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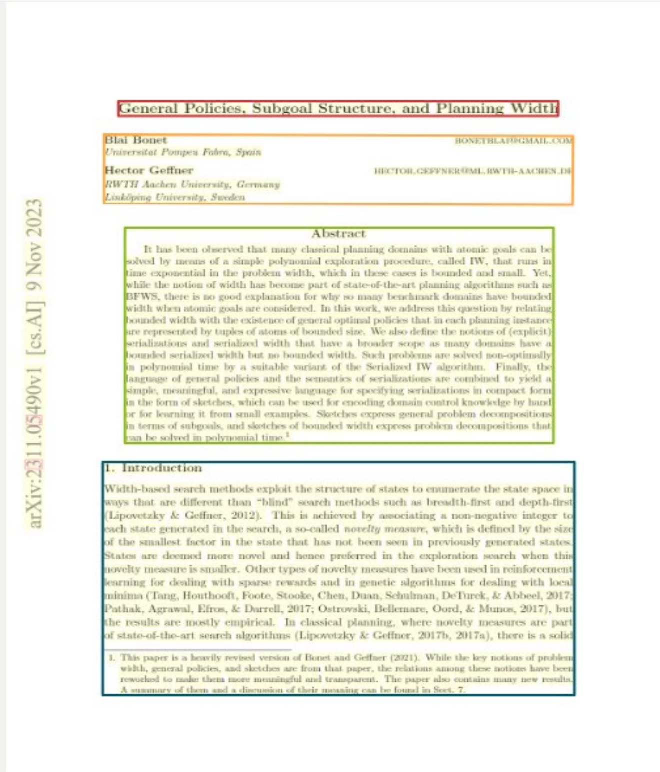

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General Policies, Subgoal Structure, and Planning Width

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Abstract

It has been observed that many classical planning domains with atomic goals can be solved by means of a simple polynomial exploration procedure, called IW, that runs in time exponential in the problem width, which in these cases is bounded and small. Yet, while the notion of width has become part of state-of-the-art planning algorithms such as BFWS, there is no good explanation for why so many benchmark domains have bounded width when atomic goals are considered. In this work, we address this question by relating bounded width with the existence of general optimal policies that in each planning instance are represented by tuples of atoms of bounded size. We also define the notions of (explicit) serializations and serialized width that have a broader scope as many domains have a bounded serialized width but no bounded width. Such problems are solved non-optimally in polynomial time by a suitable variant of the Serialized IW algorithm. Finally, the language of general policies and the semantics of serializations are combined to yield a simple, meaningful, and expressive language for specifying serializations in compact form in the form of sketches, which can be used for encoding domain control knowledge by hand or for learning it from small examples. Sketches express general problem decompositions in terms of subgoals, and sketches of bounded width express problem decompositions that can be solved in polynomial time.[1]

1. Introduction

Width-based search methods exploit the structure of states to enumerate the state space in ways that are different than "blind" search methods such as breadth-first and depth-first (Lipovetzky & Geffner, 2012). This is achieved by associating a non-negative integer to each state generated in the search, a so-called *novelty measure*, which is defined by the size of the smallest factor in the state that has not been seen in previously generated states. States are deemed more novel and hence preferred in the exploration search when this novelty measure is smaller. Other types of novelty measures have been used in reinforcement learning for dealing with sparse rewards and in genetic algorithms for dealing with local minima (Tang, Houthooft, Foote, Stooke, Chen, Duan, Schulman, DeTurck, & Abbeel, 2017; Pathak, Agrawal, Efros, & Darrell, 2017; Ostrowski, Bellemare, Oord, & Munos, 2017), but the results are mostly empirical. In classical planning, where novelty measures are part of state-of-the-art search algorithms (Lipovetzky & Geffner, 2017b, 2017a), there is a solid

1. This paper is a heavily revised version of Bonet and Geffner (2021). While the key notions of problem width, general policies, and sketches are from that paper, the relations among these notions have been reworked to make them more meaningful and transparent. The paper also contains many new results. A summary of them and a discussion of their meaning can be found in Sect. 7.

1 of 40

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