Chapter 5: Advanced Search

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meta-heuristic is a heuristic to guide another heuristic, can be used to avoid local optimal solution in favor of global optimal solution.

meta-* something to describe something else.

1 Constraint Satisfaction Search

1.1 The Eight-Queens Problem

- 8 queens must be placed on a chess board in a way that no two queens are on the same row, column or diagonal.

- Columns are labeled $a \rightarrow h$.

- Rows are labeled $1 \rightarrow 8$.

Brute force search is a search tree with 8 levels deep. The first level has a branching factor of 64. The second level has a branching factor of 63. The 8th level has a branching factor of 57. This is a very wide tree.

The branching can be significantly reduced by knowing that each column and row can only have one queen. This reduces the branching factor to 8 for the first level and 7 for the second level, . . .

If we apply each of the constraints the search tree is further reduced by removing future choices that would not fit the constraints. This is known as **forward checking**.

2 Forward Checking

Can significantly improve the performance of solutions for CSP's. As each queen is placed on the board a forward checking mechanism is used to delete a set of impossible future choices. If placing a queen removes all future choices, the system will backtrack.

A problem with chronological backtracking in the 8-queens problem is that the forward checking might backtrack moves that are not leading to errors.

3 Most-Constrained Variables

Heuristic for further performance improvement. At each stage of the search, work with the variable that has the least amount of possibilities. We can assign

a value of 1-8 to variables a-h to represent the row (1-8) and column (a-h) of each queen. If the initial state is $a = 1, b = 3, c = 5$, this leaves 3 choices for d, 3 choices for e, 1 choice for f, 3 choices for g and 4 choices for h. Then the next move should be in column f because it has the least possible choices.
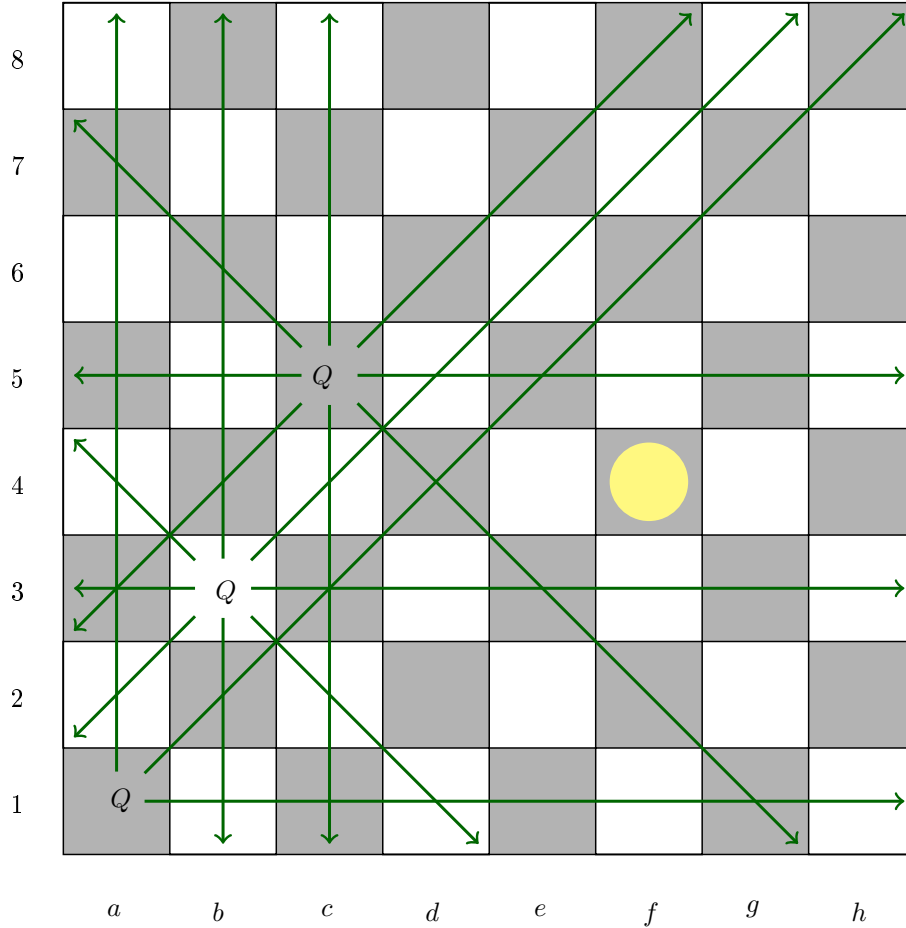

Figure 1: f is the most constrained variable.

4 Heuristic Repair

Used to improve the performance of finding solutions by generating a possible solution, either randomly or heuristic based, and altering the possible solution until it reaches the goal.

In the eight-queens problem, can be done by using a mini-conflicts heuristic. To move from one state to a state that is likely closer to the goal, select a queen that has a conflict with another queen, move this queen to a square where is conflicts with as few queens as possible, repeat this process until the goal is found.

A starting configuration with only one queen per row and column.

This method can be expanded to solve the n-queens problem, the 1,000,000-queens problem can be solved in about 50 steps where traditional search trees would involve branching factors of 10^{12}.

5 Local Search and Meta-heuristics

6 Simulated Annealing