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| Sokoban Assignment |
| Intelligent Search – Planning |
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Sokoban is a computer puzzle game in which the player pushes boxes around a maze in order to place them in designated locations. While Sokoban is just a game, it models a robot moving boxes in a warehouse. As such, it can be treated as an automated planning problem. Sokoban is an interesting problem for the field of artificial intelligence largely due to its difficulty. The difficulty of Sokoban comes not from its branching factor of 4 (up, down, left, right), but because of the huge depth of the solutions. Additionally, a move may leave the puzzle in a state in which it is impossible solve, creating a state of deadlock. An important feature of this problem is the player can only push a single box at a time and is unable to pull any box.

# Assignment Aim

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The aim of this assignment is to design and implement a solver for Sokoban.

# Solver Overview

In order to find a solution to this problem, a number of uninformed and informed search methods were available. After considering each method carefully, it was decided that the A star graph search algorithm would be implemented for this assignment.

The A star search is an informed search algorithm. This means it searches all paths for the path which incurs the smallest cost, while first considering which path appears to lead to the solution quickest. This path is determined by whichever action minimises the following equation:

*n = last node on the path*

*g(n) = cost of the path from the start node*

*h(n) = heuristic that estimates the cheapest path from n to the goal*

This form of intelligent search allows the solver to search the problem space more efficiently than other methods, provided the heuristic is admissible. More details about heuristics and performance of the solver presented are discussed below.

## Heuristics

Heuristics are functions which estimate how close the current state is to the goal state. They are specifically designed for a particular search problem, with examples including the Manhattan distance or Euclidean distance for a shortest path finding problem. However, heuristics are only optimal if they are admissible. A heuristic is only admissible if it satisfies:

*h(n) = estimated heuristic cost*

*h\*(n) = true cost to the nearest goal*

Overall heuristics are good for larger problems that humans can't solve themselves. For the solver presented, the chosen heuristic choses the shortest sum of Manhattan distances between all boxes and their closest target. This was implemented as shown in Figure 1 below.

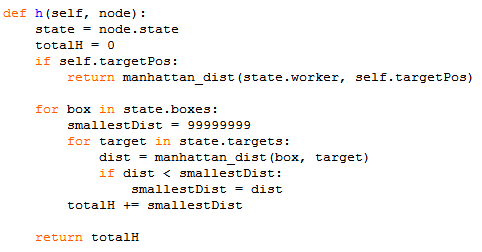


Figure 1: Python Implementation of Heuristic

An important note is that due to the use of a nested loop within the heuristic, the inner loop will be run n2 times, where n is the number or boxes/targets.

## Performance

When compared with a breadth first graph search, which searches the entire problem space for a solution, it was found that (on average) for a large search space an A star search was approximately 1.33 times faster than the BFS (as per Table 2). However, for smaller search spaces the A star search did take slightly longer than the BFS. Given the small overall time taken for both to solve the problem (less than a second), this loss of performance can be seen as negligible for smaller problem spaces. Table 1 below summarises the performance of both BFS and A star searches for different problem sizes.

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| --- | --- | --- | --- | --- | --- |
| Search Type | Number of Boxes | No. of Targets | Warehouse Size | Solution Found | Average Time Taken to Solve over 3 Runs |
| Breadth First Graph Search | 2 | 2 | 63 | Yes | 0.02604 seconds |
| A Star Graph Search | 2 | 2 | 63 | Yes | 0.03125 seconds |
| Breadth First Graph Search | 4 | 4 | 79 | Yes | 203.85 seconds |
| A Star Graph Search | 4 | 4 | 79 | Yes | 152.31 seconds |

Table 1: Performance of Breadth First and A Star Search

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| --- | --- | --- | --- | --- |
| Number of Boxes | Number of Targets | Warehouse Size | Faster Search Type | Times Faster |
| 2 | 2 | 63 | **Breadth First** Graph Search | 1.20 (approx.) |
| 4 | 4 | 79 | **A Star** Graph Search | 1.33 (approx.) |

Table 2 : Comparison of Performance for BFS and A Star

# Conclusion

The solver presented found that by applying an A star graph search to the problem, while suffering performance losses for smaller search spaces. Overall the A star graph search was faster at finding a solution than when compared with an uninformed breadth first graph search.