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From: (freecell-in-minature.appspot.com)
Subject: RE: FreeCell Solver Discussion

I was trying to solve FreeCell using a breadth-first approach but every time it got to 13 or so levels deep I would run out of memory. I asked some college student at work if he had any ideas and he suggested an A-star routine and use that to trim the positions hash and only keep the hands that scored the best (lowest). He told me that an A-star routine could measure the distance to the solution. Well, at first I didn't think it was possible to know how far you are from a solution if you hadn't solve it yet! I thought about it for a while and came up with this simple algorithm.

Start with a score of 64.
Subtract the face value of every home card (max is 13x4=52).
Subtract 1 for every empty freecell (max = 4)
Subtract 1 for every empty column (max = 8)
Add 1 for every sequence break in the columns (i.e. if the cards are not in descending sequence and opposite colors then add 1 to the score for every break)

The program keeps track of 2 algorithms at the same time and is the same as the first but includes a minor adjustment

Add 1 for every MAJOR sequence break in the columns (i.e. the next card is actually a higher rank)

If a tableau scores low enough using either algorithm, it remains in the position hash. There is a separate sorted score hash for each algorithm with the number of hands at each score so that I can figure out what the cut-off point is for the score, based on the supplied maxnodes parameter.

I went through a lot of trouble to eliminate duplicate tableaus in the position hash. An Entry.key is created by sorting the cards in the top row and concatenating it to the strings of the column cards and converting it to ASCII. The Entry.token is needed to put the Tableau back together from the key. It has an index for each card in the top row and an index for each column.

The trim process is this. I take the maxnodes number of entries and backtrack each one to the start and mark all the Entries as still alive (level=depth), then delete the rest (level<depth). Formatting the output for the website was a royal pain (card & suit ranges).

```
    Tableau
 _|KS 7C 9S 6S 5D 4C 5H 4S ← top row (freecell + home)
 ↓ 7D 9C 5C KC 5S 8C KH 7S
   TD    QD QH 6D 8H QC
 c TH    JC JS    8D JD
 o KD          7H TC
 l QS          6H 9D
 u JH          6C 8S
 m TS
 n 9H


card->key     A    2    3    4    5    6    7    8    9    T    J    Q    K
    ....0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101
D 0100....    A    B    C    D    E    F    G    H    I    J    K    L    M
C 0101....    Q    R    S    T    U    V    W    X    Y    Z    [    \    ]
H 0110....    a    b    c    d    e    f    g    h    i    j    k    l    m
S 0111....    q    r    s    t    u    v    w    x    y    z    {    |    }
```

		ASCII
sorted top row	5D 4C 7C 5H 4S 6S 9S KS	ETWetvy}
sorted columns	7D TD TH KD QS JH TS 9H	GJZM|kzi
	5C QD JC	UL[
	8C 8H 8D 7H 6H 6C	XhHgfV
	9C	Y
	KC QH JS	]l{
	KH QC JD TC 9D 8S	m\KZIx
	5S 6D	uF
	7S	w

```
Entry.key   = "ETWetvy} GJZM|kzi UL[ XhHgfV Y ]l{ m\KZIx uF w"

Entry.token = [4 5 1 6 7 3 2 0 0 2 5 1 3 6 2 7]
              +--- top row ---+--- columns ---+
```

This was my first Java program and it is a conversion of my Perl program on CPAN. The college student told me that it would be faster if I converted it to Java but I didn't realize it would be 70 times faster! I wrote it because I was upset that you could only look at 3 solution from freecellgamesolutions.com and then you were booted off for 24 hour. I put up a website with the first 33k solutions for both XP and Win 7. XP only moves 1 or max to empty columns. The website is http://freecell-in-miniature.appspot.com. I uploaded the solutions from the java program to a google app-engine/python website I wrote because they host it for free. Here is a sample of the log and upload data for one of the runs set at –maxnodes 25000 (per level), a --blocksolve of 11000 solutions and set for Win7 (I had already solved for XP with maxnodes set at 2000. About half the Win7 solutions won't work on XP) . It looks like it started to kick tableaus out at d=11. Hi score was 117 but only score 109 made the cut (algorithm2). I ran a batch set at maxnode 250000 to try to improve the solutions that were over 40 moves but you need 32M of memory to do that and they take a lot longer.

```
2013/03/10 18:44:44 INFO --gameno 22000 --maxnodes 25000  --nowinxp --blocksolve 11000
2013/03/10 18:44:44 INFO d= 0, l=      1, s=101,101,101, 122,122,122, p=      1,       1, cnt=      11
2013/03/10 18:44:44 INFO d= 1, l=      9, s= 98, 99, 99, 118,120,120, p=     10,      10, cnt=      92
2013/03/10 18:44:44 INFO d= 2, l=     55, s= 97,100,100, 117,120,120, p=     65,      65, cnt=     571
2013/03/10 18:44:44 INFO d= 3, l=    237, s= 96,100,100, 115,120,120, p=    302,     302, cnt=    2544
2013/03/10 18:44:44 INFO d= 4, l=    859, s= 95,100,100, 113,120,120, p=   1161,    1161, cnt=    6888
2013/03/10 18:44:44 INFO d= 5, l=   1972, s= 93, 99, 99, 112,119,119, p=   3133,    3047, cnt=   13277
2013/03/10 18:44:44 INFO d= 6, l=   3603, s= 91, 99, 99, 108,119,119, p=   6650,    6238, cnt=   22078
2013/03/10 18:44:44 INFO d= 7, l=   6057, s= 89, 98, 98, 106,118,118, p=  12295,   11160, cnt=   35224
2013/03/10 18:44:44 INFO d= 8, l=  10046, s= 88, 98, 98, 104,117,117, p=  21206,   18962, cnt=   54927
2013/03/10 18:44:44 INFO d= 9, l=  15859, s= 83, 98, 98,  99,117,117, p=  34821,   30645, cnt=   81100
2013/03/10 18:44:45 INFO d=10, l=  23687, s= 82, 98, 98,  97,116,116, p=  54332,   46997, cnt=  116056
2013/03/10 18:44:46 INFO d=11, l=  34432, s= 81, 93, 98,  96,109,117, p=  81429,   63031, cnt=  149771
2013/03/10 18:44:46 INFO d=12, l=  48402, s= 80, 91, 95,  94,107,113, p= 111433,   69933, cnt=  167717
2013/03/10 18:44:47 INFO d=13, l=  62232, s= 79, 90, 94,  93,105,110, p= 132165,   89235, cnt=  222245
2013/03/10 18:44:48 INFO d=14, l=  83385, s= 78, 88, 93,  91,102,109, p= 172620,   74519, cnt=  222561
2013/03/10 18:44:49 INFO d=15, l=  93425, s= 76, 85, 91,  89, 99,107, p= 167944,   63150, cnt=  214584
2013/03/10 18:44:49 INFO d=16, l=  82671, s= 75, 81, 88,  87, 95,103, p= 145821,   53415, cnt=  205399
2013/03/10 18:44:50 INFO d=17, l=  74746, s= 73, 78, 85,  85, 92, 98, p= 128161,   62431, cnt=  265392
2013/03/10 18:44:51 INFO d=18, l= 110234, s= 72, 77, 83,  83, 89, 94, p= 172665,   90450, cnt=  434919
2013/03/10 18:44:53 INFO d=19, l= 186006, s= 70, 75, 80,  81, 87, 93, p= 276456,   89833, cnt=  517058
2013/03/10 18:44:55 INFO d=20, l= 230823, s= 69, 73, 78,  80, 85, 90, p= 320656,   92584, cnt=  553061
2013/03/10 18:44:58 INFO d=21, l= 264455, s= 68, 72, 76,  78, 83, 87, p= 357039,  121668, cnt=  798366
2013/03/10 18:45:03 INFO d=22, l= 394463, s= 67, 71, 75,  77, 81, 86, p= 516131,  177578, cnt= 1215671
2013/03/10 18:45:05 INFO d=23, l= 600354, s= 66, 69, 74,  75, 79, 85, p= 777932,  122146, cnt=  750430
2013/03/10 18:45:09 INFO d=24, l= 412868, s= 64, 68, 73,  72, 77, 82, p= 535014,  155624, cnt= 1126529
2013/03/10 18:45:16 INFO d=25, l= 613677, s= 62, 67, 71,  69, 76, 81, p= 769301,  231424, cnt= 1895759
2013/03/10 18:45:20 INFO d=26, l=1019141, s= 61, 65, 71,  68, 74, 80, p=1250565,  175501, cnt= 1193704
2013/03/10 18:45:22 INFO d=27, l= 722728, s= 58, 63, 69,  65, 71, 78, p= 898229,   93431, cnt=  619067
2013/03/10 18:45:26 INFO d=28, l= 393738, s= 57, 62, 66,  64, 69, 75, p= 487169,  136009, cnt= 1184040
2013/03/10 18:45:29 INFO d=29, l= 691234, s= 55, 60, 65,  60, 67, 73, p= 827243,  108271, cnt=  817012
2013/03/10 18:45:33 INFO d=30, l= 488565, s= 52, 58, 63,  56, 65, 71, p= 596836,  115985, cnt=  937752
2013/03/10 18:45:35 INFO d=31, l= 542667, s= 50, 56, 61,  54, 62, 68, p= 658652,   95100, cnt=  838102
2013/03/10 18:45:39 INFO d=32, l= 503604, s= 47, 54, 59,  51, 59, 66, p= 598704,  104050, cnt= 1176779
2013/03/10 18:45:43 INFO d=33, l= 692017, s= 37, 51, 57,  40, 56, 62, p= 796067,   91940, cnt= 1143464
2013/03/10 18:45:44 INFO d=34, l= 598158, s= 36, 49, 54,  38, 54, 58, p= 690098,  125583, cnt=   58652
2013/03/10 18:45:44 INFO scores=[101, 122][99, 119][98, 117][98, 117][97, 116][96, 114][91, 108][91, 108][90,
106][89, 104][87, 102][87, 102][81, 95][80, 94][79, 93][78, 91][78, 91][77, 89][76, 88][75, 87][74, 85][72,
83][71, 82][68, 78][67, 77][66, 76][63, 72][63, 71][62, 69][58, 64][58, 63][52, 56][51, 55][38, 41][38, 40]
2013/03/10 18:45:44 INFO --gameno 22001 --maxnodes 25000  --nowinxp --blocksolve 11000
2013/03/10 18:45:44 INFO d= 0, l=      1, s=102,102,102, 126,126,126, p=      1,       1, cnt=      10
2013/03/10 18:45:44 INFO d= 1, l=     10, s= 98,102,102, 121,126,126, p=     11,      11, cnt=      99
2013/03/10 18:45:44 INFO d= 2, l=     54, s= 94,102,102, 115,126,126, p=     65,      65, cnt=     552
2013/03/10 18:45:44 INFO d= 3, l=    227, s= 92,102,102, 112,126,126, p=    292,     292, cnt=    2418
```

22000,35,25,w7,1|1a|KC|f|AH~2|1b|KS|f|2H~3|1c|3S|f|~4|72|8D|9C|~5|76|JC|QH|~6|17|TC-9D|JD|AD-
2D~7|a1|KC|e|~8|61|QH-JC|~9|74|JD-9D|QC|~10|8h|3H|h|~11|8a|6H|f|~12|8d|9H|f|AS-
3S~13|37|5C|6D|~14|58|7D|8C|~15|25|9C-
8D|TD|~16|2c|5D|f|~17|23|QS|KD|~18|c2|5D|6C|~19|62|4C|5D|~20|63|JH|QS|~21|6h|4S|h|~22|d6|9H|TS|~23|63|TS-
9H|JH|AC~24|28|6C-4C|7D|~25|51|TD-8D|JC|~26|25|JS|QD|2C~27|32|KD-9H|e|~28|31|7S|8D|~29|56|QD-
JS|e|3C;4H~30|3c|8S|f|~31|71|6D-5C|7S|3D;4C;5H~32|82|8C-5D|9H|~33|43|QC-9D|e|4D-7D;5C-6C;6H;5S-
7S~34|4a|TH|f|~35|4d|8H|f|8D-KD;7C-KC;7H-KH;8S-KS

22001,30,25,w7,1|2a|4S|f|AS-
2S~2|1h|3S|h|~3|ah|4S|h|~4|1a|6D|f|~5|36|QD|KC|~6|4b|TC|f|~7|5c|4H|f|AD~8|71|4C|5H|~9|86|JC|QD|~10|85|8H|9S|~11|
28|6H|7C|AC;AH~12|52|9S-8H|TD|~13|82|7C-6H|8H|~14|83|5D|6C|~15|84|QC|KH|~16|85|7D|8S|~17|15|6S-
4C|7D|~18|12|5C|6H|2C~19|61|KC-JC|e|2D~20|38|6C-5D|e|~21|3h|5S|h|~22|72|4D|5C|~23|7d|8C|f|2H-3H~24|37|TS|JD|3D-
7D;3C-7C;4H-6H;6S~25|48|KH-QC|e|~26|47|9D|TS|~27|4h|8D|h|~28|41|TH|JC|7S~29|6a|KD|f|~30|6c|QH|f|9D-KD;8C-KC;7H-
KH;8S-KS

22002,35,25,w7,1|18|TH|JS|AH~2|3a|6H|f|~3|51|5S|6D|AC-
2C~4|58|9C|TH|~5|64|TC|JH|AD~6|74|9D|TC|~7|37|7H|8S|~8|3b|3H|f|2H~9|bh|3H|h|~10|85|JS-9C|QH|~11|48|JH-
9D|QS|~12|47|6C|7H|~13|24|4S|5D|~14|2h|4H|h|~15|2b|KC|f|~16|2h|5H|h|~17|ah|6H|h|~18|47|5D-
4S|6C|~19|62|QD|KS|~20|6a|KD|f|2D-21|26|KS-QD|e|~22|26|JC|QD|AS~23|83|QS-9D|KH|~24|73|8S-
4S|9D|~25|7c|5C|f|~26|8h|3D|h|~27|86|TD|JC|~28|18|6D-5S|7C|3C-
4C~29|1d|TS|f|~30|1h|4D|h|5C~31|1c|7S|f|2S~32|41|7D|e|~33|42|QC|e|~34|45|8H|9C|5D-7D;6C-7C;7H-8H;3S-8S~35|31|KH-
9D|e|8D-KD;8C-KC;9H-KH;9S-KS

It's been awhile since I looked at this code so I'm sorry if my explanations aren't very clear.
Shirl Hart