Automated Sudoku Analyser

Khushi Khanchandani[1], Ashi Pandey[2], Sana Khan[3], Mrinalini Patil[4], Ramya Rajan[5]
ramyaranjan110@gmail.com
[1]Asst. Professor, Department of Information Technology, K J Somaiya College of Engineering, Mumbai
[2345]Student, Department of Information Technology, K J Somaiya College of Engineering, Mumbai

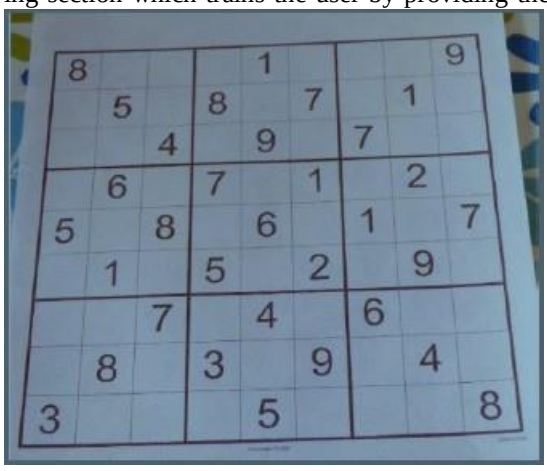
Abstract

Puzzles have been an integral part in developing a person's logical thinking. They have always influenced people's life socially and emotionally. Puzzles have always been the most interesting and fun way to learn for almost people of every age and Sudoku is one of the most played puzzles across the world. It is based on the number positioning in the grids of various sizes like 9x9,6x6,etc. Various international level and national level competitions of Sudoku is played by lakhs of people world wide.Hence it becomes necessary to develop a software which would test and solve the Sudoku accuratelyin a very less amount of time.

Keywords: Latency time, Hill Climbing, Sudoku

Introduction

Sudoku is one of the most interesting and addictive puzzle for people of every age. It is a puzzle based on the number positioning and a logical puzzle. The puzzle is based on the positioning of numbers on the 9x9, 6x6 etc. The puzzle will initially contain the unsolved or the partially solved puzzle. The unsolved puzzle is detected using digital camera and then the puzzle is checked for the accuracy . Thus the Sudoku is solved and checked using the software by data extraction. The software also contains the training section which trains the user by providing them hints.



Procedure

Module 1

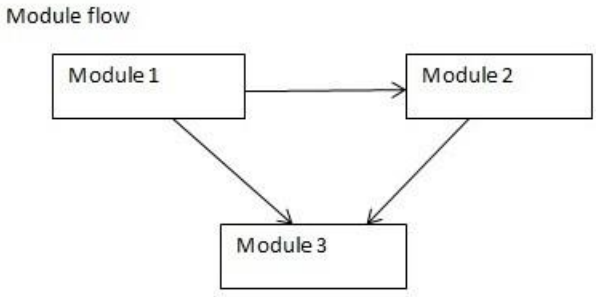
Sudoku Solving: In this procedure, the snapshot of the unsolved puzzle is taken with the help of a digital camera. The image is processed using image processing techniques. The pre-processing algorithms are applied on the image which helps us to extract data using which we can solve the Sudoku puzzle. This technique will be implemented on various type of Sudoku grids. The grid type under consideration will be 9x9, 6x6 and 16x16.

Module 2

Sudoku Verification: The Sudoku solved by the user on paper will be checked for correctness in this module. The solved Sudoku will be compared and verified based on the solutions acquired in the previous module.

Module 3

Sudoku Assistance: The Sudoku Assistant will assist the users, who are unable to go about it, with certain hints.



Related Research

Many attempts were made to check and solve the puzzles accurately and efficiently. Here are some of the good approaches we found in the paper [9] Snigdha Kamal, Sirnarpreet Singh Chawla, Nidhi Goel developed a Detection of Sudoku Puzzle using Image Processing and Solving by Backtracking, Simulated Annealing and Genetic Algorithm a Comparative Analysis IEEE in the year 2015.The

three algorithms namely Backtracking,Simulated Annealing and Genetic Algorithms was proposed for subsequent solving of the puzzles and the Sudoku puzzle gets decrypted using this, in this paper. A similar kind of approach was made by Akash Dutta in paper [1], A Sudoku puzzle is solved by the India Development of a Character Recognition Software.In this paper, a system which could extract the texts from a digital image have been strived,the puzzle is solved and a solution is provided.

Similarly,In this paper[7] Using MATLAB a solution is provided in the form of digital copy and the elements of the Sudoku are recognized and the method for detection was proposed by them. The method involves a vision-based Sudoku solver. The solver is capable of solving a Sudoku directly from an image captured from any digital camera. After applying appropriate pre-processing to the acquired image we use efficient area calculation techniques to recognize the enclosing box of the puzzle. A virtual grid is then created to identify the digit positions. Template matching is used as a method for digit recognition. The actual solution is computed using a backtracking algorithm. Experiments conducted on various types of Sudoku questions demonstrate the efficiency and robustness of our proposed approaches in real-world scenarios. The algorithm is found to be capable of handling cases of translation, perspective, illumination gradient, scaling, and background clutter.

Similarly,In this paper[4] we explore the effectiveness of solution of computationally intensive problems in FPGA (FieldProgrammable Gate Array) on an example of Sudoku game. Three different Sudoku solvers have been fully implemented and tested on a low-cost FPGA of Xilinx Spartan-3E family. The first solver is only able to deal with simple puzzles with reasoning, i.e. without search. The second solver applies breadth-first search algorithm and therefore has virtually no limitation on the type of puzzles which are solvable. We prove that despite the serial nature of implemented backtracking search algorithms, parallelism can be used efficiently. Thus, the suggested third solver explores the possibility of parallel processing of search tree branches and boosts the performance of the second solver. The trade-offs of the designed solvers are analyzed, the results are compared to software and to other known implementations, and conclusions are drawn on how to improve the suggested architectures.

Sudoku like Puzzle rules was learned by the Paper [8].A fully connected neural network which cam be implemented as an analog circuit which consisted of 8 neurons and 64 synapses by which the rules of 2 by 2 Sudoku like puzzles was learned,was designed by them and they can be solved by them.A dopamine reward signal is given to correct actions which also has a biological basis and reinforcement learning concept is used here in this circuit.

In paper[5], Sudoku puzzle tailored the -Hill Climbing algorithm. Hill climbing algorithm extends the newer version called the -Hill Climbing algorithm which escapes the local optima by using a stochastic operator named -operator.To come up with the exact solution,the Sudoku puzzle which is a popular game was formulated.To evaluate, some Sudoku puzzles are applied. In order to find the solution for the Sudoku puzzle in 19 iterations and 2 seconds, -Hill Climbing algorithm is the best paramater configuration.

In paper [6],The Sudoku Solver which is also known as SSAS (Sudoku Simulated Annealing Solver) is developed by the authors in this paper. A Sudoku board of order fifteen(15x15x15) can be solved using the general design. Xilinx Virtex II Pro based Digilent XUP board fully implements the Sudoku solver. According to the specifications of the relevant competition of the 2009 International Conference on Field Programmable Technology (FPT),on a personal computer the results get uploaded and the problems get downloaded on the serial port interface which is in the solver.Within the competition impost time limts, the SSAS Sudoku solver solves the hardware Sudoku puzzles upto order 12.

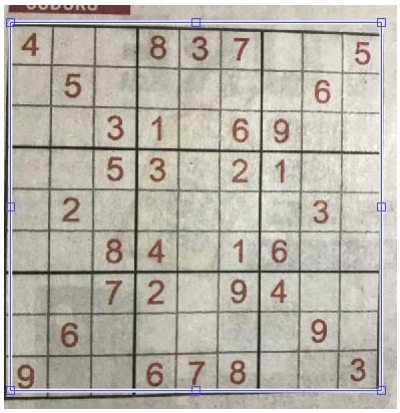
In paper[2],The mixed handwritten and printed digit recognition in Sudoku with Convolution Deep belief Network was developed by Baptiste Wicht, Jean Hennebertt . A method was proposed in which both the handwritten and the pri nted digits from the images of the Sudoku was recognized using the method that was proposed by them.The Image processing Techniques which included Hough transforms and Contour Detection detected the digits and the grid of the Sudoku Puzzle.A set of 200 Sudoku images which is captured with the smartphone cameras under varying conditionslike shadows and distortion, could be thoroughly tested by the system.. In paper [3],92 percent of the cells which was correctly classified was shown by the system as the promising results.

Implementation

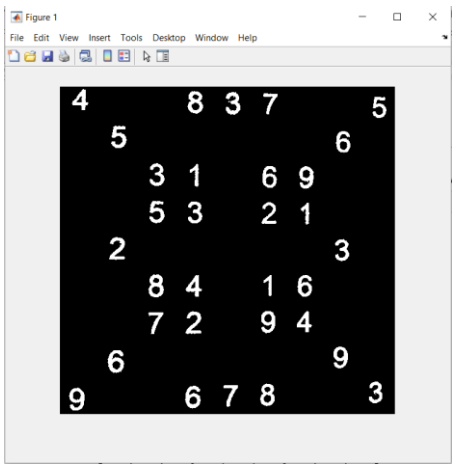
Module 1: Sudoku Solving

In this module, the snapshot of the unsolved Sudoku puzzle is taken with help of any digital camera. The image is first pre-processed using techniques like Binarising, Thresholding and Opening. These pre-processing techniques are applied on the image that helps us to extract data using which we can solve the Sudoku puzzle. After the pre-processing is done, the data from the image is extracted and stored in a 2D array. Using this 2D array, we solve the Sudoku puzzle with the help of Backtracking Algorithm. The solved Sudoku will be displayed to the user. Sudoku of different grid sizes will be taken into consideration.

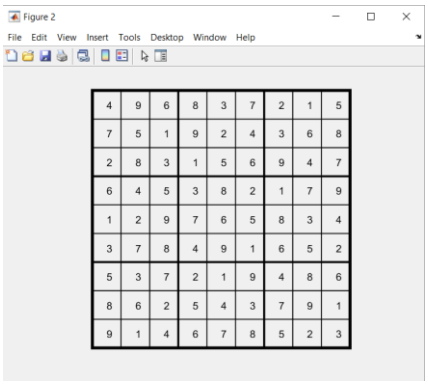
1. Snapshot of unsolved Sudoku taken with the help of a digital camera.



2. Snapshot of pre-processed data using various pre-processing techniques like Binarising, Thresholding and Opening.



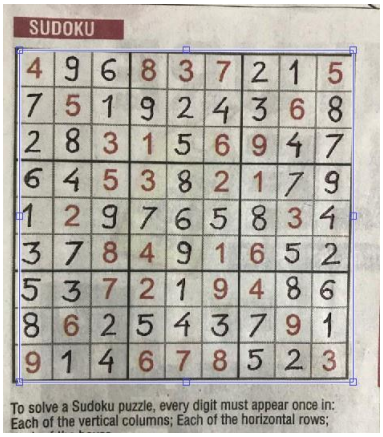
3. Snapshot of solved Sudoku using back-tracking algorithm.



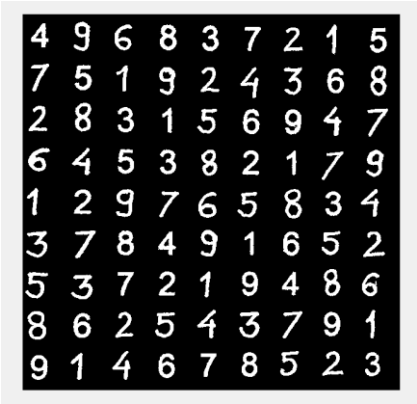
Module 2: Sudoku Verification

In this module, we compare the solution uploaded by the user with the correct solution which we have from Module-1. The image uploaded by the user is first cropped for further processing. Then OCR is applied in order to recognize the handwritten digits. Once we get the Sudoku solved by the user in digital form, we then compare it to the correct solution solved using Module-1 which is stored in the excel sheet. After the comparison between both the solutions are done, the result is notified to the user.

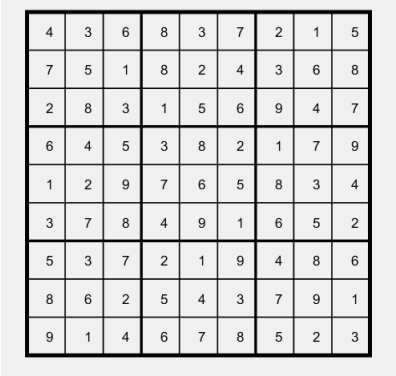
1. The image uploaded by the user is cropped for further processing.



2. Using OCR, the handwritten digits are recognized.



3. Output of Digit Recognition



4	3	6	8	3	7	2	1	5
7	5	1	8	2	4	3	6	8
2	8	3	1	5	6	9	4	7
6	4	5	3	8	2	1	7	9
1	2	9	7	6	5	8	3	4
3	7	8	4	9	1	6	5	2
5	3	7	2	1	9	4	8	6
8	6	2	5	4	3	7	9	1
9	1	4	6	7	8	5	2	3

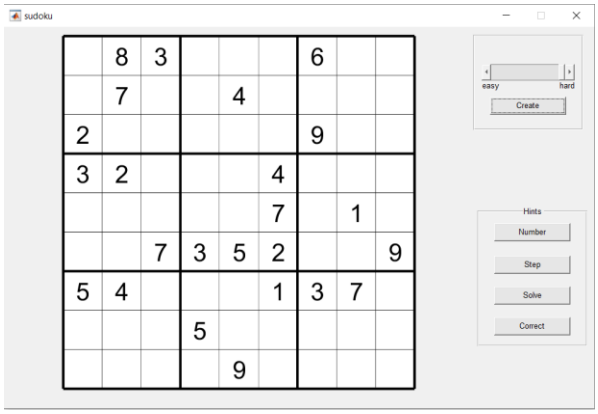
4. Result notified to the user

Module 3: Sudoku Assistance

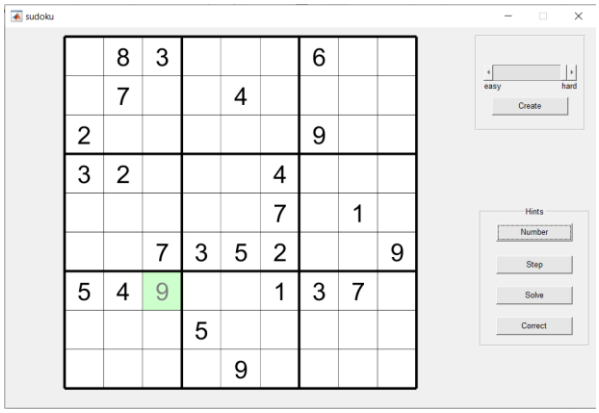
In this module, the Sudoku Assistant will assist the users, who are unable to go about it, with certain hints. The user will be given 2 options to choose from. In the first one, the user can upload his own Sudoku and Sudoku assistant will give him hints with respect to his Sudoku. In the second one, based on the difficulty level, the Sudoku will be generated by the system and the hints will be given to the Sudoku. Backtracking algorithm from Module 1 is used here. There are 4 types of hints that will be provided to the user namely:

1. **Number**: In this hint, depending on the difficulty level, any one correct number in the correct grid will be displayed after comparing it to the correct solution from Module-1.
2. **Step**: In this hint, correct numbers are displayed in each step and each step leads to proximity to the correct solution.
3. **Solve**: In this hint, the whole Sudoku is solved with the help of Module-1.
4. **Correct**: In this hint, the numbers entered by the user is shown correct/incorrect by clicking on the Correct button. All the incorrect numbers entered by the user are erased automatically.

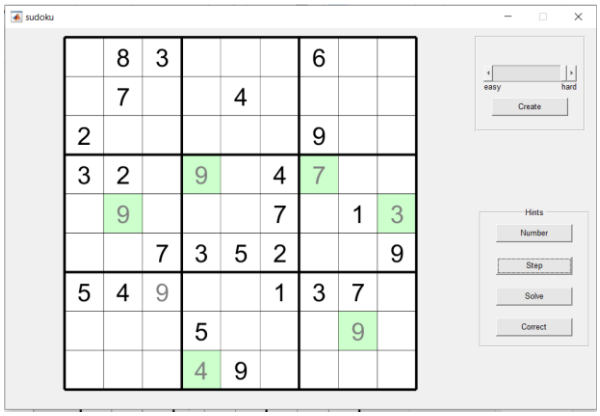
System Generated Sudoku.



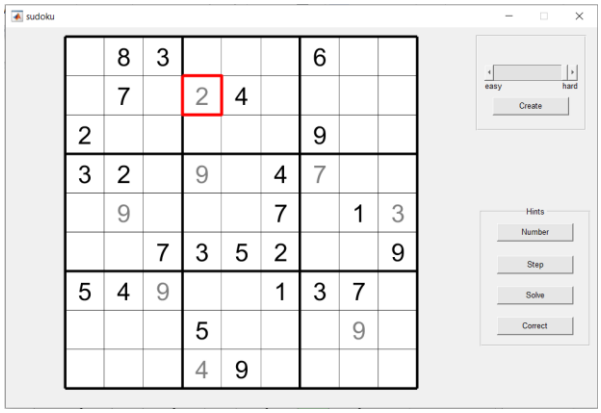
1. After Hint ”Number” is used:

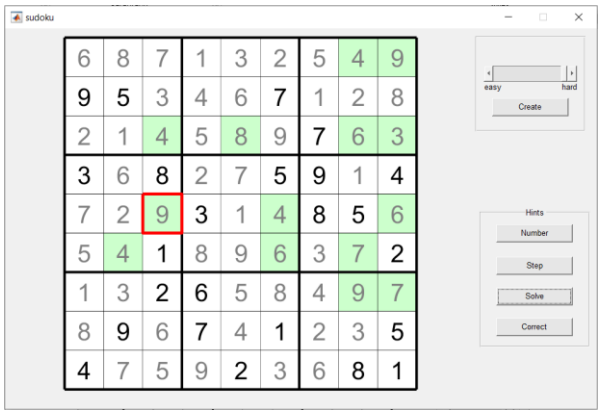


2. After Hint ”Step” is used:

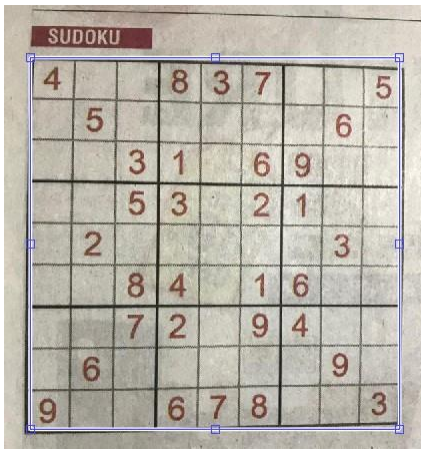


3. After Hint ”Solve” is used:

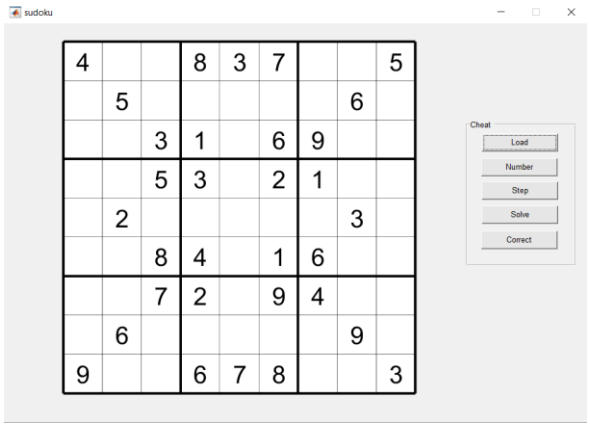




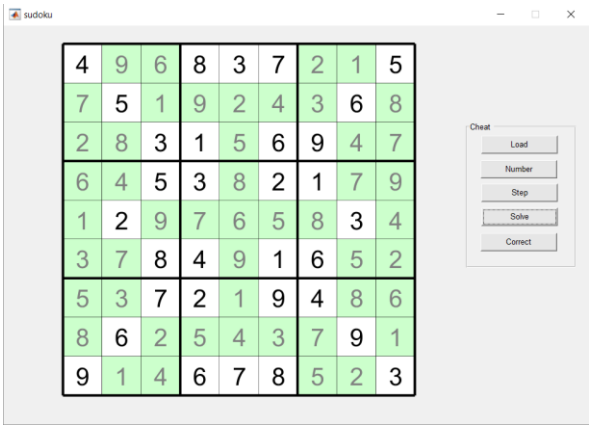
User Generated Sudoku

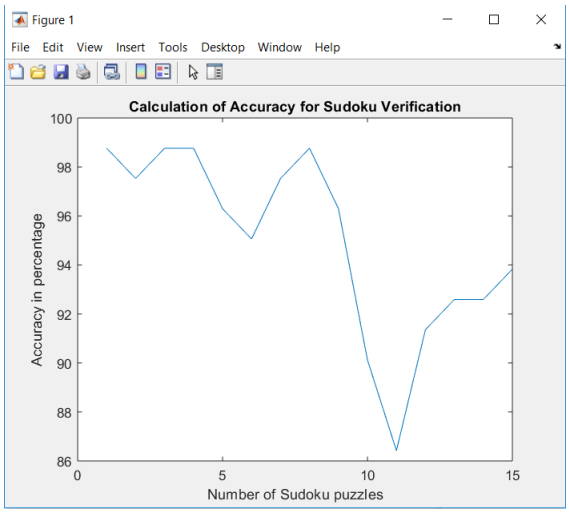


1. After the image is loaded:

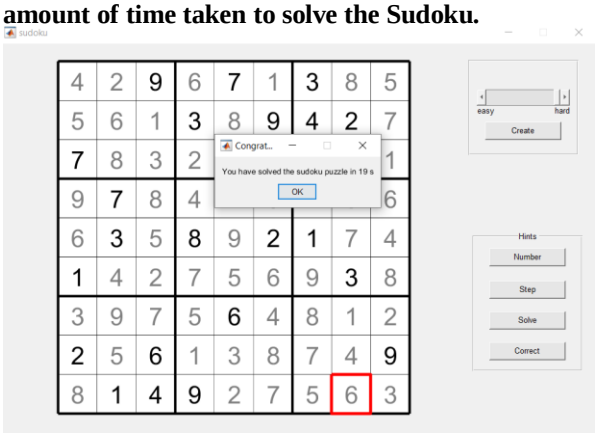


2. After hint 'solve' is used:





After the hints have been used, the system shows the amount of time taken to solve the Sudoku.

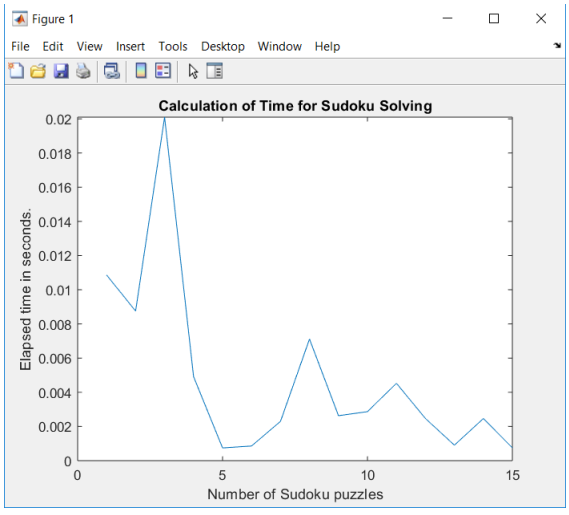


The following graph shows the average time to solve the Sudoku which is approximately 0.0048 seconds.

Result

Thus we have created the 'Automated Sudoku Analyser' comprising of Sudoku solving, verifying and assistance provided wherein the accuracy of Sudoku solving is 100 percent, detection of handwritten Sudoku is about 95 percent and Sudoku assistance is 100 percent.

The following graph shows the accuracy with respect to handwriting recognition which is 95 percent.



Conclusion

The software we have developed a aims to decrease the latency time in the checking of the different complexities of Sudoku in all the challenges and competitions. The software can be used to accurately determine the results of multiple puzzles simultaneously , thus preventing the wastage of time. The accuracy and robustness of the software makes it reliable and efficient to use by almost everyone.

References

[1] Arunabha Ghosh Akash Dutta. "Development of a Character Recognition Software to solve a Sudoku Puzzle". In: *2016 IEEE 7th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON),* (2016).

[2] Jean Hennebertt Baptiste Wicht. "Mixed handwritten and printed digit recognition in Sudoku with Convolutional Deep Belief Network". In: *2015 13th International Conference on Document Analysis and Recognition (ICDAR)* (2015).

[3] RudraPratap Singh Prateek S Sengar. Gaurav Chitranshi Sharad Tiwari. "Neural Network Based Skeleton Recognition and Sudoku Solving". In: *2016 3rd International Conference on Signal Processing and Integrated Networks (SPIN)* (2016).

[4] Valery Sklyarov Iouliia Skliarova Tiago Vallejo. "Solving Sudoku in Reconfigurable Hardware". In: (2015).

[5] Asaju Laaro Bolaji Basem O. Alijla Mohammed Azmi Al-Betar Mohammed A. Awadallah. "-Hill Climbing algorithm for sudoku game". In: *2017 Palestinian International Conference on Information and Communication Technology(PICICT)* (2017).

[6] Euripides Sotiriades Apostolos Dollas Pavlos Malakonakis Miltiadis Smerdis. "An FPGA-Based Sudoku Solver based on Simulated Annealing Methods". In: (2015).

[7] Suraj K v Pramod J Simha and Tejas Ahobala. "Recognition of Numbers and Position using Image Processing Techniques for Solving Sudoku Puzzles". In: *IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012)* (2012).

[8] Alice C. Parker Saeid Barzegarjalali. "An Analog Neural Network that Learns Sudoku-Like Puzzle Rules". In: *FTC 2016 - Future Technologies Conference* (2016).

[9] Nidhi Goel Snigdha Kamal Simarpreet Singh Chawla. "Detection of Sudoku Puzzle using Image Processing and Solving by Backtracking, Simulated Annealing and Genetic Algorithms: A Comparative Analysis". In: *2015 Third International Conference on Image Information Processing(ICIIP)* (2015).