Learning Actions and Action Verbs from Human-Agent Interaction

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Abstract

The goal of my research is to design agents that learn from human-agent interaction. Specifically, I am interested in acquisition of procedural, conceptual and linguistic knowledge related to novel actions from human-agent collaborative task execution.

Introduction

Learning by interacting with humans is a powerful learning paradigm. In a complex world learning through self-directed experience alone can be slow, requiring repeated interactions with the environment. Learning from human-agent interaction can reduce the complexity of the learning task by reducing the need of exhaustive exploration by leading the learner through useful training experiences or by explicitly identifying the elements relevant to the task. Prior work in learning from human-agent interaction has demonstrated acquisition of procedural (Huffman and Laird, 1995; Allen et al., 2007), conceptual (Boicu and Tecuci, 2004) and grounded linguistic (Cantrell, Schermerhorn, and Scheutz, 2011) knowledge.

In my thesis work, I want to investigate three aspects of learning from human-agent interaction. First, I want to explore mechanisms that enable the agent to support flexible, mixed-initiative interactions with its instructor. Second, I want to study various factors that can affect human-agent interactions in collaborative task execution and if such interactions are useful in deriving generally applicable procedural knowledge. Third, I want to study the acquisition of conceptual and linguistic knowledge (related to action verbs), grounded in agent's experiences with the world and its knowledge. I will conduct my research within the context of Soar (Laird, 2012), a cognitive architecture that incorporates the various learning (reinforcement learning, chunking), memory (procedural, episodic and semantic), and control mechanisms.

Initial Work

My initial work has been to understand the challenges involved in developing agents that can acquire procedural knowledge for executing composite actions and tasks through interactions with a human instructor. Human-agent interaction for learning with instruction can be viewed on a continuum of instructor/agent control. At one extreme are systems that learn by instructor driven interactions, such as learning by demonstration, examples or imitation(Sammut et al., 1992; Dinerstein, Egbert, and Ventura, 2007) with minimal influence from the agent.

At the other side of the continuum are architectures in which the agents completely control interactions. Prior work done in learning by instruction (Huffman and Laird, 1995) demonstrated learning systems that focus on agent-initiated interaction, where instruction is directed by impasses arising in a Soar agent. They noted that instructor-initiated interaction is difficult to support because of the likely interruption of agent's reasoning.

There are advantages to an approach which explores a mixed-initiative instructional dialog. First, an agent that can assume control on occasion can guide its own learning by requesting clarifications, asking for missing information, and correcting instructor's response based on its own understanding of the state. Second, an agent that can relinquish control on occasion, can take advantage of knowledge of task structuring and goal decomposition. In a mixed control setting, the instructor can ask the agent for information regarding its state and the environment, verify an agent's learning by questioning the agent, and provide corrections.

We are currently developing a task-oriented interaction model for instructional learning. This interaction model is a partial implementation of the theory of collaborative discourse by Grosz and Sidner (1986) and has been adapted from Rich and Sidner (1998). We have shown (Mohan and Laird, 2012) that for a specific task, this model allows the agent to effectively manage a mixed-initiative interaction with the instructor while acting in the environment. It provides sufficient context for instructions such that the agent can derive useful, generalized procedural knowledge through situated explanation.

Research Plan

My current work has focused on implementing interaction and learning mechanisms through which the agent can maintain task-oriented conversation with the human, and derive procedural knowledge from it. In future, I intend to further study the problem of learning from mixed-initiative instruction and extend learning mechanisms to allow the agent to acquire grounded representations of action verbs along with procedural knowledge associated with corresponding actions.

Mixed-Initiative Interaction

Walker and Whittaker (1995) characterize human communication as mixed-initiative, bi-directional flow of information. Conversational partners not only respond to what others say, but volunteer information, and ask questions. *Initiative* in an interaction can be understood as the control over what and how information is transferred among the participants of that interaction.

The transfer of information for successful human-agent collaborative action is influenced by various characteristics of the environment and the state of agent's knowledge. An agent that begins in a novel environment with very limited knowledge will need to communicate with a human expert about the environment to so that it can act and learn. If the environment is partially observable to either the agent, the human or both, bi-directional transfer of information is essential for reasonable action. Human-agent interaction in such scenarios needs to be mixed-initiative, in which both the human instructor and the agent can introduce topics in conversation.

I want to study various factors that influence initiative in interactions between a human instructor and a learning agent. Such understanding is essential for implementing an interaction model using which the agent can maintain and learn from a task-oriented, mixed-initiative interaction with a human instructor.

Learning Actions

Learning actions involves acquiring the following knowledge; *applicability conditions*, knowledge of conditions under which the action can be applied; *execution*, knowledge of how the state (of the environment and agent) changes as an action is applied and *termination conditions*, knowledge of the goal of an action. An agent that learns novel actions by interacting with a human instructor should be able to derive such knowledge from its interactions and observations from the environment.

Prior work (Huffman and Laird, 1995) has shown that such knowledge can be derived from an instructed example execution of a novel action and explicit interactions about its applicability and termination conditions. However, in situations where the state of the agent is not completely observable by the human instructor, such explicit interactions are impossible. The agent must derive applicability and termination conditions of the action from multiple executions. I want to investigate if a complete history of multiple executions of an action and related state changes (available from episodic memory) captures the information required to derive applicability and termination conditions.

Learning Action Verbs

Beyond simply labeling sequences of movement, verbs often encode causal and temporal structure. An ideal grounded representation of verb meaning would on one hand link to perception and control of action in the physical environment, and on the other provide structural hooks for the argument structure of verbs (Roy, 2005). It would also allow for relating similar verbs and associating affordances with objects.

Recent efforts to model grounded language acquisition have focused on models that ground the meaning of verbs in motor control structures (Feldman and Narayanan, 2004) and perceived movements of objects (Siskind, 2001). However, such systems constrain the human-agent interactions to labeling of action sequences. I am interested in exploring if explicit interactions with human instructors about various aspects of verbs combined with reasoning about its experiences with the environment would allow the agent to build rich, grounded representation of action verbs.

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