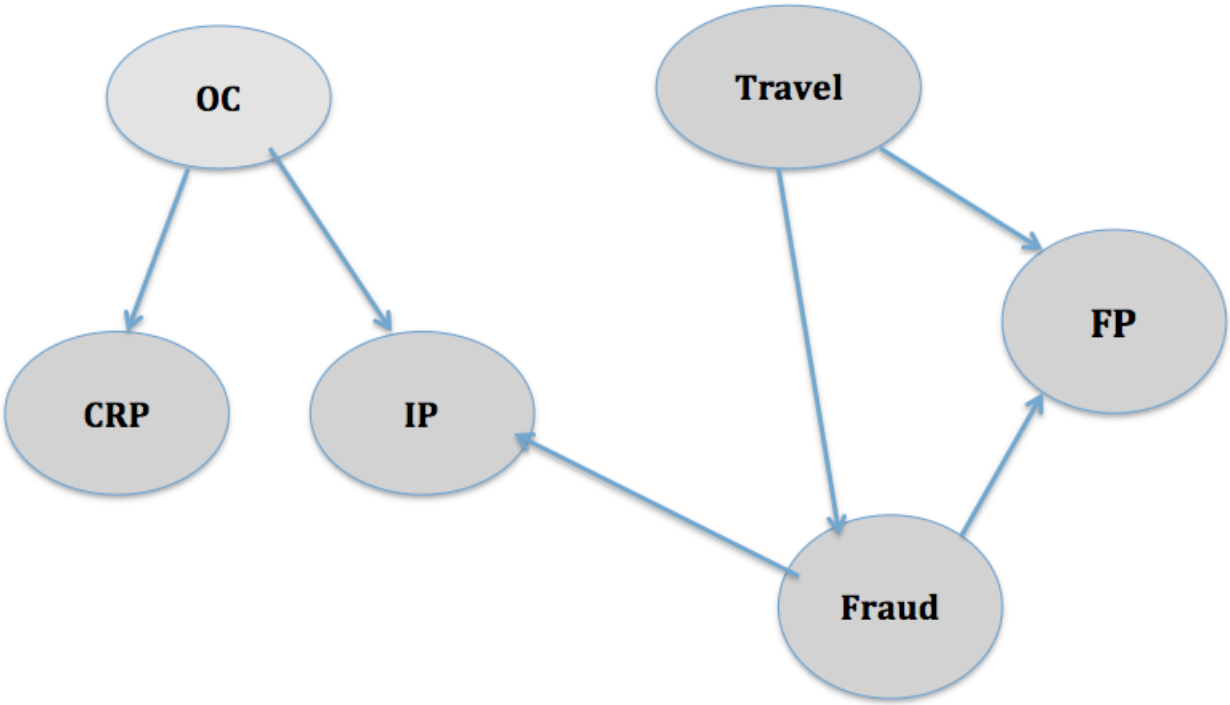
Bayesian Networks and Decision Networks

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)
T	0.01	0.99
F	0.004	0.996

P(FP | Trav, Fraud)

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

P(OC)

P(OC)	P(~OC)
0.65	0.35

P(IP | OC, Fraud)

OC	Fraud	P(IP)	P(~IP)
T	T	0.02	0.98
T	F	0.01	0.99
F	T	0.011	0.989
F	F	0.001	0.999

P(CRP | OC)

OC	P(CRP)	P(~CRP)
T	0.1	0.9
F	0.001	0.999

(b)

Prior Probability P(Fraud) = 0.0043

Query:

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

Computing Output:

```
==== Eliminating variable Trav

Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav  P
T     0.050000
F     0.950000

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000500
T     F     0.049500
F     T     0.003800
F     F     0.946200

P(Trav | Fraud, FP):
Trav  Fraud FP    P
T     T     T     0.000450
T     T     F     0.000050
T     F     T     0.044550
T     F     F     0.004950
F     T     T     0.000380
F     T     F     0.003420
F     F     T     0.009462
F     F     F     0.936738

Sumout variable Trav
P(Trav | Fraud, FP):
Fraud FP    P
T     T     0.000830
T     F     0.003470
F     T     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
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
T     T     T     0.020000
F     T     T     0.980000
T     T     F     0.010000
F     T     F     0.990000
T     F     T     0.011000
F     F     T     0.989000
T     F     F     0.001000
F     F     F     0.999000

Sumout variable IP
P(IP | OC, Fraud):
OC    Fraud P
T     T     1.000000
T     F     1.000000
F     T     1.000000
F     F     1.000000

==== Eliminating variable OC

Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC    P
T     0.650000
F     0.350000

P(OC | CRP):
OC    CRP   P
T     T     0.065000
T     F     0.585000
F     T     0.000350
```

```
F     F     0.349650

P(OC | CRP, Fraud):
OC    CRP   Fraud P
T     T     T     0.065000
T     T     F     0.065000
T     F     T     0.585000
T     F     F     0.585000
F     T     T     0.000350
F     T     F     0.000350
F     F     T     0.349650
F     F     F     0.349650

Sumout variable OC
P(OC | CRP, Fraud):
CRP   Fraud P
T     T     0.065350
T     F     0.065350
F     T     0.934650
F     F     0.934650

==== Eliminating variable CRP

Multiply Factors: [P(OC | CRP, Fraud)]
P(OC | CRP, Fraud):
CRP   Fraud P
T     T     0.065350
T     F     0.065350
F     T     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 }*

Computing Output:

```
==== Eliminating variable Trav

Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav  P
T     0.050000
F     0.950000

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000500
T     F     0.049500
F     T     0.003800
F     F     0.946200

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000450
T     F     0.044550
F     T     0.000380
F     F     0.009462

Sumout variable Trav
P(Trav | Fraud):
Fraud P
T     0.000830
F     0.054012

==== Eliminating variable OC

Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
```

```
OC    P
T     0.650000
F     0.350000

P(OC):
OC    P
T     0.065000
F     0.000350

P(OC | Fraud):
OC    Fraud P
T     T     0.063700
T     F     0.064350
F     T     0.000346
F     F     0.000350

Sumout variable OC
P(OC | Fraud):
Fraud P
T     0.064046
F     0.064700

==== Multiply Remaining Factors: [P(Trav | Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
T     0.000053
F     0.003495

Resulting Probability:
P(Fraud):
Fraud P
T     0.014984
F     0.985016
```

(c)

P(Fraud | FP, ~IP, 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    P
T     0.650000
F     0.350000

P(OC):
OC    P
T     0.065000
F     0.000350

P(OC | Fraud):
OC    Fraud P
T     T     0.063700
T     F     0.064350
F     T     0.000346
F     F     0.000350

Sumout variable OC
P(OC | Fraud):
Fraud P
T     0.064046
F     0.064700

==== Multiply Remaining Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav,
Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
T     0.000029
F     0.002882

Resulting Probability:
P(Fraud):
Fraud P
T     0.009900
F     0.990100
```

(d)

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 }*

Computing Output:

```
==== Eliminating variable Trav

Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav  P
T     0.050000
F     0.950000

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000500
T     F     0.049500
F     T     0.003800
F     F     0.946200

P(Trav | Fraud, FP):
Trav  Fraud FP    P
T     T     T     0.000450
T     T     F     0.000050
T     F     T     0.044550
T     F     F     0.004950
F     T     T     0.000380
F     T     F     0.003420
F     F     T     0.009462
F     F     F     0.936738

Sumout variable Trav
P(Trav | Fraud, FP):
Fraud FP    P
T     T     0.000830
T     F     0.003470
F     T     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
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):
OC   P
T    0.650000
F    0.350000

P(OC | CRP):
OC   CRP  P
T    T    0.065000
T    F    0.585000
F    T    0.000350
F    F    0.349650

P(OC | CRP, Fraud):
OC   CRP  Fraud P
T    T    T    0.001300
T    T    F    0.000650
T    F    T    0.011700
T    F    F    0.005850
F    T    T    0.000004
F    T    F    0.000000
F    F    T    0.003846
F    F    F    0.000350

Sumout variable OC
P(OC | CRP, Fraud):
CRP  Fraud P
T    T    0.001304
T    F    0.000650
F    T    0.015546
F    F    0.006200

==== Eliminating variable CRP

Multiply Factors: [P(OC | CRP, Fraud)]
P(OC | CRP, Fraud):
CRP  Fraud P
T    T    0.001304
T    F    0.000650
F    T    0.015546
F    F    0.006200

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

```
Fraud P
T     0.016850
F     0.006850

==== Multiply Remaining Factors: [P(Trav | Fraud, FP), P(OC | CRP,
Fraud)]
P(Fraud):
Fraud P
T     0.000072
F     0.006821
```

Resulting Probability:
P(Fraud):

Fraud	P
T	**0.010511**
F	**0.989489**

Case 2 : P(Fraud | 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 }*

Computing Output:

```
==== Eliminating variable Trav

Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav  P
T     0.050000
F     0.950000

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000500
T     F     0.049500
F     T     0.003800
F     F     0.946200

P(Trav | Fraud, FP):
Trav  Fraud FP    P
T     T     T     0.000450
T     T     F     0.000050
T     F     T     0.044550
```

```
T     F     F     0.004950
F     T     T     0.000380
F     T     F     0.003420
F     F     T     0.009462
F     F     F     0.936738

Sumout variable Trav
P(Trav | Fraud, FP):
Fraud FP    P
T     T     0.000830
T     F     0.003470
F     T     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
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):
OC    P
T     0.650000
F     0.350000

P(OC):
OC    P
T     0.065000
F     0.000350

P(OC | Fraud):
OC    Fraud P
T     T     0.001300
T     F     0.000650
F     T     0.000004
```

```
F     F     0.000000

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
T	**T**	**0**
T	**F**	**-1000**
F	**T**	**-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 }*

Computing Output

```
==== Eliminating variable Trav

Multiply Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav, Fraud)]
P(Trav):
Trav  P
T     0.050000
F     0.950000

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000500
T     F     0.049500
F     T     0.003800
F     F     0.946200

P(Trav | Fraud):
Trav  Fraud P
T     T     0.000450
T     F     0.044550
```

```
F     T     0.000380
F     F     0.009462

Sumout variable Trav
P(Trav | Fraud):
Fraud P
T     0.000830
F     0.054012

==== Eliminating variable OC

Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC    P
T     0.650000
F     0.350000

P(OC):
OC    P
T     0.065000
F     0.000350

P(OC | Fraud):
OC    Fraud P
T     T     0.063700
T     F     0.064350
F     T     0.000346
F     F     0.000350

Sumout variable OC
P(OC | Fraud):
Fraud P
T     0.064046
F     0.064700

==== Multiply Remaining Factors: [P(Trav | Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
T     0.000053
F     0.003495

Resulting Probability:
P(Fraud):
Fraud P
T     0.014984
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 }*

Computing Output

```
==== Eliminating variable OC

Multiply Factors: [P(OC), P(CRP | OC), P(IP | OC, Fraud)]
P(OC):
OC    P
T     0.650000
F     0.350000

P(OC):
OC    P
T     0.065000
F     0.000350

P(OC | Fraud):
OC    Fraud P
T     T     0.063700
T     F     0.064350
F     T     0.000346
F     F     0.000350
```

```
Sumout variable OC
P(OC | Fraud):
Fraud P
T     0.064046
F     0.064700

==== Multiply Remaining Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav,
Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
T     0.000029
F     0.002882

Resulting Probability:
P(Fraud):
Fraud P
T     0.009900
F     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    P
T     0.650000
F     0.350000

P(OC):
OC    P
T     0.065000
F     0.000350

P(OC | Fraud):
OC    Fraud P
T     T     0.063700
T     F     0.064350
```

```
F     T     0.000346
F     F     0.000350

Sumout variable OC
P(OC | Fraud):
Fraud P
T     0.064046
F     0.064700

==== Multiply Remaining Factors: [P(Trav), P(Fraud | Trav), P(FP | Trav,
Fraud), P(OC | Fraud)]
P(Fraud):
Fraud P
T     0.000024
F     0.000612

Resulting Probability:
P(Fraud):
Fraud P
T     0.038235
F     0.961765
```

Block = True
EU = -9.61765031866
Block = False
EU = -33.426142975

Conclusion:

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, ~IP, CRP) = calculated through Program = 0.82

EU_{Max}(B | FP, ~IP, CRP) = -9.85 (From solution of question 3.b.)

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

VOI = 4.06