Package 'jti'

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Title Junction Tree Inference

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Description Minimal and memory efficient implementation of the junction tree algorithm using the Lauritzen-Spiegelhalter scheme; S. L. Lauritzen and D. J. Spiegelhalter (1988) <https://www.jstor.org/stable/2345762?seq=1>. The jti package is part of the paper <doi:10.18637/jss.v111.i02>.

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Contents

`jti-package` *jti: Junction Tree Inference*

Description

Minimal and memory efficient implementation of the junction tree algorithm using the Lauritzen-Spiegelhalter scheme.

Details

The main functions are `cpt_list`, `compile`,`jt` and `query_belief` which together is sufficient to make inference using the junction tree algorithm.

Author(s)

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References

Local Computations with Probabilities on Graphical Structures and Their Application to Expert Systems by S. L. Lauritzen and D. J. Spiegelhalter (1988). Journal of the Royal Statistical Society: Series B (Methodological) volume 50, issue 2.

See Also

Useful links:

- https://github.com/mlindsk/jti

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asia *Asia*

Description

Small synthetic data set from Lauritzen and Spiegelhalter (1988) about lung diseases (tuberculosis, lung cancer or bronchitis) and visits to Asia. This copy of the data was taken from the R package "bnlearn" where all values "yes" have been converted to "y" and all values "no" have been converted to "n".

Usage

```
asia
```

Format

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 5000 rows and 8 columns.

Details

`D` **(dysponea)**

`T` **(tuberculosis)**

`L` **(lung cancer)**

`B` **(bronchitis)**

`A` **(visit to Asia)**

`S` **(smoking)**

`X` **(chest C-ray)**

`E` **(tuberculosis vs cancer/bronchitis)**

References

bnlearn-asia

`asia2` *Asia2*

Description

See the `asia` data for information. This version, has class `bn.fit`.

Usage

```
asia2
```

Format

An object of class `list` of length 8.

References

bnlearn-asia

`bnfit_to_cpts` *bnfit to cpts*

Description

Convert a `bn.fit` object (a list of cpts from the bnlearn package) into a list of ordinary array-like cpts

Usage

```
bnfit_to_cpts(x)
```

Arguments

`x`	A `bn.fit` object

compile *Compile information*

Description

Compiled objects are used as building blocks for junction tree inference

Usage

```
compile(
  x,
  evidence = NULL,
  root_node = "",
  joint_vars = NULL,
  tri = "min_fill",
  pmf_evidence = NULL,
  alpha = NULL,
  initialize_cpts = TRUE
)

## S3 method for class 'cpt_list'
compile(
  x,
  evidence = NULL,
  root_node = "",
  joint_vars = NULL,
  tri = "min_fill",
  pmf_evidence = NULL,
  alpha = NULL,
  initialize_cpts = TRUE
)
```

Arguments

x	An object returned from `cpt_list` (baeysian network) or `pot_list` (decomposable markov random field)
evidence	A named vector. The names are the variabes and the elements are the evidence.
root_node	A node for which we require it to live in the root clique (the first clique).
joint_vars	A vector of variables for which we require them to be in the same clique. Edges between all these variables are added to the moralized graph.
tri	The optimization strategy used for triangulation if x originates from a Baeysian network. One of • 'min_fill' • 'min_rfill' • 'min_sp'

- 'min_ssp'
- 'min_lsp'
- 'min_lssp'
- 'min_elsp'
- 'min_elssp'
- 'min_nei'
- 'minimal'
- 'alpha'

`pmf_evidence` A named vector of frequencies of the expected missingness of a variable. Variables with frequencies of 1 can be neglected; these are inferrred. A value of 0.25 means, that the given variable is expected to be missing (it is not a evidence node) in one fourth of the future cases. Relevant for `tri` methods 'min_elsp' and 'min_elssp'.

`alpha` Character vector. A permutation of the nodes in the graph. It specifies a user-supplied elimininination ordering for triangulation of the moral graph.

`initialize_cpts` `TRUE` if the CPTs should be initialized, i.e. multiplied together to form the clique potentials. If FALSE, the `compiled` object will save the triangulation and other information that needs only bee computed once. Herafter, it is possible to enter evidence into the CPTs, using `set_evidence`, saving a lot of computations.

Details

The Junction Tree Algorithm performs both a forward and inward message pass (collect and distribute). However, when the forward phase is finished, the root clique potential is guaranteed to be the joint pmf over the variables involved in the root clique. Thus, if it is known in advance that a specific variable is of interest, the algortihm can be terminated after the forward phase. Use the `root_node` to specify such a variable and specify `propagate = "collect"` in the juntion tree algortihm function `jt`.

Moreover, if interest is in some joint pmf for variables that end up being in different cliques these variables must be specified in advance using the `joint_vars` argument. The compilation step then adds edges between all of these variables to ensure that at least one clique contains all of them.

Evidence can be entered either at compile stage or after compilation. Hence, one can also combine evidence from before compilation with evidence after compilation. Before refers to entering evidence in the 'compile' function and after refers to entering evidence in the 'jt' function.

Finally, one can either use a Bayesian network or a decomposable Markov random field (use the `ess` package to fit these). Bayesian networks must be constructed with `cpt_list` and decomposable MRFs can be constructed with both `pot_list` and `cpt_list`. However, `pot_list` is just an alias for `cpt_list` which handles both cases internally.

Examples

```
cptl <- cpt_list(asia2)
cp1  <- compile(cptl, evidence = c(bronc = "yes"), joint_vars = c("bronc", "tub"))
print(cp1)
names(cp1)
dim_names(cp1)
```

```
plot(get_graph(cp1))
```

cpt_list *Conditional probability list*

Description

A check and conversion of cpts to be used in the junction tree algorithm

Usage

```
cpt_list(x, g = NULL)

## S3 method for class 'list'
cpt_list(x, g = NULL)

## S3 method for class 'data.frame'
cpt_list(x, g)
```

Arguments

x	Either a named list with cpts in form of array-like object(s) where names must be the child node or a `data.frame`
g	Either a directed acyclic graph (DAG) as an igraph object or a decomposable graph as an igraph object. If `x` is a list, `g` must be `NULL`. The procedure then deduce the graph from the conditional probability tables.

Examples

```
library(igraph)
el <- matrix(c(
"A", "T",
"T", "E",
"S", "L",
"S", "B",
"L", "E",
"E", "X",
"E", "D",
"B", "D"),
 nc = 2,
 byrow = TRUE
)

g <- igraph::graph_from_edgelist(el)
cl <- cpt_list(asia, g)

print(cl)
dim_names(cl)
names(cl)
plot(get_graph(cl))
```

`dim_names` *Various getters*

Description

Getter methods for `cpt_list`, `pot_list`, `charge` and `jt` objects

Usage

```
dim_names(x)

has_inconsistencies(x)

## S3 method for class 'cpt_list'
dim_names(x)

## S3 method for class 'cpt_list'
names(x)

## S3 method for class 'charge'
dim_names(x)

## S3 method for class 'charge'
names(x)

## S3 method for class 'charge'
has_inconsistencies(x)

## S3 method for class 'jt'
dim_names(x)

## S3 method for class 'jt'
names(x)

## S3 method for class 'jt'
has_inconsistencies(x)
```

Arguments

x	cpt_list, pot_list, charge or jt

get_cliques *Return the cliques of a junction tree*

Description

Return the cliques of a junction tree

Usage

```
get_cliques(x)

## S3 method for class 'jt'
get_cliques(x)

## S3 method for class 'charge'
get_cliques(x)

## S3 method for class 'pot_list'
get_cliques(x)

get_clique_root_idx(x)

## S3 method for class 'jt'
get_clique_root_idx(x)

get_clique_root(x)

## S3 method for class 'jt'
get_clique_root(x)
```

Arguments

x	A junction tree object, `jt`.

See Also

`jt`

Examples

```
# See Example 5  and 6 of the 'jt' function
```

get_graph *Get graph*

Description

Retrieve the graph

Usage

```
get_graph(x)

## S3 method for class 'charge'
get_graph(x)

## S3 method for class 'cpt_list'
get_graph(x)
```

Arguments

x	`cpt_list` or a compiled object

Value

A graph as an `igraph` object

get_triang_graph *Get triangulated graph*

Description

Retrieve the triangulated graph from

Usage

```
get_triang_graph(x)
```

Arguments

x	A compiled object

Value

A triangulated graph as a neibor matrix

`initialize` *Initialize*

Description

Initialization of CPTs

Usage

```
initialize(x)

## S3 method for class 'charge'
initialize(x)
```

Arguments

`x`	A compiled object.

Details

Multiply the CPTs and allocate them to clique potentials.

`jt` *Junction Tree*

Description

Construction of a junction tree and message passing

Usage

```
jt(x, evidence = NULL, flow = "sum", propagate = "full")

## S3 method for class 'charge'
jt(x, evidence = NULL, flow = "sum", propagate = "full")
```

Arguments

`x`	An object return from `compile`
`evidence`	A named vector. The names are the variabes and the elements are the evidence
`flow`	Either "sum" or "max"
`propagate`	Either "no", "collect" or "full".

Details

Evidence can be entered either at compile stage or after compilation. Hence, one can also combine evidence from before compilation with evidence after compilation. Before refers to entering evidence in the 'compile' function and after refers to entering evidence in the 'jt' function.

Value

A `jt` object

See Also

query_belief, mpe, get_cliques, get_clique_root, propagate

Examples

```
# Setting up the network
# ----------------------

library(igraph)
el <- matrix(c(
"A", "T",
"T", "E",
"S", "L",
"S", "B",
"L", "E",
"E", "X",
"E", "D",
"B", "D"),
 nc = 2,
 byrow = TRUE
)

g <- igraph::graph_from_edgelist(el)
plot(g)
# -----------------------

# Data
# ----
# We use the asia data; see the man page (?asia)

# Compilation
# -----------
cl <- cpt_list(asia, g) # Checking and conversion
cp <- compile(cl)

# After the network has been compiled, the graph has been triangulated and
# moralized. Furthermore, all conditional probability tables (CPTs) has been
# designated one of the cliques (in the triangulated and moralized graph).

# Example 1: sum-flow without evidence
# ------------------------------------
jt1 <- jt(cp)
```

```
plot(jt1)
print(jt1)
query_belief(jt1, c("E", "L", "T"))
query_belief(jt1, c("B", "D", "E"), type = "joint")


# Notice, that jt1 is equivalent to:
# jt1 <- jt(cp, propagate = "no")
# jt1 <- propagate(jt1, prop = "full")

# That is; it is possible to postpone the actual propagation
# In this setup, the junction tree is saved in the jt1 object,
# and one can repeadetly enter evidence for new observations
# using the set_evidence function on jt1 and then query
# several probabilites without repeadetly calculating the
# the junction tree over and over again. One just needs
# to use the propagate function on jt1.

# Example 2: sum-flow with evidence
# ---------------------------------

e2  <- c(A = "y", X = "n")
jt2 <- jt(cp, e2)
query_belief(jt2, c("B", "D", "E"), type = "joint")

# Notice that, the configuration (D,E,B) = (y,y,n) has changed
# dramatically as a consequence of the evidence

# We can get the probability of the evidence:
query_evidence(jt2)

# Example 3: max-flow without evidence
# ------------------------------------
jt3 <- jt(cp, flow = "max")
mpe(jt3)


# Example 4: max-flow with evidence
# ---------------------------------
e4  <- c(T = "y", X = "y", D = "y")
jt4 <- jt(cp, e4, flow = "max")
mpe(jt4)

# Notice, that T, E, S, B, X and D has changed from "n" to "y"
# as a consequence of the new evidence e4


# Example 5: specifying a root node and only collect to save run time
# -------------------------------------------------------------------------


  cp5 <- compile(cpt_list(asia, g), root_node = "X")
  jt5 <- jt(cp5, propagate = "collect")
```

```
  query_belief(jt5, get_clique_root(jt5), "joint")


# We can only query from the variables in the root clique now
# but we have ensured that the node of interest, "X", does indeed live in
# this clique. The variables are found using 'get_clique_root'

# Example 6: Compiling from a list of conditional probabilities
# -----------------------------------------------------------------------------

# * We need a list with CPTs which we extract from the asia2 object
#    - the list must be named with child nodes
#    - The elements need to be array-like objects

cl  <- cpt_list(asia2)
cp6 <- compile(cl)

# Inspection; see if the graph correspond to the cpts
# g <- get_graph(cp6)
# plot(g)

# This time we specify that no propagation should be performed
jt6 <- jt(cp6, propagate = "no")

# We can now inspect the collecting junction tree and see which cliques
# are leaves and parents
plot(jt6)
get_cliques(jt6)
get_clique_root(jt6)

jt_leaves(jt6)
unlist(jt_parents(jt6))

# That is;
# - clique 2 is parent of clique 1
# - clique 3 is parent of clique 4 etc.

# Next, we send the messages from the leaves to the parents
jt6 <- send_messages(jt6)

# Inspect again
plot(jt6)

# Send the last message to the root and inspect
jt6 <- send_messages(jt6)
plot(jt6)

# The arrows are now reversed and the outwards (distribute) phase begins
jt_leaves(jt6)
jt_parents(jt6)

# Clique 2 (the root) is now a leave and it has 1, 3 and 6 as parents.
```

```
# Finishing the message passing
jt6 <- send_messages(jt6)
jt6 <- send_messages(jt6)

# Queries can now be performed as normal
query_belief(jt6, c("either", "tub"), "joint")
```

---

jt_leaves *Query Parents or Leaves in a Junction Tree*

Description

Return the clique indices of current parents or leaves in a junction tree

Usage

```
jt_leaves(jt)

## S3 method for class 'jt'
jt_leaves(jt)

jt_parents(jt)

## S3 method for class 'jt'
jt_parents(jt)
```

Arguments

jt	A junction tree object, jt.

See Also

jt, get_cliques

Examples

```
# See example 6 in the help page for the jt function
```

`jt_nbinary_ops` *Number of Binary Operations*

Description

Number of binary operations needed to propagate in a junction tree given evidence, using the Lauritzen-Spiegelhalter scheme

Usage

```
jt_nbinary_ops(x, evidence = list(), root = NULL, nc = 1)

## S3 method for class 'triangulation'
jt_nbinary_ops(x, evidence = list(), root = NULL, nc = 1)
```

Arguments

x	A junction tree object or an object returned from the triangulation function
evidence	List of character vectors with evidence nodes
root	Integer specifying the root node in the junction tree
nc	Integer. The number of cores to be used in parallel

`mpd` *Maximal Prime Decomposition*

Description

Find the maximal prime decomposition and its associated junction tree

Usage

```
mpd(x, save_graph = TRUE)

## S3 method for class 'matrix'
mpd(x, save_graph = TRUE)

## S3 method for class 'cpt_list'
mpd(x, save_graph = TRUE)
```

Arguments

x	Either a neighbor matrix or a `cpt_list` object
save_graph	Logical indicating if the moralized graph should be kept. Useful when x is a `cpt_list` object.

Value

- `prime_ints`: a list with the prime components, - `flawed`: indicating which prime components that are triangulated - `jt_collect`: the MPD junction tree prepared for collecting

Examples

```
library(igraph)
el <- matrix(c(
"A", "T",
"T", "E",
"S", "L",
"S", "B",
"L", "E",
"E", "X",
"E", "D",
"B", "D"),
 nc = 2,
 byrow = TRUE
)

g <- igraph::graph_from_edgelist(el, directed = FALSE)
A <- igraph::as_adjacency_matrix(g, sparse = FALSE)
mpd(A)
```

`mpe` *Most Probable Explanation*

Description

Returns the most probable explanation given the evidence entered in the junction tree

Usage

```
mpe(x)

## S3 method for class 'jt'
mpe(x)
```

Arguments

x	A junction tree object, `jt`, with max-flow.

See Also

`jt`

Examples

```
# See the 'jt' function
```

plot.charge *A plot method for junction trees*

Description

A plot method for junction trees

Usage

```
## S3 method for class 'charge'
plot(x, ...)
```

Arguments

x	A compile object
...	For S3 compatability. Not used.

See Also

compile

plot.jt *A plot method for junction trees*

Description

A plot method for junction trees

Usage

```
## S3 method for class 'jt'
plot(x, ...)
```

Arguments

x	A junction tree object, `jt`.
...	For S3 compatability. Not used.

See Also

jt

pot_list — *A check and extraction of clique potentials from a Markov random field to be used in the junction tree algorithm*

Description

A check and extraction of clique potentials from a Markov random field to be used in the junction tree algorithm

Usage

```
pot_list(x, g)

## S3 method for class 'data.frame'
pot_list(x, g)
```

Arguments

x	Character data.frame
g	A decomposable Markov random field as an igraph object.

Examples

```
# Typically one would use the ess package:
# library(ess)
# g  <- ess::fit_graph(derma)
# pl <- pot_list(derma, ess::as_igraph(g))
# pl

# Another example
g <- igraph::sample_gnm(ncol(asia), 12)
while(!igraph::is.chordal(g)$chordal) g <- igraph::sample_gnm(ncol(asia), 12, FALSE)
igraph::V(g)$name <- colnames(asia)
plot(g)
pot_list(asia, g)
```

print.charge — *A print method for compiled objects*

Description

A print method for compiled objects

Usage

```
## S3 method for class 'charge'
print(x, ...)
```

Arguments

x	A compiled object
...	For S3 compatability. Not used.

See Also

jt

---

print.cpt_list *A print method for cpt lists*

Description

A print method for cpt lists

Usage

```
## S3 method for class 'cpt_list'
print(x, ...)
```

Arguments

x	A cpt_list object
...	For S3 compatability. Not used.

See Also

compile

print.jt — *A print method for junction trees*

Description

A print method for junction trees

Usage

```
## S3 method for class 'jt'
print(x, ...)
```

Arguments

x	A junction tree object, `jt`.
...	For S3 compatability. Not used.

See Also

jt

propagate — *Propagation of junction trees*

Description

Given a junction tree object, propagation is conducted

Usage

```
propagate(x, prop = "full")

## S3 method for class 'jt'
propagate(x, prop = "full")
```

Arguments

x	A junction tree object `jt`
prop	Either "collect" or "full".

See Also

jt

Examples

```
# See Example 1 in the 'jt' function
```

query_belief *Query probabilities*

Description

Get probabilities from a junction tree object

Usage

```
query_belief(x, nodes, type = "marginal")

## S3 method for class 'jt'
query_belief(x, nodes, type = "marginal")
```

Arguments

x	A junction tree object, jt.
nodes	The nodes for which the probability is desired
type	Either 'marginal' or 'joint'

See Also

jt, mpe

Examples

```
# See the 'jt' function
```

query_evidence *Query Evidence*

Description

Get the probability of the evidence entered in the junction tree object

Usage

```
query_evidence(x)

## S3 method for class 'jt'
query_evidence(x)
```

Arguments

x	A junction tree object, jt.

See Also

jt, mpe

send_messages *Send Messages in a Junction Tree*

Description

Send messages from the current leaves to the current parents in a junction tree

Usage

```
send_messages(jt)
```

Arguments

jt	A jt object return from the jt function

See Also

jt, get_cliques, jt_leaves, jt_parents

Examples

```
# See example 6 in the help page for the jt function
```

set_evidence *Enter Evidence*

Description

Enter evidence into a the junction tree object that has not been propagated

Usage

```
set_evidence(x, evidence, initialize_cpts = TRUE)

## S3 method for class 'jt'
set_evidence(x, evidence, initialize_cpts = FALSE)

## S3 method for class 'charge'
set_evidence(x, evidence, initialize_cpts = TRUE)
```

Arguments

x	A junction tree object, `jt`.
evidence	A named vector. The names are the variabes and the elements are the evidence.
initialize_cpts	`TRUE` if the CPTs should be initialized and then create the clique potentials. Only relevant on objects returned from `compile`.

See Also

jt, mpe

Examples

```
# See the 'jt' function
```

---

sim_data_from_bn — *Simulate data from a Bayesian network*

Description

Simulate data from a Bayesian network

Usage

```
sim_data_from_bn(
  net,
  lvls,
  nsims = 1000,
  increasing_prob = FALSE,
  p1 = 0.8,
  p2 = 1
)
```

Arguments

net	A Bayesian network as an igraph object
lvls	Named integer vector where each element is the size of the statespace of the corresponding variable
nsims	Number of simulations distributions from which the simulatios are drawn.
increasing_prob	Logical. If true, probabilities in the underlying CPTs increases with as the number of levels increses.
p1	Probability
p2	Probability

Examples

```
net <- igraph::graph(as.character(c(1,2,1,3,3,4,3,5,5,4,2,6,6,7,5,7)), directed = TRUE)
nodes_net <- igraph::V(net)$name
lvls_net  <- structure(sample(3:9, length(nodes_net)), names = nodes_net)
lvls_net  <- structure(rep(3, length(nodes_net)), names = nodes_net)
sim_data_from_bn(net, lvls_net, 10)
```

`sim_data_from_dmrf` *Simulate data from a decomposable discrete markov random field*

Description

Simulate data from a decomposable discrete markov random field

Usage

```
sim_data_from_dmrf(
  graph,
  lvls,
  nsims = 1000,
  increasing_prob = FALSE,
  p1 = 0.8,
  p2 = 1
)
```

Arguments

`graph` A decomposable discrete markov random field as an igraph object

`lvls` Named integer vector where each element is the size of the statespace of the corresponding variable

`nsims` Number of simulations distributions from which the simulatios are drawn.

`increasing_prob` Logical. If true, probabilities in the underlying CPTs increases with as the number of levels increses.

`p1` Probability

`p2` Probability

`triangulate` *Triangulate a Bayesian network*

Description

Given a list of CPTs, this function finds a triangulation

Usage

```
triangulate(
  x,
  root_node = "",
  joint_vars = NULL,
  tri = "min_fill",
  pmf_evidence = NULL,
  alpha = NULL,
  perm = FALSE,
  mpd_based = FALSE
)

## S3 method for class 'cpt_list'
triangulate(
  x,
  root_node = "",
  joint_vars = NULL,
  tri = "min_fill",
  pmf_evidence = NULL,
  alpha = NULL,
  perm = FALSE,
  mpd_based = FALSE
)
```

Arguments

`x`	An object returned from `cpt_list` (baeysian network) or `pot_list` (decomposable markov random field)
`root_node`	A node for which we require it to live in the root clique (the first clique).
`joint_vars`	A vector of variables for which we require them to be in the same clique. Edges between all these variables are added to the moralized graph.
`tri`	The optimization strategy used for triangulation if x originates from a Baeysian network. One of • 'min_fill' • 'min_rfill' • 'min_sp' • 'min_ssp'

- 'min_lsp'
- 'min_lssp'
- 'min_elsp'
- 'min_elssp'
- 'min_nei'
- 'minimal'
- 'alpha'

`pmf_evidence` A named vector of frequencies of the expected missingness of a variable. Variables with frequencies of 1 can be neglected; these are inferrred. A value of 0.25 means, that the given variable is expected to be missing (it is not a evidence node) in one fourth of the future cases. Relevant for `tri` methods 'min_elsp' and 'min_elssp'.

`alpha` Character vector. A permutation of the nodes in the graph. It specifies a user-supplied eliminination ordering for triangulation of the moral graph.

`perm` Logical. If `TRUE` the moral graph is permuted

`mpd_based` Logical. True if the triangulation should be performed on a maximal peime decomposition

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