

## CS 486 AI Assignment 2

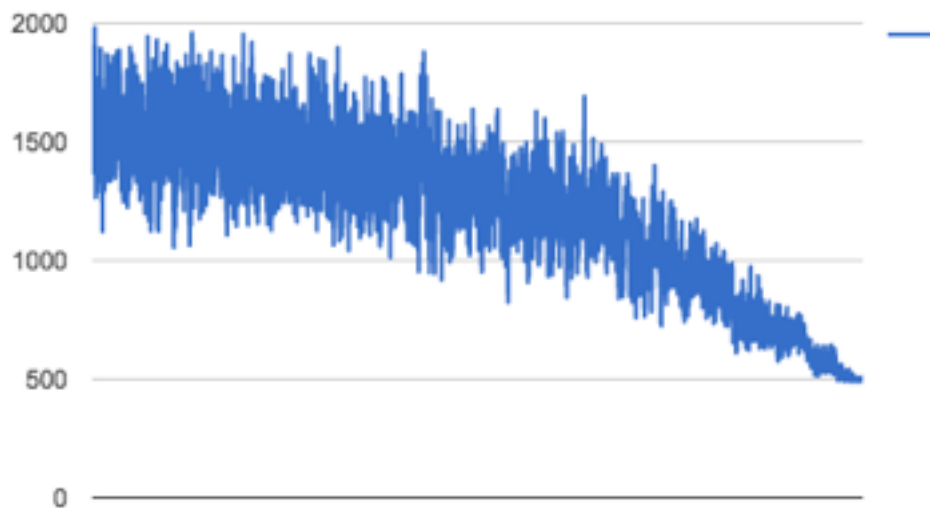
Q1:

- a) The local search operator I used is a random swap of 2 cities on a existing tour route. On a given tour, the algorithm randomly choose 2 different indexes between the total number of cities. The index is mapped to a list of cities. Then, the algorithm swap the 2 cities represented by the indexes. This preserves a tour because the operation is done using an existing tour, which always visit all cities.
- b) The experiment is ran on the 36-city TSP instance.
  - a) The first schedule is by decreasing the temperature on a percentage. The percentage is set to 0.00001 and the temperature is set to 66666. The algorithm stops when the temperature reaches 1. The eventual distance found by the schedule is 469.7 with run time 3659ms and 1110740 number of runs.
  - b) The second schedule is by a constant decrease of the temperature. The decrease for every run is 0.01 with temperature set to the same. The distance is 664. And the run time is 17296 ms.
  - c) The third schedule is by a random decrease percentage of the temperature. The random number is between 0 to 0.00001. The distance is found to be 480.22 with 2221337 number of runs and 5616ms execution time.

Result:

I would choose the first schedule with a constant decrease over a percentage in temperature, since it produces the best optimal solution with a reasonable amount of time and iterations.

c)



The y axis represents the cost of the solution, while x represents number of iterations. The cost of the best solution found was 469.7.

d) Simulated annealing is complete since it will always find a solution. The algorithm started with a randomly selected route that travels all cities. The swapping of cities will not eliminate any cities. Therefore it is complete.

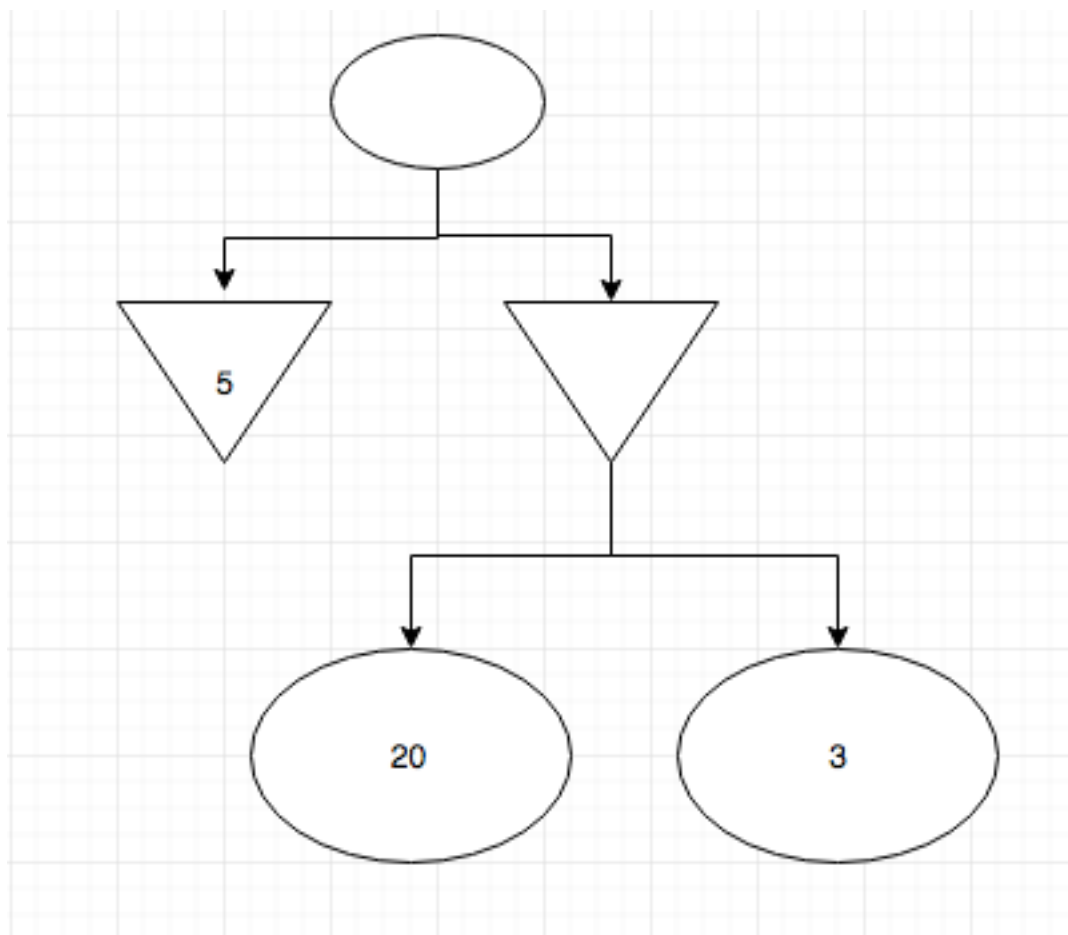
e) Whether or not it is optimal depends on the amount of resources and time it is given to run the algorithm. In theory, given enough time and resource, simulated annealing is capable of eventually finding the optimal solution. However, there is no upper bound to the amount of time it takes to find the optimal solution, or the time can be infinite. Therefore, under limited resources and time, it is not optimal.

Q2:

a)

By definition, a suboptimal MIN means that the player does not select the optimal move predicted by minimax search. In other words, it selects a move  $\geq$  minimax predicted move. On the other hand, MAX in this case always choose the optimal move, which maxes out the decisions made by MIN. As a result, the influence of choosing suboptimal MIN carries over, which made utility obtained by MAX using minimax search against a suboptimal MIN will always be greater or equal to the utility obtained playing against an optimal MIN.

b)



In this tree, MAX will choose 5 if following minimax search. However, if MAX plays sub optimally, it will choose the other utility, which is the one that MIN passes up using a suboptimal strategy. In this case, MIN would choose 20 with the suboptimal strategy, and MAX would get 20 using the suboptimal strategy.

Q3:

1)  $P_s = 0.2$  and  $P_r = 0.01$

optimal policy:

s1: b

s2: d

s3: d

s4: d

s5: d

Value function:

0	0	0	0	0
0.0	0.0	0.0	10.0	-10.0
0.0	7.6	8.36	10.95	-10.95
7.1478	9.7669	9.9484	11.04025	-11.04025
9.184923	10.24613	10.174747	17.16019275	-4.93745475
9.633008835	14.98851119	15.428638115	19.4833274762	-2.61594903625
14.1066214276	17.655146008	17.9140224862	20.0871386642	-2.01229260452
16.6566182614	18.6207031263	18.666391097	23.9694394937	1.86999352321
17.5421431228	21.7547076092	22.0572331846	26.5185053654	4.41905799818
20.5254379695	24.2874585234	24.5588144899	27.5177903797	5.4183428798
22.947702996	25.528137808	25.6508533999	30.16343955	8.06399203753
24.1115114416	27.7745602415	28.0166271369	32.4858128188	10.3863653052
26.244809789	29.9663841882	30.2270047867	33.7014945003	11.6020469865
28.3373460226	31.306748816	31.4763985011	35.6409543471	13.5415068333
29.6043685906	33.0354075788	33.253329073	37.6143215123	15.5148739985
31.2440113735	34.8636117893	35.1093664036	38.8850956886	16.7856481748
32.9866893555	36.1767589633	36.3722018708	40.4077138148	18.308266301
34.2319680883	37.5834467023	37.794009738	42.0423522114	19.9429046976
35.5659152944	39.0930425541	39.3266973145	43.2623561756	21.1629086617
37.0030881568	40.3070687787	40.5154060236	44.5187814134	22.4193338995
38.1559655251	41.4926169421	41.7025769293	45.8669246084	23.7674770946
39.2805199994	42.7424599214	42.9680205971	46.9807083617	24.8812608479
40.4693070104	43.82640574	44.0405228546	48.0480118939	25.9485643801
41.4992312067	44.8435061299	45.0549550891	49.1658186238	27.06637111
42.4644135658	45.8862883188	46.1070509055	50.152595451	28.0531479372
43.4556478129	46.8343673233	47.0506941952	51.0715701666	28.9721226528
44.3566300791	47.712923118	47.9260636896	52.0063780459	29.9069305321
45.1906643121	48.5903027073	48.8084845283	52.865524632	30.7660771182
46.0243673814	49.4099562347	49.6268848392	53.6602428269	31.5607953131
46.8033014387	50.169676233	50.3841169254	54.4485571796	32.3491096658
47.5247336079	50.9131419408	51.1300627451	55.1894356622	33.0899881484
48.2310533398	51.617468072	51.8343787006	55.8766436226	33.7771961088

48.9003438563	52.2735680869	52.4888515225	56.5458317497	34.4463842359
49.5235007181	52.9068100663	53.1231822893	57.1816480133	35.0822004995
50.1250534255	53.5103464027	53.7270666175	57.7748496752	35.6754021614
50.6985220334	54.0758515697	54.2916230496	58.345531398	36.2460838842
51.2356973006	54.6170156607	54.8331887836	58.8900618214	36.7906143075
51.7497676535	55.1336799598	55.3502110403	59.401077065	37.3016295512

2)  $P_s = 0.2$  and  $P_r = 0.03$

Optimal policy:

s1: a  
s2: d  
s3: d  
s4: d  
s5: d

value function:

0	0	0	0	0
0.0	0.0	0.0	10.0	-10.0
0.0	7.6	7.98	10.95	-10.95
6.8229	9.7669	4.962	11.04025	-11.04025
8.9981055	10.24613	9.7122585	16.88240325	-5.21524425
9.6152611725	14.77739117	14.7273363825	19.2972085112	-2.80206800125
13.5481192617	17.4735827908	17.2683808528	20.0542831111	-2.04514815763
16.226984616	18.5612358947	18.1570744498	23.4887988643	1.38935289381
17.4114202285	21.3781219569	21.1780108916	26.1055077388	4.00606037163
19.9323791948	23.9020290533	23.7022859014	27.3667875305	5.26734003064
22.3298108641	25.3401440433	25.0204862455	29.642029027	7.5425815145
23.7871551891	27.3425694287	27.0910467573	31.9079810464	9.80853353268
25.6376766045	29.4451537867	29.2251389824	33.3692758861	11.2698283723
27.6111857651	30.9552288929	30.6772848318	35.0902947061	12.9908471923
29.0897833511	32.5501174663	32.2867097786	36.9411418262	14.8416943124
30.593879852	34.2597901065	34.0220794362	38.3811732387	16.2817257249
32.198539127	35.6790517816	35.4181664114	39.8039787311	17.7045312173
33.5644504904	37.0300436742	36.7672933701	41.311128933	19.2116814192
34.849310138	38.4321662872	38.1840738538	42.6221624179	20.5227149041
36.1701866387	39.6949550322	39.4396016293	43.8452655977	21.7458180839
37.3753542832	40.8644433104	40.6046299867	45.0908098078	22.991362294
38.4897576873	42.0332596829	41.7802479803	46.2395548439	24.1401073301
39.5949640092	43.1283810211	42.8741086955	47.3015005328	25.202053019
40.6362873539	44.1435327989	43.8859890275	48.3473367785	26.2478892647
41.6031678417	45.1312471834	44.8763076491	49.3370226816	27.2375751677
42.5395172868	46.0710742028	45.8165693652	50.2577256594	28.1582781456
43.4320225857	46.9493755997	46.6930952743	51.1457712179	29.046323704
44.2677582834	47.7911674895	47.5356441882	51.9932275764	29.8937800626
45.0668852405	48.5951747811	48.3402615216	52.788289952	30.6888424382
45.8302285357	49.352183572	49.0964784994	53.547074426	31.4476269122
46.5499886649	50.0726914425	49.8170798376	54.2718174685	32.1723699547
47.2344001065	50.7603926501	50.505192266	54.956062968	32.8566154542
47.887403726	51.4110824592	51.1555928488	55.606238073	33.5067905592
48.5057788566	52.0288466027	51.7732806189	56.2263228026	34.1268752888
49.0927128367	52.6174861845	52.3621334009	56.8139415886	34.7144940748

49.6517584073	53.1759179824	52.9204884772	57.3715939263	35.2721464125
50.1823269237	53.7058358007	53.4503249582	57.9025548612	35.8031073474
50.6858106673	54.2100504966	53.9546310232	58.4066322315	36.3071847177

3)  $P_s = 0.6$ ;  $P_r = 0.1$

Optimal policy:

s1: b  
s2: d  
s3: d  
s4: d  
s5: d

Value function:

0	0	0	0	0
0.0	0.0	0.0	10.0	-10.0
0.0	3.8	6.65	10.95	-10.95
5.68575	6.3277	9.135	11.04025	-11.04025
7.30618875	7.801685	8.09354875	15.91014	-6.1875075
7.6140721125	10.49281365	12.2727803187	17.7582546813	-4.34102183125
11.2165640232	12.7290405594	14.2497906141	18.1970658509	-3.90236541778
13.2491445572	14.1704381422	14.8127754403	21.3188834957	-0.780562474837
13.9235917344	16.1783254694	17.5354116884	23.3533125285	1.25386516132
16.3155182084	18.0959042784	19.5334988224	24.1232356231	2.02378812326
18.251115723	19.4814949755	20.3816013334	26.2414754524	4.14202793988
19.1601251338	21.0762128079	22.2732661248	28.0976441111	5.99819659741
20.8638544244	22.6905460627	24.039998483	29.0511831799	6.95173566612
22.5362648733	23.9730608641	25.0231139609	30.5984579349	8.49901042113
23.5357075995	25.2920587078	26.4394298468	32.1753599705	10.0759124567
24.841604741	26.6431102523	27.9222310964	33.1796891948	11.080241681
26.2334600378	27.7948547378	28.9217987019	34.3916425271	12.2921950133
27.2203165937	28.9118913608	30.0529777235	35.6968143724	13.5973668586
28.28122603	30.0445675372	31.2763616583	36.664568053	14.5651205392
29.4280056907	31.0579393563	32.2200125291	37.6635822207	15.5641347069
30.343771253	32.015186677	33.1638164751	38.7389851765	16.6395376627
31.2377213553	32.969470773	34.1729473773	39.6241280131	17.5246804992
32.1854535363	33.8497669856	35.0256119382	40.47254392	18.3730964062
33.0045162931	34.6739338714	35.8320106719	41.363454446	19.2640069321
33.7717981723	35.4822549961	36.6703470513	42.148389603	20.0489420892
34.5614675552	36.2412733969	37.4211085666	42.8789844496	20.7795369358
35.2783872422	36.9515399271	38.1170895044	43.6235582824	21.5241107686
35.9415583143	37.6393299058	38.8198183206	44.3072591289	22.2078116151
36.605392704	38.2911765153	39.4711417819	44.939221976	22.8397744622
37.2253385304	38.9028749646	40.0733457449	45.5668368496	23.4673893358
37.7991177723	39.4900367327	40.6671658384	46.1565139442	24.0570664304
38.3613429802	40.0487962364	41.2277526631	46.70311452	24.6036670062
38.8940561101	40.5749973724	41.7483519038	47.2357441275	25.1362966136
39.3897762082	41.0773312707	42.253207146	47.7418136662	25.6423661524

4)  $P_s = 0.6$ ;  $P_r = 0.2$

Optimal policy:

s1: a

s2: d

s3: d

s4: d

s5: d

Value function:

0	0	0	0	0
0.0	0.0	0.0	10.0	-10.0
0.0	3.8	4.75	10.95	-10.95
4.06125	6.3275	5.6525	11.04025	-11.04025
5.79540375	7.801685	5.78110625	14.5211925	-7.576455
7.22100403125	9.9650136	8.76627165625	16.3345834937	-5.76469301875
9.20608201097	11.8871994796	10.6000021571	17.7257438786	-4.37368739006
11.0381333461	13.5114863773	11.9636192801	19.5551457878	-2.54430018268
12.6009435204	15.1325026344	13.6572987458	21.2953428608	-0.804104506421
14.1353793869	16.7177567887	15.3060665271	22.7968642818	0.697416781868
15.6365430961	18.1919297966	16.746500256	24.2514514825	2.15200397005
17.0395715703	19.5849515474	18.1270135145	25.673132238	3.57368472433
18.3638928722	20.9192126325	19.4736993198	27.0077812552	4.90833374138
19.6304966236	22.1869080775	20.7427593809	28.266867625	6.1674201112
20.8347035855	23.3879473017	21.9398389329	29.4694270376	7.36997952378
21.9759917836	24.5295122362	23.0817497881	30.6132671342	8.51381962036
23.0604521814	25.6148634856	24.168214602	31.6977333527	9.59828583887
24.0914512375	26.6456108608	25.1986473761	32.7279712836	10.6285237698
25.0706851536	27.6246272785	26.1773919206	33.70734808	11.6079005662
26.0007714127	28.5548298191	27.1077398132	34.6376338739	12.5381863601
26.8844527795	29.438553869	27.9915172168	35.5212347758	13.421787262
27.723986572	30.2780449201	28.8309548413	36.3607244302	14.2612769164
28.5215071311	31.075560888	29.6284650701	37.15827734	15.0588298261
29.2791477367	31.8332150953	30.3861362797	37.9159249444	15.8164774305
29.9989179415	32.5529840832	31.1059037464	38.6356841846	16.5362366707
30.6826985956	33.2367609175	31.7896758061	39.3194648375	17.2200173237
31.3322869511	33.8863503612	32.43926661	39.9690564588	17.869608945
31.9493968192	34.5034611602	33.0563785726	40.5861657068	18.4867181929
32.5356519898	35.0897158299	33.642632616	41.1724200226	19.0729725088
33.0925939736	35.6466576316	34.1995741902	41.7293623535	19.6299148396
33.6216887025	36.1757525443	34.7286693326	42.258457271	20.1590097572
34.1243288522	36.6783927133	35.2313095257	42.7610972814	20.6616497676