B.Sc. Engg. 7th Semester 24 May 2018

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
Department of Computer Science and Engineering (CSE)

SEMESTER FINAL EXAMINATION WINTER SEMESTER, 2017-2018

DURATION: 3 Hours FULL MARKS: 150

CSE 4701: Artificial Intelligence and Expert Systems

Programmable calculators are not allowed. Do not write anything on the question paper.

There are 8 (eight) questions. Answer any 6 (six) of them.

Figures in the right margin indicate marks.

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1. a) Assume we want to write an automated planner for a very simple video game: we have a world of 10 different locations, arranged horizontally as shown below. There is a game agent that wants to end up in location 10.

Table 1: Grid View of the video game world

1	2	3	4	5	6	7	8	9	10

There can be a monster in each of positions 3 and 9, and the agent cannot move to these locations when there is a monster there. The agent has a weapon that is either charged or uncharged, and there are new charges at locations 1 and 4. The following actions are available to the agent:

- The action "move right" increases our agent's location by 1 (up to 10),
- The action "move left" decreases the location by 1 (down to 1).
- The action "pickup" allows the agent to pick up a charge if it is at the charge's location. This will charge the agent's weapon and remove the charge from its location.
- The action "fire" removes every monster whose location differs from the agent's current location by 1 and discharges the agent's weapon.

i. Define the STRIPS features (variables) and their domains for this problem. The agent needs to keep track of where it is, whether locations 3 and 9 are free, whether the agent's weapon is charged, and whether each of the two charges is available. 4

ii. Give the STRIPS representation of the actions for location 4 ("move right4", "move left4", pickup4, and fire4). 5

iii. Suppose that the agent's goal is to be in location number 10, and its start state is at location 8, with monsters occupying locations 3 and 9, the weapon charged, and charges in locations 1 and 4. Draw a part of the search space that includes the optimal plan (i.e. the optimal solution path from start state to a goal state) 10

b) What is a good admissible heuristic for the planning goal in 1(a)? (Note that this is a domain-dependent heuristic since you take into account how the video game works.) To get full marks, you must also provide an explanation of why your proposed heuristic is good and is admissible. 4

c) What does ignore-delete list mean when it comes to coming up with heuristics? 2

2. a) Suppose we want to diagnose the errors school students make when adding multi-digit *binary* numbers. We will only consider adding two two-digit numbers to form a three-digit number. That is, we will consider problems of the form as shown in Figure 1: 13

$$\begin{array}{rrr} & A_1 & A_0 \\ + & B_1 & B_0 \\ \hline C_2 & C_1 & C_0 \end{array}$$

Figure 1: A sample binary addition

Here A_i, B_i and C_i are all binary digits. Suppose we want to model the process of adding two digit numbers by modeling the following mechanisms: 1) whether the student knows single-digit binary addition and 2) whether the student knows how to carry. For example, performing, the above addition would require - First adding A_0 and B_0 and finding the carry of this addition, $Carry_0$ - Then adding A1 and B1 and the carry from the previous addition. As part of the process, we need to model the following findings - If students know both single-digit binary addition and how to carry, they usually get the right answer, but sometimes make mistakes. - For each mechanism, if they don't know how to do it correctly, they just pick the result at random.

Draw a Bayesian Network keeping in mind the aforementioned dependencies [Hint: try to specify dependencies in the causal direction, also think about what things particularly effects the addition result.]

b) For Question 2(a), assume that 80% of the students know binary addition and 50% know how to carry. Further assume that students make mistakes with a probability of 5% (in either addition or carry) even if they know the underlying mechanism. Also, the probability of encountering any digit for addition is 0.5 i.e. [$P(A_0=0)$ = $P(A_0=1)$ = ...= $P(B_0=0)$ = $P(B_0=1)$ = 0.5]. Give the conditional probability tables for your network. 12

3. a) Students have to make decisions about how much to study for each course. Suppose students first have to decide how much to study for the midterm. They can study a lot, study a little, or not study at all. Whether they pass the midterm depends on how much they study and on the difficulty of the course. As a first-order approximation, they pass if they study hard or if the course is easy and they study a bit. After receiving their midterm grade, they have to decide how much to study for the final exam. Again, the final exam result depends on how much they study and on the difficulty of the course. Their final grade depends on which exams they pass; generally, they get an A if they pass both exams, a B if they only pass the final, a C if they only pass the midterm, or an F if they fail both. Of course, there is a great deal of noise in these general estimates [E.g. if someone only passes the midterm they might get some grade other than C with a small probability].
Suppose that their final utility depends on their total effort and their final grade. Suppose the total effort is obtained by adding the effort in studying for the midterm and the final.

i. Draw a decision network for the above story. 8
ii. What is the domain of each variable? 3
iii. Give an appropriate utility function for a student who just wants to pass (not get an F). 4
iv. Give an appropriate utility function for a student who wants to do really well. 4

b) Given the following joint probability table over 4 variables, compute the conditional probability distribution P (W, Y |X = true, Z = false). Write this down in a similar format as the table below. 6

Table 2: Joint Probability Distribution of the given variables

W	X	Y	Z	P (W, X, Y, Z)
true	true	true	true	0.1
true	true	true	false	0.2
true	true	false	true	0
true	true	false	false	0
true	false	true	true	0.05
true	false	true	false	0.05
true	false	false	true	0.05
true	false	false	false	0.05
false	true	true	true	0.05
false	true	true	false	0.05
false	true	false	true	0
false	true	false	false	0
false	false	true	true	0.1
false	false	true	false	0.1
false	false	false	true	0.1
false	false	false	false	0.1

4. a) In 1942, Anthony S. Filipiak made a 10-block sliding puzzle called the Traffic Cop Tangle. The point of this puzzle is to swap the positions of the blocks labeled `A' and `B', by sliding around the pieces into the empty space (the unlabeled space between the A and the B). [N.B: Picture is to scale, so, both A and B blocks are twice the area of 3 and 6; 3 and 6 have twice the area of 1 and 2] 10

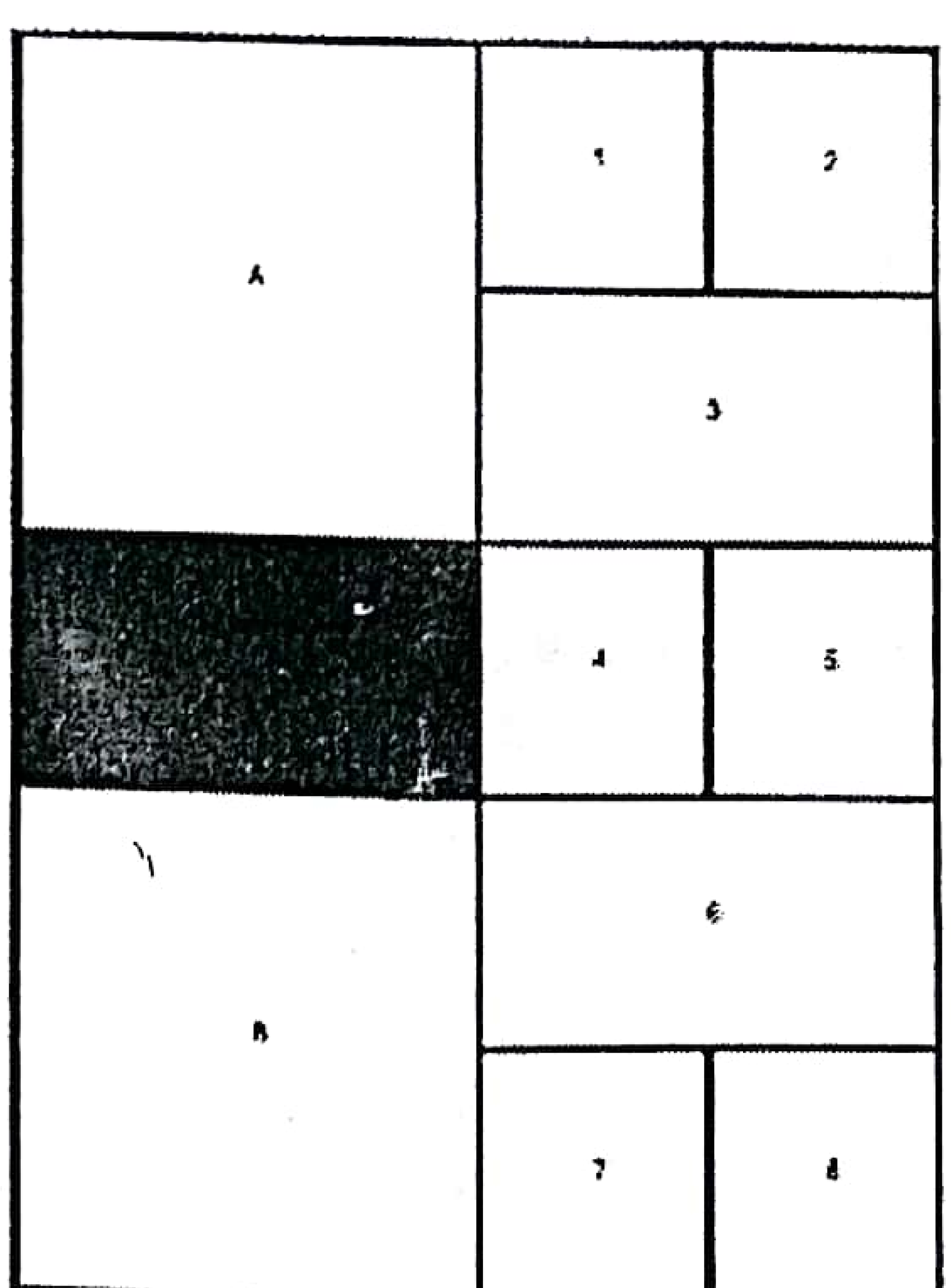

Figure 2: Traffic Cop Tangle Puzzle

Considering the puzzle to start at the given configuration as above, provide your insights of the following with respects to this problem: What is a state? An action? A goal-state? What is a solution?

b) Consider a CSP defined as follows. There are four variables, {A, B, C, D}. The domain for each variable is {1, 2, 3, 4, 5}. The following constraints hold between the variables: A>B, C – A = 1, C>D, D = A, and |D – B| = 1

i. Draw the constraint network for this CSP; you do not have to include the domains in the picture 5

ii. Assume arc consistency first considers the edges between variable A and all of its neighbors in the constraint graph. Which values are removed from A's domain in those steps of arc consistency, and why? 4

c) Differentiate between top down and bottom up proof procedure. 6

5. a) You are working at a popular marina where a number of yachts are parked in berths. Each berth can either be vacant or have exactly one yacht parked in it. Any yacht can be parked in any berth. There is only one vacant berth in the marina. Your marina has 10 berths numbered 1 to 10 and houses 9 yachts labeled y_1 to y_9.

y2 ► 1	10 ◄ y5
y4 ► 2	9
y3 ► 3	8 ◄ y7
y1 ► 4	7 ◄ y8
y9 ► 5	6 ◄ y6

Figure 3: Current state of the marina

Figure 2 shows the current state of the marina in which 9 is the initial vacant berth. The yachts were originally assigned to the berth with the same number, y_1 to berth 1, y_2 to berth 2 etc. Your customers are clearly misbehaving! The marina manager has asked you to put each yacht back to its originally assigned berth. You will only be able to move one boat at a time and you are not allowed to take yachts out of the marina. Also, because of some strange liability issues, you can only move boats from a berth b to a vacant berth b_v if one is a multiple of the other or if both are prime. You would like to find a sequence of yacht-moves such that each yacht is back in its originally assigned berth

i. Represent the marina problem as a search problem. Includes what would count as node, start state, goal state, arcs etc. 5

ii. Draw the first two levels (counting the root as level 1) of the search tree. 8

b) Consider the following search problem:

- the set of states $S = \{s_0, s_1, s_2, s_3, s_4, s_5\}$
- successors of s_0 are $\{s_0, s_1, s_2\}$
- successors of s_1 are $\{s_1, s_2, s_3\}$
- successors of s_2 are $\{s_2, s_3\}$
- successors of s_3 are $\{s_0, s_3, s_4\}$
- successors of s_4 are $\{s_4, s_5\}$
- successors of s_5 are $\{s_2, s_3, s_5\}$
- objective function f is as follows: $f(s_0) = 0$, $f(s_1) = 3$, $f(s_2) = 2$, $f(s_3) = 4$, $f(s_4) = 1$, and $f(s_5) = 5$

i. Which (if any) states are local maxima and global maxima? 4

ii. Trace hill climbing search starting in state s_0 (indicate which state is considered at each iteration, and which solution is returned when the search terminates). Does it return the optimal solution? 8

6. a) A university has asked you to write a program to help them determine whether or not to accept students who have applied for admission. There are 3 basic pathways for a student to be accepted. If a student is returning to the university after a time away and is in good academic standing with no outstanding fees, they are accepted. Students who submit a complete application and are qualified are also accepted. Students are qualified if they have high SAT scores as well as good high-school transcripts. The university also has a legacy program, wherein children of former graduates are qualified (though these students must still submit a complete application). 20

For *brevity*, let's only talk about 3 individuals: Sam is a former graduate and Chris is his son. Chris has good high-school transcripts and he submitted a complete application. Laura is a returning student in good academic standing.

Give the knowledge base representing this problem, using unary predicates accepted [1], returning [1], goodStanding [1], clearBalance [1], appComplete [1], qualified [1], legacyStudent [1], highSAT [1], goodHS [1], and graduate [1], as well as the binary predicate child [2]. The university admissions officials should be able to provide queries such as accepted(chris) and get a true or false answer.

b) Run the top-down derivation of the query accepted(chris) applied to your KB. 5

7. a) Explain minimal models and use that to prove that bottom up proof procedure is sound 15

b) You are given the following top-down derivation for a knowledge base KB. 10

yes $\leftarrow$ a.
yes $\leftarrow$ b $\wedge$ f.
yes $\leftarrow$ b $\wedge$ g $\wedge$ h.
yes $\leftarrow$ c $\wedge$ d $\wedge$ g $\wedge$ h.
yes $\leftarrow$ d $\wedge$ g $\wedge$ h.
yes $\leftarrow$ g $\wedge$ h.
yes $\leftarrow$ h.
yes $\leftarrow$.

Figure 4: Top down derivation

Derive the bottom up derivation of this top down derivation.

8. a) Consider the following belief network: 16

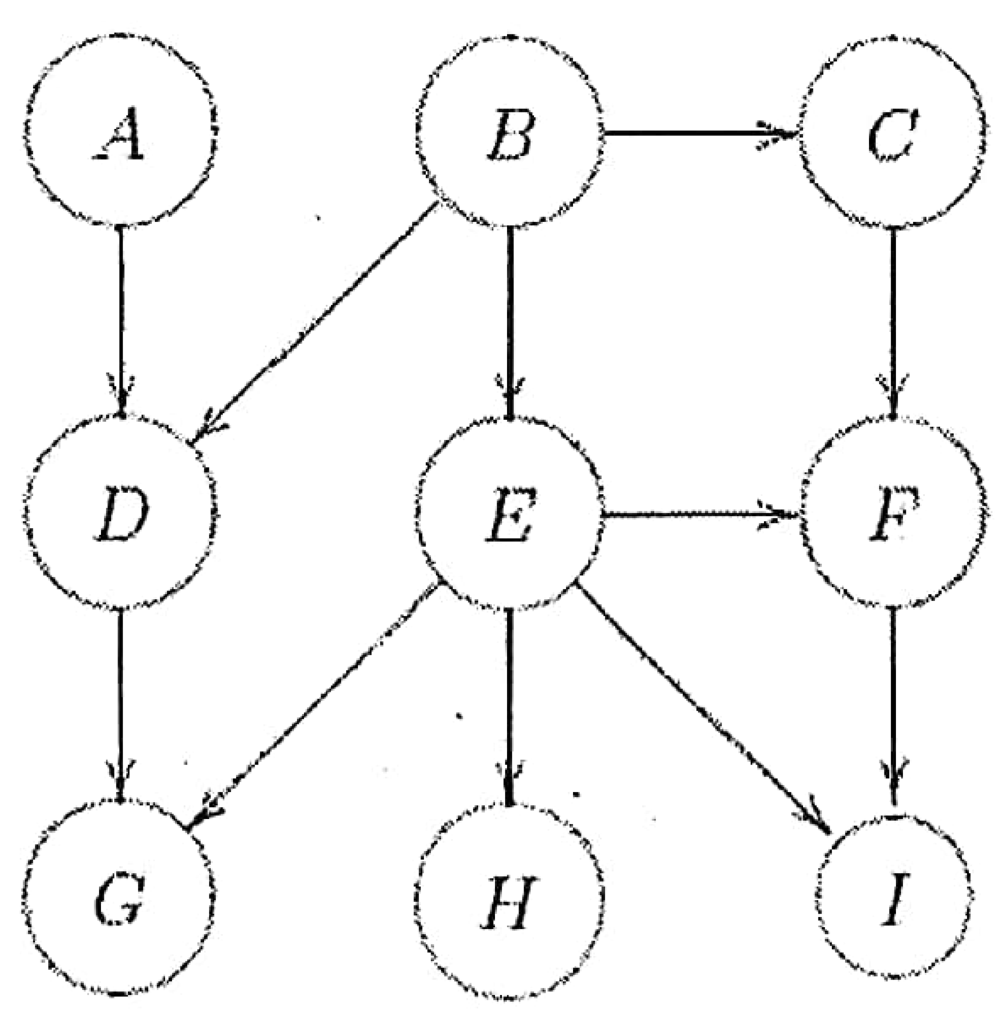

Figure 5: Belief Network

Use the variable elimination algorithm to derive algebraic expressions for the probabilities listed below. (Observe that no numbers are given, so you will be unable to give a numerical answer, i.e. the expression would be shown as factors.) *You will have to show your work.* Name factors that you create f_0, f_1, etc., make sure to follow the naming conventions that go with naming factors. *State the size* (number of variables involved) of the largest factor that you create. (It will be helpful if you choose a variable ordering that makes this quantity as small as you can, though you won't be penalized if you don't find the smallest quantity.) *You can prune any irrelevant nodes.*

i. P(E)
ii. P(A)
iii. P(A|G)
iv. P(I)

b) The following picture shows some people who are sitting at a table. 9

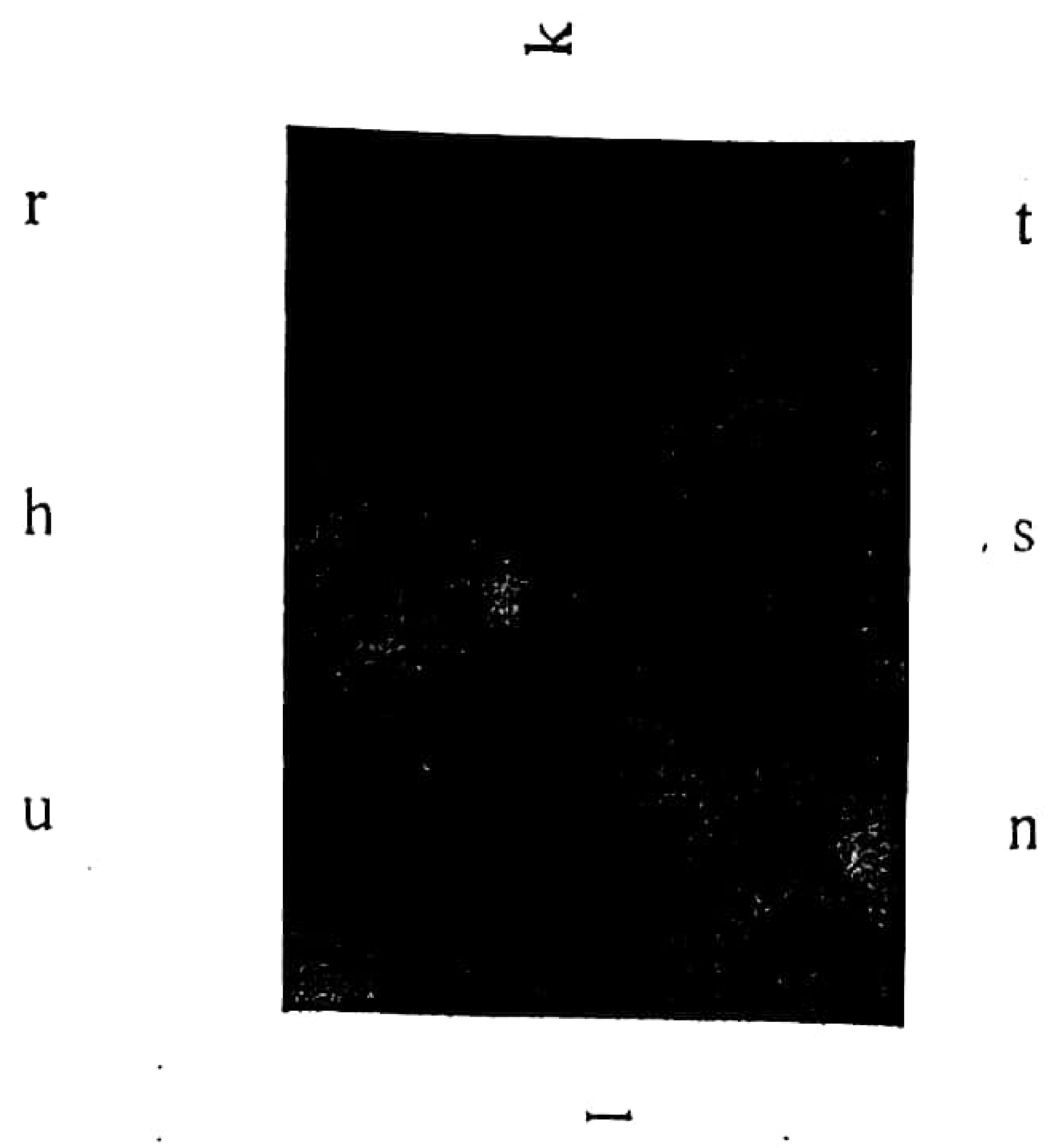

Figure 6: Position of people sitting around a table

You are given a knowledge base with the following facts where sits_right_off (a, b) means b sits at the right of a

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sits_right_of (k, r).
sits_right_of (r, h).
sits_right_of (h, u).
sits_right_of (u, l).
sits_right_of (l, n).
sits_right_of (n, s).
sits_right_of (s, t).
sits_right_of (t, k).
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Figure 7: Given facts

i. Write additional rules for the following that only uses the *facts* given above, i.e. you are not allowed to add any more facts.

- sits_left_of (X, Y) should be true if X is to the left of Y
- are_neighbors_of (X, Y, Z) should be true if X is to the left of Z and Y is to the right of Z
- next_to_each_other (X, Y) should be true if X is next to Y.