Chapter IV
A Multi-Agent Temporal Constraint Satisfaction System Based on Allen’s Interval Algebra and Probabilities

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ABSTRACT

Many real-world problems can be viewed and represented as a constraint satisfaction problem (CSP). In addition, many of these problems are distributed in nature. To this end, we combine agents with a special type of CSP called an Interval Algebra network (IA network). An IA network is a graph where each node represents an interval. Directed edges in the network are labelled with temporal interval relations. A probabilistic IA network has probabilities associated with the relations on the edges that can be used to capture preferences. A probabilistic IA agent (PIA-Agent) is assigned a probabilistic IA network. PIA-Agent’s networks are connected via edges. The overall goal is to make each PIA-Agent’s network consistent and optimal. Each PIA-Agent is independent and has sole control over its network. But, it must communicate and coordinate with other PIA-Agents when modifying or updating edges that are shared between two PIA-Agents. We present an algorithm which allows the PIA-Agents to collab-
oratively solve and recommend a temporal schedule. At the agent level, this schedule is optimal under the given local constraints. Although the global solution may not be optimal, we try to generate near optimal ones. Note that our distributed system is not centrally controlled. Our algorithm decides which PIA-Agent should be given an opportunity to update the solution next. Also, when a conflict is detected, the algorithm modifies the PIA-Agent execution order in order to deal with the inconsistency.

INTRODUCTION

Many real world problems such as scheduling, planning, and configuration can be viewed as constraint satisfaction problems (CSP). A CSP consists of variables and a domain of possible values is associated with each variable. It may not necessarily be the case that all the domains are equal. A binary constraint between two variables is a subset of the Cartesian product of their domains. A solution to a CSP is an assignment of a value to each variable from its domain such that all the constraints hold.

Another powerful tool for solving complex real world problems is intelligent agents (Chaib-draa et al., 1996). The intelligent agent paradigm has been successfully applied in many research areas, such as distributed databases and Artificial Intelligence. The agents are viewed as autonomous and goal-driven entities (Wooldridge and Jennings, 1995; Shakshuki et al., 2005). Autonomy refers to the ability of the agent to make decisions concerning its own actions without any external interference. Goal-driven refers to the ability of the agent to interact with other agents at the ‘goal level’. Furthermore, this entity can interact with the user and other software systems (agent-based or non agent-based). Due to the dynamic and flexible characteristics of these agents, they are being used in an increasingly wide variety of applications.

Recently, researchers have combined the intelligent agent and CSP paradigms into single systems. For example, Calisti and Neagu (2004) analyzed and discussed possible ways of integrating CSP and agent techniques. Other researchers (e.g., Makoto et al., 1998) used agents to solve distributed versions of a CSP (DCSP). In a DCSP, constraints are shared between agents. In Bhaskar, et al. (2001), they used a DCSP to schedule access to nearby transmission nodes of an ad hoc network and presented experimental results to demonstrate the complexity of this problem. Liu and his co-workers (Liu et al., 2002) presented a multi-agent oriented method for solving CSPs. In their method, distributed agents represent variables and a two-dimensional grid-like environment in which the agents inhabit corresponds to the domains of the variables. Researchers in Jung et al. (2001) presented a DCSP as a computational model for investigating negotiation via argumentation. They modeled argumentation as constraint propagation in DCSPs to resolve conflicts, where agents provide explicit arguments or justifications for their proposals for resolving conflicts.

In this work, we combine agents with a special type of CSP called a Probabilistic Interval Algebra network (PIA network). A PIA network is a directed graph where each node represents a temporal interval, and the edges are labelled with constraints between intervals. A PIA-Agent is an agent which has ownership and control over a PIA network. A node in one PIA-Agent’s network can be connected by an edge to a node in another PIA-Agent’s network. PIA-Agents, who can only solve their local PIA networks, must collaborate in order to solve the global network.

The problem we consider has multiple connected PIA-Agent networks as input. The output is a consistent network where the product of the probabilities on the unique label assigned to each edge is near optimal. The proposed algorithm
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