Sudoku Puzzles by using x-wing techniques

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Abstract:

The purpose of this essay is to implement and study different techniques for solving Sudoku puzzles, a problem similar to graph coloring with fixed size and dependencies. Three approaches are presented and compared regarding efficiency (time needed, space required and success rate). These approaches are rule-based solving, simulated annealing, and searching for solutions. Finally the parts found to be most important for an efficient solver are combined, creating an even better solve.

Sudoku puzzles involve a lot of mathematics. Of course, the puzzles are filled with numbers, but the solution process would be the same regardless of the symbols used. More interesting is the logic behind the solution process, which can provide extra satisfaction upon solving a puzzle (with a lot less erasing). In addition, the puzzles are examples of Latin squares–important in abstract algebra and in statis- tics, in experimental design.

Advanced solving Techniques:

In November 2006, The Times introduced a new extreme level of Sudoku giving players a more difficult level of logic: Super Fiendish. Many have welcomed the new challenge but some have asked for help. So, as we increase the difficulty Super Fiendish, the time has come to present the essential techniques for solving the most difficult Sudoku puzzles. First a couple of preliminary points: if you have ever completed any Fiendish or Super Fiendish Sudoku, you will be familiar with noting down candidates or pencil marks. Pencil marks are small numbers, usually written at the top of each unsolved square, listingall the possible values for that square. With many advanced techniques, the key is to spot patterns within your pencil marks to eliminate possibilities within other squares.

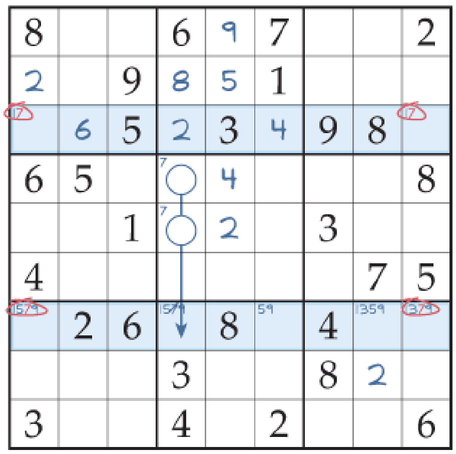
The x-wing technique:

Essentially, this method uses the fact that in certain cases, there are only two possible ways of placing two numbers in four squares which form a rectangle.

The Sudoku in Fig. 1 is partially solved using easy and medium difficulty solving techniques: singles, hidden singles and column/block intersections. Now, no more squares can be solved with these techniques; you are stuck.

Consider where you might place the 7 on the third and seventh rows (highlighted). You know it must be placed once, and only once, on each of these rows. Here, the only squares with the 7 as a possibility are in the first and last columns. So, there are two possible ways of placing the 7; how does this help you solve anything? Well, you have established that the 7 for the first column

must be in one of the two highlighted rows; not in any other squares in this column.



(Fig. 2). This leaves one square in the first column with only one pencil mark, so you can now place the 9. Now this square is solved, you can complete the Sudoku using easy methods.

In general, an x-wing is found when for two rows, there are two, and only two, possible squares in which a particular number can be placed, and for both rows these squares lie in the same two columns.

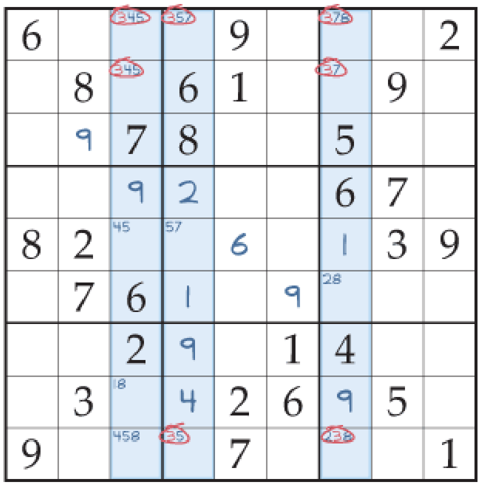
The Swordfish technique:

This is a more difficult method, one of the most complicated for any Sudoku you will find in print. From today onwards, you will find the swordfish technique become a regular feature in the Times2. A swordfish is found when for three rows, there are two or three possible squares in which a particular number can be placed, and for all three rows these squares lie in the same three columns.

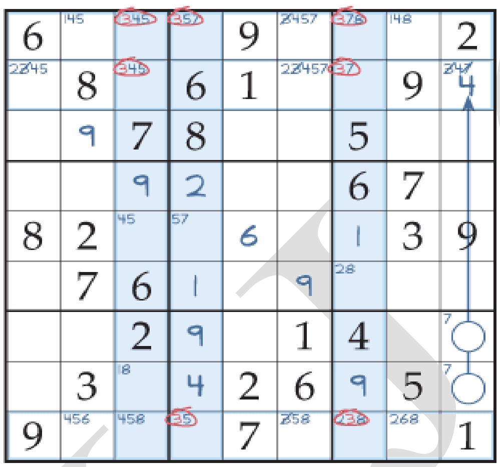
this particular number can be eliminated as a possibility for all other squares in those three columns. Of course, you can exchange rows and columns in this definition.

Fig. 3 is a partially solved Sudoku, using easy and medium difficulty solving techniques; no more squares can be solved using them. To give you a good chance of spotting the swordfish you should enter all the pencil marks in the grid as shown here.

In Fig. 4, the relevant pencil marks are entered to show that you have two possible squares in which the 3 can be placed in the third and fourth columns, and three possible squares in the seventh column (highlighted). Crucially, all of these possible squares lie in only three rows. Therefore, on each of the three intersecting rows, the 3 must be placed in one of the highlighted columns.



(Fig. 5). These eliminations, in addition with a column/block intersection to remove a 7 pencil mark, leave only one pencil mark in the last square in the second row, so you can now solve it to be a 4.



If you like playing some seriously hard Sudoku, try the puzzles at the end of The Times Sudoku 6 book with some requiring the swordfish technique.

Crook's Algorithm:

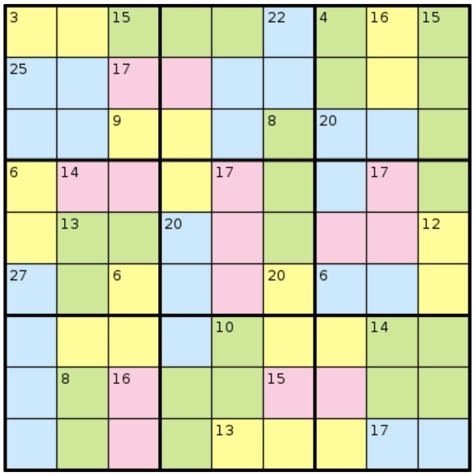
This week has seen some articles in many newspapers about a general algorithm that solves all Sudoku puzzles. For example, The Daily Mail (on-line). In a formal paper by American scientist J.F.Crook the article does indeed have a 'general' method for solving Sudoku puzzles - but at it's heart is the old game of 'Trial and Error' - and I feel I must pour some cold water on the hyperbole generated by this attempt. Now, Mr. Crook does start well with some good definitions and theorems, his "Preemptive Sets" and the "Occupancy Theorem". But in careful reading I find that the Preemptive Sets is another name for a Locked Set, something many solvers will be intimately familiar with, especially if they delve into the strategies on this web site. A Locked Set/Preemptive Set is any set of N cells occupied by exactly N candidates.

Killer SuDoku:

Killer sudoku (also killer su doku, sumdoku, sum doku, addoku, or samunamupure) is a puzzle that combines elements of sudoku and kakuro. Despite the name, the simpler killer sudokus can be easier to solve than regular sudokus, depending on the solver's skill at mental arithmetic; the hardest ones, however, can take hours to crack. A typical problem is shown on the right, using colors to define the groups of cells. More often, puzzles are printed in black and white, with thin dotted lines used to outline the "cages.

Killer sudokus were already an established variant of sudoku in Japan by the mid 1990s, where they were known as "samunamupure." The name stemmed from a Japanized form of the English words "sum number place." Killer sudokus were introduced to most of the English-speaking world by *The Times* in 2005.

Traditionally, as with regular sudoku puzzles, the grid layout is symmetrical around a diagonal, horizontal or vertical axis, or a quarter or half turn about the centre. This is a matter of aesthetics, though, rather than obligatory: many Japanese puzzle-makers will make small deviations from perfect symmetry for the sake of improving the puzzle. Other puzzle-makers may produce entirely asymmetrical puzzles.



Sudoku solving complexity:

I have an assignment in an AI class to create a sudoku solving algorithm, and it got me wondering about the complexity of solving a game. I'm not asking for help with the algorithm, but I would like to see what different approaches there are to solving it. The only solution I've thought of without looking for algorithms in google is to treat is as a graph with 81 nodes, each of which is adjacent to 20 nodes (8 per row + 8 per column + 4 additional nodes in the square) where the goal would be to color the graph with 9 available colors such that no adjacent nodes share the same color. You then move from node to node checking the possible colors you could assign. This solution however seems exceedingly complex. This is a simple and somewhat elegant solution as well. I can't really think of any other good ways to solve this problem, I have never played sudoku so I'm not too familiar with good strategies for solving the problems.

Conclusion:

Once you learn the basics of solving a Sudoku puzzle you will need to apply it to puzzles of all levels of ability. You may find yourself struggling at first but this is just subjective and over time you will find yourself flying through puzzles that are mild to challenging. There are many mistakes that you will make along the way, and you may often find yourself wedged into a dead end with no where to go. Winding up the thread and starting again is the only way that you will learn to successfully solve a Sudoku puzzle. The same puzzle may take one person thirty minutes to solve while another person may take two hours. Sometimes solving time comes down to your experience and other times it may just depend on how well you work the numbers. No matter how good or bad you are solving Sudoku puzzles, you are guaranteed that you will get a good mental workout. As keep fit for the brain, Sudoku is as good as it gets.

Reference:

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