Linear, Non-Linear and Temporal Planning

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Planning and search is a fundamental and exciting area of research Artificial Intelligence. Three key components in intelligent planning problems are goals, actions and states. These components are used by an intelligent agent to achieve some stated goal through reasoning about future states and plotting a sequence of actions towards this goal. In this paper I will discuss Linear Planning, Non-Linear Planning and Temporal Planning, three key developments in the history of planning in Artificial Intelligence.

Some of the earliest work in planning began in the 1970's with Linear Planning. [Norvig] The fundamental concept behind Linear Planning is that an agent is to work on a single goal until a problem is completely resolved. After completing the first goal the agent is then free to move on to a next goal. These linear planning algorithms rely on totally ordered action sequences, where problems can be decomposed into subgoals. [Poole] These early system are still advantageous over the other techniques in their simplicity. Linear techniques produce a small search space when compared to the later techniques because goals are resolved in a serial fashion. However the Linear Planning techniques carry a number of drawbacks. First, these may produce suboptimal solutions depending on the predefined ordering of goals. Secondly, some of the solutions can be overly specific, where some of the ordering are accidental by forcing an ordering of input operators where they aren't required to be mutually ordered. The third major drawback is known as the Sussman anomaly, which shows that by naively pursuing a subgoal, after completing another subgoal, the second goals may clobber the first goal.

The second major advancement in planning techniques was developed in 1980's through 1990's [Norvig] referred to as Non-Linear Planning. The basic theory behind Non-Linear Planning is the use the goal as a set of unordered operators instead of a stack of ordered operators. [Simmons] These techniques have the advantage of producing optimal results and executions which allow for more flexibility in the parallel execution of sub plans by taking advantage of decomposition and partial ordering of sub goals. A non-linear plan can also be considered efficient because the plan consists of a set of ordered linear plans, so it may be able to avoid backtracking through the graph if state conflicts are detected. The major disadvantage of this technique lie in the growth in the number of possible states of creates a much larger search space, this is often referred to as the curse of dimensionality. The large search space in turn requires a more complex search algorithms.

The fore mentioned two classical planning techniques of Linear and Non-Linear planning have a deficiency in that they do not account for time. They assume actions have no duration and instantaneously transform their state. However in real world problems such as scheduling and robotics we know actions can be messy, they occur over a span of time and events can overlap, run concurrently and create dependencies. These real world constraints required the development of another technique know as Temporal Planning which adds the notion of time and accounts for the duration of the agents actions. In Linear and Non-Linear planning preconditions are accounted for only at the beginning of actions, not only at the beginning and actions can begin at any point in an infinite amount of time. [Cushing] In

Temporal Planning actions are allowed to overlap with actions working concurrently. [Cushing] Multiple actions can be taken simultaneously while their durations may vary, and actions and events may have complex interdependencies which determine which combinations are possible. [Sandewall]

Planning is a fundamental component of Artificial Intelligence, rooted in very practical needs of robotics, planning and sensing. [Nrovig] This has been shown to be a fruitful area of research and development. Through the course of history in Artificial Intelligence we can see techniques have developed to better abstract the real world. However this additional intricacy in abstraction creates increasing complexity in planning techniques.

References:

Cushing, William. Mausam, Subbarao Kambhampati, Weld, Daniel S. When is Temporal Planning Really Temporal? Dept. of Comp. Sci. and Eng. Arizona State University, Dept. of Comp. Sci. and Eng. University of Washington. The AAAI conference on Artificial Intelligence.

Penberthy, J. Scott. Weld, Daniel S. Temporal Planning with Continuous Change*. IBM T.J. Watson Research Center. Department of Computer Science and Engineering, University of Washington. AAAI-94 Proceedings. Copyright © 1994

Poole, David Mackworth, Alan. 8 Planning with Certainty in Artificial Intelligence, Foundations of Computational Agents. 2010. http://artint.info/html/ArtInt_200.html

Russell, S and Norvig P. 2010 Artificial Intelligence: A Modern Approach 3rd ed. Pearson Education Limited.

Sandewall, Erik and Sweden. Current Trends in Artificial Intelligence Planning, (Frontiers in Artificial Intelligence and Applications)) European Workshop on Planning 1993.

Simmons, Reid, Veloso. Planning, Execution & Learning. 2001. https://www.cs.cmu.edu/~reids/planning/handouts/Linear.pdf