Exercise 1

Consider the following game tree corresponding to a two-player zero-sum game. Max is to start in the initial state (i.e., the root of the tree).

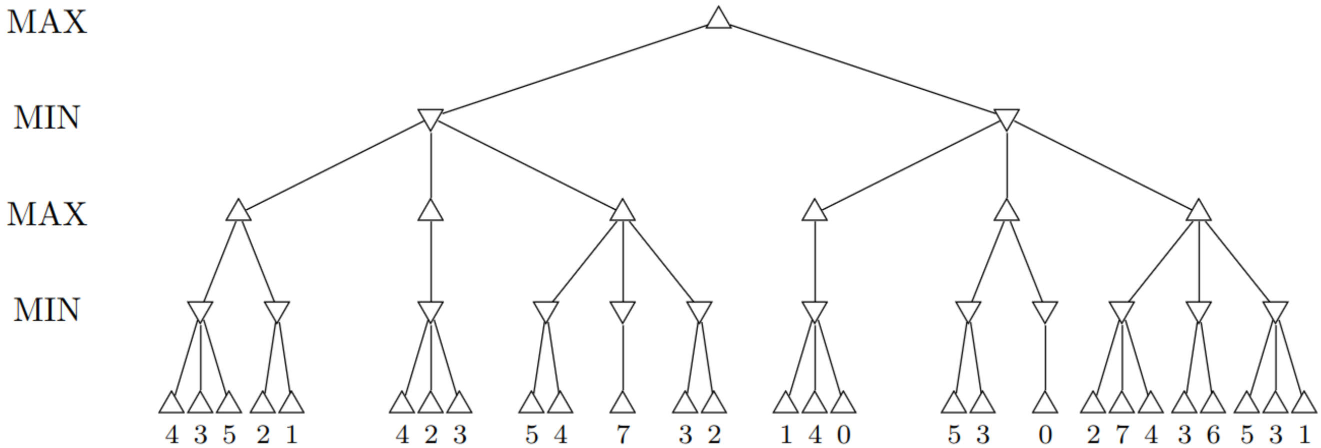
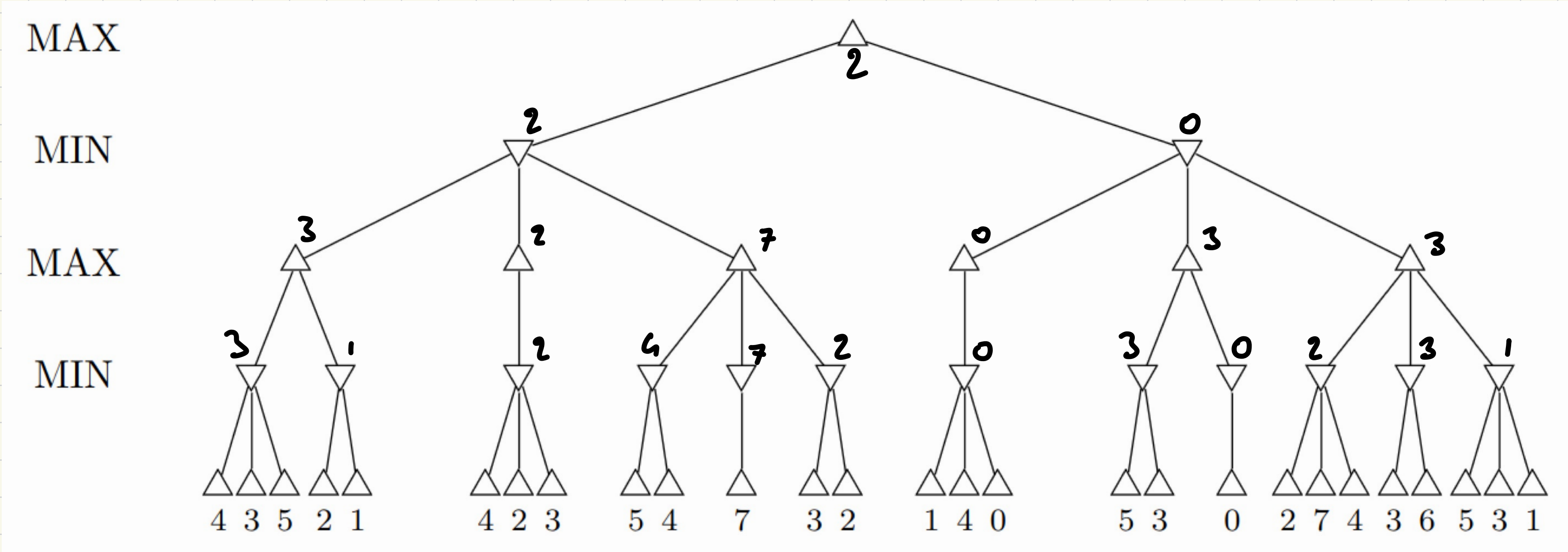


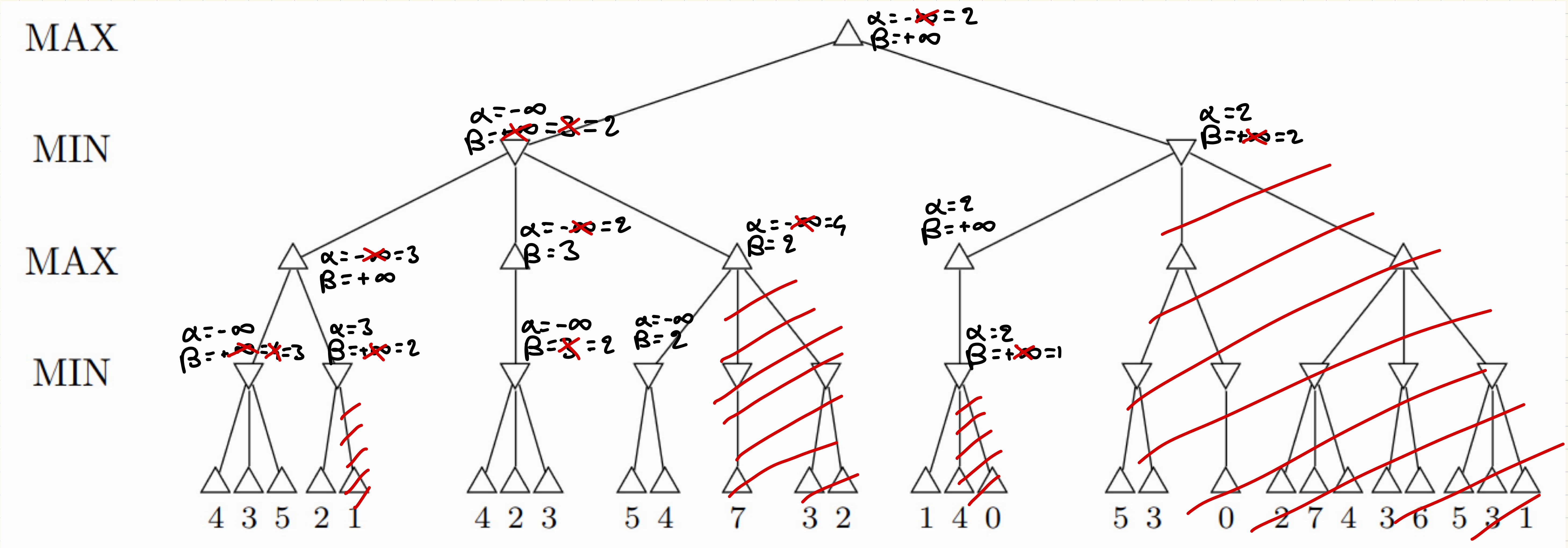
Figure 1: Game tree

- (a) Perform Minimax search on the tree, i.e., annotate all internal nodes with the correct Minimax value. Which move does Max choose?
- (b) Perform Alpha-Beta search on the tree. Annotate all internal nodes (that are not pruned) with the value that will be propagated to the parent node as well as the final [α, β] window before propagating the value to the parent. Mark which edges will be pruned.

a)



b)



$\alpha \geq \beta$

Exercise 2

Consider the following constraint network: $\gamma = (V, D, C)$:

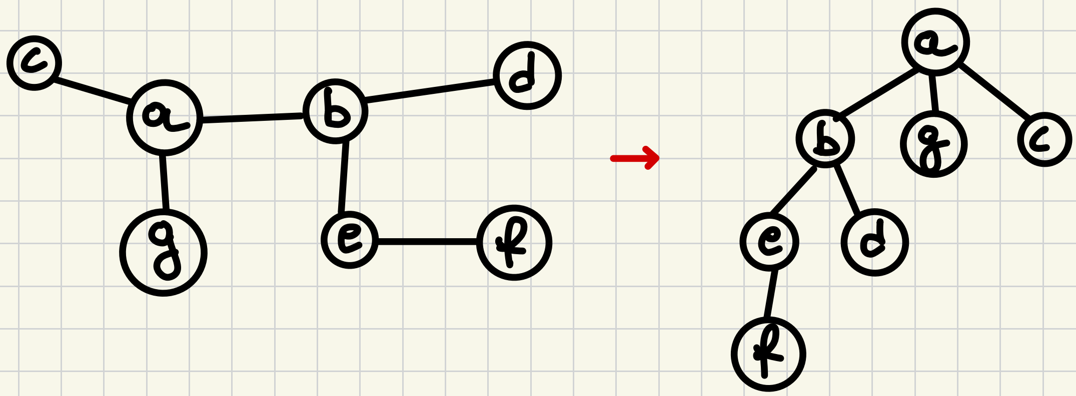
- Variables: $V = \{a, b, c, d, e, f, g\}$
- Domains: for all $v \in V, D_v = \{1, 2, 3, 4, 5\}$
- Constraints: $2a = b - 1,\ b = d,\ e = b + 2,\ 2f = e - 1,\ a - g = -2,\ c = 2a + 2$

1. (a) Draw the constraint graph γ
2. (b) Run the AcyclicCG algorithm on γ. Pick a as the root of the tree.

Variables: $V = \{a, b, c, d, e, f, g\}$

Domains: for all $v \in V, D_v = \{1, 2, 3, 4, 5\}$

Constraints: $2a = b - 1,\ b = d,\ e = b + 2,\ 2f = e - 1,\ a - g = -2,\ c = 2a + 2$



ORDINE: $\overset{1}{a}, \overset{2}{b}, \overset{3}{c}, \overset{4}{d}, \overset{5}{g}, \overset{6}{e}, \overset{7}{f}$

Revise $(\gamma, P(v_i), v_i)$

$i=7$ Revise (γ, e, f)

$e = 2f + 1$ $\quad D_e = \{3, 5\}$

$i=6$ Revise (γ, b, e)

$b = e - 2$ $\quad D_b = \{1, 3\}$

$i=5$ Revise (γ, a, g)

$a = g - 2$ $\quad D_a = \{1, 2, 3\}$

$i=4$ Revise (γ, b, d)

$b = d$ $\quad D_b = \{1, 3\}$

$i=3$ Revise (γ, a, c)

$a = \frac{c-2}{2}$ $\quad D_a = \{1\}$

$i=2$ Revise (γ, a, b)

$a = \frac{b-1}{2}$ $\quad D_a = \{1\}$

$a = 1$
$b = 3$
$c = 4$
$d = 3$
$e = 5$
$f = 2$
$g = 3$

Exercise 3

1. (a) Is $((p \to q) \land (r \to q)) \to (r \to p)$ a tautology? Is $((p \to q) \land (r \to q))$ logically equivalent to (r $\to$ p)? Prove or disprove.

2. (b) If the robot is autonomous, then it can navigate. If the robot is not autonomous, then it is remotely controlled. If the robot can navigate, then it is efficient. If the robot is either remotely controlled or efficient, then it is valuable.

   Given this set of sentences, transform them in a KB in **Propositional Logic** by using an appropriate set of propositional symbols. Prove with resolution that the robot is valuable.

3. (c) Given the following KB: $\Delta = \{\{P, Q, \neg R\}, \{P, \neg Q\}, \{\neg P\}, \{R\}, \{U\}\}$, apply the DPPL algorithm [redacted] and show the various iterations of the algorithm. Assume that the variables are selected in alphabetical order and the splitting rule attempts the value False first.

1. (a) Is $((p \to q) \wedge (r \to q)) \to (r \to p)$ a tautology? Is $((p \to q) \wedge (r \to q))$ logically equivalent to (r $\to$ p)? Prove or disprove. **NO**

P	Q	R	P ⇒ Q (A)	R ⇒ Q (B)	R ⇒ P (C)	A ∧ B (D)	D ⇒ C
0	0	0	1	1	1	1	1
0	0	1	1	0	0	0	1
0	1	0	1	1	1	1	1
0	1	1	1	1	0	1	0
1	0	0	0	1	1	0	1
1	0	1	0	0	1	0	1
1	1	0	1	1	1	1	1
1	1	1	1	1	1	1	1

TAUTOLOGICA IMPLICA TUTTO VERO

2. (b) If the robot is autonomous, then it can navigate. If the robot is not autonomous, then it is remotely controlled. If the robot can navigate, then it is efficient. If the robot is either remotely controlled or efficient, then it is valuable.

Given this set of sentences, transform them in a KB in **Propositional Logic** by using an appropriate set of propositional symbols. Prove with resolution that the robot is valuable.

1 $A \to N$ 2 $\neg A \to R$ 3 $N \to E$ 4 $(R \vee E) \to V$

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1 $\neg A \vee N$ 2 $A \vee R$ 3 $\neg N \vee E$

4 $(\neg R \wedge \neg E) \vee V \to \underbrace{(\neg R \vee V)}_{4a} \wedge \underbrace{(\neg E \vee V)}_{4b}$

Th: V ¬Th: $\neg V$ 5

5 ∈ 4a: $\neg R$ 6 6 ∈ 2: A 8 9 ∈ 3: E 10

5 ∈ 4b: $\neg E$ 7 8 ∈ 1: N 9 10 ∈ 7: {}

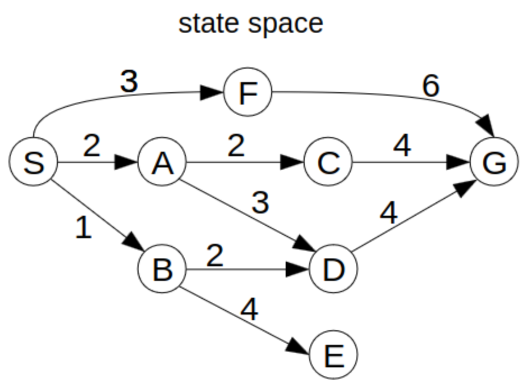
3. (c) Given the following KB: $\Delta = \{\{P, Q, \neg R\}, \{P, \neg Q\}, \{\neg P\}, \{R\}, \{U\}\}$, apply the DPPL algorithm [redacted] and show the various iterations of the algorithm. Assume that the variables are selected in alphabetical order and the splitting rule attempts the value False first.

UP) $P \to F$ $\Delta = \{\{Q, \neg R\}, \{\neg Q\}, \{R\}, \{U\}\}$

UP) $Q \to F$ $\Delta = \{\{\neg R\}, \{R\}, \{U\}\}$ NON RISOLVIBILE

Exercise 4

Consider the state space in Figure 3, where S is the initial state and G the goal state. The transitions are annotated by their costs and an heuristic function is depicted on the right for each node.



heuristic function (goal state: G)

S	A	B	C	D	E	F	G
6	4	5	2	2	8	4	0

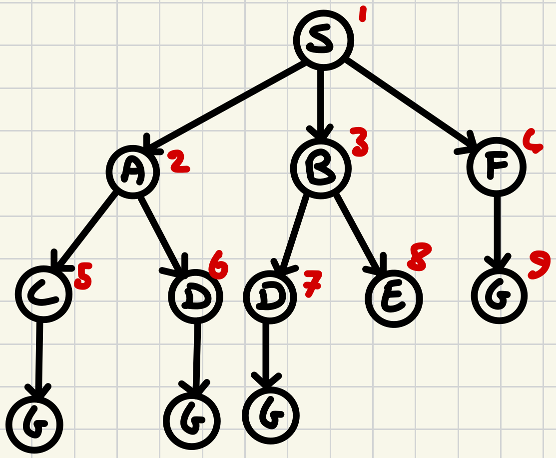
Figure 2: State space

Run on this state-space the

- (a) Breadth-First Search Algorithm
- (b) Depth-First Search Algorithm
- (c) A* Algorithm

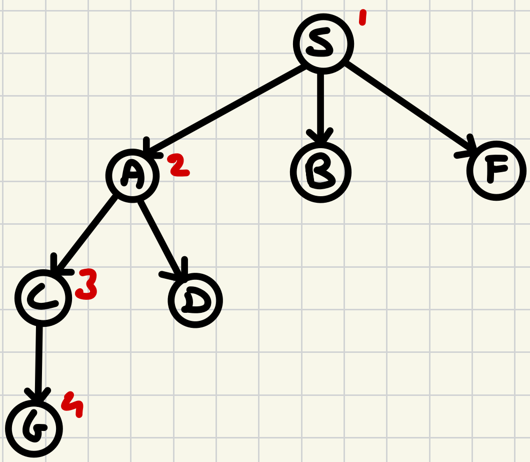
and draw for each algorithm the corresponding execution tree. If the choice of the next state to be expanded is not unique, expand the lexicographically smallest state first.

a) NON CI INTERESSA h



SOL: S, F, G COSTO: 9

b) NON CI INTERESSA h



SOL: S, A, C, G COSTO: 8

c)