

**Exercise Sheet 9**

**Exercise 28**      Learning from Data

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

$$A \perp\!\!\!\perp B \mid \emptyset, \quad A \perp\!\!\!\perp D \mid C, \quad B \perp\!\!\!\perp D \mid C$$

Assume further that only these independencies as well as those that are deducible by the graphoid axioms (cf. lecture slides) hold true (i.e. the symmetric counterparts  $B \perp\!\!\!\perp A \mid \emptyset$  etc. are satisfied). All other conditional independencies do not hold true. Which conditional independence graph over the four attributes can be read from this information?

(Hint: Remember the special properties of converging edges.)

**Exercise 29**      Learning from Data

A simple approach to learn a graphical model from data consists in constructing an optimal spanning tree w.r.t. edge weights that represent the strengths of the attributes connected by that edge. Such a tree is named after its inventors Chow-Liu tree. We consider here the construction of a maximal spanning tree in the relational setting with the Hartley information gain

$$\begin{aligned} I_{\text{gain}}^{(\text{Hartley})}(A, B) &= \log_2 \left( \sum_{i=1}^{n_A} R(A = a_i) \right) + \log_2 \left( \sum_{j=1}^{n_B} R(B = b_j) \right) \\ &\quad - \log_2 \left( \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} R(A = a_i, B = b_j) \right) \\ &= \log_2 \frac{\left( \sum_{i=1}^{n_A} R(A = a_i) \right) \left( \sum_{j=1}^{n_B} R(B = b_j) \right)}{\sum_{i=1}^{n_A} \sum_{j=1}^{n_B} R(A = a_i, B = b_j)}. \end{aligned}$$

as the measure to assess the strength of dependence between attributes  $A$  and  $B$ : Determine for the relation from exercise 13 (repeated below) the Chow-Liu tree w.r.t. the Hartley information gain! Compare the result with the result of exercise 13!

$A$	$a_1$	$a_1$	$a_2$	$a_2$	$a_2$	$a_2$	$a_3$	$a_3$
$B$	$b_1$	$b_1$	$b_1$	$b_1$	$b_3$	$b_3$	$b_1$	$b_2$
$C$	$c_1$	$c_2$	$c_2$	$c_3$	$c_2$	$c_3$	$c_2$	$c_2$

**Exercise 30**      Learning from Data

Consider the following probability distribution:

	$C = c_1$		$C = c_2$	
	$B = b_1$	$B = b_2$	$B = b_1$	$B = b_2$
$A = a_1$	4/35	12/35	4/35	1/35
$A = a_2$	1/35	3/35	8/35	2/35

Determine the Chow-Liu tree for that distribution w.r.t. the Shannon information gain

$$I_{\text{gain}}^{(\text{Shannon})}(A, B) = \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} P(A = a_i, B = b_j) \log_2 \frac{P(A = a_i, B = b_j)}{P(A = a_i) \cdot P(B = b_j)},$$

i.e. use the Shannon information gain as the edge weight and determine the maximal spanning tree! Does the result represent a correct decomposition?