An Action Guided Constraint Satisfaction Technique for Planning Problem

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ABSTRACT

This paper presents an action guided constraint satisfaction technique for planning problem. Different from the standard algorithms which are almost domain independence and cannot reflect the characteristics of the planning progress, this paper discusses how the action rules in planning act in constraint satisfaction problems. Based on the conclusion, an action directed constraint is proposed to guide the variable selected procedure in constraint satisfaction problems. Through theoretical analysis, this technique is prior an order of magnitude in variable select procedure over the ordinary heuristic technique and can be used in constraint-programmed planning problem generally. With the simulation experiments it shows that the algorithm with action guided constraint can effectively reduce the number of constraint checks during the planning procedure and has a better performance on total running time over the standard version.

KEYWORDS

Action Guided, Constraint Satisfaction, Planning, Variable Selected

1. INTRODUCTION

There has been made greatly advances in planning community due to the application of constraint satisfaction techniques (Alur, Henzinger and Vardi, 2015; Günay and Yolum, 2013) in recent years. Constraint-programmed planners (Bu, Zhang and Luo, 2016; Lozano-Perez and Kaelbling, 2014) code a planning problem into a constraint satisfaction problem (CSP) and then apply powerful CSP algorithm to inference and prune off. Clearly there are two benefits for this translation: one is the researchers can directly use the mature algorithms in CSP community with a constraint-programmed planner, and the second is AI planning and CSP stress on the different control theories respectively: planning emphasizes on search (Kautz and Selman, 1999) while CSP on inference (Veksler and Strichman, 2016). It has opened up a new way in planning community after the CSP technique brought in.

The method using CSP to solve planning problem rooted from an important technique (Kautz, Mcallester and Selman, 2003) that imposes a fixed bound on plan length, which converts the planning problem into NP (Non-Deterministic Polynomial) (Carnielli and Matulovic, 2014). So the resulting problem can then be solved by CSP, which is a NP-Complete formalism (Ghédira and Dubuisson, 2013). The first constraint-programmed planner is CPLAN (Van Beek and Chen, 2000) in 1999, with manually coded domain dependence constraints. Since then a lot of constraint-programmed planners have been developed which transfer kinds of classic planner such as GRAPHPLAN (Little and Thiébaux, 2006), HTN (Castillo, Fernández-Olivares and óscar, 2006), partial plan (Kapadia, Falk and Zünd, 2015) etc. into CSP formalism. Especially GP-CSP (Do and Kambhampati, 2001) can automatically converting a planning graph into a CSP encoding, which saves the human manually domain-setup and hand-coding cost.

Up to now, the research in constraint-programmed planning focuses on the coding of the translation and the extensions of CSP to meet the rich expressiveness of planning, such as: timeline (Cervantes, Rodríguez and López, 2013), possibility (Bodirsky, 2013), infinite data streams (Rosin, 2014) etc. However, considerably little work has been done in the solving method research, or CSP technique *"planisation"*. Without planning related guidance, the standard CSP heuristics and search methods (Stergiou, 2015; Wang and Patel, 2009) used in the planner above greatly restrict the efficiency of problem solving. In paper (Wang, 2014), a significant improvement has been made with a goal-centric CSP heuristic guidance. However, as it is stated in the paper, "a large problem comes an increased plan length (horizon), this large horizon greatly reduces the impact of the propagation resulting from the goal-state constraints."

The constraints used in this paper include: initial state constraints, goal state constraints, actions' prerequisite constraint and actions' successor state constraint. For the reason that initial and goal state constraints reduce the impact of propagation in larger and larger problems, the effects of leverage the actions' prerequisite and successor state constraint are leveraged in this paper. With an analysis of the relation between the actions' prerequisite and successor state in planning and the assignment of variables in CSP, we present a variable selection constraint of guiding the search for a solution to a constraint-programmed classical planning problem. With this method, a constraint-programmed planning problem with variables divided into multi steps should be variable-assigned step by step. Through theoretical analysis it is proved that the time complexity with this constraint is prior an order of magnitude in variable select procedure than the ordinary heuristic technique and it can reduce more redundant constraint checks. The simulation experiments verify the conclusion above.

The remainder of this paper is structured as follows: section two introduces the background about CSP and AI planning; section three describes how actions in planning play the role in CSP and based on the result we deduce the variable successor constraint. The experimental results and conclusions are presented in sections four and five.

2. BACKGROUND

Constraint satisfaction problems are mathematical problems defined as a set of objects whose state must satisfy a number of constraint or limitations. CSPs represent the entities in a problem as a homogeneous collection of finite constraints over variables, which are solved by constraint satisfaction methods. And planning is a procedure of selection and sequencing of activities such that they fulfill the expected goals and won't disobey the model constraints. It is first briefly introduced the definition of constraint satisfaction problem and AI planning (for more detail information on these topic see (Nau, Ghallab and Traverso, 2004)).

Definition 1 (CSP): A constraint satisfaction problem consists of:

- A set of variables $X = \left\{ x_1, x_2, \cdots, x_n \right\}$;
- A set of domains $D = \left\{ D_1, D_2, \cdots, D_n \right\}$ such that for each variable x_i there is a domain D_i;

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