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Artificial Intelligence Based Real Time Computer Vision and Puzzle Solver Using Web-Cam

Sonali Parkar[1]; Samikshya Gujare[2]; Harshali Malvankar[3]; Sonal Balpande[4]

[1, 3]B.E. Students,[4]Assistant Professor, Department of Computer Engineering, K.C. College Of Engineering & Management Studies & Research, Kopri, Thane(E)-400603, India

Abstract: **The research effort centralizes the idea to implement the system that employs Computer vision and Artificial Intelligence to solve the puzzle. Artificial Intelligence based real time Computer Vision and puzzle solver using web-cam allowsto provide the computer system with the Sudoku-puzzle in real-time and give the optimum solution to it. The system tries to analyze the environment by capturing the multiple image bursts from the real time and from those images it would detect the Sudoku grid. For the detection of the grid the use of Hough Transform technique has been made. Then the numbers are detected using OCR i.e. Optical Character Recognition. Thus, the system gets the total knowledge of the puzzle and then computes the final solution by making the use of Artificial Intelligence based strategies for getting the optimal solution to the Sudoku puzzle problem.**

Keywords: **Sudoku puzzle, Computer vision, Artificial Intelligence.**

I. INTRODUCTION

Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images and, in general, high-dimensional data from the real world in order to produce numerical or symbolic information, e.g., in the forms of decisions[13]. A theme in the development of this field has been to duplicate the abilities of human vision by electronically perceiving and understanding an image[13]. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory[13]. Computer vision has also been described as the enterprise of automating and integrating a wide range of processes and representations for vision perception[13]. As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images[13]. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner[13].

Artificial intelligence (AI) is the intelligence exhibited by machines or software[14]. The central problems (or goals) of AI research include reasoning, knowledge, planning, learning, natural language processing (communication), perception and the ability to move and manipulate objects[14]. General intelligence is still among the field's long-term goals[11]. Currently popular approaches include statistical methods, computational intelligence and traditional symbolic AI[11]. In the proposed system AI strategies are needed to solve the puzzle acquired using computer vision[11]. For solving the puzzle, the brute force attack strategy, standard Sudoku puzzle solving algorithms can be used[11].

II. EXISTING SYSTEM

The existing system i.e. the solvation of Sudoku puzzle needs huge mathematical computations as it contains 81 cells, in a 9 by 9 grid, and has 9 zones, each zone being the intersection of 3 rows and 3 columns[15]. Each cell may contain a number from one to nine; each number can only occur once in each zone, row, and column of the grid no digit can appear twice in a unit[15]. This implies that each square must have a different value[15]. At the beginning of the game, many cells begin

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with numbers in them, and the goal is to fill in the remaining cells[15]. If solved manually there is a wide range of strategies to solve Sudoku puzzles and will need huge efforts to do so and compute the optimal solution of the puzzle[15].

Furthermore, several researches have been made to solve Sudoku problems in a more efficient way. It has conclusively been shown that solving the puzzle, by using different algorithms, is definitely possible but most developers seek for optimizations techniques such as genetic algorithms, simulated annealing.

III. METHODOLOGY

Artificial Intelligence based real time Computer Vision and puzzle solver using web-cam allows to provide the computer system with the Sudoku-puzzle in real-time and give the optimum solution to it.

On the high-level following steps are performed:

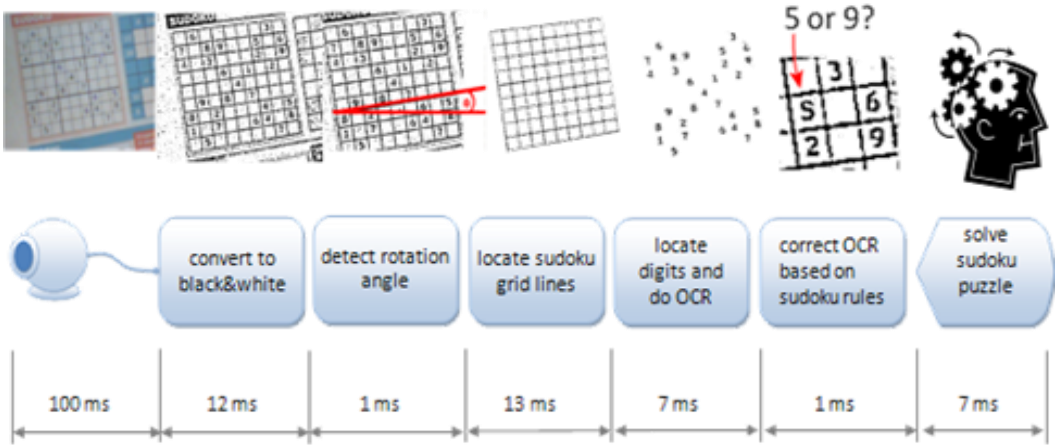


Fig.1

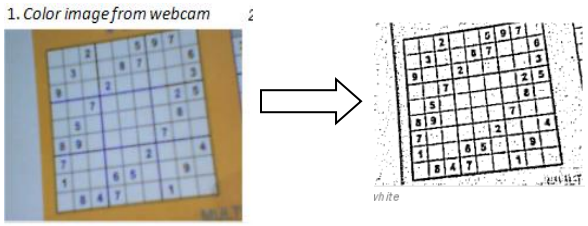
A) Capture the image:

In Real time environment the webcam first captures the puzzle so as to proceed towards the futher processing.

B) Convert to black and white:

Every computer vision application starts with the conversion from gray scale to monochrome color.

The method used to convert color to monochrome is "Thresholding".Here each pixel in an image is first replaced with black pixel if the image intensity I is less than some fixed constant T i.e(I<T),or else with a white pixel [16].



C) Detect rotation:

The puzzle captured by the webcam may not be always aligned, it is to be skewed and rotated. As the puzzle has some horizontal and vertical lines i.e grid ,this lines are used to detect the angle of rotation.The most expressive (strongest) line near to the center of the picture is detected. The most expressive line is not affected by the noise.

The algorithm used to detect lines from a monochrome image is called Hough Transform.

Working:

The Hough transform algorithm skips the white pixels. Every black pixel draws 180 virtual lines passing through that pixel. The line which is common to all pixels is considered as the strongest line.

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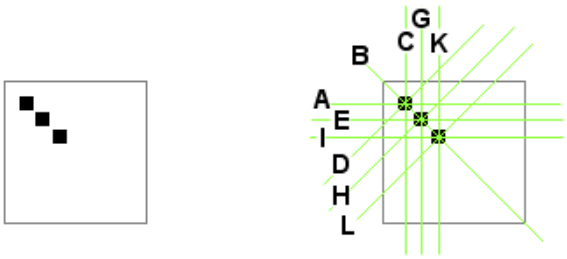


Fig.7 - can you see a line here?

The theta and rho values of this line are then considered.

y = (x * cos(theta) + rho) / sin(theta).

Here,Theta signifies the angle of the line and rho specifies the distance of line from center coordinate (0, 0).

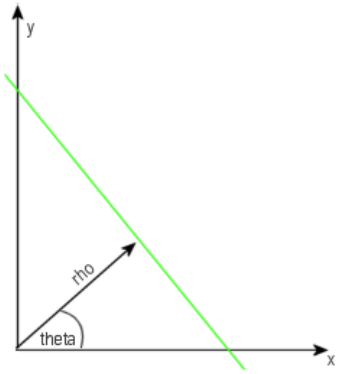
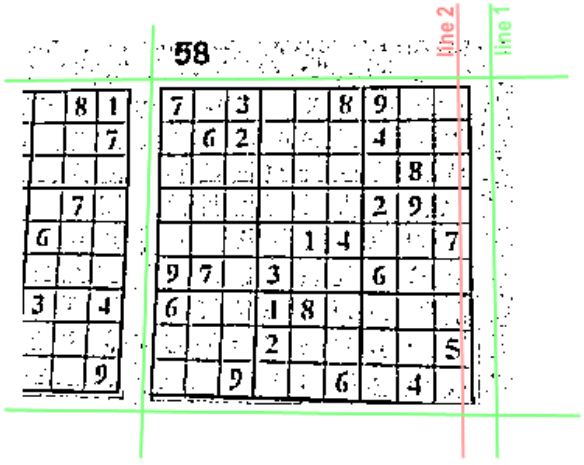


Fig.6 - line formula

D) Locate grid Lines:

To extract the numbers from the grid the Sudoku grid needs to be precisely located.But the grids printed may contain some noise i.e background data.due to which it is difficult to distinguish the noise and the actual grid lines.

So, white lines are detected instead of detecting black lines. By counting the number of times line is interrupted by black pixels accordingly it is considered whether it is outside the grid or inside.



By this the grid border lines are detected.Then hough transform is again applied inside the boundaries to detect the grid lines of the inner grid lines.

E) Optical Character Recognition (OCR):

Optical character recognition is the process of turning the picture of the text into the text itself. Below is the explanation of the role of OCR in the system.

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After the blobs which are located inside the cell, the next step will be to recognize them. The task is relatively easy in the case of Sudoku puzzle as only the numbers from 1 to 9 needs to be recognized and not all the alphabets. Every recognition algorithm has these steps:

- Determine features
- Train (learning step)
- Classify (runtime recognition)

'*Determine features*' is a part of the application design. The features for example are: the number 1 is tall or thin. This is what it makes him different from the other numbers. The number 8 has two circles, one above the other, etc.

Zone features: In this application, zone density features will be used. The next step is to *train* the application by providing training pictures of digits 1-9. The pictures are resized to 5x5 pixels, normalized, and stored in the static array which looks like:

Fig.11 - trained digits

The process of resizing the image to 5x5 is called zoning. The above shown image of array is called density features. Normalizing means that those 5x5 pictures have density values in the range 0 to 1024. Without normalizing, the zones would be incomparable.

When a blob is recognized and isolated from a webcam's image, it's resized to 5x5 pixels. Then these 25 pixels are compared, one by one, with the nine trained density feature arrays. The goal is to find the minimal difference in pixel intensity. Less difference means more similarity. This is the process which happens at runtime.

F) Puzzle Solving:

The use of three simple methods are merged together in order to find the solution to the puzzle in a better and faster way.

Those three methods are: i) Brute-Force ii) Naked single iii) Hidden single

i) Brute Force method:

Brute force is a trial and error method. It tries all the combination of values from 1 to 9 on all the empty cells until all the cells are filled with consistent values. There could be more than one solution. Brute force is the most commonly used method by programmers as however the condition maybe, it promises to give the final solution, no matter how much time it consumes. But brute force could be very slow, depending on the number of recursive iterations needed. It can be never known in advance how much iteration is needed.

The first step is to prepare the table of candidates – possible values for each empty cell. The explanation of what the candidates are is given by the image shown below. The candidates are given in blue color. Only 1,4 and 8 can be contained by reference to the Sudoku rules. For example, as 3 is already present in the two cells below it cannot be there.

Initial puzzle state

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

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With list of possible values – candidates

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

Until brute force finds the solution, it will try to combine all the blue numbers. Check the first cell. The algorithm will begin with the value 1; it will take number 3 on the fifth cell then, and so on. The algorithm will try with the different values if any of the selected values are not consistent with the other values. For example, there is number 3 at the sixth cell from the left, but as there is no consistency with the fifth cell, the algorithm will move on with the next candidate i.e. 4, etc.

ii) Naked single method:

The image below would explain what is naked single method in detail. If a cell has a single candidate that could be taken then it is 100% sure that this is a valid value for that cell. After that value is been set, the next step is to rebuild the list of candidates. The list of candidates would gradually reduce until all the candidates are singles.

Step 1. This cell has a single candidate. Fill it.

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

Step 2. Now we have next two single candidates

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

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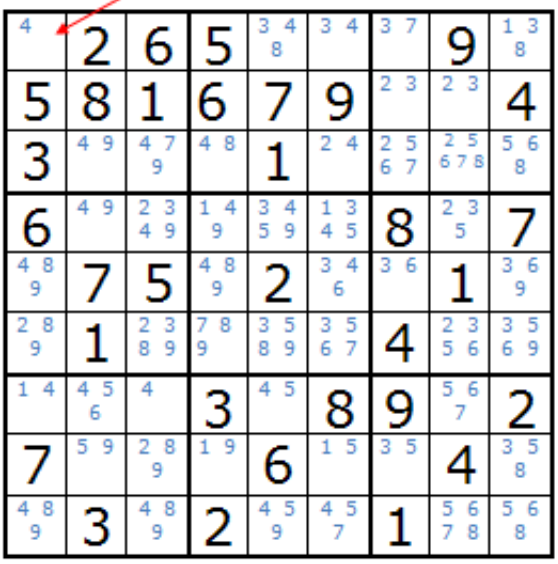
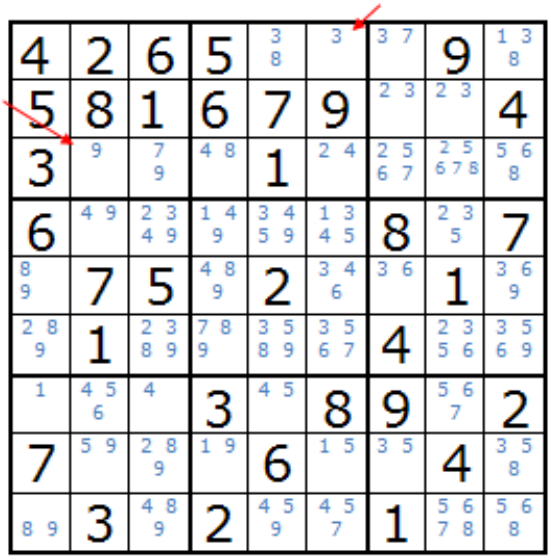
Step 3. Next single candidate. Fill it.



Step 4. Next single candidates. Etc...



iii) Hidden Single method:

The image below here explains the hidden single method. Look at the number 7 in the given image, the regular Sudoku player would be easily able to get that the number 7 would come in the pointed box. Even if the cell has four candidates: 4,7,8,9 in the adjacent figure, the trick is to search for a unique instance of candidates inside the 3x3 block, column, or row. When method 2 runs out of the single candidates, method 3 can help.

For the webcam puzzle solver, the speed is very important aspect. The brute force is not fast enough for this particular application. Therefore a combination of all three methods shall be used. The methods 2 and 3 are very fast, but they are able to solve only simple puzzles. The flowchart mentioned below gives the overview of how these methods would work together. On the left side, there are fast methods and on the right side is the brute force. Only when the left side methods fail, it will jump to the right side for further solution. Even if the left side methods are unsuccessful to solve the whole puzzle, it reduces the burden of the problem at a larger extent for brute force.

There will be three re-tries after which the program gives up. Between each retry the recursion sequence is rearranged randomly with the hope that the new sequence will lead to the fast solution. If the brute force fails three retires, it may not be the complete failure. The next camera frame might be lucky.

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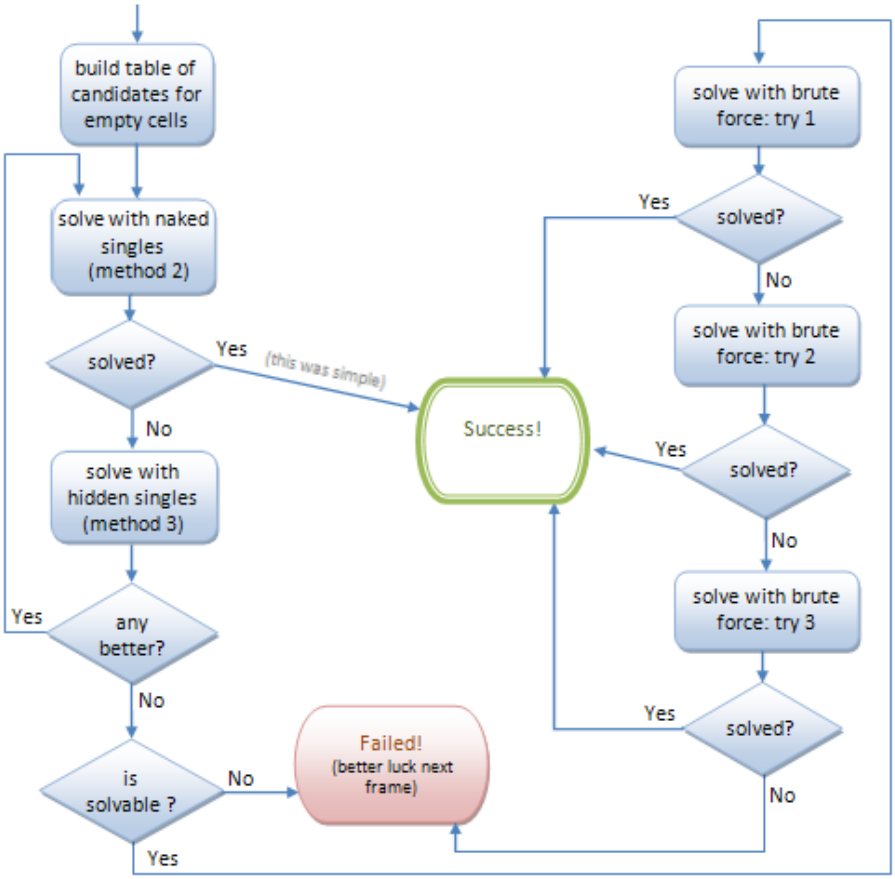

Fig.19 - Sudoku solver diagram

IV. CONCLUSION

The Sudoku solvation needs many computations and when tried doing it manually it requires too much of time and efforts to find the optimal solution to the puzzle.

- Thus, the drawbacks of the current system are:
- If solved manually players needs to check different alternatives and place the numbers in the empty squares by guessing as many options are valid.
- Needs feeding of random numbers by player and then it is checked whether valid or not for all possible solutions to the puzzle until a valid solution is found which is a time consuming procedure resulting an inefficient solver.
- As compared to real time it is time consuming and needs human efforts too which is not the case in real time puzzle solver.

The proposed system overcomes the obstacles of the current system.

- No human intervention required.
- The data of the puzzle need not be given manually because the puzzle will be detected in the real time itself.
- Less time consuming.
- Provides more accurate and optimal solution.

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