March 4 Review
for Midterm Exam March 6, 2024
COSC 4368: Artificial Intelligence

1) Best first Search and A* [10]

Consider the search space below, where *S* is the start node and *G1* and *G2* satisfy the goal test. Arcs are labeled with the cost of traversing them and the estimated cost to a goal (the h function itself) is reported inside nodes.
For each of the following search strategies, indicate which goal state is reached (if any) and list, *in order*, all the states *popped off of the OPEN list*. When all else is equal, nodes should be removed from OPEN in alphabetical order.

a) Best-First-Search (using function h only) [3]

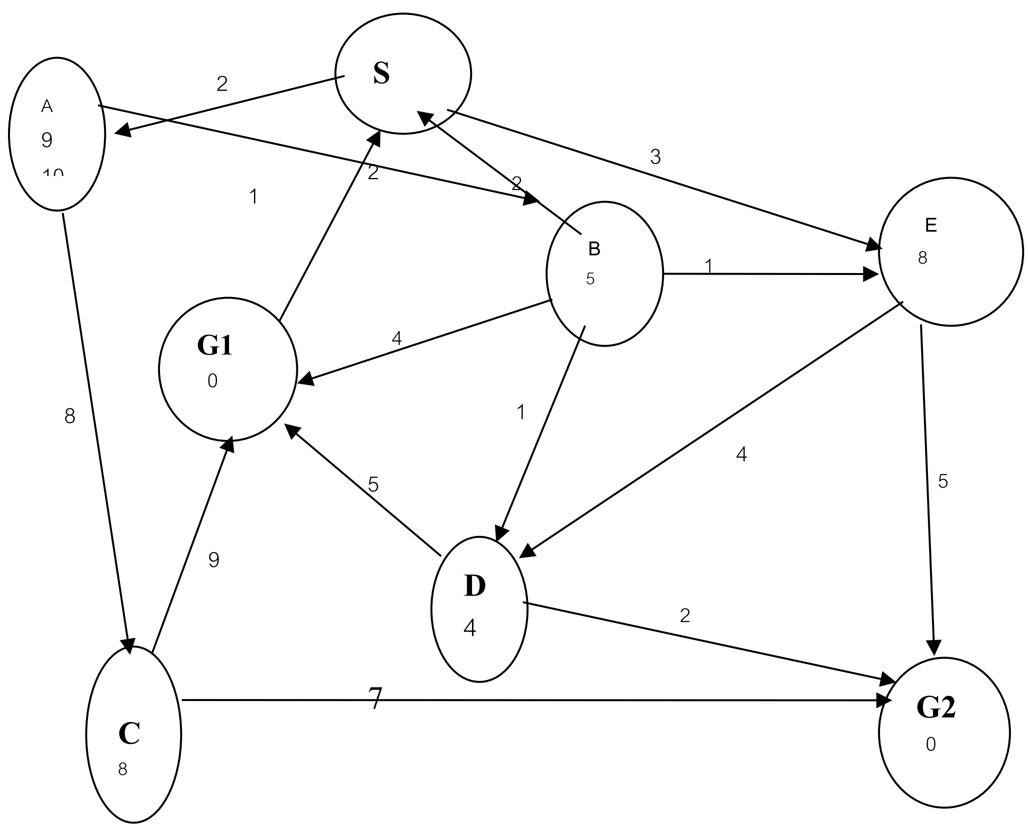
Goal state reached: G2 [1]

States popped off OPEN: S, E, G2 [2]

b) A* (using f=g+h)[4]

Goal state reached: G1 [1]

States popped off OPEN: S, A, B, G1 [3]



c) Assume you have 2 admissible heuristics h1(s) and h2(s) are given for a given seach problem. Is h3(s)=min(h1(s),h2(s)) also admissible? Would you prefer using h2 or using h3 in conjuction with A*? Give reasons for your anwers[4].

Yes, h3 is admissible. If h1 and h2 always underestimate the "true" cost then the lesser of the two will certainly underestimate the true cost as well; therefore, h3 is admissible.

I will prefer h2, because h2 is always greater equal than h3 and therefore it provides a closer approximation of the true cost. As a matter of fact, h2 dominates h3, which translates into equal or better efficiency of the search, as discussed on the bottom of page 106 of our textbook.

2) Local Search

a) Assume you apply randomized hill climbing to a minimization involving a continuous, differentiable function that has 3 minima. Will it always find the optimal solution? Give reasons for your answer! [3]

No, HC might climb down the wrong minimum depending on the chosen starting point

b) What is the “main” difference between simulated annealing and randomized hill climbing? [2]

… SA does allow downward steps…

c) When does A* terminate? Be precise!

When a goal node in the open list is expanded

Wrong: when a goal node is appearing on the open list

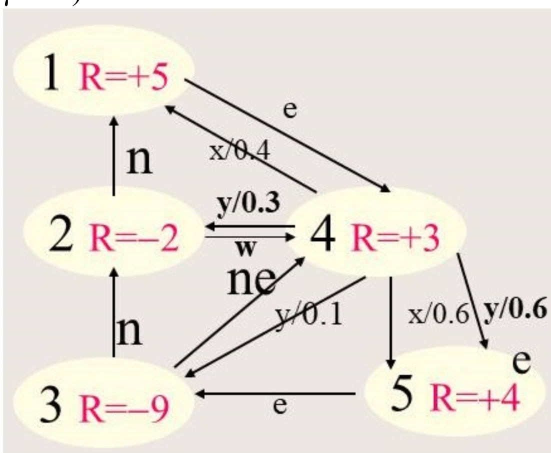
3. Game Theory

Should know the following:
a. Research goals of Game Theory
b. What a parallel game is and what a payoff matrix.
c. Compute Nash Equilibrium for a 2-Player parallel games.

4. Reinforcement Learning

a) capability to come up with Bellman equations for a given world (see GHC Group F solution)

b) Now we apply temporal difference learning to the world depicted below, assuming the agent starts in state 2 and applies the operator sequence **w-y(ending up in state 2)-w**; assume the initial utilities are 0; what are the new utilities; also assume α=0.5 and γ=0.5)?



In summary, excuting w-y-w the agents visits 2-4-2-4

General Update Formula: U(s):=(1-α)*U(s)+ α*(R(s)+ γ*U(s'))

U(2)=0+ 0.5(-2+0))=-1 because R(2)=-2 and U(4)=0
U(4)=0+0.5*(3+0.5*-1)=1.25 because R(4)=3 and U(2)=-1
U(2)=0.5*-1 + 0.5*(-2+0.5*1.25)=-0.5+0.5*-1.375=-1.1875
because R(2)=-2 U(4)=1.25
Remark; if γ would have been 1, U(2) would be greater than −1!

c) Assume you have a policy that always selects the action that leads to the state with the highest expected utility. Present arguments that this is usually not a good policy by describing scenarios in which this policy leads to suboptimal behavior of the agent!

Not suitable for unknown worlds due its lack of exploration
Not suitable for changing worlds due to its lack of exploration

Other answers might deserve credit.

d) What role does the learning rate α play in temporal difference learning; how does running temporal difference learning with low values of α differ from running it with high values of α? [2]

It determines how quickly our current beliefs/estimates are updated based on new evidence.

e) Assume you run temporal difference learning with high values of γ—what are the implications of doing that? [2]

If γ is high the agent will more focus on its long term wellbeing, and will shy away from taking actions—although they lead to immediate rewards—that will lead to the medium and long term suffering of the agent.

5. Comparison of Seach Algorithms

Compare Traditional Hill Climbing/Randomized Hill Climbing and Best-first Search!
What are the main differences between the two approaches?
Let n be the size of the search space, the number of nodes in the search tree
b the branching factor, the number of successors
m is the length of the longest path in the search tree

	Randomized HC	Best First Search
The way they search	Explore a single path	Can explore multiple paths in parallel
	Only moves forward, cannot move backward	Jumps between states; can explore multiple paths in parallel!
Storage	O(1) / O(m)[1]	O(n)
Runtime	O(m) but might stop prematurely, fast	O(n) in the worst case, not fast
Finding solutions in finite search spaces	might terminate prematurely; might go into the wrong direction and get stuck	Yes
Find global optimum	no	no, terminates permaturely
Parameter Selection	Choosing neighbor hood size and sampling rate for RHC is challenging	Straight Forward
Incorperating Heuristics	Needs good state evaluation function	Need good state evaluation function
Other	RHC is a probabilistic algorithm (usually) returns different solutions in different runs	deterministic

[1] Only if it is necessary to return the solution path, as in the 8-puzzle problem!

6) Constraint Satisfaction Problems [8]

Provide a definition[2] the letter constraint satisfaction problem given below:

1. Define the Variables
2. Define the set of values each variable can take
3. Define all constraints!

```
      T W O
  +   T W O
-------------------------------
    F  O  U  R
```

Assume each letter can take only one digit, and reciprocally each digit can be associated to at most one letter.

Variables: T, W, O, F, U, R in {0…9}
X1, X2, X3 in {0,1}

Constraints:

1. DIFF(T, W, O, F, U, R)
2. O+O=R+10*X1
3. X1+W+W=U+10*X2
4. X2+T+T=O+X3
5. X3=F

[2] Be aware of the fact that you are not asked to solve this letter constraint satisfaction problem!

7) Discrete CSPs

Assume a constraint satisfaction problems in which variables A, B, C, D which take values in {1,…,100}

- **Constraints:**
  - (C1) A*B + B*C=D*D*D
  - (C2) A*D*D*D + A*C=B*B
  - (C3) B=A*D

A brute force solution to this problem could look as follows:

```
FOR A=1,…,A=100
FOR B=1,…,B=100
FOR C=1,…,C=100
FOR D=1,…,D=100 DO {
IF C1 and C2 and C3 THEN WriteSolution(A,B,C,D)}
```

Give the code of a more efficient solution to this problem which uses less loops and/or less iterations inside the loop. Briefly describe the idea of your solution!

One approach: Eliminate B

(C1') A*A*D +A*C*D=D*D*D

(C2') A*D*D*D+A*D=A*A*D*D

Faster Loop:

```
FOR A=1,…,A=100
FOR C=1,…,C=100
FOR D=1,…,D=100 DO {
IF C1' and C2' THEN {B=A*D; WriteSolution(A,B,C,D)}
```

Maybe enhance further … ---not needed for exam!

(C2") A*D*D + A = A*A*D

(C2"') D*D+1=A*D

(C1") A*A+A*C=D*D

combine the last two getting (4) A*D – 1=A*A + A*C

now the code, displayed above, can be further simplified by solely a single equation: (4)!

8) Questions concerning Evolutionary Computing [15]

a) What role does the selection technique play in an evolutionary computing system? What role do crossover (also called recombination) operators play in an evolutionary computing system? [4]

The selection operators select solutions that participate in the breeding of the next generation based on the principles of Darwinian evolution.

The crossover is a binary exploitation operator combining partial solutions from each parent probabilistically. It does not introduce anything new, but combines what is present in one or both parents.

b) Assume we have a population with 3 solutions
s1 with fitness 3
s2 with fitness 3
s3 with fitness 6

Assuming that higher fitness values indicate better solutions; how would roulette wheel selection create a mating pool for the breeding of the next generation in the above case?

No answer given!

9. **Game Theory [6]**

a) What is the Nash Equilibrium for the following game, whose payoff matrix is depicted below that involves 2 players where player 1 has actions {A,B,C] and player 2 has actions {D,E,F}? [4]

	A	B	C
D	4, 4	8, -2	-2, 9
E	1, 3	-2, -2	3, 5
F	2, 2	9, 5	-3, 6

b) What is the main characteristic of a Nash Equilibrium? [2]
Exactly one person deviating from a NE strategy would result in the same payout or lower payout for that person [2]

	A	B	C
D	4, $\underline{4}$	$\underline{8}$, -2	-2, $\underline{9}$
E	1, 3	-2, -2	$\underline{3}$, 5
F	2, 2	$\underline{9}$, $\underline{5}$	-3, 6

Nash Equilibrium: (B,F)