A03 - Planning and Uncertainty

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Problem 1

(a)

$\forall s, o, l_1, l_2 .\, at(o, l_1, s) \to \neg at(o, l_2, s)$

(b)

$at(shakey, r_1, S_0) \land at(b_1, r_2, S_0) \land at(b_2, r_3, S_0) \land \neg lightOn(S_0)$
$\exists s.\, at(shakey, r_1, s) \land at(b_1, r_1, s) \land at(b_2, r_2, s) \land lightOn(s)$

(c)

$walkTo(loc_1, loc_2):$
$\forall loc_1, loc_2, s.\, at(shakey, loc_1, s) \land adj(loc_1, loc_2) \to$
$\neg at(shakey, loc_1, do(walkTo(loc_1, loc_2), s)) \land$
$at(shakey, loc_2, do(walkTo(loc_1, loc_2), s))$

$push(box, loc_1, loc_2):$
$\forall box, loc_1, loc_2, s.\, at(box, loc_1, s) \land adj(loc_1, loc_2) \land at(shakey, loc_1, s) \to$
$\neg at(box, loc_1, do(push(box, loc_1, loc_2), s)) \land$
$at(box, loc_2, do(push(box, loc_1, loc_2), s)))$

$turnOn:$
$\forall s.\, at(shakey, r_1, s) \land at(b_1, r_1, s) \land at(b_2, r_2, s) \to$
$lightOn(do(turnOn, s))$

(d)

$ans(do(turnOn, do(walkTo(r_2, r_1), do(walkTo(r_3, r_2), do(push(b_2, r_2),$
$do(walkTo(r_2, r_3), do(push(b_1, r_1), do(walkTo(r_1, r_2), S_0))))))))$

Problem2

(a)

- move(x, a, b):
  - Pre: {clear(x), clear(b), on(x, a), smaller(x, b)}
  - Adds: {clear(a), on(x, b)}
  - Dels: {clear(b), on(x, a)}
- move(x, y, a, b):
  - Pre: {clear(x), clear(b), on(x, y), on(y, a), smaller(y, b)}
  - Adds: {clear(a), on(y, b)}
  - Dels: {clear(b), on(y, a)}
- KB = {clear(d_1), clear(p_2), clear(p_3), on(d_1, d_2), on(d_2, d_3), on(d_3, p_1)}
- GOAL= {clear(p_1), clear(p_2), clear(d_1), on(d_1, d_2), on(d_2, d_3), on(d_3, p_3)}

(b)

$$
\begin{aligned}
S_0 &= \{clear(d_1), clear(p_2), clear(p_3), on(d_1, d_2), on(d_2, d_3), on(d_3, p_1)\} \\
A_0 &= \{move(d_1, d_2, p_2), move(d_1, d_2, p_3), move(d_1, d_2, d_3, p_2), move(d_1, d_2, d_3, p_3)\} \\
S_1 &= \{clear(d_1), clear(p_2), clear(p_3), on(d_1, d_2), on(d_2, d_3), on(d_3, p_1), \\
&\quad clear(d_2), on(d_1, p_2), on(d_1, p_3), clear(d_3), on(d_2, p_2), on(d_2, p_3)\} \\
A_1 &= \{move(d_1, d_2, d_3), move(d_1, p_2, d_2), move(d_1, p_2, d_3), move(d_1, p_2, p_3), \\
&\quad move(d_1, p_3, d_2), move(d_1, p_3, d_3), move(d_1, p_3, p_2), move(d_2, p_2, d_3), \\
&\quad move(d_2, p_2, p_3), move(d_2, p_3, d_3), move(d_2, p_3, p_2), move(d_2, d_3, p_2), \\
&\quad move(d_2, d_3, p_3), move(d_3, p_1, p_2), move(d_3, p_1, p_3), move(d_1, d_2, p_2, d_3), \\
&\quad move(d_1, d_2, p_2, p_3), move(d_1, d_2, p_3, d_3), move(d_1, d_2, p_3, p_2), \\
&\quad move(d_2, d_3, p_1, p_2), move(d_2, d_3, p_1, p_3)\} \\
S_2 &= \{clear(d_1), clear(d_2), clear(d_3), clear(p_1), clear(p_2), clear(p_3), \\
&\quad on(d_1, d_2), on(d_1, d_3), on(d_1, p_2), on(d_1, p_3), on(d_2, d_3), on(d_2, p_2), \\
&\quad on(d_2, p_3), on(d_3, p_1), on(d_3, p_2), on(d_3, p_3)\}
\end{aligned}
$$

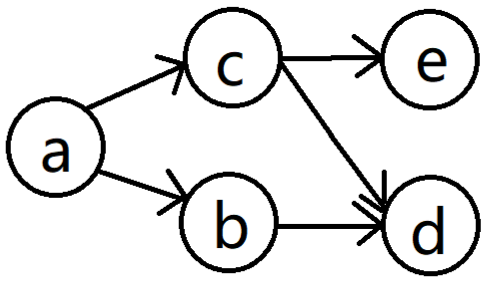
$CountActions(G, S_2):$
$G = \{clear(d_1), clear(p_1), clear(p_2), on(d_1, d_2), on(d_2, d_3), on(d_3, p_3)\}$
$G_P = \{clear(d_1), clear(p_2), on(d_1, d_2), on(d_2, d_3)\}$
$G_N = \{clear(p_1), on(d_3, p_3)\}$
$A = \{move(d_3, p_1, p_3)\}$
$NewG = \{clear(d_1), clear(p_2), on(d_1, d_2), on(d_2, d_3), clear(d_3), clear(p_3), on(d_3, p_1)\}$
$return\ 2$

$CountActions(NewG, S_1):$
$G = \{clear(d_1), clear(p_2), on(d_1, d_2), on(d_2, d_3), clear(d_3), clear(p_3), on(d_3, p_1)\}$
$G_P = \{clear(d_1), clear(p_2), on(d_1, d_2), on(d_2, d_3), clear(p_3), on(d_3, p_1)\}$
$G_N = \{clear(d_3)\}$
$A = \{move(d_2, d_3, p_1)\}$
$return\ 1$

$So\ the\ heuristic\ value\ for\ the\ initial\ state\ is\ 2.$

Problem 3

(a)



(b)

e is independent of a, given c

(c)

$$
\begin{gathered}
P(a,b,c) = P(a) * P(b|a) * P(c|a) = 0.2 * 0.7 * 0.2 = 0.028 \\
P(a,b,\neg c) = P(a) * P(b|a) * P(\neg c|a) = 0.2 * 0.7 * 0.8 = 0.112 \\
P(a,\neg b,c) = P(a) * P(\neg b|a) * P(c|a) = 0.2 * 0.3 * 0.2 = 0.012 \\
P(a,\neg b,\neg c) = P(a) * P(\neg b|a) * P(\neg c|a) = 0.2 * 0.3 * 0.8 = 0.048 \\
P(\neg a,b,c) = P(\neg a) * P(b|\neg a) * P(c|\neg a) = 0.8 * 0.2 * 0.05 = 0.008 \\
P(\neg a,b,\neg c) = P(\neg a) * P(b|\neg a) * P(\neg c|\neg a) = 0.8 * 0.2 * 0.95 = 0.152 \\
P(\neg a,\neg b,c) = P(\neg a) * P(\neg b|\neg a) * P(c|\neg a) = 0.8 * 0.8 * 0.05 = 0.032 \\
P(\neg a,\neg b,\neg c) = P(\neg a) * P(\neg b|\neg a) * P(\neg c|\neg a) = 0.8 * 0.8 * 0.95 = 0.608
\end{gathered}
$$

(d)

$$
\begin{gathered}
P(a,d,\neg e) = \sum_b \sum_c P(a)P(b|a)P(c|a)P(d|b,c)P(\neg e|c) \\
= P(a) \sum_b \sum_c P(b|a)P(c|a)P(d|b,c)P(\neg e|c) \\
= P(a) * (P(b|a)P(c|a)P(d|b,c)P(\neg e|c) + P(b|a)P(\neg c|a)P(d|b,\neg c)P(\neg e|\neg c) + \\
P(\neg b|a)P(c|a)P(d|\neg b,c)P(\neg e|c) + P(\neg b|a)P(\neg c|a)P(d|\neg b,\neg c)P(\neg e|\neg c)) \\
= 0.2 * (0.0336 + 0.1568 + 0.0126 + 0.0048) = 0.04156
\end{gathered}
$$

$$
\begin{gathered}
P(d,\neg e) = \sum_a \sum_b \sum_c P(a)P(b|a)P(c|a)P(d|b,c)P(\neg e|c) \\
= 0.00672 + 0.03136 + 0.00252 + 0.00096 + 0.00192 + 0.04256 + 0.00672 + 0.01216 = 0.10492
\end{gathered}
$$

$$
\begin{gathered}
P(a|d,\neg e) = \frac{P(a,d,\neg e)}{P(d,\neg e)} = \frac{0.04156}{0.10492} \approx 0.3961 \\
P(\neg a|d,\neg e) = 1 - P(a|d,\neg e) \approx 0.6038
\end{gathered}
$$

So the student is less inclined to have game addiction.

Problem 4

(a)

$Factors: f_1(A), f_2(B), f_3(A,B,C), f_4(B,D), f_5(C,E), f_6(C,F)$
$Query: P(E)?$
$Evidence: None.$
$Elim. Order: F, D, C, B, A$

$Restriction: None.$

$Step1: Eliminating\ F: Compute\&Add\ f_7(C) = \sum_F f_6(C,F)$
$Remove: f_6(C,F)$

$Step2: Eliminating\ D: Compute\&Add\ f_8(B) = \sum_D f_4(B,D)$
$Remove: f_4(B,D)$

$Step3: Eliminating\ C: Compute\&Add\ f_9(A,B,E) = \sum_C f_7(C) f_5(C,E) f_3(A,B,C)$
$Remove: f_7(C), f_5(C,E), f_3(A,B,C)$

$Step4: Eliminating\ B: Compute\&Add\ f_{10}(A,E) = \sum_B f_9(A,B,E) f_8(B) f_2(B)$
$Remove: f_9(A,B,E), f_8(B), f_2(B)$

$Step5: Eliminating\ A: Compute\&Add\ f_{11}(E) = \sum_A f_{10}(A,E) f_1(A)$
$Remove: f_{10}(A,E) f_1(A)$

$Last\ factors: f_{11}(E)$

$f_1(A)$	$f_2(B)$	$f_3(A,B,C)$	$f_4(B,D)$	$f_5(C,E)$	$f_6(C,F)$
a 0.8	b 0.2	abc 0.2	bd 0.1	ce 0.8	cf 0.2
~a 0.2	~b 0.8	ab~c 0.8	b~d 0.9	c~e 0.2	c~f 0.8
		a~bc 0.7	~bd 0.8	~ce 0.1	~cf 0.8
		a~b~c 0.3	~b~d 0.2	~c~e 0.9	~c~f 0.2
		~abc 0.8			
		~ab~c 0.2			
		~a~bc 0.4			
		~a~b~c 0.6			

$f_7(C)$	$f_8(B)$	$f_9(A,B,E)$	$f_{10}(A,E)$	$f_{11}(E)$
c 1.0	b 1.0	abe 0.24	ae 0.52	e 0.5032
~c 1.0	~b 1.0	ab~e 0.76	a~e 0.48	~e 0.4968
		a~be 0.59	~ae 0.436	
		a~b~e 0.41	~a~e 0.564	
		~abe 0.66		
		~ab~e 0.34		
		~a~be 0.38		
		~a~b~e 0.62		

So we can get $P(e) = 0.5032$.

(b)

$$Factors: f_1(A), f_2(B), f_3(A,B,C), f_4(B,D), f_5(C,E), f_6(C,F)$$
$$Query: P(E)?$$
$$Evidence: F = \neg f.$$
$$Elim. Order: D, C, B, A$$

$$Restriction: replace\ f_6(C,F)\ with\ f_7(C) = f_6(C,\neg f)$$

$$Step1: Eliminating\ D: Compute\&Add\ f_8(B) = \textstyle\sum_D f_4(B,D)$$
$$Remove: f_4(B,D)$$

$$Step2: Eliminating\ C: Compute\&Add\ f_9(A,B,E) = \textstyle\sum_C f_7(C) f_5(C,E) f_3(A,B,C)$$
$$Remove: f_7(C), f_5(C,E), f_3(A,B,C)$$

$$Step3: Eliminating\ B: Compute\&Add\ f_{10}(A,E) = \textstyle\sum_B f_9(A,B,E) f_8(B) f_2(B)$$
$$Remove: f_9(A,B,E), f_8(B), f_2(B)$$

$$Step4: Eliminating\ A: Compute\&Add\ f_{11}(E) = \textstyle\sum_A f_{10}(A,E) f_1(A)$$
$$Remove: f_{10}(A,E), f_1(A)$$

$f_1(A)$	$f_2(B)$	$f_3(A, B, C)$	$f_4(B, D)$	$f_5(C, E)$	$f_6(C, F)$
√(reused)	√(reused)	√(reused)	√(reused)	√(reused)	√(reused)
$f_7(C)$	$f_8(B)$	$f_9(A, B, E)$	$f_{10}(A, E)$	$f_{11}(E)$	
×(not reused)	√(reused)	×(not reused)	×(not reused)	×(not reused)	