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CS 4200

Project 2 Report

The N-Queen problem is an example of constraint satisfaction, where the goal is to place N queens on an N×N chessboard such that no two queens threaten each other. In this project, three local search algorithms were implemented to solve the 8-Queen problem:

- Steepest-Ascent Hill Climbing: iteratively selects the neighbor with the lowest heuristic value
- Simulated Annealing: introduces probabilistic moves to escape local optima
- Min-Conflicts: focuses directly on resolving conflicts for the most problematic queens

Approach:

Algorithms Implemented:

Steepest-Ascent Hill Climbing:

- generates all possible neighbors by moving each queen to a different row in its column
- selects the neighbor with the fewest conflicts
- stops when no neighbor improves the current state

Simulated Annealing:

- generates random neighbors and probabilistically accepts moves based on temperature
- gradually decreases the temperature to reduce randomness over time

Min-Conflicts:

- starts with a random configuration
- resolves conflicts by iteratively moving the most problematic queens to positions with the fewest conflicts
- supports restarts if no solution is found within a given number of steps

Testing Process:

Each algorithm was tested on 100 random instances of the 8-Queen problem.

Metrics collected:

- Success Rate: percentage of solved instances
- Average Search Cost: mean number of steps required
- Average Runtime: mean runtime in seconds

Results:

Steepest-Ascent Hill Climbing:

- Success Rate: ~12-20%
- Average Search Cost: ~3.1 steps
- Average Runtime: ~0.0005 seconds

Hill climbing performed poorly due to its tendency to get stuck in local optima. It often fails to find a solution.

Simulated Annealing:

- Success Rate: ~74-87%
- Average Search Cost: ~75 steps
- Average Runtime: ~0.0021 seconds

Simulated annealing performed well because its probabilistic moves allowed it to escape local optima. Proper tuning of the cooling rate and temperature ensured a balance between exploration and exploitation.

Min-Conflicts:

- Success Rate: ~66-80%
- Average Search Cost: ~120 steps
- Average Runtime: ~0.005 seconds

Min-Conflicts worked well by directly addressing conflicts, leading to rapid convergence. Its adaptive restarts improved performance for harder instances.

Findings:

Hill Climbing:

- Low success rate aligns with expectations due to its greedy nature
- The algorithm often gets trapped in local optima because it lacks the ability to explore worse states temporarily

Simulated Annealing:

- High success rate demonstrates the effectiveness of probabilistic exploration
- Performance depends heavily on parameter tuning

Min-Conflicts:

- Solved most instances, approaching the performance of simulated annealing
- Efficiently resolves conflicts but can struggle with poor initial configurations, requiring restarts to improve success rates

Why These Results Occur:

- **Hill Climbing:** The algorithm's greedy nature means it can easily get stuck in local optima where no single step improves the solution, leading to a low success rate. Its simplicity makes it fast but ineffective for more complex configurations.
- **Simulated Annealing:** By allowing moves to worse states probabilistically, it avoids local optima and explores the solution space more effectively. The success rate is high due to this flexibility, but performance depends on the cooling schedule and initial temperature.
- **Min-Conflicts:** The algorithm focuses on directly resolving conflicts and is designed for constraint satisfaction problems. While generally effective, it can fail if the initial

configuration is too poor or if it gets stuck cycling between near-solutions. Adaptive restarts mitigate these issues and improve success rates.

```
hill climbing success rate: 16.0%
hill climbing average steps: 3.1
hill climbing average time: 0.0005 seconds

final hill climbing solution:
. . Q . . . . .
. . . . . Q . .
. . . Q . . . .
. Q . . . . . .
. . . . . . . Q
. . . . Q . . .
. . . . . . Q .
Q . . . . . . .

simulated annealing success rate: 84.0%
simulated annealing average steps: 72.47
simulated annealing average time: 0.0020 seconds

final simulated annealing solution:
. . . . . Q . .
. . . Q . . . .
. . . . . . Q .
Q . . . . . . .
. . Q . . . . .
. . . . Q . . .
. Q . . . . . .
. . . . . . . Q

min-conflicts success rate: 74.0%
min-conflicts average steps: 112.57
min-conflicts average time: 0.0045 seconds

final min-conflicts solution:
. . . Q . . . .
. . . . . . . Q
Q . . . . . . .
. . . . Q . . .
. . . . . . Q .
. Q . . . . . .
. . . . . Q . .
. . Q . . . . .
```

```
hill climbing success rate: 12.0%
hill climbing average steps: 3.2
hill climbing average time: 0.0005 seconds

final hill climbing solution:
. . . . . . Q .
. Q . . . . . .
. . . Q . . . .
Q . . . . . . .
. . . . . . . Q
. . . . Q . . .
. . Q . . . . .
. . . . . Q . .

simulated annealing success rate: 80.0%
simulated annealing average steps: 77.77
simulated annealing average time: 0.0022 seconds

final simulated annealing solution:
. . . Q . . . .
. Q . . . . . .
. . . . . . . Q
. . . . Q . . .
. . . . . . Q .
Q . . . . . . .
. . Q . . . . .
. . . . . Q . .

min-conflicts success rate: 72.0%
min-conflicts average steps: 120.3
min-conflicts average time: 0.0049 seconds

final min-conflicts solution:
. . Q . . . . .
. . . . Q . . .
. Q . . . . . .
. . . . . . . Q
Q . . . . . . .
. . . . . . Q .
. . . Q . . . .
. . . . . Q . .
```

```
hill climbing success rate: 17.0%
hill climbing average steps: 3.14
hill climbing average time: 0.0005 seconds

final hill climbing solution:
. . . . Q . . .
. . . . . . . Q
. . . Q . . . .
Q . . . . . . .
. . Q . . . . .
. . . . . Q . .
. Q . . . . . .
. . . . . . Q .

simulated annealing success rate: 82.0%
simulated annealing average steps: 76.31
simulated annealing average time: 0.0023 seconds

final simulated annealing solution:
. . Q . . . . .
Q . . . . . . .
. . . . . . Q .
. . . . Q . . .
. . . . . . . Q
. Q . . . . . .
. . . Q . . . .
. . . . . Q . .

min-conflicts success rate: 63.0%
min-conflicts average steps: 154.54
min-conflicts average time: 0.0053 seconds

final min-conflicts solution:
. . . . Q . . .
. . . . . . Q .
Q . . . . . . .
. . . Q . . . .
. Q . . . . . .
. . . . . . . Q
. . . . . Q . .
. . Q . . . . .
```

```
hill climbing success rate: 14.000000000000002%
hill climbing average steps: 3.12
hill climbing average time: 0.0005 seconds

final hill climbing solution:
. . . Q . . . .
. . . . . . . Q
. . . . Q . . .
. . Q . . . . .
Q . . . . . . .
. . . . . . Q .
. Q . . . . . .
. . . . . Q . .

simulated annealing success rate: 81.0%
simulated annealing average steps: 75.6
simulated annealing average time: 0.0021 seconds

final simulated annealing solution:
. Q . . . . . .
. . . Q . . . .
. . . . . Q . .
. . . . . . . Q
. . Q . . . . .
Q . . . . . . .
. . . . . . Q .
. . . . Q . . .

min-conflicts success rate: 73.0%
min-conflicts average steps: 116.63
min-conflicts average time: 0.0052 seconds

final min-conflicts solution:
. . . . . Q . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . Q . . . .
. . . . . . . Q
Q . . . . . . .
. . . . Q . . .
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