Review of the PhD Thesis

Mutual Exclusion State Invariants in Classical Planning

presented by Daniel Fišer

Daniel Fišer has presented his dissertation thesis 'Mutual Exclusion State Invariants in Classical Planning' where he summarizes results of his PhD research performed at the Czech Technical University, Faculty of Electrical Engineering, Department of Computer Science. The candidate has performed substantial amount of relevant theoretical, technical and experimental work contributing to the research field of automated planning in the context of extraction of structural information, namely the state invariants. This fact has been demonstrated by the list of publications including a SCI-impacted journal and four CORE A* publications, where the student was the main author of all of them and the sole author of one of them − the publication were published in the Journal of Artificial Intelligence Research (JAIR), at the AAAI Conference on Artificial Intelligence, and at the International Conference on Automated Planning and Scheduling (ICAPS).

The objectives of the dissertation were aimed at several research questions answering theoretical and practical questions about the concept of mutexes and mutex groups for classical planning, namely: (i) the theoretical analysis of the mutex groups, (ii) design and analysis of the novel concept of Fact Alternating Mutex (FAM) groups, (iii) adaption of the FAM groups to the lifted context, (iv) usage of mutexes for disambiguation and potential heuristics, and (v) mutual exclusion between operators (i.e. operator mutexes).

The core motivation for the doctoral work of Daniel Fišer was efficiency improvement of classical automated single-agent planning. There are several directions how this task can be tackled, including improving the search algorithms, heuristics, and automated extraction of structural information used for more efficient representation of the planning problems and/or for improving efficiency during the search. The direction taken by Daniel is not new in the planning, but until his work, it was rather neglected in the literature and never analyzed in such detail and scope. There were technically only two solutions used. One as part of the FastDownward planning system for translation of the lifted planning tasks to the ground representation (called grounding) used in the heuristic search algorithms. Second, based on the h^m heuristics family, the most commonly used method for inferring mutexes as tuples (practically used only for pairs by h^2). The overall idea of the novel mutex groups proposed in the thesis is that by analysing of the operators, it can be efficiently deduced what facts alternate between each other (or are removed) in states reachable from a defined initial state. That is why the invariants were coined Fact Alternating Mutex groups. Such invariants are easier to deduce (NP-complete) than the general mutexes, which to deduce is as hard as planning (PSPACE-complete). The thesis provides proofs not only of the novel FAM group class, but also for the general class, which was known to be PSPACE-complete, but not proven in detail. The FAM groups, since defined from the initial state, are, in comparison to the other mutexes, usable for removing of parts of the planning problem which are not essential for finding a solution, i.e. for pruning. This principle with experimental evaluation was another contribution of the thesis and pushed the efficiency of planning

in comparison to the state of the art. Similarly, using the mutexes for improving the potential heuristics (one of the most efficient admissible heuristics for optimal classical planning), provided improvement in the overall number of solved problems in the benchmarks used by the planning community to compare efficiency of the planners − concretely, the International Planning Competition (IPC) benchmark set. Although the mutex inference and grounding processes can run separately, a hypothesis of the thesis was, binding them together could help the efficiency. The thesis proves that the commonly used mutex groups in the lifted form are the FAM groups after grounding and that inference of schematic mutex groups in the lifted representation provides more concise representation of the grounded problem from the lifted one. Finally, the thesis generalizes the state mutexes and provides theoretical and experimental insights into mutually exclusive operators combined with structural symmetries. As the other results contribute to efficiency improvement of classical planning, the operator mutexes are not of any difference.

Daniel Fišer undoubtedly showed deep understanding of the studied topic and exhaustive knowledge of the state of the art in the area of mutual exclusive groups and structural information in classical planning. This fact is demonstrated in the Related Work, Background and Mutex and Mutex Group chapters of the thesis. Not only the summary is comprehensive, but provides formal proofs of complexity of well known algorithms, which was not well present in literature at the time. The original work goes through all the following chapters and builds on the novel concept of FAM groups. Not only the concept was proposed solely by the student, it was designed with practical usability. That required thorough theoretical complexity analyses and improved efficiency of classical planning in more than one aspect. Those aspects studied in the thesis are pruning of planning tasks, usage in grounding from the lifted representation, and strengthening of the potential heuristics. All these aspects together with the extension to operator mutexes were presented to the AI and planning research communities. Together with high amount of top-tier automated planning and artificial conference papers and the impacted journal (all of which the candidate is the first author) and citations (Google Scholar: 418, H-index: 6), the dissertation work as a whole shows extraordinary research, technical and publication qualities of the candidate.

The candidate was able to demonstrate his capability of independent, creative research activity in the field of computer science. The presented thesis fulfills the requirements for the PhD thesis in the field of computer science. Therefore I recommend the candidate to be awarded by a PhD degree.

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