Representations and Models for Collaboratively Intelligent Robots

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We are motivated by the problem of building autonomous robots that are able to work collaboratively with other agents, such as human co-workers. While the basic notion of assistive systems has had a long history, such systems have not yet achieved the level at which one may comfortably overlook (1) that their co-worker is an artificial agent. This level of comfort is crucial in enabling not just wide-spread adoption of such technologies, but also trustworthy operation once deployed.

One key attribute of such an autonomous system is the ability to make predictions about the actions and intentions of other agents in a dynamic environment - both to interpret the activity context as it is being played out and to adapt actions in response to that contextual information.

Drawing on examples from robotic systems we have developed in my lab, including mobile robots that can navigate effectively in crowded spaces and humanoid robots that can cooperate in assembly tasks, I will present recent results addressing three questions: (a) how to efficiently capture the hierarchical nature of activities, (b) how to rapidly estimate latent factors, such as hidden goals and intent, (c) how to optimally make sequential decisions in interactive settings, with incomplete prior knowledge of the profiles of other agents.

Firstly, I will describe a procedure for topological trajectory classification (2), using the concept of persistent homology, which enables unsupervised extraction of certain kinds of relational concepts in motion data. One use of this representation is in devising a multi-scale version of Bayesian recursive estimation (3) which is a step towards reliably grounding human instructions in sensorimotor signals. In general, such recursive estimation over latent factors can be unacceptably expensive for our application scenarios. I will describe how in many robotics problems, one can structure the problem as one of counterfactual reasoning over a smaller set of simulation models. While this basic idea is intuitive, it can also be made formal and applied to situations involving multi-agent decision-making. By conceptualizing the interaction in terms of policy types in an incomplete information game (4), we obtain a learning algorithm that combines the benefits of Harsanyis notion of types and Bellmans notion of optimality in sequential decisions. As preliminary human-machine experiments show, such an algorithm achieves a better rate of coordination than alternate multi-agent learning algorithms.

References

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