

# A one-minute introduction to the **gRain** package

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## 1 Introduction

The **gRain** package implements propagation in [gra]phical [i]ndependence [n]etworks (hereafter abbreviated **grain**). Such networks are also known as probabilistic networks and Bayesian networks.

To cite **gRain** in publications, please use:

Søren Højsgaard (2012). Graphical Independence Networks with the **gRain** Package for R. Journal of Statistical Software, 46(10), 1-26. <http://www.jstatsoft.org/v46/i10/>.

More information about the package, other graphical modelling packages and development versions is available from

<http://people.math.aau.dk/~sorenh/software/gR>

## 2 A worked example: chest clinic

CPTspec with probabilities:

```
P( asia )
P( tub | asia )
P( smoke )
P( lung | smoke )
P( bronc | smoke )
P( either | lung tub )
P( xray | either )
P( dysp | bronc either )
```

Independence network: Compiled: FALSE Propagated: FALSE

Nodes: chr [1:8] "asia" "tub" "smoke" "lung" "bronc" "either" ...

This section reviews the chest clinic example of Lauritzen and Spiegelhalter (1988) (illustrated in Figure 1) and shows one way of specifying the model in **gRain**. Lauritzen and Spiegelhalter (1988) motivate the chest clinic example as follows:

“Shortness-of-breath (dyspnoea) may be due to tuberculosis, lung cancer or bronchitis, or none of them, or more than one of them. A recent visit to Asia increases the chances of tuberculosis, while smoking is known to be a risk factor for both lung cancer and bronchitis. The results of a single chest X-ray do not discriminate between lung cancer and tuberculosis, as neither does the presence or absence of dyspnoea.”

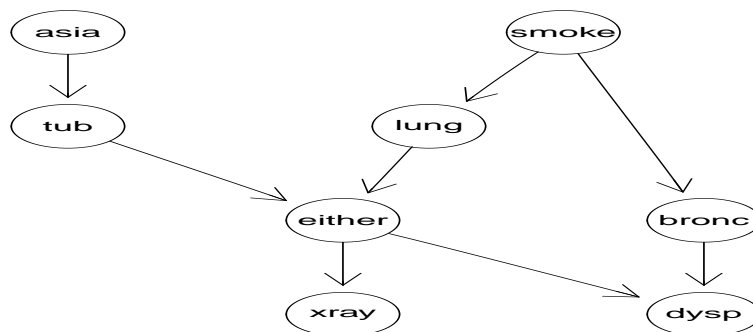


Figure 1: Chest clinic example from LS.

### 2.1 Building a network

A Bayesian network is a special case of graphical independence networks. In this section we outline how to build a Bayesian network. The starting point is a probability distribution

factorising according to a DAG with nodes  $V$ . Each node  $v \in V$  has a set  $pa(v)$  of parents and each node  $v \in V$  has a finite set of states. A joint distribution over the variables  $V$  can be given as

$$p(V) = \prod_{v \in V} p(v|pa(v)) \quad (1)$$

where  $p(v|pa(v))$  is a function defined on  $(v, pa(v))$ . This function satisfies that  $\sum_{v^*} p(v = v^*|pa(v)) = 1$ , i.e. that for each configuration of the parents  $pa(v)$ , the sum over the levels of  $v$  equals one. Hence  $p(v|pa(v))$  becomes the conditional distribution of  $v$  given  $pa(v)$ . In practice  $p(v|pa(v))$  is specified as a table called a conditional probability table or a CPT for short. Thus, a Bayesian network can be regarded as a complex stochastic model built up by putting together simple components (conditional probability distributions).

Thus the DAG in Figure 1 dictates a factorization of the joint probability function as

$$p(V) = p(\alpha)p(\sigma)p(\tau|\alpha)p(\lambda|\sigma)p(\beta|\sigma)p(\epsilon|\tau, \lambda)p(\delta|\epsilon, \beta)p(\xi|\epsilon). \quad (2)$$

In (2) we have  $\alpha = \text{asia}$ ,  $\sigma = \text{smoker}$ ,  $\tau = \text{tuberculosis}$ ,  $\lambda = \text{lung cancer}$ ,  $\beta = \text{bronchitis}$ ,  $\epsilon = \text{either tuberculosis or lung cancer}$ ,  $\delta = \text{dyspnoea}$  and  $\xi = \text{xray}$ . Note that  $\epsilon$  is a logical variable which is true if either  $\tau$  or  $\lambda$  are true and false otherwise.

## 2.2 Queries to networks

Suppose we are given the finding (evidence) that a set of variables  $E \subset V$  have a specific value  $e^*$ . For example that a person has recently visited Asia and suffers from dyspnoea, i.e.  $\alpha = \text{yes}$  and  $\delta = \text{yes}$ .

With this finding, we are often interested in the conditional distribution  $p(v|E = e^*)$  for some of the variables  $v \in V \setminus E$  or in  $p(U|E = e^*)$  for a set  $U \subset V \setminus E$ .

In the chest clinic example, interest might be in  $p(\lambda|e^*)$ ,  $p(\tau|e^*)$  and  $p(\beta|e^*)$ , or possibly in the joint (conditional) distribution  $p(\lambda, \tau, \beta|e^*)$ .

Interest might also be in calculating the probability of a specific event, e.g. the probability of seeing a specific finding, i.e.  $p(E = e^*)$ .

## 3 A one-minute version of gRain

A simple way of specifying the model for the chest clinic example is as follows.

1. Specify conditional probability tables (with values as given in Lauritzen and Spiegelhalter (1988)):

```
> yn <- c("yes", "no")
> a    <- ctable(~asia, values=c(1,99), levels=yn)
> t.a  <- ctable(~tub|asia, values=c(5,95,1,99), levels=yn)
```

```

> s      <- cptable(~smoke, values=c(5,5), levels=yn)
> l.s    <- cptable(~lung|smoke, values=c(1,9,1,99), levels=yn)
> b.s    <- cptable(~bronc|smoke, values=c(6,4,3,7), levels=yn)
> e.lt   <- cptable(~either|lung:tub, values=c(1,0,1,0,1,0,0,1), levels=yn)
> x.e    <- cptable(~xray|either, values=c(98,2,5,95), levels=yn)
> d.be   <- cptable(~dysp|bronc:either, values=c(9,1,7,3,8,2,1,9), levels=yn)

```

2. Create the network from the conditional probability tables:

```

> plist <- compileCPT(list(a, t.a, s, l.s, b.s, e.lt, x.e, d.be))
> plist

CPTspec with probabilities:
P( asia )
P( tub | asia )
P( smoke )
P( lung | smoke )
P( bronc | smoke )
P( either | lung tub )
P( xray | either )
P( dysp | bronc either )

> net1 <- grain(plist)
> net1

Independence network: Compiled: FALSE Propagated: FALSE
Nodes: chr [1:8] "asia" "tub" "smoke" "lung" "bronc" "either" "xray" ...

```

3. The network can be queried to give marginal probabilities:

```

> querygrain(net1,nodes=c("lung","bronc"), type="marginal")

$lung
lung
  yes    no
0.055 0.945

$bronc
bronc
  yes    no
0.45 0.55

```

Likewise, a joint distribution can be obtained.

```

> querygrain(net1,nodes=c("lung","bronc"), type="joint")

      bronc
lung    yes    no
yes 0.0315 0.0235
no  0.4185 0.5265

```

4. Findings can be entered as:

```
> net12 <- setFinding(net1,nodes=c("asia","dysp"),states=c("yes","yes"))
```

5. The network can be queried again:

```
> querygrain(net12,nodes=c("lung","bronc"))

$lung
lung
      yes      no
0.09952515 0.90047485

$bronc
bronc
      yes      no
0.8114021 0.1885979

> querygrain(net12,nodes=c("lung","bronc"), type="joint")

      bronc
lung      yes      no
  yes 0.06298076 0.03654439
  no  0.74842132 0.15205354
```

6. Zero probabilities

Consider setting the finding

```
> net13 <- setFinding(net1,nodes=c("either","tub"),states=c("no","yes"))
```

Under the model, this finding has zero probability;

```
> pFinding(net13)
```

```
[1] 0
```

Therefore, all conditional probabilities are (under the model) undefined;

```
> querygrain(net13,nodes=c("lung","bronc"), type="joint")
```

```
      bronc
lung yes  no
  yes NaN NaN
  no  NaN NaN
```

## References

Steffen Liholt Lauritzen and David Spiegelhalter. Local computations with probabilities on graphical structures and their application to expert systems. *J. Roy. Stat. Soc. Ser. B*, 50(2):157–224, 1988.