King Saud University

College of Computer and Information Sciences

Department of Computer Science

Project CSC 361: Artificial Intelligence

Second Semester 1444 H

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Solution description

Our solution to the Tenner Grid problem, employs diverse techniques including backtracking, forward checking, and the minimum remaining values (MRV) heuristic with forward checking to solve the grid . Initially, an initial state is generated randomly adhering to the problem's constraints. The backtracking solver method recursively explores potential solutions, trying different numbers for each empty cell and backtracking when necessary. The forward checking solver enhances this approach by maintaining domains of valid values for each cell and updating them as values are assigned, thereby reducing the search space. Additionally, the MRV heuristic with forward checking selects empty cells with the fewest remaining possible values, potentially expediting the solution process. Throughout the solving process, the code tracks the number of consistency checks and variable assignments. Finally, upon finding a solution or determining its absence, our code presents the solved grid along with relevant performance metrics for each solving technique.

Number of consistency checks (over five runs)

	Run 1	Run 2	Run 3	Run 4	Run 5	Median
Backtracking	21619	15290	1871466	8307	750787	21619
Forward Checking	18117	11195	1360049	6282	553930	18117
FC+MRV	5913	8930	1428825	8099	292315	8930

Therefore, according to our solution FC+MRV works best for solving the problem

You can click on Run from the table to see the results

Sample Runs

Run 1

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```
Initial State:
[6, 3, 2, -1, -1, 5, 9, 8, -1, 1]
[-1, -1, -1, -1, -1, -1, -1, 3, 2, 6]
[0, -1, 4, 7, -1, -1, -1, -1, 5, 9]
[11, 12, 15, 12, 11, 10, 17, 17, 14, 16]
solution of example with backtrack:
[6, 3, 2, 4, 0, 5, 9, 8, 7, 1]
[5, 7, 9, 1, 8, 4, 0, 3, 2, 6]
[0, 2, 4, 7, 3, 1, 8, 6, 5, 9]
[11, 12, 15, 12, 11, 10, 17, 17, 14, 16]

Number of Variable Assignments: 597
Number of Consistency Checks: 21619
Time Used to Solve the Problem: 0 milliseconds
solution with FC:
[6, 3, 2, 4, 0, 5, 9, 8, 7, 1]
[5, 7, 9, 1, 8, 4, 0, 3, 2, 6]
[0, 2, 4, 7, 3, 1, 8, 6, 5, 9]
[11, 12, 15, 12, 11, 10, 17, 17, 14, 16]

Number of Variable Assignments: 597
Number of Consistency Checks: 18117
Time Used to Solve the Problem: 4 milliseconds
solution with FC+MRV:
[6, 3, 2, 4, 0, 5, 9, 8, 7, 1]
[5, 7, 9, 1, 8, 4, 0, 3, 2, 6]
[0, 2, 4, 7, 3, 1, 8, 6, 5, 9]
[11, 12, 15, 12, 11, 10, 17, 17, 14, 16]

Number of Variable Assignments: 215
Number of Consistency Checks: 5913
Time Used to Solve the Problem: 1 milliseconds
```

Run 2

Back to table

```
Initial State:
[-1, -1, 1, 8, -1, 2, 5, -1, 6, -1]
[-1, -1, 0, -1, -1, 1, -1, -1, 7, 6]
[-1, -1, -1, 1, 6, -1, 2, -1, 3, 0]
[17, 22, 5, 11, 19, 11, 10, 18, 16, 6]
solution of example with backtrack:
[3, 7, 1, 8, 4, 2, 5, 9, 6, 0]
[5, 8, 0, 2, 9, 1, 3, 4, 7, 6]
[9, 7, 4, 1, 6, 8, 2, 5, 3, 0]
[17, 22, 5, 11, 19, 11, 10, 18, 16, 6]

Number of Variable Assignments: 470
Number of Consistency Checks: 15290
Time Used to Solve the Problem: 2 milliseconds
solution with FC:
[3, 7, 1, 8, 4, 2, 5, 9, 6, 0]
[5, 8, 0, 2, 9, 1, 3, 4, 7, 6]
[9, 7, 4, 1, 6, 8, 2, 5, 3, 0]
[17, 22, 5, 11, 19, 11, 10, 18, 16, 6]

Number of Variable Assignments: 430
Number of Consistency Checks: 11195
Time Used to Solve the Problem: 3 milliseconds
solution with FC+MRV:
[3, 7, 1, 8, 4, 2, 5, 9, 6, 0]
[5, 8, 0, 2, 9, 1, 3, 4, 7, 6]
[9, 7, 4, 1, 6, 8, 2, 5, 3, 0]
[17, 22, 5, 11, 19, 11, 10, 18, 16, 6]

Number of Variable Assignments: 348
Number of Consistency Checks: 8930
Time Used to Solve the Problem: 2 milliseconds
```

Run 3

Back to table

```
Initial State:
[-1, 7, -1, -1, -1, -1, -1, 8, 6, -1]
[-1, 8, 5, -1, -1, -1, 0, -1, 2, 9]
[0, 1, -1, -1, 9, -1, -1, -1, -1, -1]
[5, 16, 10, 11, 20, 14, 11, 16, 15, 17]
solution of example with backtrack:
[1, 7, 2, 3, 4, 9, 5, 8, 6, 0]
[4, 8, 5, 6, 7, 1, 0, 3, 2, 9]
[0, 1, 3, 2, 9, 4, 6, 5, 7, 8]
[5, 16, 10, 11, 20, 14, 11, 16, 15, 17]

Number of Variable Assignments: 56319
Number of Consistency Checks: 1871466
Time Used to Solve the Problem: 21 milliseconds
solution with FC:
[1, 7, 2, 3, 4, 9, 5, 8, 6, 0]
[4, 8, 5, 6, 7, 1, 0, 3, 2, 9]
[0, 1, 3, 2, 9, 4, 6, 5, 7, 8]
[5, 16, 10, 11, 20, 14, 11, 16, 15, 17]

Number of Variable Assignments: 56319
Number of Consistency Checks: 1360049
Time Used to Solve the Problem: 14 milliseconds
solution with FC+MRV:
[1, 7, 2, 3, 4, 9, 5, 8, 6, 0]
[4, 8, 5, 6, 7, 1, 0, 3, 2, 9]
[0, 1, 3, 2, 9, 4, 6, 5, 7, 8]
[5, 16, 10, 11, 20, 14, 11, 16, 15, 17]

Number of Variable Assignments: 58375
Number of Consistency Checks: 1428825
Time Used to Solve the Problem: 26 milliseconds
```

Run 4

Back to table

```
Initial State:
[6, -1, -1, -1, 1, 9, -1, 2, 3, 7]
[4, -1, 2, -1, -1, -1, -1, 7, -1, 5]
[3, -1, -1, -1, 5, 9, 8, -1, 2, -1]
[13, 14, 6, 15, 6, 24, 17, 15, 13, 12]
solution of example with backtrack:
[6, 4, 0, 5, 1, 9, 8, 2, 3, 7]
[4, 9, 2, 3, 0, 6, 1, 7, 8, 5]
[3, 1, 4, 7, 5, 9, 8, 6, 2, 0]
[13, 14, 6, 15, 6, 24, 17, 15, 13, 12]

Number of Variable Assignments: 253
Number of Consistency Checks: 8307
Time Used to Solve the Problem: 0 milliseconds
solution with FC:
[6, 4, 0, 5, 1, 9, 8, 2, 3, 7]
[4, 9, 2, 3, 0, 6, 1, 7, 8, 5]
[3, 1, 4, 7, 5, 9, 8, 6, 2, 0]
[13, 14, 6, 15, 6, 24, 17, 15, 13, 12]

Number of Variable Assignments: 253
Number of Consistency Checks: 6282
Time Used to Solve the Problem: 1 milliseconds
solution with FC+MRV:
[6, 4, 0, 5, 1, 9, 8, 2, 3, 7]
[4, 9, 2, 3, 0, 6, 1, 7, 8, 5]
[3, 1, 4, 7, 5, 9, 8, 6, 2, 0]
[13, 14, 6, 15, 6, 24, 17, 15, 13, 12]

Number of Variable Assignments: 331
Number of Consistency Checks: 8099
Time Used to Solve the Problem: 3 milliseconds
```

Run 5

Back to table

```
Initial State:
[-1, 8, 9, -1, -1, -1, 7, -1, -1, 4]
[-1, 6, 5, 8, -1, -1, -1, -1, -1, 7]
[-1, 1, -1, -1, 5, 8, 7, 9, -1, -1]
[11, 15, 16, 11, 20, 15, 15, 14, 7, 11]
solution of example with backtrack:
[2, 8, 9, 0, 6, 3, 7, 5, 1, 4]
[3, 6, 5, 8, 9, 4, 1, 0, 2, 7]
[6, 1, 2, 3, 5, 8, 7, 9, 4, 0]
[11, 15, 16, 11, 20, 15, 15, 14, 7, 11]

Number of Variable Assignments: 24207
Number of Consistency Checks: 750787
Time Used to Solve the Problem: 45 milliseconds
solution with FC:
[2, 8, 9, 0, 6, 3, 7, 5, 1, 4]
[3, 6, 5, 8, 9, 4, 1, 0, 2, 7]
[6, 1, 2, 3, 5, 8, 7, 9, 4, 0]
[11, 15, 16, 11, 20, 15, 15, 14, 7, 11]

Number of Variable Assignments: 24207
Number of Consistency Checks: 553930
Time Used to Solve the Problem: 25 milliseconds
solution with FC+MRV:
[2, 8, 9, 0, 6, 3, 7, 5, 1, 4]
[3, 6, 5, 8, 9, 4, 1, 0, 2, 7]
[6, 1, 2, 3, 5, 8, 7, 9, 4, 0]
[11, 15, 16, 11, 20, 15, 15, 14, 7, 11]

Number of Variable Assignments: 13279
Number of Consistency Checks: 292315
Time Used to Solve the Problem: 6 milliseconds
```