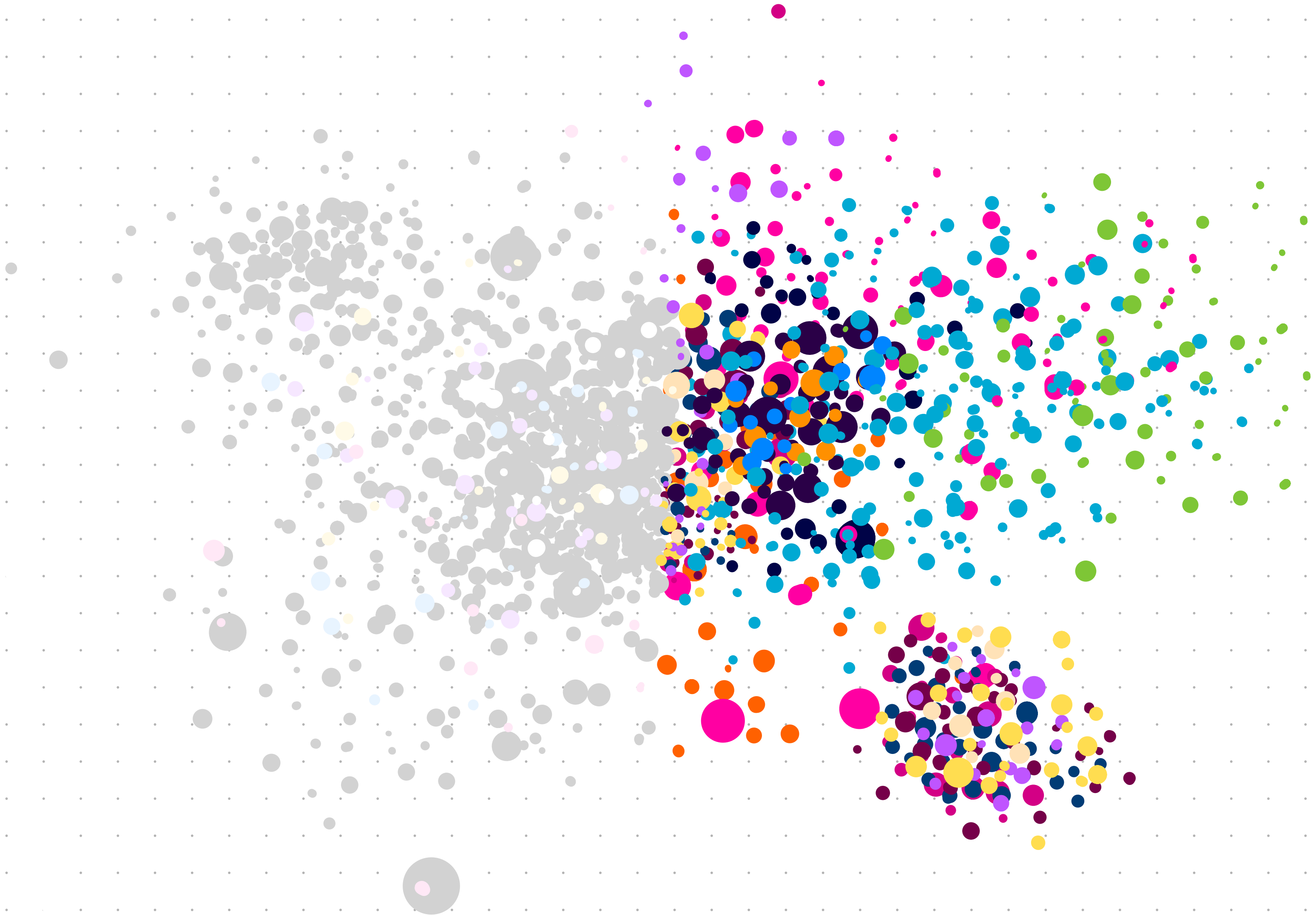
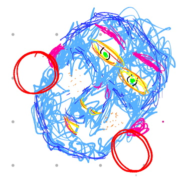


AI EXAM 2019



Don Julio The Audience Participation Mascot

1a) $\alpha = A \vee C$

$KB = A \wedge (A \vee B) \wedge (B \vee \neg C) \wedge (\neg B \vee C)$

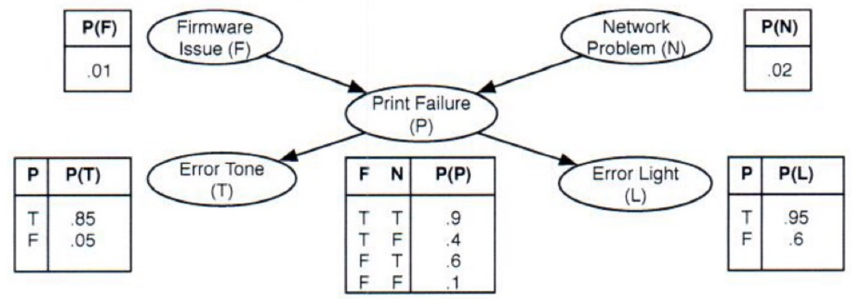
A	B	C	A ∨ B	B ∨ ¬C	¬B ∨ C	A	KB	A ∨ C (α)
T	T	T	T	T	T	T	T	T
T	T	F	T	T	F	T	F	T
T	F	T	T	F	T	T	F	T
T	F	F	T	T	T	T	T	T
F	T	T	T	T	T	F	F	T
F	T	F	T	T	F	F	F	F
F	F	T	F	F	T	F	F	T
F	F	F	F	T	T	F	F	F

Since α is true whenever KB is true, KB entails α.

1. (a) Given a knowledge base KB and query sentence α, such that $\alpha = A \vee C$ and $KB = A \wedge (A \vee B) \wedge (B \vee \neg C) \wedge (\neg B \vee C)$, use inference by enumeration to determine whether $KB \models \alpha$. [4]

(b) Suppose that there are two tests, that use independent methods, for determining whether a site might be of archaeological interest. Test A has a true positive rate of 79% and a false positive rate of 12%. Test B has a true positive rate of 73% and a false positive rate of 9%. Suppose there are a number of possible sites and you must select one for investigation. Each site has a 1 in 100 chance of being of archaeological interest. If you must select just one of the tests, which would you choose and why? Justify your answer mathematically, giving the relevant probabilities. [6]

(c) Given the following Bayesian network use inference by enumeration to compute the probability of N given that T and L are observed. [12]



(d) Suppose that you are given an ordered set of nodes $\langle X_1, X_2, \ldots, X_n \rangle$. Describe how you would use Pearl's construction algorithm to create a Bayesian Network. [3]

1b) $p(A \mid \text{interesting}) = 0.79$

$p(A \mid \neg\text{interesting}) = 0.12$

$p(B \mid \text{interesting}) = 0.73$

$p(B \mid \neg\text{interesting}) = 0.09$

$p(\text{interesting}) = 0.01$

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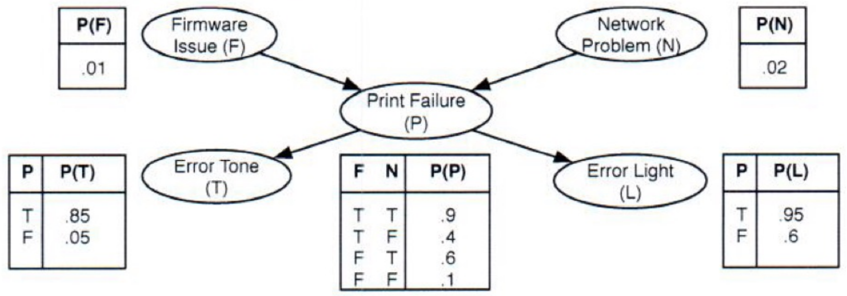

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Remember

$$p(A \mid B) = \frac{p(B \mid A)\, p(A)}{p(B)}$$

$$p(\text{Interesting} \mid A) = \frac{p(A \mid \text{interesting})\, p(\text{interesting})}{p(A)} = \frac{p(A \mid \text{interesting})\, p(\text{interesting})}{p(A \mid I)p(I) + p(A \mid \neg I)p(\neg I)} = \frac{0.79 \times 0.01}{(0.79 \times 0.01) + (0.12 \times 0.99)} = 0.0624$$

$$p(\text{Interesting} \mid B) = \frac{p(B \mid \text{interesting})\, p(\text{interesting})}{p(B)} = \frac{p(B \mid \text{interesting})\, p(\text{interesting})}{p(B \mid I)p(I) + p(B \mid \neg I)p(\neg I)} = \frac{0.73 \times 0.01}{(0.73 \times 0.01) + (0.09 \times 0.99)} = 0.0757$$

$\therefore$ $p(\text{interesting} \mid B) > p(\text{interesting} \mid A)$ so use test B

1c) $P(N \mid T \land L)$

$P(N \land T \land L \land P \land F)$
$P(N \land T \land L \land P \land \neg F)$
$P(N \land T \land L \land \neg P \land F)$
$P(N \land T \land L \land \neg P \land \neg F)$

$P(N) \times P(F) \times P(P \mid F \land N) \times P(T \mid P) \times P(L \mid P)$
$P(N) \times P(\neg F) \times P(P \mid \neg F \land N) \times P(T \mid P) \times P(L \mid P)$
$P(N) \times P(F) \times P(\neg P \mid F \land N) \times P(T \mid \neg P) \times P(L \mid P)$
$P(N) \times P(\neg F) \times P(\neg P \mid \neg F \land N) \times P(T \mid \neg P) \times P(L \mid \neg P)$

$= 0.00947665$

1d) **PEARLS CONSTRUCTION ALGORITHM**

1) Given an ordering of nodes $(X_1, X_2 \dots X_n)$
2) Process each Node in order
   - → add to network
   - → add arcs from minimal parent set s.t. node independent of every other preceding node
   - → define $PA_{X_i} \subseteq \{X_1, X_2, \dots, X_n\}$
3) Define the Conditional Probability Table for X_i

1. (a) Given a knowledge base KB and query sentence α, such that $\alpha = A \lor C$ and $KB = A \land (A \lor B) \land (B \lor \neg C) \land (\neg B \lor C)$, use inference by enumeration to determine whether $KB \models \alpha$. [4]

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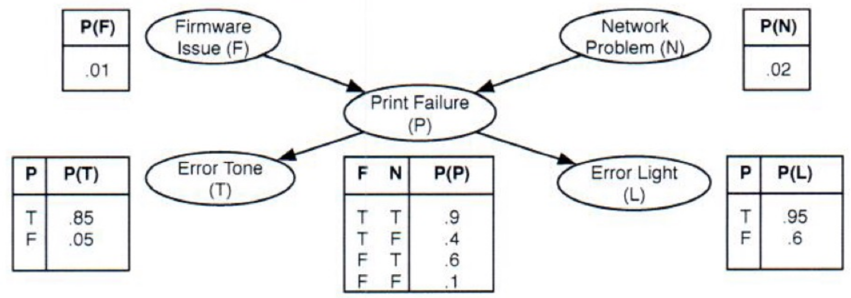

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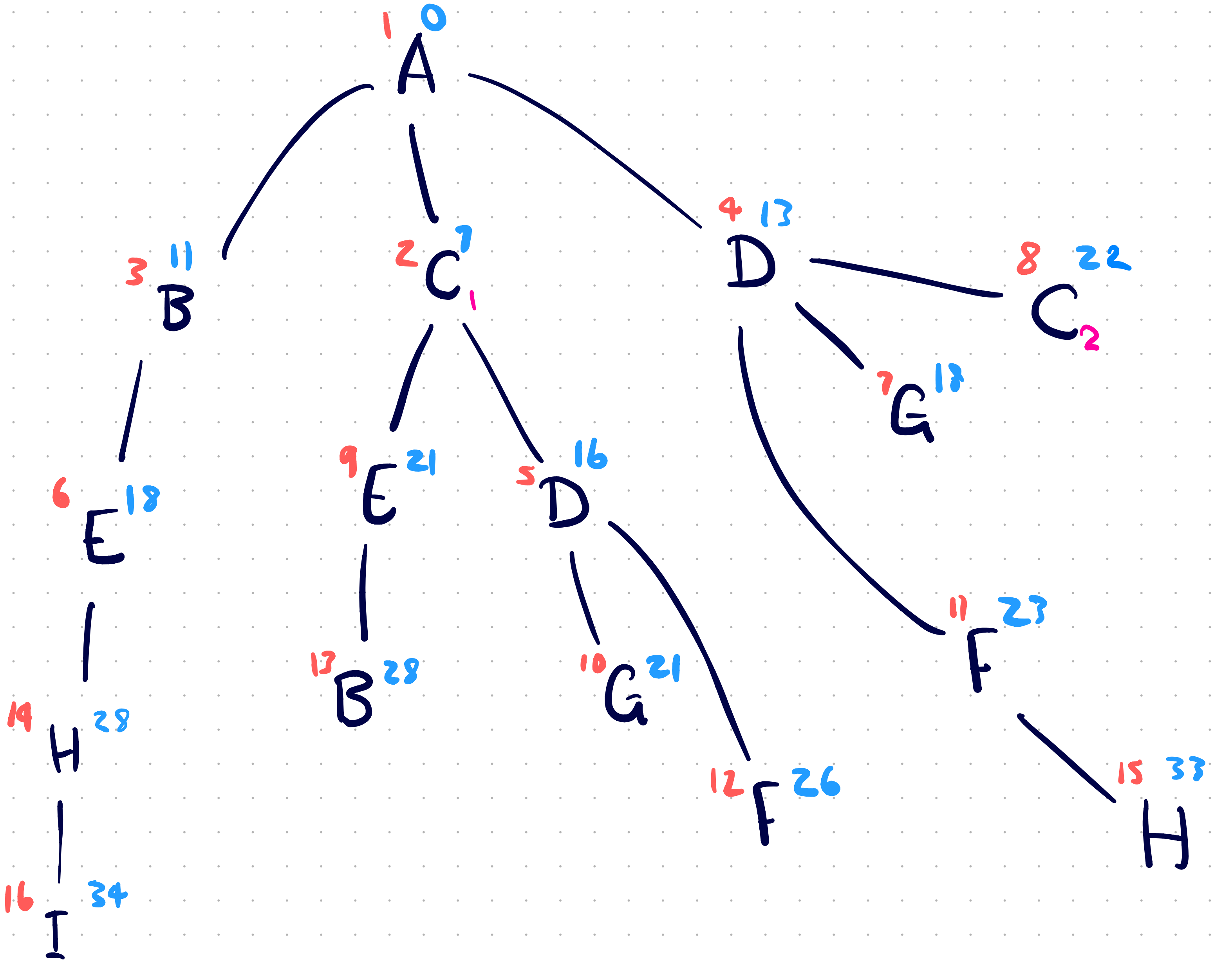
2ai)

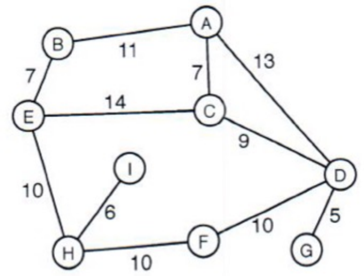


NODES EXPANDED: A C_1 B_1 D_1 D_2 E_1 G_1 C_2 E_2 G_2 F_1 F_2 B_2 H_1 H_2 I

ROUTE: ⟨A B E H I⟩ @ cost: 34

2. (a) Consider the state space shown below, in which the arcs represent the legal successors of a node. Arcs are bi-directional and are labelled with the cost of performing the corresponding action. The start state is A and the goal is I. Suppose that you are given a heuristic, h_1, defined by the following table.

Node	A	B	C	D	E	F	G	H	I
h_1	34	23	30	39	15	16	44	6	0



For each of the following search methods, show the resulting search tree, list the sequence in which nodes are removed from the queue, and state how many nodes are expanded. You should also state the route found and its associated cost. In the case of ties between nodes, assume that nodes are inserted into the queue in alphabetical order. When expanding a node, do not generate its parent.

i. Uniform cost search. [5]

ii. Greedy best-first search. [4]

iii. A* search. [5]

(b) Now suppose that you are given another heuristic, h_2, defined by the following table.

Node	A	B	C	D	E	F	G	H	I
h_2	34	28	24	38	17	16	85	7	0

Is this heuristic guaranteed to result in the optimal path being discovered by the A* algorithm? Explain your reasoning. [2]

(c) Explain how iterative deepening can be used to reduce the memory overhead of A*. [5]

(d) Explain how tree search can be modified to perform a graph search. Why might this be useful? [4]

Continued...

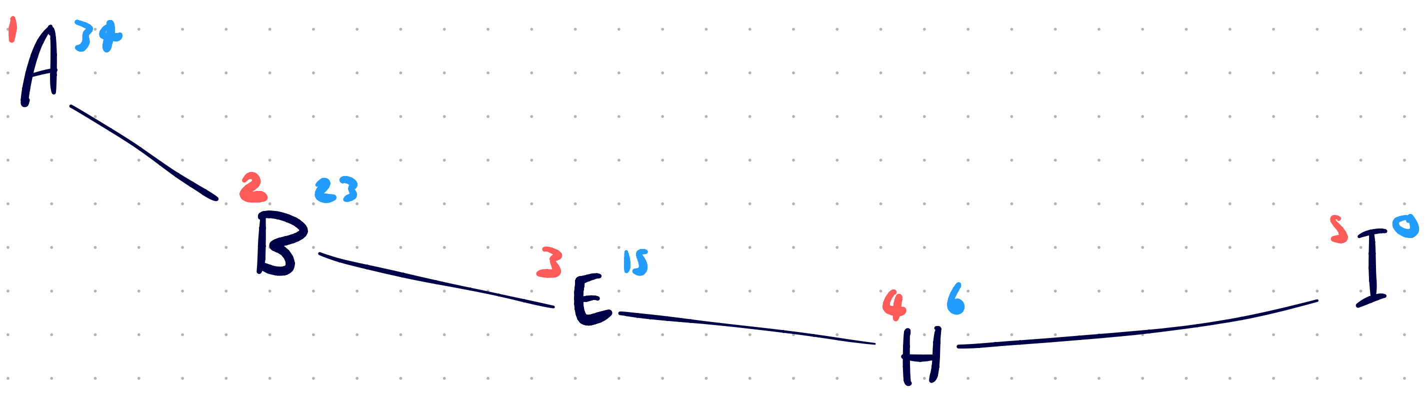
2aii) Greedy Best First Search

Start A, goal I

GRAPH

STEP	QUEUE	ClOSED LIST	ACTION
1	$\langle A \rangle_{34}$		
2	$\langle AB \rangle_{23}$ $\langle AC \rangle_{30}$ $\langle AD \rangle_{39}$	A	expand A
3	$\langle ABE \rangle_{17}$ $\langle AC \rangle_{30}$ $\langle AD \rangle_{39}$	A, B	expand AB
4	$\langle ABEH \rangle_{7}$ $\langle ABEC \rangle_{24}$ $\langle AC \rangle_{30}$ $\langle AD \rangle_{39}$	A, B, E	expand ABE
5	$\langle ABEHI \rangle_{0}$ $\langle ABEHF \rangle_{16}$ $\langle ABEC \rangle_{24}$ $\langle AC \rangle_{30}$ $\langle AD \rangle_{39}$	A,B,E,H	expand ABEH
6	reached I via ABEHI path cost 34		expand ABEHI

TREE



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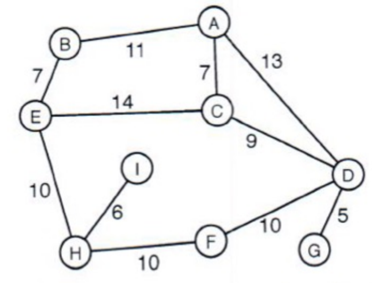

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Continued...

Pruning Note

can expand all paths

prune when expanding

NODES EXPANDED: ⟨A B E H I⟩

ROUTE FOUND: ⟨A B E H I⟩ @ cost: 34

2aiii) A* Search

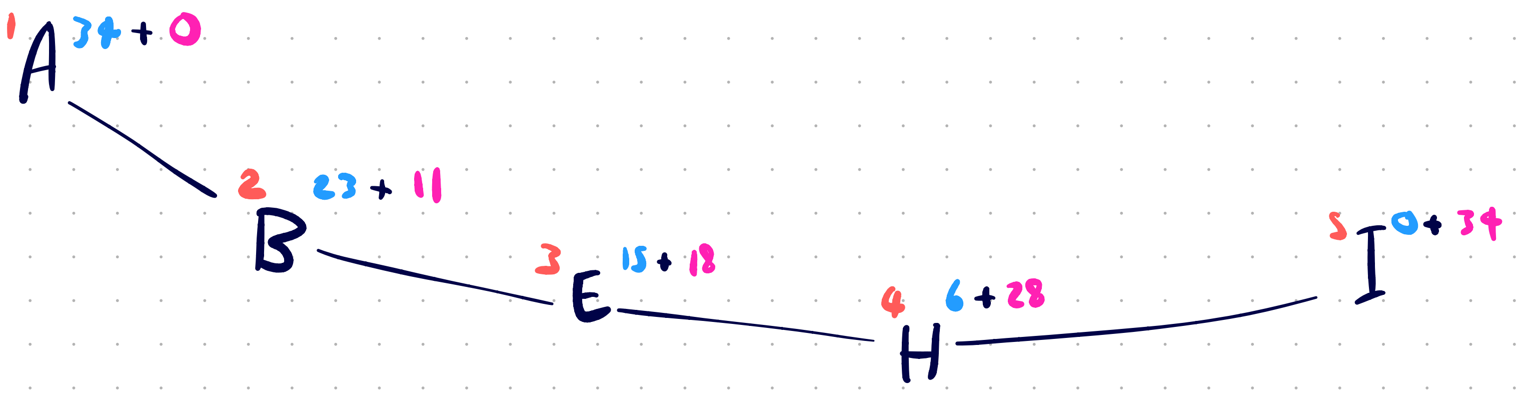
path cost + heuristic

Graph

STEP	QUEUE	CLOSED LIST	ACTION
1	⟨A⟩$^{0}_{34}$		
2	⟨AB$^{11}_{23}$⟩ ⟨AC$^{7}_{30}$⟩ ⟨AD$^{13}_{39}$⟩	A	expand ⟨A⟩
3	⟨ABE$^{18}_{15}$⟩ ⟨AC$^{7}_{30}$⟩ ⟨AD$^{13}_{39}$⟩	A, B	expand ⟨AB⟩
4	⟨ABEH$^{28}_{7}$⟩ ⟨AC$^{7}_{30}$⟩ ⟨AD$^{13}_{39}$⟩ ⟨ABEC$^{32}_{24}$⟩	A, B, E	expand ⟨ABE⟩
5	⟨ABEHI$^{34}_{0}$⟩ ⟨ABEHF$^{38}_{16}$⟩ ⟨AD$^{13}_{39}$⟩ ⟨ABEC$^{32}_{24}$⟩	A, B, E, H	expand ⟨ABEH⟩
6	reached I ; PATH → ABEHI COST → 34	A, B, E, H, I	expand ⟨ABEHI⟩

tree

● = heuristic value
● = path cost



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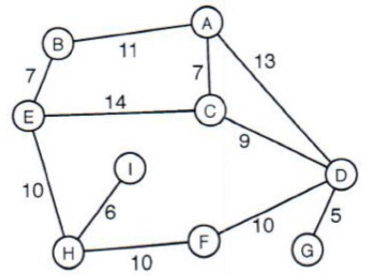

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Continued...

2b) h_2 is not admissable, and as such no general guarantee can be made that it will always find the optimal path

2c) IDA* performs repeated depth-bounded depth-first searches.

DFS requires a stack of nodes representing the current branch of the tree it is expanding. Therefore, the maximum amount of space required is linear in d $\rightarrow$ $O(d)$ space

2d)

1) keep track of paths instead of nodes
2) Queue is a frontier of paths rather than nodes
3) keep a closed list of expanded nodes.

allows for multiple path pruning & cycle checking using closed list

2. (a) Consider the state space shown below, in which the arcs represent the legal successors of a node. Arcs are bi-directional and are labelled with the cost of performing the corresponding action. The start state is A and the goal is I. Suppose that you are given a heuristic, h_1, defined by the following table.

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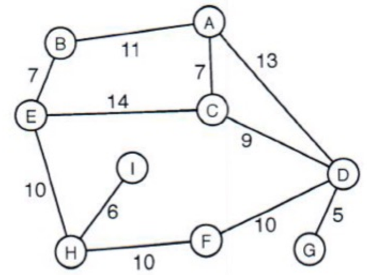

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Continued...

3a) KB = A   A → B, A → C, B → D   infer D

FORWARD

all possible rules applied

A
A → B
A → C ← unneccesary
B → D

BACKWARD

B → D
A → B
A

optimal rule application for D

3. (a) Explain, using examples, how *forward* and *backward* chaining control reasoning in rule-based systems. [3]

(b) i. What is meant by conflict resolution in the context of rule-based systems? [2]

ii. Describe how and why recency, refractoriness and specificity are useful techniques for conflict resolution. [3]

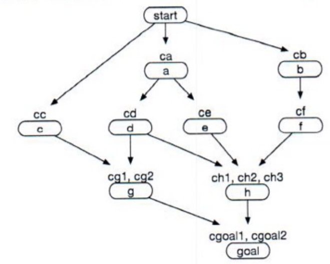
(c) Suppose that a rule-base contains the following rules, with initial known facts $\{A, B\}$. Suppose that the aim is to infer H. Show how both forward chaining and backward chaining approaches operate, stating which rules are fired and the state of the knowledge base at each point of the reasoning process. [7]

$A \rightarrow F$
$A \wedge D \rightarrow E$
$B \rightarrow D$
$B \wedge F \rightarrow G$
$E \wedge B \rightarrow C$
$F \rightarrow H$
$G \rightarrow H$
$H \rightarrow E$

(d) i. Explain the process of selecting and fulfilling open preconditions in a partial-order planner. [2]

ii. Describe how a clobbering conflict might occur during planning, and how to resolve it. [3]

iii. Explain what is meant by action monitoring and plan monitoring. Considering the following plan, assuming a, b, c, d and e have been executed and g is selected for execution, what is the result of action monitoring and plan monitoring?



[5]

3bi) Conflict Resolution

↳ the process of [choosing which rule to fire] when [more than one rule] could be fired.

ii) RECENCY → fire the rule that uses the newest data in the KB
useful because it prioritises recent additions to the working memory which are more likely to be relevant

SPECIFICITY → Fire the most specific rule
more conditions mean the rule is more likely to be relevant to the current situation

REFRACTORINESS → only allow a rule to fire once on the same data
prevents loops in inference

3c) **FORWARD** (APPLY ALL RULES EXHAUSTIVELY)

KB	RULE TO FIRE
A, B	A → F
A, B, F	B → D
A, B, F, D	A ∧ D → E
A, B, F, D, E	B ∧ F → G
A, B, F, D, E, F	E ∧ B → C
A, B, F, D, E, F, C	F → H
A, B, F, D, E, F, C, H	all rules exhausted

CONFLICT RESOLUTION TECHNIQUES USED:

1) Basic rule: apply in order
2) Refractoriness

BACKWARD

F → H

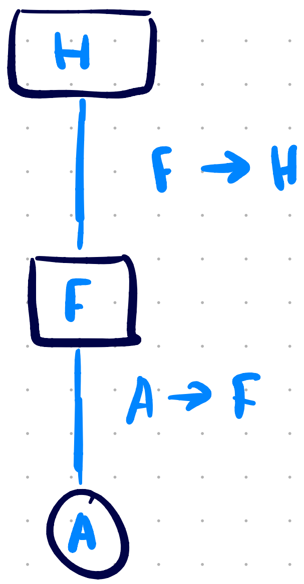
we need to create F

A → F

we need A to create F

we know A

A



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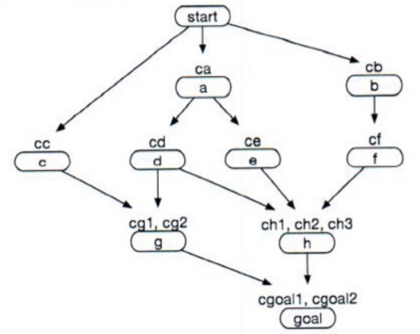
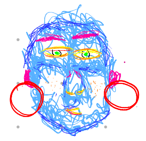


[5]

3d i)

1. select any one of the open preconditions
2. choose an operator, or add a new one, (if no existing op satisfies precond.) that satisfies the selected precondition
3. Add a causal link between the precondition & operator
4. Resolve any clobbering steps that threaten the CL



3d ii)

clobbering occurs when an operations POST CONDITION threatens a CAUSAL LINK

we therefore have to

1) PROMOTE the clobbering step by putting the clobbering step AFTER the threatened CAUSAL LINK

OR ⊗ ····· $S_i \rightarrow S_j$ S_x ····· ⊗

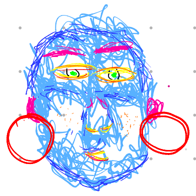
2) DEMOTE the clobbering step by putting the clobbering step BEFORE the threatened CAUSAL LINK

⊗ · S_x $S_i \rightarrow S_j$ ········· ⊗
start end

3d iii)

ACTION MONITORING: make sure all preconditions of some next action g succeed & make sure g succeeds

PLAN MONITORING: make sure all preconditions of causal links at current time are satisfied / met



action monitoring: cg1 cg2
then check g succeeds

plan monitoring: cg1 cg2 ch1 ch2 cf

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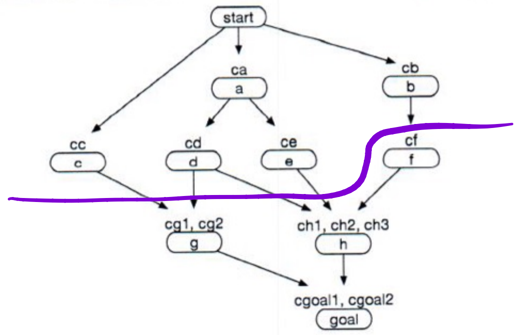


[5]

4a)

MINIMUM REMAINING VALUES

→ a count of possible values each variable can be assigned. choose variable with lowest count WHY? fail first to reduce depth

DEGREE HEURISTIC

↳ tie breaker among clashing MRV WHY? fail first to reduce depth

↳ choose the variable with the most constraints on REMAINING VARIABLES

and therefore reduce branching factor of FUTURE CHOICES

LEAST CONSTRAINING VALUES WHY? Reduce branching factor

↳ given a variable, choose the value that rules out the FEWEST VALUES in remaining variables

4. (a) Explain the following heuristics, and how and why they are used in a backtracking search:

- minimum remaining values,
- degree heuristic, and
- least constraining value. [6]

(b) Suppose that you have a CSP containing variables $\{A, B, C, D, E, F\}$ which must be assigned values from the set $\{1, 2, 3\}$, such that the following constraints hold.

$\{A \neq B, A \neq C, A \neq D\}$
$\{B \neq A, B \neq C, B \neq D, B \neq E, B \neq F\}$
$\{C \neq A, C \neq B, C \neq F\}$
$\{D \neq A, D \neq B, D \neq E\}$
$\{E \neq B, E \neq D, E \neq F\}$
$\{F \neq B, F \neq C, F \neq E\}$

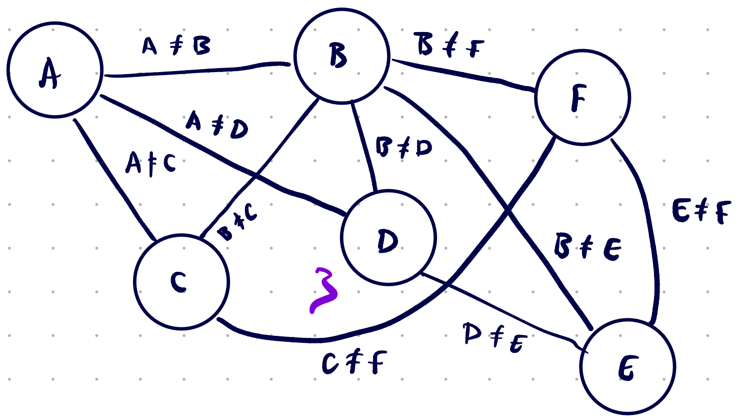
i. Draw the constraint graph for this problem. [3]

ii. Find a solution to this problem using the backtracking algorithm with forward checking and application of appropriate heuristics to select variables and values. Show all the steps carried out by the algorithm. [6]

(c) Explain how cutset conditioning could be used in the CSP from part (b) to make the search more efficient, and state the upper bound on the number of nodes expanded with and without cutset conditioning. [6]

(d) Suppose that the behaviour of a smart heating system is controlled by n parameters. Describe how you would use a genetic algorithm to find values for these parameters, including in your answer an explanation of how crossover and mutation operate in this context. [4]

4bi)



4bii)

A	B	C	D	E	F	STEP
1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	MRV = any DH = B LCV = any (1)
2 3	1	2 3	2 3	2 3	2 3	MRV = any DH = any (A) = LCV = any
2	1	3	3	2 3	2 3	MRV = CD DH = CD LCV = 3
2	1	3	3	2 3	2	MRV = DF DH = DF LCV = 3
2	1	3	3	2	2	MRV = EF DH = EF LCV = 2
2	1	3	3	2	∅	

Clear no solution
domain of 2 & DH> 2
for all nodes

4 c) CUTSET CONDITIONING involves instantiating a set of variables such that the remaining variables form a tree.

this is then much more efficient to solve:

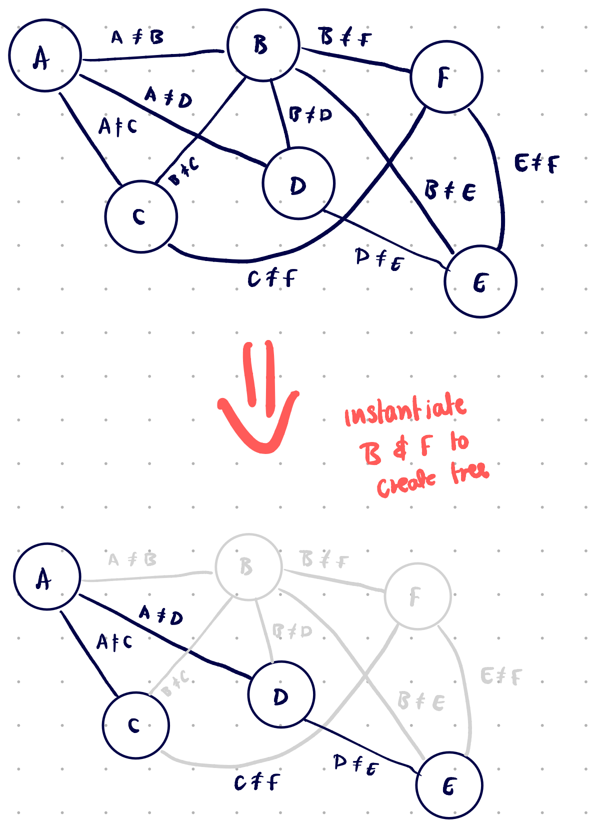
Formulae:

- w/o cutset : d^n
- with cutset : $d^c (n-c) d^2$

$d = 3$

$n = 6$

$c = 2$



w/o CC : $3^6 = 729$

w. CC : $3^2 (6-2) 3^2 = 324$

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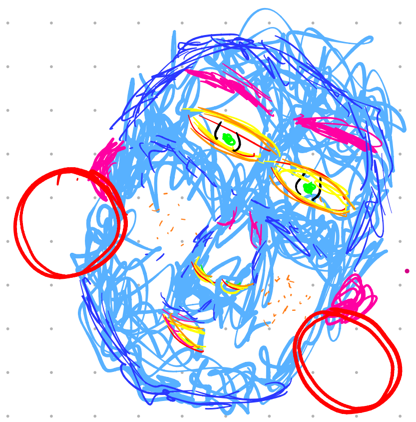


5 a)

$P(\text{wet} \mid \text{rain}) = 0.8$

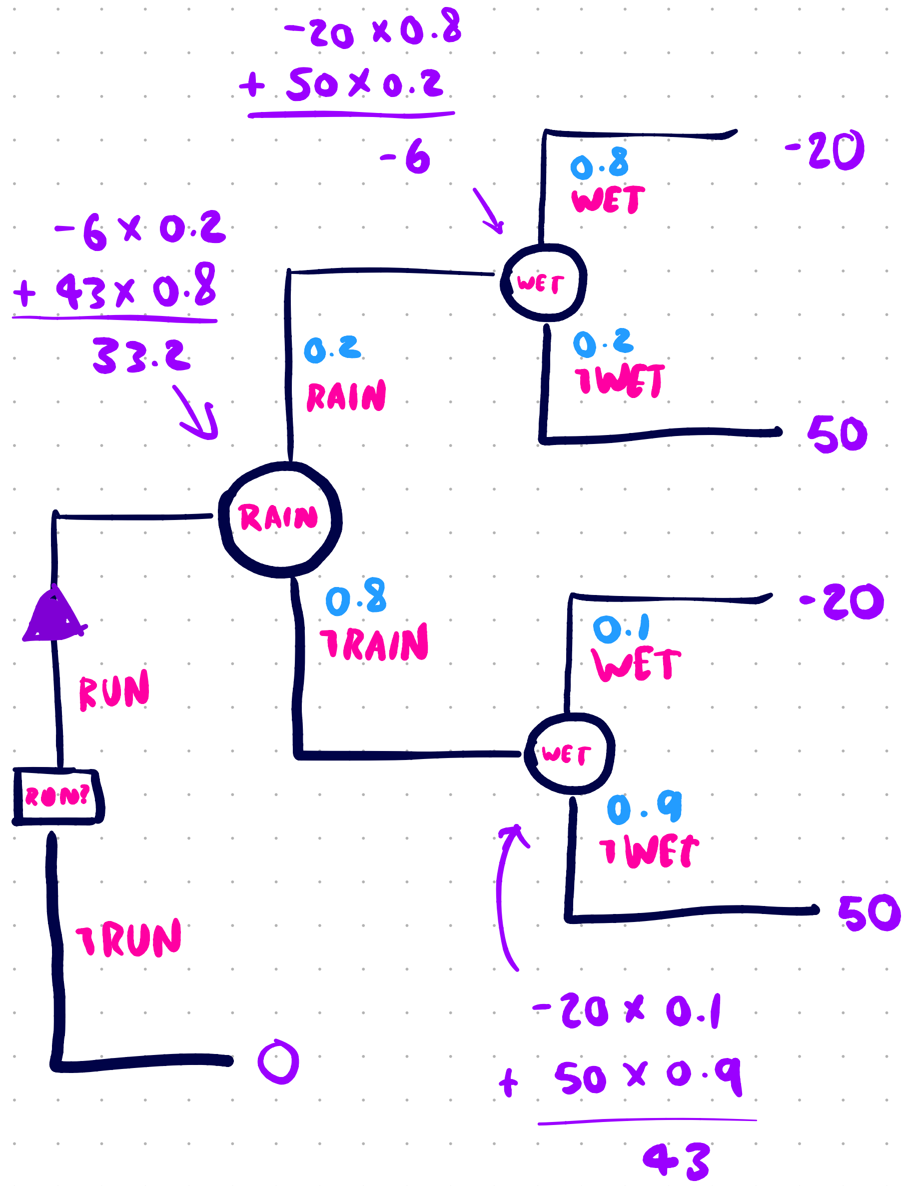
$P(\text{wet} \mid \neg\text{rain}) = 0.1$

$P(\text{rain}) = 0.2$

$\text{utility}(\text{run}, \text{not wet}) = 50$

$\text{utility}(\text{run}, \text{wet}) = 20$

$\text{utility}(\text{no run}) = 0$



utility expected from running 33.2 compared to 0 ∴ RUN

5. (a) Suppose you are deciding whether to go for a run or not. Your running jacket is old, sometimes leaks, and is not breathable, meaning you sometimes get sweaty. If you go for a run, the probability of getting wet if it rains is 0.8, and is 0.1 otherwise. The probability of rain is 0.2. You associate running without getting wet a utility of +50, you give the outcome of getting wet while running a utility of −20 and not going out a utility of 0.

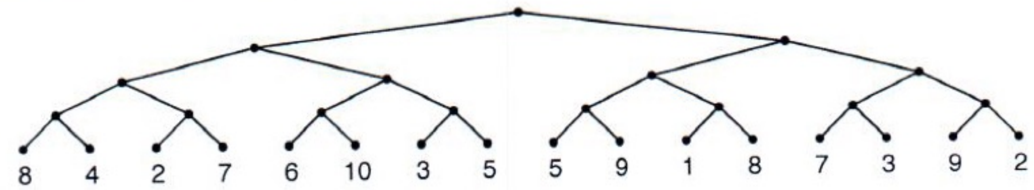
i. Show a decision tree for the problem. [4]

ii. Solve the decision tree to determine whether you should go for a run. [6]

(b) Explain what is meant by syntax, semantics and pragmatics in the context of knowledge based systems. [3]

(c) Using inference by enumeration, show whether the following is valid:
$p \rightarrow q, \neg q \rightarrow r, r; \therefore p$ [3]

(d) Describe the minimax with alpha-beta pruning algorithm and show how it operates on the following tree, where the first player is the maximising player. State which move the first player should choose, and what utility they should expect. You should show the resulting search tree. [7]



(e) In games where the legal moves by a player are determined by chance, explain how the minimax algorithm can be extended to determine the optimal move for a player. [2]

5b)

SYNTAX → Syntax describes the possible configurations of symbols that constitute valid sentences

SEMANTICS → determine the facts in the world to which the symbols refer
semantics allow us to make claims about our belief about the world state.

PRAGMATICS → ? semantics + context

5c) $p \to q \,//\, \neg q \to r \,//\, r$

p	q	$p \to q$	$\neg q \to r$	r
T	T	T	T	T
T	F	F	T	T
F	T	T	T	T
F	F	T	T	T

REMEMBER in future → 2^n rows
KB column

∴ not valid

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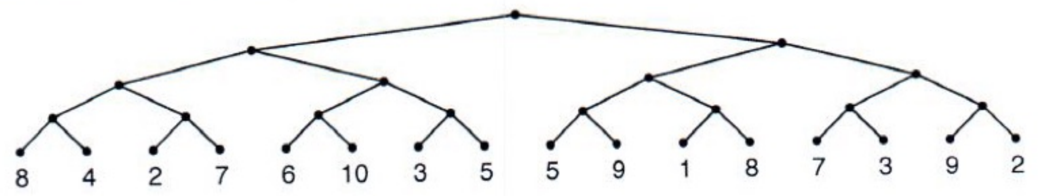

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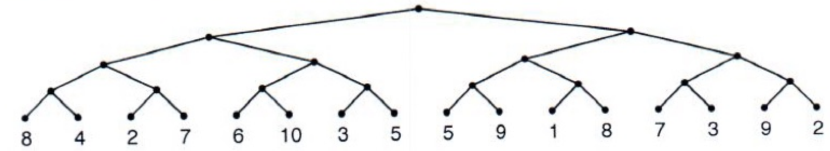

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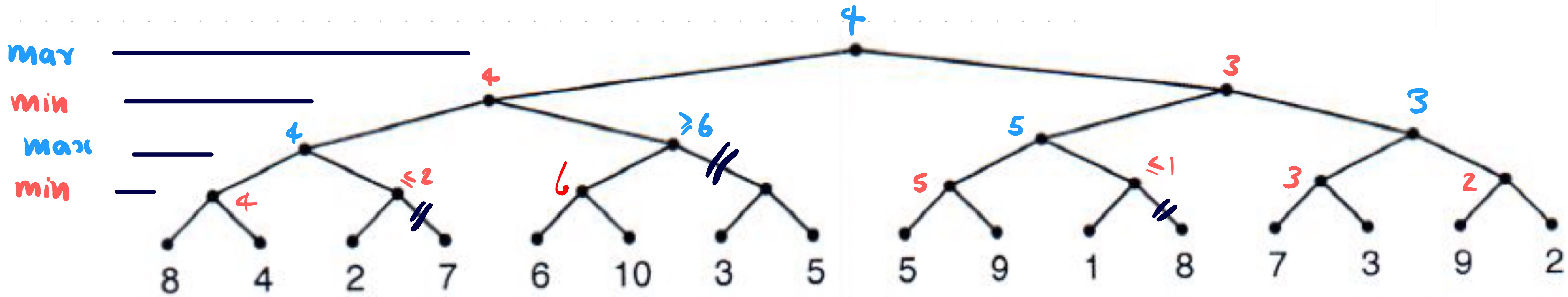
5d) Minimax algorith is used in two agent zero sum games that can be charaterized by a single value that one agent wants to maximise, and the other minimize.

minimax achieves the best possible play against the best play.

Choose Left
expect: 4



5e) Add chance nodes labelled with the expected probability
run minmax on sub trees → probability X expected utility.