

University of California, Irvine
Introduction to Artificial Intelligence
CS-271P, Fall 2019

Sudoku Solver Project Report

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Programming Language Used: **Java**

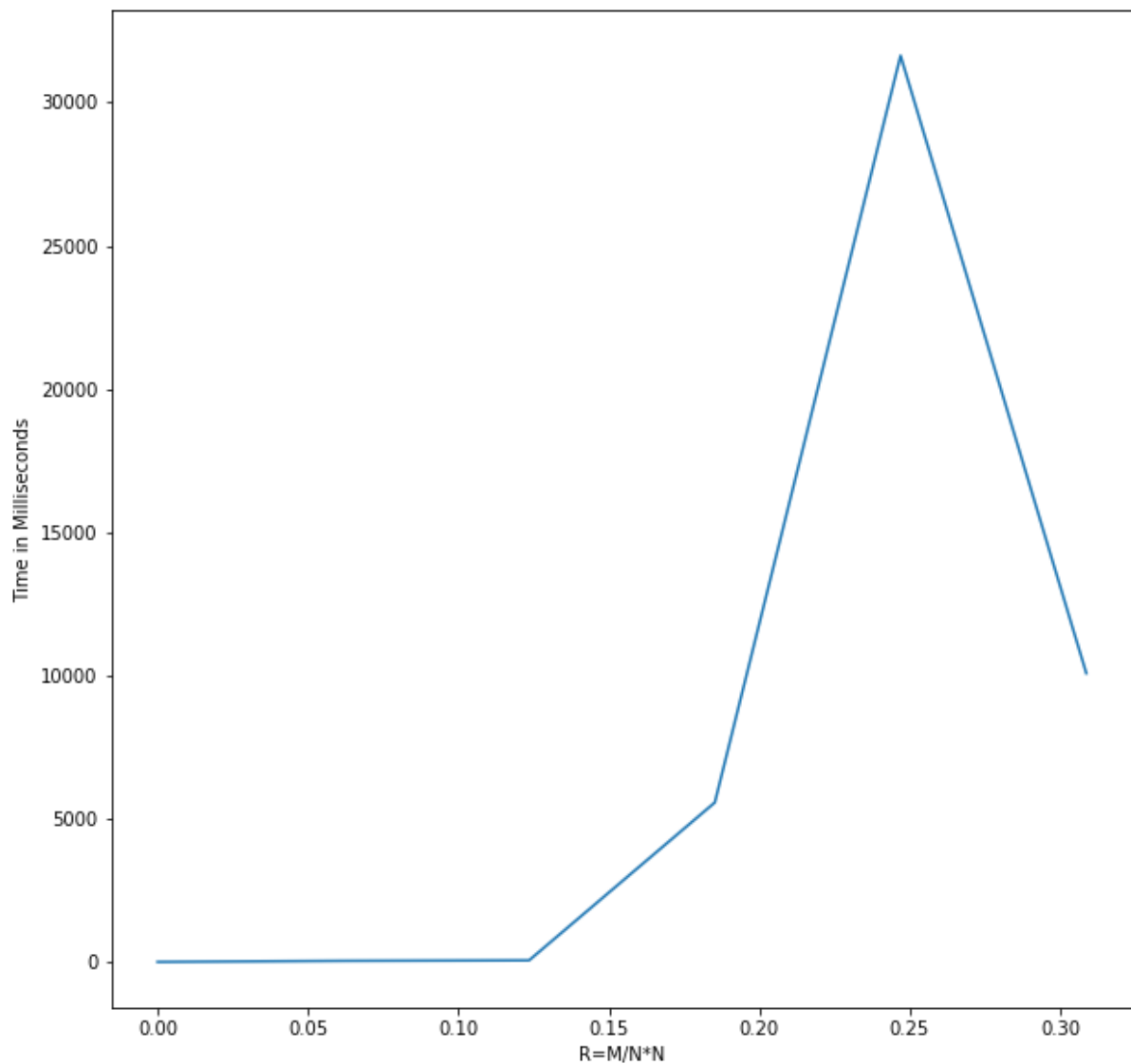
Heuristics used in Tournament Final AI:

Forward Checking (FC), MRV with Degree Heuristic (MAD), Least Constraining Value (LCV).

By turning in this assignment, we do affirm that we did not copy any code, text, or data except course material provided to us by the textbook, class website, class gitlab, or teaching staff.

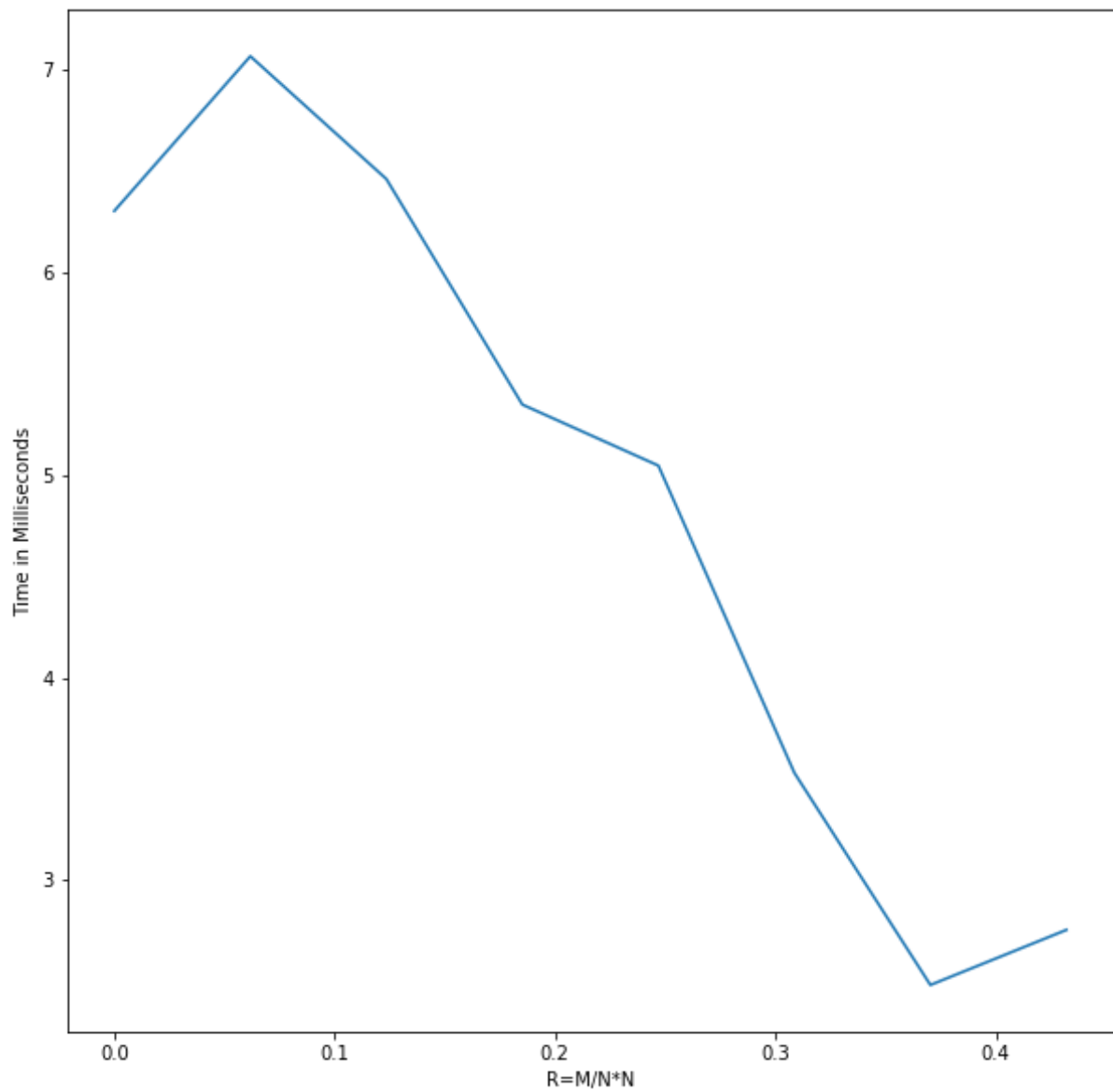
A. The Critical Value of “Hardest M” for N = 9

A.1. Find the critical value of “hardest M” for N = 9 and BT.



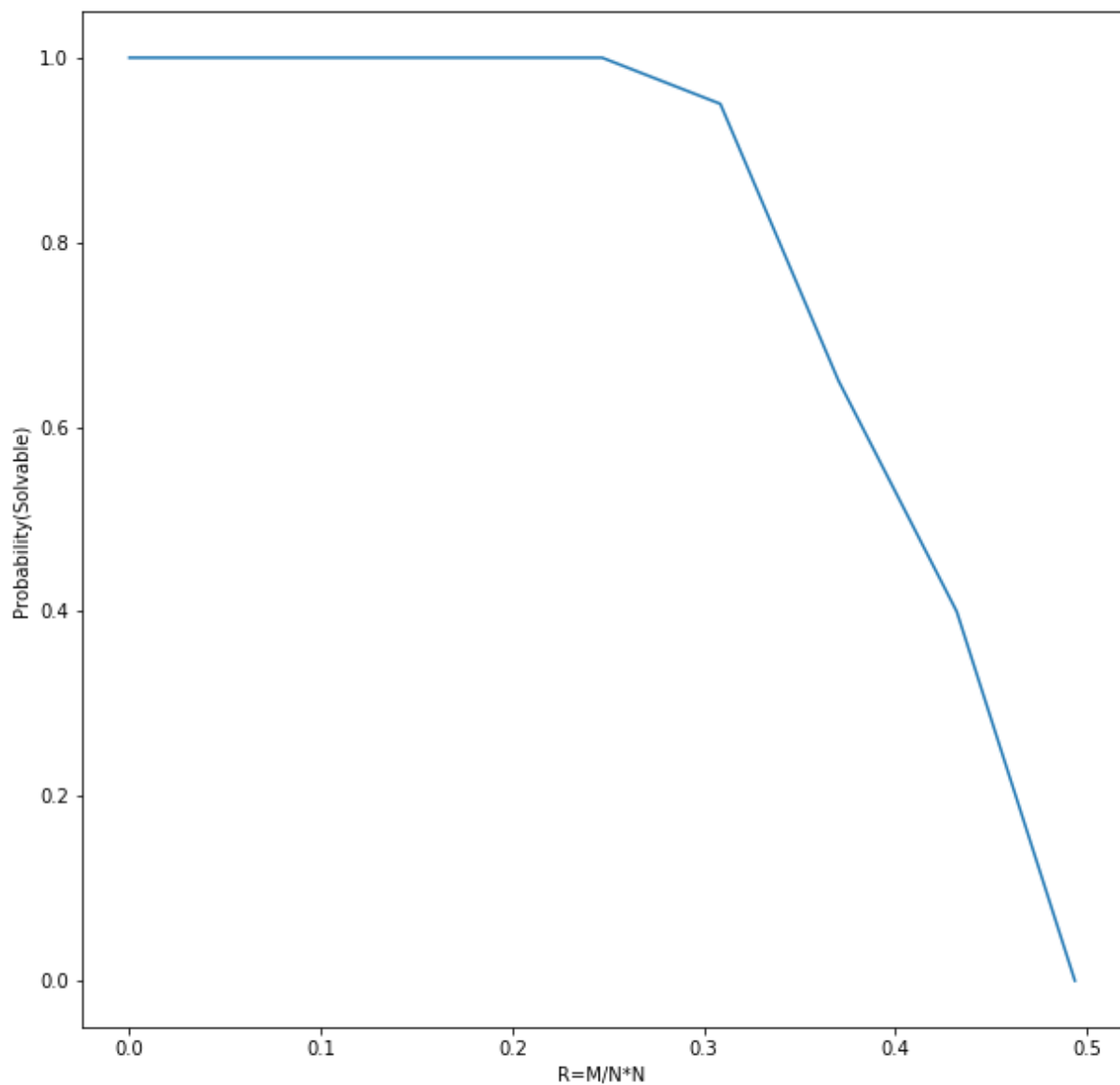
Ans- $M=20$

A.2. Find the critical value of “hardest M” for $N = 9$ and BT with FC (BT+FC)



Ans- $M=5$

A.3. How does puzzle solvability for BT+FC vary with $R = M / N^2$?



Ans - Puzzle solvability decreases with increasing value of R

A.4. Answer these questions (for $N=9$):

A.4.a. What critical value of “hardest M ” do you get for BT (in A.1)? for BT+FC (in A.2)? Are these values approximately the same?

Ans- For BT $M=20$

For BT+FC $M=5$

No, the values are not the same

A.4.b. For “hardest M,” what is the mean and standard deviation of the total time for BT? for BT+FC? Are these values approximately the same?

Ans- For BT Mean and std deviation are - 7911, 11239.2

For BT+FC mean and std deviation are - 4.99, 1.7185

No, the values are not the same

A.4.c. For what value of M does $P(\text{solvable}) \approx 0.5$ (“half-solvable M”) occur for BT+FC? Is this value approximately the same as your value of “hardest M” for BT+FC (in A.4.a)?

Ans- $M=32$ for $P(\text{solvable})=0.5$

This value is not the same as the hardest M for BT+FC.

B. Combinations of Methods for N = 9

B.1. Find mean (sdev) total time (in seconds), “hardest M,” and “half-solvable M” for N = 9 and the method combinations specified below.

Mean (Sdev) Total Time(ms)	Hardest M	Half-Solvable M	Combination of Methods
7911, 11239.2	20	22	BT
4.99, 1.7185	5	32	BT+FC
6.25, 1.5201	10	30	BT+FC+MRV
8.79, 2.193	10	30	BT+FC+MRV+LCV
12.14, 4.075	5	29	BT+FC+MAD+LCV
50.24, 10.657	15	19	BT+FC+MAD+LCV+NOR
8.79, 2.193	5	29	Tournament Final AI

B.2. Answer these questions (for N=9):

B.2.a. Which more sophisticated methods let you solve N = 9 for “hardest M” puzzles faster than BT+FC?

Ans - BT+FC+MRV, BT+FC+MRV+LCV, BT+FC+MAD+LCV.

B.2.b. Which more sophisticated methods have overhead costs that outweigh their potential benefit? (I.e., they make your solver run slower than BT+FC.)

Ans- BT+FC+MAD+LCV+NOR

B.2.c. Do you get (approximately, i.e., within sampling error) the same values of “hardest M” and “half-solvable M” for the different combinations that you tested?

Ans-No (But half solvable M is approximately same for 4 heuristic combinations)

C. “Monster” Sudoku for $N > 9$

C.1. Find mean times, “hardest M,” and “half-solvable M” for $N > 9$.

Largest Solvable N	Mean (Sdev) Time	Hardest M	Half-Solvable M	Combination of Methods
3	7911, 11239.2	20	22	BT
4	320, 1103.86	7	110	BT + FC
5	291.7, 136.36	138	290	BT + FC+ MRV
5	283.3,104.6	146	291	BT+FC+MRV+LCV
5	616,340	145	273	BT+FC+MAD+LCV
5	40243, 49083	195	195	BT+FC+MAD+LCV+NOR
5	283.3,104.6	146	291	Tournament AI

C.2. Answer these questions:

C.2.a. Which more sophisticated methods let you to reach larger values of N for “hardest M” puzzles? Does the answer to this question change as N increases?

Ans- BT+FC+MRV+LC, BT+FC+MAD+LCV.

Yes, BT+FC does not perform well for $N > 16$ boards.

C.2.b. Which more sophisticated methods have overhead costs that outweigh their benefit? (I.e., they make it slower.) Does the answer to this question change as N increases?

Ans- BT+FC+MAD+LCV+NOR

Our implementation of Norvig uses an optimized FC internally. The overhead of Norvig outweighs its advantage.

C.2.c. Do you get (approximately) the same value of “hardest M” for different N and different method combinations? for “half-solvable M?”

Ans

Yes for hardest M combinations

a) BT + FC+ MRV

b) BT+FC+MAD+LCV

have approx. same values

Yes, for half solvable M combinations

a) BT + FC+ MRV

b) BT+FC+MRV+LCV

have approximately the same values.