AI Planning, A Historical Overview

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Goals

1. Provide a historical overview of the developments in the field of AI Planning and Search
2. Select 3 important developments and describe the impact on the field of AI
3. Present the report as research_review.pdf

Overview

The overall techniques in Planning are

- State Space Search
- Plan Space Search
- Linear PLanning
- Partial Ordered Planning (non-linear)
- Graph Plan
- SAT
- Symbolic Search
- Temporal Planners

Timeline

Some of the documents as gathered from the Russel, Norvig text and other sources.

year	topic	authors	advancement	notes
1961	Linear		General Problem Solver (GPS)	
1963	Linear	John McCarthy	Situational Calculus	The situation calculus approach to planning was introduced
1971	Representation		STRIPS	

1974	Linear	Warren	WARPLAN	
1975	Linear		result: Linear Planning is incomplete	
1975	Linear	Waldinger	Interleaving achieved via goal-regression planning	
1975	POP	Tate	Detection of conflicts	
1975	POP	Sussman	Protection of achieved conditions from interference	
1977	POP	Sacerdoti	NOAH Planner	Pioneered construction of POP (aka task networks)
1977	POP	Tate	NONLIN Planner	
1986	Representation		Action Description Language (ADL)	
1987	POP		Searializable subgoals	
1987	POP	Chapman	Formal Exposition of POP with TWEAK Planner	Proof of completeness and intractability
1990	Survey	Allen	Readings in Planning	Comprehensive anthology of early work in the field
1991	POP	McAllester and Rosenblitt	Complete partial order planner	
1991	POP	Soderland and Weld	SNLP Planner	widely distributed

1992	POP	Penberthy and Weld	UCPOP Planner	
1992	Representation		result: STRIPS is PSPACE-complete	
1992	SAT	Kautz, Selman	Planning as satisfiability	Proc. ECAI-92, Vienna, Austria, 359–363
1994	Graph Planning	Ghallab, Laruelle	IXTET partial-order planner used it to derive accurate heuristics to guide searches	Data structure closely resembling the planning graph
1996	State Space	Drew McDermott	UNPOP program	First to suggest the ignore-delete-list heuristic
1997	Graph Plan	Avrim Blum, Merrick Furst	GRAPHPLAN	Revitalized the field of planning with their GRAPHPLAN system, which was orders of magnitude faster than the partial-order planners of the time
1997	Representation	Ernst		Automatic “compiler” for generating propositional representations from PDDL problems
1997	Graph Planning	Koehler	IPP	
1998	Binary Decision	Cimatti	Planner based on Binary Decision Diagrams	
1998	Graph Planning	Fox,Long	STAN	
1998	Graph Planning	Weld	SGP	

1998	Graph Planning	Kautz,Selman	BLACKBOX planner	Combines ideas from GRAPHPLAN and SATPLAN
1998	Representation		PDDL	
1994,1999	Survey	Weld	Provides two excellent surveys of planning algorithms of the 1990s. It is interesting to see the change in the five years between the two surveys: the first concentrates on partial-order planning, and the second introduces GRAPHPLAN and SATPLAN.	
1999	Constraint	van Beek	CPLAN	Based on constraint satisfaction
1999-2006	State Space	Bonet and Geffner, Haslum	Heuristic Search Planner HSP	Made state-space search practical for large planning problems, HSP searches in the forward direction
1999	State Space	Bonet and Geffner	HSPR	searches backward
2000	Representation		ADL to STRIPS compiling	
2001	POP	Nguyen and Kambhampati	REPOP Planner (scales better than GRAPHPLAN in parallelizable domains), Uses	

			accurate heuristics derived from a planning graph	
2001, 2005	State Space	Hoffman, Nebel	FF	The most successful state-space searcher, winner of the AIPS 2000 planning competition
2001	General	Vosse		survey the use of integer programming for planning
2001	Analysis	Nguyen		thoroughly analyze heuristics derived from planning graphs.
2001	Survey	Helmert		Analyzes several classes of planning problems, and shows that constraint-based approaches such as GRAPHPLAN and SATPLAN are best for NP-hard domains, while search-based approaches do better in domains where feasible solutions can be found without backtracking. GRAPHPLAN and SATPLAN have trouble in domains with many objects because that means they must create many actions. In some cases the problem can be delayed or avoided by generating the propositionalized actions dynamically, only as needed, rather than instantiating them all before the search begins.
				searched planning graphs

2002	Planning graph	Gerevini, Serina	LPG	using a local search technique inspired by WALKSAT. The winner of the 2002 AIPS planning competition.
1994, 2004	Analysis	Bylander, Ghallab		discuss the computational complexity of several variants of the planning problem
2003	Analysis	Helmert		proves complexity bounds for many of the standard benchmark problems
2004	Textbooks	Ghallab	Automated Planning	An excellent textbook on all aspects of planning
2005	Analysis	Hoffmann		analyzes the search space of the ignore-delete-list heuristic
2006	Textbooks	LaValle	Planning Algorithms	Covers classical and stochastic planning, with extensive coverage of robot motion planning
2006	State Space	Helmert, Ritcher	FASTDOWNWARD	Forward state-space search planner that preprocesses the action schemas into an alternative representation which makes some of the constraints more explicit. Won the 2004 planning competition
2008	State Space	Richter and Westphal	LAMA	Base'd on FASTDOWNWARD with improved heuristics, won the 2008 competition
		Edelkamp,		Described how to construct

2009	Analysis	Haslum		pattern databases for planning heuristics

Important Developments

Non-Linear Planning

Around 1975, Linear planning was discovered to be incomplete. It could not handle simple cases as described in Sussman Anamoly. Researchers explored Parial ordered planners (non-linear planning)for more efficient solutions. Partial Ordered Planners(POP) were proven to be complete. This technique are best suited for problems that could be decomposed into independent sub tasks. Using a least-commitment approach, multiple paths are explored in parallel. It can be implemented as a search of partially-ordered plans. Ordering constraints and causal links can be used to encode the plan. Some of the Non-linear plans:

- NOAH Planner(defined task networks)
- NONLIN Planner
- TWEAK Planner(Proof of completeness and intractability)
- SNLP Planner
- UCPOP Planner

Impact: Expanded the capability of AI planners to allow decomposability and solve problems that were not solvable by linear planners.

GRAPHPLAN

Introduced by Blum, Furst in 1997, GRAPHPLAN outperformed the partial order planners of its day. The authors introduced the concept of a Planning Graph. Planning graph is constructed from the problem statements described in STRIPS (or PDDL). The planning graph encodes the problem in such a way that many useful constraints are explicitly available to reduce search space. Also the Planning Graph is not a state-space graph. A path in the Planning Graph is essentially a flow. The search combines aspects of both total and partial order planners. It guarantees the shortest path. It is a directed levelled graph with alternating levels of propositions and actions. Once the Planning Graph is constructed, a GRAPHPLAN algorithm is run on it to extract a valid plan.

Impact: Order of magnitude reduction in time taken to solve planning problems

SATPLAN

Proposed in 1992 by Kautz, Selman in their paper "Planning as satisfiability", it was a new way to encode palnning problems. Soon compilers were developed to translate the STRIPS domain representation to a SAT domain representation, which was then solved using a Solver (systematic or stochastic). The basic representation is a function and quantifier free typed predicate logic. The problem is encoded as a schema which is conjunction of formulas. The advantage of such a system is tha any intermediate state constraints can be represented easily. Since the length of a theory is bounded by O(kc^d), where d is the number of quantifiers nesting in a schema (arguments to a predicate). Simple Action Splitting is used to reduce n-ary fluents (predicates) to unary predicates. Davis-Putman procedure (DP) or GSAT (randomized local search) procedure is used for solving.

Impact: Provided a new way of modelling planning problems as SAT problems to use existing SAT solvers to find solutions. It moved from deduction formalized planning to first order propositional satisfiability.

Temporal Planning

Recently temporal planning explores AI planning in real world time domain, instead of time-steps as used by planners. Problems are representing using temporal extensions to PDDL or using NDL. The problem domain is reduced to SMT (Satisfiability Modulo Theories) and then solved.

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