

Package ‘FaultTree’

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FaultTree-package	<i>Fault Trees for Risk and Reliability Analysis</i>
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Description

A package for constructing,calculating and displaying fault trees.

Introduction

FaultTree provides functions for building tree structures as dataframe objects. The fault tree incorporates logic nodes (primarily AND and OR) which process input and may direct output "upwards" through the tree structure. Data is entered through component entries. Component event entries may be active (failures immediately revealed) or dormant (failures remain hidden until activation or inspection). The fault tree may also accept pure probability or pure demand input components.

Author(s)

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References

- Ericson, Clifton A. II (2011) Fault Tree Analysis Primer CreateSpace Inc.
- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

addActive	<i>Add an Active Component Event</i>
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Description

Modifies an existing fault tree with the addition of an active component event.

Usage

```
addActive(DF, at, mttf, mtrr, display_under=NULL, tag="", label="",
          name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from <code>ftee.make</code> or related <code>add...</code> functions.
at	The ID of the parent node for this addition.
mttf	The mean time to failure. It is the user's responsibility to maintain constant units of time.
mtrr	The mean time to repair (restore). It is the user's responsibility to maintain constant units of time.
display_under	Optionally, the ID of a sibling event under an OR gate for vertical alignment of the component node in the graphic display.
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of <code>label</code> in <code>ftee.make</code> defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for the basic event.

Value

Returns the input fault tree dataframe appended with an entry row for the defined component event.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
 O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
 Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
 Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
 Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <-ftree.make(type="or")
mytree <- addActive(mytree, at=1, mttf=3, mttr=12/8760,name="pump failure")
```

addDemand	<i>Add a Pure Demand Event</i>
-----------	--------------------------------

Description

Modifies an existing fault tree with the addition of a pure demand event.

Usage

```
addDemand(DF, at, mttf, tag="", label="", name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID of the parent node for this addition.
mttf	The mean time interval to events. It is the user's responsibility to maintain constant units of time.
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for the resultant event.

Value

Returns the input fault tree dataframe appended with an entry row for the defined component event. Note that when a pure demand is used in combination under an AND gate, the result will contain only a conditional fail rate.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
 O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
 Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
 Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
 Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <-ftree.make(type="and")
mytree <- addDemand(mytree, at=1, mttf=1, name="power interruption")
```

addDuplicate	<i>Add a duplicated (repeated) event or entire branch to a fault tree.</i>
--------------	--

Description

Modifies an existing fault tree with the addition of the repeated nodes.

Usage

```
addDuplicate(DF, at, dup_id=NULL, dup_of=NULL, display_under=NULL,
collapse=FALSE)
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID of the parent node for this addition.
dup_id	The ID or tag name of a component event or root node of a branch to be repeated in a fault tree. Must provide either dup_id or dup_of.
dup_of	Alternative argument for the ID or tag name of a component event or root node of a branch to be repeated in a fault tree. If dup_id is provided, dup_of is ignored.
display_under	Optionally, the ID of a sibling event under an OR gate for vertical alignment of only component nodes (MOE, not MOB) in the graphic display.
collapse	A logical to determine whether a branch should be collapsed on initial view.

Details

This function is used to replicate the source event(s), not just copy for a similar item. Both the source and replicated nodes are notated in a MOE column of the fault tree dataframe. This notation will be used by future minimal cut set determination. Additionally, future editing functions can be notified and likely blocked on these items.

Value

Returns the input fault tree dataframe appended with a entry row(s) for the defined component event.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers
- Ericson II, Clifton A. (2011) Fault Tree Analysis Primer CreateSpace Inc.

Examples

```
mytree <- ftree.make(type="or")
mytree <- addLogic(mytree, at=1, type="and", name="A and B failed")
mytree <- addProbability(mytree, at=2, prob=.01, name="switch A failure")
mytree <- addProbability(mytree, at=2, prob=.01, name="switch B failure")
mytree <- addLogic(mytree, at=1, type="and", name="A and C failed")
mytree <- addDuplicate(mytree, at=5, dup_id=3)
mytree <- addProbability(mytree, at=5, prob=.01, name="switch C failure")
```

addExposed

Add a Time Dependant, Non-Repairable, Event

Description

Adds a basic component event to a fault tree in which probability of failure is defined by a probability distribution and exposure time.

Usage

```
addExposed(DF, at, mttf, dist="exponential", param=NULL, display_under=NULL,
tag="", exposure=NULL, label="", name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID or tag name of the parent node for this addition.
mttf	The mean time to failure. It is the user's responsibility to maintain constant units of time.
dist	The probability distribution to be used for defining probability of failure from mttf, and a possible extra parameter. Options for "exponential" and "weibull" have been implemented.
param	A vector containing shape and time_shift for weibull exposed events in that order.
display_under	Optionally, the ID of a sibling event under an OR gate for vertical alignment of the component node in the graphic display.
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
exposure	This is to be a seldom-used override of system mission time applicable only to exponentially exposed events.
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for this probability.

Details

The lambda for exponential definition is taken as $1/\text{mttf}$, which is the value stored in CFR for the tree node. Weibull distributions have a mean, which differs from the classical scale parameter by a factor determined as $\gamma(1+1/\text{shape})$. The weibull scale is determined from the value stored in CFR (as $1/\text{mttf}$) for the tree node. Additional parameters to fully define the specific distribution of expected failure times are the shape and any time_shift.

Value

Returns the input fault tree dataframe appended with an entry row for the defined failure event.

References

- Ericson, Clifton A. II (2011) Fault Tree Analysis Primer CreateSpace Inc.
- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mission_time<-0.5
mytree <-ftree.make(type="or", name="6-month task", name2="incomplete")
mytree <- addExposed(mytree, at=1, mttf=3, name="pump fails",
  name2="before completion")
```

addHouse

Add a Given Condition

Description

Modifies an existing fault tree with the addition of a 'house' element. House elements signify some underlying condition and can only have probability of 1 (True) or 0 (False). They have traditionally been added to fault trees for clarity of presentation only.

Usage

```
addHouse(DF, at, prob=1, tag="", label="", name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID of the parent node for this addition.
prob	A probability value of 1 or 0
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for this condition.

Value

Returns the input fault tree dataframe appended with an entry row for the defined house element.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <-ftree.make(type="and", name="Pump Function", name2="Failed")
mytree<-addActive(mytree,at=1,mttf=3,mttr=12/8760, name="Pump")
mytree <- addHouse(mytree, at=1, prob=1, name="Pump Function", name2="Required")
```

addLatent

Add a Latent Component Event

Description

Modifies an existing fault tree with the addition of a latent component event.

Usage

```
addLatent(DF, at, mttf, mttr=NULL, inspect=NULL, risk="mean",
display_under=NULL, tag="", label="",
name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID of the parent node for this addition.
mttf	The mean time to failure. It is the user's responsibility to maintain constant units of time.
mttr	The mean time to repair (restore). This should only be provided when system remains at risk, while repair is in progress, as it modifies probability by factor "pzero". It is the user's responsibility to maintain constant units of time.
inspect	The time interval between inspections for the dormant component. (It will be possible upon future development to enter the string for the named inspection dataframe object. In this case the inspection object will be read to get the inspection interval. An inspection object must be a dataframe with interval and duration columns. If a positive duration value other than zero is found it is taken that the system is at risk during the time of inspection. An unavailable probability calculated as duration/(interval+duration) will be added to the fractional downtime.
risk	An opportunity to utilize the "max" risk probability occurring at the end of inspection duration.
display_under	Optionally, the ID of a sibling event under an OR gate for vertical alignment of the component node in the graphic display.
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.

name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for the basic event.

Value

Returns the input fault tree dataframe appended with an entry row for the defined component event.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
 O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
 Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
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 Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <- ftree.make(type="and")
mytree <- addLatent(mytree, at=1, mttf=5, mttr=12/8760, inspect=1/26, name="e-gen set fails")
```

addLogic	<i>Add a Logic Gate</i>
----------	-------------------------

Description

Modifies an existing fault tree with the addition of a logic gate.

Usage

```
addLogic(DF, type, at, reversible_cond=FALSE, cond_first=TRUE, human_pbf=NULL,
vote_par=NULL, tag="", label="", name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
type	A string signifying the type of logic to be applied. Implemented gate types "or", "and", "inhibit", "conditional" (or "cond"), vote, and "alarm" have been implemented.
at	The ID or tag name of the parent node for this addition.

reversible_cond	A boolean value used only by the conditional gate type indicating whether repair of the input condition is viable to the model.
cond_first	A boolean signifying whether the first child to an INHIBIT, ALARM, or PRIORITY logic gate should be taken as the condition. Alternatively, if FALSE, the second child will be taken as a condition. This is primarily a graphic display issue.
human_pbf	A probability of failure for a human to respond as needed to an alarm. This value is only used by the alarm gate.
vote_par	A vector of vote parameters as c(k,n) for k of n voting.
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for the resultant event.

Value

Returns the input fault tree dataframe appended with an entry row to accept the result of the logic calculation.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <-ftree.make(type="cond", reversible_cond=TRUE, name="power outage")
mytree<-addLogic(mytree, at=1, type="and", name="neither emergency", name2="generator operable")
mytree<-addLatent(mytree, at=2, mttf=5,mttr=12/8760,inspect=1/26, name="e-gen set fails")
mytree<-addLatent(mytree, at=2, mttf=5,mttr=12/8760,inspect=1/26, name="e-gen set fails")
mytree <- addDemand(mytree, at=1, mttf=1, name="incomming power", name2="interruption")
```

addProbability	<i>Add a Pure Probability</i>
----------------	-------------------------------

Description

Modifies an existing fault tree with the addition of a pure probability.

Usage

```
addProbability(DF, at, prob, display_under=NULL, tag="",
label="", name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID of the parent node for this addition.
prob	A probability value >0 && <1
display_under	Optionally, the ID of a sibling event under an OR gate for vertical alignment of the component node in the graphic display.
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for this probability.

Value

Returns the input fault tree dataframe appended with an entry row for the defined probability.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <- ftree.make(type="and", name="common cause failure", name2="of redundant pumps")
mytree<-addActive(mytree,at=1,mttf=3,mttr=12/8760, name="Pump")
mytree <- addProbability(mytree, at=1, prob=.05, name="common cause", name2="beta factor")
```

addUndeveloped

*Enter a Probability for an Undeveloped Event***Description**

Modifies an existing fault tree with the addition of an undeveloped probability.

Usage

```
addUndeveloped(DF, at, prob=0, tag="", label="",
name="", name2="", description="")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	The ID or tag name of the parent node for this addition.
prob	A probability value ≥ 0 && < 1
tag	A very short identifying string (typically 5 characters or less) uniquely identifying a basic event for minimal cutset evaluation
label	An identifying string for the logic gate. Use of label in ftree.make defines the convention for rest of tree construction.
name	A short identifying string (typically less than 24 characters)
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for this probability.

Value

Returns the input fault tree dataframe appended with an entry row for the undeveloped probability.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <-ftree.make(type="and", name="pumping failures")
mytree<-addActive(mytree,at=1,mttf=3,mttr=12/8760, name="Pump Mechanical", name2="Failures")
mytree <- addUndeveloped(mytree, at=1, prob=.05, name="external causes", name2="of pump failure")
```

 applyCollapse

Set a gate node for collapsed state on initial rendering.

Description

Modifies an existing fault tree by setting the Collapse field of the selected node to 1.

Usage

```
applyCollapse(DF, on)
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
on	The ID of the basic element node to be defined uncertain.

Value

Returns the input fault tree dataframe amended with an entry defining collapsed initial state for the selected node.

References

Rauzy, Antoine, et. al. (2013) Open PSA Model Exchange Format v2.0 open-psa.org

Limnios, Nikolaos (2007) Fault Trees ISTE Ltd.

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center

O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons

Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission

Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA

Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Ericson II, Clifton A. (2011) Fault Tree Analysis Primer CreateSpace Inc.

Examples

```
mytree <-ftree.make(type="or")
mytree <- addLogic(mytree, at=1, type= "and", name="A and B failed")
mytree <- addProbability(mytree, at=2, prob=.01, name="switch A failure")
mytree <- addProbability(mytree, at=2, prob=.01, name="switch B failure")
mytree <- addLogic(mytree, at=1, type= "and", name="A and C failed")
mytree <- addDuplicate(mytree, at=5, dup_id=3)
mytree <- addProbability(mytree, at=5, prob=.01, name="switch C failure")
mytree <- applyCollapse(mytree, on=5)
```

cutsets	<i>Fault Tree Minimal Cut Set Determination</i>
---------	---

Description

Determines minimal cutsets by various methods.

Usage

```
cutsets(DF, ft_node=1, method="mocus", by="tag")
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... func- tions.
ft_node	A gate node ID treated as top of (sub)tree to be calculated.
method	The method for calculation either 'mocus' or 'prime-implicants'
by	Selection of identifier for each element of the cutset either 'tag' or 'id'

Value

Returns a list of matrices for each of cut set lengths found. Each element is defined by its unique ID assigned in the fault tree or by its unique Tag applied by the user.

References

Fussell, J., Vesely, W.E. (1972) A New Method for Obtaining Cut Sets for Fault Trees Transactions ANS, No. 15

Ericson, Clifton A. II (2011) Fault Tree Analysis Primer CreateSpace Inc.

Ericson, Clifton A. II (2005) Hazard Analysis Techniques for System Safety John Wiley & Sons

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Limnios, Nikolaos (2007) Fault Trees ISTE,Ltd.

Bedford, Tim, Cooke, Roger (2012) Probabilistic Risk Analysis Foundations and Methods Cambridge University Press

Examples

```
minex2<-ftree.make(type="and")
minex2<-addProbability(minex2, at="top", prob=.01, tag="X1", name="X1")
minex2<-addLogic(minex2, at="top", type="or", tag="G1", name="G1")
minex2<-addProbability(minex2, at="G1", prob=.02, tag="X2", name="X2")
minex2<-addProbability(minex2, at="G1", prob=.03, tag="X3", name="X3")
minex2<-addLogic(minex2, at="top", type="or", tag="G2", name="G2")
minex2<-addDuplicate(minex2, at="G2", dup_of="X3")
minex2<-addProbability(minex2, at="G2", prob=.04, tag="X4", name="X4")
minex2_cs<-cutsets(minex2)
```

ftee.calc

Fault Tree Calculation

Description

ftee.calc performs gate-by-gate calculations from bottom to top of fault tree.

Usage

```
ftee.calc(DF, use.bdd=FALSE)
```

Arguments

DF	A fault tree dataframe such as returned from ftee.make or related add... functions.
use.bdd	A logical determining whether to use the bdd for probability calculations rather than simple solutions.

Value

Returns a dataframe containing 18 columns for holding data, results, and connection information.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers
- Rauzy, Antoine (1993) "New algorithms for fault trees analysis" Reliability Engineering System Safety, volume 40
- Limnios, Nikolaos (2007) Fault Trees ISTE,Ltd.
- Bedford, Tim, Cooke, Roger (2012) Probabilistic Risk Analysis Foundations and Methods Cambridge University Press

Examples

```
minex2<-ftree.make(type="and")
minex2<-addProbability(minex2, at="top", prob=.01, tag="X1", name="X1")
minex2<-addLogic(minex2, at="top", type="or", tag="G1", name="G1")
minex2<-addProbability(minex2, at="G1", prob=.02, tag="X2", name="X2")
minex2<-addProbability(minex2, at="G1", prob=.03, tag="X3", name="X3")
minex2<-addLogic(minex2, at="top", type="or", tag="G2", name="G2")
minex2<-addDuplicate(minex2, at="G2", dup_of="X3")
minex2<-addProbability(minex2, at="G2", prob=.04, tag="X4", name="X4")
minex2<-ftree.calc(minex2, use.bdd=TRUE)
```

ftree.make

Fault Tree Creation

Description

ftree.make prepares an initial, single row, dataframe, which will be built upon as the tree is developed.

Usage

```
ftree.make(type, reversible_cond=FALSE, cond_first=TRUE, human_pbf=NULL,
  start_id=1, system_mission_time=NULL, label="", name="", name2="",
  description="")
```

Arguments

type	The logic type for the top gate. Possible gates are "or", "and", "inhibit", "priority", and "alarm". Gate types "vote" and "atleast" are disallowed in top event, place these under an OR gate.
reversible_cond	A boolean value used only by the conditional gate type indicating whether repair of the input condition is viable to the model.
cond_first	A boolean signifying whether the first child to an INHIBIT, ALARM, or PRIORITY logic gate should be taken as the condition. Alternatively, if FALSE, the second child will be taken as a condition. This is primarily a graphic display issue.
human_pbf	A probability of failure for a human to respond as needed to an alarm. This value is only used by the alarm gate.
start_id	An integer value for the starting unique ID, useful for transfer objects.
system_mission_time	An optional method for setting mission_time for the entire tree. It is also possible to set mission_time as a global variable. Use of system_mission_time in ftree.make will take precedence.
label	An identifying string for the logic gate. Use of label defines the convention for rest of tree construction.
name	An identifying string for the logic gate.
name2	A second line, if needed for the identifying string label
description	An optional string providing more detail for the resultant event.

Value

Returns a dataframe holding data, results, and connection information.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
- Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA
- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <- ftree.make(type="and", name="a specific undesired event")
```

`ftree2bdd`*Generation of Binary Decision Diagram*

Description

Prepares a BDD string in if-then-else form '`<tag,if,else>`'

Usage

```
ftree2bdd(DF, ft_node=1)
```

Arguments

DF	A fault tree dataframe object.
ft_node	A gate node ID treated as top of (sub)tree to be calculated.

References

Rauzy, Antoine (1993) "New algorithms for fault trees analysis" Reliability Engineering System Safety, volume 40

Limnios, Nikolaos (2007) Fault Trees ISTE,Ltd.

`ftree2html`*Fault Tree Rendered in HTML*

Description

Prepares a web page from an ftree dataframe for a visualization of the data.

Usage

```
ftree2html(DF,dir="", write_file=TRUE)
```

Arguments

DF	A fault tree dataframe object.
dir	A character string for an absolute directory in which R can read and write.
write_file	A logical controlling whether to perform the write operation.

Value

Returns a character vector with escaped quote characters, suitable for writing to disk. Optionally, this vector will be written to a file taking the name of the object passed in as DF and appending '.html'.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
 O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons

Examples

```
mytree <- ftree.make(type="or", name="site power loss")
ftree2html(mytree, write_file=FALSE)
```

ftree2table

Fault Tree Tabular Subview

Description

Delivers an informative subview from an ftree dataframe with condensed output.

Usage

```
ftree2table(DF)
```

Arguments

DF A fault tree dataframe object.

Value

Returns a new condensed dataframe that is a subview of the ftree object.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
 O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons

Examples

```
mytree <- ftree.make(type="or", name="site power loss")
ftree2table(mytree)
```

hierarchyDF2json	<i>JSON formatting for tabular hierarchy data</i>
------------------	---

Description

Converts data from a flat-table dataframe to a recursive json structure suitable for passing to D3 heirarchy objects.

Usage

```
hierarchyDF2json(DF, id.col=1, parent.col=2, data.col=NULL,
  children.key="children", keys.tolower=TRUE, reverse_child_order=FALSE,
  dir="", write_file=FALSE )
```

Arguments

DF	A dataframe object with unique identification column and a column containing parent node identifications. The first row must contain the root node of the hierarchy.
id.col	The name or number of the column holding unique identifiers, default is 1.
parent.col	The name or number of the column holding parent node identifications, default is 2. Entry in row one of this column will be ignored.
data.col	A vector of column numbers from the dataframe to be passed as json data, default is all columns.
children.key	A string to be used as the key for children entries.
keys.tolower	A logical indicating whether to convert column names of the input dataframe to lower case, when passing keys to the json format.
reverse_child_order	A logical indicating whether to reverse the order of child nodes under each parent. This is useful when desiring nodes to form from top to bottom in a horizontal tree structure.
dir	A character string for an absolute directory in which R can read and write.
write_file	A logical controlling whether to perform the write operation.

Value

Returns a character vector with escaped quote characters, suitable for writing to disk. Optionally, this vector will be written to a file taking the name of the object passed in as DF and appending '.json'.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
 O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
 Ericson II, Clifton A. (2011) Fault Tree Analysis Primer CreateSpace Inc.

Examples

```
mytree <- ftree.make(type="or", name="conveyor belt fire")
hierarchyDF2json(mytree, id.col=1, parent.col=2, data.col=c(1,2))
```

parameter_conversion *Parameter Conversion Helper Functions*

Description

Access to a set of functions performing parameter conversions applicable to FaultTree scripting needs,

Usage

```
parameter_conversion(conv, param)
```

Arguments

conv	A string holding the name of a conversion function, or its assigned numerical equivalent.
param	A vector holding values appropriate for the requested conversion. See Details below.

Details

Conversion functions and their expected arguments are listed as follows:

```
conv param[1] param[2] param[3] 1 "prob2lam" prob 2 "prob2meanw" prob wshape time_shift 3
"wscale2mean" wscale wshape time_shift 4 "meanw2scale" wmean wshape time_shift 5 "sigma2ef"
sigma conf_limit 6 "ef2sigma" ErrFunc conf_limit 7 "meanln2mu" meanln sigma
```

Value

Returns a value according to the conversion requested.

References

Fussell, J., Vesely, W.E. (1972) A New Method for Obtaining Cut Sets for Fault Trees Transactions ANS, No. 15

Ericson, Clifton A. II (2011) Fault Tree Analysis Primer CreateSpace Inc.

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center

O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons

Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission

Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA

Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mission_time=20
mttf<-1/parameter_conversion("prob2lam", .2)
```

pc

*Parameter Conversion Helper Functions***Description**

Access to a set of functions performing parameter conversions applicable to FaultTree scripting needs,

Usage

```
pc(conv, param)
```

Arguments

conv	A string holding the name of a conversion function, or its assigned numerical equivalent.
param	A vector holding values appropriate for the requested conversion. See Details below.

Details

Conversion functions and their expected arguments are listed as follows:

```
conv param[1] param[2] param[3] 1 "prob2lam" prob 2 "prob2meanw" prob wshape time_shift 3
"wscale2mean" wscale wshape time_shift 4 "meanw2scale" wmean wshape time_shift 5 "sigma2ef"
sigma conf_limit 6 "ef2sigma" ErrFunc conf_limit 7 "meanln2mu" meanln sigma
```

Value

Returns a value according to the conversion requested.

References

Fussell, J., Vesely, W.E. (1972) A New Method for Obtaining Cut Sets for Fault Trees Transactions ANS, No. 15

Ericson, Clifton A. II (2011) Fault Tree Analysis Primer CreateSpace Inc.

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center

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Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission

Vesely, W.E., Stamatelato, M., Dugan, J., Fragola, J., Minarick, J., Railsback, J. (2002) Fault Tree Handbook with Aerospace Applications NASA

Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mission_time=20  
mttf<-1/pc(1, .2)
```

prob2lam

reverse calculation of exponential lambda from probability

Description

A simplistic helper function for converting fixed probability to a fail rate using known exposure time.

Usage

```
prob2lam(prob)
```

Arguments

prob	A fixed probability value that is to be converted to fail rate for exposed element entry.
------	---

Value

Returns the lambda value that will produce the fixed probability with environment object mission_time.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
Ericson II, Clifton A. (2011) Fault Tree Analysis Primer CreateSpace Inc.

Examples

```
mission_time<-8760  
mttf=1/prob2lam(.6)
```

probability

Probability Calculation by BDD or mcub

Description

Performs a calculation at a selected fault tree gate node.

Usage

```
probability(DF, ft_node=1, method="bdd")
```

Arguments

DF	A fault tree dataframe object.
ft_node	A gate node ID treated as top of (sub)tree to be calculated.
method	The method for calculation either 'bdd' or 'mcub'

Details

For BDD probability a binary decision diagram is generated on which a recursive algorithm is operated to generate the exact probability. For mcub (minimal cutset upper bound) the mocus algorithm is run to determine minimal cutsets. The upper bound estimate for probability is calculated by a probabilistic sum of the individual cutset probabilities.

References

Ericson, Clifton A. II (2011) Fault Tree Analysis Primer CreateSpace Inc.

Ericson, Clifton A. II (2005) Hazard Analysis Techniques for System Safety John Wiley & Sons

Rauzy, Antoine (1993) "New algorithms for fault trees analysis" Reliability Engineering System Safety, volume 40

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tagconnect

Interpretation of Node ID by tag Name

Description

Enables tree building improvement by allowing reference to nodes by tag.

Usage

```
tagconnect(DF, at, source=FALSE)
```

Arguments

DF	A fault tree dataframe such as returned from ftree.make or related add... functions.
at	An ID value or tag name for reference to a node.
source	A logical indicating whether to evaluate multiple occurrences of the tag to identify the source of duplication. Default of FALSE will cause the function to fail in case of multiple occurrence of tag provided as 'at'.

Value

Returns the ID value for the node whether it is a tag string or the actual ID value.

References

- Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
- O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons
- Vesely, W.E., Goldberg, F.F., Roberts, N.H., Haasl, D.F. (1981) Fault Tree Handbook U.S. Nuclear Regulatory Commission
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- Doelp, L.C., Lee, G.K., Linney, R.E., Ormsby R.W. (1984) Quantitative fault tree analysis: Gate-by-gate method Plant/Operations Progress Volume 3, Issue 4 American Institute of Chemical Engineers

Examples

```
mytree <- ftree.make(type="and", name="common cause failure", name2="of redundant pumps")
mytree <- addActive(mytree, at="top", mttf=3, mttr=12/8760, tag="p1", name="Pump")
mytree <- addProbability(mytree, at="top", prob=.05, name="common cause", name2="beta factor")
pumpIDvalue <- tagconnect(mytree, at="p1")
```

test.ftree

Fault Tree Object Test

Description

test.ftree compares dataframe column names with those of an ftree object.

Usage

```
test.ftree(DF)
```

Arguments

DF	A FaultTree dataframe object
----	------------------------------

Value

Returns True for object match, else False.

References

Nicholls, David [Editor] (2005) System Reliability Toolkit Reliability information Analysis Center
O'Connor, Patrick D.T. (1991) Practical Reliability Engineering John Wiley & Sons

Examples

```
mytree <- ftree.make(type="or", name="site power loss")  
test.ftree(mytree)
```

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