Uncertainty

Sources of uncertainty in Human-Robot Interaction

- Intentions
- Communication
- Perception
- Prediction of future states

HRI systems assuming perfect abilities of the robot have many limitations in actual deployment.
Uncertainty in intentions

Intentions or goals of the humans are often not known or only partially known to the robot and they may change over time.

• How can the robot understand or anticipate user need?
• How can the robot understand that user needs are changed?

Approaches:
• **Passive**: the robot waits for user commands
• **Active**: the robot asks users if they need help

Uncertainty in communication

Several HRI actions are based on explicit communication (speech, gestures, ...) requiring robust and effective understanding and explanation procedures on the robot.

• How can the robot understand user communications?
• How can the robot express its mental state to humans?

Approaches:
• **Speech understanding**: semantic analysis of spoken text
• **Explanation**: multi-modal generation of robot-to-human interactions
Uncertainty in perception

Analysis of sensor data for HRI tasks is usually more difficult when humans are the focus of the task.

• How can the robot correctly perceive the situation around (including human activities/emotions/intentions/…)?

Approaches:
• **Human activity recognition**: semantic analysis of audio/video (including person detection and tracking, face/emotion recognition, sound detection, …)

Uncertainty in prediction

Prediction of the effect of actions or of the evolution of the current situation is very difficult when the future depends also from actions performed by humans in the environment.

• How can the robot predict the effect of its actions and evaluate consequences?
• How can the robot estimate the evolution of the current situation?

Approaches:
• **Reasoning under Uncertainty**:
  • POMDP
  • KR&R ???
Examples

POMDP [Taha et al. ICRA 2011]

• St: status of the user
• In: intentions
• Ta: tasks to be executed during the collaboration
• Sa: user's satisfaction in the outcome of the collaboration
Examples

[Doshi and Roy, 2008]
- Model of uncertainty in speech interaction
- Adding User Model variable representing "how the user interacts"
- Learning is effective even after a few iterations (10-20)
Discussion

- POMDP based approaches requires accurate choices of parameters (transition prob., observation prob., and reward)
- Learning all the parameters can require large amount of data and time
- KR&R approaches in HRI are less developed

Unexpected situations

Service robots (thus including HRI applications) cannot avoid to deal with unexpected situations (in contrast with industrial robots).

Dealing with unexpected situations is often a main goal (i.e., an opportunity) for a service robot

What is a better service robot?
- Robot can do very well only a limited number of tasks
- Robot can do reasonably well almost everything
Unexpected situations in planning

Unexpected situations = not modeled in the (planning) domain

Not possible to avoid unexpected situations (i.e., model everything)

KR&R/Planning approaches
• Plan monitoring
• Recovery
• Re-planning

Plan monitoring and local recovery procedures can improve HRI tasks

Example: if a person is encountered in a corridor during a goto action, the robot could stop and greet the person instead of just trying to avoid him/her (human aware navigation).
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**How can we express these requirements in a declarative way?**

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**Execution rules**

Declarative rules to monitor the execution of a plan and specify recovery procedures

```plaintext
if <something> during <some action> do <something>
```

Conditions are evaluated at execution time and they do not need to be variables of the planning domain (hence the approach is scalable).

[Iocchi et al. ICAPS 2016]
Execution rules and robustification

- Domain
- Goal
- Execution Rules

Conditional Planner → Robustification → PNP → PNP-ROS

Planning and Execution Component

Execution rules in PNP

Using the interrupts

\[ t_{\text{inter}} \]

\[ p_{i_1} \rightarrow t_{s_1} \rightarrow p_{e_1} \rightarrow t_{c_1} \rightarrow p_{o_1} \]

\[ p_{i_2} \rightarrow t_{s_2} \rightarrow p_{e_2} \rightarrow t_{c_2} \rightarrow p_{o_2} \]
Execution rules

Examples

if personhere and closetotarget during goto do skip_action
if personhere and not closetotarget during goto do say_hello;
waitfor_not_personhere; restart_action
if lowbattery during * do recharge; fail_plan
after receivedhelp do say_thanks
after endinteraction do say_goodbye
when say do display
**Robot Office Assistant**

Run 1 - without Execution Rules

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**References**

