2018-10-19.R

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2020-10-19

#if (!requireNamespace("BiocManager", quietly = TRUE))  
# install.packages("BiocManager")  
#install.packages("bnlearn")  
#BiocManager::install("RBGL")  
#BiocManager::install("Rgraphviz")  
#BiocManager::install("gRain")  
  
  
####################################Identify d-separation###########################################################  
####################################Assigment1#  
library(bnlearn)

## Warning: package 'bnlearn' was built under R version 4.0.3

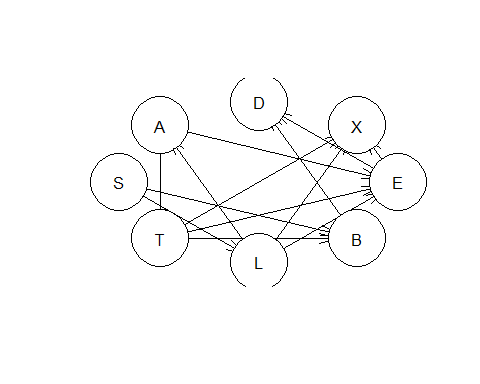
library(gRain)

## Loading required package: gRbase

##   
## Attaching package: 'gRbase'

## The following objects are masked from 'package:bnlearn':  
##   
## ancestors, children, parents

data(asia)  
View(asia)  
  
#Learn a BN from the Asia dataset. Learn both the structure and the parameters. Use any algorithm setting that  
#you consider appropriate. Identify a d-separation in the BN learned and show that it indeed corresponds  
# to an independence in the probability distribution represented by the BN. To do so you may want to use exact or  
#approximate inference with the help of the bnlearn and gRain packages  
  
  
### Learn the structure  
set.seed(123)  
BN\_structure = hc(asia, score = "bde", iss = 10)  
  
plot(BN\_structure)



cpdag(BN\_structure)

##   
## Bayesian network learned via Score-based methods  
##   
## model:  
## [partially directed graph]  
## nodes: 8   
## arcs: 13   
## undirected arcs: 3   
## directed arcs: 10   
## average markov blanket size: 4.00   
## average neighbourhood size: 3.25   
## average branching factor: 1.25   
##   
## learning algorithm: Hill-Climbing   
## score: Bayesian Dirichlet (BDe)   
## graph prior: Uniform   
## imaginary sample size: 10   
## tests used in the learning procedure: 119   
## optimized: TRUE

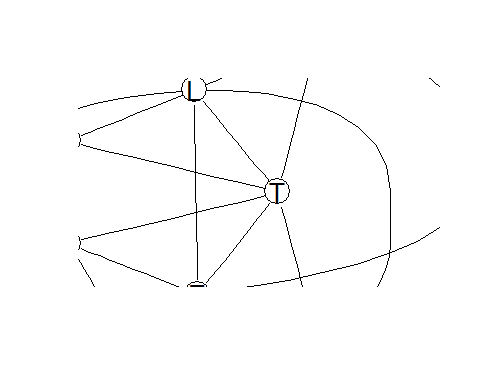
score(BN\_structure, asia)

## [1] -11160.48

#plotting the structure we can see that b is independent from E is independent  
  
  
### Learn the parameters  
# Using bn.fit we get the conditional probability tables for the different nodes. All these conditional probabilities   
# define the joint probability. In conclusion we know have the joint probability but now need the marginal probability  
# in order to be able to compute the marginal probability distribution for teh searched node  
BN\_fit = bn.fit(BN\_structure, data = asia, method = "bayes")  
BN\_fit

##   
## Bayesian network parameters  
##   
## Parameters of node A (multinomial distribution)  
##   
## Conditional probability table:  
##   
## L  
## A no yes  
## no 0.991336898 0.980597015  
## yes 0.008663102 0.019402985  
##   
## Parameters of node S (multinomial distribution)  
##   
## Conditional probability table:  
## no yes   
## 0.497006 0.502994   
##   
## Parameters of node T (multinomial distribution)  
##   
## Conditional probability table:  
##   
## A  
## T no yes  
## no 0.991033649 0.904255319  
## yes 0.008966351 0.095744681  
##   
## Parameters of node L (multinomial distribution)  
##   
## Conditional probability table:  
##   
## S  
## L no yes  
## no 0.98534137 0.88154762  
## yes 0.01465863 0.11845238  
##   
## Parameters of node B (multinomial distribution)  
##   
## Conditional probability table:  
##   
## , , T = no  
##   
## S  
## B no yes  
## no 0.7030014 0.2822080  
## yes 0.2969986 0.7177920  
##   
## , , T = yes  
##   
## S  
## B no yes  
## no 0.4183673 0.3367347  
## yes 0.5816327 0.6632653  
##   
##   
## Parameters of node E (multinomial distribution)  
##   
## Conditional probability table:  
##   
## , , T = no, L = no  
##   
## A  
## E no yes  
## no 0.999863990 0.983221477  
## yes 0.000136010 0.016778523  
##   
## , , T = yes, L = no  
##   
## A  
## E no yes  
## no 0.015923567 0.192307692  
## yes 0.984076433 0.807692308  
##   
## , , T = no, L = yes  
##   
## A  
## E no yes  
## no 0.001933488 0.119047619  
## yes 0.998066512 0.880952381  
##   
## , , T = yes, L = yes  
##   
## A  
## E no yes  
## no 0.119047619 0.500000000  
## yes 0.880952381 0.500000000  
##   
##   
## Parameters of node X (multinomial distribution)  
##   
## Conditional probability table:  
##   
## , , L = no, E = no  
##   
## T  
## X no yes  
## no 0.95646424 0.50000000  
## yes 0.04353576 0.50000000  
##   
## , , L = yes, E = no  
##   
## T  
## X no yes  
## no 0.50000000 0.50000000  
## yes 0.50000000 0.50000000  
##   
## , , L = no, E = yes  
##   
## T  
## X no yes  
## no 0.50000000 0.01515152  
## yes 0.50000000 0.98484848  
##   
## , , L = yes, E = yes  
##   
## T  
## X no yes  
## no 0.00802139 0.11904762  
## yes 0.99197861 0.88095238  
##   
##   
## Parameters of node D (multinomial distribution)  
##   
## Conditional probability table:  
##   
## , , E = no  
##   
## B  
## D no yes  
## no 0.8997410 0.2140392  
## yes 0.1002590 0.7859608  
##   
## , , E = yes  
##   
## B  
## D no yes  
## no 0.2813620 0.1496815  
## yes 0.7186380 0.8503185

#in order to make inference we have to modify the network to a grain object. This makes it possible for setEvidence and   
# querygrain to perform posterior inference via belief propagation. This only works for discrete networks. Also important  
# that as.grain foes not allow for conditional probabilities to be Nan. This happens when estimating with maximum  
# likelihood and some parent configurations are not observed in the data. In this case the as.grain will give a warning   
# and replace the nan with a uniform distribution, much like the baysian posterior would  
  
fit\_grain = as.grain(BN\_fit)  
  
#compile the network = create the junction tree and establishing the clique potentials. It is now an undirected MN  
compiled\_network = compile(fit\_grain)  
plot(compiled\_network)



# Using querygrain we get the marginal distribution of a set of variable given evidence of set of variable  
# Evidence is added by using setEvidence which extracts the probability tables for node(S) which can be in states x  
# setEvidence allows for specification of hard evidence and likelihood evidence for variables. In this case we want to  
# prove that there is a d-separation present on node s and that there is an independence in the probability distribution  
# We therfor want to extract get the evidence (the probability table) for node s which can be in state x.  
  
### vad ger querygrain?? marginal distribution?? Hur gör man approximate inference??  
prop.table(table(querygrain(compiled\_network)))

## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.490237694295215, S = 0.497005988023952, X = 0.115207491473733, D = 0.468666361263353  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
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## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.5 0.0  
## 0.99061876247505 0.0 0.0  
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## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.490237694295215, S = 0.502994011976048, X = 0.115207491473733, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.0755035872978657, B = 0.490237694295215, S = 0.502994011976048, X = 0.115207491473733, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.924496412702134, B = 0.490237694295215, S = 0.502994011976048, X = 0.115207491473733, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
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##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.509762305704785, S = 0.502994011976048, X = 0.115207491473733, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.0755035872978657, B = 0.509762305704785, S = 0.502994011976048, X = 0.115207491473733, D = 0.531333638736647  
##   
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## 0.0093812375249501 0.0 0.0  
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##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.924496412702134, B = 0.509762305704785, S = 0.502994011976048, X = 0.115207491473733, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.490237694295215, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.0755035872978657, B = 0.490237694295215, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.924496412702134, B = 0.490237694295215, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.924496412702134, B = 0.490237694295215, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.5  
##   
## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.509762305704785, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.0755035872978657, B = 0.509762305704785, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.924496412702134, B = 0.509762305704785, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.924496412702134, B = 0.509762305704785, S = 0.497005988023952, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.490237694295215, S = 0.502994011976048, X = 0.884792508526267, D = 0.531333638736647  
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## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
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## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
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## 0.0093812375249501 0.0 0.0  
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##   
## , , T = 0.990219560878243, E = 0.924496412702134, B = 0.490237694295215, S = 0.502994011976048, X = 0.884792508526267, D = 0.531333638736647  
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## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.00978043912175648, E = 0.0755035872978657, B = 0.509762305704785, S = 0.502994011976048, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
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## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0  
##   
## , , T = 0.990219560878243, E = 0.924496412702134, B = 0.509762305704785, S = 0.502994011976048, X = 0.884792508526267, D = 0.531333638736647  
##   
## L  
## A 0.0668662674650699 0.93313373253493  
## 0.0093812375249501 0.0 0.0  
## 0.99061876247505 0.0 0.0

querygrain(compiled\_network)

## $A  
## A  
## no yes   
## 0.990618762 0.009381238   
##   
## $L  
## L  
## no yes   
## 0.93313373 0.06686627   
##   
## $T  
## T  
## no yes   
## 0.990219561 0.009780439   
##   
## $E  
## E  
## no yes   
## 0.92449641 0.07550359   
##   
## $B  
## B  
## no yes   
## 0.4902377 0.5097623   
##   
## $S  
## S  
## no yes   
## 0.497006 0.502994   
##   
## $X  
## X  
## no yes   
## 0.8847925 0.1152075   
##   
## $D  
## D  
## no yes   
## 0.5313336 0.4686664

# In order to prove independence between two nodes and therefor prove the presens of d-separation we want to get the   
# conditional probabilities for Independent node | parentnode1, parentnode2, independent\_node. For the same pair of   
# states in parentnodes the conditional probability should therfore be the same.  
  
  
# nodes = parent nodes + comparing node, states = all combinations of states  
hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("yes","yes","yes"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.3367347 0.6632653

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("yes","yes","no"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.3367347 0.6632653

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("yes","no","yes"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.282208 0.717792

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("yes","no","no"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.282208 0.717792

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("no","yes","yes"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.4183673 0.5816327

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("no","yes","no"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.4183673 0.5816327

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("no","no","yes"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.7030014 0.2969986

hc7<-setFinding(compiled\_network,nodes=c("S","T","E"),states=c("no","no","no"))  
querygrain(hc7,c("B"))

## $B  
## B  
## no yes   
## 0.7030014 0.2969986

#In the example above we can see that for the same combination of yes/no for the nodes S, T we get the same conditional  
# probability for B. This implies that B is independent from E and that d-separation is present.