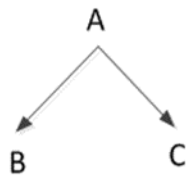
CSci 384: Artificial Intelligence **Spring, 2020**

Instructor: Dr. M. E. Kim **Date: April 10, 2020**

Home Assignment 6: Solution

Q1. [10] In the given Bayesian network where P(a) = .4, P(b|a) = .3, P(b|$\neg a$) = .2, P(c|a) = .8, P(c|$\neg a$) =.5, compute the ***distribution*** of P(B | c).



$<P(b \mid c),\ P(\sim b \mid c)> = \alpha < P(b, c),\ P(\sim b, c) >$ where $\alpha = 1/ P(c)$

$= \alpha < \sum_a P(a, b, c),\ \sum_a P(a, \sim b, c) >$

$= \alpha < \sum_a P(a)P(b|a)P(c|a),\ \sum_a P(a)P(\sim b|a)P(c|a) >$

$= \alpha < P(a)P(b|a)P(c|a)+ P(\sim a)P(b|\sim a)P(c|\sim a),\ P(a)P(\sim b|a)P(c|a)+ P(\sim a)P(\sim b|\sim a)P(c|\sim a) >$

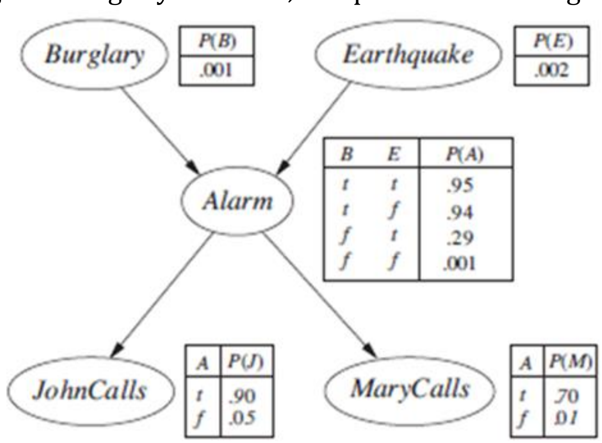
$= \alpha <.4*.3*.8+.6*.2*.5,\ .4*.7*.8+.6*.8*.5 >$

$= \alpha < .156,\ .464 >$

$= < .156 / (.156 + .464),\ .084/(.156 + .464) >$

$= < 0.2516,\ 0.7484 >$

Q2. [35] In the given Burglary Network, compute the followings.



(1) the distribution of P(A), P(J), P(M), i.e. (P(a), P($\neg a$)),

P(a) = P(a, b, e) + P(a, ~b, e) + P(a, b, ~e) + P(a, ~b, ~e)

= P(a|b, e)P(b, e) + P(a|~b, e)P(~b, e) + P(a|b, ~e)P(b, ~e) + P(a|~b, ~e)P(~b, ~e)

= 0.95*0.001*0.002 + 0.29*0.999*0.002 + 0.94*0.001*0.998 + 0.001*0.999*0.998

= 0.00252.

So, <P(a), P(~a)> = <**0.00252, 0.99748** >

$P(j) = P(j, a) + P(j, \sim a) = P(j|a)P(a) + P(j|\sim a)P(\sim a)$

$= 0.9 * 0.00252 + 0.05 * 0.99748$

$= 0.052142$

So, $<P(j), P(\sim j)> = <$ **0.052142, 0.947858** $>$

$P(m) = P(m, a) + P(m, \sim a) = P(m|a)P(a) + P(m|\sim a)P(\sim a)$

$= 0.7 * 0.00252 + 0.01 * 0.99748$

$= 0.011739$

So, $<P(m), P(\sim m)> = <$ **0.011739, 0.988261** $>$

(2) $P(j \mid b) = P(j, b)/P(b) = [P(j, b, a) + P(j, b, \neg a)]/P(b)$

$= [P(j|a)P(a|b)P(b) + P(j|\sim a)P(\sim a|b)P(b)] / P(b)$

$= P(j|a)P(a|b) + P(j|\sim a)P(\sim a|b)$

where $P(a|b)^{**} = P(a,b)/P(b) = [P(a, b, e) + P(a, b, \sim e)] /P(b)$ **

$= [P(a|b, e)P(b, e) + P(a|b,\sim e)P(b, \sim e)] /P(b)$

$= [P(a|b, e)P(b)P(e)+P(a|b, \sim e)P(b)P(\sim e)]/P(b)$

$= P(a|b, e)P(e) + P(a|b, \sim e)P(\sim e)$

$= P(j|a)[P(a|b, e)P(e) + P(a|b, \sim e)P(\sim e)] + P(j|\sim a) [P(\sim a|b, e)P(e) + P(\sim a|b, \sim e)P(\sim e)]$

$= 0.9 * (0.95 * 0.002 + 0.94 *0.998) + 0.05 * (0.05 * 0.002 + 0.06 * 0.998)$

= **0.849017**

(3) $P(a \mid b)^{**} = P(a|b, e)P(e) + P(a|b, \sim e)P(\sim e)$

$= 0.95 *0.002 + 0.94 * 0.998$

= **0.94002**

(4) $P(j \text{ or } m \mid b)$

Using De Morgan's law:

$P(j \text{ or } m \mid b) = P(\sim(\sim j, \sim m) \mid b) = 1 - P(\sim j, \sim m|b)$

$= 1 - [P(\sim j|a)P(\sim m|a)P(a|b) + P(\sim j|\sim a)P(\sim m|\sim a)P(\sim a|b)]$ **

$= 1 - [0.1 * 0.3 * 0.94002 + .95 * 0.99 * 0.05998$

= 0.915388

OR

$P(j \text{ or } m \mid b) = P(j \mid b) + P(m \mid b) - P(j, m \mid b)$

{ where $P(m|b) = P(m,b)/P(b) = [P(m, b, a) + P(m, b, \neg a)]/P(b)$

$= [P(m|a)P(a|b)P(b) + P(m|\sim a)P(\sim a|b)P(b)] / P(b)$

$= P(m|a)P(a|b) + P(m|\sim a)P(\sim a|b)$

$= P(m|a)[P(a|b,e)P(e)+P(a,|b,\sim e)P(\sim e)]$

$+ P(m|\sim a)[P(\sim a|b, e)P(e) + P(\sim a|b, \sim e)P(\sim e)]$

$= 0.7* (0.95 * 0.002 + 0.94 *0.998)$

$+ 0.01*(0.05 * 0.002 + 0.06 * 0.998)$

$= 0.658614$

where $P(j, m| b) = P(j,m|a)P(a|b) + P(j,m|\sim a)P(\sim a|b)$

$= P(j|a)P(m|a)P(a|b) + P(j|\sim a)P(m|\sim a)P(\sim a|b)$

$= 0.9 * 0.7 * 0.94002 + .05 * 0.01 * 0.05998$

= 0.592513 }

= 0.849017 + 0.658614 - 0.592513

= 0.912119

(5) $P(b \mid m)$ = P(m|b)P(b) / P(m) = 0.658614 * 0.001/ 0.011739

= 0.056105

(6) $P(e|\neg a)$ = P(e, ~a)/P(~a)

= [P(e, ~a, b) + P(e, ~a, ~b)] / P(~a)

= [P(~a|b, e)P(b)P(e) + P(~a|~b, e)P(~b)P(e)] /P(~a)

= [0.05 * 0.01 * 0.002 + 0.71 * 0.999 * 0.002] / 0.99748 from (1)

= 0.001423

Q3. [10] A diagnostic system is to be made for a dynamo-powered bicycle light using a Bayesian network. The variables are defined below:

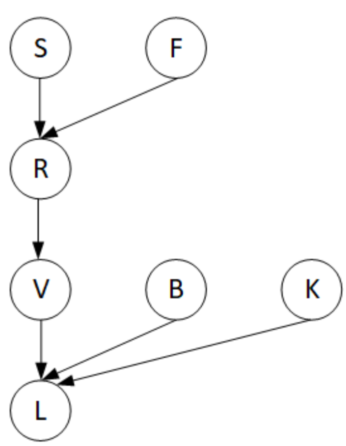
Variable	**Value**	**Meaning**
L	true / false	Light is on
S	dry, wet, snow	Street condition
F	true / false	Dynamo flywheel worn out
R	true / false	Dynamo sliding
V	true / false	Dynamo shows voltage
B	true / false	Light bulb OK
K	true / false	Cable OK

The following variables are independent: S, F, B, K.

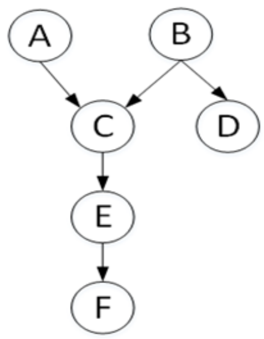
Th following pairs of variables are independent: (R, B), (R, K), (V, B), (V, K)

and the following equation holds: P(L | V, R) = P(L|V), P(V |R, S) = P(V | R), P(V | R, F) = P(V | R).

Draw the Bayesian network with the given variables in the Causal model.



Q4. [30] Consider the following belief network with Boolean variables and the following conditional probabilities:



$P(a) = 0.02$	$P(d \mid b) = 0.9$
$P(b) = 0.01$	$P(d \mid \neg b) = 0.01$
$P(c \mid a, b) = 0.5$	$P(e \mid c) = 0.88$
$P(c \mid a, \neg b) = 0.99$	$P(e \mid \neg c) = 0.001$
$P(c \mid \neg a, b) = 0.85$	$P(f \mid e) = 0.75$
$P(c \mid \neg a, \neg b) = 0.0001$	$P(f \mid \neg e) = 0.01$

(1) [15] a) Compute the conditional distribution $P(A \mid d, f)$ using Variable Elimination (VE).
b) Which variables are irrelevant to inference? First, prune irrelevant variables. Show the complete computation steps with the factors that are created for a given elimination ordering.

All the variables are relevant because they're ancestors of {A, D, F}.

$P(\mathbf{A} \mid \mathbf{d}, \mathbf{f}) = \alpha P(\mathbf{A}, \mathbf{d}, \mathbf{f})$ where $\alpha = 1 / P(d, f)$

$= \alpha \sum_b \sum_c \sum_e P(\mathbf{A}, b, c, \mathbf{d}, e, \mathbf{f})$

$= \alpha \sum_b \sum_c \sum_e P(\mathbf{A})P(b)P(c|A, b)P(d|b)P(e|c)P(f|e)$

$= \alpha P(A) \sum_b P(b)P(d|b) \sum_c P(c|A, b) \sum_e P(e|c)P(f|e)$

$= \alpha P(A) \sum_b P(b)P(d|b) \sum_c P(c|A, b) \sum_e f_4(E, C)\, f_5(f, E)$

where

$f_5(f, E) = P(f|E) = (P(f|e), P(f|{\sim}e)) = (.75,\ .01)$

$f_4(E, C) = P(E|C) = \begin{pmatrix} P(e|c) & P(e|{\sim}c) \\ P({\sim}e|c) & P({\sim}e|{\sim}c) \end{pmatrix} = \begin{pmatrix} .88, & .001 \\ .12, & .999 \end{pmatrix}$

$= \alpha P(A) \sum_b P(b)P(d|b) \sum_c P(c|A, b)\, f_6(f, C)$

where

$f_6(f, C) = \sum_e f_4(E, C)\, f_5(f, E)$

$= \sum_e \begin{pmatrix} .88, & .001 \\ .12, & .999 \end{pmatrix} (.75,\ .01)$

$= (.88 * .75 + .12 * .01,\quad .001 * .75 + .999 * .01)$

$= (.6612,\ .01074) \qquad = (P(f|c),\ P(f|{\sim}c))$

$= \alpha\, P(A) \sum_b P(b)P(d|b) \sum_c f_7(C, A, B)\, f_6(f, C)$

where

$$f_7(C,A,B) = P(c|A,b) = \left(\begin{pmatrix} P(c|a,b) & P(c|a,\sim b) \\ P(c|\sim a,b) & P(c|\sim a,\sim b) \end{pmatrix} \begin{pmatrix} P(\sim c|a,b) & P(\sim c|a,\sim b) \\ P(\sim c|\sim a,b) & P(\sim c|\sim a,\sim b) \end{pmatrix} \right)$$

$$= \left(\begin{pmatrix} .5 & .99 \\ .85 & .0001 \end{pmatrix} \begin{pmatrix} .5 & .01 \\ .15 & .9999 \end{pmatrix} \right)$$

$= \alpha\, P(A) \sum_b P(b)P(d|b)\, f_8(f, A, B)$

where

$$f_8(f, A, B) = \sum_c f_7(C, A, B)\, f_6(f, C)$$

$$= \sum_c \left(\begin{pmatrix} P(c|a,b) & P(c|a,\sim b) \\ P(c|\sim a,b) & P(c|\sim a,\sim b) \end{pmatrix} \begin{pmatrix} P(\sim c|a,b) & P(\sim c|a,\sim b) \\ P(\sim c|\sim a,b) & P(\sim c|\sim a,\sim b) \end{pmatrix} \right) (P(f|c),\ P(f|\sim c))$$

$$= \sum_c \left(\begin{pmatrix} .5 & .99 \\ .85 & .0001 \end{pmatrix} \begin{pmatrix} .5 & .01 \\ .15 & .9999 \end{pmatrix} \right) (.6612,\ .01074)$$

$$= \left(\begin{pmatrix} .5 & .99 \\ .85 & .0001 \end{pmatrix} * 0.6612 + \begin{pmatrix} .5 & .01 \\ .15 & .9999 \end{pmatrix} * 0.01074 \right)$$

$$= \begin{pmatrix} .33597 & .654695 \\ .563631 & .010805 \end{pmatrix} \qquad = \begin{pmatrix} P(f|a,b) & P(f|a,\sim b) \\ P(f|\sim a,b) & P(f|\sim a,\sim b) \end{pmatrix}$$

$= \alpha\, P(A) \sum_b f_{10}(B)\, f_9(d, B)\, f_8(f, A, B)$

$f_9(d, B) = (P(d|b),\ P(d|\sim b)) = (\ .9,\ .01\ )$

$f_{10}(B) = (\ P(b),\ P(\sim b)\ ) = (.01,\ .99)$

$= \alpha\, P(A)\, f_{11}(A, d, f\,)$

where

$$f_{11}(\,A, d, f\,) = \sum_b f_{10}(B)\, f_9(d, B)\, f_8(f, A, B)$$

$$= \sum_b (\ P(b),\ P(\sim b))\ (P(d|b),\ P(d|\sim b)) \begin{pmatrix} P(f|a,b) & P(f|a,\sim b) \\ P(f|\sim a,b) & P(f|\sim a,\sim b) \end{pmatrix}$$

$$= \sum_b (.01,\ .99)\ (\ .9,\ .01\ ) \begin{pmatrix} .33597 & .654695 \\ .563631 & .010805 \end{pmatrix}$$

$$= .01*.9*\begin{pmatrix} .33597 \\ .56363 \end{pmatrix} + .99 * .01 * \begin{pmatrix} .6547 \\ .01081 \end{pmatrix}$$

$$= \begin{pmatrix} .003024 \\ .005073 \end{pmatrix} + \begin{pmatrix} .006481 \\ ..000107 \end{pmatrix}$$

$$= \begin{pmatrix} .009505 \\ .00518 \end{pmatrix} \qquad = \begin{pmatrix} P(f,d|a) \\ P(f,d|\sim a) \end{pmatrix}$$

$= \alpha\, f_{12}(A)\, f_{11}(A, d, f\,)$

where

$f_{12}(A) = (P(a), P(\sim a)) = (\ .02,\ .98\ )$

$$= \ \alpha\ (\ .02,\ .98\ ) \begin{pmatrix} .009505 \\ .00518 \end{pmatrix}$$

$= \ \alpha\ (\ .00019,\ \ .005076\ ) \qquad = (P\ (f, d, a),\ \ P(f, d, \sim a)\ )$

$= \ \left(\frac{.00019}{(.00019+.005076)}, \frac{.005076}{(.00019+.005076)} \right) \qquad$ where $\alpha = 1\ /\ P(d, f)$

= (.036099, .963901) = < P(*a* | *d, f*), P(~*a* | *d, f*) >

(2) [15] c) Compute P(e | b) using VE. a) Which variables are irrelevant to inference? b) Which factors can be reused from (1)? d) Show the factors that are different from those in (1).

a) Irrelevant variables D and F

b) The reused factors

f1(C, **e**) = P(e|C) = (P(e|c), P(e|~c)) = (.88, .001) - part of f4 in 1) with **e**.

f2(A, C, **b**) = $\begin{pmatrix} P(c|a,b) & P(\sim c|a,b) \\ P(c|\sim a,b) & P(\sim c|\sim a,b) \end{pmatrix} = \begin{pmatrix} .5 & .5 \\ .85 & .15 \end{pmatrix}$ - part of f7 in 1) with **b**.

c) P(e | b) = α P(e, b) where α = 1/P(b)

= α $\sum_a \sum_c \sum_d \sum_f$ P(a, b, c, d, e, f)

= α $\sum_a \sum_c$ P(a, b, c, e) because D and F are irrelevant.

= α $\sum_a \sum_c$ P(A)P(b)P(C|A, b)P(e|C)

= α P(b)$\sum_a$ P(A) $\sum_c$ P(C|A, b) P(e|C)

= α P(b)$\sum_a$ P(A) $\sum_c$ f2(A, C, b) f1(C, e)

where f1(C, **e**) = P(e|C) = (P(e|c), P(e|~c)) = (.88, .001) - part of f4 in 1) with **e**.

f2(A, C, **b**) = $\begin{pmatrix} P(c|a,b) & P(\sim c|a,\ b) \\ P(c|\sim a,b) & P(\sim c|\sim a,b) \end{pmatrix} = \begin{pmatrix} .5 & .5 \\ .85 & .15 \end{pmatrix}$ - part of f7 in 1) with **b**.

= α P(b)$\sum_a$ P(A) f3(A, **b**)

where

f3(A, **b**) = $\sum_c$ f2(A, C, b) f1(C, e)

$= \sum_c \begin{pmatrix} P(c|a,b) & P(\sim c|a,b) \\ P(c|\sim a,b) & P(\sim c|\sim a,b) \end{pmatrix}$ (P(e|c), P(e|~c))

$= \sum_c \begin{pmatrix} .5 & .5 \\ .85 & .15 \end{pmatrix}$(.88, .001)

$= \begin{pmatrix} .5 \\ .85 \end{pmatrix} * .88 + \begin{pmatrix} .5 \\ .15 \end{pmatrix} * .001$

$= \begin{pmatrix} .4405 \\ .74815 \end{pmatrix} \qquad = \begin{pmatrix} P(e|a,b) \\ P(e|\sim a,b) \end{pmatrix}$

= α P(b)f4(b)

= f4(b) since α = 1/P(b)

= $\sum_a$ P(A) f3(A, b)

$= \sum_a (P(a),\ P(\sim a)) \begin{pmatrix} P(e|a,b) \\ P(e|\sim a,b) \end{pmatrix}$

$= \sum_a (.02, .98) \begin{pmatrix} .4405 \\ .74815 \end{pmatrix}$

= .02 * .4405 + .98* .74815

= **.821287 = P(e | b)**

Q5. [15] In the given Bayesian network, compute the following probabilities.

(1) [15] Compute the probability that an elderly female who is over 60 gets no cancer (i.e. benign).

P(C=malignant | Age > 60, Gender=female)

= α ∑e ∑s P(C=malignant, old, female, e, s)

where e = Exposure2Toxic, s = Smoking

= α ∑e ∑s P(C=malignant |e, s) P(e| old) P(s | old, female) P(old) P(female)

$= \alpha$ P(old) P(female) $\sum e \sum s$ P(e| old) P(C=malignant |e, s) P(s | old, female)
i.e. P(C=malignant| old, female)
$= \alpha$ P(old) P(female) [P(e| old) P(malignant | e, s)P(s| old, female)
+ P(e| old) P(malignant | e, ~s)P(~s | old, female)
+ P(~e| old) P(malignant | ~e, s)P(s| old, female)
+ P(~e| old) P(malignant | ~e, ~s)P(~s | old, female)]
$= \alpha$ P(old) P(female) [.7*.9*.1 + .7*.6*.9 + .3*.6*.1 + .3*.1*.9]
$= \alpha$ P(old) P(female) *.0.486 where P(C=malignant | old female) = 0.486
$= \alpha'$ *.0.486 where $\alpha' = \alpha$ P(old) P(female) = 1
Similarly,
P(C=benign | old, female) = $= \alpha \sum e \sum s$ P(C=benign, old, female, e, s)
$= \alpha$ P(old) P(female) $\sum e \sum s$ P(e| old) P(C=benign |e, s) P(s | old, female)
i.e. P(C=benign)
$= \alpha$ P(old) P(female) *P(C=benign | old female)
$= \alpha'$ *.514 where P(C=benign |old, female) = 1 – P(malignant |old, female)
Thus,
< P(malignant| old, female), P(benign | old, female) >
= < .486/(.486+.514), .514/(.486+.514) >
= <.486, .514 >
OR

P(C=benign | Age > 60, Gender=female) $= \alpha \sum e \sum s$ P(C=benign, old, female, e, s)
where e = Exposure2Toxic, s = Smoking
$= \alpha \sum e \sum s$ P(C=malignant |e, s) P(e| old) P(s | old, male) P(old) P(male)
$= \alpha$ P(old) P(female) $\sum e \sum s$ P(e| old) P(C=benign |e, s) P(s | old, female)
since α = 1 / P(old, female) = 1 / P(old)P(female)
$= \sum e \sum s$ P(e| old) P(C=benign |e, s) P(s | old, female)
= [P(e| old) P(benign| e, s)P(s| old, female)
+ P(e| old) P(benign | e, ~s)P(~s | old, female)
+ P(~e| old) P(benign | ~e, s)P(s| old, female)
+ P(~e| old) P(benign| ~e, ~s)P(~s | old, female)]
= [.7*.1*.1 + .7*.4*.9 + .3*.4*.1 + .3*.9*.9] = 0.514

(2) [15, optional] Compute the probability that an elderly female patient with low Serum Calcium to have no cancer (i.e. benign).

Compute P(C=benign | SC = low, Age > 60, Gender=female) .

Method A.
P(C=benign | SC=low, Age > 60, Gender=female)
$= \alpha$ P(C=benign, SC=low, old, female) where α= P(SC=low, old, female)
$= \alpha$ P(SC=low | C=benign, old, female)P(C=benign, old, female)
// Since SC is conditionally independent of its non-decendants (i.e. Age, Gender) given its parent, Cancer, P(SC= low | benign, old, female) = P(SC=low | malignant)

$= \alpha$ P(SC=low | C=benign)P(C=benign| old, female)P(old, female)
$= \alpha$ P(SC=low | C=benign)P(C=benign| old, female)P(old)P(female)
$= \alpha'$ P(SC=low | C=benign)P(C=benign| old, female)   where $\alpha' = \alpha \cdot$ P(old)P(female)
$= \alpha'\ 0.5 \cdot 0.514$ where P(C=benign| old, female) = 0.514 from (1)
$= 0.257\alpha'$

Similarly,
P(C=malignant | SC=low, old, female)
$= \alpha'$ P(SC=low | C=malignant)P(C=malignant| old, female)   where $\alpha' = \alpha \cdot$ P(old)P(female)
$= \alpha'\ 0.1 \cdot 0.486$ where P(C=malignant| old, female) = 0.486 from (1)
$= 0.0486\ \alpha'$

After normalization,
< P(C=benign | SC=low, old, female), P(C=malignant | SC=low, old, female) >
= < $0.257\alpha'$, $0.0486\ \alpha'$ >
= < 0.257/(0.257 + 0.0486), 0.0486/(0.257 + 0.0486) >
= < **0.841**, 0.159 >

Method B.
Since Cancer is conditionally independent of Age and Gender given its Markov Blanket (Serum Calcium), P(C=benign | SC = low, Age > 60, Gender=female) = P(C=benign | SC = low) .
So, we can simply compute P(C=benign | SC =low).

P(C=malignant | SC = low) = α P(SC=low | C=malignant) P(malignant) = α .1 * .486 = .0486 α
P(C=benign | SC = low) = α P(SC=low | C=benign) P(benign) = α .5 * .514 = .257α

where P(SC = low | C=malignant) = .1 and P(SC = low | C=benign) = .5 in CPT
and P(malignant |old, male) = .486 in (1) and P(benign | old, male) = .514 in 1)

Thus,
< P(C=malignant | SC = low), P(C=benign | SC = low) >
= <.0486α, .257α > = < .0486/(.0486+.257), .257/(.0486+.257)> = **<.159, .841**>

Method C. P(C=malignant | SC = low, Age > 60, Gender=female)
= α P(SC=low | C=malignant, old, female) P(malignant | old, female)
Since SC is conditionally independent of its non-decendants (i.e. Age, Gender) given its parent, Cancer,
P(SC= low | malignant, old, female) = P(SC=low | malignant)
= α P(SC=low | C=malignant) P(malignant| old, female)
= α .1*.486 = .0486 α

Similarly,
P(benign| old, female) = α P(C = benign| old, female) * P(SC = low | C =benign)
= α P(SC = low | C =benign) $\cdot$ P(C = benign| old, female) *

$= \alpha .5 *514$

$= .257\alpha$

After normalization of $<.0486\alpha, .257\alpha> = < ..159,$ **.841** $>$

Method D.

$P(SC = low \mid old, female) = \sum_{cancer} P(SC{=}low \mid Cancer, old, female) * P(Cancer \mid old, female)$

$= P(SC{=}low \mid malignant, old, female)P(malignant \mid old, female)$

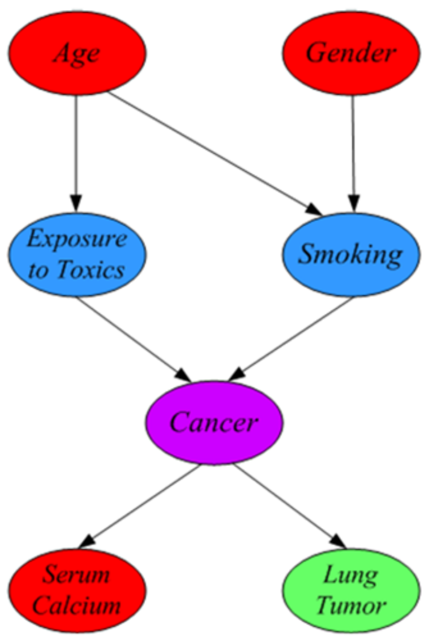
$\quad + P(SC{=}low \mid benign, old, female) P(benign \mid old, female)$

$= .1 * .486 + .5 *(.514) = .0486 + .257 = .3056$

$P(benign \mid SC{=}low, old, female) = (.1 * .486) / .3056 =$ **.841**

Age	P(age)
0 ≤ age < 20	.2
20 ≤ age < 40	.25
40 < age ≤ 60	.25
60 < age	.3

Gender	P(gender)
Male	.6
Female	.4



Age	P(exposure to Toxics | Age)
0 ≤ age < 20	.1
20 ≤ age < 40	.3
40 < age ≤ 60	.6
60 < age	.7

Age	Gender	P(smoking|Age, Gender)
0 ≤ age < 20	Male	.05
0 ≤ age < 20	Female	.02
20 ≤ age < 40	Male	.4
20 ≤ age < 40	Female	.3
40 < age ≤ 60	Male	.4
40 < age ≤ 60	Female	.2
60 < age	Male	.3
60 < age	Female	.1

Exposure to Toxics	Smoking	P(Cancer=malignant | Exposure, Smoking)
True	True	.9
True	False	.6
False	True	.6
False	false	.1

Cancer	P(lung tumor|Cancer)
malignant	.99
benign	.4

Cancer	P(Serum Calcium=high|Cancer)	P(Serum Calcium=med|Cancer)
malignant	.6	.3
benign	.1	.4