CPSC 490 Project Proposal

Training a Robot to Collaborate with a Human Partner

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Abstract

The goal of this project is to build a machine learning system that allows human participants to train Baxter to intelligently help the participant in a collaborative task. Baxter will begin with a set of basic actions but no knowledge of the task at hand. Through interactive training sessions, the human participant will provide feedback at each step of the task to gradually improve Baxter's decision-making ability. The primary focus (and deliverable) is for Baxter to emerge from the training sessions with a decision-making matrix enabling it to demonstrate intelligent human collaboration in a live demo. A secondary emphasis will be placed on creating natural and speedy training sessions, so that users could intuitively train the robot on a variety of tasks without special training of their own.

Background

As robots become more pervasive, more attention has been drawn to the field of human-robot collaboration. Tasks that require the precision or strength of a robot combined with the intelligence or dexterity of a human are ideal applications. However, two significant obstacles to human-robot collaboration are the complexity of programming a robot to help a human with a particular task and the time cost of training humans to use the robot effectively. Machine learning can overcome both of these actions. Rather than investing in a knowledge-based program for a particular application, manufacturers can give robots the ability to learn to perform any task that they are physically capable of. Moreover, human partners do not need to be trained on the robot beyond basic safety and interfacing. Instead, they train the robot to respond correctly through natural patterns of interaction and feedback. In the future, the 1950s vision of personal, general-purpose robots to assist with day-to-day tasks might be possible with machine learning.

This project is a branch of Corina Grigore's human robot collaboration project. The project focuses on developing frameworks and algorithms that enable the robot to learn how to predict supportive behaviors during a human-robot collaboration (HRC) task. These behaviors are intended to help human workers more efficiently perform assembly tasks, like furniture assembly. For this project, we are currently using a flat pack furniture set, and focusing on a small chair requiring complex assembly. Corina's project includes a perceptual component, in which Baxter will need to parse visual inputs to understand the state of the world (currently provided by proxy), and it will eventually transition into a more in-depth investigation of machine learning for human-robot collaboration.

Implementation

I plan to model the state of the workspace and the human participant (either as another agent in a multi-agent system or as part of the environment). I will start with a small number of states and implement a basic learning system such as Q-learning to train a desired set of behaviors. From there, I hope to expand the state space and try different learning methods such as genetic algorithms or deep learning through a neural network. Initially, the machine learning system will operate without visual input from the environment, instead using the existing proxy for perception in Corina's larger project. Baxter will infer the positions of objects based on its own actions, and the human partner will deliver feedback through an electronic interface. Eventually, I would like to use Baxter's visual systems to gather state information and human feedback directly from the environment. Since machine vision is outside the scope of my project, I hope to use perceptual input systems developed by another student investigating machine vision for Baxter. Or, if I meet my own basic deliverables ahead of schedule, I could work on a simple machine vision system myself. However, this is not a core feature.

I have a rough idea of the framework for the robot's behavior patterns. Baxter will start with a small set of general-purpose actions, such as 'pick up object,' 'put down object,' and 'hold object in place.' Each of these actions will have a set of discrete (and possibly continuous) parameters. For example: which object to interact with, where to place it, where to hold it, and what orientation to hold it in. The set of basic actions and their parameters will form the output range of the machine learning function.

Deliverables

The primary deliverable will be a live demo of Baxter collaborating with a human, demonstrating intelligent behavior based on earlier training with the human partner. I will show that Baxter started with no knowledge of the task at hand, but was able to learn to offer supportive behavior based only on training. Second, there will be the standard CS 490 report and html page. Finally, I will create documentation for my machine learning system, including an evaluation of its strengths and weaknesses, which will allow other investigators to use and improve it. Included in this evaluation will be metrics of the speed and complexity of the system, such as how many demonstrations were necessary during the training phase or the dimensions of the global state space and robot action space. After the basic deliverables are met, I have some stretch goals. As mentioned earlier, one is to build a simple perceptual system that uses Baxter's camera to replace proxy perception. Some additional stretch goals are for Baxter to learn the different behavioral preferences of various human partners (for example, Alice wants it to hold a peg steady for her, while Bob wants it to leave it on the table). Or, if I'm able to train Baxter to an intelligent level via two different machine learning systems (GA and DL, for example), I could do a comparative analysis of its behaviors that reveal some of the application-specific strengths and weaknesses of these training methods for behavioral patterns in a real-world environment.