Automatic Generation of Bayesian networks in Forensic Science

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Automatic Generation of Bayesian networks in Forensic Science

Jacob de Zoete, Norman Fenton

Queen Mary University of London

September 6, 2017

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Bayesian network
Conditional probabilities
shiny package
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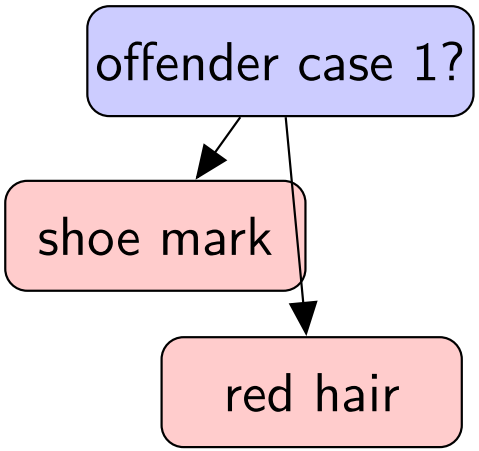
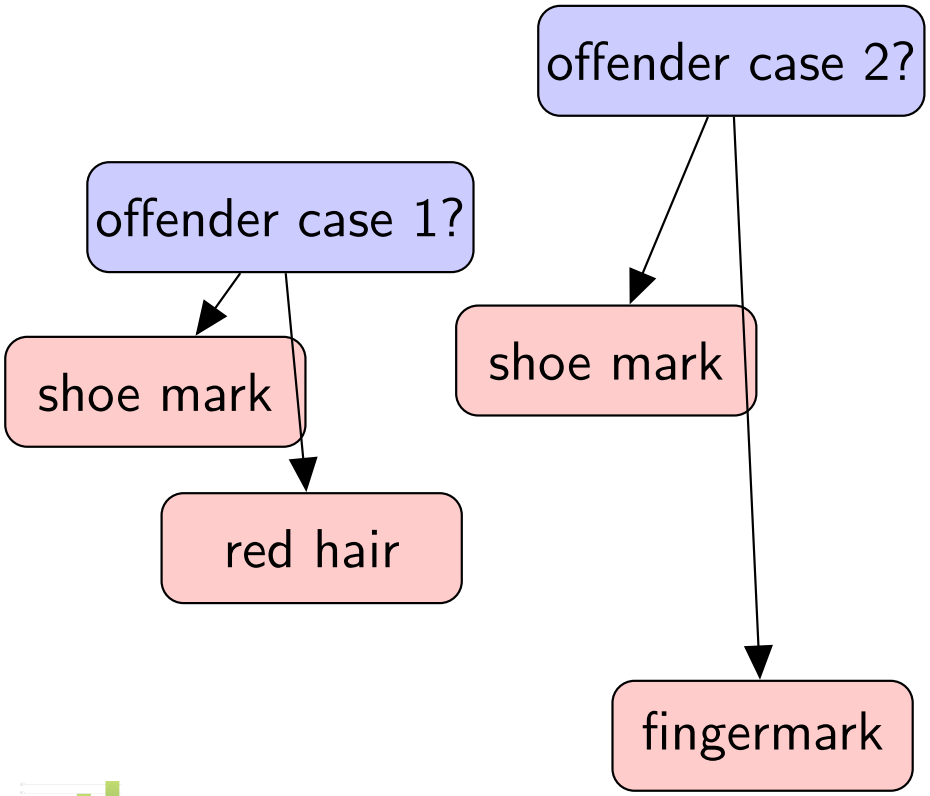
Goal

- Use the computer to generate BN structures.
- $\Rightarrow$ Example for crime linkage situations.

2 crimes



2 crimes



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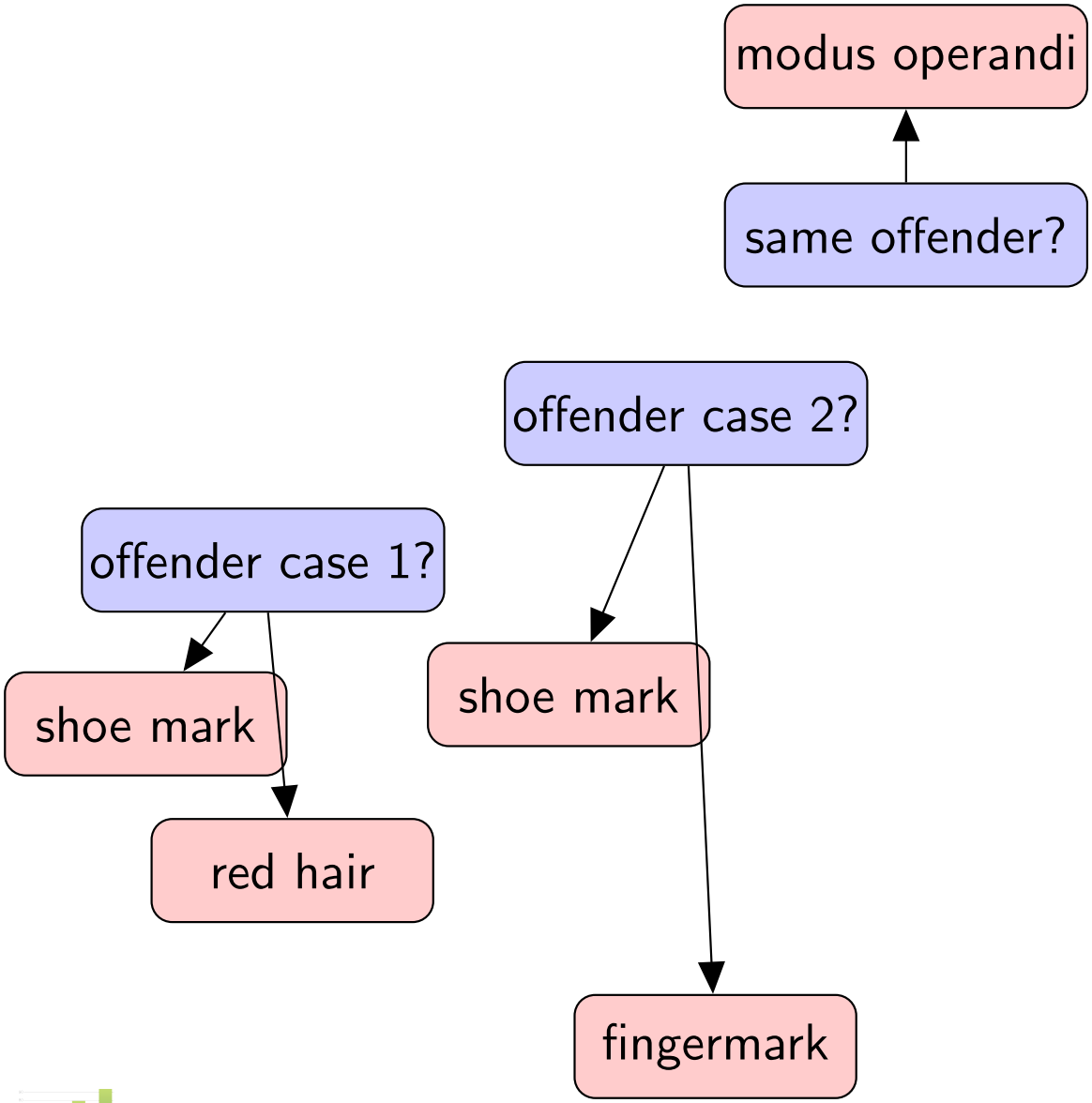
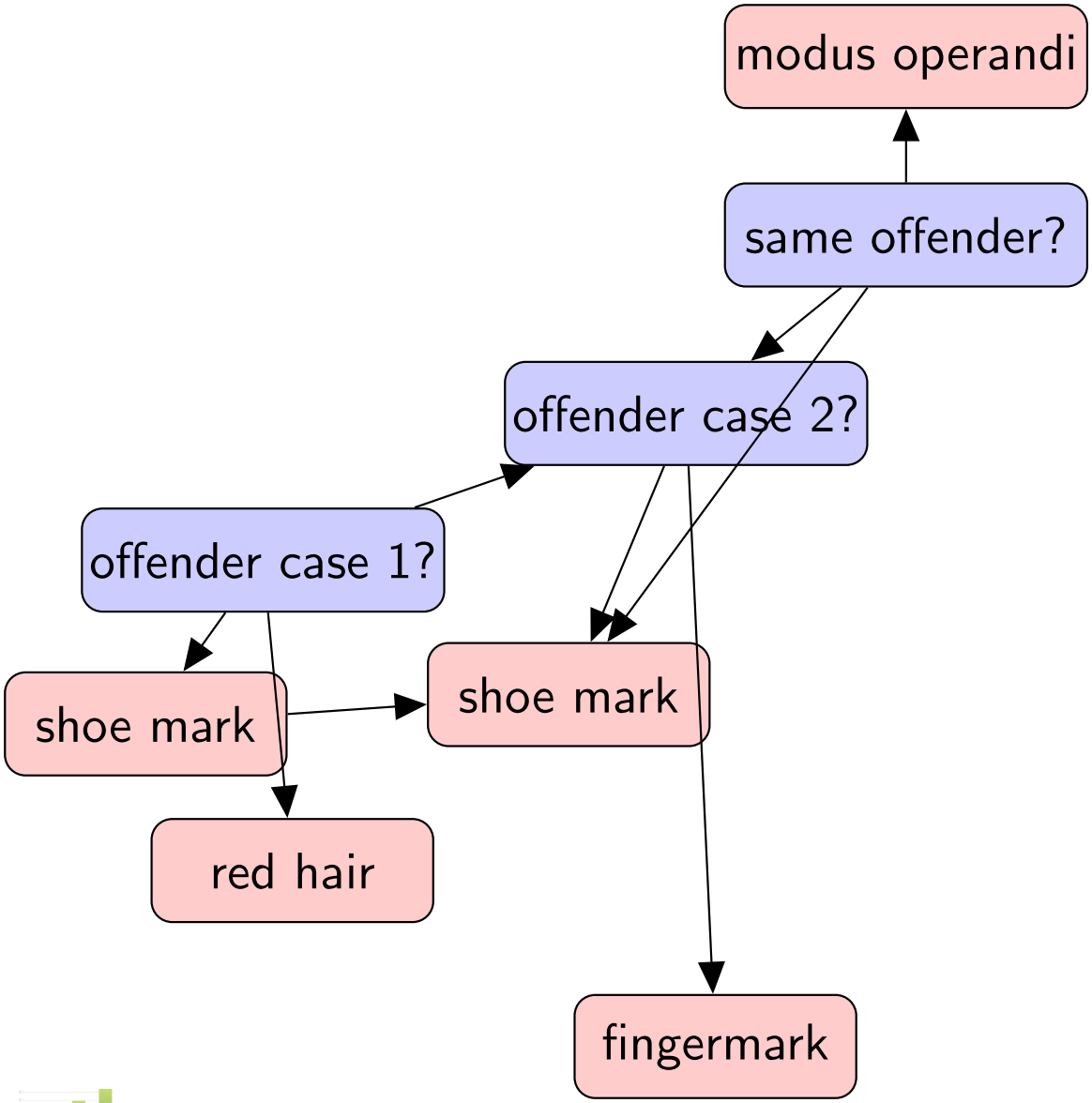
2 crimes


modus operandi
same offender?
offender case 2?
offender case 1?
shoe mark
shoe mark
red hair
fingermark

2 crimes



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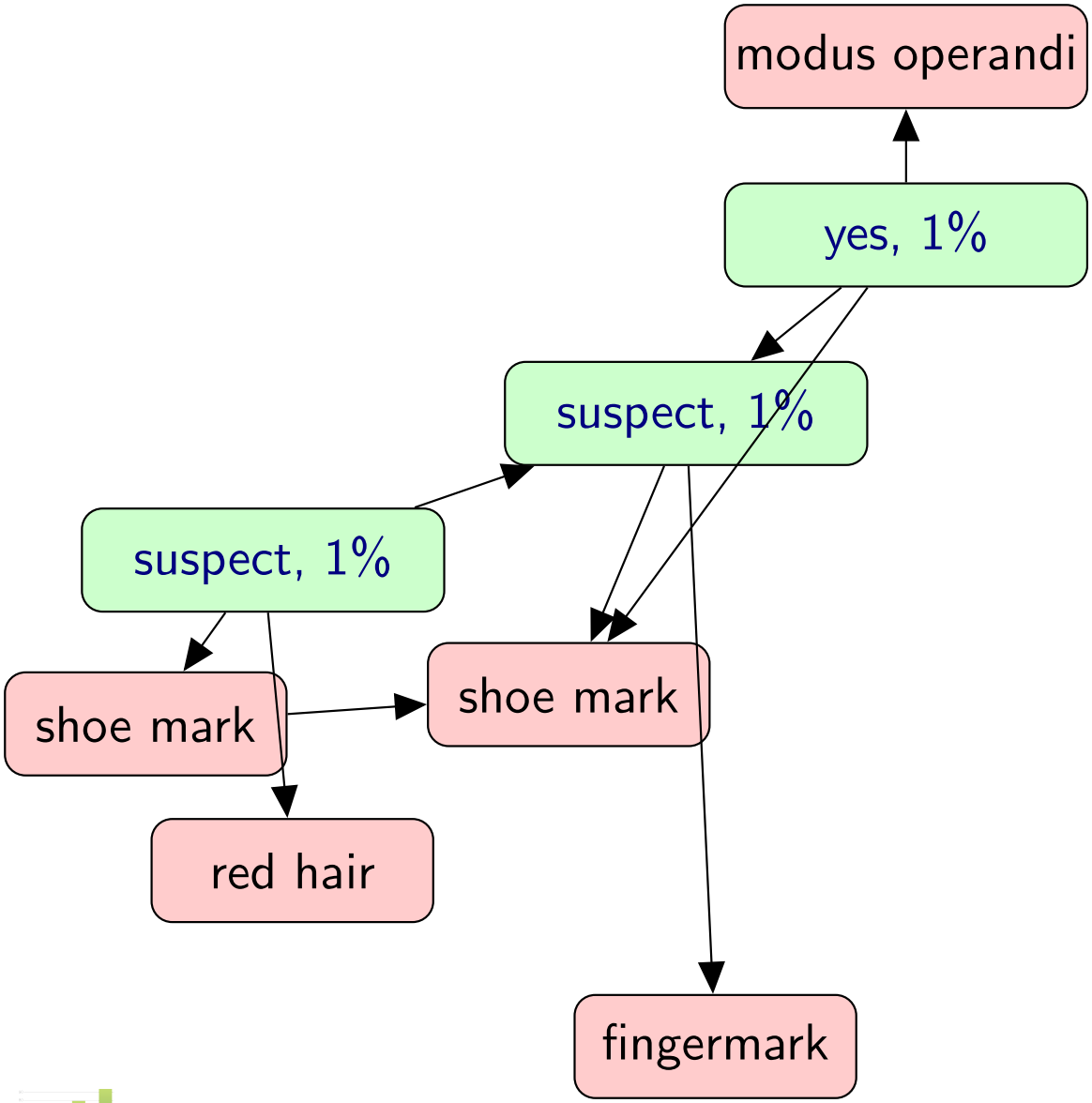
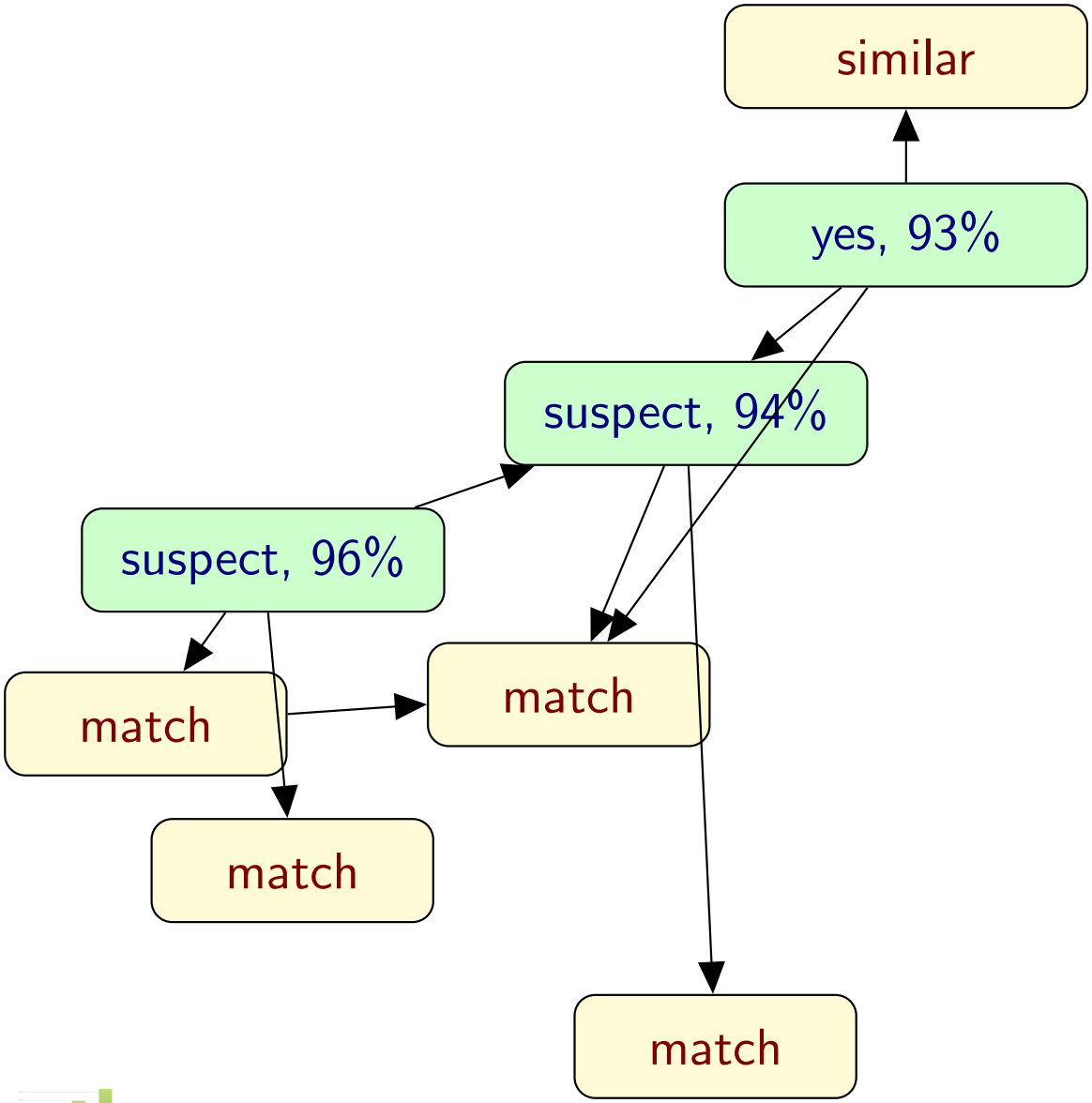
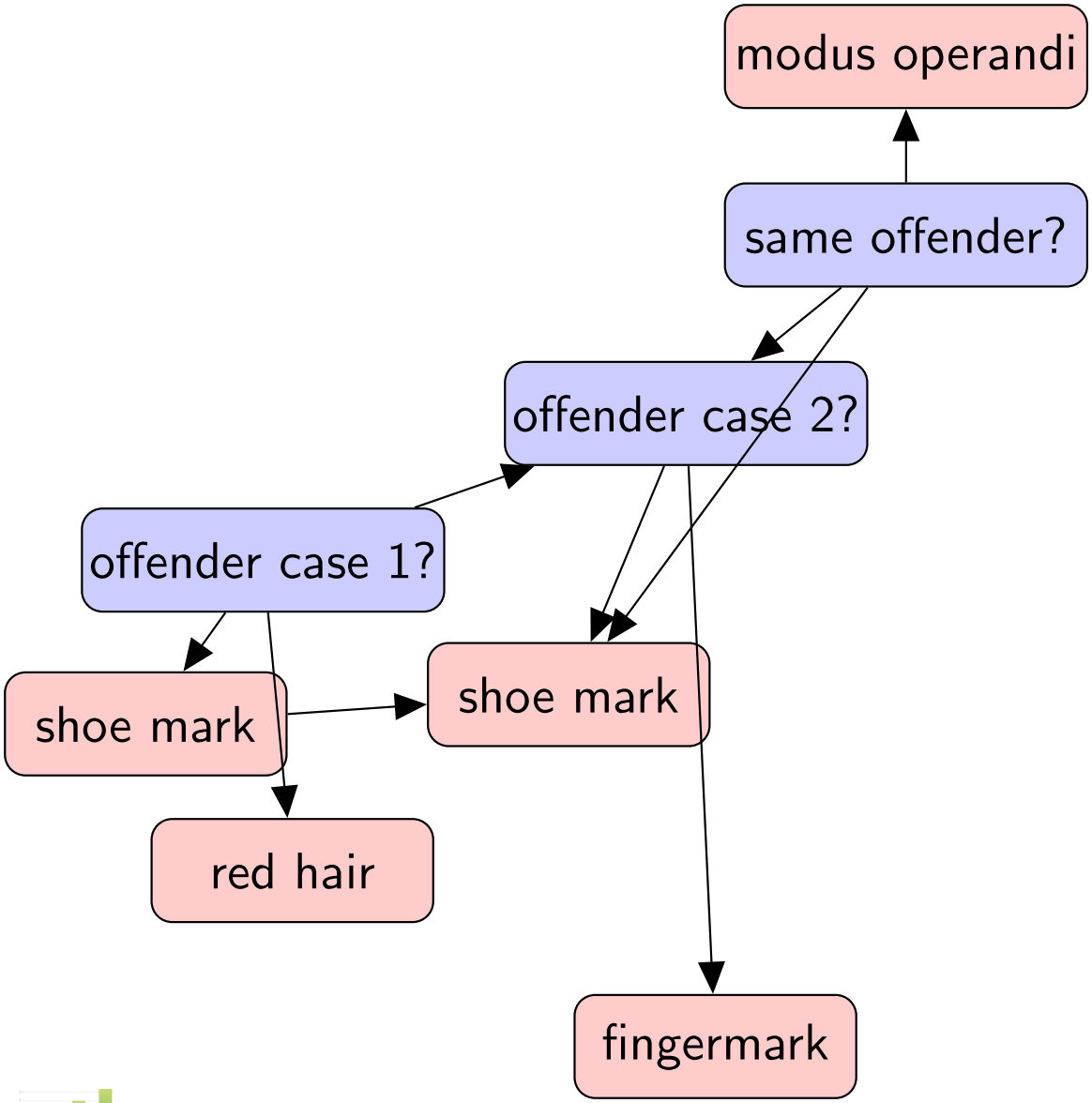
2 crimes


modus operandi
yes, 1%
suspect, 1%
suspect, 1%
shoe mark
shoe mark
red hair
fingermark

2 crimes


similar
yes, 93%
suspect, 94%
suspect, 96%
match
match
match
match

2 crimes



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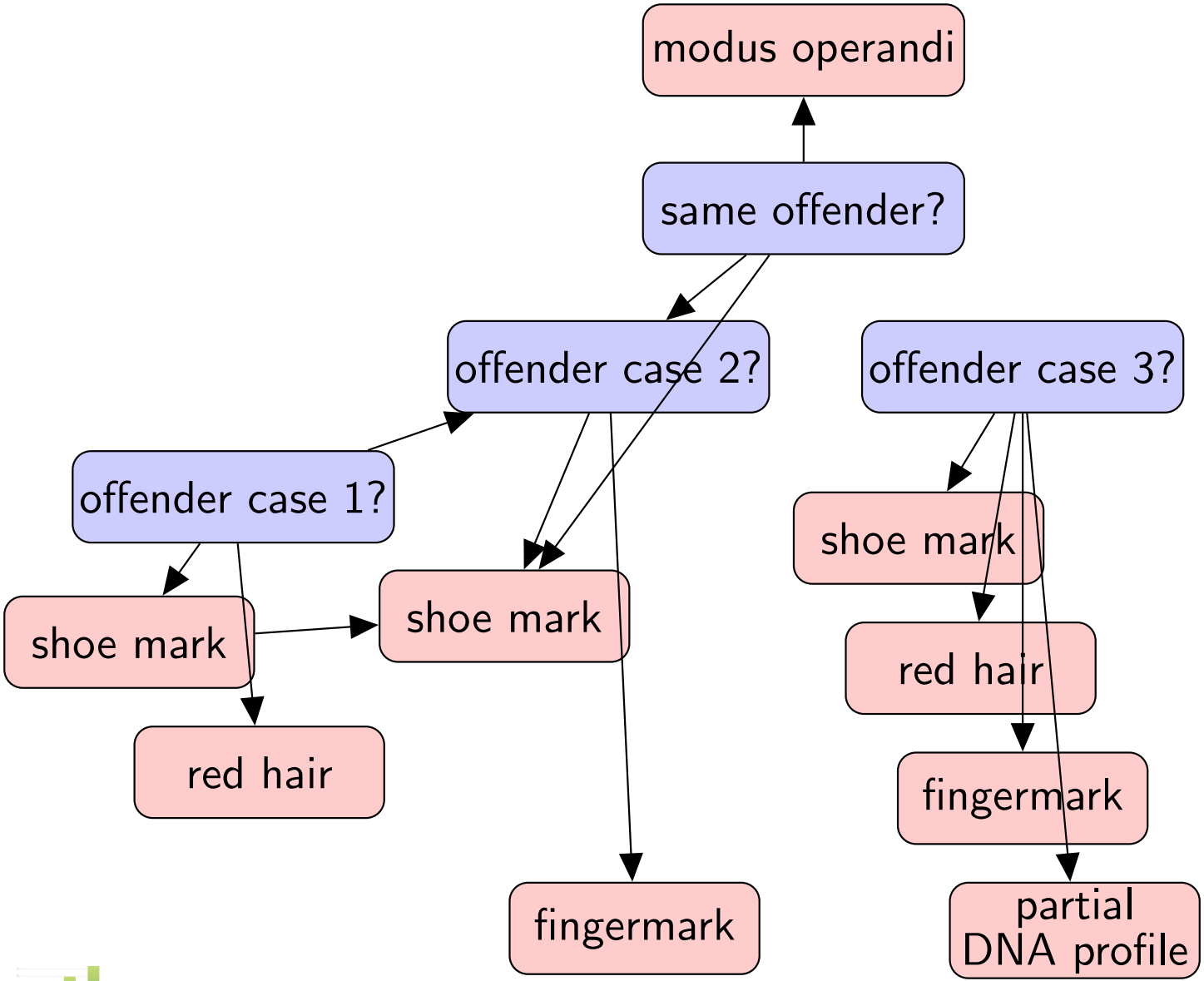
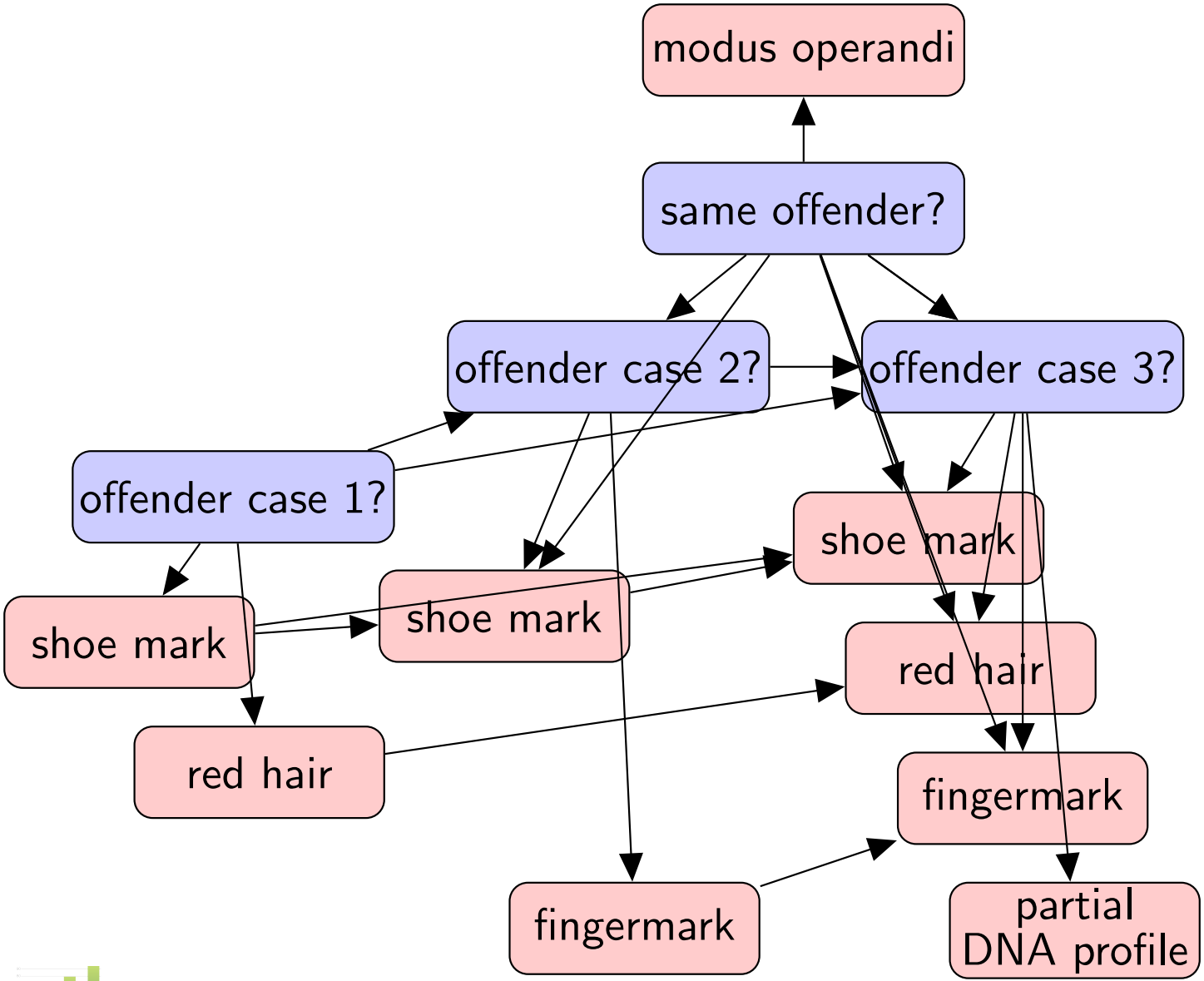
3 crimes


modus operandi
same offender?
offender case 2?
offender case 3?
offender case 1?
shoe mark
shoe mark
red hair
fingermark
shoe mark
red hair
fingermark
partial
DNA profile

3 crimes



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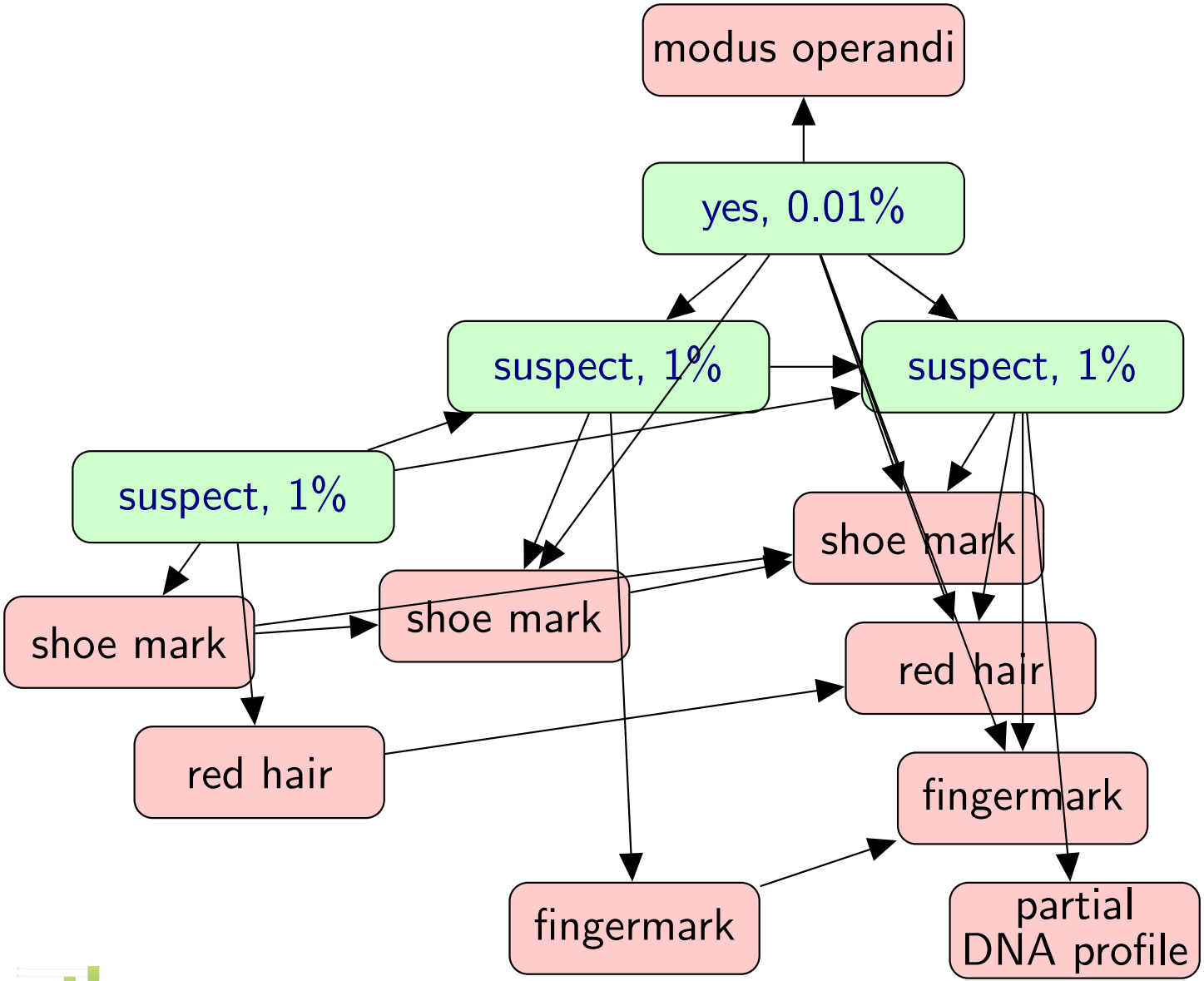
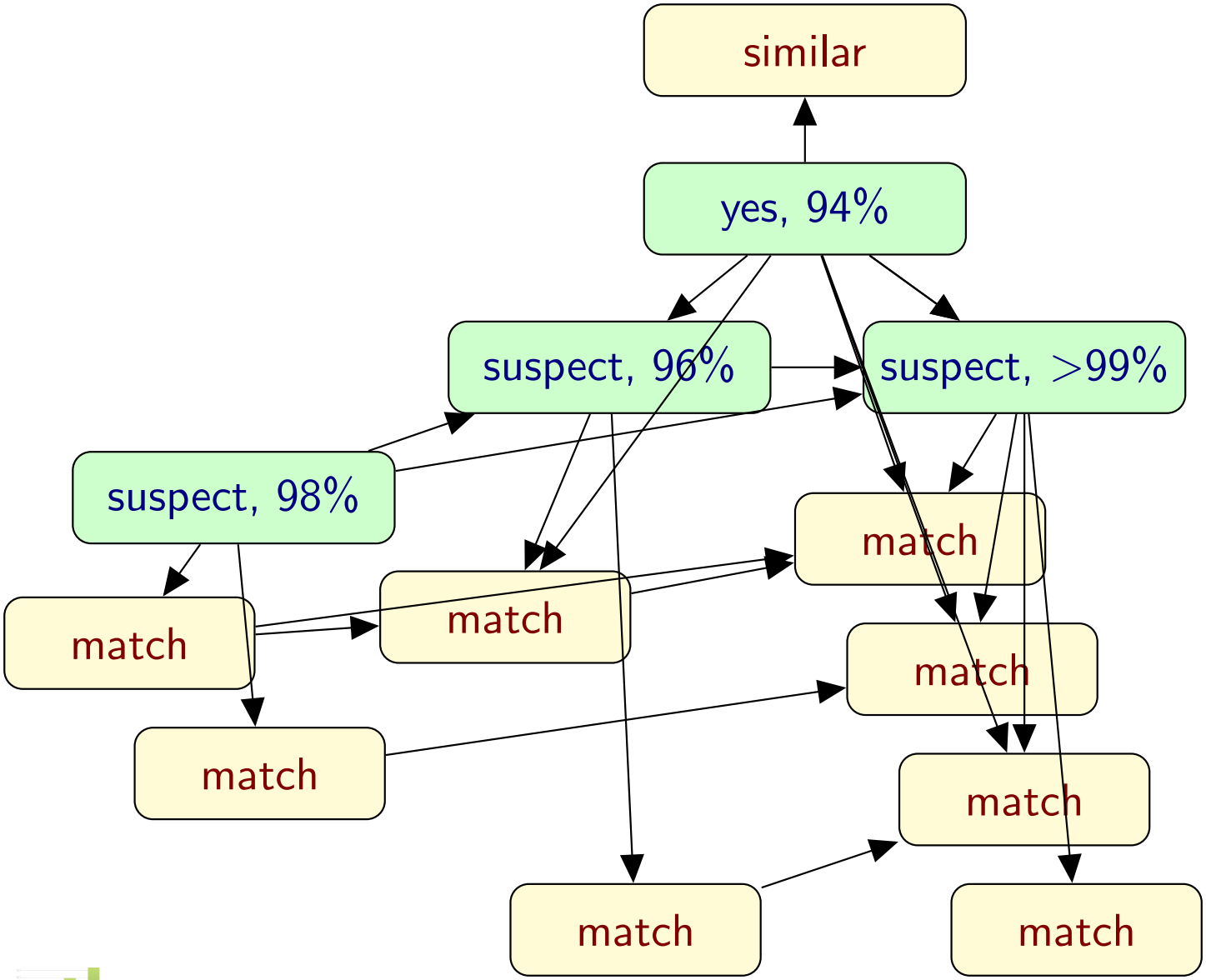
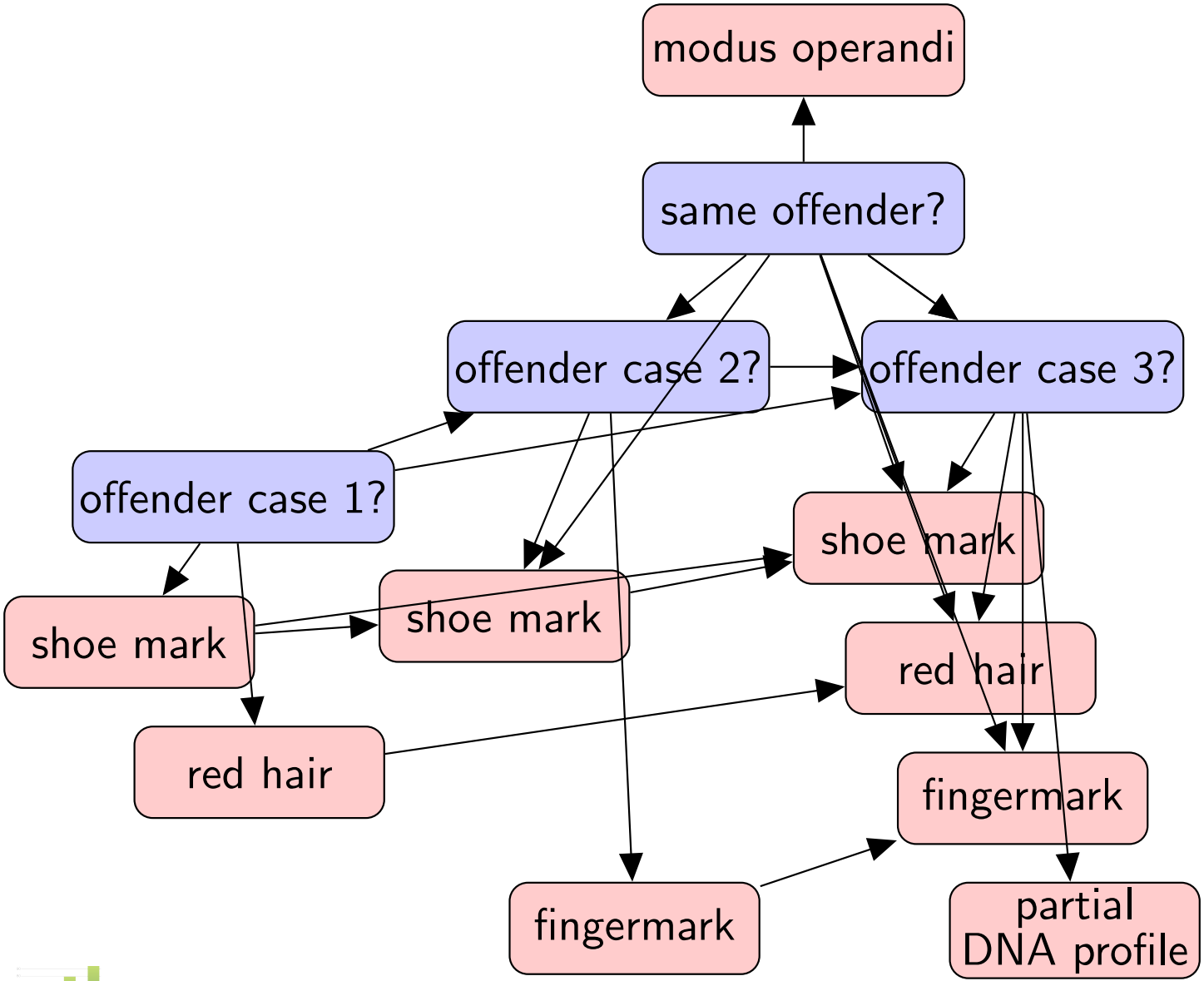
3 crimes


modus operandi
yes, 0.01%
suspect, 1%
suspect, 1%
suspect, 1%
shoe mark
shoe mark
shoe mark
red hair
red hair
fingermark
fingermark
partial
DNA profile

3 crimes


similar
yes, 94%
suspect, 96%
suspect, >99%
suspect, 98%
match
match
match
match
match
match
match
match

3 crimes



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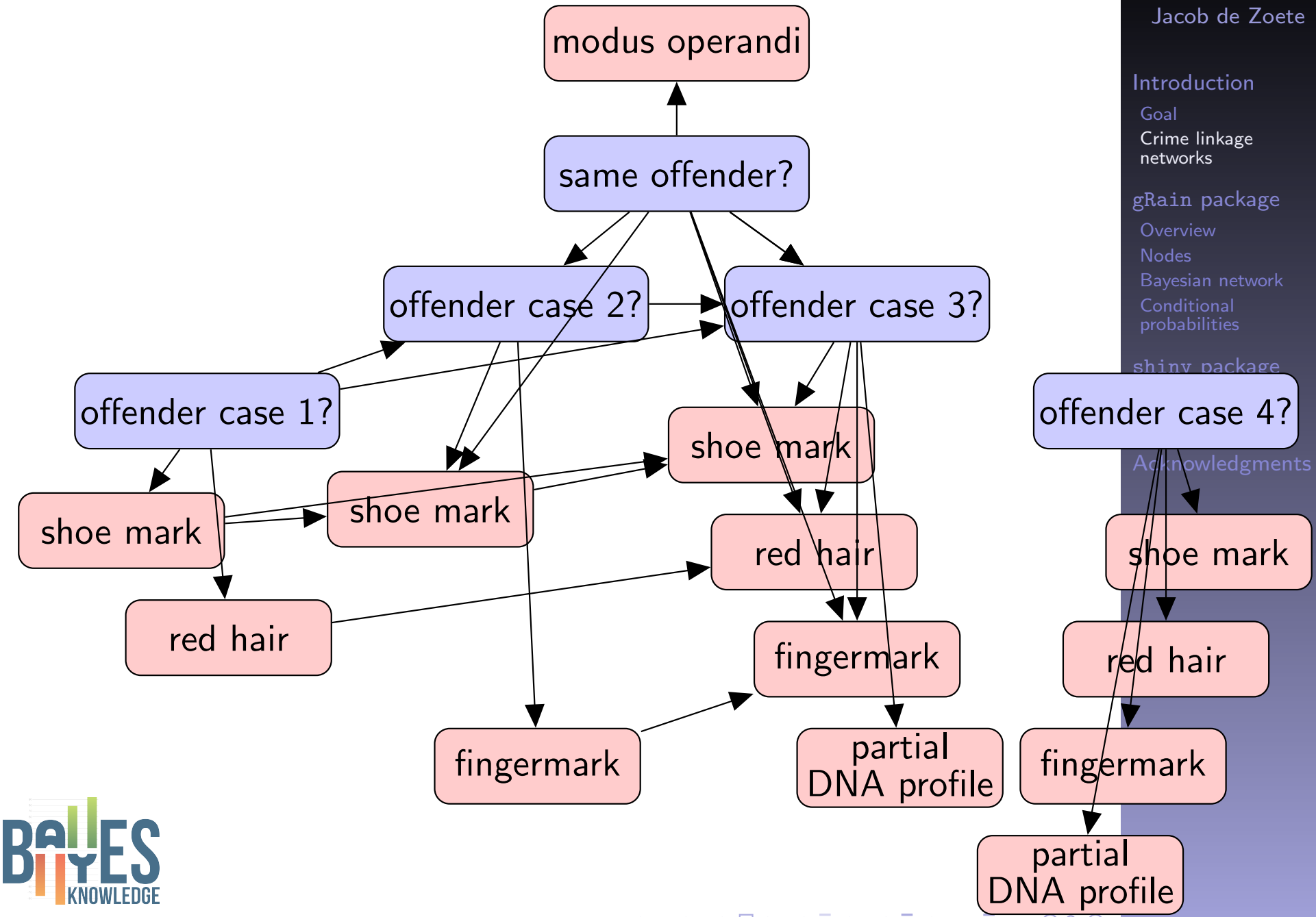
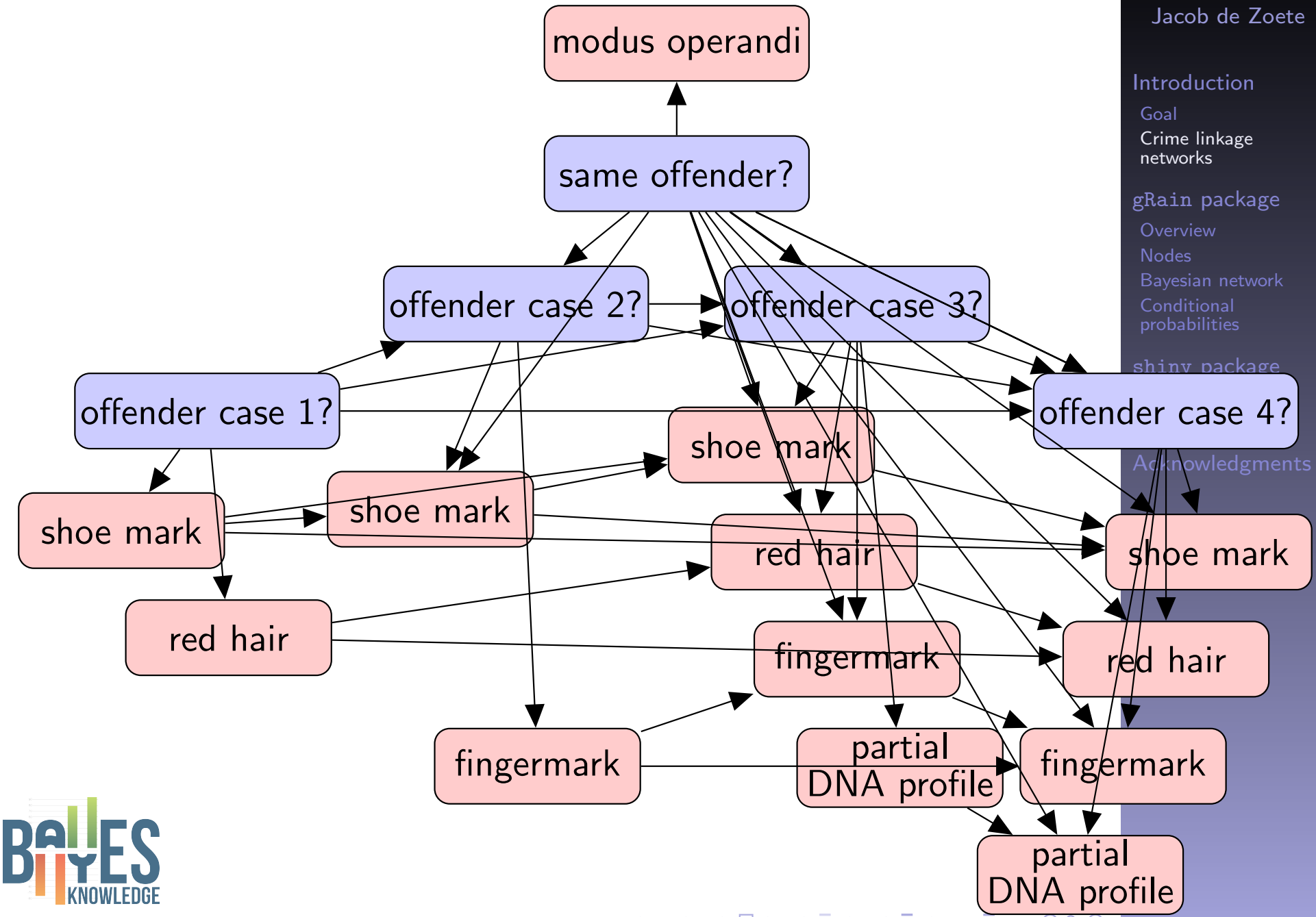
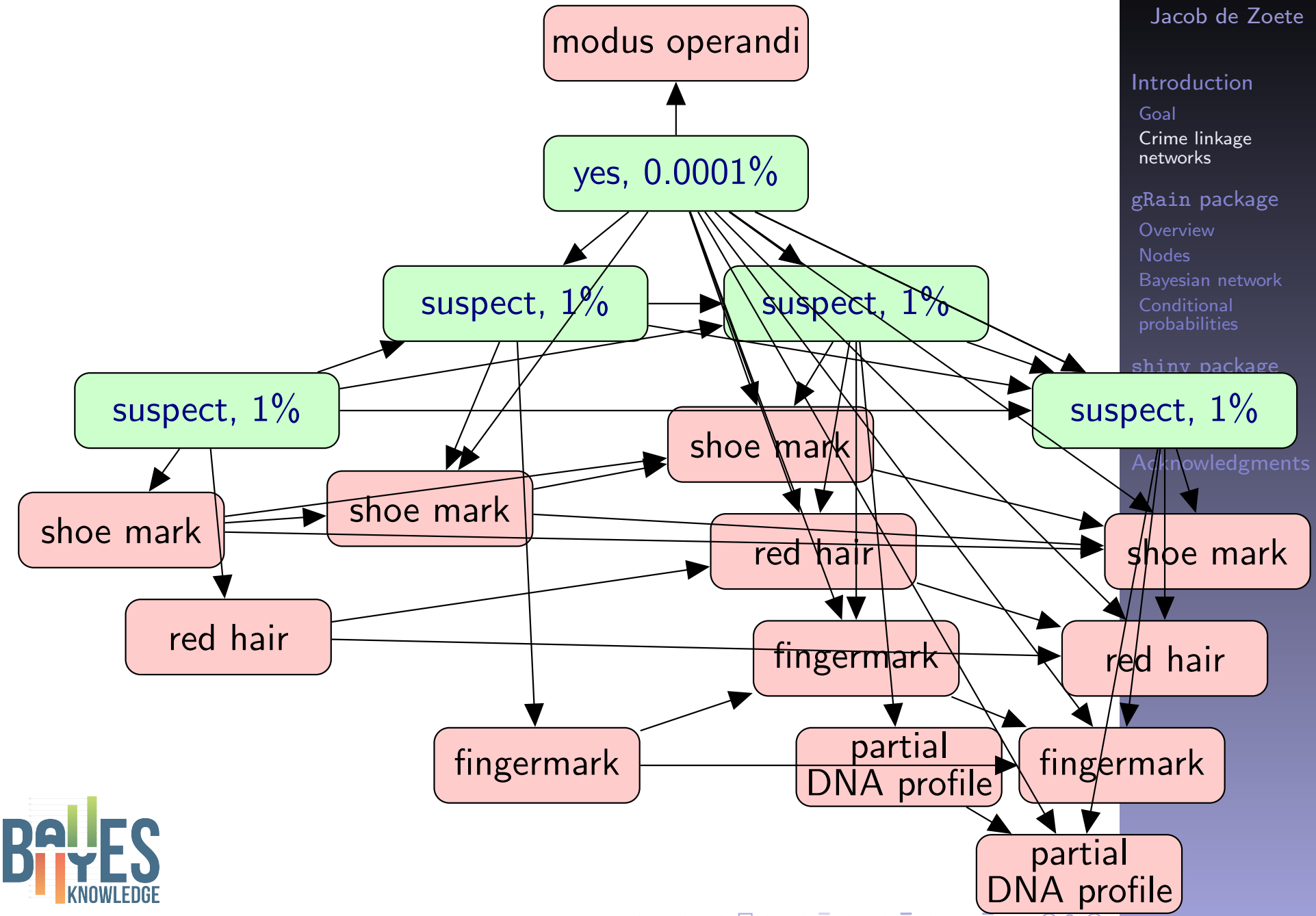
4 crimes


modus operandi
same offender?
offender case 2?
offender case 3?
offender case 1?
offender case 4?
shoe mark
shoe mark
shoe mark
shoe mark
red hair
red hair
fingermark
fingermark
partial DNA profile
fingermark
partial DNA profile

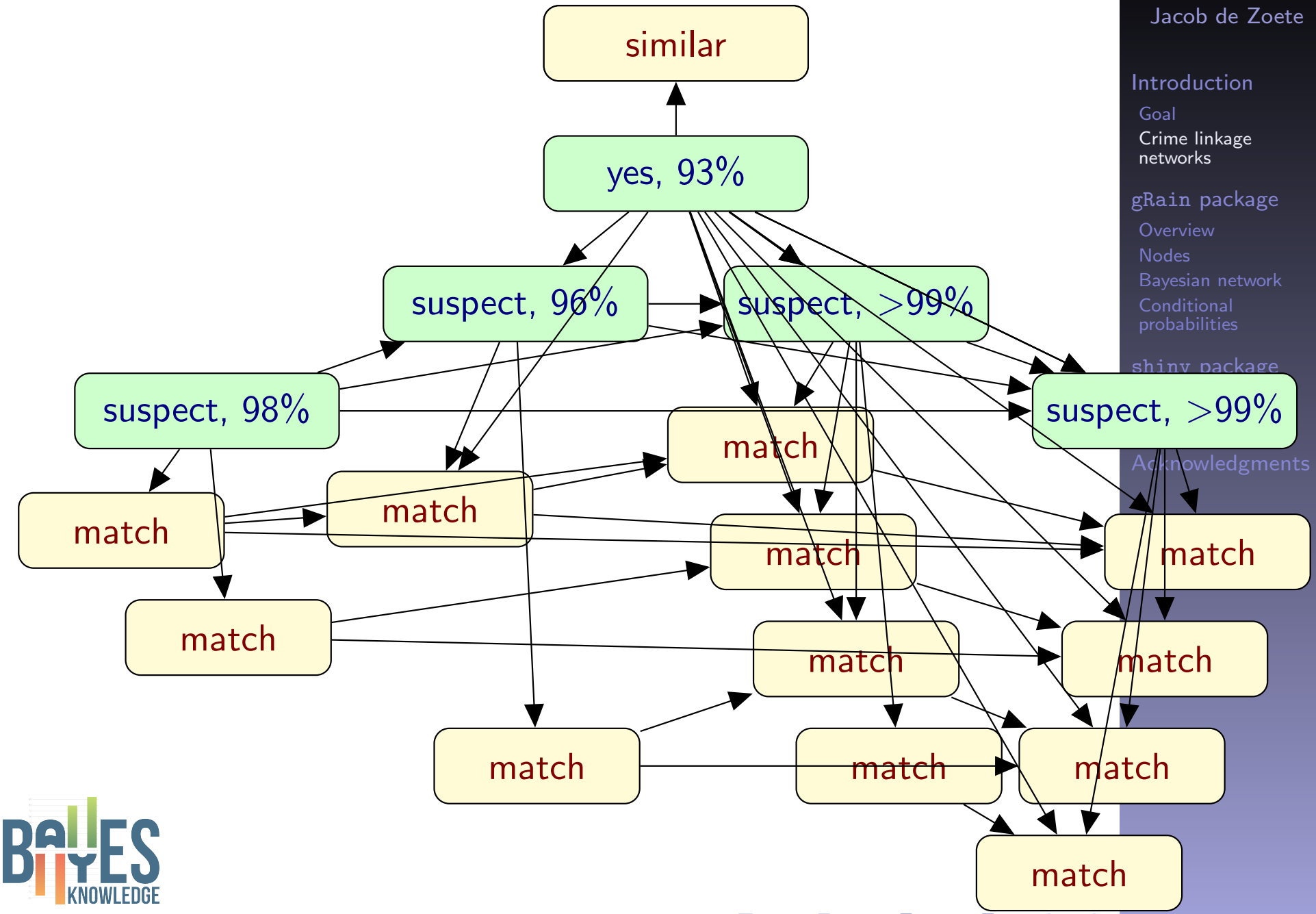
4 crimes


modus operandi
same offender?
offender case 2?
offender case 3?
offender case 1?
offender case 4?
shoe mark
shoe mark
shoe mark
red hair
shoe mark
red hair
fingermark
red hair
fingermark
partial DNA profile
fingermark
partial DNA profile

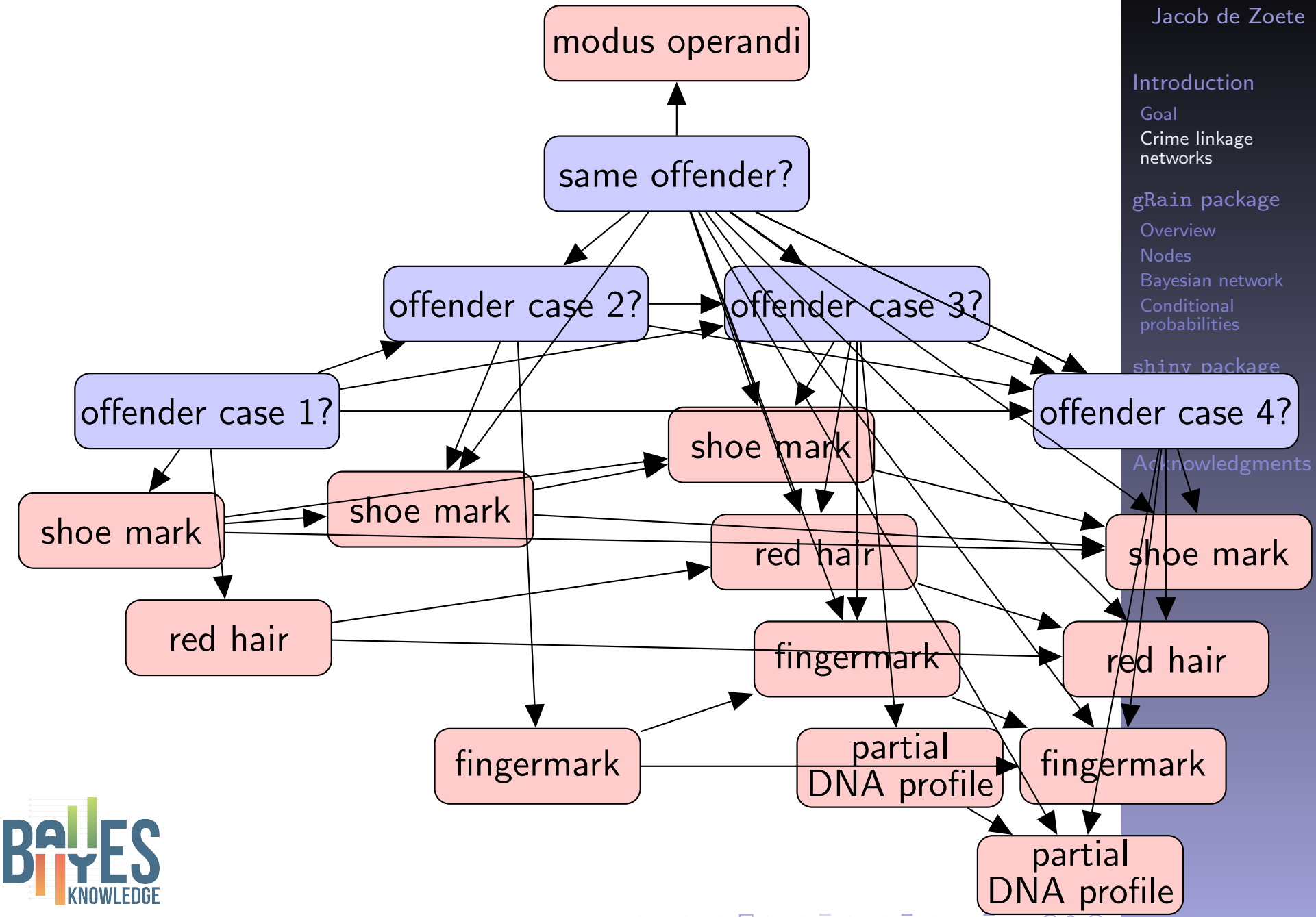
4 crimes


modus operandi
yes, 0.0001%
suspect, 1%
suspect, 1%
suspect, 1%
suspect, 1%
shoe mark
shoe mark
shoe mark
red hair
shoe mark
red hair
fingermark
red hair
fingermark
partial DNA profile
fingermark
partial DNA profile

4 crimes


similar
yes, 93%
suspect, 96%
suspect, >99%
suspect, 98%
suspect, >99%
match
match
match
match
match
match
match
match
match
match
match

4 crimes


modus operandi
same offender?
offender case 2?
offender case 3?
offender case 1?
offender case 4?
shoe mark
shoe mark
shoe mark
red hair
shoe mark
red hair
fingermark
red hair
fingermark
partial DNA profile
fingermark
partial DNA profile

4 crimes


modus operandi
NEVER SEND A HUMAN
TO DO A MACHINE'S JOB
fingermark
DNA profile
fingermark
partial
DNA profile

gRain package

- R is an open source programming language for statistical computing.
- The capabilities of R are extended through user-created packages.
- gRain is an R package for probability propagation in Bayesian networks.

gRain package

```
of1 <-cptable(~offender_1,                                    1
              levels  = c("suspect","unknown"),               2
              values  = c(0.1,0.9))                           3
```

Generating BNs

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gRain package

```
of1 <-cptable(~offender_1,  → node name                    1
              levels  = c("suspect","unknown"),            2
              values  = c(0.1,0.9))                        3
```

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gRain package

```
of1 <-cptable(~offender_1,                                    1
              levels  = c("suspect","unknown"),  → states     2
              values  = c(0.1,0.9))                           3
```

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```
of1 <-cptable(~offender_1,                                    1
              levels  = c("suspect","unknown"),               2
              values  = c(0.1,0.9)) → probability table       3
```

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gRain package

```
of1 <-cptable(~offender_1,
              levels  = c("suspect","unknown"),
              values  = c(0.1,0.9))
```

```
e11<-cptable(~evidence_11 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  0.01, 0.99))
```

gRain package

```
of1 <-cptable(~offender_1,                                    1
              levels  = c("suspect","unknown"),               2
              values  = c(0.1,0.9))                           3

e11<-cptable(~evidence_11 + offender_1,  → node parents       4
              levels  = c("match","no match"),                5
              values  = c(1,0,  0.01, 0.99))                  6
```

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gRain package

```
of1 <-cptable(~offender_1,
              levels  = c("suspect","unknown"),
              values  = c(0.1,0.9))

e11<-cptable(~evidence_11 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  0.01, 0.99))

e12<-cptable(~evidence_12 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  0.02, 0.98))
```


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```
of1 <-cptable(~offender_1,
              levels  = c("suspect","unknown"),
              values  = c(0.1,0.9))

e11<-cptable(~evidence_11 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  0.01, 0.99))

e12<-cptable(~evidence_12 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  0.02, 0.98))

plist <-compileCPT(list(of1,e11,e12))
pn    <-grain(plist)
```

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```
of1 <-cptable(~offender_1,                                    1
              levels  = c("suspect","unknown"),               2
              values  = c(0.1,0.9))                           3

e11<-cptable(~evidence_11 + offender_1,                       4
              levels  = c("match","no match"),                5
              values  = c(1,0,  0.01, 0.99))                  6

e12<-cptable(~evidence_12 + offender_1,                       7
              levels  = c("match","no match"),                8
              values  = c(1,0,  0.02, 0.98))                  9

plist <-compileCPT(list(of1,e11,e12))   → compile             10
pn    <-grain(plist)                                          11
```

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gRain package

```
of1 <-cptable(~offender_1,                                  1
              levels  = c("suspect","unknown"),             2
              values  = c(0.1,0.9))                         3

e11<-cptable(~evidence_11 + offender_1,                     4
              levels  = c("match","no match"),              5
              values  = c(1,0,  0.01, 0.99))                6

e12<-cptable(~evidence_12 + offender_1,                     7
              levels  = c("match","no match"),              8
              values  = c(1,0,  0.02, 0.98))                9

plist <-compileCPT(list(of1,e11,e12))                       10
pn    <-grain(plist)    → construct BN                      11
```

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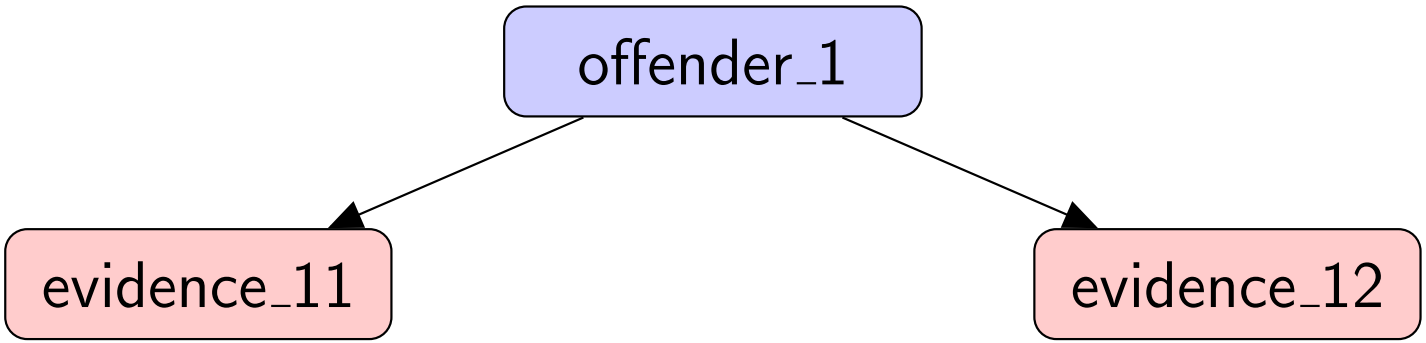
gRain network



gRain package - second offender

```
sof <-cptable(~same_offender,                    10
              levels  = c("yes","no"),           11
              values  = c(0.1,0.9))              12
```

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gRain package - second offender

```
sof <-cptable(~same_offender,                                    10
              levels  = c("yes","no"),                           11
              values  = c(0.1,0.9))                              12

of2 <-cptable(~offender_2 + offender_1 + same_offender,          13
              levels  = c("suspect","unknown"),                  14
              values  = c(1,0,  0,1,  0.1,0.9, 0.1,0.9))         15
```

gRain package - second offender

```
sof <-cptable(~same_offender,                                          10
              levels  = c("yes","no"),                                 11
              values  = c(0.1,0.9))                                    12

of2 <-cptable(~offender_2 + offender_1 + same_offender,                13
              levels  = c("suspect","unknown"),                        14
              values  = c(1,0,  0,1,  0.1,0.9, 0.1,0.9))               15

e21<-cptable(~evidence_21 + offender_2,                                16
              levels  = c("match","no match"),                         17
              values  = c(1,0,  0.01, 0.99))                           18
```

gRain package - second offender

```
sof <-cptable(~same_offender,                                    10
              levels  = c("yes","no"),                           11
              values  = c(0.1,0.9))                              12

of2 <-cptable(~offender_2 + offender_1 + same_offender,          13
              levels  = c("suspect","unknown"),                  14
              values  = c(1,0,  0,1,  0.1,0.9, 0.1,0.9))         15

e21<-cptable(~evidence_21 + offender_2,                          16
              levels  = c("match","no match"),                   17
              values  = c(1,0,  0.01, 0.99))                     18
```

gRain package - second offender

```
parents_e21<-c("offender_2")
```

gRain package - second offender

```
parents_e21<-c("offender_2")

if ( exists ("e11"){
  parents_e21<-paste(parents_e21, "+ evidence_11 + same_offender")
}
```

gRain package - second offender

```
parents_e21<-c("offender_2")

if (exists ("e11")){    → check whether variable exists
  parents_e21<-paste(parents_e21, "+ evidence_11 + same_offender")
}
```

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gRain package - second offender

```
parents_e21<-c("offender_2")                                          1

if ( exists ("e11"){                                                  2
  parents_e21<-paste(parents_e21, "+ evidence_11 + same_offender")    3
}                                                                     4
```

↓

"offender_2"

gRain package - second offender

```
parents_e21<-c("offender_2")                                          1

if ( exists ("e11"){                                                  2
  parents_e21<-paste(parents_e21, "+ evidence_11 + same_offender")    3
}                                                                     4
```

↓

"offender_2 + evidence_11 + same_offender"

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gRain package - second offender

```
sof <-cptable(~same_offender,                                          10
              levels  = c("yes","no"),                                 11
              values  = c(0.1,0.9))                                    12

of2 <-cptable(~offender_2 + offender_1 + same_offender,                13
              levels  = c("suspect","unknown"),                        14
              values  = c(1,0,  0,1,  0.1,0.9, 0.1,0.9))               15

e21<-cptable(~evidence_21 + parents_e21,                               16
              levels  = c("match","no match"),                         17
              values  = c(1,0,      1,     0,  0,1,     0,    1,       18
                          1,0,  0.01, 0.99, 1,0, 0.01, 0.99))          19

plist <-compileCPT(list(of1,e11,e12,sof,of2,e21))                      20
pn    <-grain(plist)                                                   21
```

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gRain package - second offender

```
sof <-cptable(~same_offender,                                          10
              levels  = c("yes","no"),                                 11
              values  = c(0.1,0.9))                                    12

of2 <-cptable(~offender_2 + offender_1 + same_offender,                13
              levels  = c("suspect","unknown"),                        14
              values  = c(1,0,  0,1,  0.1,0.9, 0.1,0.9))               15

e21<-cptable(~evidence_21 + parents_e21,                               16
              levels  = c("match","no match"),                         17
              values  = c(1,0,      1,     0,  0,1,     0,    1,       18
                          1,0,  0.01, 0.99, 1,0, 0.01, 0.99))          19

plist <-compileCPT(list(of1,e11,e12,sof,of2,e21))                      20
pn    <-grain(plist)                                                   21
```

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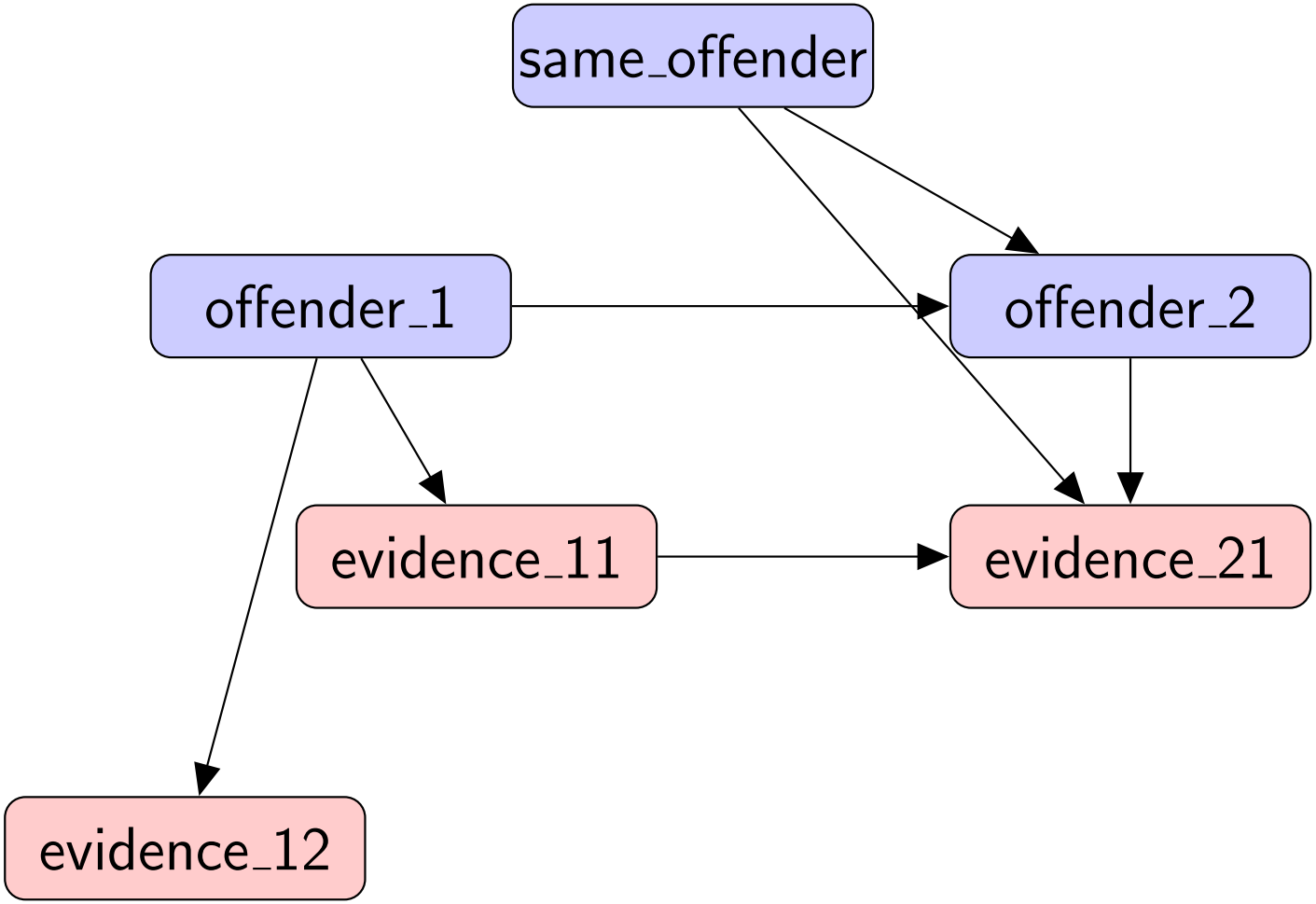
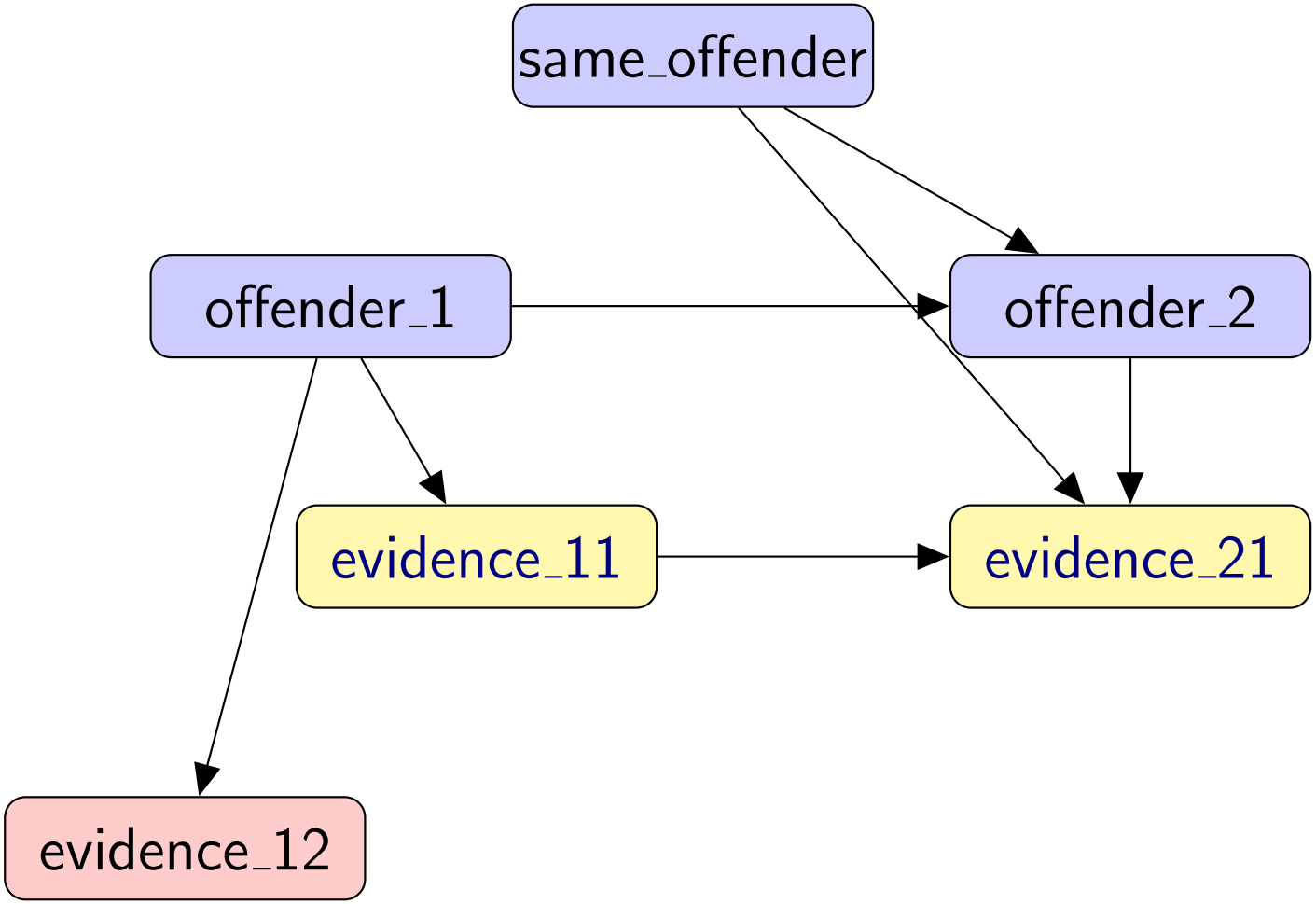
gRain network



gRain network



Conditional probabilities

evidence_11		
offender_1	*suspect*	*unknown*
match	1	0.01
no match	0	0.99

evidence_21					
offender_2	*suspect*	*unknown*			
same_off.	*	*yes*		*no*	
evidence_11	*	*match*	*no match*	*match*	*no match*
match	1	1	0	0.01	0.01
no match	0	0	1	0.99	0.99

Conditional probabilities

evidence_11		
offender_1	*suspect*	*unknown*
match	1	0.01
no match	0	0.99

evidence_21					
offender_2	*suspect*	*unknown*			
same_off.	*	*yes*		*no*	
evidence_11	*	*match*	*no match*	*match*	*no match*
match	1	1	0	0.01	0.01
no match	0	0	1	0.99	0.99

Conditional probabilities

evidence_11		
offender_1	*suspect*	*unknown*
match	1	p_evid_1
no match	0	1−p_evid_1

evidence_21					
offender_2	*suspect*	*unknown*			
same_off.	*	*yes*		*no*	
evidence_11	*	*match*	*no match*	*match*	*no match*
match	1	1	0	p_evid_1	p_evid_1
no match	0	0	1	1−p_evid_1	1−p_evid_1

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gRain package

```
of1 <-cptable(~offender_1,
              levels  = c("suspect","unknown"),
              values  = c(1/N, 1-1/N))

e11<-cptable(~evidence_11 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  p_evid_1, 1-p_evid_1))

e12<-cptable(~evidence_12 + offender_1,
              levels  = c("match","no match"),
              values  = c(1,0,  p_evid_2, 1-p_evid_2))
```

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```
of1 <-cptable(~offender_1,                                  1
              levels  = c("suspect","unknown"),             2
              values  = c(1/N, 1-1/N))                      3

e11<-cptable(~evidence_11 + offender_1,                     4
              levels  = c("match","no match"),              5
              values  = c(1,0,  p_evid_1, 1-p_evid_1))      6

e12<-cptable(~evidence_12 + offender_1,                     7
              levels  = c("match","no match"),              8
              values  = c(1,0,  p_evid_2, 1-p_evid_2))      9
```


Generating BNs

Jacob de Zoete

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shiny package

- shiny is an R package for building interactive web applications.
- Using your own R code, it is relatively easy to construct a GUI.
- Furthermore, this application can be accessed online, which removes the necessity of having R installed.

shiny application

http://bayes-knowledge.com/

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Generating BNs for crime linkage scenarios

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