			4.	5.	6.	7.	8.	9.	10.	11.	Σ
9	14	6	12	20	4	8	7	8	6	6	100

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. HÁNY KÜLÖNBÖZŐ ÁLLAPOT LEHET?

1. KIRÁLYNŐ 16 HELYRE KERÜLHET

2. KIRÁLYNŐ 15

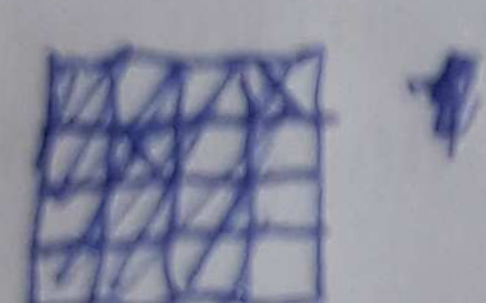
3. K. 14

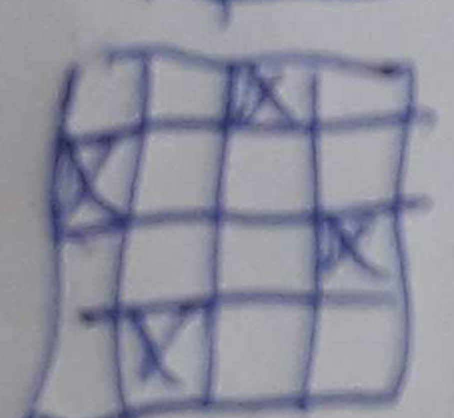
4. K. 13

16·15·14·13

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?

ER.:

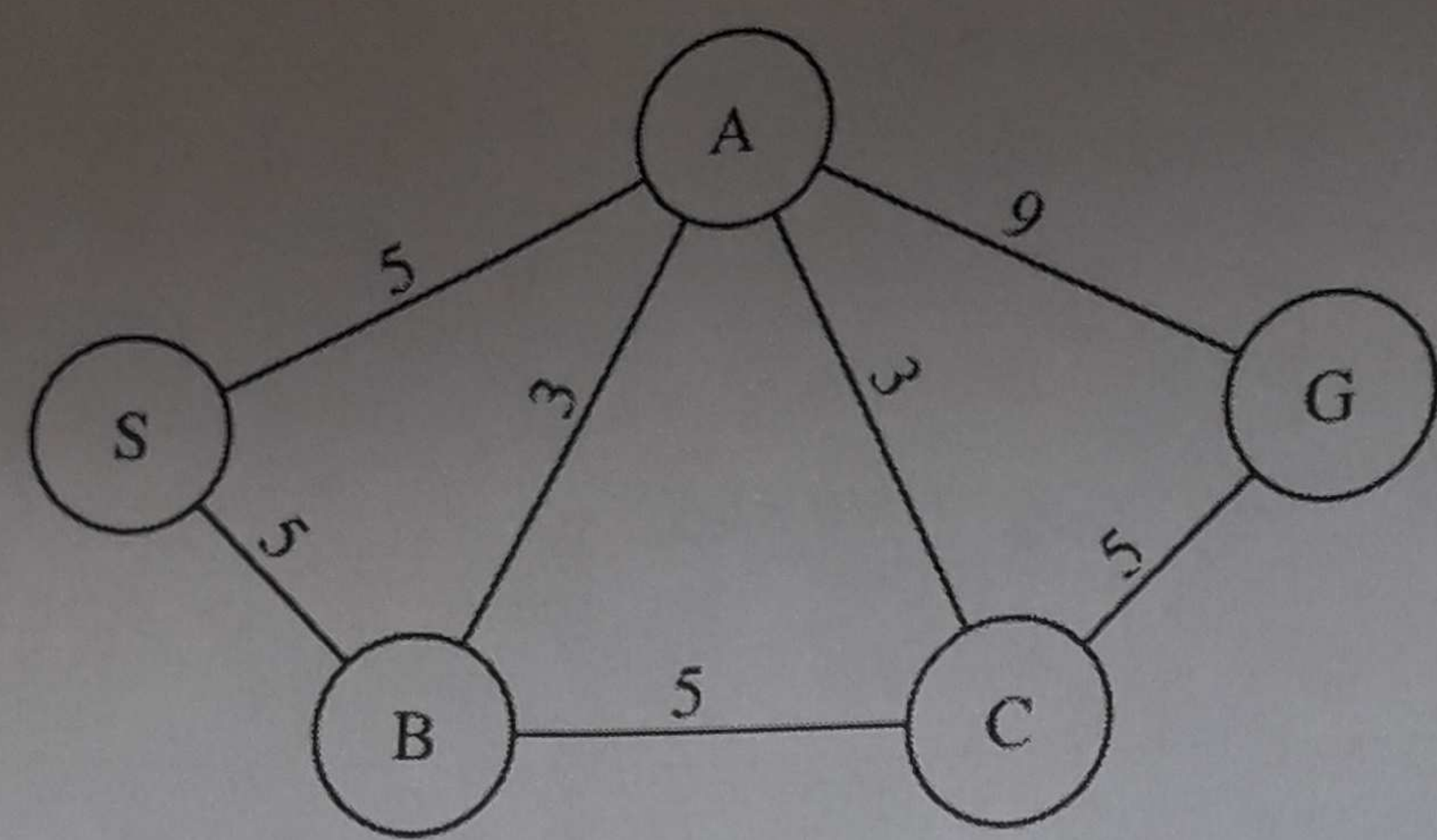




EZ A KÉT ÁLLAPOT LÉTEZIK

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.

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

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.

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.

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

$\underline{S} \rightarrow A_{17}, B_{14}$

$\underline{B_{14}}, A_{17} \rightarrow \cancel{A_{20}}, C_{15}$

$\underline{C_{15}}, A_{17} \rightarrow A_{25}, G_{15}$

$G_{15} \Rightarrow$ GOAL

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.

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

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

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.

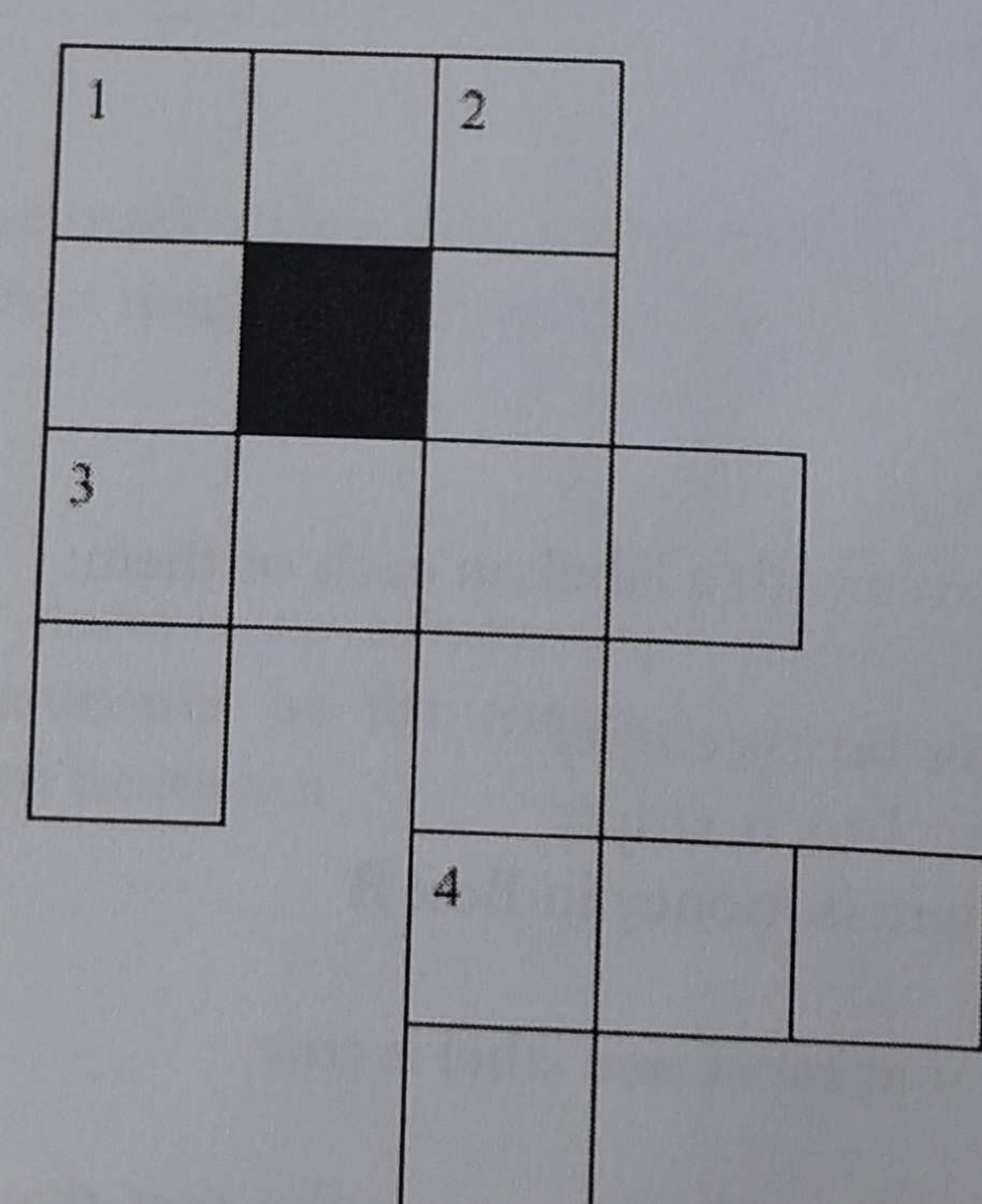
b.) (*4 pts*) Axiomatize the domain by defining a knowledge base (KB) such that the interpretation above is a model of the KB. Use the following variables:

B_n: box n covers the money;
L_n: the label on box n is true.

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

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.

5. (*22 pts*) Consider the crossword puzzle given below:



Suppose we have the following words in our dictionary: *ant, ape, big, bus, car, has, bard, book, buys, hold, lane, year, rank, browns, ginger, symbol, syntax*. The goal is to fill the puzzle with words from the dictionary.

a.) (*5 pts*) Formalize the problem as a constraint satisfaction problem by specifying the variables, their domains, and the constraints.

b.) (*2 pts*) Show the resulting constraint network.

c.) (*3 pts*) Give a sketch of how the problem would be solved. In what decisions (choices) can the agent use a heuristic?

d.) (*6 pts*) Fill in the gaps in the following sentences:

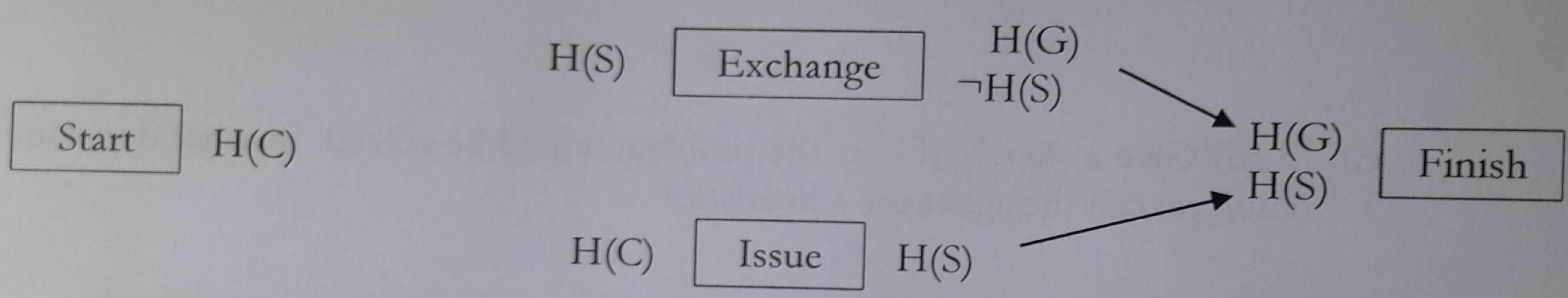
According to the minimum remaining values heuristic the .... that is constrained the .... should be instantiated to bring dead ends upper in the .... This means that the .... with the .... domain is chosen, and if this instantiation eventually leads to a good solution, then it is good to cover it early, but if it cannot lead to a viable solution, then less variables will need to be .... before we run into a ....

A good heuristic when choosing a .... is to pick the one that rules out the .... values in the remaining .... It does not make sense to choose the most constrained one, since eventually all .... need to be tried and it is better to .... the chance of picking a good one as soon as possible.

e.) (*4 pts*) Show how the Minimum Remaining Values heuristic would be used, showing how the first two words would be selected.

6. *(4 pts)* Formulate the effect axiom in situation calculus of the CLOSE operator (applicable to doors) using the CLOSED predicate.

7. *(8 pts)* A partial order planner has found the operators satisfying two partial goals:



a.) *(2 pts)* List all threats and the threatened links and mark them in the graph.

b.) *(2 pts)* What temporal ordering(s) need(s) to be added to eliminate the threats?

c.) *(4 pts)* Complete the plan by adding any missing causal link(s), step(s), and temporal ordering(s) to the plan in order to complete it. Draw the resulting plan.

8. *(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)

9. *(8 pts)* We would like to compute the conditional probability value $P(a, b | c, d)$, having only the following values are available:

$P(a)$, $P(b)$, $P(c)$,
$P(a|d)$, $P(b|d)$, $P(c|d)$,
$P(d|a)$,
$P(a, b)$, $P(c, d)$,
$P(a|c, d)$, $P(b|c, d)$,
$P(c|a, b)$, $P(d|a, b)$.

For each of the following assumptions decide if $P(a, b | c, d)$ can be computed, and give the formula to calculate it if it is possible.

a.) a and b are conditionally independent given c and d.

b.) c and d are conditionally independent given a and b.

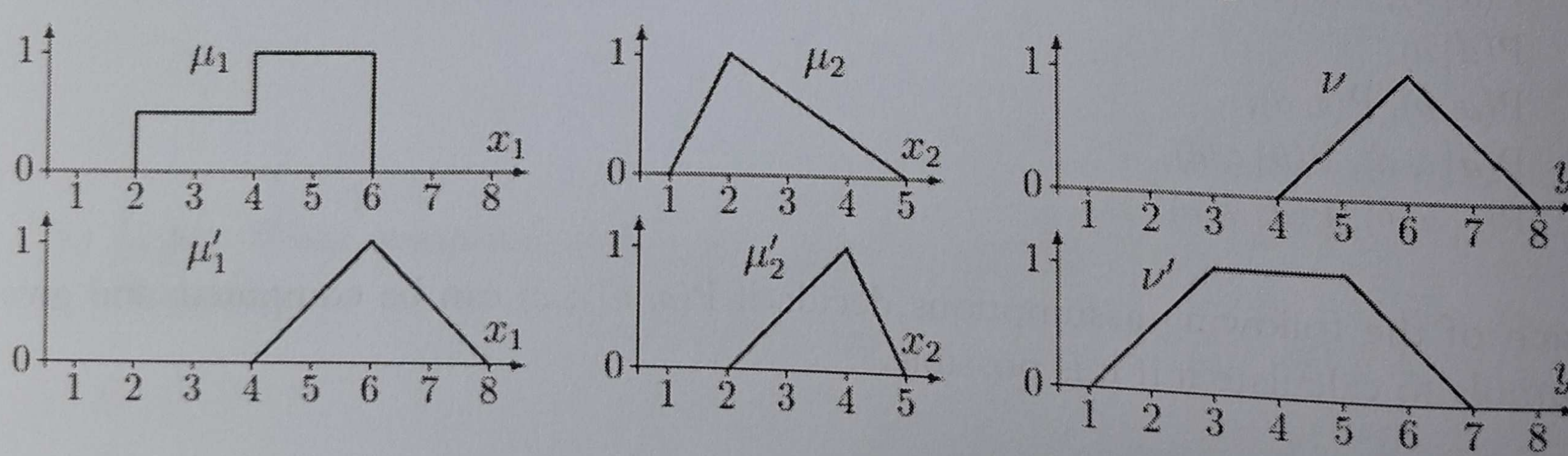
10. (*6 pts*) Give a Bayesian network that satisfies the following conditions:

(i) A is independent of B
(ii) A depends on B given C
(iii) A depends on D
(iv) A is independent of D given C

11. (*6 pts*) Consider the following fuzzy sets and rules:

(R_1) If x_1 is μ_1 and x_2 is μ_2, then y is ν,
(R_2) 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)?

1, N KIRÁLYNŐ

a, ÁLLAPOTTÉR MÉRETE $n=4$ AMENNYIBEN A KIRÁLYNŐ FELHELYEZÉSE AZ OPERÁTOR

ÜTHETIK EGYMÁST, 1 MEZŐN MAX 1 KIRÁLYNŐ LEHET

1. KIRÁLYNŐ 16 HELYRE MEHET
2. K. 15
3. K. 14
4. K. 13

$$16 \cdot 15 \cdot 14 \cdot 13 = \frac{16!}{12!} = \frac{(n^2)!}{[n(n-1)]!}$$

MEGKÜLÖNBÖZTETHETŐEK (SORRENDISÉG)

$$\frac{1}{24} \cdot \frac{16!}{12!} = \frac{(n^2)!}{n! \cdot [n(n-1)]!}$$

b, NEM ÜTHETIK EGYMÁST

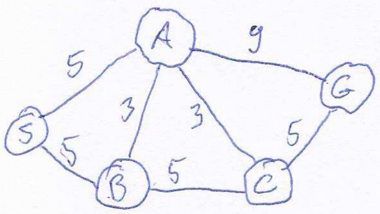
$4^4 = 256$

C, LEHETSÉGES-E SZIMMETRIATULAJDONSÁGGAL CSÖKKENTENI AZ ÁLLAPOTTÉR SZÁMÁT

FORGATÁSOK $\longrightarrow$ 4-EL ELOSZTHATÓ, MERT 4 ESETBEN AZONOS LESZ A TÁBLA

VÍZSZINTES
FÜGGŐLEGES } TÜKRÖZÉS $\rightarrow$ 2-VEL OSZTJA A LEHETŐSÉGEKET $\quad 1/2 \cdot 4^4 = 125$
ÁTLÓS

2,



a, SOROLJA FEL A HEURISZTIKÁKAT, AMIKET EGYIK SEM DOMINÁL ÉS AMIKET DOMINÁLNAK

DOMINÁNT	DOMINATED
h_1	h_2, h_3, h_5
h_4	h_2, h_3

h_1 DOMINÁLJA A h_2, h_3, h_5-T

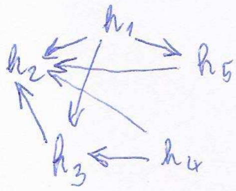
b, SOROLJA FEL AZOKAT A HEU.., MELYEK <u>NEM</u> MEGENGEDHETŐEK A, C ÁLLAPOT SZEMPONTJÁBÓL (KÖZVETLEN SZOMSZÉD)

C-BŐL 5 AZ ÚT $\longrightarrow h_1, h_4$

A-BÓL 8 TÚLBECSÜLIK

MEGJEGYZÉS
DOMINÁNS HEURISZTIKÁINK
NEM MEGENGEDHETŐEK

C, DOMINANCIAGRÁF FELRAJZOLÁSA



d, h_1-EL A^* KERESÉS, OPTIMÁLIS-E AZ ÚT

HA A HEURISZTIKA MEGENGEDHETŐ, AKKOR OPTIMÁLIS

HA OPTIMÁLIS LESZ
↳ SZERENCSÉNK VOLT

HA NEM
↳ NEM MEGLEPŐ

$\underline{S}_{12} \rightarrow A_{5+12}, B_{5+9}$

$\underline{B}_{14}, A_{17} \rightarrow A_{\underbrace{\cancel{5+3+12}}_{20}}, C_{5+5+5}$

$\underline{C}_{15}, A_{17} \rightarrow A_{\underbrace{5+5+3+12}_{25}}, G_{5+5+5+0}$

G_{15}, A_{17}

VANNAK RÖVIDEBB UTAK $\rightarrow$ NEM OPTIMÁLIS
↳ NEM VOLT MEGENGEDHETŐ A HEURISZTIKA

e, CSAK A h_2, h_3, h_5 MEGENGEDHETŐ

$$N = \sum_{i=1}^{d} b^i = \frac{b^{d+1}-1}{b-1}$$ HA A CSOMÓPONTOK SZÁMA AZONOS

MEGENGEDHETŐ DOMINÁLÓ HEURISZTIKÁK
h_3, h_5

4, ~~NEGYEDIK KITEJTI A~~

1, h_2 ESETÉN

$\underline{S}_{0+12} \rightarrow A_{5+4}, B_{5+3}$

$\underline{B}_8, A_9 \rightarrow S_{10+12}, A_{8+4}, B_{10+12}$

$\underline{A}_9, C_{12}, S_{22} \rightarrow B_{5+3+3}, S_{10+12}, C_{8+2}, G_{5+9+0}$

$\underline{C}_{10}, B_{11}, G_{14}, S_{22} \rightarrow B_{5+3+5+3}, A_{11+4}, G_{13+0}$

$\underline{B}_{11}$ 2. KIFEJTÉS LENNE

3, ÖSSZEHASONLÍTÁS (IDŐ, MEMÓRIA HASZNÁLAT)

A^* – MEMÓRIA – TELJES KERESÉSI FA
– IDŐ – OPTIMÁLIS ⇒ JÓ MEGOLDÁST AD GYORSAN

RBFS – CSAK AZ AKTUÁLIS LÁNCOT JEGYZI MEG (LINEÁRIS)
– VERGŐDÉS – HA MÉGSE JÓ ÚJRA KELL FEJTENI
– IDŐBEN HOSSZÚ LEHET

SMA* – MEMÓRIA KORLÁTIG A^* MEGY
– UTÁNA LEGROSSZABBAT ELDOBJA
– VERGŐDÉS KEVÉSBÉ ZAVARÓ

MEMÓRIA

RBFS ≤ SMA* ≤ A^*

IDŐ

A^* ≤ SMA* ≤ RBFS

4, 3 DOBOZ LEGFELJEBB 1 IGAZ

A ÜRES

B ÜRES

C B NEM ÜRES

a, $\neg(A \wedge B) \wedge \neg(A \wedge C) \wedge \neg(B \wedge C)$

A, B EGYSZERRE NEM LEHET IGAZ ...

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

DISZJUNKTÍV

b, B_A – A TARTALMAZ PÉNZT

L_A – A CÍMKÉJE IGAZ

KB.

$L_A \Leftrightarrow \neg B_A$

$L_B \Leftrightarrow \neg B_B$

$L_C \Leftrightarrow B_B$

$\neg(L_A \wedge L_B)$

$\neg(L_A \wedge L_C)$

$\neg(L_B \wedge L_C)$

c,

$\neg L_A \vee \neg B_A$

$\neg L_B \vee \neg B_B$

$\neg L_C \vee B_B$

$\} \neg L_B \vee \neg L_C$

$\neg L_A \vee \neg L_B$

$\neg L_A \vee \neg L_C$

$\neg L_B \vee \neg L_C$

$L_A \vee B_A$

$L_B \vee B_B$

$L_C \vee \neg B_B$

d, TFH A IGAZ ⇒ B, C HAMIS ↯ EGYSZERRE NEM LEHET

↳ A HAMIS ⇒ VAN BENNE PÉNZ

TFH $\neg B_A$

$L_A \vee B_A$

L_A

$\neg L_B$

$\neg L_C$

$L_B \vee B_B$

$L_C \vee \neg B_B$

B_B

$\neg B_B$

↯

5, a, FORMALIZÁLÁS, KÉNYSZEREK

a) $F1 = \{4 \text{ BETŰS SZAVAK}\}$ $\quad F_1[1] = V_1[1]$

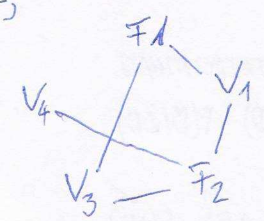
$V1 = \{3 \text{ BETŰS}\}$ $\quad V1[3] = F2[1]$

$F2 = \{\#6\}$ $\quad F_1[3] = V3[1]$

$V3 = \{\#4\}$ $\quad F_2[5] = V4[1]$

$V4 = \{\#3\}$ $\quad V3[3] = F2[3]$

b,



c, PROBLÉMA VÁZLATA
VÁLASZTOK VÁLTOZÓT
VÁLASZTOK ÉRTÉKET

d, 1. VÁLTOZÓ
2. LEGJOBBAN
3. KERESÉSI FÁBAN
4. VÁLTOZÓ
5, LEGKISEBB
6, PÉLDÁNYOSÍTANI
7, ELLENTMONDÁSRA
8, ÉRTÉKET
9, LEGKEVESEBB
10, VÁLTOZÓKBÓL
11, VÁLTOZÓ
12, MAXIMALIZÁLJUK

e, LEGKEVESEBB MEGMARADÓ ÉRTÉK
3 BETŰS : 6 DB
4 BETŰS : 7 DB
6 BETŰS : 4 DB $\quad V1[3] = F2[1] \Rightarrow$ BROWNS

F2 = "SYNTAX"

	MÉRET	
F_1	7	2
V_1	6	6
F_2	4	~~4~~
V_3	7	2
V_4	6	2

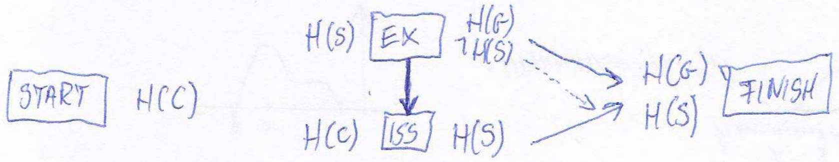
6, CLOSE OPERÁTOR A HATÁS AXIÓMA
MINDEN EGYES PREDIKÁTUM ADOTT SZITUÁCIÓBAN LESZ ÉRVÉNYES

SZITUÁCIÓ AMIKOR IGAZ

$CLOSED(x, S)$ $\qquad S = RESULT(CLOSE(x), S_0)$

$(\forall S, X)\ CLOSED(X, RESULT(CLOSE(X), S))$

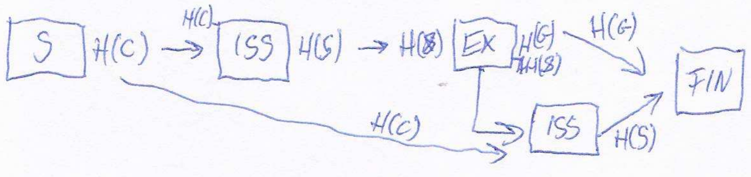
7,



a, ¬H(S) VESZÉLYEZTETI AZ ISS → FIN

b, EXCHANGE-T AZ ISSUE ELŐTT KELL VÉGREHAJTANI
$T_{EX} < T_{ISS}$

c,



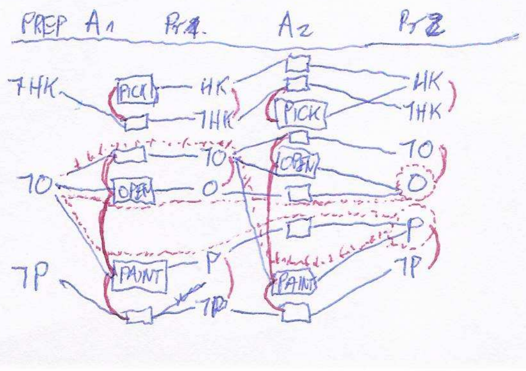
C, BEFEJEZNI AZ ÁBRÁT

8, GRAPH PLAN
START: ¬HK, ¬O, ¬P
END: O, P

OPEN: PRE: ¬O
EFF: O

PICK: PRE: —
EFF: HK

PAINT: PRE: ¬O
EFF: P



9, $P(ab \mid cd) = ?$

ADOTT $P(A)$
$P(B)$
$P(C)$
$P(A \mid D)$
$P(B \mid D)$
$P(C \mid D)$
$P(D \mid A)$
$P(A,B)$ $P(CD)$
~~P(A|A)~~ !
$P(A \mid CD)$
$P(B \mid CD)$
$P(C \mid AB)$
$P(D \mid AB)$

a, ~~A,B FÜGGETLEN?~~ → FELBONTHATÓ

$$P(AB \mid CD) = P(A \mid CD) \cdot P(B \mid CD)$$

b, BAYES TÉTELLEL

$$P(AB \mid CD) = \frac{P(CD \mid AB)^{?} \cdot P(AB)}{P(CD) \checkmark} \checkmark$$

$$P(CD \mid AB) = P(C \mid AB) \cdot P(D \mid AB)$$

FÜGGETLENEK

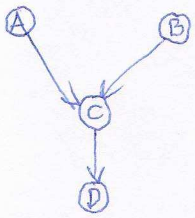
c, A,B FÜGGETLEN

$$\frac{P(ABCD)}{P(CD)}$$! NINCS MEGOLDÁSA

d, A,B,C FELT. FGTLENEK FELTÉVE D

$$P(AB \mid CD) = P(AB \mid D) = P(A \mid D) \cdot P(B \mid D)$$

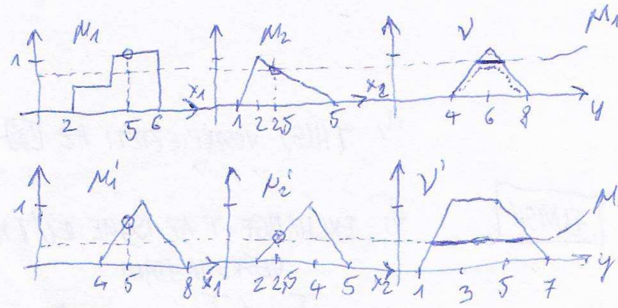
10, BAYESIAN NETWORK



KONVERGENS
- CSOMÓPONT ISMERETE VAGY LESZÁRMAZOTTJA BEFOLYÁSOLJA

11, R_1: IF x_1 μ_1 AND x_2 μ_2 THEN y IS ν
R_2: IF x_1 μ_1' AND x_2 μ_2' THEN y IS ν'

$X(5; 2,5)$



$\mu_1 \wedge \mu_2 \Rightarrow$ MINIMUM

$\mu_1' \wedge \mu_2' \Rightarrow$ MINIMUM

SUPREMUMÁT KELL VENNI
(MAXIMUMÁT)