

Since AI planning gradually unfolds with the development of other areas like state-space search, theorem proving, control theory, as well as the need for practical purposes like robotics, scheduling and other domains (AIMA, Russel and Norvig, 2010), it has undergone several important transformations and is still a developing area in the present age. This review will introduce three of the important transformations, including the development of Action Language, the transition from totally ordered planning to partially ordered planning, and the later resurgence of partially ordered planning.

An Action Language is a language for specifying state transition system and is commonly used to create formal models of actions in the world<sup>1</sup>. In the AI planning context, Action language is used to denote the composition of components that define a transition in state space. The first major Action Language, the Action Description Language (ADL), advances from STRIPS (Stanford Research Institute Problem Solver)<sup>2</sup>, covers broader syntax to describe more variety of problems than STRIPS does, for instance, ADL allows goals to have conjunctions and disjunctions and supports equality predicate<sup>3</sup>. While later, another type of language named PDDL (Planning Domain Definition Language), is an attempt to standardize AI planning languages by introducing a computer-parsable, standardized syntax for representing planning problems and it has been used as the standard language for International Planning Competition (IPC) since 1998 (AIMA, Russel and Norvig, 2010). The latest version of this language is version 3.1, which introduced object-fluents<sup>4</sup>, meaning that functions' range could now be any object-type instead of limited to numerals.

With the language transition in mind, the structure of planning also undergoes significant change, marked first by the transition from totally ordered planning to partially ordered planning. One of biggest issue that totally ordered planning, a.k.a linear planning, has proposed is its incompleteness, illustrated by its lack for interleaving (AIMA, Russel and Norvig, 2010), which means that actions from different subplans cannot be drawn independently to form a parent plan (AIMA, Russel and Norvig, 2010). Partially ordered planning proposes a solution to this problem by introducing a system of conflict detection and interference protection (AIMA, Russel and Norvig, 2010).

However, in 1996, there has been a resurgence of interest in state-space planning, pioneered by McDermott's UNPOP program (AIMA, Russel and Norvig, 2010). This program suggests an ignore-delete-list heuristic, which proposes that all negative effects of available planning operators are empty<sup>5</sup> and has led to many future state-space search innovations such as FF (Fast Forward) and FD (Fast Downward) (AIMA, Russel and Norvig, 2010).

These considerable developments in AI planning has advanced and sparked more researches in this area, particularly because of the usefulness of planning to solve, practical, NP-Hard problems<sup>6</sup>. Currently, there have been regular international planning conferences and workshops available globally, offering a wide platform to communicate and learn.

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<sup>1</sup> Michael Gelfond, Vladimir Lifschitz (1998) "Action Languages", *Linköping Electronic Articles in Computer and Information Science*, vol 3, nr 16.

<sup>2</sup> Richard E. Fikes, Nils J. Nilsson (Winter 1971). "STRIPS: A New Approach to the Application of Theorem Proving to Problem Solving" (PDF). *Artificial Intelligence*. 2 (3–4): 189–208

<sup>3</sup> Edwin P.D. Pednault. ADL. Exploring the Middle Ground Between STRIPS and the Situation Calculus. In Proceedings of KR-89, 324-332

<sup>4</sup> Helmert, M. (2008). "Changes in PDDL 3.1". *Unpublished summary from the IPC-2008 website*

<sup>5</sup> Hoffmann, J. (2005). "Where "Ignoring Delete Lists" Works: Local Search Topology in Planning Benchmarks". *Journal of Artificial Intelligence Research* 24 (2005) 685-758

<sup>6</sup> Ghallab, Malik; Nau, Dana S.; Traverso, Paolo (2004) *Automated Planning: Theory and Practices*