Lehr- und Forschungsgebiet Informatik 5
RWTH Aachen

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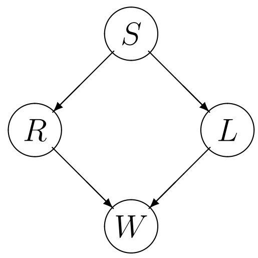
Introduction to Artificial Intelligence (Winter 2016)
6. Assignment

Submit your solution electronically via the L2P until 31.01.2017.

Homework assignments are optional but strongly recommended.

Exercise 6.1 (21 points)

In the belief network on the right the random variables S, R, L, W stand for "season", "raining", "lawn sprinkler on", "sidewalk wet", respectively. The CPTs (Conditional Probability Tables) for R, L, W are given by the following tables:



S	$P(R \mid \ldots)$
spring	0.45
summer	0.15
autumn	0.35
winter	0.20

S	$P(L \mid \ldots)$
spring	0.15
summer	0.30
autumn	0.05
winter	0.00

R	L	$P(W \mid \ldots)$
T	T	0.95
T	F	0.95
F	T	0.90
F	F	0.05

The prior probability for each of the four seasons (*spring*, *summer*, *autumn*, *winter*) is 0.25. The accuracy of your answers (to all parts of this exercise) should be at least three decimal places.

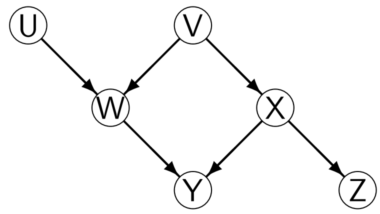
(a) Compute $P(W \wedge \neg L \wedge R \wedge S{=}spring)$.

(b) If it is not raining and the lawn sprinkler is off: how likely is winter?
(i. e.: Compute $P(S{=}winter \mid \neg R \wedge \neg L)$.)

(c) What is the probability for rain in the summer when the sidewalk is wet? [1]
(i. e.: What is $P(R \mid W \wedge S{=}summer)$?)

Exercise 6.2 (24 points)

Consider the belief network shown on the right.



Use d-separation to determine which of the following holds.

(a) $\{\mathsf{U}\}$ is independent of $\{\mathsf{V}\}$ given $\{\mathsf{Z}\}$.

(b) $\{\mathsf{U}, \mathsf{W}\}$ is independent of $\{\mathsf{X}, \mathsf{Z}\}$ given $\{\mathsf{Y}\}$.

(c) $\{\mathsf{U}, \mathsf{W}\}$ is independent of $\{\mathsf{X}, \mathsf{Z}\}$ given $\{\mathsf{V}\}$.

(d) $\{\mathsf{W}\}$ is independent of $\{\mathsf{X}\}$ given $\{\mathsf{U}\}$.

(e) $\{\mathsf{U}\}$ is independent of $\{\mathsf{V}\}$ given $\{\}$.

(f) $\{\mathsf{U}\}$ is independent of $\{\mathsf{Z}\}$ given $\{\}$.

[1] Before computing it, try a rough guess. (Guess at least whether it is greater or less than 0.5?)

Exercise 6.3 **(25 points)**

The opposite table contains (fictitious) examples of holiday trips and also shows how much fun the holiday trip was.

Generate a decision tree from these examples using the DECISION-TREE-LEARNING algorithm in order to predict the expected fun for arbitrary holiday trips.

example	attributes				goal
	country	season	type	weeks	fun
1	Italy	summer	repose	2	much
2	Italy	winter	sports	1	much
3	Austria	winter	culture	1	little
4	Austria	winter	repose	3	little
5	Austria	winter	sports	1	much
6	Spain	summer	repose	3	much
7	Spain	summer	sports	2	much
8	Spain	winter	repose	2	little

(You may assume that all possible values of the attributes are already mentioned in the examples.) Report all the information gains from the attribute tests that have to be computed when choosing the *best* attribute.

Exercise 6.4 **(30 points)**

The table on the right contains (again fictitious) examples of car observations (brand of the car, number of persons in the car, driving attitude of the driver, parking skills of the driver) and also shows the gender of the driver.

In this exercise a perceptron shall be trained using the examples in the table.

example	attributes				goal
	brand	persons	attitude	parking	gender
1	VW	2	defensive	good	female
2	BMW	3	offensive	bad	male
3	BMW	1	offensive	normal	male
4	Audi	2	defensive	bad	female
5	Audi	1	offensive	good	female
6	VW	3	defensive	bad	female
7	BMW	1	offensive	good	female
8	VW	2	offensive	bad	male

To this end, in part (a), the attributes have to be transformed into numeric inputs first.

Then, in part (c), NEURAL-NETWORK-LEARNING can be applied.

(a) For encoding the examples use the eight inputs I_{A}, I_{B}, I_{V}, $I_{\#}$, I_{*}, I_{g}, I_{n}, I_{b}, where the attributes "brand", "attitude", "parking" are encoded by the following schemes:

brand	I_{A}	I_{B}	I_{V}
Audi	1	0	0
BMW	0	1	0
VW	0	0	1

attitude	I_{*}
defensive	1
offensive	0

parking	I_{g}	I_{n}	I_{b}
good	1	0	0
normal	0	1	0
bad	0	0	1

The values of the attribute "persons" can directly serve as input $I_{\#}$ since they are numeric. For the goal attribute "gender", 1 represents "female" and 0 represents "male".

Set up the following table of transformed examples where T denotes the correct output.

example	I_A	I_B	I_V	$I_\#$	I_*	I_g	I_n	I_b	T
1	0	0	1	2	1	1	0	0	1
2									
⋮									
8									

(b) Determine for all the attributes "brand", "persons", "attitude", "parking", and "gender" whether local encoding or distributed encoding was used in part (a).

(c) Use the transformed examples of part (a) to train a perceptron that has eight inputs, namely I_A, I_B, I_V, $I_\#$, I_*, I_g, I_n, I_b with corresponding weights W_A, W_B, W_V, $W_\#$, W_*, W_g, W_n, W_b. Let the activation function be $step_0$, the learning rate be 2, and the weights initialized by +1. (For the given examples, these settings yield a fast convergence.)

As a trace of the Neural-Network-Learning algorithm applied to the examples of part (a), set up the following table where O denotes the perceptron output and $E = T - O$ is the error. You must include the output and the error for every example but you may omit weights whose values are not changed. In the table below, the first half of epoch 1 is already entered. [2]

	example	O	E	W_A	W_B	W_V	$W_\#$	W_*	W_g	W_n	W_b
initial.				+1	+1	+1	+1	+1	+1	+1	+1
epoch 1	1	1	0								
	2	1	−1		−1		−5				−1
	3	0	0								
	4	0	+1	+3			−1	+3			+1
	5										
	6										
	7										
	8										
epoch 2	1										
	⋮										
	8										
epoch 3	⋮										

[Hint: If you did not make a mistake — neither here nor in part (a) — it should turn out that all examples are correctly predicted in epoch 3. Thus use this hint to verify your solution (as a necessary (but not sufficient) condition).]

[2] You are invited to solve this exercise by implementing the perceptron learning algorithm on a computer and applying this program to the given examples. Of course, this exercise can be solved "by hand", too.