

# Planning – Research Review

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AI Planning has made its place as a sub-field of AI with the introduction of STRIPS (Stanford Research Institute Problem Solver) by Fikes and Nilsson (Long and Fox 2002) (Norvig and Russell 2009). In this research review we will introduce 3 planning systems that has advanced the field of AI Planning over the years.

Initial planning system which got wide success was the GraphPlan system. Graph plan operated in STRIPS like domains and works by building Planning Graphs. Many constraints are encoded in the problem such that the graph can be searched easily. Planning Graphs don't create graphs of the state space, rather they create a network of actions which leads to the goal state. Planning Graphs have 2 types of nodes representing Propositions and Actions. The edges represent the relation between the proposition and the action state. Mutual Exclusion relations where performing 2 actions at the same level leads the planner to an invalid plan are encoded the planning graph. This speeds up the search and helps reduce the time taken to find a valid plan. Search is performed through backward propagation recursively searching for actions starting from the goal state. This leads us to a valid plan or terminates if a valid plan is not possible in the graph. GraphPlan's limitation is that it only works in STRIPS like domains (Blum 1997). If there is uncertainty in the precondition or effect such as the action "Paint everything in the room red" GraphPlan does not work well in these domains.

Success of GraphPlan led to research in planning based on heuristics. One of the planning systems developed which made use of heuristics is HSP (Heuristic Search Planner). HSP was submitted as a planner in the AIPS98 planning contest and was the first practical planner that implemented state space search[4]. HSP derives the heuristic function from the high level representation of state and goals. Hence the planner itself is domain independent. The HSP Planner builds the heuristic function by ignoring the "delete list" or the negative effects of actions (Bonnet and Geffner 1998). The algorithm used in the original planner was a greedy search which restarts if it is detected to be stuck in the local minima. Greedy search was chosen mainly for speed, however other heuristic search algorithms such as A\*, hill-climbing search can also be used. HSP is not guaranteed to be optimal.

MIPS (Model-Checking Integrated Planning System) is a relatively newer planning system which is as competitive as GraphPlan or SAT based systems. MIPS uses BDDs (Binary Decision Diagrams) to compute an optimal plan with less computing resources than other plans. BDDs are advantageous given that they represent states in a compact manner. BDDs use a tree data structure with a positive and negative sink. They are similar to decision trees however they achieve compactness through reductions such as unnecessary variable tests and isomorphisms in subgraphs (Edelkamp and Helmert 2001). MIPS encodes PDDL states as Boolean logic states and precompiles it into a BDD which shows if an action is possible or not in the state. It then uses Breadth First Search to find the optimal plan if it exists. The algorithm terminates if such a plan does not exist. The main advantage of MIPS is that during

precompilation the state space is represented concisely through BDDs which makes it easy to do represent states and do transitions.

In this paper we saw the GraphPlan, HSP and MIPS planning system. As more research is being done in this field, planners are getting better and is being widely used in scientific and industrial fields.

## Bibliography

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