Chapter 54
Robot Task Planning in Deterministic and Probabilistic Conditions Using Semantic Knowledge Base

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ABSTRACT

A new method is proposed to increase the reliability of generating symbolic plans by extending the Semantic-Knowledge Based (SKB) plan generation to take into account the amount of information and uncertainty related to existing objects, their types and properties, as well as their relationships with each other. This approach constructs plans by depending on probabilistic values which are derived from learning statistical relational models such as Markov Logic Networks (MLN). An MLN module is established for probabilistic learning and inference together with semantic information to provide a basis for plausible learning and reasoning services in support of robot task-planning. The MLN module is constructed by using an algorithm to transform the knowledge stored in SKB to types, predicates and formulas which represent the main building block for this module. Following this, the semantic domain knowledge is used to derive implicit expectations of world states and the effects of the action which is nominated for insertion into the task plan. The expectations are matched with MLN output.

DOI: 10.4018/978-1-7998-1754-3.ch054

1. INTRODUCTION

Plan generation by an autonomous robot planner acting in human environments is a complex task as it involves dealing with uncertainty and non-deterministic situations. Indeed, in such situations, a variable number of objects may be relevant to its tasks and these objects may be related in various ways. Uncertainty is a feature related to robots acting in real environments, and may occasionally lead to failure in robot operation. To deal with unexpected planning contingencies, robotic task planning employs probabilistic inference procedures, based on reasoning techniques, to ensure that the generation of its plans does not mean that said plans deviate from their intended course of action (Bouguerra, Karlsson & Saffiotti, 2007). Most approaches to plan generation focus on deterministic information regarding the robot environment, such as the exact objects and their properties, and explicit actions' details (pre-conditions and post-conditions). For instance, the explicit effect of a robot moving to a kitchen is that the robot's new position is the kitchen. In contrast, the implicit effect is that the robot should observe that there is a fridge and an oven.

In a real world environment this is not always realistic, as planning with uncertainty is a complex process. As such, more advanced forms of probabilistic reasoning engaging with semantic knowledge should be proposed to derive probabilistic implicit information which is related to the existence of objects, predicting their types, properties and the relationships among said objects. For example, it is highly likely that a robot moving into a living room would see a TV-set and a sofa, although the probability of the robot encountering a bed and sink is significantly lower.

If the robot is entering a kitchen instead, there is a higher probability that it will see a fridge and a sink. These probabilities are details that would add more complexity to the task planner, if the robot itself is left to process them. In light of this, it is important to build a separate unit based on semantic knowledge and the action descriptions used by the planner. Indeed, the planner has the ability to learn from a knowledge base and then infer probable information about the robot environment by depending on robot observations to support its task planner.

In this paper, the robot planning system infrastructure is based on a semantic knowledge base and represented by Description Logic (DL) (Baader, McGuinness, Nardi & Patel-Schneider, 2010). This type of system has the ability to infer the types of things and the automatic classification of things based on their classes and properties, following which it can develop a general algorithm for this system based on DL. With this, the robot can derive new information from its existing knowledge. Pure description logics inference is completely deterministic, so it is often desirable to represent uncertain information in a way that can be more useful to the robot planner.

A second process has been developed that takes into its consideration probabilistic uncertainty in the state of the world, i.e. uncertainty about the type of objects and places in the robot environment and the relations between them. This process depends on Markov Logic Networks which allow for probabilistic inferences that combine the expressiveness of first-order logics with the representation of uncertainty (Richardson & Domingos, 2006). The influence of such relational structures, involving variable sets of objects on the facts relevant to the robot's tasks, must clearly be omitted from consideration for a model that involves a fixed set of propositions. As such, a unification stage between the principles of first-order logic is crucial, as this makes objects and relations the main building blocks of the representation, and probabilistic graphical models, which enable reasoning in the face of uncertainty, to create a single representation formalism. This approach makes it possible, by combining the respective semantics, to