Autonomy: great for tasks dangerous or inconvenient

Problems exist:
- SWAPC Constraints
- Uncertainty

If people can benefit from robots, why can’t robots benefit from people?
Motivation

What kind of information do humans communicate?
• “Soft” semantic data

Humans = Semantic Sensors
• Volunteering Information
• Answering Questions

Robotic tasks can benefit from human information, if only they could ask the right questions!

Question: Where’s your talk being held?

29.569° N
95.084° W

VS

At JSC’s Gilruth Center
Example Scenario

Questions a Human could help answer!

Could I climb that debris pile?
What room am I in?
Is that a person over there?
Is this area dangerous?
FRIENDS?

FRIEND—

Process "Negotiate with humans" has encountered an error and was shut down.

...CLOSE ENOUGH!
Planning for Human Input

**POMDPs**: Partially Observable Markov Decision Processes

- Creating policies based on robot’s “belief”
- Framing questions as information gathering actions
- Humans as sensors

Extended for Large Continuous Spaces: CDC 2017

Applied to Complex Indoor Environments on Hardware Testbed: FUSION 2018

Adapted for Unknown/Dynamic Outdoor Scenarios: (Submitted) FUSION 2019
Cops and Robots 2.0

Camera 1: Study

Cop Video

Camera 2: Hallway

Belief Map

Camera 3: Kitchen

Robot Questions

Is Zhora inside the study?
Yes  No  ?

Is Zhora inside the library?
Yes  No  ?

Is Zhora right of the desk?
Yes  No  ?

Last question was:
Last answer was:

Human Observations

Position (Objects)

<table>
<thead>
<tr>
<th>Position (Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>the study</td>
</tr>
<tr>
<td>the library</td>
</tr>
<tr>
<td>the hall</td>
</tr>
<tr>
<td>the dining room</td>
</tr>
<tr>
<td>the kitchen</td>
</tr>
</tbody>
</table>

I know a robber...

Send  Clear
Pursuit Behavior

• Patrols Hallway, briefly surveys rooms
• Catches robber crossing hallway

• Moves from room to room
• Pursues and corners robber
Nothing Detected

Prior Belief of Location

Careful, there are some trees over there.

Human Sketch for “Trees”

I just saw a small someone southwest of those trees.

Human State Observation for “southwest” of “Trees”

Sw

Revised Belief of Location

Understood, which way are they traveling?
Planning in Unknown Environments

- Answer
- Sketch
- Observe

- Update Belief
- Update Model

- Plan
- Question
- Move
Sketch Interface
Moving Forward

**Improved Simulation Environments**
Realistic Deployment Testing

(Microsoft Airsim)

**Flight Hardware**
Real Humans, Real Robots

(Mehta, McCourt, Doucette, Curtis, IEEE SMC 2014)
Moving Forward

Alternative Perception Systems

Terrain Mapping

Place Recognition

Object Recognition

(Wellington, Courville, Stentz, RSS 2005)

(Ramos, RAS 2012)

(Burchfiel, Konidaris, RSS 2017)