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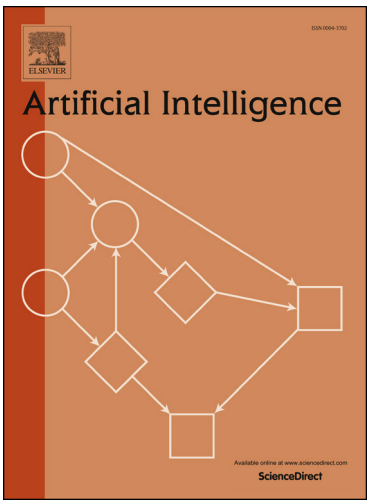

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Automatically Improving Constraint Models in Savile Row

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Abstract

When solving a combinatorial problem using Constraint Programming (CP) or Satisfiability (SAT), modelling and formulation are vital and difficult tasks. Even an expert human may explore many alternatives in modelling a single problem. We make a number of contributions in the automated modelling and reformulation of constraint models. We study a range of automated reformulation techniques, finding combinations of techniques which perform particularly well together. We introduce and describe in detail a new algorithm, X-CSE, to perform Associative-Commutative Common Subexpression Elimination (AC-CSE) in constraint problems, significantly improving existing CSE techniques for associative and commutative operators such as $+$. We demonstrate that these reformulation techniques can be integrated in a single automated constraint modelling tool, called Savile Row, whose architecture we describe. We use Savile Row as an experimental testbed to evaluate each reformulation on a set of 50 problem classes, with 596 instances in total. Our recommended reformulations are well worthwhile even including overheads, especially on harder instances where solver time dominates. With a SAT solver we observed a geometric mean of 2.15 times speedup compared to a straightforward tailored model without recommended reformulations. Using a CP solver, we obtained a geometric mean of 5.96 times speedup for instances taking over 10 seconds to solve.

1. Introduction

In numerous contexts today we are faced with making decisions of increasing size and complexity, where many different considerations interlock in complex ways. Consider, for example, a staff rostering problem to assign staff to shifts while respecting required shift patterns and staffing levels, physical and staff resources, and staff working preferences. The decision-making process is often further complicated by the need also to optimise an objective, such as to maximise profit or to minimise waste.

It is natural to characterise such problems as a set of decision variables, each representing a choice that must be made in order to solve the problem at hand (e.g. which

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