School of Data and Computer Science, Sun Yat-sen University

T03 Planning and Uncertainty

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Contents

1 Situation Calculus

(a) $\forall s \forall o \forall l_1 \forall l_2 [(at(o, l_1, s) \land l_1 \neq l_2) \rightarrow \neg at(o, l_2, s)]$

(b) Initial Situation:

$$\neg lightOn(s_0) \land at(shakey, r_1, s_0) \land at(b_1, r_2, s_0) \land at(b_2, r_3, s_0)$$

Goal Situation:

$$\exists s(lightOn(s) \land at(b_1, r_1, s) \land at(b_2, r_2, s) \land at(shakey, r_1, s))$$

(c)
- $walkTo(loc_1, loc_2)$:

$$\begin{aligned} \forall s, l_1, l_2 . at(shakey, l_1, s) \land adj(l_1, l_2) \\ &\rightarrow at(shakey, l_2, do(walkTo(l_1, l_2), s)) \\ &\land \neg at(shakey, l_1, do(walkTo(l_1, l_2), s)) \end{aligned}$$

- $push(box, loc_1, loc_2)$:

$$\begin{aligned} \forall s, b, l_1, l_2 . at(shakey, l_1, s) \land at(b, l_1, s) \land adj(l_1, l_2) \\ &\rightarrow \neg at(shakey, l_1, do(push(b, l_1, l_2), s)) \\ &\land \neg at(b, l_1, do(push(b, l_1, l_2), s)) \\ &\land at(shakey, l_2, do(push(b, l_1, l_2), s)) \\ &\land at(b, l_2, do(push(b, l_1, b_2), s)) \end{aligned}$$

- $turnOn$:

$$\begin{aligned} \forall s . at(shakey, r_1, s) \land at(b_1, r_1, s) \land at(b_2, r_2, s) \land \neg lightOn(s) \\ \rightarrow lightOn(do(turnOn, s)) \end{aligned}$$

(d)

$$\begin{aligned} \sigma = &do(turnOn, \\ &\quad do(push(b_1, r_2, r_1), \\ &\quad do(push(b_2, r_3, r_2), \\ &\quad do(walkTo(r_2, r_3), \\ &\quad do(walkTo(r_1, r_2), \\ &\quad s_0))))) \end{aligned}$$

2 STRIPS and Reachability Analysis

(a)
- Actions:
  - $move(x, a, b)$:
    - Pres:$\{clear(x), clear(b), on(x, a), smaller(x, b)\}$
    - Adds:$\{clear(a), on(x, b)\}$
    - Dels:$\{clear(b), on(x, a)\}$
  - $moveTwo(x, y, a, b)$:
    - Pre:$\{clear(x), clear(b), on(x, y), on(y, a), smaller(y, b)\}$
    - Adds:$\{clear(a), on(y, b)\}$
    - Dels:$\{clear(b), on(y, a)\}$
- Initial 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:

$$\{on(d_1, d_2), on(d_2, d_3), on(d_3, p_3)\}$$

(b)
- States And Action Layers:
  - $S_0 = \{clear(d_1), clear(p_2), clear(p_3), on(d_1, d_2), on(d_2, d_3), on(d_3, p_1)\}$
  - $A_0 = \{move(d_1, d_2, p_2), move(d_1, d_2, p_3), moveTwo(d_1, d_2, d_3, p_2), moveTwo(d_1, d_2, d_3, p_3)\}$
  - $S_1 = S_0 \cup \{clear(d_2), clear(d_3), on(d_1, p_2), on(d_1, p_3), on(d_2, p_2), on(d_2, p_3)\}$
  - $A_1 = \{move(d_1, d_2, d_3), move(d_1, p_2, p_3), move(d_1, p_2, d_2), move(d_1, p_2, d_3), move(d_1, p_3, p_2)$
    $move(d_1, p_3, d_2), move(d_1, p_3, d_3), move(d_2, d_3, p_2), move(d_2, d_3, p_3), move(d_2, p_2, p_3)$
    $move(d_2, p_2, d_3), move(d_2, p_3, p_2), move(d_2, p_3, d_3), move(d_3, p_1, p_2), move(d_3, p_1, p_3)$
    $moveTwo(d_1, d_2, p_2, d_3), moveTwo(d_1, d_2, p_2, p_3), moveTwo(d_1, d_2, p_3, d_3),$
    $moveTwo(d_1, d_2, p_3, p_2), moveTwo(d_2, d_3, p_1, p_2), moveTwo(d_2, d_3, p_1, p_3)\}$
  - $S_2 = S_1 \cup \{on(d_3, p_3), ...\}$
  - $Goal \subseteq S_2$，停止计算。
- $CountAction(G, S_2)$
  - $G = \{on(d_1, d_2), on(d_2, d_3), on(d_3, p_3)\}$:
  - $G_P = \{on(d_1, d_2), ond_2, d_3\}$
  - $G_N = \{on(d_3, p_3)\}$

- $A = \{move(d_3, p_1, p_3)\}$
- $G_1 = G_P \cup Pre(A) = \{on(d_1, d_2), on(d_2, d_3), clear(d_3), clear(p_3), on(d_3, p_1)\}$
- return $1 + CountAction(G_1, S_1)$

- $CountAction(G_1, S_1)$:
  - $G_1 = \{on(d_1, d_2), on(d_2, d_3), clear(d_3), clear(p_3), on(d_3, p_1)\}$
  - $G_P = \{on(d_1, d_2), on(d_2, d_3), clear(p_3), on(d_3, p_1)\}$
  - $G_N = \{clear(d_3)\}$
  - $A = \{moveTwo(d_1, d_2, d_3, p_2)\}$
  - $G_2 = G_P \cup Pre(A) = \{on(d_1, d_2), on(d_2, d_3), clear(p_3), on(d_3, p_1), clear(d_1), clear(p_2)\}$
  - return $1 + CountAction(G_2, S_0)$
- $CountAction(G_2, S_0) = 0$
- So,$CountAction(G, S_2) = 1 + 1 + 0 = 2$

3 Bayesian Networks

1. (a) See the Figure 1.

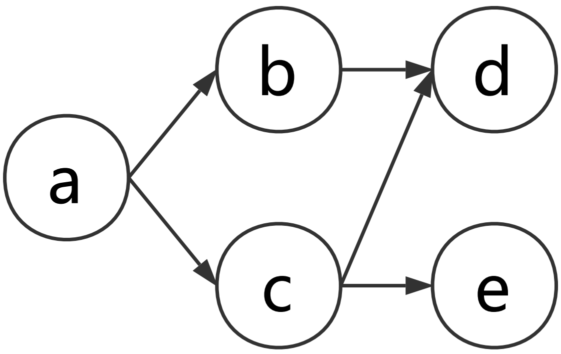

Figure 1: Bayesian Network: a:Addicted to games. b:Lake of exercise. c:Low score in the final exam. d:Unpopular among classmates. e:Rejection of scholarship application.

(b) 在给定 a 的情况下，b, c 独立。因为 b, c 中的两条通路:$b \leftarrow a \rightarrow c$ 和 $b \rightarrow d \leftarrow c$ 均被阻塞。

(c) • $p_1 = p(a, b, c, \neg d, e) = p(a) \times p(b|a) \times p(c|a) \times p(\neg d|b, c) \times p(e|c) = 392/10^5$

- $p_2 = p(a, b, \neg c, \neg d, e) = p(a) \times p(b|a) \times p(\neg c|a) \times p(\neg d|b, \neg c) \times p(e|\neg c) = 2016/10^5$
- $p_3 = p(a, \neg b, c, \neg d, e) = p(a) \times p(\neg b|a) \times p(c|a) \times p(\neg d|\neg b, c) \times p(e|c) = 252/10^5$
- $p_4 = p(a, \neg b, \neg c, \neg d, e) = p(a) \times p(\neg b|a) \times p(\neg c|a) \times p(\neg d|\neg b, \neg c) \times p(e|\neg c) = 2736/10^5$
- $p_5 = p(\neg a, b, c, \neg d, e) = p(\neg a) \times p(b|\neg a) \times p(c|\neg a) \times p(\neg d|b, c) \times p(e|c) = 112/10^5$
- $p_6 = p(\neg a, b, \neg c, \neg d, e) = p(\neg a) \times p(b|\neg a) \times p(\neg c|\neg a) \times p(\neg d|b, \neg c) \times p(e|\neg c) = 2736/10^5$
- $p_7 = p(\neg a, \neg b, c, \neg d, e) = p(\neg a) \times p(\neg b|\neg a) \times p(c|\neg a) \times p(\neg d|\neg b, c) \times p(e|c) = 672/10^5$
- $p_8 = p(\neg a, \neg b, \neg c, \neg d, e) = p(\neg a) \times p(\neg b|\neg a) \times p(\neg c|\neg a) \times p(\neg d|\neg b, \neg c) \times p(e|\neg c) = 34656/10^5$
- $p(\neg d, e) = \sum_{A,B,C} p(A, B, C, \neg d, e) = \sum_i p_i = 43572/10^5$

Answers:

- $p(a, b, c|\neg d, e) = \frac{p_1}{p(\neg d,e)} = \frac{392}{43572}$
- $p(a, b, \neg c|\neg d, e) = \frac{p_2}{p(\neg d,e)} = \frac{2016}{43572}$
- $p(a, \neg b, c|\neg d, e) = \frac{p_3}{p(\neg d,e)} = \frac{252}{43572}$
- $p(a, \neg b, \neg c|\neg d, e) = \frac{p_4}{p(\neg d,e)} = \frac{2736}{43572}$
- $p(\neg a, b, c|\neg d, e) = \frac{p_5}{p(\neg d,e)} = \frac{112}{43572}$
- $p(\neg a, b, \neg c|\neg d, e) = \frac{p_6}{p(\neg d,e)} = \frac{2736}{43572}$
- $p(\neg a, \neg b, c|\neg d, e) = \frac{p_7}{p(\neg d,e)} = \frac{672}{43572}$
- $p(\neg a, \neg b, \neg c|\neg d, e) = \frac{p_8}{p(\neg d,e)} = \frac{34656}{43572}$

(d)

$$p(a|\neg d, e) = \frac{p(a, \neg d, e)}{p(\neg d, e)} = \frac{\sum_{B,C} p(a, B, C, \neg d, e)}{p(\neg d, e)} = \frac{p_1 + p_2 + p_3 + p_4}{p(\neg d, e)} = \frac{5396}{43572} \approx 0.123 < 0.2$$

所以，在得知 $\neg d, e$ 之后，$p(a)$ 的值会变小。

2. (a) 有关的变量为:A, B, C, E

- Factors:
  - $f_1(A)$

a	$\neg a$
0.8	0.2

  - $f_2(B)$

b	$\neg b$
0.2	0.8

  - $f_3(A, B, C)$

	ab	$a\neg b$	$\neg ab$	$\neg a\neg b$
c	0.2	0.7	0.8	0.4
$\neg c$	0.8	0.3	0.2	0.6

- $f_4(C,E)$

	c	$\neg c$
e	0.8	0.1
$\neg e$	0.2	0.9

- 消去 A:$f_5(B,C)=\sum_A f_1(A)f_3(A,B,C)$

	b	$\neg b$
c	$\frac{32}{100}$	$\frac{64}{100}$
$\neg c$	$\frac{68}{100}$	$\frac{36}{100}$

- 消去 B:$f_6(C)=\sum_B f_2(B)f_5(B,C)$

c	$\neg c$
$\frac{636}{1000}$	$\frac{424}{1000}$

- 消去 C:$f_7(E)=\sum_C f_6(C)f_4(C,E)$

e	$\neg e$
$\frac{5512}{10000}$	$\frac{5088}{10000}$

- 归一化:$P(e)=\frac{5512}{5512+5088}=\frac{5512}{10600}=0.52$

(b) 有关变量为 A,B,C,E,F

- Factors:
  - $f_1(A),f_2(B),f_3(A,B,C),f_4(C,E)$ 与第一问中一样。
  - $f_5(C,F)$:

	c	$\neg c$
f	0.2	0.8
$\neg f$	0.8	0.2

- 将 $\neg f$ 代入 $f_5(C,F)$ 得：$f_6(C)$

c	$\neg c$
0.8	0.2

- 消去 A:$f_7(B,C)=\sum_A f_1(A)f_3(A,B,C)$，与 (a) 中 $f_5(B,C)$ 一样。
- 消去 B:$f_8(C)=\sum_B f_2(B)f_7(B,C)$，与 (a) 中 $f_6(C)$ 一样。
- 消去 C:$f_9(E)=\sum_C f_4(C,E)f_6(C)f_8(C)$:

e	$\neg e$
$\frac{41552}{100000}$	$\frac{17808}{100000}$

- 归一化:$p(e|\neg f)=\frac{41552}{41552+17808}=0.7$
- 计算过程中 $f_1(A),f_2(B),f_3(A,B,C),f_4(C,E),f_7(B,C),f_8(C)$ 均可使用 (a) 中得计算结果。