# Package 'FaultTree'

August 26, 2023

**Version** 1.0.1

**Date** 2023-8-26

**Title** Fault Trees for Risk and Reliability Analysis

**Description** Construction, calculation and display of fault trees. Methods derived from Clifton A. Ericson II (2005, ISBN: 9780471739425) <DOI:10.1002/0471739421>, Antoine Rauzy (1993) <DOI:10.1016/0951-8320(93)90060-C>, Tim Bedford and Roger Cooke (2012, ISBN: 9780511813597) <DOI:10.1017/CBO9780511813597>, Nikolaos Limnios, (2007, ISBN: 9780470612484) <DOI:10.1002/9780470612484>.

**License** GPL (>= 3)

**Copyright** copyright (c) OpenReliability.org 2015-2022

**URL** http://www.openreliability.org/fault-tree-analysis-on-r/

**LazyLoad** yes

**Imports** Rcpp (>= 0.12.4)

**LinkingTo** Rcpp, RcppArmadillo

**Author** David Silkworth [aut],
Jacob Ormerod [cre],
OpenReliability.org [cph]

**Maintainer** Jacob Ormerod <jake@openreliability.org>

**NeedsCompilation** yes

**Suggests** magrittr

**Repository** CRAN

**Date/Publication** 2023-08-26 17:00:05 UTC

# R topics documented:

---

FaultTree-package          *Fault Trees for Risk and Reliability Analysis*

---

### 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)

David J. Silkworth

Maintainer: Jacob T. Ormerod <jake@openreliability.org>

## 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                          *Add an Active Component Event*

---

## Description

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

## Usage

```
addActive(DF, at, mttf, mttr, 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). 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 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

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                           *Add a Pure Demand Event*

---

**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 | *Add a duplicated (repeated) event or entire branch to a fault tree.* |
|---|---|

---

## 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 probabilty 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/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/shape). The weibull scale is determined from the value stored in CFR (as 1/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 occuring 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

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

---

| addLogic | *Add a Logic Gate* |
| --- | --- |

---

## 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 PRI-ORITY 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`                         *Add a Pure Probability*

---

**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 | *Fault Tree Minimal Cut Set Determination* |

---

## 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... functions. |
| 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

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" Reliabiity 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_cs<-cutsets(minex2)
```

---

ftree.calc                          *Fault Tree Calculation*

---

## Description

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

## Usage

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

## Arguments

| | |
|---|---|
| DF | A fault tree dataframe such as returned from ftree.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" Reliabiity 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 precidence. |
| `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" Reliabiity 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                    *JSON formatting for tabular hierarchy data*

---

### 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 paramter conversions applicable to FaultTree scripting needs,

**Usage**

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

**Arguments**

conv            A string holding the name of a cnversion 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 paramter conversions applicable to FaultTree scripting needs,

## Usage

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

## Arguments

conv            A string holding the name of a cnversion 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/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 Calculstion 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 recusive algorithm is operated to generate the exact probablility. 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" Reliabiity 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

---

| 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 occurences of the tag to identify the source of duplication. Default of FALSE will cause the function to fail in case of multiple occurence 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

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="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)
```

# Index