A Summary of STRIPS, GRAPHPLAN, and ASPEN

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The Stanford Research Institute Problem Solver (STRIPS) was the result of the efforts of Richard Fikes, Nils Nilsson, Bertram Raphael, Thomas Garvey, John Munson, and Richard Waldinger. STRIPS is a framework for problem solving that was central in AI research during its time. As a problem solver, STRIPS attempts to transform initial world conditions through a sequence of operators in order to achieve a goal state. STRIPS focused on a “...class of problems faced by a robot in re-arranging objects and in navigating...” (Fikes and Nilsson, 1971). From 1966 to 1972, Shakey the Robot, the seminal contribution to AI, used STRIPS to assess its environment and construct a plan to achieve various goals during this project (Kuipers, et. al., 2017).

GRAPHPLAN revolutionized the study of AI planning. It was developed by Avrim Blum and Merrick Furst in 1997 and develops plans in “STRIPS-like” domains by constructing and analyzing a planning graph, and generating a shortest possible partial order plan. The planning graph is represented by levels of states and actions of the planning problem, and from which is extracted a solution by conducting a regressive search of the solution for each subgoal. By using mutual exclusion to prune the search space, recording unreachable goal sets at specific points in time, considering partial parallel plans that to keep search cost low, and constructing planning graphs in advance of search, GRAPHPLAN outperformed other planners of its day (Blum and Furst, 1997, and Weld, 1999).

Automated Scheduling and Planning Environment (ASPEN) has been used in automating space operations (Chien, et. al., 2000). It automates the generation of low-level spacecraft sequences from high level goals. The central data structure ASPEN is an activity, which describes a specific function the spacecraft performs for a specific time using one or more resources (Sherwood, et. al., 1998). ASPEN uses an iterative repair algorithm to search the space of schedules and resolve activity conflicts (Rabideau, et. al., 1999). ASPEN’s heuristics for plan selection include preferring those conflicts that require new activities, preferring moving an activity over other types of deconfliction, and time intervals that resolve the conflict but do not create other conflicts. ASPEN has been used in Citizen Explorer-1, Antarctic Mapping Mission-2, and the Deep Space Terminal.

References:

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Sherwood, R., Govindjee, A., Yan, D., Rabideau, G., Chien, S., & Fukunaga, A. Using ASPEN to Automate EO-1 Activity Planning. *Proceedings of the 1998 IEEE Aerospace Conference*, Aspen, CO, March 1998.

A summary Three key developments in the topics of AI Search and Planning are

- What is it

- Primary developer

- Who was involved

- What ja sot led to

- What is the impact

STRIPS

1. <http://ai.stanford.edu/~nilsson/OnlinePubs-Nils/PublishedPapers/strips.pdf>
2. <http://aima.cs.berkeley.edu/2nd-ed/newchap11.pdf>
3. <http://ai.stanford.edu/~nilsson/OnlinePubs-Nils/General%20Essays/Shakey-aimag-17.pdf>

- Stanford Research Institute Problem Solver

- Problem solver

- Developed by in Bertrmn Raphael, Thomas Garvey, John Mtmson, ndd Richard Waldinger, all members of the Artificial Intelligence Group at SRL (1)

- Finds a sequence of operators to transform initial states to goal states

- Operators are applied to applicable states resulting into new states. A sequence of operations finally leads to the goal.

- Researchers would like to generate computer programs. (1)

It would only be able to achieve goals that require just a single preprogrammed action. To do more, Shakey has to be able to compose a sequence of actions into a plan. That’s the job of STRIPS, the Stanford Research Institute Problem Solver, which constitutes the next higher software level

- It is the foundation from which other planning languages grew, “Almost all planning systems since then have used one variant or another of the STRIPS language” (Norvig & Russell, 2009)

STRIPS was designed as the planning component of the software for the Shakey robot project at SRI.

GRAPHPLAN

- 1. <https://www.aaai.org/ojs/index.php/aimagazine/article/viewFile/1459/1358>

Recent Advances in AI Planning

- 2. <https://www.cs.cmu.edu/~avrim/Papers/graphplan.pdf>; Fast Planning Through Planning Graph Analysis

Graphplan (Blum & Furst, 1997)

- Able to solve solve problems quickly than previous problem solver of it’s time (1)

- starting with a Planning Graph that only has a single proposition level containing the Initial Conditions, Graphplan runs in stages. In stage i Graphplan takes the Planning Graph from stage i − 1, extends it one time step (the next action level and the following proposition level), and then searches the extended Planning Graph for a valid plan of length i. Graphplan’s search either finds a valid plan (in which case it halts) or else determines that the goals are not all achievable by time i (in which case it goes on to the next stage).

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HSP

- 1. <http://www.cs.toronto.edu/~sheila/2542/s14/A1/bonetgeffner-heusearch-aij01.pdf>

- <http://www.cs.toronto.edu/~sheila/2542/w06/readings/RintanenHoffmann01.pdf>

- Bonet Geffner 1999

Impact? Made state space planning Practical for large planning problems

More recently, Bonet and Geffner's HSP planners[Bonet and Geffner, 2001], which use plain forward or backward chaining, have showed very good performance on many benchmark problems, and increased interest in heuristic search as a planning technique.

BDD as a solution to planning problem

Plan represented as BDD

Cimmatti article

ASPEN

https://www.researchgate.net/publication/2431151\_ASPEN\_-\_Automated\_Planning\_and\_Scheduling\_for\_Space\_Mission\_Operations

ASPEN (Automated Scheduling and Planning ENvironment) encodes spacecraft operability constraints, flight rules, spacecraft hardware models, science experiment goals, and operations procedures to allow for automated generation of low-level spacecraft sequences. By automating the command sequence generation process and by encapsulating the operations specific knowledge, ASPEN enables space missions to be controlled by a small operations team - thereby reducing costs  
*ASPEN - Automated Planning and Scheduling for Space Mission Operations (PDF Download Available)*. Available from: <https://www.researchgate.net/publication/2431151_ASPEN_-_Automated_Planning_and_Scheduling_for_Space_Mission_Operations> [accessed Jul 3, 2017].

The job of a planner/scheduler, whether manual or automated, is to accept high-level goals and generate a set of low-level activities that satisfy the goals, do not violate any of the spacecraft flight rules or constraints, and optimize the quality of the plan.  
*ASPEN - Automated Planning and Scheduling for Space Mission Operations (PDF Download Available)*. Available from: <https://www.researchgate.net/publication/2431151_ASPEN_-_Automated_Planning_and_Scheduling_for_Space_Mission_Operations> [accessed Jul 3, 2017].

ASPEN has been applied to automated sequence generation for rovers and is also being use foronboard planning for rovers.

<https://sensorweb.jpl.nasa.gov/public/papers/ieee98_eo1.pdf>

The central data structure in ASPEN is an activity. An activity represents an action or step in a plan/schedule. An activity has a start time, an end time, and duration. In

As previously mentioned, activities are the central data structure of ASPEN. An activity is a data structure that performs a specific function.

https://www.aaai.org/ojs/index.php/aimagazine/article/view/1278/1179

To reduce this development effort, the AI group at JPL has been working on ASPEN (Fukunaga et al. 1997a), a modular, reconfigurable application framework that is capable of supporting a wide variety of planning and scheduling applications. ASPEN provides a set of reusable software components that implement the elements commonly found in complex planning-scheduling systems, including an expressive modeling language, a resource-management system, a temporal reasoning system, several search engines, and a graphic user interface (GUI). The primary application area for ASPEN is the spacecraft operations domain.

Planetary Rovers

https://www.frc.ri.cmu.edu/projects/mars/publications/global\_local\_icra2000.pdf