Solutions and/or hints for the EDAF70 exam from 2018–03–15

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1 Search (JM)

Question 1 As I didn't mention anything about node ordering, every path of depth 3 would be OK here, as we talk about **breadt-first search**. So both G_1 and G_2 are valid answers, with one of the paths $SADG_1$, $SBDG_1$, $SBCG_2$, or $SBEG_2$.

Question 2 Let us expand the nodes, one by one, using the heuristic function of expert 1. X_{g+h}^{PPP} denotes the search node X, with current path PPP and with the evaluation function value $f = g + h$:

1. S_{0+10}, expand S;
2. $A_{6+9}^{SA}, B_{4+8}^{SB}$, expand B;
3. $A_{6+9}^{SA}, A_{5+9}^{SBA}, C_{9+5}^{SBC}, D_{9+3}^{SBD}, E_{6+6}^{SBE}$, expand D;
4. $A_{6+9}^{SA}, A_{5+9}^{SBA}, C_{9+5}^{SBC}, E_{6+6}^{SBE}, F_{10+2}^{SBDF}, G1_{15+0}^{SBDG1}$, expand E;
5. $A_{6+9}^{SA}, A_{5+9}^{SBA}, C_{9+5}^{SBC}, F_{10+2}^{SBDF}, G1_{15+0}^{SBDG1}, F_{9+2}^{SBEF}, G2_{14+0}^{SBEG2}$, expand F_{9+2};
6. $A_{6+9}^{SA}, A_{5+9}^{SBA}, C_{9+5}^{SBC}, F_{10+2}^{SBDF}, G1_{15+0}^{SBDG1}, G2_{14+0}^{SBEG2}, G1_{12+0}^{SBEFG1}, G2_{13+0}^{SBEFG2}$, expand F_{10+2} (alphabetical order again!);
7. $A_{6+9}^{SA}, A_{5+9}^{SBA}, C_{9+5}^{SBC}, G1_{15+0}^{SBDG1}, G2_{14+0}^{SBEG2}, G1_{12+0}^{SBEFG1}, G2_{13+0}^{SBEFG2}, G1_{13+0}^{SBDFG1}, G2_{14+0}^{SBDFG2}$, expand $G1_{12+0}^{SBEFG1}$;
8. GOAL node!

So the order of node expansion is $SBDEFFG_1$, the path is $SBEFG_1$ and the university chosen is G_1.

Question 3 No. The distance from A to goal is 7, thus h_1 overestimates and cannot be admissible.

Question 4 No. The distance from A to goal is 7, thus h_2 overestimates and cannot be admissible.

Question 5 The optimal heuristic would provide the actual distances to the goal:

S	12
A	7
B	8
C	6
D	4
E	6
F	3
G1	0
G2	0

The order of node expansion:

1. S_{0+12}, expand S;
2. $A^{SA}_{6+7}, B^{SB}_{4+8}$, expand B;
3. $A^{SA}_{6+7}, A^{SBA}_{5+7}, C^{SBC}_{9+6}, D^{SBD}_{9+4}, E^{SBE}_{6+6}$, expand A_{5+7};
4. $A^{SA}_{6+7}, C^{SBC}_{9+6}, D^{SBD}_{9+4}, E^{SBE}_{6+6}, D^{SBAD}_{8+4}$, expand D_{8+4};
5. $A^{SA}_{6+7}, C^{SBC}_{9+6}, D^{SBD}_{9+4}, E^{SBE}_{6+6}, F^{SBADF}_{9+3}, G1^{SBADG1}_{14+0}$, expand E;
6. $A^{SA}_{6+7}, C^{SBC}_{9+6}, D^{SBD}_{9+4}, F^{SBADF}_{9+3}, G1^{SBADG1}_{14+0}, F^{SBEF}_{9+3}, G2^{SBEG2}_{14+0}$, expand F^{SBADF} (note a tie, two possibilities!);
7. $A^{SA}_{6+7}, C^{SBC}_{9+6}, D^{SBD}_{9+4}, G1^{SBADG1}_{14+0}, F^{SBEF}_{9+3}, G2^{SBEG2}_{14+0}, G1^{SBADFG1}_{12+0}, G2^{SBADFG2}_{13+0}$, expand F^{SBEF} (alphabetical ordering!);
8. $A^{SA}_{6+7}, C^{SBC}_{9+6}, D^{SBD}_{9+4}, G1^{SBADG1}_{14+0}, G2^{SBEG2}_{14+0}, G1^{SBADFG1}_{12+0}, G2^{SBADFG2}_{13+0}, G1^{SBEFG1}_{12+0}$, $G2^{SBEFG2}_{13+0}$, expand $G1_{12+0}$ (note a tie again!!);
9. GOAL node!

The order of node expansion in all four cases will be SBADEFFG1 and there will be two possible solutions: SBADFG1 and SBEFG1. Either is, of course, correct.

Question 6 Any heuristic function underestimating at one or more positions will do, e.g.,

S	10
A	6
B	7
C	2
D	3
E	5
F	2
G1	0
G2	0

2 Planning (JM)

Here we have quite much freedom in choosing the predicates and operators. What is necessary is to characterize all positons as empty or not, arms as holding something or not, plates as being drilled through or not.

Task 1 State predicates I used:

- $plate(x)$
- $feeder(x)$
- $hashole(x)$
- $fixture(x)$
- $inlocation(obj, loc)$
- $outputtray(x)$
- $holding(hand, obj)$
- $empty(x)$
- $hand(x)$
- $screwed(obj1, obj2)$

Task 2 I assume just two plates, more would need to be introduced by their proper names.

- $hand(LH)$
- $empty(LH)$
- $hand(RH)$
- $empty(RH)$
- $plate(plate1)$

- $inlocation(plate1, feeder1)$
- $plate(plate2)$
- $inlocation(plate2, feeder1)$
- $feeder(feeder1)$
- $outputtray(ot1)$
- $fixture(fx1)$
- $empty(ot1)$
- $empty(fx1)$

Task 3 There are at least four operators needed: $pick(hand, object, from)$, $place(hand, object, to)$, $screw(object1, object2)$, $drill(object)$. Possible formalizations look as follows:

TO BE COMPLETED

Task 4 Goal:

$screwed(plate1, plate2) \wedge inlocation(plate1, ot1) \wedge inlocation(plate2, ot1)$

The last literal is not necessary.

Task 5 The answer depends actually on your formalization: if there are negative preconditions then the domain is NOT a STRIPS domain, otherwise it is.

3 Reasoning (JM), 3+5+5

It suffices to use propositional logic to formalize the problem. Let us use the following symbols:

T - a teacher
D - a docent
P - a professor
A - an artist
PhD - has defended a PhD
Pic - has painted a picture

The knowledge provided in the text can be formalized as follows:

$$T \to D, \quad P \to T, \quad D \to PhD \vee (A \wedge Pic), \quad A \to \neg PhD, \quad T$$

The question amounts to proving P, D, and PhD, respectively.

Only the second one, D, is true given the contents of our knowledge base (a teacher needs not to be a professor, nor does she need to have defended a PhD).

Backward Chaining

1. Goal: D;
2. Given $T \rightarrow D$, goal: T;
3. Given T, success.

Resolution Transform the knowledge base into the disjunctive normal form:

$$\neg T \vee D$$

$$\neg P \vee T$$

$$\neg D \vee PhD \vee A$$

$$\neg D \vee PhD \vee Pic$$

$$\neg A \vee \neg PhD$$

$$T$$

Add the negation of the query:

$$\neg D$$

and we immediately get empty clause from (1) first resolving $\neg T \vee D$ with T and obtaining D and (2) then resolving it with $\neg D$.

4 Machine learning (PN)

No answers will be provided.

5 Probabilistic reasoning / Bayesian Networks (EAT), 8 + 4 + 6 + 10 + 2

Please note: As probabilistic reasoning tasks most often require quite some interpretation and hence reasoning themselves, this solution is probably not the absolute truth. Other solutions might have generated points as well, given a comprehensible and thought through explanation and argumentation.

a) Two networks are accepted, one that describes exactly the situation in the mixed bowl, and one that describes the entire task's base distribution. The most important item was to identify the "coating" (dark or milk chocolate) as absolutely independent from everything else in either case. The networks and CPTs are shown in the following figures:

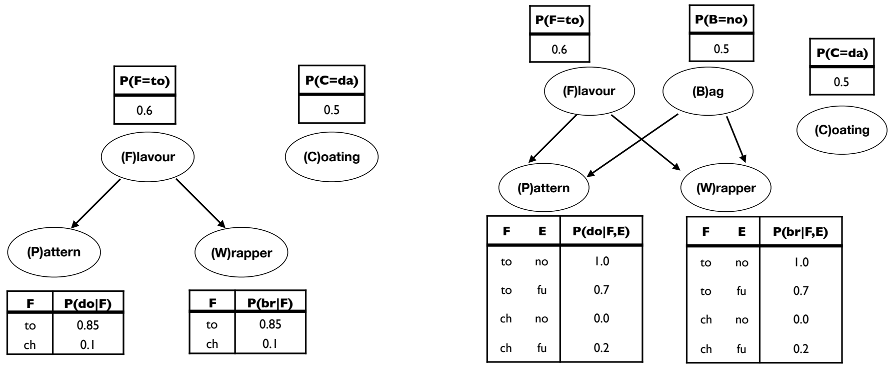

Figure 1: Mixed case only (left) and general BN (right)

The probability of getting chili in a dark, dotted, brown wrapped egg is then found, e.g., by calculating the probability distribution over Flavour $= < Toffee, Chili >$ for the mixed bowl:

$$\begin{aligned}
\mathbb{P}(F|da, do, br) &= 0.5 * \mathbb{P}(F|do, br) \\
&= 0.5 * \alpha * P(do, br|F)\mathbb{P}(F) \\
&= \alpha * P(do|F) * P(br|F) * \mathbb{P}(F) \\
&= \alpha * < 0.85 * 0.85 * 0.6, \quad 0.1 * 0.1 * 0.4 > \\
&=< 0.991, 0.009 >
\end{aligned}$$

Hence, getting toffee flavour when going for a brown egg that has dots on it has a probability of 0.991.

b) There are different ways of getting to the solution (simple counting and accepting “partial eggs” for the calculation was one of them), but essentially it boils down to calculating (in the mixed setting):

$$P(F = ch|br) = \frac{P(br|ch) * P(ch)}{P(brown)} = \frac{0.1 * 0.4}{0.55} \approx 0.073$$

with

$$P(br) = P(br|ch) + P(br|to) = 0.85 * 0.6 + 0.1 * 0.4 = 0.55.$$

This means, that the probability of getting chili flavour in a brown egg is very low, only about 0.073.

c) This is using the same approach as in a), but only using the “fun bag” as basis (or, if the network reflects the general case, using the network) to calculate the probability distribution for Flavour $= < toffee, chili >$:

$$\begin{aligned}\mathbb{P}(F|da, do, br) &= 0.5 * \mathbb{P}(F|do, br)\\ &= 0.5 * \alpha * P(do, br|F)\mathbb{P}(F)\\ &= \alpha * P(do|F) * P(br|F) * \mathbb{P}(F)\\ &= \alpha * < 0.7 * 0.7 * 0.6, 0.2 * 0.2 * 0.4 >\\ &\approx < 0.95, 0.05 > .\end{aligned}$$

Your uncle would thus have a good chance of picking something suitable, i.e., 0.95.

d) Now, you look for the a posteriori probabilities for the two hypotheses "h1: B = normal" and "h2: B = funny" after two observations. One assumption you can make here is that the observation (grabbing) of one egg does not change the distributions in the bowl, which is not entirely true, but allowed for the sake of simplicity. We get then for the distribution over Bag $= < normal, funny >$

$$\begin{aligned}\mathbb{P}(B|da, wa, re, ch) &= \alpha * P(da, wa, re, ch|B) * \mathbb{P}(B)\\ &= \alpha * P(da, wa, re, |ch, B) * P(ch|B)\mathbb{P}(B)\\ &= \alpha * P(da, wa, re, |ch, B) * P(ch)\mathbb{P}(B)\end{aligned}$$

knowing that Flavour and Bag are independent of each other. This means for the MAP-hypotheses after the two observations:

$$\begin{aligned}P(h1|da, wa, re, ch) &= \alpha * P(da, wa, re, |ch, h1)^2 * P(ch)^2 P(h1)\\ &= \alpha * (0.5 * 1.0 * 1.0 * 0.4)^2 \approx 0.71 \quad and\\ P(h2|da, wa, re, ch) &= \alpha * P(da, wa, re, |ch, h2)^2 * P(ch)^2 P(h2)\\ &= \alpha * (0.5 * 0.8 * 0.8 * 0.4)^2 \approx 0.29.\end{aligned}$$

This tells us, that it is much more likely that the bowl the eggs were taken from is the classic, or normal, bag, however, we cannot be absolutely sure. Observing a single egg with brown wrapper and waves however, no matter the flavour or coating, will tell us immediately and with certainty (given that no mistakes are made in the factory), that the eggs are from a funny bag, as the combination of wave pattern and brown wrapper is not possible in a normal one.

e) Check with the lecture material on Bayesian Learning, i.e., compare the formulas. Both the OBC and the FF approaches use a MAP calculation to base their predictions on. These calculations are done on previous observations, i.e., one could state that FF uses an optimal Bayes Learner to handle the filtering process.