

## Comparative study on Sudoku using Backtracking algorithm

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### Abstract

Sudoku puzzles appear in magazines, newspapers, internet pages or in books on day basis. In truth, humans across the arena apprehend a way to play Sudoku. The technology behind this game is tons extra complex than it appears. This is the main strength of investigation for researcher community to have positioned a extraordinary quantity of attempt to generate green algorithms to remedy these puzzles. Some researchers might even advise that an algorithm to remedy Sudoku games without trying a large quantity of variations does now not exist. Within this decade, fixing the Sudoku would be expected to in everyone's ardour. The simpler and more challenging requirement would be the mathematical skills which cause people to have huge hobby in accepting challenges that encounters to solve the puzzle. Consequently, researchers attempted to find good procedure to generate puzzles that could be solved through very simple programming. At this venture there is a fixed of policies known as naïve primarily based on essential hassle solving. The motive is to put into impact an extra green algorithm and then observe it with every other Sudoku solver set of guidelines named as lower back tracking. Backtracking set of regulations is a stylish algorithm that may be hired in to any troubles. The outcomes have proved that the backtracking set of rules solves the puzzle faster and more powerful than the naïve set of policies.

**Keywords.** Sudoku, Backtracking Algorithm, Running time, Naive Bayes Algorithm.

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### 1. INTRODUCTION

Currently, Sudoku puzzles have become more and more popular the various humans all over the world. The game has turned out to be more successful among human mankind in variety of countries. Efforts have also been taken to attempt to generate even more complex and thrilling games that entertain humans. In the proposed study, algorithm for solving Sudoku namely naïve bayes is used along with backtracking approach is used to solve the puzzles for finding the best strategy. The naïve set of rules is formulated based totally on human strategies which implies that a set of rules is applied primarily based on human perceptions. The returned monitoring algorithm is then used to evaluate with this set of rules with the intention to evaluate the performance of the proposed algorithm.

The backtracking is well known with a set of rules than may is implemented to find a feasible and efficient solution in terms of running time is concerned. The proposed procedure aims at generating possible solutions that finds best solution. The simple principle of a backtracking algorithm with reference to Sudoku is to move forward one square at a time and to supply a working Sudoku grid. When a trouble takes place, the set of rules takes itself returned one step and tries a unique route. It's almost not possible to supply a legitimate Sudoku through randomly plotting numbers and trying to cause them to match. Likewise, backtracking with a random placement technique is equally useless.

Backtracking exceptional works in a linear technique. it's far rapid, powerful if executed successfully. The reason of the machine is to research the backtracking set of rules and the naïve algorithm. Later these two techniques are compared analytically. it's far predicted here to locate an efficient technique to clear up the Sudoku puzzles. This study aims at implementation of the returned tracking set of rules that simulate answer of the puzzle. The reason of the machine is to research the backtracking algorithm and the naïve algorithm. its miles predicted here to locate an efficient technique to solve the Sudoku puzzles.

The proposed work is organized as follows, while section 1 discusses on some general aspects on the ideology and importance of the proposed study, section 2 describes the related study that exists on Sudoku Puzzle implemented using various algorithms. Section 3 elaborates on the research basics and discusses on the naive bayes and backtracking algorithms, followed by proposed work with an architecture in section 4. Section 5 concludes the study analyzing the performance of research work using time complexity metric.

## 2. LITERATURE SURVEY

Backtracking set of regulations is less complicated than extraordinary algorithms that guarantees a choice to the maximum tough puzzles. games and puzzles were a platform for utility of mathematics, artificial intelligence and exclusive diverse techniques. The past years have delivered into hobby a completely popular puzzle known as Sudoku. The common Sudoku puzzle grid is a nine-through-9 cells into nine three-by way of manner of-3 squares. The suggestions of the game are: each row, column, and square (of three-by-3) should be filled with every of the numbers 1 until 9 and that range cannot seem extra than as quickly as in any of the row, column, or rectangular. The initial grid is populated with some digits, known as clues. In evaluation to magic squares and other numeric puzzles, no arithmetic is worried; the elements in a Sudoku grid must just as well be letters of the alphabet or some other symbols. Sudoku has led exclusive researchers to three advances in set of rules design and implementation. These paintings modified into largely inspired by means of the interesting mathematical requirements behind it. This paper describes the development of a Sudoku solver using MATLAB.

A few authors are presenting a search-based answer through the usage of some heuristic elements in a changed steepest hill ascent. some researchers, are suggesting the format of a genetic algorithm via manner of representing the puzzle as a block of chromosomes, extra specific as an array of eighty-one integers. Any crossover appears a number of the 3x3 grids and any mutations arise only within the 3x3 grids. Geem is proposing a Sudoku solver model based totally on concord are trying to find those mimics the tendencies of a musician. Santos-Garcia and Palomino are suggesting a way for fixing Sudoku puzzles the usage of easy precise judgment with rewriting regulations to mimic human intelligence. Others are suggesting neural networks thru modeling an power pushed quantum (Q'tron) neural community to resolve the Sudoku puzzles. Barlett and Langville are imparting an answer based totally mostly on binary integer linear programming (BILP). To formulate in a simple manner the approach, we are able to say that it makes use of binary variables to select a digit for any cellular in a Sudoku puzzle. Our MATLAB software uses most effective one pattern—singletons—collectively with a primary laptop technological know-how technique, recursive Backtracking [3].

The backtracking set of rules is an improvement of the brute pressure algorithm that finds out the answers to issues amongst all possible solutions systematically. Backtracking is a normal form of recursive set of rules and is primarily based on DFS (Depth First Search) in locating the proper solution. Backtracking policy works with several opportunities that cause the solution till it finds the optimum ones. So, there is no want to check all feasible solutions, however it's miles enough that most effective results in the answer, specifically by using sorting pruning the nodes that do not purpose the answer. The distinction with the

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brute stress algorithm is the fundamental concept, particularly, in backtracking, all solutions are made inside the form of an answer tree \, after which the tree may be traced in DFS (intensity-First are seeking for) to locate the first-rate-favoured answer.[4]

The essential precept of a backtracking set of regulations, with regard to Sudoku, one mobile at a time, to supply a running Sudoku grid. Sudoku become advanced with the aid of the use of an American architect, Howard Garnes, in 1979, as a numerical combinatorial puzzle. The puzzle acquired popularity in 2004, when Wayne Gould glad the times in London to submit it. There are 6,670,903,752,021,072,936,960 possible combos for completing a nine-via-9. Sudoku grid, but simplest 5,472,730,538 of them truly count number for great solutions and for this reason one needs a handful of lifetimes to clear up all of them.[5]

Sudoku is a superb judgment-primarily based definitely, combinatorial number placement puzzle. The word “Sudoku” is brief for Suji wadoku shinnikagiru (in Japanese), which means that “the numbers should be unmarried”. The set of guidelines is also the correct method to find out a solution quicker and greater efficient. Sudoku is a puzzle undertaking played on a grid that consists of 9 x 9cells each belonging to three corporations: considered one of 9 rows, genuinely certainly one of nine columns and one among nine sub grids (now and again referred to as regions). the sport of Sudoku is basically based on Latin squares. The Sudoku became incepted within the 12 months 1979 and emerge as first posted within the Dell Magazines as “variety region” in the year1984. The time period Sudoku manner a single quantity. the game begins with numbers already revealed in a few cells. The player needs to fill inside the empty cells with the numbers 1 to 9 such that every column, row and area carries that range precisely as soon as. there are various Sudoku packages that have already been evolved by means of many programmers around the world. in this paper, we provide an overview of the paintings that we have completed at the development of the sport of Sudoku that generates a 9 x nine puzzle grid with numerous trouble stages.

The utility additionally permits customers to go into their very personal puzzle and to be solved with the aid of the computer [6]. The superior software additionally consists of advanced abilities which encompass maintain, load and speedy input validation. The solving set of policies of the developed Sudoku utility has additionally been as compared to some present Sudoku programs for assessment. Many methods as well as their hybrids are available to solve Sudoku puzzles. However, those techniques have several shortcomings at the side of not being capable of clearing up the puzzles. This overlook constraints violations in Sudoku policies have several steps similarly to missing capacity possibilities for finding feasible solution. The research study advises on hybrid backtracking set of

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rules and pencil and paper technique to conquer the constraints of the existing techniques [7]. Experimental consequences show that the proposed approach is greater powerful further to green in solving puzzles of different hassle levels than the opportunity to be had technique.

### **3. RESEARCH BASICS**

#### **3.1. Backtracking algorithm**

The backtracking set of policies makes use of an array of the crook numbers inside the cellular to attempt a answer earlier than it moves directly to the subsequent mobile. If an answer cannot be observed, it backtracks and attempts to remedy the board once more with a extraordinary wager choice. The greater errors the solver makes, the greater backtracks it have to carry out, which decreases its commonplace efficiency and will growth its effective runtime. exams of the fixing set of rules have been completed using 195 base solutions with more than one preliminary board configurations were carried out to investigate the distinction in the set of rules performance via using comparing the variety of recursive backtracks among sequential and randomly distributed guesses [10].

#### **3.2. Naïve Bayes algorithm**

Naïve Bayes set of policies is a easy probabilistic algorithm in class method which gets its opportunity price based at the calculation of frequency and price combos from the associated series [8]. This set of rules assumes that each one attributes are unbiased [9]. The class technique of Naïve Bayes wishes numerous clues or recommendations to determine the magnificence of the data to be analyzed.

### **4. PROPOSED APPROACH**

The proposed approach right here is the backtracking algorithm with an incomplete board. The architecture is presented in Fig 4.1. The steps involved are:

1. Locate a few empty areas.
2. Attempt to place the digits 1-9 in that area
3. Take a look at if that digit is valid in the modern-day spot primarily based at the modern board.
  - a. If the digit is legitimate, recursively try to fill the board the usage of steps 1-3.
  - b. If it isn't legitimate, reset the Square you simply stuffed and move again to the previous step.

4. Once the board is full by the definition of this algorithm there's an answer.

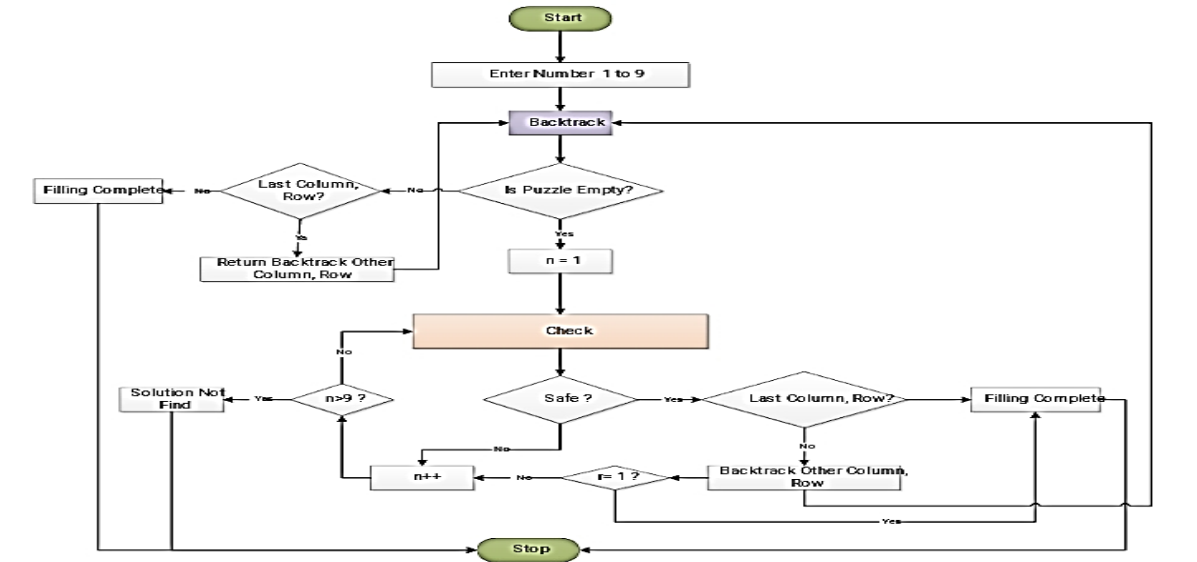


Fig 4.1 Proposed architecture work flow diagram

The results are compared with the algorithms presented in section 1 and the running time is measured and results are presented in Fig 4.2. The time complexity is presented in equation 4.1. For each unassigned index, there are 9 possible options so the time complexity is  $O(9^{(n*n)})$ . The time complexity stays the same but there might be some early pruning so the time taken can be an entire lot less than the naive set of regulations but the upper certain time complexity remains the equal. The naïve bayes (shown in blue colour) and backtracking algorithm (shown in red colour) is presented in Fig 4.2.

$$O(9^{(n*n)}) \tag{4.1}$$

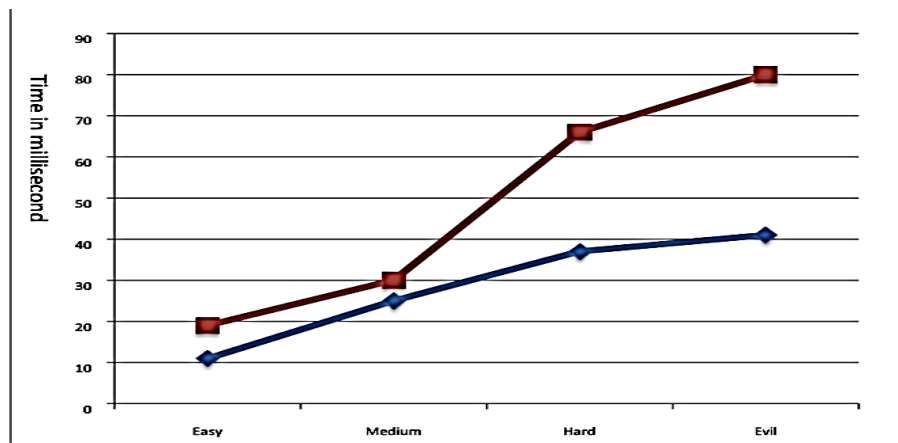


Fig 4.2 Running time of naïve bayes and backtracking algorithm

## 5. CONCLUSION

The paper has ended with result to solve sudoku board which shows that the backtracking with set of rules is a best approach. The set of guidelines is likewise the proper technique to find a solution faster and extra inexperienced compared to the naïve algorithm. The performance of monitoring set of rules is better than the naïve algorithm with appreciate to the computing time to treatment any puzzle which is found out from the time complexity calculation. The naïve algorithm also gives a completely unique output. However, naïve set of rules isn't inexperienced due to the truth the extent of problems is irrelevant to the set of rules. This set of guidelines exams all possible answers to the puzzle until a legitimate solution is located that is a time-ingesting procedure resulting an inefficient solver. The future work may be enhancement of the Backtracking algorithm to growth its performance. This look at shows that Backtracking algorithm is greater possible to resolve any Sudoku puzzles, additionally the quality technique to find a solution faster and additional green in fixing capability, illustration, and performances with any level of difficulties. This have a look at can also be useful in statistical tests and method to find out a few greater consequences for comparing.

## REFERENCES

1. Pouria Kaviani, Sunita Dhotre, 2017, Short Survey on Naive Bayes Algorithm, International Journal of Advance Engineering and Research Development.
2. H. Lloyd and M. Amos 2019 Solving Sudoku with Ant Colony Optimization, IEEE Trans. Games, pp. 1–1, 2019.

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Green Energy Technologies (ICSGET 2022)

3. Charu Gupta, 2017, Solving Sudoku using Backtracking algorithm, international journal of Modern Trends and Research
4. T. H. Cormen, Ed., 2009, Introduction to algorithms, 3rd ed. Cambridge, Mass: MIT Press.
5. Lekha. K, Vadivu. G, 2017, Performance Analysis of Sudoku Puzzle Solver, International Journal of Pure and Applied Mathematics
6. Abhishek Majumder, Abhay Kumar, Nilu Das and Nilotpal Chakraborty, 2010, International Journal of Computer Science and Network Security, VOL.10 No.8, August 2010
7. Abdullah-Al-Wadud, 2021, An Improved Hybrid Method Combining Backtracking for solving Sudoku puzzles, ISEIEEE Conference
8. T. R. Patil and S. S. Shrekar, "Performance Analysis of Naive Bayes and J48 Classification Algorithm for Data Classification," Int. J. Comput. Sci. Appl., vol. 6, no. 2, pp. 256–262, 2013.
9. R. Abraham, J. B. Simha, and S. S. Iyengar, "A Comparative Analysis of Discretization Methods for Medical Datamining with Naïve Bayesian Classifier," in Proceedings - 9th International Conference on Information Technology, 2007, pp. 235–236.
10. Moriel Schottlender, 2014, The effect of guess choices on the efficiency of a backtracking algorithm in a Sudoku solver, IEEE Long Island Systems, Applications and Technology (LISAT) Conference 2014
11. Atilla Ergugen, Erdal Erdal, 2020, Sudoku Solution Using Backtracking Algorithm, International Journal of Advances in Electronics and Computer Science.