

## Q1. Logic

(a) Prove, or find a counterexample to, each of the following assertions:

(i) If  $\alpha \vDash \gamma$  or  $\beta \vDash \gamma$  (or both) then  $(\alpha \wedge \beta) \vDash \gamma$

(ii) If  $(\alpha \wedge \beta) \vDash \gamma$  then  $\alpha \vDash \gamma$  or  $\beta \vDash \gamma$  (or both).

(iii) If  $\alpha \vDash (\beta \vee \gamma)$  then  $\alpha \vDash \beta$  or  $\alpha \vDash \gamma$  (or both).

(b) Decide whether each of the following sentences is valid, unsatisfiable, or neither.

(i)  $Smoke \implies Smoke$

(ii)  $Smoke \implies Fire$

(iii)  $(Smoke \implies Fire) \implies (\neg Smoke \implies \neg Fire)$

(iv)  $Smoke \vee Fire \vee \neg Fire$

(v)  $((Smoke \wedge Heat) \implies Fire) \iff ((Smoke \implies Fire) \vee (Heat \implies Fire))$

(vi)  $(Smoke \implies Fire) \implies ((Smoke \wedge Heat) \implies Fire)$

(vii)  $Big \vee Dumb \vee (Big \implies Dumb)$

(c) Suppose an agent inhabits a world with two states,  $S$  and  $\neg S$ , and can do exactly one of two actions,  $a$  and  $b$ . Action  $a$  does nothing and action  $b$  flips from one state to the other. Let  $S^t$  be the proposition that the agent is in state  $S$  at time  $t$ , and let  $a^t$  be the proposition that the agent does action  $a$  at time  $t$  (similarly for  $b^t$ ).

(i) Write a successor-state axiom for  $S^{t+1}$ .

(ii) Convert the sentence in the previous part into CNF.

## Q2. First Order Logic

Consider a vocabulary with the following symbols:

- $Occupation(p, o)$ : Predicate. Person  $p$  has occupation  $o$ .
- $Customer(p1, p2)$ : Predicate. Person  $p1$  is a customer of person  $p2$ .
- $Boss(p1, p2)$ : Predicate. Person  $p1$  is a boss of person  $p2$ .
- $Doctor, Surgeon, Lawyer, Actor$ : Constants denoting occupations.
- $Emily, Joe$ : Constants denoting people.

Use these symbols to write the following assertions in first-order logic:

(iii) Emily is either a surgeon or a lawyer.

(iv) Joe is an actor, but he also holds another job.

(v) All surgeons are doctors.

(vi) Joe does not have a lawyer (i.e., is not a customer of any lawyer).

(vii) Emily has a boss who is a lawyer.

(viii) There exists a lawyer all of whose customers are doctors.

(ix) Every surgeon has a lawyer.

### Q3. [Optional] Local Search

**(a) Hill Climbing**

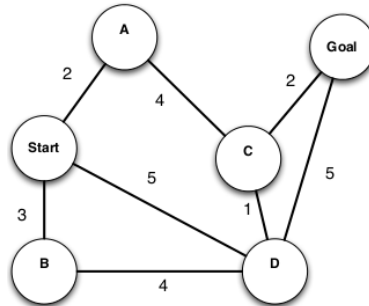
- (i) Hill-climbing is complete.  True  False
- (ii) Hill-climbing is optimal.  True  False

**(b) Simulated Annealing**

- (i) The higher the temperature  $T$  is, the more likely the randomly chosen state will be expanded.  True  False
- (ii) In one round of simulated annealing, the temperature is 2 and the current state  $S$  has energy 1. It has 3 successors:  $A$  with energy 2;  $B$  with energy 1;  $C$  with energy  $1 - \ln 4$ . If we assume the temperature does not change, What's the probability that these states will be chosen to expand after  $S$  eventually?
- (iii) On a undirected graph, If  $T$  decreases slowly enough, simulated annealing is guaranteed to converge to the optimal state.  True  False

**(c) Local Beam Search**

The following state graph is being explored with 2-beam graph search. A state's score is its accumulated distance to the start state and lower scores are considered better. Which of the following statements are true?



- States A and B will be expanded before C and D.
- States A and D will be expanded before B and C.
- States B and D will be expanded before A and C.
- None of above.

**(d) Genetic Algorithm**

- (i) In genetic algorithm, cross-over combine the genetic information of two parents to generate new offspring.  True  False
- (ii) In genetic algorithm, mutation involves a probability that some arbitrary bits in a genetic sequence will be flipped from its original state.  True  False

**(e) Gradient Descent**

- (i) Gradient descent is optimal.  True  False
- (ii) For a function  $f(x)$  with derivative  $f'(x)$ , write down the gradient descent update to go from  $x_t$  to  $x_{t+1}$ . Learning rate is  $\alpha$ .