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1) Constants: $A_1, A_2, A_3, C_1, C_2, C_3$, Boat

Predicates:

is-child (x) : x is a child

is-adult (x) : x is an adult.

in-leftBank (x): x is in left side of river.

in-rightBank (x): x is in right side of river.

boat-in-left (Boat): Boat is in left side.

boat-in-right (Boat): Boat is in right side.

Actions:

1) CA-MOVE_LR (x,y):

Pre-condition: in-leftBank(x) ∧ in-leftBank(y) ∧ is-child(x) ∧ is-adult(y) ∧ boat-in-left (Boat)

Effect: in-rightBank(x) ∧ in-rightBank(y) ∧ ¬in-leftBank(x) ∧ ¬in-leftBank(y) ∧ boat-in-right(Boat) ∧ ¬boat-in-left(Boat)

2) AA-MOVE_LR (x,y):

Pre-condition: is-adult(x) ∧ is-adult(y) ∧ in-leftBank (x) ∧ in-leftBank (y) ∧ boat-in-left (Boat)

Effect: in-rightBank(x) ∧ in-rightBank(y) ∧ ¬in-leftBank(x) ∧ ¬in-leftBank(y) ∧ boat-in-right(Boat) ∧ ¬boat-in-left (Boat)

3) A-MOVE_RL (x,y)

Pre-condition. in-rightBank (x) ∧ is-adult (x) ∧ boat-in-right (Boat)

Effect: in-leftBank(x) ∧ boat-in-left (Boat) ∧ ¬boat-in-right (Boat) ∧ ¬in-rightBank(x)

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Initial state:

in-leftBank (A_1) ∧ in-leftBank (A_2) ∧ in-leftBank (A_3) ∧ in-leftBank (C_1) ∧ in-leftBank (C_2) ∧ in-leftBank (C_3) ∧ boat-in-left (Boat) ∧ is-adult (A_1) ∧ is-adult (A_2) ∧ is-adult (A_3) ∧ is-child (C_1) ∧ is-child (C_2) ∧ is-child (C_3)

Goal-state:

in-rightBank (A_1) ∧ in-rightBank (A_2) ∧ in-rightBank (A_3) ∧ in-rightBank (C_1) ∧ in-rightBank (C_2) ∧ in-rightBank (C_3) ∧ boat-in-right (Boat)

2) i) $P(A=4 \mid B \neq 3) = 0.0575 + 0.0150 + 0.0028 + 0.0243$

$= 0.0996$ //

ii) $P(A=1 \vee B=4)$

$= 0.0425 + 0.0702 + 0.0124 + 0.0370 + 0.0803 + 0.0031 + 0.0652 + 0.0028$

$= 0.3135$ //

iii) $P(A \neq B)$

$= 0.0695 + 0.0819 + 0.0575 + 0.0702 + 0.0595 + 0.0150 + 0.0124 + 0.0575 + 0.0619 + 0.037 + 0.0031 + 0.0652 + 0.0803 + 0.0795 + 0.0344 + 0.0243$

$= 0.8042$ //

iv) Conditions for total independence:

$$P(A \mid B) = P(A)$$

$$P(A, B) = P(A) \cdot P(B)$$

$$P(B \mid A) = P(B)$$

Let's take value = 1

$$P(A=1 \mid B=1) = 0.0425$$

$$P(A=1) = 0.0425 + 0.0702 + 0.0124 + 0.0370 + 0.0803$$

$$= 0.2424$$

Since,

$$P(A=1 \mid B=1) \neq P(A=1)$$

we can say that, A and B are totally independent.

3) $P(A=T \mid C=T, D=F) = \dfrac{P(A=T, C=T, D=F)}{P(C=T, D=F)}$

Now,

Numerator:

$P(A=T, C=T, D=F) = P(A=T, C=T, D=F, B=T) + P(A=T, C=T, D=F, B=F)$

$= P(A=T) \cdot P(B=T) \cdot P(C=T \mid A=T, D=F) \cdot P(D=F \mid B=T) + P(A=T) \cdot P(B=F) \cdot P(C=T \mid A=T, D=F) \cdot P(D=F \mid B=F)$

$= (0.7 \times 0.4 \times 0.6 \times (1-0.9)) + (0.7 \times 0.6 \times 0.6 \times (1-0.2))$

$= 0.0168 + 0.2016$

$= 0.2184$

Denominator:

$P(C=T, D=F)$

$= P(A=T, B=T, C=T, D=F) + P(A=T, B=F, C=T, D=F) + P(A=F, B=T, C=T, D=F) + P(A=F, B=F, C=T, D=F)$

$= (0.7 \times 0.4 \times 0.6 \times 0.1) + (0.7 \times 0.6 \times 0.6 \times 0.8) + (0.7 \times 0.4 \times 0.2 \times 0.1) + (0.7 \times 0.6 \times 0.2 \times 0.8)$

$= 0.2912$

Now,

$P = \dfrac{0.2184}{0.2912} = 0.75$ //

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4) Here, Given:

$$P(A_1,B_1) = P(A_2,B_2)$$

$$P(A_1,B_1) = P(A_1, B_1) \cdot P(B_1)$$

$$= \frac{P(B_1|A_1) \cdot P(A_1)}{P(B_1)} \times P(B_1)$$

$$= P(B_1|A_1) \cdot P(A_1)$$

Now, we can calculate the same for:

$$P(A_2,B_2) = P(A_2|B_2) \cdot P(B_2)$$

From the given true case:

$$P(A_1,B_1) = P(A_2,B_2)$$

$$\Rightarrow P(B_1|A_1) \cdot P(A_1) = P(A_2|B_2)\ P(B_2)$$

Here, the corresponding probability should be same in the above equation:

$$x_1 = P(B_2) = P(A_1) = 0.1208$$

$$P(A_2|B_2) = P(B_1|A_1)$$

So, we can write,

B_2	$P(A_2\|B_2)$
T	$x_2 = 0.4308$
F	$x_3 = 5360$

$\therefore x_1 = 0.1208$

$x_2 = 0.4308$

$x_3 = 0.5360$.

6)

i) Patrons $\xrightarrow{\text{Full}}$ WaitEstimate $\xrightarrow{\text{10-30}}$ Hungry $\xrightarrow{\text{yes}}$ Alternate $\xrightarrow{\text{yes}}$ Raining $\xrightarrow{\text{yes}}$ T

True class

ii) Patrons $\xrightarrow{\text{Full}}$ WaitEstimate $\xrightarrow{\text{30-60}}$ Alternate $\xrightarrow{\text{yes}}$ Fri/Sat $\xrightarrow{\text{yes}}$ T

True class

7) Class X : 6

Class Y : 6

$$\text{Entropy (root)} = -\frac{6}{12}\log_2\frac{6}{12} - \frac{6}{12}\log_2\frac{6}{12}$$

$$= 1$$

For test A:

Class	1	2	3
X	2	2	2
Y	2	2	2

$$\text{Entropy}(1) = -\frac{2}{4}\log_2\frac{2}{4} \quad \frac{2}{4}\log_2\frac{2}{4} = 1$$

$$\text{Entropy}(2) = -\frac{2}{4}\log_2\frac{2}{4} - \frac{2}{4}\log_2\frac{2}{4} = 1$$

$$\text{Entropy}(3) = -\frac{2}{4}\log_2\frac{2}{4} - \frac{2}{4}\log_2\frac{2}{4} = 1$$

$$\text{Information gain (A)} = 1 - \frac{4}{12}\times 1 - \frac{4}{12}\times 1 - \frac{4}{12}\times 1$$

$$= 0$$

For test B:

Class	1	2	3
x	4	2	0
y	0	2	4

$$\text{Entropy}(1) = -\frac{4}{4}\log_2\frac{4}{4} - \frac{0}{4}\log_2 0/4 = 0$$

$$\text{Entropy}(2) = -\frac{2}{4}\log_2\frac{2}{4} - \frac{2}{4}\log_2 2/4 = 1$$

$$\text{Entropy}(3) = -0/4\log_2 0/4 - 4/4\log_2 4/4 = 0$$

$$\text{Information gain(B)} = 1 - \frac{4}{12}\times 0 - \frac{4}{12}\times 1 - \frac{4}{12}\times 0$$

$$= 0.667$$

For test C:

class	1	2	3
x	1	2	3
y	1	3	2

$$\text{Entropy}(1) = -\frac{1}{2}\log_2\frac{1}{2} - \frac{1}{2}\log_2\frac{1}{2} = 1$$

$$\text{Entropy}(2) = -\frac{2}{5}\log_2\frac{2}{5} - \frac{3}{5}\log_2\frac{3}{5} = 0.97$$

$$\text{Entropy}(3) = -\frac{3}{5}\log_2\frac{3}{5} - \frac{2}{5}\log_2\frac{2}{5} = 0.97$$

$$\text{Information Gain (C)} = 1 - \frac{2}{12}\times 1 - \frac{5}{12}\times 0.97 - \frac{5}{12}\times 0.97$$

$$= 0.025$$

Now,

$IG(B) > IG(C) > IG(A)$

Here, Since information gain of B is greatest, the best test to use at root is B.