

RESEARCH BRIEF

ORDERED TASK DECOMPOSITION FOR AI PLANNING SOFTWARE

Developing resources for planners

Dana Nau and his research team develop theories, algorithms, and Artificial Intelligence (AI) planning software to aid human planners in project management, plan storage and retrieval, and automatic scheduling. Their ordered task decomposition approach has been implemented in several different award-winning planning systems.

Better planning tools are needed

Computer programs such as project management software, plan storage and retrieval and automatic schedule generation already aid human planners. However, for some problems, we really want to generate plans automatically. This is much more difficult for software to do, and there are very few successful programs for realistic problems. Of the few really good plan generation systems, most involve AI planning techniques. In theory, AI planning involves symbolic computations, a single agent (the planner), and perfect information. However, AI planning in practice involves complex numeric computations, multiple agents and imperfect information from external information sources. Better theories of planning are needed that take into account real-world conditions so that more useful planning software results.

The ordered task decomposition approach

Hierarchical task network (HTN) planning creates a plan to perform a set of tasks. It works through problem reduction: the planner recursively decomposes tasks into subtasks, stopping when it reaches primitive tasks that can be performed directly by planning operators. It has a set of methods, where each method is a schema for decomposing a particular kind of task into a set of subtasks (provided that some set of preconditions is satisfied). This tells the planner how to decompose nonprimitive tasks into subtasks. Of course, there may be more than one applicable method for each task, and thus more than one way to decompose the task into subtasks. The planner may have to try several alter-

native decompositions before finding one that is solvable at a lower level.

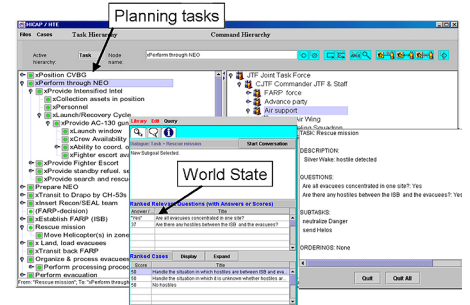
Ordered task decomposition (OTD) is a special case of HTN planning in which the planning algorithm always builds plans forward from the initial state of the world in the same order that the tasks will later be performed. At each point in its planning process, the planner has already planned every action that will occur beforehand, so it has already determined what the current state will be. It is both forward and goal-directed at the same time.

This allows the ISR researchers to put powerful precondition-evaluation mechanisms into the planning algorithm. These can include logical inferences, complex numeric computations, and calls to external programs.

Examples

The SHOP project has developed a family of planning systems that can be configured to work in many different domains. When SHOP is given a state (a set of ground atoms), a linear list of tasks and a domain (methods, operators and axioms), it can output the first plan it finds, all possible plans, a least-cost plan, all least-cost plans, and so forth. The SHOP family includes SHOP, SHOP2 and JSHOP.

Bridge Baron. Nau's team incorporated OTD into Bridge Baron commercial computer bridge-play-



JSHOP is being used as part of the Naval Research Laboratory's HICAP plan-authoring system.

OTD puts powerful precondition-evaluation mechanisms like logical inferences, complex numeric computations, and calls to external programs into the planning algorithm.

The SHOP family of AI planning software has won international awards for its capabilities.

ing software. Bridge is a game of planning, and the team created code for a game tree for declarer play. This code enabled Bridge Baron to win the 1997 World Bridge Computer Challenge, the world championship of computer bridge. Bridge Baron's victory received mention in both The New York Times and The Washington Post. It has been used in all versions of the software since then.

Electronic design and manufacturing. EDAPS, the Electro-Mechanical Design and Planning System, was a prototype that augmented the traditional engineering design loop by planning and evaluating what manufacturing processes will be needed, predicting the cost, time, quality and manufacturing problems, and modifying the design to improve its manufacturability. EDAPS was able to express planning using "recipes" that fit well into HTN methods. It generated and evaluated multiple process plans, estimated times and costs and displayed the results graphically.

Noncombatant Evacuation Operations. The Naval Research Laboratory is using JSHOP as part of its HICAP plan-authoring system. This system could someday assist in evacuating noncombatants, nonessential military personnel, host-nation citizens, and third-country nationals during times of foreign joint or multinational task force crisis. HICAP is an interactive decision support tool, guided by military doctrine, with the user in control.

Internet agents. ASHOP, an agentized version of JSHOP, runs in the IMPACT multi-agent environment developed by V.S. Subrahmanian's group (CS/ISR), which provides an environment for developing and deploying software agents. IMPACT has users worldwide. Nau's group developed the theory and implementation for ASHOP and deployed ASHOP as an agent in the IMPACT framework. ASHOP was able to develop correct plans and could be accelerated substantially by modifying it to cache the results of its queries to the other agents.

Awards

SHOP2 won one of the top four prizes in the International Planning Competition at AIPS-2002.

Bridge Baron won the 1997 World Bridge Computer Challenge.

Downloads available

SHOP2, SHOP, and JSHOP may be downloaded at no charge at www.cs.umd.edu/projects/shop/download.html.

The software package has been downloaded hundreds of times and is being actively used by researchers at several different labs, including the Naval Research Laboratory and the National Institute of Standards and Technology.

The software is ©2002 University of Maryland and is distributed under an MPL/GPL/LGPL triple license, on an "AS IS" basis, WITHOUT WARRANTY OF ANY KIND, either express or implied. SHOP and SHOP2 require Common Lisp to run, while JSHOP requires Java 2 (JDK 1.2 or greater).

Contact

Dana S. Nau

Professor, ISR and Computer Science
3245 A.V. Williams Bldg.
University of Maryland
College Park, MD 20742

Phone: 301.405.2684
Fax: 301.314.9920
Email: nau@cs.umd.edu
Web: www.cs.umd.edu/~nau/

Publications related to ordered task decomposition are available at Dana Nau's web site.