‚Review of the Doctoral Thesis
Constraint Programming in Planning
submitted by RNDr. Pavel Surynek

a) ***Is the treated topic up to date?***

Planning is an ability to design such a sequence of available actions that gradually transforms current state into a state where the considered goal is achieved. Number of the tasks appearing in the domain of artificial intelligence or computer science can be described as planning problems - that is why finding efficient planning methodology is considered to be a key to solving many important problems ranging from automated programming and automated program testing to design of autonomous robots. Complexity of planning problems depends on properties of the considered world and actions and the way these properties are expressed by the language used for description. In general, planning can be unsolvable. This doctoral thesis is concerned with the extensive set of cases when planning is NP complete. Since this set is of high practical importance any improvement of the planning methodology is most welcome as it promises to enhance the number of instances of planning problems that can be resolved. It is no doubt that the treated topic is most up to date.

b) ***What methods have been selected?***

Constraint programming proved to be very successful in scheduling during last 20 years. That is why it seems to be a very good idea to apply it even in the more general area of planning. The author is inspired by sophisticated consistency techniques and he introduces his own original constraint propagation (CP) techniques, which are well suited for the considered types of planning problems. The author carefully studies properties of his CP techniques, he proves number of rigorous claims e.g. about their complexity and he applies the suggested techniques in several variants of the planning algorithm he implements. Finally, the thesis presents results of thorough experimental testing of the implemented algorithms when applied to number of benchmark problems.

The used methods are appropriate and they have been very well selected. The text reflects deep knowledge of relevant recent references. The author tries to make his text self-contained and describes all necessary notions in his uniform framework. It is not an easy task and there are some places, which seem to be unclear or cumbersome. The following items should be explained during the defence of the thesis:

- When he introduces *no-op actions* in the introductory chapter **2 Classical Planning**, one loses the feel for difference between actions and operators (page 15). I would recommend paying some attention to the classical frame problem here as well.
- I cannot agree with the statement (p. 17[4]) that "It never happens (supposing that the set of planning operators is correctly formed) that more than one *at(TRUCK,LOCATION)* atoms occur in a state for a single truck ...". Is it really the case that a collision of two cars is caused by the available set of planning operators?
- It sounds strange if one can read on a single page (17) the sentence "There are no function symbols in the language of state variable representation" together with the definition of the state variable where function variable symbols play an important role.
- Well chosen illustrative running example of Dock Worker Robots for loading trucks used already in the chapter 2 is really helpful to understand the concepts described in the chapter **3 Contributions to Planning Using Planning Graphs**. There are used 3 different planning environments for testing the suggested algorithms described in **3.2.2.** In this chapter, I have lacked definitions of some notions used in the proofs (e.g. "amortized number" in Propositions 3.4 and 3.5).
- It would be nice if a similar level of illustrations used in the chapter **3** appears in the chapter **4 Contributions to Boolean Satisfiability**, too. A simple motivating example could be of great help when explaining arc-consistency (p.102).

c) ***Did the thesis succeed to achieve its goal?***

The thesis suggests new original ideas how to improve performance of the baseline planner. These ideas are implemented and their results are clearly documented by extensive well-designed experiments, which prove speed-up in order of magnitude compared with one of the current state of the art planners. Very interesting and original results are obtained in the section **3.4** Tractable Class …

Moreover, the author succeeds to achieve new results even outside the scope of planning when he modifies his ideas used in planning so that they can be applied for solving Boolean satisfiability problems. He designs a special pre-processing method called clique consistency, which gradually modifies the input CNF formula and thus simplifies the studied problem significantly. The experimental evaluation of the proposed method proved highly positive impact of the suggested approach.

The thesis did accomplish its goals and intentions.

d) ***Evaluation of the presented results and their originality***

Some partial results described in the thesis have been accepted for presentation at several prestigious international scientific meetings with strict reviewing processes, e.g. the 11th and 12th ERCIM Workshops (Caparica - Portugal 2006 and Rocquencourt – France 2007) or 20th FLAIRS Conference and they appear in several volumes published by Springer Verlag (Proceedings of 7th Int. Symposium Abstraction, Reformulation and Abstraction SARA 2007, Whistler – Canada, Post-proceedings of CSCLP 2007 Workshop). This is a clear proof of their high quality and originality.

e) ***What are the merits for practical applications and for further advance of science?***

The suggested methods of consistency checking and of pre-processing difficult SAT instances can be well integrated into planning algorithms or into SAT solvers. This step seems to be worth of doing since complexity of these methods is low polynomial while often they provide improvement in order of magnitude (see Fig. 3.13-3.16). The planning algorithm suggested in the thesis makes it possible to shift the border of difficult problems and gain deeper understanding of the relation between structural properties of the planning problems and their complexity. The same holds for the presented results concerned with SAT problems.

The thesis raises further new attractive questions mentioned in the last chapter. I wonder whether the efforts invested into creation of the planning graph constructed for the specific planning environment can be fructified later when answering different planning tasks.

f) ***Can the thesis be classified as an original creative research of its author? Does it include new scientific results published by the author?***

The submitted thesis describes original creative research of its author and it presents valuable scientific results. The chosen topic is systematically treated, it builds on extensive amount of preliminary knowledge described in the cited literature. It is not an easy reading but certainly the presented results prove high research competence of its author. The thesis meets all requirements expected by the Czech law.

I recommend accepting this thesis for the defence procedure.

Prague, 11th August 2008