

A thick black L-shaped frame is positioned around the text. It starts at the top left, goes right, then down, then right again, and finally down to the bottom right corner.

# RANKING CLUES IN SUDOKU SOLVERS

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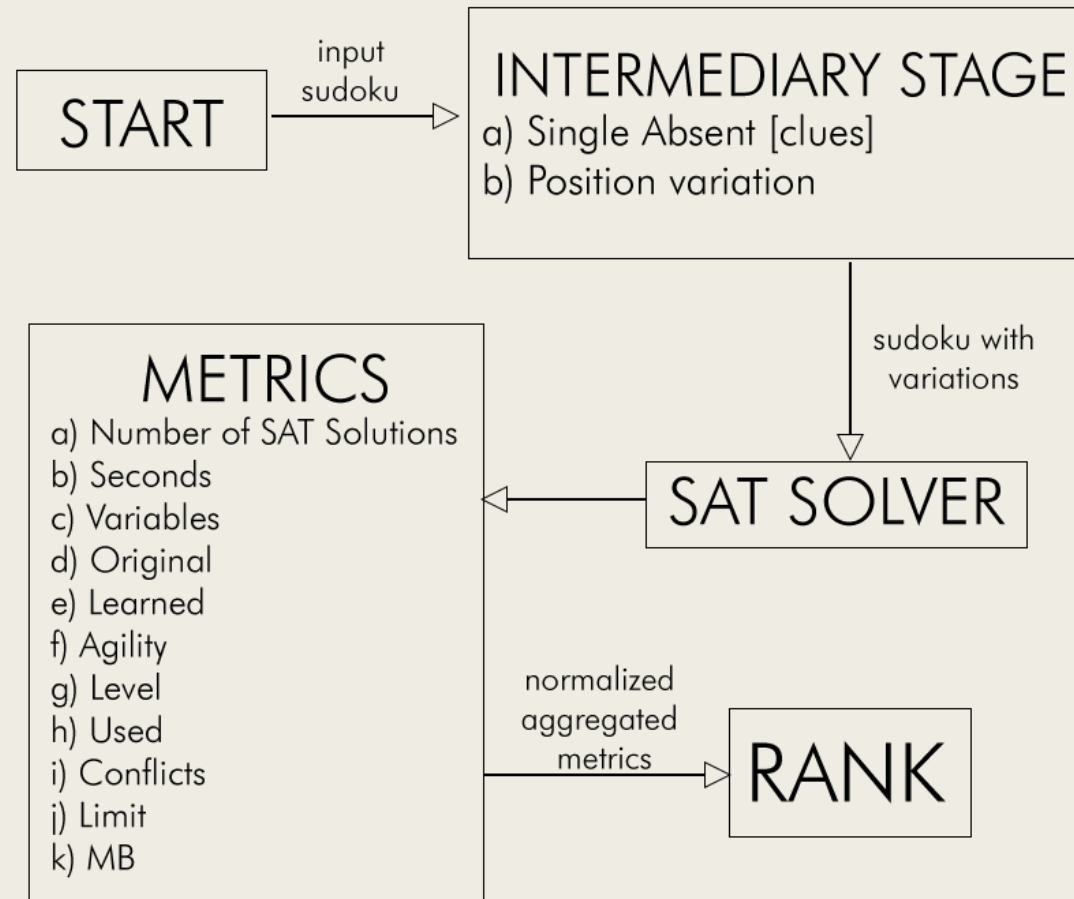
# Abstract

- The aim of this paper is to analyze the variations of clues in terms of orientation, existence, arrangement and position. It discusses the parameters of the initial sudoku state which is achieved by running it through PycoSAT in non-deterministic mode. The metrics generated by PycoSAT are used to rank each variation of the given sudoku to compare which variation (spatial or non-spatial) is favoured by the sat solver.

# Assumptions

- Input sudokus used are minimal (unique soln)
- Equal weights are assigned to the metrics generated as outputs
- Metrics for multiple solutions of a given variation are aggregated as average, minimum and maximum values.

# Experimental Setup



# Input Sudoku

007000000500000006000920300098000005700200900000800470009305007640

For our understanding, we will follow the procedure with a single sudoku puzzle

# Intermediate Input

Rolled Variation – Shifted all characters by 1

000700000050000000600092030009800000570020090000080047000930500764000000010000600

We have used all the 80 rolled sudoku variations.

Single Absent Variation – Replaced 1<sup>st</sup> Clue (7) with 0

000000000500000006000920300098000005700200900000800470009305007640000000100006000

We have used all the 23 single absent variations – our input sudoku has 23 clues.

# Observation: Metric Table

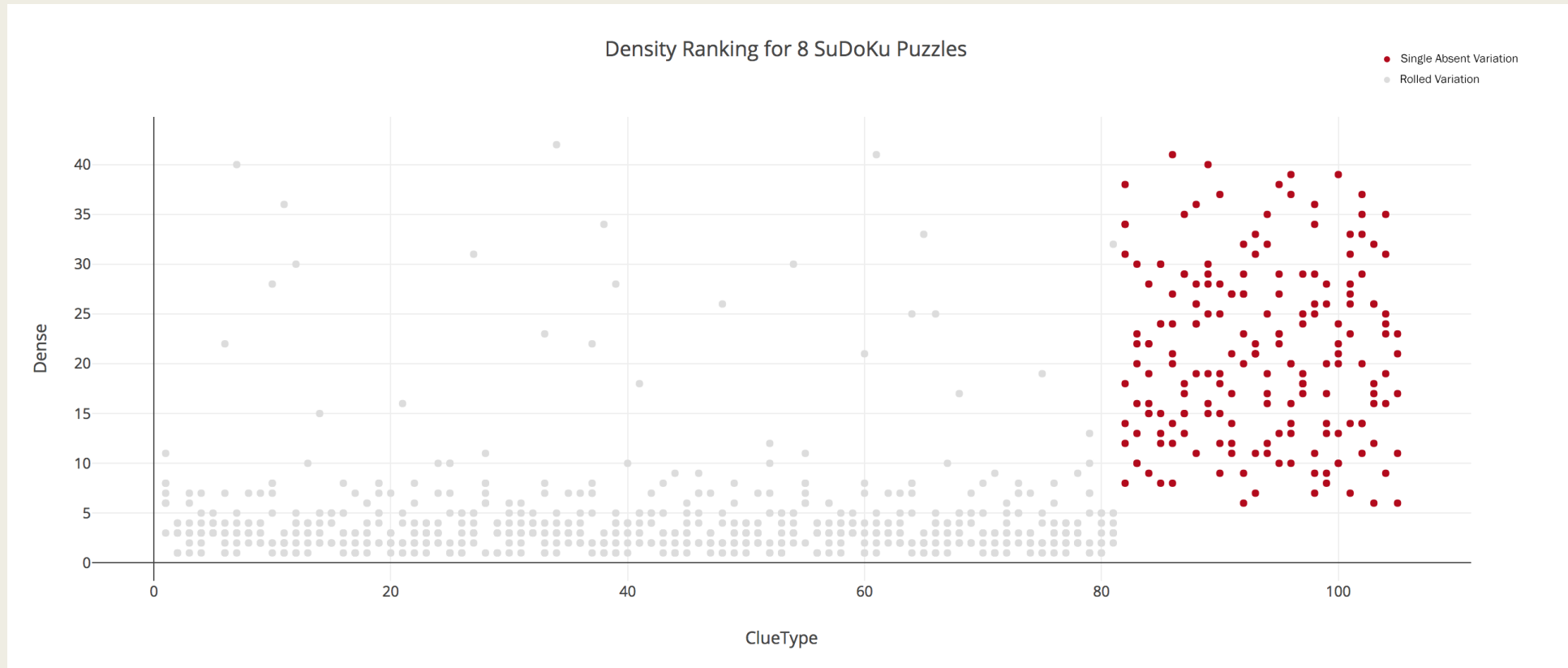
ID	# of SAT Solutions	Learned Clauses			Conflicts			Conflict Decision Ratio		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
*	8	16	12	20	136	132	140	11.56	2	18
S2	0	1	1	1	324	324	324	0	0	0
C1	57	61.62	28	96	220.5	192	249	193.45	5	335

# Observation: Ranks

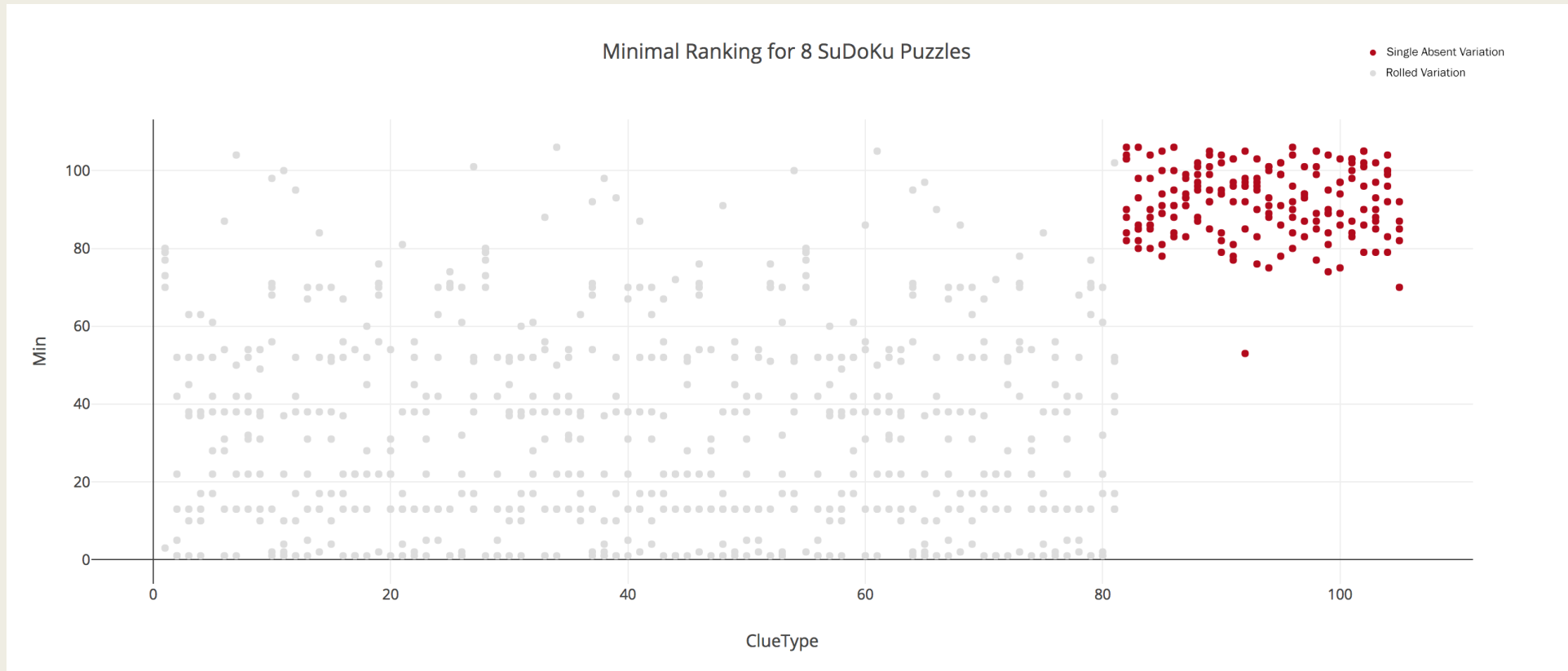
Clue Category	Clue Type	Clue	Minimum	Dense
0	8	S2	10	4
1	82	C1	90	24



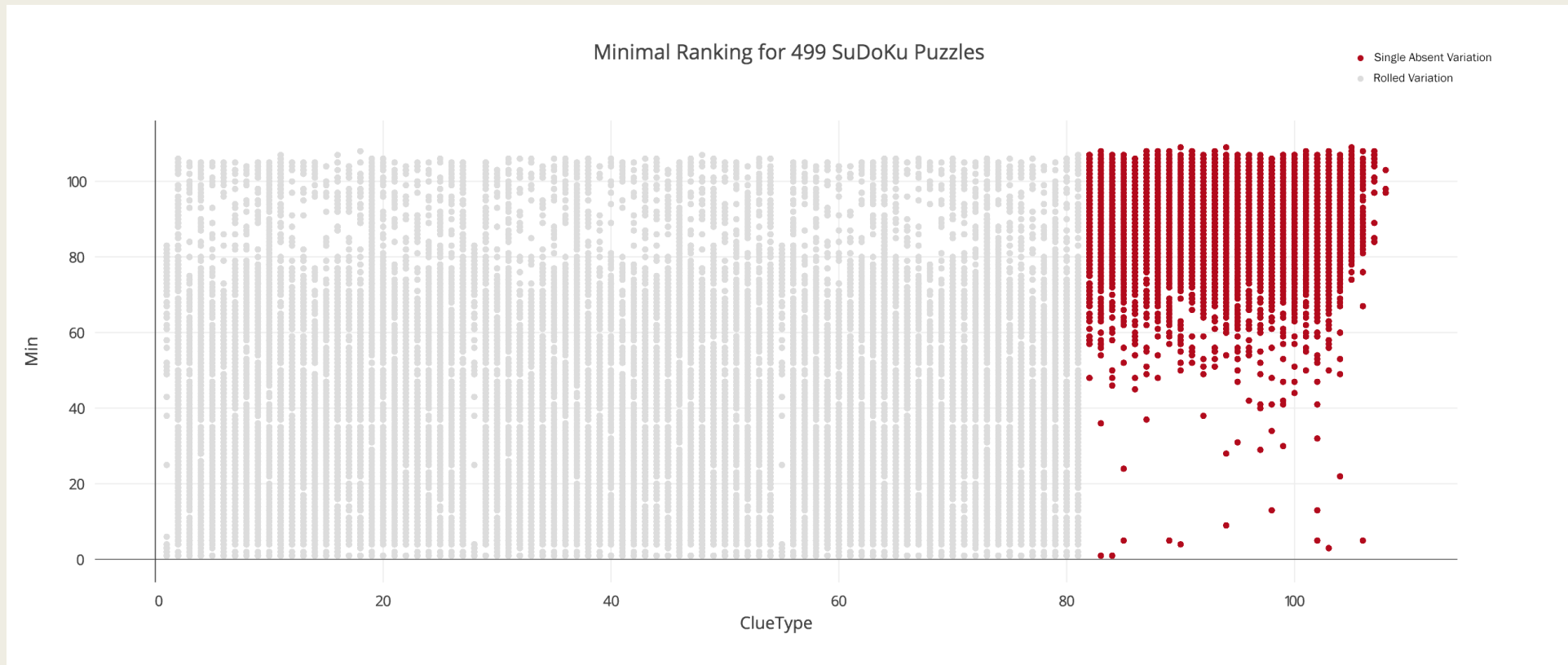
# Graph: 8 sudoku puzzles (density)



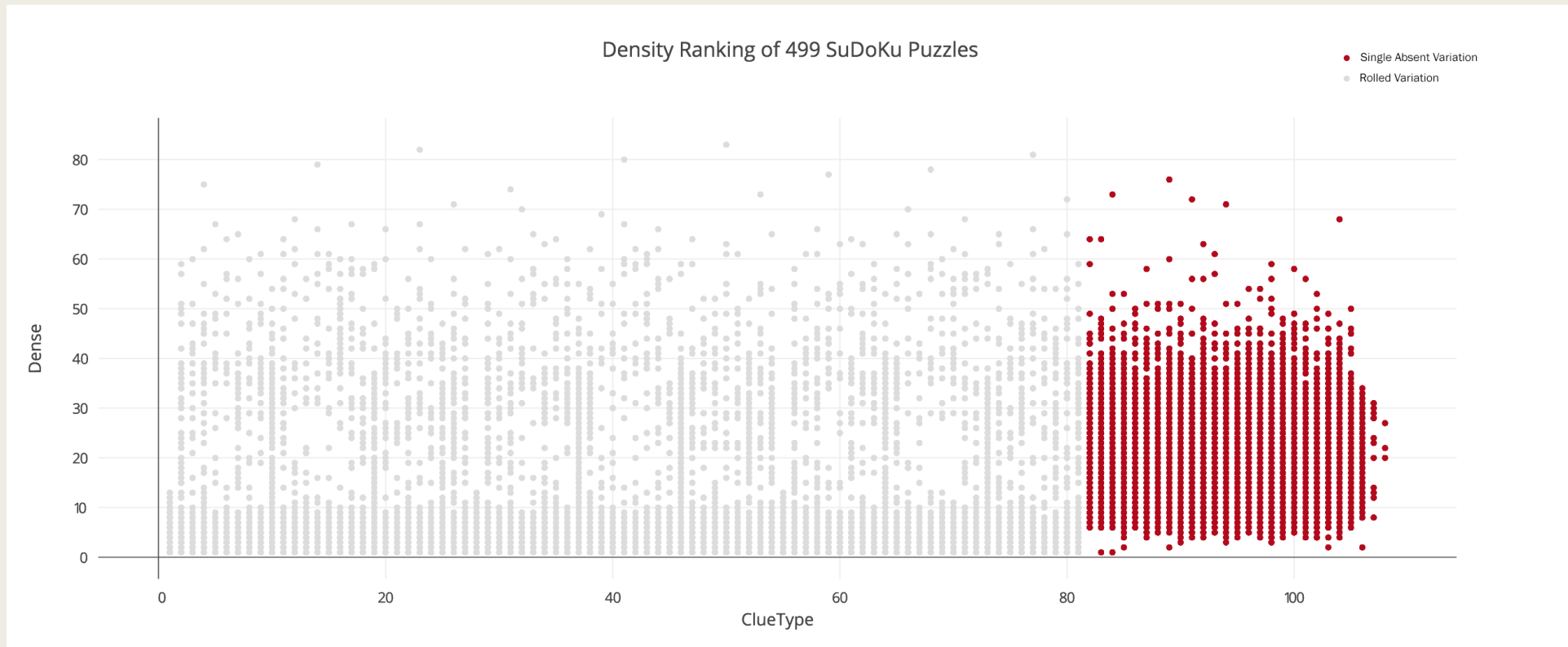
# Graph: 8 sudoku puzzles (minimum)



# Graph: 499 sudoku puzzles (minimum)



# Graph: 499 sudoku puzzles (density)



# Conclusion

Variations of 'rolled' sudokus have a higher ranking than the variations of 'single absent' sudokus.

# Limitations

- Input sudoku used are minimal
- The ranking system is trivial.
- Metrics are aggregated to create a AVG/MIN/MAX version

# Applications

- Courier delivery networks
- Classroom assignment for universities
- Strategy games

# Future Research

- The sat solver metrics can be fine tuned and weighted more proportionally.
- More additional variations can lead to better results. For instance, we can generate more variations by rotating the sudoku puzzle.
- In the ranking system, we can account for the symmetries of sudoku. For example we can assign a huge favour to the variation that leads to a symmetrically equivalent solution to the solution of the original sudoku.
- The whole experiment can be repeated on other kinds of SAT solvers and different sudoku encodings.



# Source Codes

1. The altered version of an existing pycosat implementation of a sudoku solver is available at: <https://github.com/gulfaraz/sudoku-sat-solver>
2. A modified version of pycosat is required to run the experiment for improved readability and some additional metrics. This is available at: <https://github.com/gulfaraz/pycosat/tree/alter-logging>
3. The detailed explanation is present in a report : <https://github.com/gulfaraz/sudoku-sat-solver/blob/master/docs/report.pdf>
4. Video presentation of the project is available at: <https://youtu.be/4q6rZw8TVw4>

Thank You! 😊

ありがとうございました!!