Integrating Expert Knowledge and Experience

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Abstract

A major challenge in the field of AI is combining symbolic and statistical techniques. My dissertation work aims to bridge this gap in the domain of *real-time strategy games*.

Introduction

Building systems capable of demonstrating human-level intelligence in complex, real-time domains requires an ensemble of knowledge-rich and knowledge-weak AI techniques. Symbolic approaches, such as planning, provide a way of explicitly encoding domain knowledge into a system. In planning systems, this is achieved through the specification of operators or hierarchical decomposition of tasks. A major limitation of this approach is that domain engineering becomes an unreasonable task in complex domains. Statistical approaches, such as machine learning, provide domain independent methods for learning from unstructured or semi-structured data. A major challenge for applying statistical approaches is developing suitable encodings of the state space. Each of these approaches has strengths and weaknesses and what is really needed is a combination of the two (Dietterich et al. 2008).

The domain of real-time strategy (RTS) games provides several challenges that need to be addressed to build real-world AI systems, including real-time decision making, enormous state spaces and imperfect information. Performing well in RTS games requires goal formulation, intent recognition, planning and reacting to unexpected second-by-second state changes. There are two main forms of recorded knowledge available for analysis in this domain: human-readable information, such as community websites on game-specific tactics and commentated replays, and machine-readable information, such as gameplay traces (Weber and Mateas 2009a).

My dissertation work aims to utilize both forms of knowledge in an integrated agent architecture that combines symbolic and statistical AI techniques. The system will utilize a combination of human authored and learned behaviors. Human authored behaviors will enable the system to take advantage of the large amount of sophisticated domain knowledge available in human-readable format, while learned behaviors will enable the agent to adapt to new situations and track the evolving meta-game. Achieving this goal will require addressing the following research questions:

1. What behaviors can be learned automatically and what behaviors must be human authored?
2. How can domain knowledge be automatically extracted from gameplay traces in a representation usable by symbolic techniques?
3. How can symbolic and statistical approaches be applied to imperfect information environments?

Addressing these questions successfully in the domain of RTS games will require developing techniques that operate in real-time, scale up to thousands of examples and minimize domain engineering.

Progress to Date

My progress to date consists of two projects which focused on human authoring and learning from expert traces as separate problems.

Human Authoring

The first project applies expert knowledge to a RTS game in the form of a human-authored reactive plan. It builds upon the integrated agent framework of McCoy and Mateas (2008), which plays complete games of *Wargus*. The agent is partitioned into domains of competence, based upon analysis of expert human gameplay and is implemented in the reactive planning language ABL (Mateas and Stern 2002).

Authoring behaviors to deal with all possible counter-strategies on a large number of maps became an authorial burden. We extended the agent to interface with a case-based reasoning component that selects build orders from a collection of expert game traces (Weber and Mateas 2009b). The retrieval process incorporated several forms of domain knowledge including preconditions for recalling cases, feature subsets based on retrieved cases and domain-specific distance metrics. The CBR component interfaced with the planner using ABL's working memory as a blackboard. Additional behaviors were also authored to enable the agent to operate in an imperfect information environment. The agent was shown to outperform the built-in AI of *Wargus* and performed favorably with related work in this area (Ontañón et al. 2008).

Learning from Expert Examples

The second project focused on automatically acquiring domain knowledge about *StarCraft* gameplay by applying machine learning techniques to a corpus of game traces (Weber and Mateas 2009a). We introduced a novel representation for encoding the strategic actions taken by a player during a game into a single feature vector. Off-the-shelf algorithms were applied to the tasks of classifying an opponent's strategy as well as predicting when an opponent will perform specific actions. Our results showed that domain independent learning algorithms were capable of predicting an opponent's strategy minutes before it is executed, exhibiting foresight.

Proposed Work

My proposed work is to integrate human authoring techniques with domain knowledge learned from analyzing game traces. Precondition and method learning techniques (Hogg et al. 2008) will be used to enhance a human authored reactive plan and address the first research question. I will expand upon these techniques by integrating a goal formulation component into the agent. The case-based goal formulation component will select goals for the agent to pursue based on analysis of the library of game traces and will address the second research question. The third question will be addressed through the application of qualitative spatial reasoning and simulation techniques.

Case-Based Goal Formulation

Developing long-term plans for the reactive planner will require changing focus from recognizing a specific strategy to building a general model of intent recognition and goal formulation. Techniques will be developed for predicting a player's future actions based on the current game state and previous actions taken by the player. Accurately predicting a player's future actions will enable the agent to formulate goals for the reactive planner to pursue and provide a form of opponent modeling. Case-based reasoning, as well as instance-based and model-based learning algorithms will be applied to goal formulation.

Imperfect Information

My agent will operate in an imperfect information environment. To deal with this constraint, it will use a mental model to track the expected strategic and tactical actions of the opponent. The model will use qualitative spatial annotations based on map analysis to learn suitable locations for performing tactical maneuvers. The agent will combine this knowledge with simulation based approaches, including Monte Carlo methods and particle filters, to estimate the game state in an imperfect information environment.

Expected Results and Outcomes

The agent will be evaluated in the RTS game *StarCraft*, which is a complex RTS environment with a large, highly-competitive player base. Building an agent for this domain will enable evaluation against several bots as well as skilled human players. We will also evaluate the authoring effort required to build an agent with fully specified behavior, versus an agent that learns additional behavior from game traces.

My work aims to combine symbolic and statistical AI techniques through the use of precondition and method learning as well as goal formulation. The expected outcomes of integrating these approaches are techniques for building adaptive agents and reducing the amount of domain engineering required to build agents for complex, real-time domains.

References

Dietterich, T.G., Domingos, P., Getoor, L., Muggleton, S., and Tadepalli, P. 2008. Structured machine learning: the next ten years. *Machine Learning*, 73(1): 3-23.

Hogg, C., Muñoz-Avila, H., and Kuter, U. 2008. HTN-MAKER: Learning HTNs with Minimal Additional Knowledge Engineering Required. In *Proceedings of AAAI*, 950-956. Menlo Park, California: AAAI Press.

Mateas, M., and Stern, A. 2002. A behavior language for story-based believable agents. *IEEE Intelligent Systems*, 17(4): 39-47.

McCoy, J., and Mateas, M. 2008. An Integrated Agent for Playing Real-Time Strategy Games. *In Proceedings of AAAI*, 1313-1318. Menlo Park, California: AAAI Press.

Ontañón, S., Mishra, K., Sugandh, N., and Ram, A. 2008. Learning from Demonstration and Case-Based Planning for Real-Time Strategy Games. In *Soft Computing Applications in Industry*, 293-310. Berlin, Germany: Springer.

Weber, B., and Mateas M. 2009a. A Data Mining Approach to Strategy Prediction. In *IEEE Symposium on Computational Intelligence and Games*, 140-147. IEEE.

Weber, B., and Mateas M. 2009b. Conceptual Neighborhoods for Retrieval in Case-Based Reasoning. In *Proceedings of the 8th International Conference on Case-Based Reasoning*, 343-357. Berlin, Germany: Springer.