

Introduction to Möbius

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1. Brief introduction to the Möbius tool
2. Elements of the projects
3. TMR example

Atomic model

Reward models

Set study model

Simulator Solver

Brief introduction to Möbius Tool



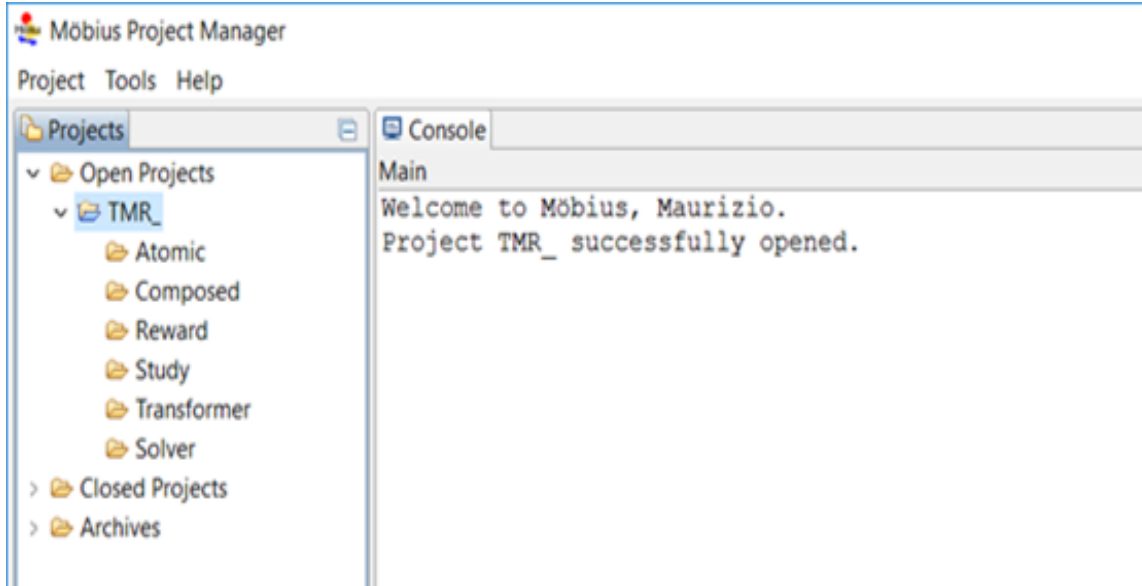
Möbius™ is a software tool for modeling the behavior of complex systems.

It was originally developed for studying the reliability, availability, and performance of computer and network systems.

It is used for a broad range systems, from biochemical reactions within genes to the effects of malicious attackers on secure computer systems.

- **Multiple modeling languages**
- **Hierarchical modeling paradigm**
- **Customized measures of system properties**
- **Study the behavior of the system under a variety of operating conditions**
- **Numerical solution techniques and Simulation**

Möbius Features



Every project is made of 6 kinds of elements:

1. Atomic Model

2. Composed Model

3. Reward

4. Study

5. Transformer

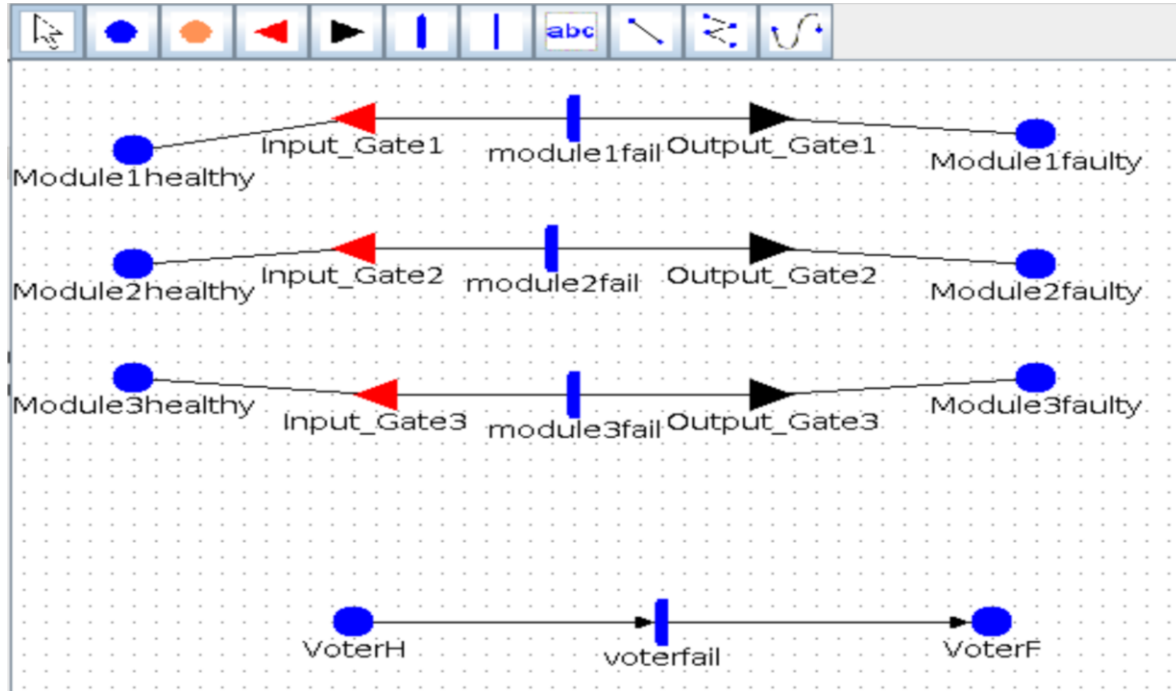
6. Solver

Atomic model

Each model is composed of one or more sub-models, also referred to as atomic models.

You can create and edit atomic models using different graphic editors.

These models also allow the definition of global variables, usually used to represent rate of events.



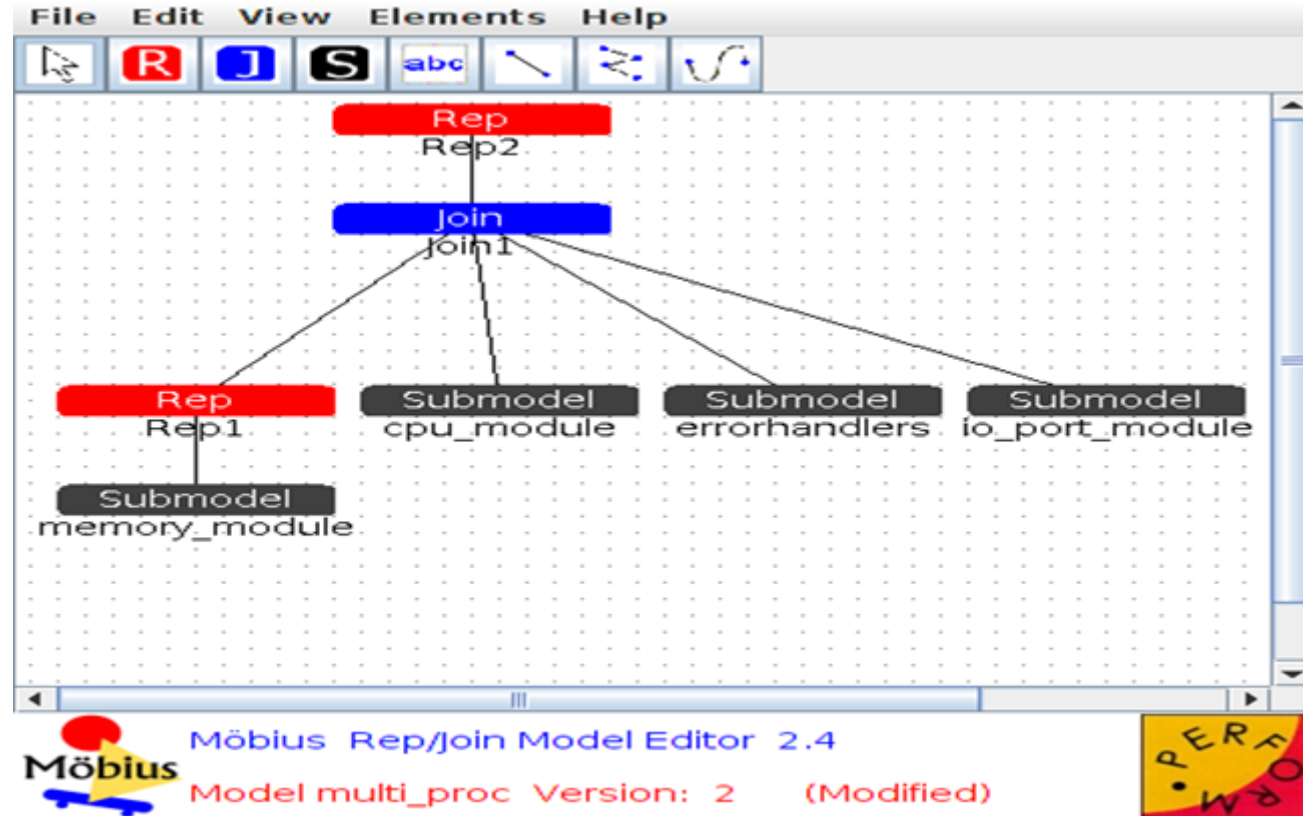
Composed Models



The Möbius tool allows for the construction of composed models from previously defined (atomic) submodels.

The Join operator is used to compose different sub-models.

The Rep operator is used to compose copies of a same sub-model.



Reward model 1/2



TMR: TMR_reward2

File Edit Help

Performance Variables | Model

(Enter new variable name)

Add Variable:

Variable List

reliability

Variable Name: reliability

Submodels | Rate Rewards | Impulse Rewards | Time | Simulation

Available State Variables (double click to insert)

TMR->Node1

TMR->Event1In

TMR->Event2In

TMR->Event3In

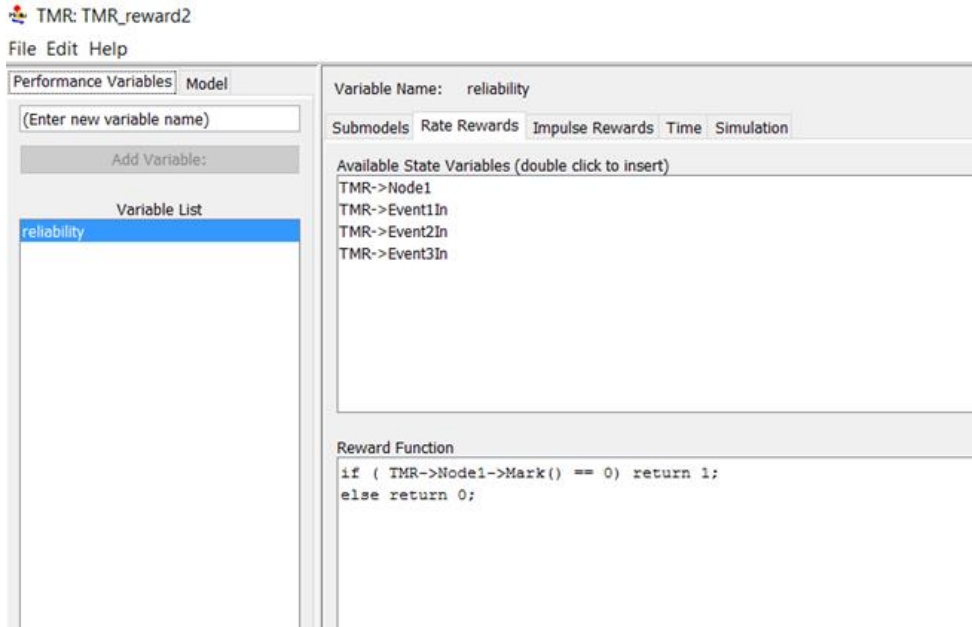
Reward Function

```
if ( TMR->Node1->Mark() == 0) return 1;
else return 0;
```

A reward model is a set of Performance Variable(PV) that describe system properties

A PV is computed by performing certain operations(e.g. mean) on the set of values returned by an associated Reward Function(RF)

Reward model 2/2



The values of the RF can be evaluated:

- at specified times (Instant of time PV's)
- accumulated over a specified interval of time (Interval of time PV's)
- averaged over a specified interval of time (Time averaged interval of time PV's)
- or evaluated when the system has reached a steady state (Steady state PV's)

Study



A study defines sets of values that will be assigned to each global variable.

In a range study, experiments are generated for all possible combinations of variable values.

In a set study only user-defined combinations are used.

File Edit Help

Study: vary_num_co... Reward Model: multi_proc... 2 Active of 3 Total Experime...

[Change Reward Model](#) [Experiment Activator](#)

Variable Name	Variable Type	Variable Value
CPU_cov	double	0.995
IO_cov	double	0.99
RAM_cov	double	0.998
comp_cov	double	0.95
failure_rate	double	8.766E-4
mem_cov	double	0.95
num_comp	short	Incremental Range
num_mem_mod	short	3

[Incremental Range](#) [Functional Range](#) [Manual Range](#) [Random Range](#)



Möbius Range Study Editor 2.4

vary_num_comp Version Number: 3



Möbius provides two types of solvers for obtaining solutions on measures of interest: simulation and numerical solvers.

In general, the simulation solver can be used to solve all models that were built in Möbius, whereas numerical solvers can be used on only those models that have only exponentially and deterministically distributed actions.

On the other hand, all numerical solvers in Möbius are capable of providing exact solutions (up to machine precision), whereas simulation provides statistically accurate solutions within some user-specifiable confidence interval.

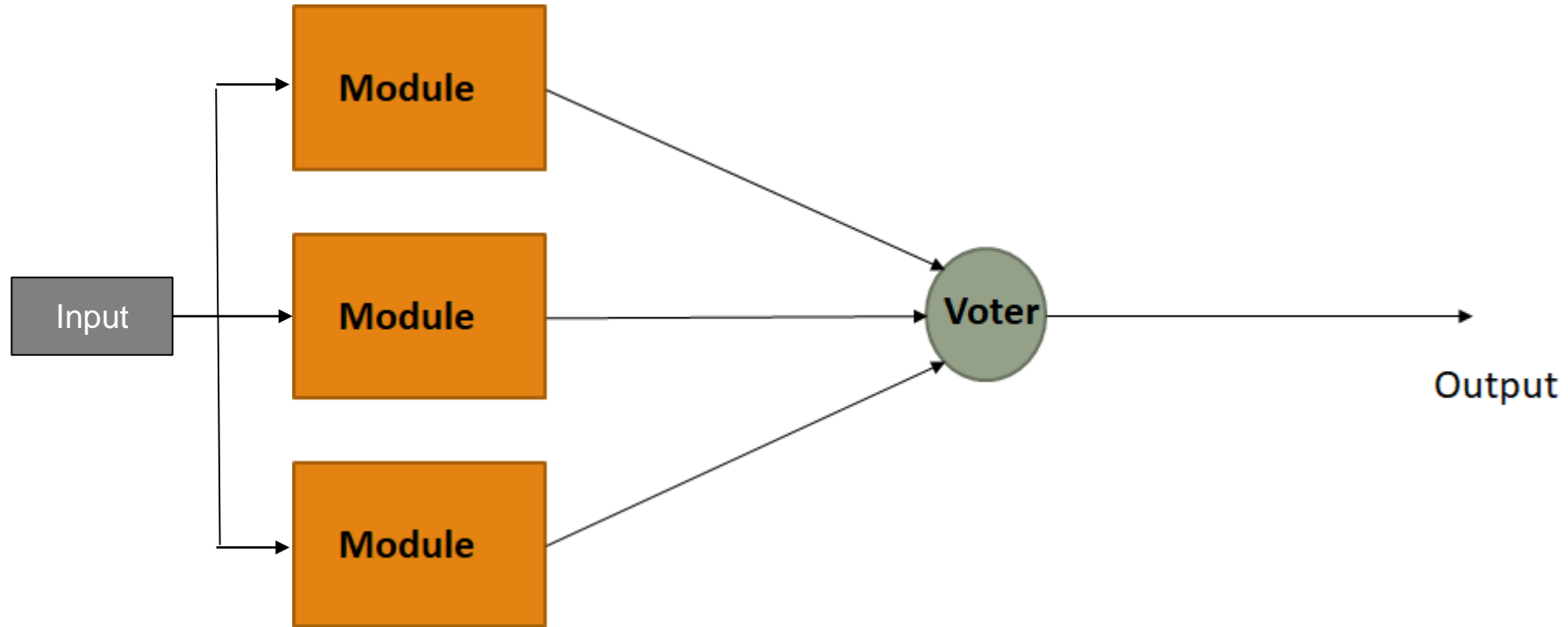
Some of the solution techniques within Möbius, such as the simulator, operate directly on the high-level model representation defined using the Atomic and Composed editors.

The numerical solvers require a different representation of the model as an input.

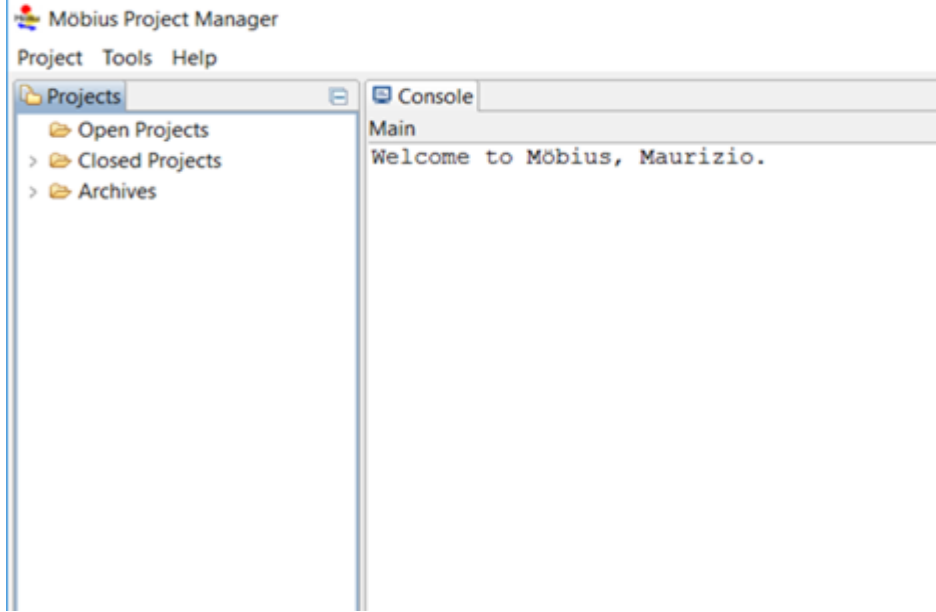
Instead of operating on the high-level model description, numerical solution techniques use a lower-level, state space representation, namely the Markov chain.

The transformer produces the low-level model starting from the high-level one.

TMR example



Create a project

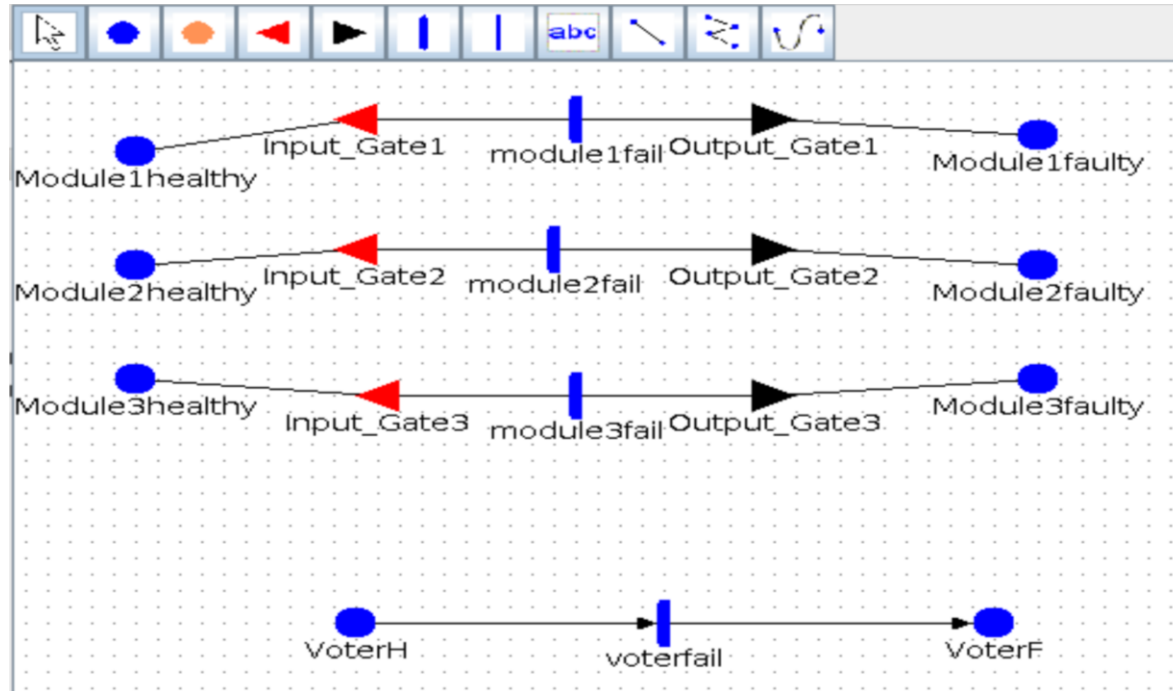


Start with the creation of a new project

Right click on Open projects-> New project

Enter the project name

Atomic model of TMR



Time tab for Rewards



Performance Variables

Model

Add Variable:

Variable List

reliability

reliabilitySingleModule

reliabilityVoter

Rename

Copy

Delete

Up

Down

Variable Name: reliabilityVoter

Submodels

Rate Rewards

Impulse Rewards

Time

Simulation

Type

Instant of Time

Time Point definition method:

Incremental Range

First time point in series:

1.0

Upper Bound of series:

1000.0

Step size in series:

50.0

Length of time interval:

0.0

Number of Time Measurements:

20

Time Series:

1.0, 51.0, 101.0, ... 851.0, 901.0, 951.0

Apply Changes

Discard Changes

TMR reliability Function



Performance Variables

Model

(Enter new variable name)

Add Variable:

Variable List

reliability

reliabilitySingleModule

reliabilityVoter

RenameCopyDeleteUpDown

Variable Name: reliability

SubmodelsRate RewardsImpulse RewardsTimeSimulation

Available State Variables (double click to insert)

TMR->Module1healthy
TMR->Module2healthy
TMR->Module3healthy
TMR->Module1faulty
TMR->Module2faulty
TMR->Module3faulty
TMR->VoterH
TMR->VoterF

Reward Function

if (
 (
 TMR->Module1faulty->Mark() +
 TMR->Module2faulty->Mark() +
 TMR->Module3faulty->Mark() <=1
)
 &&
 (
 TMR->VoterF->Mark()==0
)
) return 1;
else return 0;

Apply ChangesDiscard Changes

Single module reliability Function



Performance Variables

Model

Add Variable:

Variable List

reliability

reliabilitySingleModule

reliabilityVoter

Rename

Copy

Delete

Up

Down

Variable Name: reliabilitySingleModule

Submodels

Rate Rewards

Impulse Rewards

Time

Simulation

Available State Variables (double click to insert)

TMR->Module1healthy
TMR->Module2healthy
TMR->Module3healthy
TMR->Module1faulty
TMR->Module2faulty
TMR->Module3faulty
TMR->VoterH
TMR->VoterF

Reward Function

if (TMR->Module1faulty->Mark() == 0) return 1;
else return 0;

Apply Changes

Discard Changes

Voter reliability Function



Performance Variables

Model

Add Variable:

Variable List

reliability

reliabilitySingleModule

reliabilityVoter

Rename

Copy

Delete

Up

Down

Variable Name: reliabilityVoter

Submodels

Rate Rewards

Impulse Rewards

Time

Simulation

Available State Variables (double click to insert)

TMR->Module1healthy

TMR->Module2healthy

TMR->Module3healthy

TMR->Module1faulty

TMR->Module2faulty

TMR->Module3faulty

TMR->VoterH

TMR->VoterF

Reward Function

if (TMR->VoterH->Mark() ==1) return 1;

else return 0;

Apply Changes

Discard Changes

Study of TMR



File Edit Help

Study: study Reward Model: reward 3 Active of 3 Total Experiments

[Change Reward Model](#) [Experiment Activator](#)

Experiments

Name	Type	Exp1	Exp2	Exp3
lambda	double	0.001	0.001	0.001
lambdavo...	double	0	1.0E-5	1.0E-4

[Add](#) [Delete](#) [Copy](#) [Rename](#) [Import](#) [Export](#)

Analysis of simulation results



Simulation Parameters		Network Setup	Run Simulation	Simulation Info	Results
Name	Time	Mean		Confidence Interval	
reliability	1.0	1.0000000000E00	+/-	0.0000000000E00	
reliability	51.0	9.9276000000E-01	+/-	6.9062047280E-04	
reliability	101.0	9.7414000000E-01	+/-	1.2929239453E-03	
reliability	151.0	9.4665000000E-01	+/-	1.8306695660E-03	
reliability	201.0	9.1242000000E-01	+/-	2.3027558738E-03	
reliability	251.0	8.7383000000E-01	+/-	2.7048273990E-03	
reliability	301.0	8.3202000000E-01	+/-	3.0453954995E-03	
reliability	351.0	7.8875000000E-01	+/-	3.3251870090E-03	
reliability	401.0	7.4450000000E-01	+/-	3.5528415029E-03	
reliability	451.0	7.0027000000E-01	+/-	3.7320366297E-03	
reliability	501.0	6.5631000000E-01	+/-	3.8688864982E-03	
reliability	551.0	6.1335000000E-01	+/-	3.9669910644E-03	
reliability	601.0	5.7177000000E-01	+/-	4.0308557539E-03	
reliability	651.0	5.3154000000E-01	+/-	4.0649224372E-03	
reliability	701.0	4.9491000000E-01	+/-	4.0728229369E-03	
reliability	751.0	4.5876000000E-01	+/-	4.0591560243E-03	
reliability	801.0	4.2413000000E-01	+/-	4.0258700628E-03	
reliability	851.0	3.9192000000E-01	+/-	3.9767391347E-03	(*)
reliability	901.0	3.6110000000E-01	+/-	3.9127150285E-03	(*)
reliability	951.0	3.3200000000E-01	+/-	3.8362358828E-03	(*)
reliabilitySingleModule	1.0	9.9903000000E-01	+/-	1.9294493169E-04	
reliabilitySingleModule	51.0	9.5142000000E-01	+/-	1.3325181597E-03	
reliabilitySingleModule	101.0	9.0596000000E-01	+/-	1.8091270391E-03	
reliabilitySingleModule	151.0	8.6132000000E-01	+/-	2.1421379006E-03	
reliabilitySingleModule	201.0	8.1916000000E-01	+/-	2.3855573445E-03	
reliabilitySingleModule	251.0	7.7945000000E-01	+/-	2.5698389342E-03	
reliabilitySingleModule	301.0	7.4177000000E-01	+/-	2.7126653679E-03	
reliabilitySingleModule	351.0	7.0561000000E-01	+/-	2.8248938501E-03	
reliabilitySingleModule	401.0	6.7125000000E-01	+/-	2.9116104736E-03	
reliabilitySingleModule	451.0	6.3795000000E-01	+/-	2.9787622381E-03	
reliabilitySingleModule	501.0	6.0646000000E-01	+/-	3.0279853127E-03	
reliabilitySingleModule	551.0	5.7704000000E-01	+/-	3.0620399398E-03	
reliabilitySingleModule	601.0	5.4953000000E-01	+/-	3.0838048194E-03	
reliabilitySingleModule	651.0	5.2270000000E-01	+/-	3.0958521383E-03	
reliabilitySingleModule	701.0	4.9811000000E-01	+/-	3.0990254619E-03	
reliabilitySingleModule	751.0	4.7297000000E-01	+/-	3.0945158309E-03	
reliabilitySingleModule	801.0	4.5015000000E-01	+/-	3.0836067295E-03	
reliabilitySingleModule	851.0	4.2797000000E-01	+/-	3.0667212968E-03	

Analysis of Transient Solver results



```
Performance variable : reliability
Time                : 651.000000
Mean                : 5.322660e-01
Variance            : 2.489589e-01
Plot files          (pdf) : Exp1.trs.reliability.651.000.pdf.splot
                   (cdf)  : Exp1.trs.reliability.651.000.cdf.splot
*****
Performance variable : reliabilitySingleModule
Time                : 651.000000
Mean                : 5.215240e-01
Variance            : 2.495367e-01
Plot files          (pdf) : Exp1.trs.reliabilitySingleModule.651.000.pdf.splot
                   (cdf)  : Exp1.trs.reliabilitySingleModule.651.000.cdf.splot
*****
Performance variable : reliabilityVoter
Time                : 651.000000
Mean                : 1.000000e+00
Variance            : 2.220446e-16
Plot files          (pdf) : Exp1.trs.reliabilityVoter.651.000.pdf.splot
                   (cdf)  : Exp1.trs.reliabilityVoter.651.000.cdf.splot
*****
Performance variable : reliability
Time                : 701.000000
Mean                : 4.941336e-01
Variance            : 2.499656e-01
Plot files          (pdf) : Exp1.trs.reliability.701.000.pdf.splot
                   (cdf)  : Exp1.trs.reliability.701.000.cdf.splot
*****
Performance variable : reliabilitySingleModule
Time                : 701.000000
Mean                : 4.960890e-01
Variance            : 2.499847e-01
Plot files          (pdf) : Exp1.trs.reliabilitySingleModule.701.000.pdf.splot
                   (cdf)  : Exp1.trs.reliabilitySingleModule.701.000.cdf.splot
*****
Performance variable : reliabilityVoter
Time                : 701.000000
Mean                : 1.000000e+00
Variance            : -2.220446e-16
Plot files          (pdf) : Exp1.trs.reliabilityVoter.701.000.pdf.splot
                   (cdf)  : Exp1.trs.reliabilityVoter.701.000.cdf.splot
*****
```