OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG | INF FAKULTÄT FÜR INFORMATIK

Department for Intelligent Cooperating Systems
Computational Intelligence
Prof. Dr. R. Kruse, A. Dockhorn

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Written exam "Bayesian Networks"

Name, first name:	Faculty:	Course:	Matriculation no.:
Type of exam: ☐ First attempt ☐ Second attempt ☐ Certificate	Signature invigilator:		#Sheets:

Task 1	Task 2	Task 3	Task 4	Task 5	Sum
/10	/14	/16	/10	/10	/60

Task 1 Bayesian Theorem and Combinatorics (6 + 4 = 10 20 min)

a) Only one out of hundred woman younger than 35 develop breast cancer. Most diseases can be detected using a mammogram. However every tenth ill patient remains undetected. Only rarely it occurs that a healthy patient is mis-classified. Therefore, it happens that 8 out of 100 woman have a positive mammogram without having cancer.

In your position as medical advisor: what is a young woman's probability of having cancer (C^+), given a positive mammogram (M^+). Also determine the probability of a young woman not having cancer (C^-), given a negative mammogram (M^-).

b) Calculate the number of 8-bit binary numbers with **at least** three digits equal to 1. (e.g. the number 10101010 is an 8-bit number with four 1s)

Task 2 Bayesian Networks (10 + 4 = 14 30 min)

Consider the following three-dimensional probability distribution.

p_{ABC}	$A = a_1$, $B = b_1$	$A = a_1$, $B = b_2$	$A = a_2$, $B = b_1$	$A = a_2$, $B = b_2$
$C = c_1$	$^3/_{32}$	$^2/_{32}$	$^1/_{32}$	$^2/_{32}$
$C = c_2$	$^6/_{32}$	$^3/_{32}$	$^6/_{32}$	$^9/_{32}$

a) Determine and draw the underlying network structure for the given joint distribution.

b) Two students compare their results on a similar task (with another joint distribution). The bayes network of the first student is shown in Figure 1a, the second student's network is shown in Figure 1b. Both networks perfectly represent the given joint distribution.

1. What are the networks induced probability functions?
2. Which network should be favored and why?

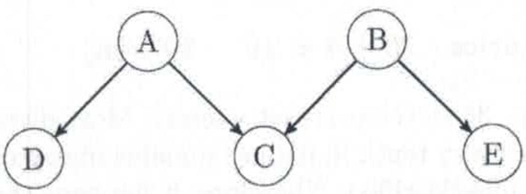
(a) Student A's network

(b) Student B's network

Figure 1: Two student created network structures.

Task 3 Probabilistic Propagation (4 + 12 = 16 30 min)

Consider the following Bayesian network and the corresponding (conditional) probability distributions:



$P(D\|A)$	$A = a_1$	$A = a_2$
$D = d_1$	0.2	0.7
$D = d_2$	0.8	0.3

$P(E\|B)$	$B = b_1$	$B = b_2$
$E = e_1$	0.5	0.2
$E = e_2$	0.5	0.8

$P(A)$	$A = a_1$	$A = a_2$
	0.5	0.5

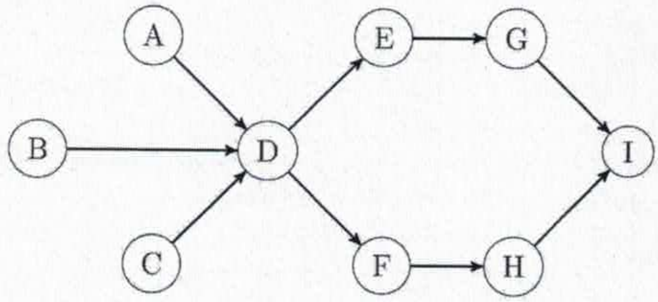
$P(B)$	$B = b_1$	$B = b_2$
	0.3	0.7

$P(C \mid A,\ B)$	$A = a_1$		$A = a_2$	
	$B = b_1$	$B = b_2$	$B = b_1$	$B = b_2$
$C = c_1$	0.4	0.9	0.2	0.3
$C = c_2$	0.6	0.1	0.8	0.7

a) Calculate the a-priori distribution of the attributes C, D, and E.

b) After some time you observe $D = d_1$ and $E = e_1$. Propagate this evidence across the network and determine the a-posteriori distribution of the attributes A, B, and C.

Task 4 **Construction of Clique Trees ($2+2+2+2+2=10$ 20 min)**



Construct for the depicted Bayesian network

a) the moral graph,
b) a triangulated moral graph
c) a perfect ordering using maximum cardinality search, and
d) a clique tree/join tree!

Which of the construction steps are **in general** deterministic/non-deterministic?

Task 5 **Structure from Independences ($7+3=10$ 20 min)**

Assume the following conditional independencies between the attributes A, B, C, D, E, F, G and H (as in former exercises, the notation $X \perp\!\!\!\perp Y \mid Z$ states that X is independent of Y given Z):

$$\begin{array}{lll} C \perp\!\!\!\perp G \mid \emptyset & CFG \perp\!\!\!\perp E \mid \emptyset & CG \perp\!\!\!\perp ABDEH \mid F \\ CDEFGH \perp\!\!\!\perp A \mid B & ABCEFG \perp\!\!\!\perp D \mid H & EH \perp\!\!\!\perp B \mid F \end{array}$$

Assume further that only these independencies as well as those that are deducible by the graphoid axioms hold true (i.e. the symmetric counterparts $EG \perp\!\!\!\perp A \mid DH$ etc. are satisfied). All other conditional independencies do not hold true.

a) Which conditional independence graph over all attributes can be read from this set of marginal and conditional indepencies?

b) Provide the rules for building the graph from these indepency statements!