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T03 Planning and Uncertainty

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目录

1 Q1

(a) $(at(o, l1, s) \bigwedge \neg at(o, l2, s)) \bigvee (at(o, l2, s) \bigwedge \neg at(o, l1, s))$

(b) s_0: $\neg lightOn(s_0) \bigwedge at(shakey, r1, s_0) \bigwedge at(b1, r2, s_0) \bigwedge at(b2, r3, s_0)$
goal situation: $\exists s, lightOn(\phi(s))$

(c) walkTo(loc1,loc2)
precondition: at(shakey,loc1,s)
effect: $at(shakey, loc2, s) \bigwedge \neg at(shakey, loc1, s)$

push(box,loc1,loc2)
precondition: $at(shakey, loc1, s) \bigwedge at(box, loc1, s)$
effect: $at(box, loc2, s) \bigwedge \neg at(box, loc1, s)$

turnOn
precondition: $at(b1, r1, s) \bigwedge at(b2, r2, s) \bigwedge at(shakey, r1, s)$
effect: $lightOn(s)$

(d) $do(turnOn, do(walkTo(r2, r1), do(push(b1, r2, r1), do(walkTo(r3, r2),$
$do(push(b2, r3, r2), do(walkTo(r2, r3), do(walkTo(r1, r2)))))))$

2 Q2

(a)
- actions:
  - move(x, a, b):
    Pre:{on(x, a), clear(x), clear(b), smaller(x, b)}
    Adds:{on(x, b), clear(a)}
    Dels:{on(x, a), clear(b)}
  - moveTwo(x, y, a, b):
    Pre:{on(x, y), on(y, a), clear(x), clear(b), smaller(y, b)}
    Adds:{on(y, b), clear(a)}
    Dels:{on(y, a), clear(b)}
- initial KB: $\{on(d_1, d_2), on(d_2, d_3), on(d_3, p_1), clear(d_1), clear(p_2), clear(p_3)\}$
- goal: $\{on(d_1, d_2), on(d_2, d_3), on(d_3, p_3), clear(d_1), clear(p_1), clear(p_2)\}$

(b) Reachability Analysis:

$S_0 = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2), on(d_3, p_1), clear(p_3)\}$

$A_0 = \{[on(d_1, d_2), clear(d_1), clear(p_2), smaller(d_1, p_2)]move(d_1, d_2, p_2)[on(d_1, p_2), clear(d_2)],$

$[on(d_1, d_2), clear(d_1), clear(p_3), smaller(d_1, p_3)]move(d_1, d_2, p_3)[on(d_1, p_3), clear(d_2)],$

$[on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2), smaller(d_2, p_2)]move(d_1, d_2, d_3, p_2)[on(d_2, p_2), clear(d_3)]$

$[on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_3), smaller(d_2, p_3)]move(d_1, d_2, d_3, p_3)[on(d_2, p_3), clear(d_3)]\}$

$S_1 = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2), on(d_3, p_1), clear(p_3), on(d_1, p_2),$

$on(d_1, p_3), clear(d_2), on(d_2, p_2), on(d_2, p_3), clear(d_3)\}$

$A_1 = \{[on(d_3, p_1), clear(d_3), clear(p_3), smaller(d_3, p_3)]move(d_3, p_1, p_3)[on(d_3, p_3), clear(p_1)] \cdots\}$

$S_2 = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2), on(d_3, p_3), clear(p_1), on(d_3, p_1),$

$clear(p_3), on(d_1, p_2), on(d_1, p_3), clear(d_2), on(d_2, p_2), on(d_2, p_3), clear(d_3) \cdots\}$

因为goal $\notin S_1$, goal $\in S_2$, 所以停止, 接下来计算启发式函数的值。

$CountAction(G, S_2)$:

$G_P = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2)\}$

$G_N = \{on(d_3, p_3), clear(p_1)\}$

$A = \{move(d_3, p_1, p_3)\}$

$G_1 = G_P \cup Pre(A) = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2), on(d_3, p_1), clear(d_3), clear(p_3)\}$

$return\ 1 + CountAction(G_1, S_1)$

$CountAction(G_1, S_1)$:

$G_P = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2)\}$

$G_N = \{on(d_3, p_1), clear(d_3), clear(p_3)\}$

$A = \{move(d_1, d_2, d_3, p_2)\}$

$G_2 = G_P \cup Pre(A) = \{on(d_1, d_2), on(d_2, d_3), clear(d_1), clear(p_2)\}$

$return\ 1 + CountAction(G_2, S_0)$

$CountAction(G_2, S_0) = 0$

综上：$CountAction(G, S_2) = 1 + 1 + 0 = 2$

3 Q3

1. (a) see the Figure 1.

   (b) e is independent of a,b,d, given c.

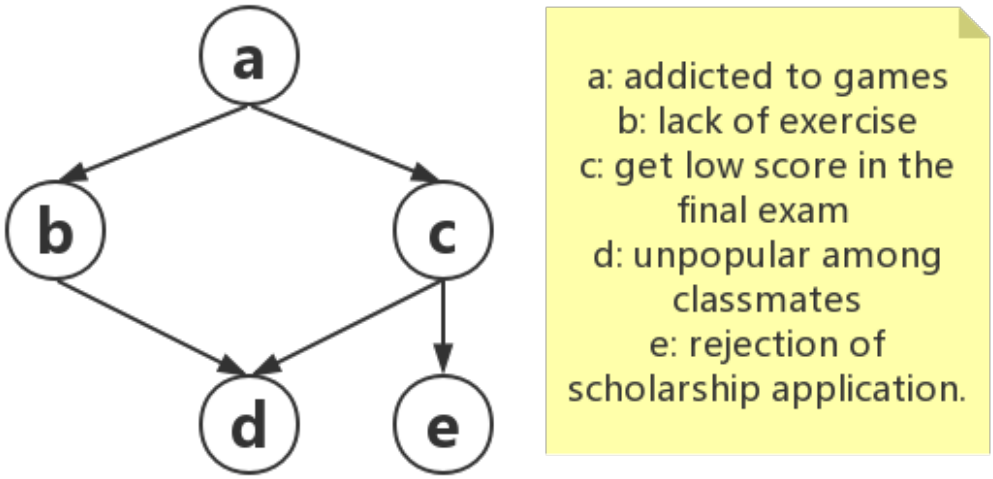

图 1: Q3 1(a)

b is independent of c, given a.

d is independent of a, given b and c.

(c) 设节点a的因子为$f_1(A)$, 节点b因子为$f_2(A,B)$, 节点c因子为 $f_3(A,C)$, 节点d因子为$f_4(B,C,D)$, 节点e因子为$f_5(C,E)$，由题目已知条件得到表1

						bcd	0.8		
						$bc\neg d$	0.2		
		ab	0.7	ac	0.2	$b\neg cd$	0.7	ce	0.7
a	0.2	$a\neg b$	0.3	$a\neg c$	0.8	$b\neg c\neg d$	0.3	$c\neg e$	0.3
$\neg a$	0.8	$\neg ab$	0.2	$\neg ac$	0.05	$\neg bcd$	0.7	$\neg ce$	0.6
		$\neg a\neg b$	0.8	$\neg a\neg c$	0.95	$\neg bc\neg d$	0.3	$\neg c\neg e$	0.4
						$\neg b\neg cd$	0.05		
						$\neg b\neg c\neg d$	0.95		

表 1: $f_1(A), f_2(A,B), f_3(A,C), f_4(B,C,D), f_5(C,E)$

$$
\begin{aligned}
&P(A,B,C|-d,e)\\
&=\sum_{A,B,C}P(A,B,C,-d,e)\\
&=\sum_{A,B,C}P(A)P(B|A)P(C|A)P(-d|B,C)P(e|C)\\
&=\sum_{A}P(A)\sum_{B}P(B|A)\sum_{C}P(C|A)P(e|C)P(-d|B,C)\\
&=P(a)\sum_{B}P(B|a)\sum_{C}P(C|a)P(e|C)P(d|B,C)\\
&+P(-a)\sum_{B}P(B|-a)\sum_{C}P(C|-a)P(e|C)P(d|B,C)\\
&=P(a)P(b|a)\sum_{C}P(C|a)P(e|C)P(d|b,C)\\
&+P(a)P(-b|a)\sum_{C}P(C|a)P(e|C)P(d|-b,C)\\
&+P(-a)P(b|-a)\sum_{C}P(C|-a)P(e|C)P(d|b,C)\\
&+P(-a)P(-b|-a)\sum_{C}P(C|-a)P(e|C)P(d|-b,C)\\
&=P(a)P(b|a)P(c|a)P(e|c)P(d|b,c)+P(a)P(b|a)P(-c|a)P(e|-c)P(d|b,-c)\\
&+P(a)P(-b|a)P(c|a)P(e|c)P(d|-b,c)+P(a)P(-b|a)P(-c|a)P(e|-c)P(d|-b,-c)\\
&+P(-a)P(b|-a)P(c|-a)P(e|c)P(d|b,c)+P(-a)P(b|-a)P(-c|-a)P(e|-c)P(d|b,-c)\\
&+P(-a)P(-b|-a)P(c|-a)P(e|c)P(d|-b,c)+P(-a)P(-b|-a)P(-c|-a)P(e|-c)P(d|-b,-c)
\end{aligned}
$$

将它们归一化后我们可以得到表2

abc	0.1041	$-abc$	0.7506
$ab-c$	0.0033	$-ab-c$	0.0234
$a-bc$	0.0140	$-a-bc$	0.1010
$a-b-c$	0.0004	$-a-b-c$	0.0032

表 2: $f_1(A), f_2(A,B), f_3(A,C), f_4(B,C,D), f_5(C,E)$

(d) 计算$P(a)$，先要计算分布$P(A)$，查询变量为A，证据变量为$D=\neg d, E=e$，相关变量为A,B,C,D,E。

首先限制因子，$f_6(C)=f_5(C,E=e)$,$f_7(B,C)=f_4(B,C,D=-d)$见表3

设消元顺序为B,C。

B: $f_2(A,B), f_7(B,C)$

C: $f_3(A,C), f_6(C)$

消去B，即$f_8(A,C) = \sum_B f_2(A,B) \times f_7(B,C) = f_2(A,b)f_7(b,C) + f_2(A,-b)f_7(-b,C)$

ac	0.1041	$-abc$	0.7506
$a-c$	0.0033	$-ab-c$	0.0234
$-ac$	0.0140	$-a-bc$	0.1010
$-a-c$	0.0004	$-a-b-c$	0.0032

表 3: $f_1(A), f_2(A,B), f_3(A,C), f_4(B,C,D), f_5(C,E)$

2. 设节点A的因子为$f_1(A)$, 节点B因子为$f_2(B)$, 节点C因子为 $f_3(A,B,C)$, 节点D因子为$f_4(B,D)$, 节点E因子为$f_5(C,E)$, 节点F因子为$f_6(C,F)$

				abc	0.2						
				$ab\neg c$	0.8						
				$a\neg bc$	0.7	bd	0.1	ce	0.8	cf	0.2
a	0.8	b	0.2	$a\neg b\neg c$	0.3	$b\neg d$	0.9	$c\neg e$	0.2	$c\neg f$	0.8
$\neg a$	0.2	$\neg b$	0.8	$\neg abc$	0.8	$\neg bd$	0.8	$\neg ce$	0.1	$\neg cf$	0.8
				$\neg ab\neg c$	0.2	$\neg b\neg d$	0.2	$\neg c\neg e$	0.9	$\neg c\neg f$	0.2
				$\neg a\neg bc$	0.4						
				$\neg a\neg b\neg c$	0.6						

表 4: $f_1(A), f_2(B), f_3(A,B,C), f_4(B,D), f_5(C,E), f_6(C,F)$

(a) 计算P(e), 先要计算分布P(E),查询变量为E, 证据变量无, 那么我们只需考虑查询变量E和E的祖先即可,相关变量为E, C, A, B。

设消元顺序为A,B,C。

$A: f_1(A), f_3(A,B,C)$

$B: f_2(B)$

$C: f_5(C,E)$

消去A, 即$f_7(B,C) = \sum_A f_1(A) \times f_3(A,B,C) = f_1(a)f_3(a,B,C) + f_1(\neg a)f_3(\neg a,B,C)$, 见表(5)。

$B: f_2(B), f_7(B,C)$

$C: f_5(C,E)$

消去B, 即$f_8(C) = \sum_B f_2(B) \times f_7(B,C) = f_2(b)f_7(b,C) + f_2(\neg b)f_7(\neg b,C)$,见表(5)。

$C: f_5(C,E), f_8(C)$

消去C, 即$f_9(E) = \sum_C f_5(C,E), f_8(C) = f_5(c,E)f_8(c) + f_5(\neg c,E)f_8(\neg c)$,见表(5)。

因此$P(e) = P(E=e) = f_9(e) = 0.5032$

bc	0.32
$b\neg c$	0.68
$\neg bc$	0.64
$\neg b\neg c$	0.36

c	0.576
$\neg c$	0.424

e	0.5032
$\neg e$	0.4968

表 5: $f_7(B,C), f_8(C), f_9(E)$

(b) 计算$P(e|\neg f)$, 要计算分布$P(E|\neg f) = \alpha P(E,\neg F)$, 相关的变量有E和E的祖先A,B,C还有F(因为证据变量F是相关变量C的后代)。

设消元顺序为A,B,C。

首先限制因子, $f_{10}(C) = f_6(C, F=\neg f)$,见图(6)

$A: f_1(A), f_3(A,B,C)$

$B: f_2(B)$

$C: f_5(C,E), f_{10}(C)$

消去A, 即$f_7(B,C) = \sum_A f_1(A) \times f_3(A,B,C)$, (a)中已经计算出来了，可以直接使用, 见(a)中表(5)。

$B: f_2(B), f_7(B,C)$

$C: f_5(C,E), f_{10}(C)$

消去B, 即$f_8(C) = \sum_B f_2(B) \times f_7(B,C)$, (a)中已经计算出来了，可以直接使用, 见(a)中表(5)。

$C: f_5(C,E), f_{10}(C), f_8(C)$

消去C, 即$f_{11}(E) = \sum_C f_5(C,E) \times f_{10}(C) \times f_8(C)$

最后对$f_{11}(E)$归一化, $f_{12}(E) = \alpha f_{11}(E)$, $\alpha = 1/\sum_E f_{11}(E)$,见表(6)。

因此$P(e|\neg f) = P(E=e|\neg f) = f_{12}(e) = 0.6912$

c	0.8
$\neg c$	0.2

e	0.6912
$\neg e$	0.3088

表 6: $f_{10}(C), f_{12}(E)$