Report: SAT-based Sudoku Solving

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Summary:

We are using java for our project. We found that the original sudoku solvers uses the naive implementation (ie: back tracking/ searching algorithms). In order to have a better sudoku solver, they used some sort of search heuristic or constraint propagation method to deal with the puzzle. However, the task of SAT is to determine if there exists an interpretation that satisfies a given propositional formula, which is quite different from the sudoku solver. Our program takes the puzzle as a text file, converts it into a boolean formula of clauses to input into Minisat, then it outputs the solved puzzle as a text file. The test cases are referenced from: https://projecteuler.net/project/resources/p096_sudoku.txt. Below is the result of our program and the run time.

Results:

Input Puzzle	Output Puzzle	Runtime
Grid 01 003020600 900305001 001806400 008102900 700000008 006708200 002609500 800203009 005010300	4 8 3 9 2 1 6 5 7 9 6 7 3 4 5 8 2 1 2 5 1 8 7 6 4 9 3 5 4 8 1 3 2 9 7 6 7 2 9 5 6 4 1 3 8 1 3 6 7 9 8 2 4 5 3 7 2 6 8 9 5 1 4 8 1 4 2 5 3 7 6 9 6 9 5 4 1 7 3 8 2	385ms
Grid 02 200080300 060070084 030500209 000105408 000000000 402706000 301007040 720040060 004010003	2 4 5 9 8 1 3 7 6 1 6 9 2 7 3 5 8 4 8 3 7 5 6 4 2 1 9 9 7 6 1 2 5 4 3 8 5 1 3 4 9 8 6 2 7 4 8 2 7 3 6 9 5 1 3 9 1 6 5 7 8 4 2 7 2 8 3 4 9 1 6 5 6 5 4 8 1 2 7 9 3	382ms
Grid 03 000000907 000420180 000705026 100904000 050000040 000507009 920108000	4 6 2 8 3 1 9 5 7 7 9 5 4 2 6 1 8 3 3 8 1 7 9 5 4 2 6 1 7 3 9 8 4 2 6 5 6 5 9 3 1 2 7 4 8 2 4 8 5 6 7 3 1 9 9 2 6 1 7 8 5 3 4 8 3 4 2 5 9 6 7 1	361ms

034059000 507000000	5 1 7 6 4 3 8 9 2	
Grid 04 030050040 008010500 460000012 070502080 000603000 040109030 250000098 001020600 080060020	1 3 7 2 5 6 8 4 9 9 2 8 3 1 4 5 6 7 4 6 5 8 9 7 3 1 2 6 7 3 5 4 2 9 8 1 8 1 9 6 7 3 2 5 4 5 4 2 1 8 9 7 3 6 2 5 6 7 3 1 4 9 8 3 9 1 4 2 8 6 7 5 7 8 4 9 6 5 1 2 3	377ms
Grid 05 020810740 700003100 090002805 009040087 400208003 160030200 302700060 005600008 076051090	5 2 3 8 1 6 7 4 9 7 8 4 5 9 3 1 2 6 6 9 1 4 7 2 8 3 5 2 3 9 1 4 5 6 8 7 4 5 7 2 6 8 9 1 3 1 6 8 9 3 7 2 5 4 3 4 2 7 8 9 5 6 1 9 1 5 6 2 4 3 7 8 8 7 6 3 5 1 4 9 2	396ms
Grid 06 100920000 524010000 000000070 050008102 000000000 402700090 060000000 000030945 000071006	1 7 6 9 2 3 5 8 4 5 2 4 8 1 7 6 3 9 8 9 3 6 5 4 2 7 1 9 5 7 3 4 8 1 6 2 6 3 8 1 9 2 4 5 7 4 1 2 7 6 5 3 9 8 2 6 5 4 8 9 7 1 3 7 8 1 2 3 6 9 4 5 3 4 9 5 7 1 8 2 6	310ms
Grid 07 043080250 600000000 000001094 900004070 000608000 010200003 820500000 000000005 034090710	1 4 3 9 8 6 2 5 7 6 7 9 4 2 5 3 8 1 2 8 5 7 3 1 6 9 4 9 6 2 3 5 4 1 7 8 3 5 7 6 1 8 9 4 2 4 1 8 2 7 9 5 6 3 8 2 1 5 6 7 4 3 9 7 9 6 1 4 3 8 2 5 5 3 4 8 9 2 7 1 6	361ms
Grid 08 480006902 002008001 900370060 840010200 003704100 001060049 020085007 700900600 609200018	4 8 7 1 5 6 9 3 2 3 6 2 4 9 8 7 5 1 9 1 5 3 7 2 8 6 4 8 4 6 5 1 9 2 7 3 5 9 3 7 2 4 1 8 6 2 7 1 8 6 3 5 4 9 1 2 4 6 8 5 3 9 7 7 3 8 9 4 1 6 2 5 6 5 9 2 3 7 4 1 8	399ms
Grid 09 000900002 050123400 030000160 908000000 070000090	8 1 4 9 7 6 5 3 2 6 5 9 1 2 3 4 7 8 7 3 2 8 5 4 1 6 9 9 4 8 2 6 5 3 1 7 2 7 5 3 4 1 8 9 6 1 6 3 7 9 8 2 4 5	398ms

000000205 091000050 007439020 400007000	3 9 1 6 8 2 7 5 4 5 8 7 4 3 9 6 2 1 4 2 6 5 1 7 9 8 3	
Grid 10 001900003 900700160 030005007 050000009 004302600 200000070 600100030 042007006 500006800	7 6 1 9 2 8 4 5 3 9 2 5 7 4 3 1 6 8 4 3 8 6 1 5 9 2 7 3 5 7 4 6 1 2 8 9 8 9 4 3 7 2 6 1 5 2 1 6 5 8 9 3 7 4 6 8 9 1 5 4 7 3 2 1 4 2 8 3 7 5 9 6 5 7 3 2 9 6 8 4 1	411ms
Grid 11 000125400 008400000 420800000 030000095 060902010 510000060 000003049 000007200 001298000	9 7 6 1 2 5 4 3 8 1 5 8 4 3 6 9 2 7 4 2 3 8 7 9 1 5 6 2 3 4 7 6 1 8 9 5 8 6 7 9 5 2 3 1 4 5 1 9 3 8 4 7 6 2 7 8 2 5 1 3 6 4 9 3 9 5 6 4 7 2 8 1 6 4 1 2 9 8 5 7 3	425ms
Grid 12 062340750 100005600 570000040 000094800 400000006 005830000 030000091 006400007 059083260	9 6 2 3 4 1 7 5 8 1 4 8 9 7 5 6 2 3 5 7 3 2 6 8 1 4 9 3 2 1 6 9 4 8 7 5 4 8 7 5 1 2 9 3 6 6 9 5 8 3 7 4 1 2 8 3 4 7 2 6 5 9 1 2 1 6 4 5 9 3 8 7 7 5 9 1 8 3 2 6 4	366ms
Grid 13 300000000 005009000 200504000 020000700 160000058 704310600 000890100 000067080 000005437	3 9 7 6 8 1 5 2 4 6 4 5 2 7 9 8 1 3 2 1 8 5 3 4 9 7 6 8 2 3 9 5 6 7 4 1 1 6 9 7 4 2 3 5 8 7 5 4 3 1 8 6 9 2 4 7 2 8 9 3 1 6 5 5 3 1 4 6 7 2 8 9 9 8 6 1 2 5 4 3 7	389ms
Grid 14 630000000 000500008 005674000 000020000 003401020 000000345 000007004 080300902 947100080	6 3 9 2 1 8 4 5 7 4 7 1 5 3 9 2 6 8 8 2 5 6 7 4 1 3 9 5 6 4 8 2 3 7 9 1 7 9 3 4 5 1 8 2 6 2 1 8 7 9 6 3 4 5 3 5 2 9 8 7 6 1 4 1 8 6 3 4 5 9 7 2 9 4 7 1 6 2 5 8 3	399ms
Grid 15 000020040 008035000 000070602	6 9 7 1 2 8 3 4 5 4 2 8 6 3 5 1 9 7 3 1 5 4 7 9 6 8 2 5 3 1 2 4 6 9 7 8	385ms

	286397451	
031046970	974581263	
200000000	149852736	
000501203	752963814	
049000730	863714529	
000000010		
800004000		
Grid 16	361725948	401ms
361025900	587964213	
080960010	492831657	
400000057	638259471	
008000471	174683592	
000603000	259147836	
259000800	746392185	
740000005	923518764	
020018060	815476329	
005470329		
Grid 17	359867124	421ms
050807020	648312597	
600010090	712549836	
702540006	876924351	
070020301	524731968	
504000908	193685472	
103080070	931476285	
900076205	465298713	
060090003	287153649	
080103040		
Grid 18	786945312	391ms
080005000	219863457	
000003457	534271869	
000070809	165482973	
060400903	327619548	
007010500	498537126	
408007020	951728634	
901020000	842356791	
842300000	673194285	
000100080		
Grid 19	743512986	468ms
003502900	589346217	
000040000	126987345	
106000305	934251768	
900251008	671498532	
070408030	852763491	
800763001	398675124	
308000104	417829653	
000020000	265134879	
005104800		
Grid 20	782614359	367ms
000000000	439825176	
009805100	651937428	
051907420	293471865	
290401065	568392714	
000000000	147568293	
140508093	326749581	
026709580	975183642	
005103600	814256937	
000000000		
Grid 21	428531796	322ms
020030090	365947182	

000907000 900208005 004806500 607000208 003102900 800605007 000309000 030020050	9 7 1 2 6 8 4 3 5 2 1 4 8 9 6 5 7 3 6 9 7 4 5 3 2 1 8 5 8 3 1 7 2 9 6 4 8 4 9 6 1 5 3 2 7 7 5 2 3 8 9 6 4 1 1 3 6 7 2 4 8 5 9	
Grid 22 005000006 070009020 000500107 804150000 000803000 000092805 907006000 030400010 200000600	4 2 5 7 8 1 9 3 6 1 7 8 3 6 9 5 2 4 3 6 9 5 2 4 1 8 7 8 9 4 1 5 7 3 6 2 6 5 2 8 4 3 7 9 1 7 1 3 6 9 2 8 4 5 9 8 7 2 1 6 4 5 3 5 3 6 4 7 8 2 1 9 2 4 1 9 3 5 6 7 8	336ms
Grid 23 040000050 001943600 009000300 600050002 103000506 800020007 005000200 002436700 030000040	3 4 8 2 6 7 9 5 1 5 7 1 9 4 3 6 2 8 2 6 9 1 8 5 3 7 4 6 9 7 3 5 1 4 8 2 1 2 3 8 7 4 5 9 6 8 5 4 6 2 9 1 3 7 4 1 5 7 9 8 2 6 3 9 8 2 4 3 6 7 1 5 7 3 6 5 1 2 8 4 9	368ms
Grid 24 004000000 000030002 390700080 400009001 209801307 600200008 010008053 900040000 000000800	1 2 4 9 8 6 7 3 5 8 6 7 4 3 5 9 1 2 3 9 5 7 1 2 6 8 4 4 7 8 3 5 9 2 6 1 2 5 9 8 6 1 3 4 7 6 3 1 2 7 4 5 9 8 7 1 2 6 9 8 4 5 3 9 8 3 5 4 7 1 2 6 5 4 6 1 2 3 8 7 9	392ms
Grid 25 360020089 000361000 000000000 803000602 400603007 607000108 000000000 000418000 970030014	3 6 1 5 2 4 7 8 9 7 8 9 3 6 1 4 2 5 5 2 4 8 7 9 3 6 1 8 9 3 1 5 7 6 4 2 4 1 2 6 8 3 5 9 7 6 5 7 9 4 2 1 3 8 1 4 8 7 9 6 2 5 3 2 3 5 4 1 8 9 7 6 9 7 6 2 3 5 8 1 4	402ms
Grid 26 500400060 009000800 640020000 000001008 208000501 700500000 000090084 003000600 060003002	5 8 1 4 7 9 2 6 3 3 2 9 1 5 6 8 4 7 6 4 7 3 2 8 1 5 9 9 5 6 7 3 1 4 2 8 2 3 8 9 6 4 5 7 1 7 1 4 5 8 2 9 3 6 1 7 2 6 9 5 3 8 4 8 9 3 2 4 7 6 1 5 4 6 5 8 1 3 7 9 2	412ms

Grid 27 007256400 400000005 010030060 000508000 008060200 000107000 030070090 200000004 006312700	3 8 7 2 5 6 4 1 9 4 6 9 7 8 1 3 2 5 5 1 2 4 3 9 8 6 7 1 2 3 5 4 8 9 7 6 7 5 8 9 6 3 2 4 1 6 9 4 1 2 7 5 8 3 8 3 5 6 7 4 1 9 2 2 7 1 8 9 5 6 3 4 9 4 6 3 1 2 7 5 8	427ms
Grid 28 000000000 079050180 800000007 007306800 450708096 003502700 700000005 016030420 000000000	3 4 5 8 7 1 2 6 9 2 7 9 6 5 3 1 8 4 8 6 1 4 2 9 5 3 7 1 9 7 3 4 6 8 5 2 4 5 2 7 1 8 3 9 6 6 8 3 5 9 2 7 4 1 7 3 8 2 6 4 9 1 5 5 1 6 9 3 7 4 2 8 9 2 4 1 8 5 6 7 3	431ms
Grid 29 030000080 009000500 007509200 700105008 020090030 900402001 004207100 002000800 070000090	2 3 5 7 6 1 4 8 9 4 1 9 3 2 8 5 7 6 8 6 7 5 4 9 2 1 3 7 4 6 1 3 5 9 2 8 5 2 1 8 9 6 7 3 4 9 8 3 4 7 2 6 5 1 3 9 4 2 8 7 1 6 5 6 5 2 9 1 3 8 4 7 1 7 8 6 5 4 3 9 2	391ms
Grid 30 200170603 050000100 000006079 000040700 000801000 009050000 310400000 005000060 906037002	2 9 8 1 7 5 6 4 3 6 5 7 3 9 4 1 2 8 1 3 4 2 8 6 5 7 9 8 2 1 6 4 9 7 3 5 5 7 3 8 2 1 4 9 6 4 6 9 7 5 3 2 8 1 3 1 2 4 6 8 9 5 7 7 8 5 9 1 2 3 6 4 9 4 6 5 3 7 8 1 2	398ms
Grid 31 000000080 800701040 040020030 374000900 000030000 005000321 010060050 050802006 080000000	7 6 1 5 4 3 2 8 9 8 3 2 7 9 1 6 4 5 5 4 9 6 2 8 1 3 7 3 7 4 2 1 5 9 6 8 1 2 8 9 3 6 5 7 4 6 9 5 4 8 7 3 2 1 4 1 7 3 6 9 8 5 2 9 5 3 8 7 2 4 1 6 2 8 6 1 5 4 7 9 3	421ms
Grid 32 000000085 000210009 960080100 500800016 000000000 890006007 009070052 300054000	1 3 2 6 4 9 7 8 5 7 5 8 2 1 3 6 4 9 9 6 4 7 8 5 1 2 3 5 4 3 8 9 7 2 1 6 2 7 6 5 3 1 8 9 4 8 9 1 4 2 6 5 3 7 6 1 9 3 7 8 4 5 2 3 2 7 1 5 4 9 6 8 4 8 5 9 6 2 3 7 1	381ms

480000000		
Grid 33 608070502 050608070 002000300 500090006 040302050 800050003 005000200 010704090 409060701	6 9 8 1 7 3 5 4 2 3 5 4 6 2 8 1 7 9 1 7 2 5 4 9 3 6 8 5 3 1 8 9 7 4 2 6 9 4 6 3 1 2 8 5 7 8 2 7 4 5 6 9 1 3 7 6 5 9 3 1 2 8 4 2 1 3 7 8 4 6 9 5 4 8 9 2 6 5 7 3 1	391ms
Grid 34 050010040 107000602 000905000 208030501 040070020 901080406 000401000 304000709 020060010	8 5 2 7 1 6 9 4 3 1 9 7 8 4 3 6 5 2 4 6 3 9 2 5 1 8 7 2 7 8 6 3 4 5 9 1 6 4 5 1 7 9 3 2 8 9 3 1 5 8 2 4 7 6 7 8 6 4 9 1 2 3 5 3 1 4 2 5 8 7 6 9 5 2 9 3 6 7 8 1 4	474ms
Grid 35 053000790 009753400 100000002 090080010 000907000 080030070 500000003 007641200 061000940	4 5 3 2 1 8 7 9 6 6 2 9 7 5 3 4 8 1 1 7 8 4 9 6 5 3 2 7 9 6 5 8 2 3 1 4 3 1 4 9 6 7 8 2 5 2 8 5 1 3 4 6 7 9 5 4 2 8 7 9 1 6 3 9 3 7 6 4 1 2 5 8 8 6 1 3 2 5 9 4 7	361ms
Grid 36 006080300 049070250 000405000 600317004 007000800 100826009 000702000 075040190 003090600	5 1 6 2 8 9 3 4 7 8 4 9 1 7 3 2 5 6 7 3 2 4 6 5 9 1 8 6 9 8 3 1 7 5 2 4 3 2 7 9 5 4 8 6 1 1 5 4 8 2 6 7 3 9 9 6 1 7 3 2 4 8 5 2 7 5 6 4 8 1 9 3 4 8 3 5 9 1 6 7 2	396ms
Grid 37 005080700 700204005 320000084 060105040 008000500 070803010 450000091 600508007 003010600	9 4 5 6 8 1 7 2 3 7 8 1 2 3 4 9 6 5 3 2 6 7 5 9 1 8 4 2 6 9 1 7 5 3 4 8 1 3 8 9 4 2 5 7 6 5 7 4 8 6 3 2 1 9 4 5 7 3 2 6 8 9 1 6 1 2 5 9 8 4 3 7 8 9 3 4 1 7 6 5 2	432ms
Grid 38 000900800 128006400 070800060 800430007 500000009 600079008	3 6 5 9 4 2 8 7 1 1 2 8 7 5 6 4 9 3 9 7 4 8 1 3 5 6 2 8 1 9 4 3 5 6 2 7 5 3 7 2 6 8 1 4 9 6 4 2 1 7 9 3 5 8 2 9 6 3 8 4 7 1 5	278ms

090004010 003600284 001007000	7 5 3 6 9 1 2 8 4 4 8 1 5 2 7 9 3 6	
Grid 39 000080000 270000054 095000810 009806400 020403060 006905100 017000620 460000038 000090000	1 3 4 5 8 7 2 9 6 2 7 8 1 6 9 3 5 4 6 9 5 2 3 4 8 1 7 3 5 9 8 1 6 4 7 2 8 2 1 4 7 3 5 6 9 7 4 6 9 2 5 1 8 3 9 1 7 3 4 8 6 2 5 4 6 2 7 5 1 9 3 8 5 8 3 6 9 2 7 4 1	355ms
Grid 40 000602000 400050001 085010620 038206710 000000000 019407350 026040530 900020007 000809000	1 9 3 6 7 2 4 8 5 4 6 2 3 5 8 9 7 1 7 8 5 9 1 4 6 2 3 5 3 8 2 9 6 7 1 4 6 7 4 1 3 5 2 9 8 2 1 9 4 8 7 3 5 6 8 2 6 7 4 1 5 3 9 9 4 1 5 2 3 8 6 7 3 5 7 8 6 9 1 4 2	234ms
Grid 41 000900002 050123400 030000160 908000000 070000090 000000205 091000050 007439020 400007000	8 1 4 9 7 6 5 3 2 6 5 9 1 2 3 4 7 8 7 3 2 8 5 4 1 6 9 9 4 8 2 6 5 3 1 7 2 7 5 3 4 1 8 9 6 1 6 3 7 9 8 2 4 5 3 9 1 6 8 2 7 5 4 5 8 7 4 3 9 6 2 1 4 2 6 5 1 7 9 8 3	356ms
Grid 42 380000000 000400785 009020300 060090000 800302009 000040070 001070500 495006000 000000092	3 8 4 5 6 7 9 2 1 1 2 6 4 3 9 7 8 5 7 5 9 8 2 1 3 4 6 5 6 3 7 9 8 2 1 4 8 4 7 3 1 2 6 5 9 9 1 2 6 4 5 8 7 3 2 3 1 9 7 4 5 6 8 4 9 5 2 8 6 1 3 7 6 7 8 1 5 3 4 9 2	186ms
Grid 43 000158000 002060800 030000040 027030510 000000000 046080790 050000080 004070100 000325000	4 6 9 1 5 8 3 7 2 7 1 2 4 6 3 8 5 9 5 3 8 2 9 7 6 4 1 9 2 7 6 3 4 5 1 8 3 8 5 7 1 9 4 2 6 1 4 6 5 8 2 7 9 3 6 5 3 9 4 1 2 8 7 2 9 4 8 7 6 1 3 5 8 7 1 3 2 5 9 6 4	354ms
Grid 44 010500200 900001000 002008030	3 1 6 5 4 9 2 7 8 9 8 7 3 2 1 6 4 5 4 5 2 6 7 8 9 3 1 5 9 4 2 3 6 8 1 7	364ms

500030007 008000500 600080004 040100700 000700006 003004050	2 3 8 4 1 7 5 6 9 6 7 1 9 8 5 3 2 4 8 4 5 1 6 2 7 9 3 1 2 9 7 5 3 4 8 6 7 6 3 8 9 4 1 5 2	
Grid 45 080000040 000469000 400000007 005904600 070608030 008502100 900000005 000781000 060000010	5 8 6 1 2 7 9 4 3 7 2 3 4 6 9 8 5 1 4 9 1 8 5 3 2 6 7 1 3 5 9 7 4 6 2 8 2 7 9 6 1 8 5 3 4 6 4 8 5 3 2 1 7 9 9 1 7 2 4 6 3 8 5 3 5 2 7 8 1 4 9 6 8 6 4 3 9 5 7 1 2	258ms
Grid 46 904200007 010000000 000706500 000800090 020904060 040002000 001607000 000000030 300005702	9 5 4 2 1 3 6 8 7 6 1 7 5 4 8 9 2 3 8 3 2 7 9 6 5 4 1 7 6 3 8 5 1 2 9 4 1 2 8 9 7 4 3 6 5 5 4 9 3 6 2 1 7 8 2 8 1 6 3 7 4 5 9 4 7 5 1 2 9 8 3 6 3 9 6 4 8 5 7 1 2	418ms
Grid 47 000700800 006000031 040002000 024070000 010030080 000060290 000800070 860000500 002006000	1 5 9 7 4 3 8 6 2 2 7 6 5 8 9 4 3 1 3 4 8 6 1 2 7 5 9 6 2 4 9 7 8 3 1 5 9 1 7 2 3 5 6 8 4 5 8 3 1 6 4 2 9 7 4 3 5 8 2 1 9 7 6 8 6 1 4 9 7 5 2 3 7 9 2 3 5 6 1 4 8	354ms
Grid 48 001007090 590080001 030000080 000005800 050060020 004100000 080000030 100020079 020700400	8 6 1 3 5 7 2 9 4 5 9 7 4 8 2 3 6 1 4 3 2 6 1 9 7 8 5 9 1 6 2 7 5 8 4 3 3 5 8 9 6 4 1 2 7 2 7 4 1 3 8 9 5 6 7 8 9 5 4 1 6 3 2 1 4 3 8 2 6 5 7 9 6 2 5 7 9 3 4 1 8	358ms
Grid 49 000003017 015009008 060000000 100007000 009000200 000500004 000000020 500600340 340200000	2 9 4 8 6 3 5 1 7 7 1 5 4 2 9 6 3 8 8 6 3 7 5 1 4 9 2 1 5 2 9 4 7 8 6 3 4 7 9 3 8 6 2 5 1 6 3 8 5 1 2 9 7 4 9 8 6 1 3 4 7 2 5 5 2 1 6 7 8 3 4 9 3 4 7 2 9 5 1 8 6	244ms
Grid 50 300200000	3 5 1 2 8 6 4 9 7 4 9 2 1 5 7 6 3 8	245ms

000107000	7 8 6 9 3 4 5 1 2	
706030500	2 7 5 4 6 9 1 8 3	
070009080	9 3 8 5 2 1 7 6 4	
900020004	6 1 4 8 7 3 2 5 9	
010800050	8 2 9 6 4 5 3 7 1	
009040301	1 6 3 7 9 2 8 4 5	
000702000	5 4 7 3 1 8 9 2 6	
000008006		