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

E09 Variable Elimination

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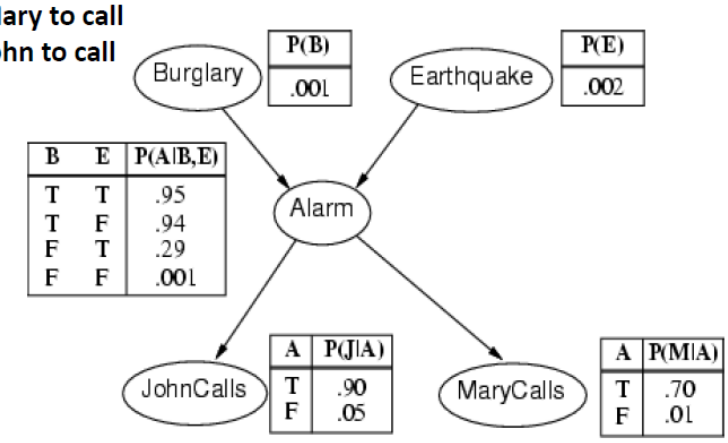
1 VE

The burglary example is described as following:

- **A burglary can set the alarm off**
- **An earthquake can set the alarm off**
- **The alarm can cause Mary to call**
- **The alarm can cause John to call**

Note that these tables only provide the probability that Xi is true.
(E.g., Pr(A is true|B,E))
The probability that Xi is false is 1- these values




```
P(Alarm) =
0.002516442

P(J&&~M) =
0.050054875461

P(A |J&&~M) =
0.0135738893313

P(B |A) =
0.373551228282

P(B |J&&~M) =
0.0051298581334

P(J&&~M |~B) =
0.049847949
```

Here is a VE template for you to solve the burglary example:

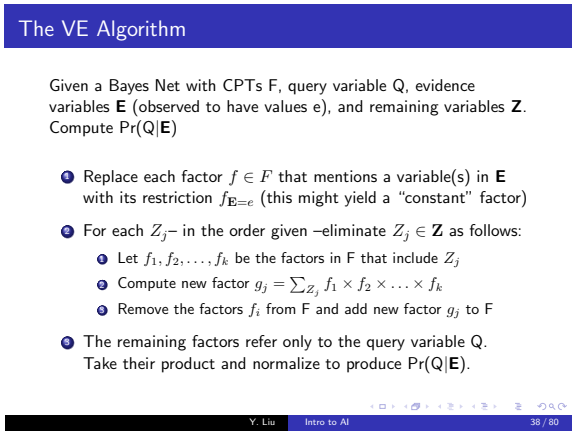
```
class VariableElimination:
    @staticmethod
    def inference(factorList, queryVariables,
    orderedListOfHiddenVariables, evidenceList):
        for ev in evidenceList:
            #Your code here
        for var in orderedListOfHiddenVariables:
            #Your code here
        print "RESULT:"
```

```
        res = factorList[0]
        for factor in factorList[1:]:
            res = res.multiply(factor)
        total = sum(res.cpt.values())
        res.cpt = {k: v/total for k, v in res.cpt.items()}
        res.printInf()
    @staticmethod
    def printFactors(factorList):
        for factor in factorList:
            factor.printInf()
class Util:
    @staticmethod
    def to_binary(num, len):
        return format(num, '0' + str(len) + 'b')
class Node:
    def __init__(self, name, var_list):
        self.name = name
        self.varList = var_list
        self.cpt = {}
    def setCpt(self, cpt):
        self.cpt = cpt
    def printInf(self):
        print "Name = " + self.name
        print " vars " + str(self.varList)
        for key in self.cpt:
            print "    key: " + key + " val : " + str(self.cpt[key])
        print ""
    def multiply(self, factor):
        """function that multiplies with another factor"""
        #Your code here
        new_node = Node("f" + str(newList), newList)
        new_node.setCpt(new_cpt)
        return new_node
```

```
    def sumout(self, variable):
        """function that sums out a variable given a factor"""
        #Your code here
        new_node = Node("f" + str(new_var_list), new_var_list)
        new_node.setCpt(new_cpt)
        return new_node
    def restrict(self, variable, value):
        """function that restricts a variable to some value
        in a given factor"""
        #Your code here
        new_node = Node("f" + str(new_var_list), new_var_list)
        new_node.setCpt(new_cpt)
        return new_node
# create nodes for Bayes Net
B = Node("B", ["B"])
E = Node("E", ["E"])
A = Node("A", ["A", "B","E"])
J = Node("J", ["J", "A"])
M = Node("M", ["M", "A"])

# Generate cpt for each node
B.setCpt({'0': 0.999, '1': 0.001})
E.setCpt({'0': 0.998, '1': 0.002})
A.setCpt({'111': 0.95, '011': 0.05, '110':0.94,'010':0.06,
'101':0.29,'001':0.71,'100':0.001,'000':0.999})
J.setCpt({'11': 0.9, '01': 0.1, '10': 0.05, '00': 0.95})
M.setCpt({'11': 0.7, '01': 0.3, '10': 0.01, '00': 0.99})

print "P(A) **********"
VariableElimination.inference([B,E,A,J,M], ['A'], ['B', 'E', 'J','M'], {})

print "P(B | J~M) **********"
VariableElimination.inference([B,E,A,J,M], ['B'], ['E','A'], {'J':1,'M':0})
```

2 Task

- You should implement 4 functions: `inference`, `multiply`, `sumout` and `restrict`. You can turn to Figure 1 and Figure 2 for help.
- Please hand in a file named E09_YourNumber.pdf, and send it to ai_2020@foxmail.com



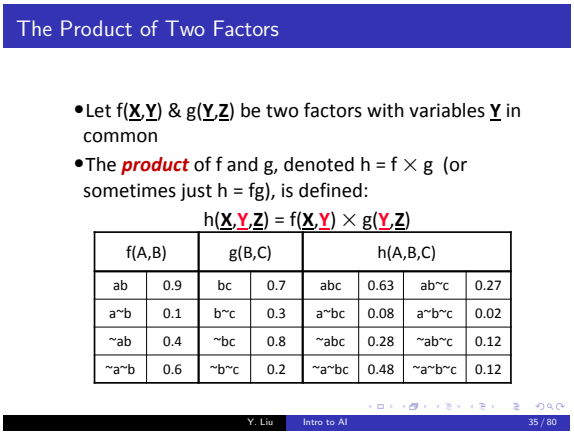
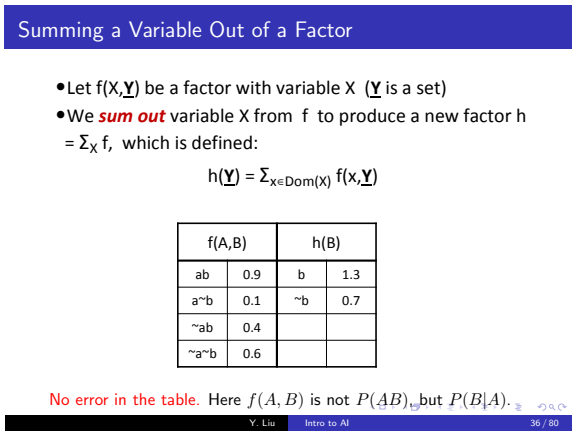


Figure 1: VE and Product



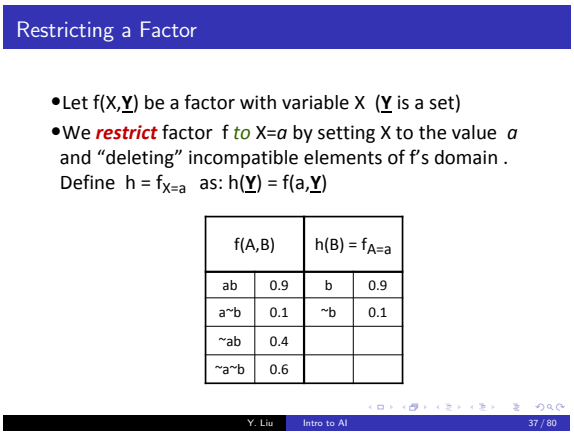


Figure 2: Sumout and Restrict

3 Codes and Results

3.1 Codes

```
class VariableElimination:
    @staticmethod
```

```
def inference(factorList, queryVariables,
orderedListOfHiddenVariables, evidenceList):
    for ev in evidenceList:
        #Your code here
        for i in range(len(factorList)):
            if ev in factorList[i].varList:
                factorList[i] = factorList[i].restrict(ev, evidenceList[ev])
    for var in orderedListOfHiddenVariables:
        #Your code here
        new_factor = None
        i = 0
        while True:
            while i < len(factorList):
                if var in factorList[i].varList:
                    if new_factor is None:
                        new_factor = factorList[i]
                    else:
                        new_factor = new_factor.multiply(factorList[i])
                    del factorList[i]
                    break
                i += 1
            else:
                break
        if new_factor is not None:
            factorList.append(new_factor.sumout(var))
    print "RESULT:"
    res = factorList[0]
    for factor in factorList[1:]:
        res = res.multiply(factor)
    total = sum(res.cpt.values())
    res.cpt = {k: v/total for k, v in res.cpt.items()}
    res.printInf()
@staticmethod
```

```
    def printFactors(factorList):
        for factor in factorList:
            factor.printInf()
class Util:
    @staticmethod
    def to_binary(num, len):
        return format(num, '0' + str(len) + 'b')
class Node:
    def __init__(self, name, var_list):
        self.name = name
        self.varList = var_list
        self.cpt = {}
    def setCpt(self, cpt):
        self.cpt = cpt
    def printInf(self):
        print "Name = " + self.name
        print " vars " + str(self.varList)
        for key in self.cpt:
            print "    key: " + key + " val : " + str(self.cpt[key])
        print ""
    def multiply(self, factor):
        """function that multiplies with another factor"""
        #Your code here
        same_var = set()
        same_var_pos = list()
        for i in range(len(self.varList)):
            for j in range(len(factor.varList)):
                if self.varList[i] == factor.varList[j]:
                    same_var.add(self.varList[i])
                    same_var_pos.append((i, j))
                    break
        newList = self.varList[:]
        for var in factor.varList:
```

```
            if var not in same_var:
                newList.append(var)
        new_node = Node("f" + str(newList), newList)
        new_cpt = dict()
        for k1, v1 in self.cpt.items():
            for k2, v2 in factor.cpt.items():
                for i, j in same_var_pos:
                    if k1[i] != k2[j]:
                        break
                else:
                    new_k2 = list()
                    for i in range(len(k2)):
                        if factor.varList[i] not in same_var:
                            new_k2.append(k2[i])
                    new_cpt[k1 + ''.join(new_k2)] = v1 * v2
        new_node.setCpt(new_cpt)
        return new_node
    def sumout(self, variable):
        """function that sums out a variable given a factor"""
        #Your code here
        pos_x = self.varList.index(variable)
        new_var_list = self.varList[:pos_x] + self.varList[pos_x + 1:]
        new_node = Node("f" + str(new_var_list), new_var_list)
        new_cpt = dict()
        for k, v in self.cpt.items():
            new_k = k[:pos_x] + k[pos_x + 1:]
            if new_cpt.get(new_k) is None:
                new_cpt[new_k] = v
            else:
                new_cpt[new_k] += v
        new_node.setCpt(new_cpt)
        return new_node
    def restrict(self, variable, value):
```

```
        """function that restricts a variable to some value
        in a given factor"""
        #Your code here
        pos_x = self.varList.index(variable)
        new_var_list = self.varList[:pos_x] + self.varList[pos_x + 1:]
        new_node = Node("f" + str(new_var_list), new_var_list)
        new_cpt = dict()
        for k, v in self.cpt.items():
            if k[pos_x] == str(value):
                new_cpt[k[:pos_x] + k[pos_x + 1:]] = v
        new_node.setCpt(new_cpt)
        return new_node
# create nodes for Bayes Net
B = Node("B", ["B"])
E = Node("E", ["E"])
A = Node("A", ["A", "B","E"])
J = Node("J", ["J", "A"])
M = Node("M", ["M", "A"])

# Generate cpt for each node
B.setCpt({'0': 0.999, '1': 0.001})
E.setCpt({'0': 0.998, '1': 0.002})
A.setCpt({'111': 0.95, '011': 0.05, '110':0.94,'010':0.06,
'101':0.29,'001':0.71,'100':0.001,'000':0.999})
J.setCpt({'11': 0.9, '01': 0.1, '10': 0.05, '00': 0.95})
M.setCpt({'11': 0.7, '01': 0.3, '10': 0.01, '00': 0.99})

print "P(A) **********"
VariableElimination.inference([B,E,A,J,M], ['A'], ['B', 'E', 'J','M'], {})

print "P(B | J~M) **********"
VariableElimination.inference([B,E,A,J,M], ['B'], ['E','A'], {'J':1,'M':0})
```

3.2 Results

```
❯ python2 VE.py
P(A) **********************
RESULT:
Name = f['A']
 vars ['A']
    key: 1 val : 0.002516442
    key: 0 val : 0.997483558

P(B | J~M) **********************
RESULT:
Name = f['B']
 vars ['B']
    key: 1 val : 0.0051298581334
    key: 0 val : 0.994870141867
```