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Approximate Inference in Influence Diagrams using Binary Trees

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Abstract

This paper introduces binary trees, a new kind of representation of the potentials involved in Influence Diagrams. This kind of tree allows representing context-specific independencies that are finer-grained compared to those encoded using other representations, such as numerical trees or tables. This enhanced capability can be used to improve the efficiency of the algorithms used for Influence Diagrams.

1 Introduction

Decision problems under uncertainty have traditionally been represented and solved using *Decision Trees* (Raiffa, 1968). However, they have a problem of exponential growth of the representation. An alternative are *Influence Diagrams* (IDs), which can encode the independence relations between variables in a way that avoids this exponential growth.

For complex decision problems, the evaluation of an ID becomes unfeasible due to its computational cost: The set of information states exceeds the storage capacity of PCs or the optimal policy must be obtained in a short period of time. It is thus necessary to use approximate methods for ID evaluation such as *LMIDs* (Lauritzen and Nilsson, 2001), or sampling techniques (Charnes and Shenoy, 2004; Cano et al., 2006). Some of the deterministic methods use alternative representations for potentials, such as *numerical trees* (NTs) (Cano et al., 2000). This representation offers the possibility of taking advantage of *context-specific independencies*. NTs can be pruned and converted into smaller trees when potentials are too large, thus leading to approximate algorithms. Here, we introduce a new kind of tree for the representation of potentials, namely, *binary trees* (BTs), where the internal nodes always have two children. These trees allow the specification of finer-grained context-specific independencies than NTs, and should lead to more efficient algorithms.

The paper is organized in the following way: Section 2 introduces some concepts and notation about IDs; Section 3 presents basic concepts of NTs; Section 4 describes key issues about BTs and how they are used during the evaluation of IDs; Section 6 includes the experimental work and results; finally Section 7 details our conclusions and lines for future work.

2 Influence Diagrams

An ID (Olmsted, 1984) is a Bayesian network (BN) augmented with two new types of nodes: *decision nodes* (mutually exclusive actions which the decision maker can control) and utility nodes (representing decision maker preferences). Utility variables may depend on both random (or chance) variables and decision variables. IDs are used for representing and solving decision problems.

The set of chance nodes is denoted by V_C, the set of decision nodes is denoted by V_D, and the set of utility nodes is denoted by V_U. Direct predecessors of a decision node D are called *informational parents*. The set of all possible combinations of states of the informational parents is called the *information set* for D. The elements of this set are denoted *information states for* D. The *universe* of the ID