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Competition of Distributed and Multiagent Planners (CoDMAP)*

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Abstract

As a part of the workshop on Distributed and Multiagent Planning (DMAP) at the International Conference on Automated Planning and Scheduling (ICAPS) 2015, we have organized a competition in distributed and multiagent planning. The main aims of the competition were to consolidate the planners in terms of input format; to promote development of multiagent planners both inside and outside of the multiagent research community; and to provide a proof-of-concept of a potential future multiagent planning track of the International Planning Competition (IPC). In this paper we summarize course and highlights of the competition.

Introduction and Aims of CoDMAP

Various forms of multiagent planning have recently found their way to the automated planning research community, nevertheless, there was no competition of multiagent planners in the tradition of IPC yet. As the organizers of DMAP'15, we have decided to run a co-located competition of multiagent planners.

We chose an approach similar to that of classical planning competitions, to start with the smallest possible subset of features and possibly extend them in the future. One of the main focuses of the competition design was to allow as many existing planners as possible to enter without large-scale modifications. In order to foster our awareness of the existing planners and their possible extensions, we have conducted a public poll. Out of the poll and other considerations arose three main restrictions of the multiagent planning model: deterministic, non-durative actions, full observability (with respect to privacy), cooperative agents and offline planning.

Formalism and Input Language

A crucial point of the competition was to determine a formalism and an input language. For the formalism, we have chosen MA-STRIPS (Brafman and Domshlak 2008) for its simplicity and wide acceptance among existing planners. MA-STRIPS extends the STRIPS (Fikes and Nilsson 1971) formalism with two concepts: (i) *factorization* and (ii) *privacy*. Factorization is defined in the planning problem and prescribes what STRIPS actions can be executed by which agents. A STRIPS fact is private if it is not affected and cannot affect more than one agent.

Following the minimalistic extension of STRIPS to MA-STRIPS, we wanted a simple extension of the common planning language PDDL (McDermott et al. 1998) towards multiagent planning, also compatible with MA-STRIPS. After analysis of candidate languages, we have decided to extend MA-PDDL (Kovacs 2012). The extension[1] came in two flavors, a *factored* description, which allowed the definition of separate domain and problem description for each agent, and an *unfactored* description, which allowed the definition of factorized privacy in a single domain and problem description. Additionally, our generalized definition of privacy was enough to comprise MA-STRIPS privacy, but allowed for more general definitions, possibly usable in future multiagent planning competitions.

Competition Tracks

A success of a planning competition is determined to large extent by the number of contestants and as there was no historical experience from previous multiagent planning competitions, we wanted to open the competition to the widest possible audience. A survey of literature on multiagent planners together with the competition poll[2] provided enough information to set the rules for the competition so that an ample amount of already existing multiagent planners could

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[1] The extended BNF can be found at http://agents.fel.cvut.cz/codmap/MA-PDDL-BNF.pdf

[2] The poll form can be found at: http://bit.ly/1IsNoqY

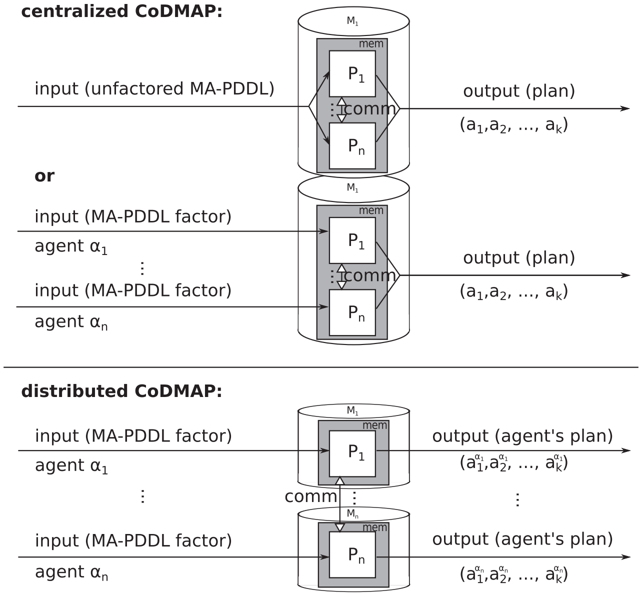

Figure 1: Comparison of the centralized CoDMAP track (top two variants) and distributed CoDMAP track (bottom). $P_1, \ldots, P_n$ represent processes of the planner. In the centralized CoDMAP track, there can be arbitrary number of planner processes (e.g., only P_1 for centralized planners). In the distributed CoDMAP track, the processes correspond to n agents $\alpha_1, \ldots, \alpha_n$ running on machines $M_1, ..., M_n$. Communication among the planner's processes and (shared) memory are denoted as *comm* and *mem* respectively. The output plan(s) are ordered lists of k actions $a_1, \ldots, a_k$, where in the distributed CoDMAP, an agent's α_i action is denoted as a^{α_i}. In the case of the centralized CoDMAP track, a planner can arbitrarily use unfactored and/or factored inputs.

compete and still the key motivations of the competition remained satisfied.

The fundamental discriminator of current multiagent planners is whether they can work distributively on multiple interconnected physical machines, or not. To accommodate planners running in either modes, the competition was split in two tracks (see Figure 1):

- *Centralized Track*, aiming for maximal compatibility with classical IPC and existing multiagent planners; the input of a planner was either unfactored or factored MA-PDDL; the planners run on a single machine, with no other restrictions or requirements; communication was not restricted; privacy was not enforced.

- *Distributed Track*, much more strict aiming for a proper multiagent setting; the input was limited to distributed factored MA-PDDLs for each agent; planners run distributively on a grid of machines; planners had to communicate over TCP/IP; preservation of privacy of the local data was required.

Coverage					
centralized track			distributed track		
1.-2.	ADP (GBR)	222	1.	PSM (CZE)	180
3.	MAP-LAPKT (CAN)	216	2.	MAPlan (CZE)	174
4.	CMAP (ESP)	210	3.	MH-FMAP (ESP)	107

Table 1: Best performing planners in the metrics of solved problems out of overall 240 benchmarks.

Evaluation and Benchmarks

Each run of a planner in the competition was restricted to 30 minutes on 4 computational cores and 8GB per machine.

The metrics used to compare the planners were coverage (number) of solved problems, IPC Score over the plan quality, and IPC score over the planning time. In the distributed track, the plan quality was evaluated both in terms of total cost (sum of costs of all used actions) and makespan (the maximum timestep of the plan if executed in parallel).

The planners were evaluated over a set of 12 benchmark domains. The domains were motivated by important and interesting real-world problems and/or by problems exposing and testing theoretical features of the planners. We used domains from literature on multiagent planning: BLOCKSWORLD, DEPOT, DRIVERLOG, ELEVATORS08, LOGISTICS00, ROVERS, SATELLITES, SOKOBAN, WOODWORKING, and ZENOTRAVEL, each with 20 problem instances, with varying size, number of objects, constants, agents, and thus complexity. Additionally, we have added two novel domains inspired by well-known multiagent problems, not modeled in MA-STRIPS or MA-PDDL previously: TAXI and WIRELESS. The first one was a model of on-demand transport by taxis in a city, while the other modeled a group of communicating autonomous nodes in a wireless sensor network.

The validity and quality of plans was evaluated using the VAL[3] tool, which can handle parallel plans and performs the mutex checks.

Selected Results

For the centralized track, we have received 12 planners in 17 configurations prepared by 8 teams. For the distributed track 6 configurations of 3 planners by 3 teams. Complete, detailed, and interactive results including detailed description of the planners and their authors can be found on the official competition webpage[4], selected results are presented in Table 1.

The winning planners of the centralized track were two variants of the ADP (Agent Decomposition-based Planner) planner (Crosby, Rovatsos, and Petrick 2013) based on the idea of automatic decomposition of classical planning problems to multiple agents, the MAP-LAPKT planner (Muise, Lipovetzky, and Ramirez 2015) based on solving of an encoded multiagent problem by a classical planner and CMAP (Borrajo and Fernández 2015) based on subgoal extraction and factored compilation to classical planning.

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[3] http://www.inf.kcl.ac.uk/research/groups/planning

[4] CoDMAP results: http://agents.cz/codmap/results

The distributed track won a variant of the PSM planner (Tozicka, Jakubuv, and Komenda 2014) based on intersection of finite automatons representing sets of agents' local plans coined Planning State Machines (PSM). Second place occupied MAPlan (Fišer, Štolba, and Komenda 2015), a distributed heuristic search planner. The multi-heuristic partial-order forward-chaining planner MH-FMAP (Torreño, Onaindia, and Sapena 2014) placed as third.

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