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Introduksjon til Kunstig Intelligens (TDT4136)

30th November 2015

Tid: 09:00 – 13:00

Language: English-Bokmål-Nynorsk

Aid - Tillatte hjelpemidler: D

No printed or hand written material is allowed. Simple calculator is allowed. Ingen trykte eller håndskrevne hjelpemidler tillatt.

Bestemt, enkel kalkulator tillatt.

English. Bokmål på side xx, nynorsk på side xx. I tilfelle du er usikker på betydningen av noen av begrepene (noen er ikke så lette å oversette), se på den engelske versjonen.

Dersom du mener at opplysninger mangler i en oppgaveformulering, gjør kort rede for de antagelser og forutsetninger som du finner nødvendige.

Problem 1 (20 pts, 2pts each question)

Answer the following questions with TRUE or FALSE.

- a) Knitting is a fully observable, episodic, stochastic, static and exciting agent environment.
ANSWER: False. not episodic, not stochastic
- b) Procedural attachment is used in semantic networks.
ANSWER: True .
- c) Ontology is not a key component in simple-reflex agents.
ANSWER: True.
- d) *Recall* is an evaluation metric used in information retrieval that measures the proportion of returned documents that are truly relevant
ANSWER: False. This is precision
- e) Simulated annealing is a local search method.
ANSWER: True
- f) Term Frequency (TF) defines the count of a term t in a collection of documents.
ANSWER: False. In a single document.
- g) A common heuristic function for 8-puzzle game is Manhattan distance which is the sum of the distances of the tiles to their goal positions.
ANSWER: TRUE
- h) If both H_1 and H_2 are admissible heuristics for a problem and $H_2 < H_1$, then H_2 is a better heuristic.
ANSWER: False
- i) An agent must think like a human in order to pass the Turing test.
ANSWER: False. It has to act like a human.
- j) Iterative deepening search is optimal if step-costs is a constant, the search-space is finite and a goal exists. ANSWER: True .

Problem 2 (15 pts, 3 pts each question)

Choose the correct answers (one for each question) to the questions below.

- a) Suppose the following action schema in a planning system for 8-puzzle.

$Action(Slide(t, s_1, s_2),$

PRECOND : $On(t, s_1) \wedge Tile(t) \wedge Blank(s_2) \wedge Adjacent(s_1, s_2)$

EFFECT : $On(t, s_2) \wedge Blank(s_1) \wedge \neg On(t, s_1) \wedge \neg Blank(s_2)$)

Which of the following needs to be removed from the action schema in order to get "number-of-misplaced-tiles" heuristic?

- A. $Blank(s_1)$
- B. $Blank(s_2)$
- C. $Adjacent(s_1, s_2)$
- D. $Blank(s_2) \wedge Adjacent(s_1, s_2)$
- E. None of the above

ANSWER: d - $Blank(s_2) \wedge Adjacent(s_1, s_2)$.

- b) We look at a Constraint Satisfaction Problem (CSP) with the three variables X , Y and Z . Let the domain for each of these variables be the set of integers from 1 to 3:

$$D_X = D_Y = D_Z = \{1, 2, 3\}$$

Let the following binary constraint $C_{X,Y}$ apply between X and Y , and $C_{Y,Z}$ between Y and Z :

$$C_{X,Y} = [(1, 1), (2, 1), (2, 2), (3, 1), (3, 2), (3, 3)]$$

$$C_{Y,Z} = [(2, 1), (3, 1), (3, 2)]$$

After running AC-3, what is the domain of X ?

- | | | |
|------------------|---------------|------------|
| A. $\{1, 2, 3\}$ | D. $\{1, 2\}$ | G. $\{3\}$ |
| B. $\{2, 3\}$ | E. $\{1\}$ | |
| C. $\{1, 3\}$ | F. $\{2\}$ | H. $\{\}$ |

ANSWER: B

As described in Chapter 6.1 in the textbook (7.1 in the green version), a constraint specifies the *valid* combinations of values between two given variables. Given that there is a constraint between two variables, any combination of values that is not explicitly listed in the constraint will thus not be valid. Therefore, according to $C_{X,Y}$ above, X has the following valid values:

- 1, if Y is 1
- 2, if Y is 1 or 2
- 3, if Y is 1, 2 or 3

Y's domain is currently $\{1, 2, 3\}$, so we cannot yet remove any values from X's domain. However, we then move on to $C_{Y,Z}$ and see if any values can be removed from Y's domain. According to $C_{Y,Z}$, Y has the following valid values:

- 2, if Z is 1
- 3, if Z is 1 or 2

Hence, 1 is not a valid value for Y's domain, so the domain is now reduced to $\{2, 3\}$. A crucial point is that we now need to check $C_{X,Y}$ again, to see if there are any consequences for X's domain from the changes in Y's domain. Indeed there is; with 1 removed from Y's domain, 1 is no longer a valid value for X either. X's domain is thus $\{2, 3\}$.

c) Z is then set to 2 in the CSP from the previous question, and AC-3 is run again. What is now the domain of X?

- | | | |
|------------------|---------------|------------|
| A. $\{1, 2, 3\}$ | D. $\{1, 2\}$ | G. $\{3\}$ |
| B. $\{2, 3\}$ | E. $\{1\}$ | |
| C. $\{1, 3\}$ | F. $\{2\}$ | H. $\{\}$ |

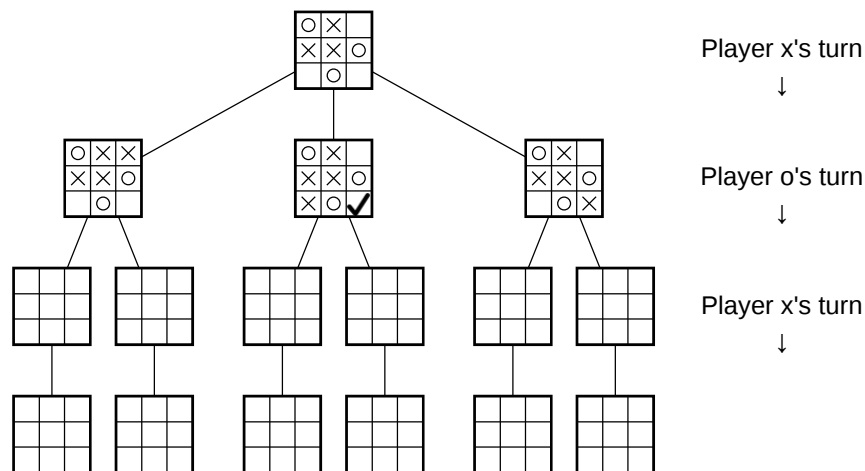
ANSWER: G

Recall that, according to $C_{Y,Z}$, Y has the following valid values:

- 2, if Z is 1
- 3, if Z is 1 or 2

Z is 2, so the only valid value for Y is 3. According to $C_{X,Y}$, then 3 is also the only valid value for X.

d) Consider the following (incomplete) game tree for tic-tac-toe. Tic-tac-toe is a two-player game where players "x" and "o" take alternating turns to place their respective symbols in an empty cell on the 3×3 game board, with the goal of getting three in a row (horizontally, vertically or diagonally):



Which one of the following statements is true?

- A. Player x is guaranteed to win
- B. Player o is guaranteed to win
- C. Player x can win, but only if player o plays suboptimally
- D. Player o can win, but only if player x plays suboptimally
- E. Either player can win, if the other player plays suboptimally
- F. Neither/none of the players can win

ANSWER: C

e) Which of the following may be most useful in generation of a semantic network automatically from documents?

- A. Information retrieval
- B. Sentiment analysis
- C. Syntactic parsing
- D. Information extraction
- E. none of the above.

ANSWER: D. information extraction.

Problem 3 (15 points)

- a) (2 points) For the following sentence in English, is the accompanying sentence in first-order logic a good translation? If yes, answer yes. If no, explain why not.

No two NTNU students have the same ID number.

$$\neg \exists x, y, z (NTNUStudent(x) \wedge NTNUStudent(y) \wedge \neg(x = y)) \implies (IDNum(x, z) \wedge IDNum(y, z))$$

ANSWER: This is NOT correct because it uses \implies instead of \wedge when quantified by \exists .

$$\text{CORRECT: } \neg \exists x, y, z NTNUStudent(x) \wedge NTNUStudent(y) \wedge \neg(x = y) \wedge (IDNum(x, z) \wedge IDNum(y, z))$$

- b) (2 points) For the following sentence in English, is the accompanying sentence in first-order logic a good translation? If yes, answer yes. If no, explain why not.

All mammals except whales are similar to humans.

$$\forall x, y Mammal(x) \wedge \neg Whale(x) \implies Mammal(y) \wedge Human(y) \wedge Similar(x, y)$$

ANSWER: This is NOT correct because it says that if there is at least one mammal that is not a whale, then every mammal has to be a human.

$$\text{CORRECT: } \forall x, y Mammal(x) \wedge \neg Whale(x) \wedge Mammal(y) \wedge Human(y) \implies Similar(x, y)$$

- c) (2 points) Consider the following knowledge base containing four sentences in propositional logic: $A \implies (B \vee C)$

$$\neg A \implies (B \vee C)$$

$$\neg C$$

$$(B \vee D) \implies E$$

Can these four sentences be converted to a set of Horn clauses? If yes, write them down; if not, explain why not.

ANSWER: No because the first sentence has two literals on the right hand side, meaning that the CNF has two positive literals in it.

- d) (2 points) Consider the following knowledge base containing four sentences in propositional logic: $A \implies (B \vee C), \neg A \implies (B \vee C), \neg C, (B \vee D) \implies E$

Convert the four sentences above into conjunctive normal form(CNF) and show the result as a set of clauses.

ANSWER:

$$\neg A \vee B \vee C, A \vee B \vee C, \neg C, \neg B \vee E, \neg D \vee E$$

- e) (3 points) Is the following sentence (1) the correct skolemization (i.e., elimination of existential quantifier) of the sentence $\forall x Person(x) \iff \exists y Heart(y) \wedge Has(x, y)$?

$$(1) \quad \forall x Person(x) \implies Heart(H1) \wedge Has(x, H1).$$

Why not? Write down the correct one.

ANSWER: No because this means that everyone has the same heart called H1. Heart should be a function of a person.

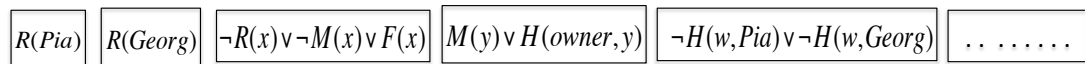
$$\text{CORRECT: } (1) \forall x Person(x) \implies Heart(H(x)) \wedge Has(x, H(x)).$$

- f) (4 points) Suppose the following facts are in the knowledge base:

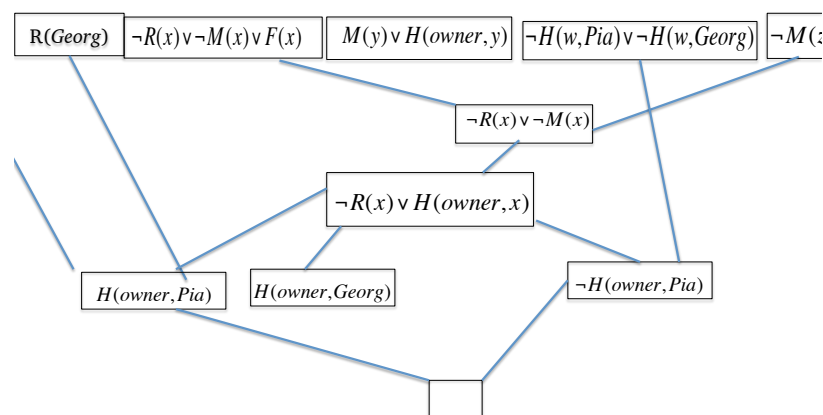
- Pia works in a restaurant
 $R(Pia)$
- Georg works in a restaurant
 $R(Georg)$
- Anyone who works in a restaurant and makes a big mistake is fired
 $\forall x R(x) \wedge M(x) \implies F(x)$
- The restaurant owner is happy with anyone who doesn't make a big mistake
 $\forall y \neg M(y) \implies H(owner, y)$
- Anyone who is happy with Pia is unhappy with Georg
 $\forall w H(w, Pia) \implies \neg H(w, Georg)$

Using resolution refutation, prove that "there exists someone who makes a big mistake and is fired". Show your proof on a tree starting from the boxes in the figure below. Copy the boxes into your answer sheet and fill in the last box. Apply resolution and clearly

indicate the clauses being resolved in each step. Show also the binding of variables in each step/link.



ANSWER:



Problem 4 (10 points)

NOTE: There is a correction in the points of the sub-questions. (a) should be 4 points and (b) is 2 points.

We changed the rules of the wumpus world. First of all, we are dealing only with wumpuses, not with gold, breeze, stench, etc. There may be more than one wumpus in the grid and they may be in any square. In the beginning of the game all squares are blank and the agent does not know which square(s) contains a wumpus. When the agent clicks on a square with a wumpus, she loses the game. If the square that the agent clicked on does not contain a wumpus, a number will appear on that square indicating the number of wumpuses adjacent to the square. Adjacency here means the four squares to the immediate left, right, top and bottom, excluding the diagonals. The goal of the game is to click on all squares which do not have wumpuses. Suppose you are playing the game in the following figure showing the current state of the grid. In the figure, squares marked *a*, *b*, *c*, and *d* are not clicked on yet. You may refer to these squares by these variables. The upper-left square is labeled 1, meaning that it

is adjacent to exactly one wumpus. The other squares show the number of wumpuses in their adjacent squares.

1	a
b	2
d	c

- a) (4 points) Represent the current state of the grid using propositional logic. Use the predicate $W(s)$ to express that square s contains a wumpus, and $\neg W(s)$ s not having a wumpus.
- b) (2 points) Suppose you click on the lower-left square (which is a d in the beginning, see the figure) and number two (2) is revealed. This means that there is no wumpus in that square but two of squares adjacent to it have wumpuses. Represent this situation of the grid using propositional logic.
- c) (4 points) Prove $\neg W(a)$, that is, the square labeled a does not contain a wumpus. For this use the combination of initial knowledge base and the new knowledge obtained by clicking on d . Show your proof by resolution refutation on a drawing.

ANSWER:

a) **First part** (upper left is 1):

$$(W(a) \wedge \neg W(b)) \vee (W(b) \wedge \neg W(a))$$

Or one of the equivalent expressions:

- $W(a) \Leftrightarrow \neg W(b)$
- $(W(a) \Rightarrow \neg W(b)) \wedge (\neg W(b) \Rightarrow W(a))$
- $(W(a) \vee W(b)) \wedge (\neg W(a) \vee \neg W(b))$

- $(W(a) \vee W(b)) \wedge \neg(W(a) \wedge W(b))$
- ...

Second part (middle right is 2):

$$\begin{aligned} & (W(a) \wedge W(b) \wedge \neg W(c)) \vee \\ & (W(a) \wedge W(c) \wedge \neg W(b)) \vee \\ & (W(b) \wedge W(c) \wedge \neg W(a)) \end{aligned}$$

Or: $((W(a) \wedge W(b)) \vee (W(a) \wedge W(c)) \vee (W(b) \wedge W(c))) \wedge \neg(W(a) \wedge W(b) \wedge W(c))$

Or even simply $W(c)$, *assuming the first part is correct*.

b) Both b and c should have a wumpus. Therefore we can write

$$W(b) \wedge W(c)$$

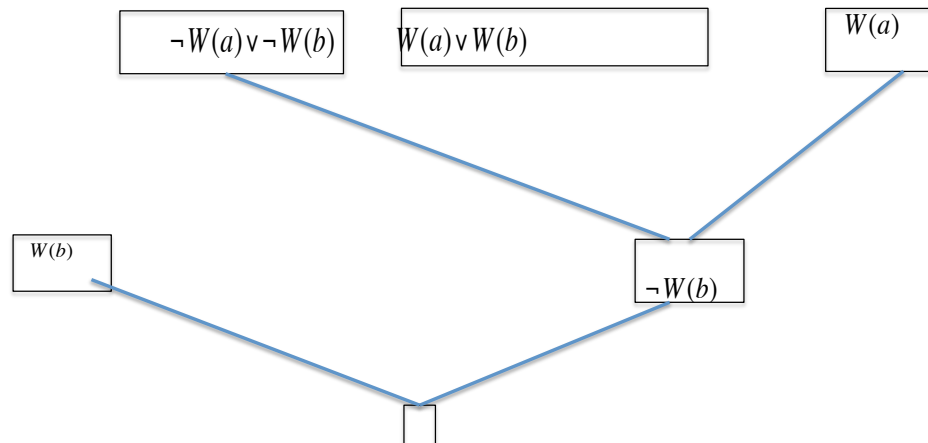
c) First convert the KB into CNF form. E.g.,

$$(W(a) \vee W(b)) \wedge (\neg W(a) \vee \neg W(b))$$

In CNF form: $(W(a) \vee W(b)) \wedge (\neg W(a) \vee \neg W(b))$ etc.

To prove, add the contradiction (i.e. $W(a)$) of the query to the KB. Then resolve $W(a)$ with $(\neg W(a) \vee \neg W(b))$ to conclude $\neg W(b)$.

Apply AND-elimination on $W(b) \wedge W(c)$ to get $W(b)$. Resolve this with $\neg W(b)$ obtained above to get the contradiction.


Problem 5 (10 points)

This is a planning problem to be solved using GraphPlan algorithm. The initial state is represented as $\{R, H, Q\}$. The goal state is $\{D, P, C\}$. There are four actions (Cx , Wx , Tx , and Vx) of which preconditions and effects (in terms of add and delete) are shown in the following figure.

Action	Precond	Add	Delete
Cx	$\{H\}$	$\{D\}$	$\{\}$
Wx	$\{Q\}$	$\{P\}$	$\{\}$
Tx	$\{\}$	$\{C\}$	$\{H, R\}$
Vx	$\{\}$	$\{C\}$	$\{Q, R\}$

- a) (1 point) Under which conditions does a plan graph level off (i.e., stops expanding)?
- b) (3 points) Starting from state level zero (i.e., S_0) **draw** the graph of the plan (i.e, the state and the action levels with mutex relations) applying the GraphPlan algorithm. Expand the graph as long as it is necessary for obtaining a plan. Use "NOP" for the persistence (no operation/maintenance) actions.
- c) (3 points) Is it possible to find a plan for this problem at state level S_1 ? In case it is possible, write down the plan. In case it is not possible, justify your answer by writing down the mutex relation(s) that hinders the extraction of a plan from the graph. Write down each mutex relation (both those between the states and between the actions) and explain why it is mutex.
- d) (3 points) Are the following plans in (1) and (2) below valid plans, according to your answers above? Explain why or why not.
1. $Cx \rightarrow Wx \rightarrow Tx$
 2. $Wx \rightarrow Cx \rightarrow Tx$

ANSWER:

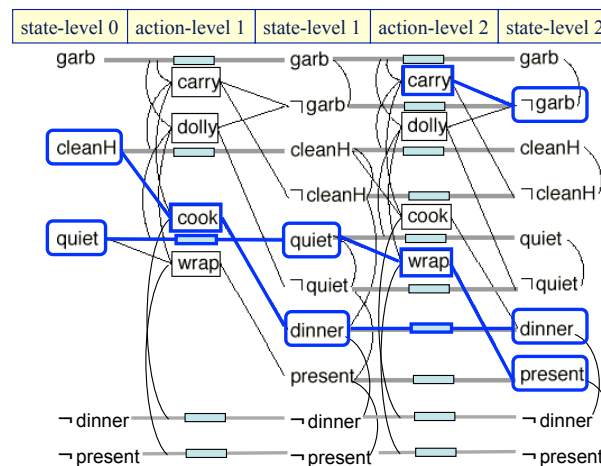
In order to leave off, the last state must include all goals in the goal state without mutex between them, and when back-searching on the graph there must be actions without mutex at each action level so that this chaining goes back to the initial state. Or the two consecutive states are equal- no change any longer.

At S_1 : It is not possible to find a plan at this level. Because: mutex between Tx and Cx , and Vx and Wx .

Expand with A_1 and S_2 . At A_0 there is mutex between Cx and Tx as well as Wx and Vc . At S_2 the goal $\{D, P, C\}$ seems possible. Which actions enable this? $\{Cx, Wx, NO(C)\}$ is possible, without mutex. Now, need to check if the new goal $\{H, Q, C\}$ is possible at A_0 . No action set for this at A_0 . Backtrack to S_2 , try another action set. What about $\{Cx, NO(P), Vx\}$. This is OK. Then Try to find a nonmutex set of actions in A_0 to get the newest goal $\{H, P\}$. Yes: $\{NO(H), Wx\}$. New goal now $\{H, Q\}$ which is possible at S_0 . Done. There are indeed more than one possible plans.

In our question, both plans (1) and (2) are valid plans, because $\{Cx, Wx\} \rightarrow Tx$ is a valid plan.

The following figure shows the graphplan where Cook corresponds to Cx in the question in this exam, while Wrap: Wx, Carry: Tx and Dolly: Vx. Also. CleanH: H, Quiet: Q, Dinner: D, Present: P and Garbage: R in the exam question.



Problem 6 (10 pts, 2 pts each question)

Choose the correct answers (one for each question) to the questions below.

a) What is the primary drawback of hill-climbing search?

- A. The search can get stuck in a local maximum
- B. The algorithm requires a lot of memory
- C. The search can get stuck in a global maximum
- D. The result depends strongly on the temperature schedule

ANSWER: A

b) When we illustrate the Minimax algorithm, we use the symbols \triangle and ∇ for nodes in the search tree. A variation of the Minimax algorithm additionally uses the symbol \bigcirc for some of the nodes. What does this symbol represent?

- A. A second opponent in a multiplayer game

- B. A game rule has been broken
- C. An element of chance in the game
- D. An estimated score, due to cutoff
- E. A tie between the players

ANSWER: C

- c) Which of the following researchers did not participate in the Dartmouth conference where the name "artificial intelligence" was coined?
- A. John McCarthy
 - B. Marvin Minsky
 - C. Herbert Simon
 - D. Allen Newell
 - E. Alan Turing

ANSWER: E. Alan Turing

- d) Which of the following is the main inference mechanism in semantic networks?
- A. Resolution refutation
 - B. Generalized modus ponens
 - C. Inheritance
 - D. Skolemization
 - E. De Morgan's law

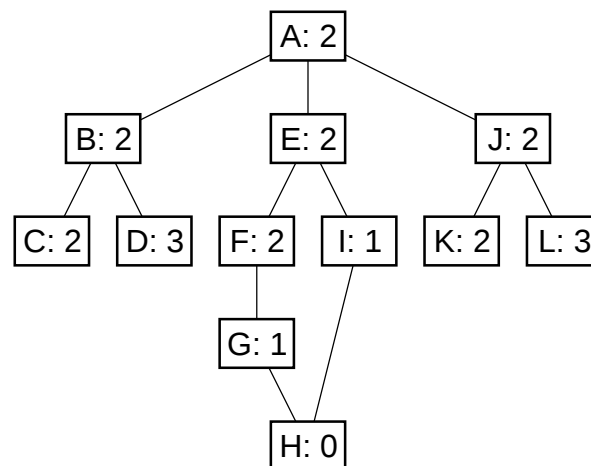
ANSWER: C. inheritance .

- e) Which of the following would you choose as the unifier for $UNIFY(Loves(Per, x), Loves(y, z))$? Explain why. No points will be given without correct explanation.
- A. $(y/Per, x/z)$
 - B. $(y/Per, x/Per, z/Per)$
 - C. $(y/Per, x/z, z/Siri)$
 - D. none of the above are suitable unifiers.

ANSWER: A. (y/Per, x/z). Most general is chosen.

Problem 7 (10 points)

Consider the following search problem:



The initial node is A and the goal node is H. All step costs are 1, and a heuristic value is given for each node in the figure (for example, the heuristic value for node D is given as 3). Assume that there is a goal-test function which will be called by the search algorithm every time it needs to determine whether a node is a goal node.

- a) (2 points) Using breadth-first search (BFS): What is the sequence of nodes for which the goal-test function will be called? Write the letters for each node, and in the correct order.

ANSWER: ABEJCDFIKLGH

- b) (1 point) Using breadth-first search (BFS): What will be returned as the shortest path to the goal?

ANSWER: AEIH

- c) (6 points) Using A*: What is the sequence of nodes for which the goal-test function will be called? Whenever several nodes have the same estimated cost, always choose the node that comes first alphabetically.

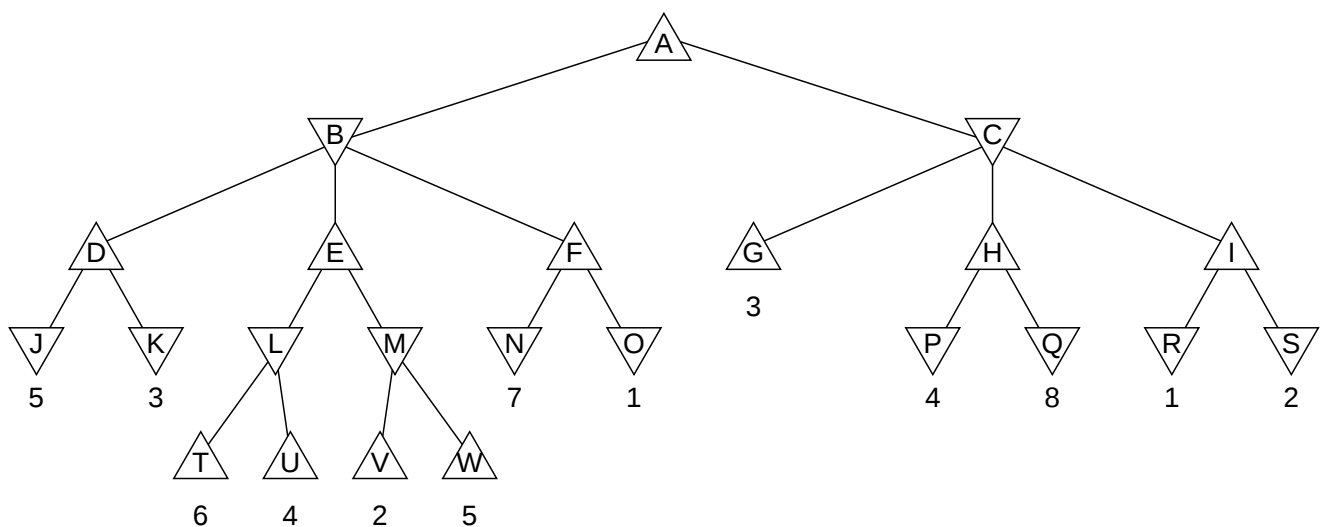
ANSWER: ABEIH

- d) (1 point) Using A*: What will be returned as the shortest path to the goal?

ANSWER: AEIH

Problem 8 (10 points)

Consider the following Minimax tree:



The leaf nodes have their final utility values given as numbers below them.

- a) (2 points) What is the final value in node A, after running Minimax?

ANSWER: 4

- b) (3 points) What is the final value of the rest of the internal nodes, after running Minimax? Write the values for the nodes in alphabetical order, and do not include the root node or the leaf nodes. In other words, write the numbers in the order B, C, D, E, F, H, I, L, M.

ANSWER: 425478242

- c) (5 points) Which nodes will be pruned when using alpha-beta pruning on this tree (assuming nodes are evaluated from left to right)? Give the answer as a list of the nodes' letters in alphabetical order, and include *all* of the nodes in the branches that are pruned.

ANSWER: HIOPQRSW

GOOD LUCK!