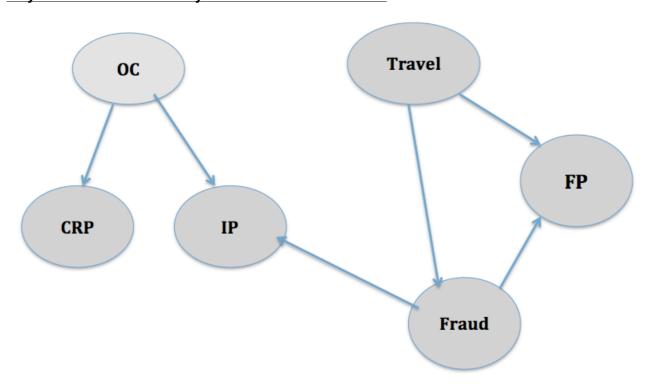
# **Bayesian Networks and Decision Networks**

Assignment 2

2.

(a)

# **Bayes Network to identify fraudulent transactions**



# **Conditional Probability Tables**

## P(Trav)

P(Trav)	P(~Trav)
0.05	0.95

## P(Fraud | Trav)

Trav	P(Fraud)	P(~Fraud)
Т	0.01	0.99
F	0.004	0.996

# P(FP | Trav, Fraud)

Trav	Fraud	P(FP)	P(~FP)
Т	Т	0.9	0.1
Т	F	0.9	0.1
F	Т	0.1	0.9
F	F	0.01	0.99

# P(OC)

P(OC)	P(~OC)
0.65	0.35

# P(IP | OC, Fraud)

ос	Fraud	P(IP)	P(~IP)
Т	Т	0.02	0.98
Т	F	0.01	0.99
F	Т	0.011	0.989
F	F	0.001	0.999

# $P(CRP \mid OC)$

ос	P(CRP)	P(~CRP)
Т	0.1	0.9
F	0.001	0.999

## **Prior Probability P(Fraud) = 0.0043**

## Query:

- queryVariables = Fraud
- orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
- evidenceList = *Empty*

```
==== Eliminating variable Trav
Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav P
Т
   0.050000
F
    0.950000
P(Trav | Fraud):
Trav Fraud P
    Т
        0.000500
Т
   F
        0.049500
F
   T
        0.003800
   F
        0.946200
P(Trav | Fraud, FP):
Trav Fraud FP
             Ρ
    т т
             0.000450
Τ
        F
Τ
    Т
             0.000050
Τ
    F
         Т
             0.044550
        F
Τ
   F
             0.004950
F
   Τ
        Т
             0.000380
F
   Т
        F
             0.003420
        Т
F
    F
             0.009462
              0.936738
F
    F
        F
Sumout variable Trav
P(Trav | Fraud, FP):
Fraud FP
        Р
Τ
    Τ
        0.000830
    F
        0.003470
Τ
        0.054012
F
   Т
F
   F 0.941688
==== Eliminating variable FP
Multiply Factors: [P(Trav | Fraud, FP)]
```

```
P(Trav | Fraud, FP):
Fraud FP P
Τ
   Т
        0.000830
   F
Τ
        0.003470
F
   T 0.054012
F
   F 0.941688
Sumout variable FP
P(Trav | Fraud, FP):
Fraud P
T 0.004300
F 0.995700
==== Eliminating variable IP
Multiply Factors: [P(IP | OC, Fraud)]
P(IP | OC, Fraud):
IP OC Fraud P
Т
    Т
         T 0.020000
        T
F
   Т
            0.980000
        F
Τ
   Т
            0.010000
        F 0.990000
F
   Т
        T 0.011000
T 0.989000
F 0.001000
Т
   F
F
   F
   F
Т
F
   F F
            0.999000
Sumout variable IP
P(IP | OC, Fraud):
OC Fraud P
   T 1.000000
        1.000000
Т
   F
F
   Т
        1.000000
   F 1.000000
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC P
   0.650000
T
F
   0.350000
P(OC | CRP):
OC CRP P
Т
   T 0.065000
Т
   F
        0.585000
F T 0.000350
```

```
F F 0.349650
P(OC | CRP, Fraud):
OC
   CRP Fraud P
Τ
    Τ
        T
            0.065000
        F
Τ
   Т
             0.065000
        Т
   F
Τ
            0.585000
Τ
   F
        F
            0.585000
        Т
F
   Т
            0.000350
        F 0.000350
T 0.349650
F
   Т
F
   F
   F F 0.349650
F
Sumout variable OC
P(OC | CRP, Fraud):
CRP Fraud P
Т
   T 0.065350
   F
Τ
        0.065350
F
   T
        0.934650
        0.934650
F
   F
==== Eliminating variable CRP
Multiply Factors: [P(OC | CRP, Fraud)]
P(OC | CRP, Fraud):
CRP Fraud P
        0.065350
Т
   Т
   F
        0.065350
F
   Т
        0.934650
F
   F 0.934650
Sumout variable CRP
P(OC | CRP, Fraud):
Fraud P
T 1.000000
F
   1.000000
==== Multiply Remaining Factors: [P(Trav | Fraud, FP), P(OC | CRP,
Fraud)]
P(Fraud):
Fraud P
T 0.004300
F 0.995700
```

```
Resulting Probability:
P(Fraud):
Fraud P
T 0.004300
F 0.995700
```

## EXTENSION: P(Fraud | FP, ~IP, CRP) = 0.014984

## Query:

- queryVariables = Fraud
- orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
- evidenceList = { FP: True, IP: False, CRP: True }

```
==== Eliminating variable Trav
Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav P
   0.050000
   0.950000
P(Trav | Fraud):
Trav Fraud P
Т
   T 0.000500
Т
   F
        0.049500
F
    Т
        0.003800
   F
        0.946200
P(Trav | Fraud):
Trav Fraud P
    T
        0.000450
T
   F
        0.044550
F
   Т
        0.000380
   F
        0.009462
Sumout variable Trav
P(Trav | Fraud):
Fraud P
T 0.000830
   0.054012
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
```

```
OC
     Ρ
    0.650000
Т
    0.350000
F
P(OC):
OC
    P
     0.065000
Т
     0.000350
P(OC | Fraud):
OC Fraud P
    Т
         0.063700
Τ
     F
         0.064350
Т
    Т
         0.000346
F
F
    F
         0.000350
Sumout variable OC
P(OC | Fraud):
Fraud P
Т
   0.064046
F
    0.064700
==== Multiply Remaining Factors: [P(Trav | Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
Т
    0.000053
    0.003495
Resulting Probability:
P(Fraud):
Fraud P
Т
     0.014984
F
     0.985016
(c)
P(Fraud I FP, \simIP, CRP, Trav) = 0.0099
Query:
  • queryVariables = Fraud
  • orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
  • evidenceList = { FP: True, IP: False, CRP: True, Trav: True }
Computing Output:
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
```

```
P(OC):
OC
   Р
Τ
   0.650000
F
     0.350000
P(OC):
OC
Τ
     0.065000
F
     0.000350
P(OC | Fraud):
   Fraud P
        0.063700
Τ
    F
         0.064350
Τ
F
    Т
         0.000346
    F 0.000350
Sumout variable OC
P(OC | Fraud):
Fraud P
     0.064046
Т
     0.064700
==== Multiply Remaining Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav,
Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
     0.000029
     0.002882
Resulting Probability:
P(Fraud):
Fraud P
Т
     0.009900
F
     0.990100
(d)
```

## u)

## Case 1: P(Fraud | IP) = 0.010511

This is giving the probability when the person do not take any precaution to do Fraud Transaction.

#### Query:

- queryVariables = Fraud
- orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
- **evidenceList** = { *IP*: *True* }

```
T F 0.003470
F T 0.054012
F F 0.941688

Sumout variable FP
P(Trav | Fraud, FP):
Fraud P
T 0.004300
```

```
F 0.995700
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
   Р
OC
Τ
   0.650000
F
   0.350000
P(OC | CRP):
OC CRP P
    T 0.065000
Т
Τ
   F
        0.585000
F
   T
        0.000350
F
   F 0.349650
P(OC | CRP, Fraud):
   CRP Fraud P
OC
        T 0.001300
Т
   Т
        F
T
   Т
             0.000650
        Т
   F
             0.011700
Τ
        F 0.005850
T 0.000004
F 0.000000
T 0.003846
Τ
   F
F
   T
F
   Т
F
   F
   F F 0.000350
F
Sumout variable OC
P(OC | CRP, Fraud):
CRP Fraud P
Т
   T 0.001304
Τ
   F
        0.000650
F
   Т
        0.015546
F
   F
        0.006200
==== Eliminating variable CRP
Multiply Factors: [P(OC | CRP, Fraud)]
P(OC | CRP, Fraud):
CRP Fraud P
Τ
   Т
        0.001304
```

F

Т

F

Sumout variable CRP
P(OC | CRP, Fraud):

0.000650

0.015546

0.006200

Τ

F

F

```
Fraud P
T 0.016850
F
   0.006850
==== Multiply Remaining Factors: [P(Trav | Fraud, FP), P(OC | CRP,
Fraud)]
P(Fraud):
Fraud P
    0.000072
F
     0.006821
Resulting Probability:
P(Fraud):
Fraud P
     0.010511
Т
F
     0.989489
```

## Case 2 : P(Fraud I IP, CRP) = 0.008584

This give the Probability when the person take the precautions to do the fraud Transaction, clearly it has been reduced.

#### Query:

- queryVariables = Fraud
- orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
- evidenceList = { FP: True, IP: False, CRP: True, Trav: True }

```
==== Eliminating variable Trav
Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav P
   0.050000
F
    0.950000
P(Trav | Fraud):
Trav Fraud P
Τ
   Т
        0.000500
Т
   F
        0.049500
F
    Τ
        0.003800
        0.946200
   F
P(Trav | Fraud, FP):
Trav Fraud FP
   Т
        Т
             0.000450
         F
             0.000050
Т
    Т
Т
   F
        Т
             0.044550
```

```
F F 0.004950
Т
        T 0.000380
F 0.003420
T 0.009462
F
   Т
   T
F
F
F
F
   F F 0.936738
Sumout variable Trav
P(Trav | Fraud, FP):
Fraud FP P
   Т
        0.000830
Т
   F
        0.003470
F
   Т
        0.054012
F F 0.941688
==== Eliminating variable FP
Multiply Factors: [P(Trav | Fraud, FP)]
P(Trav | Fraud, FP):
Fraud FP P
T T 0.000830
T F 0.003470
        0.054012
F
   T
   F 0.941688
F
Sumout variable FP
P(Trav | Fraud, FP):
Fraud P
T 0.004300
F
   0.995700
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC P
Τ
   0.650000
   0.350000
P(OC):
OC
   0.065000
T
F
   0.000350
P(OC | Fraud):
OC Fraud P
Т
   T 0.001300
Τ
   F
        0.000650
F T 0.00004
```

```
F F 0.00000
Sumout variable OC
P(OC | Fraud):
Fraud P
T 0.001304
F 0.000650
==== Multiply Remaining Factors: [P(Trav | Fraud, FP), P(OC | Fraud)]
P(Fraud):
Fraud P
T 0.000006
F 0.000648
Resulting Probability:
P(Fraud):
Fraud P
T
   0.008584
```

F 0.991416

**Utility Table:** 

Fraud	Block	Utility
Т	Т	0
Т	F	-1000
F	Т	-10
F	F	5

## (b) Finding EU(Block | FP, ~IP, CRP)

Case I: Block = True, EU = -9.85 Case II: Block = False, EU = -10.058

## Query:

- queryVariables = Fraud
- orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
- evidenceList = { FP: True, IP: False, CRP: True }

```
==== Eliminating variable Trav
Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav P
   0.050000
    0.950000
P(Trav | Fraud):
Trav Fraud P
    T 0.000500
   F
        0.049500
F
    Т
        0.003800
   F
        0.946200
P(Trav | Fraud):
Trav Fraud P
    Т
        0.000450
Τ
   F
        0.044550
```

```
F T 0.000380
   F
        0.009462
F
Sumout variable Trav
P(Trav | Fraud):
Fraud P
   0.000830
F
   0.054012
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC P
   0.650000
Т
F
   0.350000
P(OC):
OC
   0.065000
Т
F
   0.000350
P(OC | Fraud):
OC Fraud P
Τ
    T 0.063700
Τ
   F
        0.064350
   Т
F
        0.000346
   F 0.000350
Sumout variable OC
P(OC | Fraud):
Fraud P
T 0.064046
   0.064700
==== Multiply Remaining Factors: [P(Trav | Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
T 0.000053
   0.003495
Resulting Probability:
P(Fraud):
Fraud P
   0.014984
Τ
F 0.985016
```

Block = True

```
EU = -9.85016188587
Block = False
EU = -10.0587304705
```

# So, The EU for Block is greater than ~Block, so the transaction will be blocked.

## (c)

## Finding EU (Block | FP, ~IP, CRP)

Case I:	Block = True, Trav = True,	EU(1) = -9.901
Case II:	Block = False, Trav = True,	EU(2) = -4.9495
Case III:	Block = True, Trav = False,	EU(3) = -9.618
Case IV:	Block = False, Trav = False,	EU(4) = -33.426

## Query:

- queryVariables = Fraud
- orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
- evidenceList = { FP: True, IP: False, CRP: True, Trav: True }

```
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC
   Ρ
     0.650000
Т
    0.350000
P(OC):
OC
Τ
     0.065000
     0.000350
P(OC | Fraud):
OC
    Fraud P
Т
    Т
         0.063700
    F
Τ
         0.064350
F
         0.000346
F
    F
         0.000350
```

```
Sumout variable OC
P(OC | Fraud):
Fraud P
     0.064046
    0.064700
==== Multiply Remaining Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav,
Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
    0.000029
    0.002882
Resulting Probability:
P(Fraud):
Fraud P
Т
    0.009900
    0.990100
Block = True
EU = -9.90100005232
Block = False
EU = -4.94949474144
Query:
  • queryVariables = Fraud
  • orderedListOfHiddenVariables = [Trav, FP, Fraud, IP, OC, CRP]
  • evidenceList = { FP: True, IP: False, CRP: True, Trav: False }
Computing Output
==== Eliminating variable OC
Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC
    Р
    0.650000
Τ
    0.350000
F
P(OC):
OC
Τ
     0.065000
F
    0.000350
P(OC | Fraud):
OC
    Fraud P
Т
     Τ
          0.063700
```

0.064350

Т

F

```
T 0.000346
         0.000350
F
    F
Sumout variable OC
P(OC | Fraud):
Fraud P
     0.064046
    0.064700
==== Multiply Remaining Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav,
Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
   0.000024
   0.000612
Resulting Probability:
P(Fraud):
Fraud P
Т
   0.038235
    0.961765
Block = True
EU = -9.61765031866
Block = False
EU = -33.426142975
```

## <u>Conclusion</u>:

So, the transaction will be blocked when she is not travelling but company will not block the transation when she is travelling.

Value of Information VOI = 4.06

## **Computing Value of Information:**

EU(2) & EU(3) are max among their category.

**So, Value of Information:** 

 $\{\Sigma_{Trav} EU_{MAX}(B \mid FP, \sim IP, CRP, Trav) * P(Trav \mid FP, \sim IP, CRP)\} - EU_{Max}(B \mid FP, \sim IP, CRP)$ 

The value of P(Trav | FP,  $\sim$ IP, CRP) = calculated through Program = 0.82

 $EU_{Max}(B \mid FP, \sim IP, CRP) = -9.85$  (From solution of question 3.b.)

VOI = 
$$[-4.9495*0.82 + (-9.62*0.18)] - (-9.85)$$
  
VOI =  $4.06$