

Project 1: Classical Planning

Robot Intelligence: Planning 8803

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1 Administrative

- **Due Date:** 11:59pm September 21, 2009
- **Deliverables:** Email the TA+Instructor a zip file that includes your code and results in an organized form with a README on how to run the code to re-create the results. Also, attach a 3-4 page PDF summary that describes your work, results and addresses the questions posed below. The summary should list your group members' names. **Print the summary and bring it to class.**

2 Pre-Project: Towers of Hanoi

A famous problem in classical planning is the *Towers of Hanoi*. Apparently, some priests in Vietnam are required to stack enormous discs from one tower to another by command of an ancient prophecy. Lets help them out with modern automation. The discs must always be stacked in order of increasing height. The goal is to move all the discs from the first tower to the third.

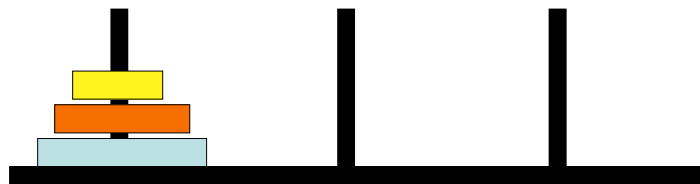
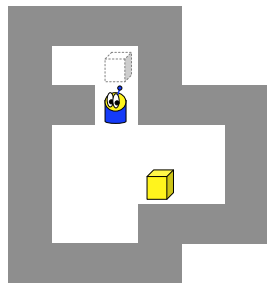


Figure 1: The towers of Hanoi

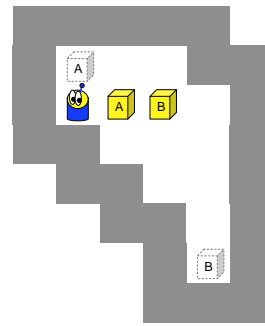
Experiment with at least two different classical planners to solve this problem. Links to the domain are provided on the course web page. Note the separation between the domain and problem definitions. The page also contains links to some recommended planners. You are welcome and recommended to try other planners as well.

2.1 Questions

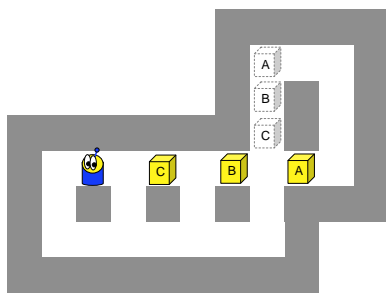
1. Explain the method by which each of the two planners finds a solution.
2. Which planner was fastest?
3. Explain why the winning planner might be more effective on this problem.



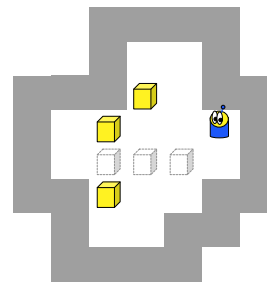
(a) Problem 2.1



(b) Problem 2.2



(c) Problem 2.3



(d) Sokoban Challenge

Figure 2: Sokoban Problems

3 Project Part I: Sokoban PDDL

During the times of Pong, Pac-Man and Tetris, Hiroyuki Imabayashi created an complex game that tested the human abilities of planning: Sokoban. Many folks are still addicted to solving Sokoban puzzles and you can join them by playing any of the versions freely distributed on the web. The goal is for the human, or robot, to push all the boxes into the desired locations. The robot can move horizontally and vertically and push one box at a time.

Describe the Sokoban domain in PDDL. For each of the problems in Figure 2, define a problem in PDDL. In addition you may are also try other problems you invent or find on the web. How well do your two planners perform on these problems? If no planner seems to be solving it, perhaps you should consider a different method for defining your problems. While Sokoban typically does not explicitly state where each box should go, existing planners don't fare well with complex goals. It is OK to specify desired locations for each box as shown in the figure.

3.1 Questions

1. Show successful plans from at least one planner on the Sokoban problems in Figure 2 (1-3).
2. Compare the performance of two planners on this domain. Which one works better? Does this make sense, why?

3. Clearly PDDL was not intended for this sort of application. Discuss the challenges in expressing geometric constraints in semantic planning.
4. In many cases, geometric and dynamic planning are insufficient to describe a domain. Give an example of a problem that is best suited for semantic (classical) planning. Explain why a semantic representation would be desirable.

4 Project Part II: Sokoban Planner

You may now think that the difficulty of this problem has to do with PDDL. Your instructor seriously doubts that. Lets try an experiment. Define the Sokoban in any way that you like and write a computer program that solves it. Your instructor recommends you start with some kind of simple state space search and then see if you can make it faster.

Test your planner on the sample problems in Figure 2 and any other examples you find interesting. **Make sure that your planner addresses the following points:**

- The planner must be complete.
- Your state representation should be efficient.
- The planner should make an effort to be fast.

To give you feedback on how well you accomplished these objectives we conduct an informal competition for who can produce the most *optimal* planner for the 4th problem. Purportedly this is a difficult problem for humans to solve - have a go at it before you let your planner do the work! If your planner can solve it, include the solution and report the following pieces of information:

1. Computation time for "Sokoban Challenge" (and the other problems)
2. Number of steps in your plan
3. Number of states explored
4. Language used
5. Machine vitals

The winner will get a banana!

4.1 Questions

1. Give successful plans from your planner on the Sokoban problems in Figure 2 and any others.
2. Compare the performance of your planner to the PDDL planners you used in the previous problem. Which was faster? Why?
3. Prove that your planner was complete. Your instructor has a math background: a proof "is a convincing argument." Make sure you address each aspect of completeness and why your planner satisfies it. Pictures are always welcome.
4. What methods did you use to speed up the planning? Give a short description of each method and explain why it did or didn't help on each relevant problem.

5 Post-Project: Towers of Hanoi Revisited

Having struggled to solve Imabayashi-san's puzzles, maybe we have a better feel for what planning is all about. Lets take another trip out to Hanoi. With modern automation, the monks aspire to even greater challenges. They can now solve Hanoi tower problems where there are six (6) disks on the first tower. Can your planners from Problem 1 do this? Change the PDDL specification so that you can solve the problem with 6, and even 10 disks.



Figure 3: The towers with N disks.

5.1 Questions

1. Give successful plans from at least one planner with 6 and 10 disks.
2. Do you notice anything about the structure of the plans? Can you use this to increase the efficiency of planning for Towers of Hanoi? Explain.
3. In a paragraph or two, explain a general planning strategy that would take advantage of problem structure. Make sure your strategy applies to problems other than Towers of Hanoi. Would such a planner still be complete?