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CS 171

MiniProject Report

Goal:

Our goal is to identify the ideal combination of the implemented heuristics, consistency checks, and heuristic checks in solving Sudoku puzzles. This combination should be ideal in terms of minimizing the number of backtracks and running time, while maintaining a good success rate of solving the puzzles.

Experimental Design:

After completing the implementations of the heuristic functions and consistency checks, we began our testing by mapping out all of the combinations that we would want to try. This list of combinations can be seen in Table 1. We then proceeded to run all of these combinations with a selection of the "easy" problems. The results of these tests can also be found in Table 1.

At this point, based on our results in Table 1 and in conjunction with intuition and our knowledge of these heuristics and consistency checks, we began to select for further testing the combinations we believed would provide the best results in terms of number of backtracks and runtime. For these combinations, we began to run tests with "medium" difficulty problems. The results of these tests can be found in Table 2.

After analyzing the results of these "medium" difficulty tests, we selected the four combinations we believed to be the most likely best combinations. With these four combinations, we proceeded to run tests using the rest of the "medium" difficulty problems as well as the "hard" difficulty problems. The "medium" difficulty test results can be found in Table 3 and the "hard" difficulty test results can be found in Table 4.

Hypothesis:

We believe that "AC + MRV + LCV + NP" (Arc Consistency + Minimum Remaining Values + Least Constraining Value + Naked Pairs) combination of methods is the most ideal combination for Sudoku problem solving. Our justification for this is that this combination tends to outperform its competitors in runtime and backtracks. Of the four finalists we selected, this combination had the lowest number of average backtracks (Table 5).

Table 1

Combination	PE1 backtracks	PE1 Time(sec)	PE1 Time/ Backtracks	PE3 Backtracks	PE3 Time(sec)	PE3 Time /Backtracks
Forward Checking	6	0.18	0.03	69	0.905	0.013
Arc Consistency	3	0.76	0.253	29	2.12	0.073
FC + MRV	6	0.24	0.04	42	0.745	0.018
FC + Degree	2	0.24	0.12	3083	41.938	0.014
FC + LCV	1	0.226	0.226	72	0.88	0.012
AC + MRV	3	0.77	0.257	13	1.383	0.106
AC + Degree	1	0.38	0.38	1024	41.623	0.041
AC + LCV	0	0.29	0	24	1.83	0.076
FC + MRV + LCV	1	0.208	0.208	27	0.516	0.019
FC + Degree + LCV	6	0.266	0.044	2372	33.53	0.014
AC + MRV + LCV	0	0.285	0	8	1.084	0.136
AC + Degree + LCV	1	0.417	0.417	862	34.675	0.04
FC + MRV + NP	5	0.214	0.043	40	0.765	0.019
FC + Degree + NP	12	0.378	0.032	66	1.258	0.019
FC + LCV + NP	1	0.220	0.22	58	0.82	0.014
AC + MRV + NP	3	0.737	0.246	11	1.316	0.12
AC + Degree + NP	1	0.418	0.418	23	1.525	0.066
AC + LCV + NP	0	0.280	0	12	1.329	0.111
FC + MRV + LCV + NP	1	0.196	0.196	29	0.646	0.022
FC + Degree + LCV + NP	1	0.274	0	32	0.774	0.024
AC + MRV + LCV + NP	0	0.288	0	8	1.04	0.13
AC + Degree + LCV + NP	1	0.424	0.424	17	1.363	0.08
FC + MRV + NT	6	0.235	0.039	38	0.833	0.022
FC + Degree + NT	2	0.263	0.132	2042	31.84	0.016
FC + LCV + NT	1	0.199	0.199	62	0.963	0.016
AC + MRV + NT	3	0.781	0.26	13	1.467	0.113
AC + Degree + NT	2	0.411	0.411	687	29.64	0.043
AC + LCV + NT	0	0.29	0	24	1.726	0.072
FC + MRV + LCV + NT	1	0.247	0.247	23	0.629	0.027
FC + Degree + LCV + NT	6	0.28	0.047	1454	22.87	0.016
AC + MRV + LCV + NT	0	0.297	0	8	1.158	0.145
AC + Degree + LCV + NT	1	0.384	0.384	531	23.04	0.043
FC + MRV + NP + NT	5	0.229	0.046	36	0.88	0.024
FC + Degree + NP + NT	12	0.434	0.036	66	1.377	0.021
FC + LCV + NP + NT	1	0.250	0.25	53	0.935	0.018
AC + MRV + NP + NT	3	0.739	0.246	11	1.416	0.129
AC + Degree + NP + NT	1	0.39	0.39	23	1.572	0.068
AC + LCV + NP + NT	0	0.30	0	12	1.36	0.113
FC + MRV + LCV + NP + NT	1	0.218	0.218	25	0.714	0.029
FC + Degree + LCV + NP + NT	1	0.26	0.26	32	0.864	0.027
AC + MRV + LCV + NP + NT	0	0.293	0	8	1.108	0.139
AC + Degree + LCV + NP + NT	1	0.424	0.424	17	1.36	0.08

Table 2

Combination	PM1 Success	PM1 Backtracks	PM1 Time (sec)	PM1 Time/ Backtracks
Forward Checking	Yes	2947	14.297	0.005
Arc Consistency	Yes	1719	27.176	0.016
FC + MRV	Yes	170	0.93	0.005
FC + LCV	Yes	1313	5.67	0.004
AC + MRV	Yes	71	1.78	0.025
AC + LCV	Yes	726	12.536	0.017
FC + MRV + LCV	Yes	627	3.08	0.005
AC + MRV + LCV	Yes	319	6.388	0.02
FC + MRV + NP	Yes	27	0.516	0.019
AC + MRV + NP	Yes	3	0.623	0.208
FC + MRV + LCV + NP	Yes	20	0.566	0.028
AC + MRV + LCV + NP	Yes	8	0.489	0.061
AC + Degree + LCV + NP	Yes	14532	218.529	0.015
FC + MRV + LCV + NT	Yes	341	9.33	0.027
AC + MRV + LCV + NT	Yes	140	5.638	0.04
FC + MRV + NP + NT	Yes	27	1.333	0.049
FC + LCV + NP + NT	Yes	20	1.005	0.05
AC + MRV + NP + NT	Yes	3	0.886	0.295
AC + LCV + NP + NT	Yes	9	0.809	0.09
FC + MRV + LCV + NP + NT	Yes	20	1.187	0.059
FC + Degree + LCV + NP + NT	Yes	38876	654.471	0.017
AC + MRV + LCV + NP + NT	Yes	8	0.846	0.106
AC + Degree + LCV + NP + NT	Yes	12706	311.564	0.025

Table 3

Combination	PM2 Success	PM2 Back tracks	PM2 Time (sec)	PM2 Time/ Back tracks	PM3 Success	PM3 Back tracks	PM3 Time (sec)	PM3 Time/ Back tracks
FC + MRV + NP	Yes	48	0.93	0.019	Yes	100	1.525	0.015
AC + MRV + NP	Yes	40	2.5	0.063	Yes	58	1.963	0.034
FC + MRV + LCV + NP	Yes	50	0.993	0.019	Yes	48	1.023	0.021
AC + MRV + LCV + NP	Yes	32	1.8	0.0563	Yes	27	1.518	0.056

Combination	PM4 Success	PM4 Back tracks	PM4 Time (sec)	PM4 Time/ Back tracks	PM5 Success	PM5 Back tracks	PM5 Time (sec)	PM5 Time/ Backtracks
FC + MRV + NP	Yes	2	0.676	0.338	Yes	505	5.925	0.01
AC + MRV + NP	Yes	3	1.291	0.43	Yes	329	9.09	0.028
FC + MRV + LCV + NP	Yes	52	1.363	0.026	Yes	791	9.157	0.01
AC + MRV + LCV + NP	Yes	26	2.205	0.085	Yes	459	10.63	0.023

Table 4

Combination	PH1 Success	PH1 Back tracks	PH1 Time (sec)	PH1 Time/ Back tracks	PH2 Success	PH2 Back tracks	PH2 Time (sec)	PH2 Time/ Back tracks
FC + MRV + NP	Yes	6	1.98	0.33	Yes	15	1.199	0.08
AC + MRV + NP	Yes	1	16.646	16.6	Yes	13	3.735	0.287
FC + MRV + LCV + NP	Yes	6	6.935	1.156	Yes	87	4.06	0.047
AC + MRV + LCV + NP	Yes	1	16.992	16.99	Yes	51	4.469	0.088

Combination	PH3 Success	PH3 Back tracks	PH3 Time (sec)	PH3 Time/ Back tracks	PH4 Success	PH4 Back tracks	PH4 Time (sec)	PH4 Time/ Back tracks
FC + MRV + NP	Yes	10778	323.528	0.03	Yes	3204	93.919	0.029
AC + MRV + NP	Yes	5884	289.08	0.049	Yes	2157	120.123	0.056
FC + MRV + LCV + NP	Yes	5079	153.09	0.03	Yes	3891	112.242	0.029
AC + MRV + LCV + NP	Yes	2471	123.621	0.05	Yes	3751	204.079	0.054

Table 5

Combination	Avg Easy Backtracks	Avg Medium Backtracks	Avg Hard Backtracks
FC + MRV + NP	22.5	136.4	3500.75
AC + MRV + NP	7	86.6	2013.75
FC + MRV + LCV + NP	15	192.2	2265.75
AC + MRV + LCV + NP	4	110.4	1577.5