Thomas Varney, Frank McShan, Jack Ciroli

CS 4341: Assignment 1 - Analysis

Number of nodes expanded for each heuristic:

	Board 1	Board 2	Board 3	Board 4	Board 5	Board 6	Board 7	Board 8	Board 9	Board 10
Heuristic 1	180667	180668	180677	180672	180661	180671	180674	180672	180675	180677
Heuristic 2	181002	180981	180999	181004	181034	181027	180984	180988	180988	180984
Heuristic 3	181013	180987	181001	180952	180989	180990	180973	180964	180939	180975
Heuristic 4	181054	181121	181119	181135	181114	181099	181122	181104	181167	181120
Heuristic 5	196440	195879	196188	196174	196422	196848	196987	197555	195792	196146
Heuristic 6	275935	268166	271029	271721	271092	272664	272479	278105	267223	272734

Average number of nodes expanded for each heuristic:

Heuristic 1	Heuristic 2	Heuristic 3	Heuristic 4	Heuristic 5	Heuristic 6
180671.4	180999.1	180978.3	181115.5	196443.1	272114.8

Effective branching factor for each heuristic:

	Board 1	Board 2	Board 3	Board 4	Board 5	Board 6	Board 7	Board 8	Board 9	Board 10
Heuristic 1	1.0109	1.0108	1.0108	1.0107	1.0110	1.0106	1.0105	1.0107	1.0108	1.0107
Heuristic 2	1.0110	1.0108	1.0109	1.0107	1.0110	1.0105	1.0105	1.0108	1.0108	1.0107
Heuristic 3	1.0109	1.0108	1.0108	1.0107	1.0110	1.0105	1.0104	1.0107	1.0108	1.0107
Heuristic 4	1.0107	1.0109	1.0108	1.0107	1.0108	1.0106	1.0104	1.0108	1.0108	1.0108
Heuristic 5	1.0110	1.0109	1.0109	1.0107	1.0110	1.0105	1.0110	1.0108	1.0109	1.0107
Heuristic 6	1.0111	1.0111	1.0111	1.0110	1.0113	1.0108	1.0109	1.0110	1.0111	1.0110

Mean effective branching factors:

Heuristic 1	Heuristic 2	Heuristic 3	Heuristic 4	Heuristic 5	Heuristic 6
1.01075	1.01077	1.01073	1.01073	1.01084	1.01104

Time for each heuristic (seconds):

	Board 1	Board 2	Board 3	Board 4	Board 5	Board 6	Board 7	Board 8	Board 9	Board 10
Heuristic 1	38.298	26.700	47.978	27.540	34.287	29.527	27.791	48.306	26.922	29.623
Heuristic 2	36.050	42.226	29.165	34.771	25.167	28.671	30.977	30.648	32.824	34.360
Heuristic 3	25.537	49.167	29.748	34.138	30.892	48.622	25.339	46.740	49.141	42.969
Heuristic 4	27.074	48.539	32.703	29.337	49.148	24.110	48.945	47.990	28.442	29.920
Heuristic 5	31.811	30.833	53.099	32.161	27.169	52.719	32.433	53.454	52.752	31.786
Heuristic 6	48.311	74.961	76.334	74.795	57.862	48.040	48.293	76.255	44.894	48.895

Mean time for each heuristic (seconds):

Heuristic 1	Heuristic 2	Heuristic 3	Heuristic 4	Heuristic 5	Heuristic 6
33.6972	32.4859	38.2293	36.6208	39.8217	59.864

Each of the heuristics varied in effectiveness, with heuristic 6 having the greatest average number of nodes expanded and heuristic 1 having the smallest average number of nodes expanded. In comparing heuristics 1 and 2, heuristic 1 takes longer on average to determine a path, but has a smaller branching factor. Heuristic 5 is not noticeably more effective than the other heuristics. In fact, heuristic 5 performed slightly worse on average, with it taking longer and having a larger mean effective branching factor than heuristics 1, 2, 3 and 4. Comparing heuristics 5 and 6, heuristic 6 doesn't necessarily find the shortest path and produces noticeably worse A* scores than those of the other heuristics, and it takes longer on average to complete.

Heuristic	# Nodes Expanded	Branching Factor	Time (seconds)	Memory Used (GB)	k-constant
1	180671.4	1.01075	33.6972	0.25	0.0000019490
2	180999.1	1.01077	32.4859	0.26	0.0000019833
3	180978.3	1.01073	38.2293	0.25	0.0000019919
4	181115.5	1.01073	36.6208	0.27	0.0000021513
5	196443.1	1.01084	39.8217	0.32	0.0000022620
6	272114.8	1.01104	59.864	0.46	0.0000026157

$k = memory\ used\ /\ b^d$

Using heuristic 5, we can solve a board that is about size 286 x 286 in 30 seconds. The memory required to solve this board is about 0.215 GB.

$16GB\ /\ k\ =\ b^d$

$log_b(16GB\ /\ k)\ =\ d$

Heuristic 1: $log_{1.01075}(16\ /\ 0.0000019490)\ =\ 1488.949$

Heuristic 2: $log_{1.01077}(16\ /\ 0.0000019833)\ =\ 1484.570$

Heuristic 3: $log_{1.01073}(16\ /\ 0.0000019919)\ =\ 1489.670$

Heuristic 4: $log_{1.01073}(16\ /\ 0.0000021513)\ =\ 1482.457$

Heuristic 5: $log_{1.01084}(16\ /\ 0.0000022620)\ =\ 1462.839$

Heuristic 6: $log_{1.01104}(16\ /\ 0.0000026157)\ =\ 1423.249$

The largest board that could be solved by each heuristic using 16GB of memory is:

Heuristic 1	Heuristic 2	Heuristic 3	Heuristic 4	Heuristic 5	Heuristic 6
1488.949	1484.570	1489.670	1482.457	1462.839	1423.249

$Board\ Size\ /\ Solution\ Depth\ =\ 425/1100\ =\ 0.3864$

$Heuristic\ 1\ =\ 0.3864\ *\ 1488.949\ =\ 575\ X\ 575\ Board$

$Heuristic\ 2\ =\ 0.3864\ *\ 1484.570\ =\ 574\ X\ 574\ Board$

$Heuristic\ 3\ =\ 0.3864\ *\ 1489.670\ =\ 575\ X\ 575\ Board$

$Heuristic\ 4\ =\ 0.3864\ *\ 1482.457\ =\ 574\ X\ 574\ Board$

$Heuristic\ 5\ =\ 0.3864\ *\ 1462.839\ =\ 565\ X\ 565\ Board$

$Heuristic\ 6\ =\ 0.3864\ *\ 1423.249\ =\ 550\ X\ 550\ Board$

$time\ =\ k\ *\ b^{d}$

$59.864\ seconds\ =\ k\ *\ 1.01104^{1100}\ ->\ k\ =\ 0.00034040$

$time\ =\ 0.00034040\ *\ 1.01104^{1423.249}\ =\ 2082$

With a k-value of 0.0003404 and a branching factor of 1.01104, It would take Heuristic 6 about 2,082 seconds to solve this board.

$39.8217\ seconds\ =\ k\ *\ 1.01084^{1100}\ ->\ k\ =\ 0.00028149$

$86400\ seconds\ =\ 0.00028149\ *\ 1.01084^{d}\ ->\ d\ =\ 1812$

$Memory\ Used\ =\ 0.0000022620\ *\ 1.01084^{1812}\ =\ 690$

For heuristic 5 to solve a problem that takes 24 hours, it would need about 690 GB of memory.

$86400\ seconds\ =\ 0.0003404\ *\ 1.01104^{d}\ ->\ d\ =\ 1762$

$Memory\ Used\ =\ 0.0000026157\ *\ 1.01104^{1762}\ =\ 660$

For heuristic 6 to solve a problem that takes 24 hours, it would need about 660 GB of memory.