Anticipation and Planning in Human-Aware Robotics

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We discuss the concept of anticipation in the context of intelligent robotic systems that operate in the presence of humans. For instance, it might be a domestic robot doing household chores, a warehouse robot transporting items and assisting human workers, or an industrial assistance robot taking over dangerous tasks. Such robots need to plan their actions and activities in a manner that takes into account human actions, activities, preferences and requests. This might also include cooperation with humans in case of shared goals. We call this human-aware planning [1, 2].

In order to perform human-aware planning, the robot needs the ability to communicate concerning requests, to weigh in human preferences, and to identify ongoing actions and activities and reason about how they relate, what consequences they have and what objectives they may serve, and it need to take these things into account while generating its own plans. But to be effective, the robot also needs to be able to *anticipate* future actions and activities.

This form of anticipation and planning poses several challenges as follows.

There are multiple, potentially infinitely many, futures that can be anticipated. How can the robot planner in an efficient manner find the most likely ones, and how can the planner in an efficient manner reason about those and how they interact with the robot plans? This requires reasoning with several dimensions of uncertainty. Fortunately, the currently ongoing activities can give clues about the humans' intentions and plans, and previously observed actions and activities can indicate habits. Hence, certain future activities associated with human intentions, plans and habits can be assigned higher probabilities. For instance, if a human goes to the kitchen at around 12 am, then the activities of cooking and eating becomes probable. But even in these cases, significant uncertainties remain.

As too much uncertainty makes accurate prediction hard, the robot needs to deliberate on its own capabilities to deal with unforeseen situations when they manifest. Considering all possible futures is computationally infeasible in the real world. At the same time, we expect the robot to successfully execute its plans. How can a robot planner reason about its own uncertainty and anticipate how likely it will be able to deal with the unexpected on-the-fly? This can involve both events that may cause the plan to fail or become more costly, and events that introduce opportunities to improve the plan.

The robot planner needs to obtain adequate models of human actions and activities and their dependencies and consequences. Such models may include quite a lot of variation and obtaining them may require learning. They may also depend on culture and on the individual, and therefore need to be personalized.

The robot planner also needs to obtain models of social rules and human preferences and goals. Like actions and activities, these may vary from culture to culture and also between individuals.

The planning process may include not just a single robot but also other robots, humans and organisations. Thus, it will involve communication in order to share information, coordinate, negotiate and collaborate, and these communications might also need to be included in the model. If shared goals are pursued in cooperation with humans, the robot should adapt its planning process in anticipation of the "human planning process".

We have made some initial progress for some of these issues at AASS. The techniques we have addressed includes:

- Probabilistic contingency planning under consideration of possible human agendas [1]. This approach generated plans that could assume a number of possible human agendas and associate those with probabilities, and that branched based on what activities would be observed during execution.
- Interaction constraints for modelling which interactions between robot and human activities are permitted and which are prohibited [1,2]. The interaction constrains were logical and temporal statements that the robot plan and human anticipated activities and actions must satisfy.
- Context/activity recognition for understanding human activities in the environment [3, 4]. These works consider how activities and context can be modelled and derived from sensor data. The models include temporal durations of and relations between actions/activities.
- Constraint-based human-aware planning system with features for social constraints, pro-activity, and context-awareness [2]. In particular, temporal constraints are considered in this approach. The approach also supports selective inclusion of other types of constraints, making it adaptable to many different applications while remaining computationally efficient.
- Culturally aware and personalized robotic planning and execution [5]. This work addresses how to generate and execute robot plans that respect given cultural preferences. In particular, the approach is applied to Swedish, French and Japanese conditions.

Still, much of the challenges for anticipation and planning remains to be addressed, and the approaches above need to be further developed and refined in order to be practically useful. The challenges also need to be addressed in a cross-disciplinary manner involving both computational and behavioural sciences.

References

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