CSCE 582 Spring 2020

Final Exam

Take Home Exam to be Turned in via Departmental Dropbox on 2020-05-02 by 23:55.

Version of 2020-04-24
Open Book and Notes

This is a take-home exam. You are allowed to use your textbook, notes, and materials on the course website. You are not allowed to consult with each other or with anyone else. You are not allowed to review solutions of textbook exercises, old exams, or other material from websites. If in doubt, please assume a strict version of this policy or ask me.

If you obtained fewer than 90% of the points on any assignment exercise during the semester, you are allowed to resubmit it with the final exam.

Please submit your work as a single pdf file, with the resubmitted exercises clearly labeled (with homework number and exercise numbers) at the end of the file. Also submit Hugin .net files in a .zip archive; this archive may contain files related to resubmitted exercises.

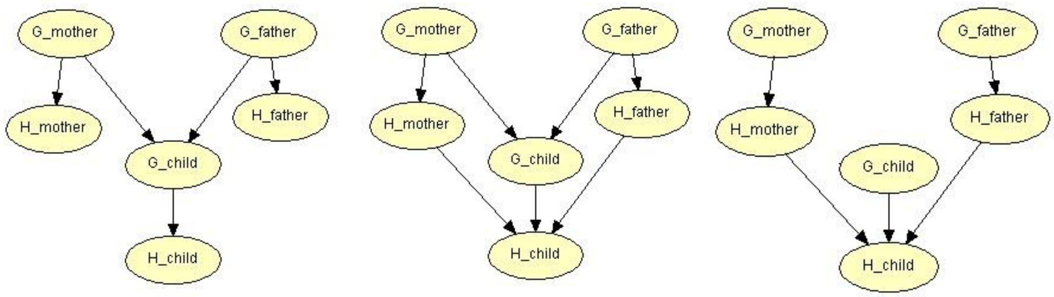
Question 1 (60 points; no Hugin file required)

This question is from Chapter 14 of: Russell, Stuart and Norvig, Peter. *Artificial Intelligence: A Modern Approach, 3rd edition*, Prentice-Hall, 2010.

Let H_x be a random variable denoting the handedness of an individual *x*, with possible values *l* or *r*. A common (and almost certainly incorrect) hypothesis is that left- or righthandedness in inherited by a simple mechanism: that is, perhaps there is a gene G_x, also with values *l* or *r*, and perhaps actual handedness turns out to be the mostly the same (with some probability *s*) as the gene an individual possesses. Furthermore, perhaps the gene itself is equally likely to be inherited from either of an individual's parents, with a small nonzero probability *m* of random mutation flipping the handedness.

a. Which of the three networks below claim(s) that $P(G_{father}, G_{mother}, G_{child}) = P(G_{father})P(G_{mother})P(G_{child})$? Explain your answer using d-separation.

(c) claims that $P(G_{father}, G_{mother}, G_{child}) = P(G_{father})P(G_{mother})P(G_{child})$. There is a diverging connection between each pair in G_{father}, G_{mother}, G_{child}.



(a) (b) (c)

b. Which of the three networks make independence claims that are consistent with the hypothesis about the inheritance of handedness?

(a) & (b)

c. Which of the three networks is the best description of the hypothesis? Justify your answer. Choose one of the three networks.

(a). Since (b) does not stay true to the hypothesis because it allows for additional dependencies. (c) is not consistent with the hypothesis about the inheritance of handedness

d. Fill in the CPT for the G_{child} node in network (a) in terms of s and m. Let the values of G_{child}, G_{father}, and G_{mother} be l (for left-handed) and r (for right-handed). Some values are entered for you.

G_{father}	l	l	r	r
G_{mother}	l	r	l	r
l	$l-m$	$1/2$	$1/2$	m
r	m	½	$1/2$	$l-m$

e. Suppose that $P(G_{father} = l) = P(G_{mother}=l) = q$. In network (a), derive an expression for $P(G_{child} = l)$ in terms of m and q only, by conditioning on its parent nodes. Start as follows:

$$(\qquad =) = \qquad\qquad = \qquad , \qquad , \qquad = \cdots$$

,

f. Under conditions of genetic equilibrium, we expect the distribution of genes to be the same across generations. Use this to calculate the value of q, and, given what you know about handedness in humans, explain why the hypothesis described at the beginning of the question must be wrong.

e.) $P(G_{child} = 1) = \sum_{g_m, g_f} P(G_{child} = 1 \mid g_m, g_f)\, P(g_m, g_f) =$

$$P(G_{child} = 1) = \sum_{g_m g_f} P(G_{child} = 1 \mid g_m, g_f)\, P(g_m, g_f)$$

$$= \sum_{g_m g_f} P(G_{child} = 1 \mid g_m, g_f)\, P(g_m)\, P(g_f)$$

$$= (1-m)\, q^2 + 0.5\, q\, (1-q) + 0.5\, (1-q)\, q + m\, (1-q)^2$$

$$= q^2 - mq^2 + q - q^2 + m - 2mq + mq^2$$

$$= q + m - 2mq$$

f.) Equilibrium means that $P(G_{child} = 1)$ must equal $P(G_{mother} = 1)$ and $P(G_{father} = 1)$

$$q + m - 2mq = q \quad \therefore \quad q = 0.5$$

Question 2 (60 points. Hugin file required. Adapted from [J96], i.e. Finn V. Jensen, *An Introduction to Bayesian Networks*, Springer, 1996.)

You must interpret a scene consisting of an image that shows a breakfast table for one person, and the task is to determine whether it is a continental or a British breakfast table. British breakfast is usually composed of tea, bacon and eggs, and toast with marmalade (which is orange), while continental breakfast consists of coffee, boiled eggs, and rolls with strawberry jam (which is red).

Possible objects include a plate (usually big for British breakfast or small for continental breakfast), a cup (for tea or coffee), either a tea pot or a coffee pot, a jar (with either orange or red contents), and cutlery. We assume that a British breakfast always requires fork and knife, while a continental breakfast always requires spoon and knife.

Big plates are confused with small plates (and vice versa) with probability 0.1. Teacups may be taken for coffee cups with probability 0.3 and coffee cups for teacups with probability 0.2. Tea pots and coffee pots are confused with probability 0.4. The color of the contents of a jar is determined correctly in 95% of the cases. Knives are taken for spoons with probability 0.05 and for forks with probability 0.1. Spoons are never taken for knives, but for forks with probability 0.25. A fork is recognized as a spoon with probability 0.2, and as a knife with probability 0.1.

Cutlery never come in identical (e.g., two forks) pairs, and if there is a fork, then there is also a knife on the table.

Six objects are identified on the table: a pot, a jar, a plate, a cup, two pieces of cutlery.

Construct a model for interpretation of the scene. First, draw a Bayesian network structure (30 points). Second, add prior and conditional probability tables (30 points). You may want to interpret “usual” as 99 out of 100. Try your model on some configurations of objects. Include screenshots of the results of running Hugin on these configurations in your pdf file.

Question 3 (30 points; no Hugin file required)

Do exercise 9.8 in the textbook.

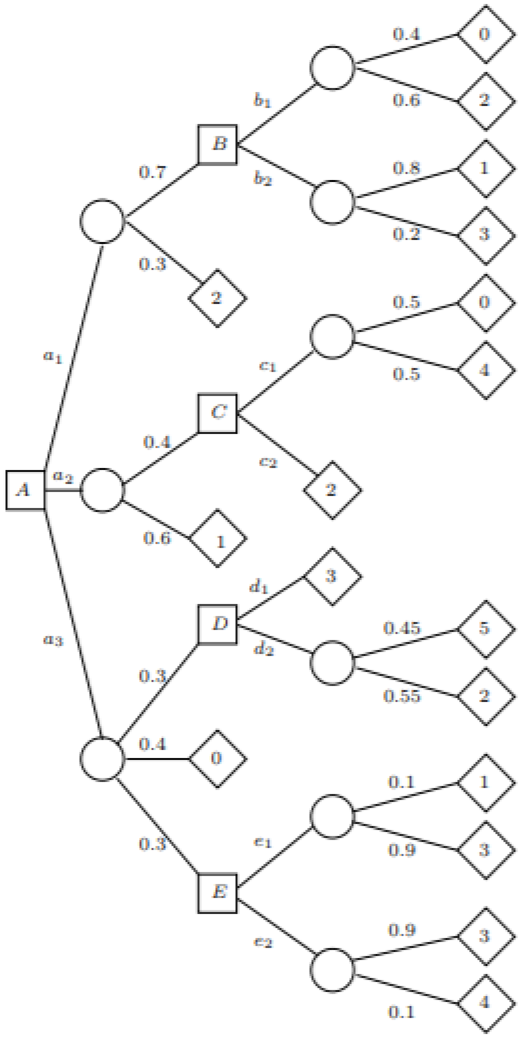


Fig. 9.47. Figure for Exercise 9.8.

First choose a3. Then if observation is the upper branch, then choose d2, if lower branch, then choose e2. The expected utility of the strategy is 1.905

Question
4 (20 points; no Hugin file required)

This question is based on: Allan L. Jensen and Finn V. Jensen. "MIDAS---An Influence Diagram for Management of Mildew in Winter Wheat." *Proceedings of UAI-96*, pp.349356.

(a) Approximately two months before harvesting a wheat field a farmer can observe the state of the crop and can observe whether it has been attacked by mildew. If there is an attack, the farmer should decide on a treatment with fungicides. Draw both a perfect recall influence diagram and a LIMID with the following nodes:

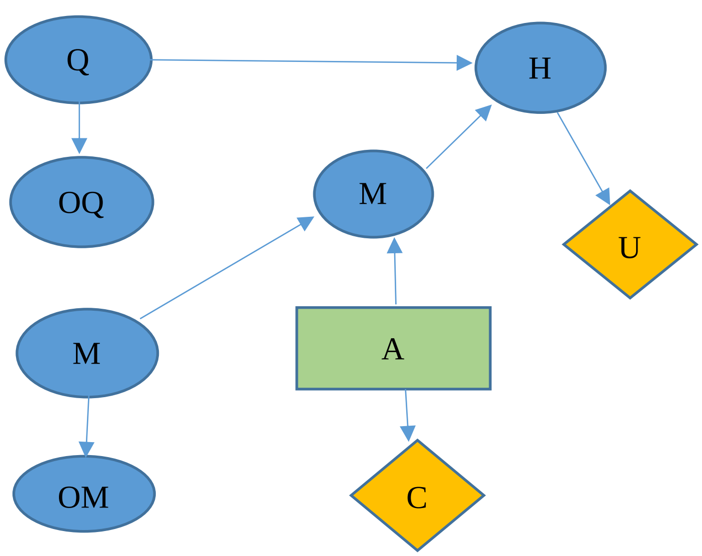
Six chance nodes:

- *The current state of the crop,* ***Q*** *with states fair (f), average (a), good (g) and very good (v)*
- *The current mildew-situation,* ***M*** *with states no, little (l), moderate (m) and severe (s)*
- *The mildew situation after fungicide-treatment,* ***M****, *which has the same states as* ***M***, *and which has the same distribution as* ***M*** *if there is no fungicide-treatment.*
- *The state of the crop at harvest time,* ***H*** *with the states from* ***Q*** *plus rotten (r), bad (b) and poor (p)*
- *The observation,* ***OQ***, *of* ***Q***
- *The observation,* ***OM***, *of* ***M***

One action node, ***A*** *(modeling the fungicide-treatment) with actions no, light (l), moderate (m) and heavy (h).*

Two utility nodes: ***C*** *(the cost of treatment) and* ***U*** *(the price obtained at harvest time).*

Explain the reason for the additional edges in the LIMID.



The influence diagram

Question

5 (30 points for part (i); 30 points for part (ii): 60 points total; Hugin file required). Do Exercise 9.11 [J07].

The expected utility of the strategy is $22,500.

Question

6 (Required for graduate students only; extra credit for undergraduate students; 60 points; Hugin file required): Do Exercise 3.27. You do not need to write a formal proof for part (iv); a brief argument or proof sketch is enough. Recall that the satisfiability problem for formulas in 3CNF is NP-complete.

(i) Hugin file attached. Since the probability of Result = y is positive, there are assignments of truth values making the expression true.

(ii) Insert A = n and B = n as evidence and propagate. If you insert "Result = y" and propagate, the assignments must be C = y, D = y, E = y, F = y.