Evolutionary algorithms - CT20A6300
Alternative Project work 2008
Timo Mantere

If the problems in WCCI seem too difficult, you can do alternative project work – Solving Sudoku's with using Evolutionary algorithms.

Sudoku is a logic-based number puzzle game, where 9x9 grid should be filled so, that each column, row 3x3 subgrid contains all numbers: {1, 2, 3, 4, 5, 6, 7, 8, 9} once and only once. See more info on Sudoku's: http://en.wikipedia.org/wiki/Sudoku

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

Medium Sudoku 4

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

Solution for Sudoku in left

Column contain all numbers {1 … 9}

3x3 Subgrid contains all numbers {1 … 9}

Row contains all numbers {1 … 9}

In addition, in Sudoku puzzle there is some fixed numbers, **givens** that should appear exactly in the same given position in the final solution.

Because Sudoku is a combinatorial problem, the natural approach would be code permutation genetic algorithms. However, it is possible to approach this problem also with totally different ways; you can use genetic programming, ant colony optimization, cultural algorithms etc. It is also totally possible to use normal floating point coded GA or differential evolution, where the solution will be rounded to integers.

Your task is to code a program that solves Sudoku puzzles by using some evolutionary algorithm. You should analyze the efficiency of your program by solving the given example Sudoku's (next page). It is probably best to start with Easy Sudoku's 1-3, then continue to the medium Sudoku's 1-4 (4 in this page), and if your program is successful with these then try to continue to the Super difficult Sudoku's 1-3.

You can code your program whatever programming language you prefer, even with Matlab etc. You should return report and program code.

The next page gives some references to papers that have studied the solving of Sudoku's with different evolutionary algorithms. You can start by reading how these have approached the Sudoku problem, then you can code either similar approach or totally different based on your belief on how Sudoku's should be solved with EAs.

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

Easy Sudoku 1

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

Easy Sudoku 2

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

Easy Sudoku 3

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

Medium Sudoku 1

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

Medium Sudoku 2

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

Medium Sudoku 3

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

GA generated Super difficult Sudoku 1

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

AI Escarcot – Claim to be the most difficult Sudoku 2

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

Super difficult Sudoku from www.sudoku.com 3

References to articles that have presented Sudoku solving with EAs:

1. Gold, M.; Using Genetic Algorithms to Come up with Sudoku Puzzles. Sep 23, 2005. Available via WWW: http://www.c-sharpcorner.com/UploadFile/mgold/Sudoku09232005003323AM/Sudoku.aspx?ArticleID=fba36449-ccf3-444f-a435-a812535c45e5 (here generated new Sudoku's with GA)
2. Moraglio, A.; Togelius, J.; Lucas, S.; Product Geometric Crossover for the Sudoku Puzzle. IEEE Congress on Evolutionary Computation, CEC 2006, 16-21 July 2006 Page(s):470 – 476 (IEEE Explore http://ieeexplore.ieee.org/search/advsearch.jsp or http://julian.togelius.com/Moraglio2006Product.pdf)
3. Nicolau, M.; Ryan, C.; Genetic Operators and Sequencing in the GAuGE System. IEEE Congress on Evolutionary Computation, CEC 2006, 16-21 July 2006 Page(s):1561 – 1568 (available IEEE Explore)
4. Mantere, Timo and Janne Koljonen; Solving and rating Sudoku puzzles with genetic algorithms. In New Developments in Artificial Intellingence and the Semantic Web – Proc. of the 12th Finnish Artificial Conference STeP 2006, HUT, Espoo, Finland, October 26-27, 2006, pp. 86-92. Available WWW: http://www.stes.fi/scai2006/proceedings/step2006-86-mantere-solving-and-rating-sudoku-puzzles.pdf
5. Mantere, Timo; Koljonen, Janne; Solving, rating and generating Sudoku puzzles with GA. IEEE Congress on Evolutionary Computation, CEC 2007, 25-28 Sept. 2007 Page(s):1382 – 1389 Digital Object Identifier 10.1109/CEC.2007.4424632 (available IEEE Explore)
6. Mantere, Timo; Koljonen, Janne; Analyzing and solving Sudoku's with cultural algorithms. Accepted to be published in IEEE Congress on Evolutionary Computation, CEC 2008, 1-6 June 2008 (available later via IEEE Explore)