# Colored Trails: A Multiagent System Testbed for Decision-Making Research

# (Demo Paper)

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## 1. INTRODUCTION

With increasing frequency, computer agents participate in collaborative and competitive multiagent domains in which humans reason strategically to make decisions. The deployment of computer agents in such domains requires that the agents understand something about human behavior so that they can interact successfully with people; the computer agents must be sensitive to how people reason in strategic settings as well as to the social utilities people employ to inform their reasoning. To date, these design requirements for computer agents have received relatively little attention. To further research in this area, we are developing the Colored Trails (CT) testbed [5], a configurable and extensible open-source system for use by the research community at large to investigate multiagent decision making.

CT is a situated multiagent game environment that can be played by humans, computer agents, or a mixture of the two. CT can involve any number of players and supports one-shot and repeated games, games with simultaneous and sequential decision making, and games with imperfect and incomplete information. The players may act as individuals or within teams. The game may place players (or teams) in competition or call for coordination and cooperation. CT is parameterized to allow for increasing a scenario's complexity along a number of different dimensions that may influence the performance of decision making approaches. Thus, CT is a versatile framework for expressing and studying a variety of decision-making scenarios.

CT is played on a board of colored squares. Each player has a piece on the board as well as a collection of colored chips that can be used to move the piece on the board. Player pieces can move only to adjacent squares; to move a piece to an adjacent square, a player must turn in a chip of the same color as the square. One or more of the board squares are designated as *goal squares*, and the objective of each player is to move her piece as close as possible to (and preferably onto) an appropriate goal square. A player may lack certain chips needed to reach a goal square, but another player may have these needed chips. Players may negotiate with each other to exchange chips. Thus, the CT framework provides a situated environment where each player has *objectives* (e.g., arrive at or come closer to a goal square), *tasks* that must be performed to meet an objective (e.g., take a step on a path to reach the goal), and *resources* (e.g., chips that may be useful to move or trade with another player).

## 2. REPRESENTATIVE STUDIES WITH CT

The CT framework has been used for research on decision making in a variety of scenarios, with most scenarios involving human-subjects trials. For example, Gal et al. [4] investigate human reasoning in a two-player full-information negotiation game. A model of human play is first learned from data, and then a computer agent is constructed that formulates a best-reply to the human model. The agent is deployed in subsequent human-subjects trials along with other agents that play Nash equilibrium and Nash bargaining strategies for the game. The computer agent that used the human model outscored the game-theoretic agents as well as other humans. In later work, Gal and Pfeffer [3] consider an iterated version of the two-player negotiation game to investigate reciprocity in human play. This work models human reasoning in terms of both retrospective thinking about others' past behaviors and prospective predictions

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about future behavior. Results show that reasoning about human reciprocity significantly improves the accuracy of a predictive model of human behavior as compared to alternative models that do not reason about reciprocity, or that play various game theoretic equilibria.

Kamar and Grosz [7] use CT to investigate interruption management. Their research aims to determine the circumstances under which a human will consent to being interrupted by a computer agent in a multiagent task. Through such modeling, they are able to construct a computer agent that maximizes the expected outcome of an interruption; thus, the agent is able to avoid costly and unproductive interruptions of human work. Hendrix and Grosz [6] construct a CT-inspired scenario involving only computer agents to investigate the effects of reputation. By varying the number of agents, the distribution of agent abilities in the task scenario, and the way reputation was used and reported, they were able to describe how the efficacy of reputation hinged on the particulars of the situation. Reputation was found to be especially useful in the early stages of an interaction, even when the reputation information was error prone.

Most recently, Ficici and Pfeffer [1, 2] use CT to build a three-player negotiation game where two of the players have only partial information about each other's game state. This game is used to investigate human strategic reasoning under uncertainty [1]. Do people explicitly reason about other players in the game? If so, do people also consider the possible states of other players for which only partial information is known? A variety of models are learned from human data. The most successful models are hierarchical and capture the reasoning of the other players. Using these models, computer agents are able to achieve human-level performance in the game. The same game is used to investigate how human beliefs about others affect strategic reasoning [2]. The models learned in this work are able to distinguish the effects of an individual's preferences from her beliefs about another's preferences. Results show that people have slightly incorrect beliefs about others' preferences in this game.

The CT framework has been used in courses on multiagent systems at Harvard and Bar Ilan University. Research groups from universities such as Bar Ilan and the University of Melbourne have used and are currently using CT.

## 3. TECHNOLOGY

The Colored Trails platform has been developed through funding from the NSF and DARPA. CT supports mixed networks of interacting human and computer agents; to accommodate such mixed networks, CT must operate as a distributed system. CT currently runs over local area networks and will eventually run over the Web.

The CT system is currently in beta release and has been published under the GNU open-source license on our web site: **www.eecs.harvard.edu/ai/ct**. Those interested in using CT can download source code, tutorial materials, and our research papers. People can also submit feature requests and join our CT mail list to receive announcements.

The CT testbed is designed to be extensible and configurable to meet specific experimental needs. The core CT system provides robust networking (via JMS), data logging, and experiment management services. Aspects that are specific to particular experiments are left under the control of the researcher. CT allows custom game logic to be implemented through a dynamically loaded *game configuration class* written by the experimenter; this class operates with the server and provides the game designer with full access to state information and the ability to monitor and react to player communications. The experimenter can create custom message types to implement new types of inter-player communication; for example, a message may concern an offer to trade chips, a reply to an offer, or a request for information (e.g., about the game state or about the reputation of another player). The CT agent API allows the experimenter to create a custom graphical user interface (GUI) as required for human players; standard GUI components are provided. For computer agents, the agent API provides easy access to all aspects of the system.

## 4. DEMO DESCRIPTION

We will demonstrate the current beta version of our CT framework as well as an older code base that was used in the experiments described in Ficici and Pfeffer [1, 2]. People will be able to run sample CT scenarios implementing two- and three-player negotiation games, as well as interact with the computer agents that use models of human behavior learned from human data [1].

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