Introduction to artificial intelligence – Final examination

- *You have 95 minutes to answer the questions.*
- *To receive full score you have to justify your answers, unless indicated otherwise.*
- *Complete the fields on the right at the start. Exam sheets with incomplete an header will not get evaluated.*
- *Work on your own. Any form of communication will result in immediate disqualification.*
- *Raise your hand if you have any questions and speak quietly to let others keep focus.*

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Σ
9	14	6	12	8	6	7	20	6	6	94
6	9	2.5	2	8	5.5	0	5	3	3	44

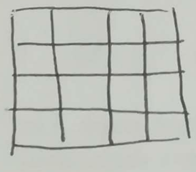
1. (*9 pts*) In the n-queens problem we want to place n chess queens on an $n \times n$ chessboard so that no two queens attack each other.

a.) (*3 pts*) Compute the size of the state space for n 4, if placing a queen on any square of the chessboard is considered the only operator and a maximum of 4 queens are allowed in the state space.

$n \times n = 4 \times 4 = 16$ mező található. Különböző mezőkön kell lennie a 4 királynőnek. => 4 mezőt kell kiválasztani 16-ból. $\binom{16}{4}$

3p

b.) (*3 pts*) Define a representation that takes into account that only one queen is possible in a row without their attacking each other. What is the size of the state space in this case?



∀ sorban egy királynő lehet, ∀-ben négy pozíció van. $4 \times 4 \times 4 = 4^{(3)\,4}$ a state space mérete

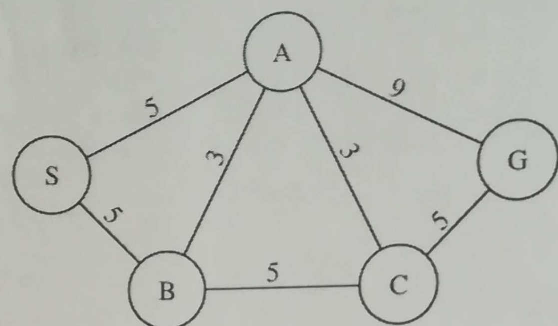
3p

c.) (*3 pts*) Is it possible to further decrease the state space considering some symmetry property? Describe the way and compute the new size if it is, or prove that it is impossible.

0

14p

2. (*14 pts*) Let us consider the following search space with node S and G representing the start and the goal states, respectively.



Node\Heuristic	h_1	h_2	h_3	h_4	h_5
S	12	12	12	12	12
A	12	4	4	6	8
B	9	3	3	5	5
C	5	2	5	10	2
G	0	0	0	0	0

a.) (*3 pts*) List the heuristics in the following table that are not dominated by any other heuristic, and give the heuristics that are dominated by them.

Dominant heuristic	Dominated heuristics
h1	h2, h5, h3
h4	h2, h3
h5	h2
h3	h2

2p

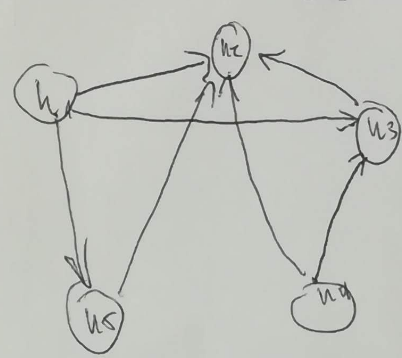
b.) (*1 pt*) List the heuristics that can be proven not to be admissible solely by examining the direct neighbors of the node representing the goal state.

by examining B : h1

by examining A: h1, h4, h5

1p

c.) (*2 pts*) Draw the dominance relationships among the heuristics on a directed graph. Let the heuristics be the nodes of the graph and let the edges point towards dominated heuristics.



✓ 2p

d.) (*4 pts*) Perform A* search with heuristic h_1 and determine the proposed path. Is this path optimal? Why?

S_{12} ← a_{17} b_{14}

b_{14} a_{17} ← ~~d~~ c_{15}

c_{15} a_{17} ← d G_{15}

path: s b c G   length: 15

optimal path is: s a G   length: 14

~~The path is not optimal, since h1 ...~~

A path nem optimális mert h_1 nem admissible.

4p

e.) (*2 pts*) Choose the heuristics from the ones defined above that are guaranteed to lead to an optimal solution and at the same time no other heuristic can be found using the dominance graph that has a lower effective branching rate but is still optimal.

h_2: S_{12} ← a_9 b_8 ; b_8 G

h_3: S_{12} ← a_9 b_8 ; G

h_4: S_{12} ← a_{11} b_{10} G

h_5

Egyik sem vezet el optimális megoldáshoz.

?

f.) (*2 pts*) Which heuristic can expand a node twice (without using a visited list)? Provide an example for a node.

0

3. (*6 pts*) Compare A*, RBFS and SMA* in terms of memory usage and time requirement. Explain the difference between their bottlenecks.

A*: exponenciális memória használat, ∀ node-ot tárol, a sebessége a heurisztika minőségétől függ.

SMA*: a rendelkezésre álló memóriát használja, A* memória igényének javított változata [illegible] ki. Ideje heurisztika minőségétől függ.

RBFS: Memória igénye alacsonyabb a BOUND-os elágazást [illegible], de [illegible] a sok BOUND változtatástól.

2.5p

4. (*12 pts*) There are three boxes with a label on each of them:

Box **A**:	This box is empty	(1)
Box **B**:	This box is empty	(2)
Box **C**:	There is money in Box **B**	(3)

The only thing we know is that at most one label is true. (4)

a.) (*2 pts*) Give a logic formula expressing the fact that at most one variable is true out of three. *Hint*: Try to avoid using Disjunctive Normal Form (this would make your work much harder), rather use the fact that two variables cannot be true.

Ø

b.) (*4 pts*) Axiomatize the domain by defining a knowledge base (KB) such that the interpretation above is a model of the KB. Use the following variables:

1

$B_{\#}$: box # covers the money;
$L_{\#}$: the label on box # is true.

$L_C \rightarrow B_B$
$L_B \rightarrow B_A$
$L_A \rightarrow \neg$

$\Rightarrow$? $L_C \wedge \neg L_B \wedge \neg L_A \rightarrow B_B \wedge \neg B_A \wedge \neg B_C$?
$\neg L_C \wedge L_B \wedge \neg L_A \rightarrow B_A \wedge \neg B_B \wedge \neg B_C$
$\neg L_C \wedge \neg L_B \wedge L_A \rightarrow$ Ha L_A igaz $\Rightarrow \neg L_B$ és … kell lennie $\Rightarrow$ Ellent…
$\neg L_C \wedge \neg L_B \wedge \neg L_A \rightarrow L_B$ és L_C nem lehet …

c.) (*2 pts*) Convert the statements in the KB to Conjunctive Normal Form (CNF).

1

~~$(\neg L_C \vee B_B) \wedge (\neg L_B \vee B_A)$~~
$(\neg L_C \vee L_B \vee L_A) \vee B_B \wedge \neg B_A \wedge \neg B_C$?
$(L_C \vee \neg L_B \vee \neg L_A) \vee B_A \neg B_B \wedge \neg B_C$

d.) (*4 pts*) If you can have one of the boxes without opening any of them, which one would you take? Explain your choice using a resolution refutation proof.

0

5. (*8 pts*) Consider the following expression returned by a situation calculus planner:

$$\text{RESULT}(A, \text{RESULT}(F, \text{RESULT}(D, \text{RESULT}(Q, s_0))))$$

8

a.) (*2 pts*) What is the role of s_0 in the expression?

A kezdőállapot, innen indulunk.

2

b.) (*2 pts*) What is the total number of situations the agent meets when executing the plan? Justify your answer.

2

Starting state + states : $1+4 = 5$

c.) (*4 pts*) Extract the plan in the form of a graph from the expression.

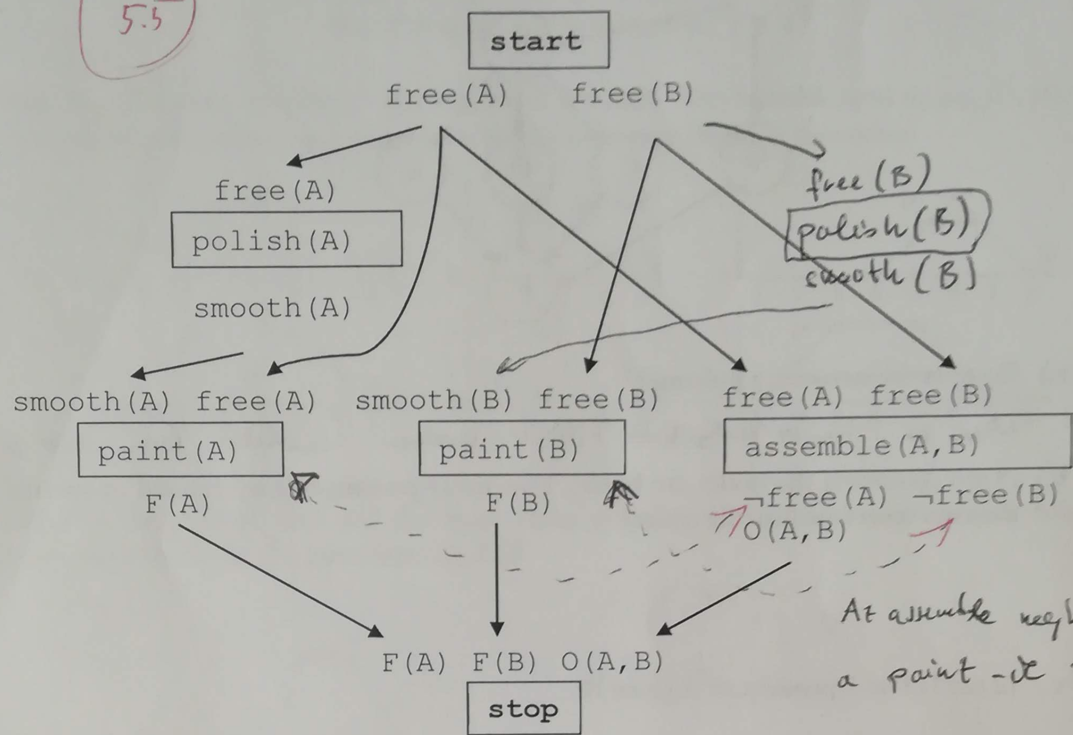
4

$Q \rightarrow D \rightarrow F \rightarrow A$

$s_0 \rightarrow$ RESULT(Q, s_0) [s_1] $\rightarrow$ RESULT(D, RESULT(Q, s_0)) [s_2] $\rightarrow$

$\rightarrow$ RESULT(F, RESULT(D, RESULT(Q, s_0))) [s_3] $\rightarrow$ RESULT(A, …)

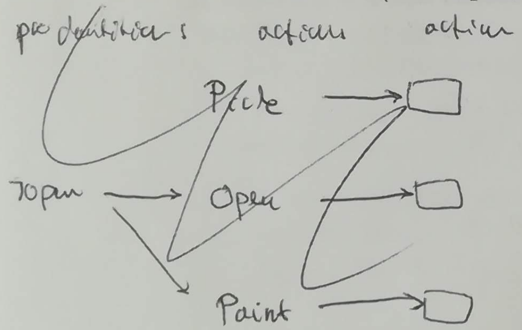
6. (*6 pts*) Let us consider the following incomplete partially ordered plan. What steps are missing to complete the plan? Mark them in the graph.



7. (*7 pts*) Use the *Graphplan* algorithm to draw a graph of two levels based on the description below. Mark all mutexes.

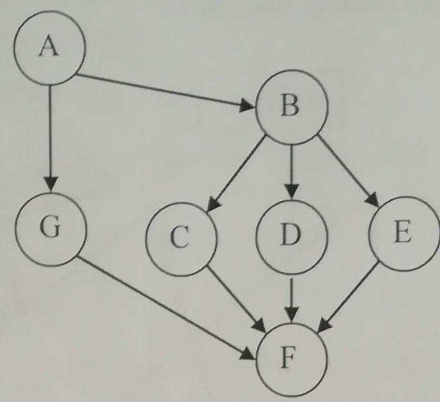
Start state: ¬has_key, ¬open, ¬painted.
Goal state: open, painted.

- Pick: (*Pre*:) (*Eff*: has_key)
- Open: (*Pre*: ¬open) (*Eff*: open)
- Paint: (*Pre*: ¬open) (*Eff*: painted)



8. *(20 pts)* Consider a Bayesian network with the following structure.

5



a.) (2 *pts*) Is the network a polytree?

2 Nem az, ha az irányítatlan éleket számoljuk, akkor lesz kör a gráfban

b.) (*3 pts*) Assuming the nodes are binary, how many parameters are required to specify the conditional probability tables?

0

c.) (*2 pts*) Is F independent of A given B?

0

d.) (*2 pts*) Is G independent of E given A and F?

G

e.) (*2 pts*) Is B independent of F given C, D, and E?

1 ~~[illegible]~~ Nem független tőle.

Why?

f.) (*3 pts*) Give an expression for P(d|c) (where d and c are specific, not necessarily binary values of variables D and C) in terms of parameters stored in the network?

0

g.) (*2 pts*) Which variables are irrelevant to the query P(d|c)?

2 G, F, E

h.) (*4 pts*) What factors are created by variable elimination using order A, B, E, F, G?

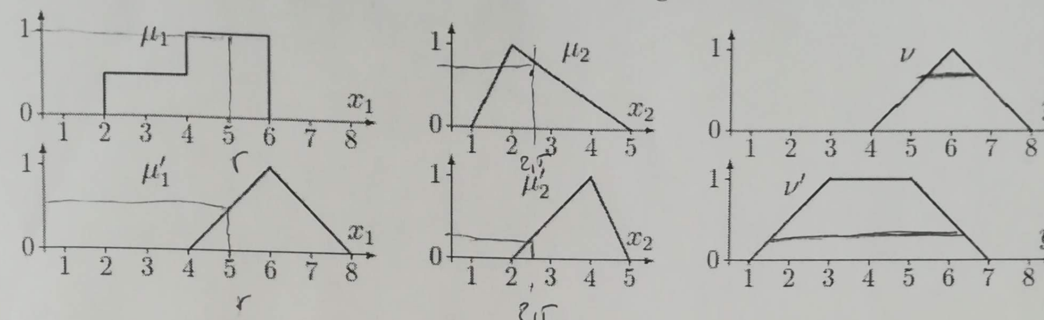
0

3

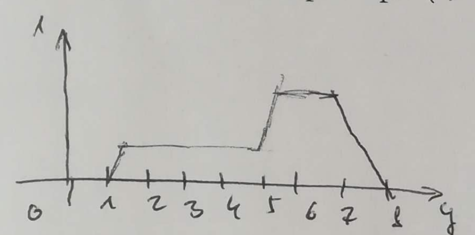
9. (*6 pts*) Consider the following fuzzy sets and rules:

(R₁) If x_1 is μ_1 and x_2 is μ_2, then y is ν,
(R₂) If x_1 is μ'_1 and x_2 is μ'_2, then y is ν',

where x_1 and x_2 are input fuzzy variables, y is the output fuzzy variable, and μ_1, μ_2, μ'_1, μ'_2, ν, and ν' are predicates for the fuzzy variables with the following member functions:



Based on these fuzzy sets and the rules, what output μ_{out} does a controller with Mamdani implication return for the input tuple (5, 2.5)?



$\mu_1 \wedge \mu_2$ } ν
$\mu_1' \wedge \mu_2$

3

10. (*6 pts*) Decide whether the following statements are true or false and justify your answer. Points are only given for the justification.

a.) Admissible heuristics are by nature optimistic, because they think the cost of solving the problem is usually less than it actually is.

1 Igaz, definíció szerint a heurisztikának alulbecslőnek kell lennie mint az a valódi költség. (az összes...?) ?

b.) Alpha-beta pruning can only alter the computed minimax value of the root of a game search tree if the order of the terminal nodes is inconsistent.

2 Hamis, az alfa-béta vágás ugyanazt az eredményt adja legrosszabb esetben mint a minimax. A sorrend csak az időigényét befolyásolja

c.) If the premises are consistent, first-order resolution terminates without a contradiction.

0 Igaz, ez a premis consistency definíciójából egyenesen következik