Introduction to Möbius

Contacts

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Overview

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

Brief introduction to Möbius Tool

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

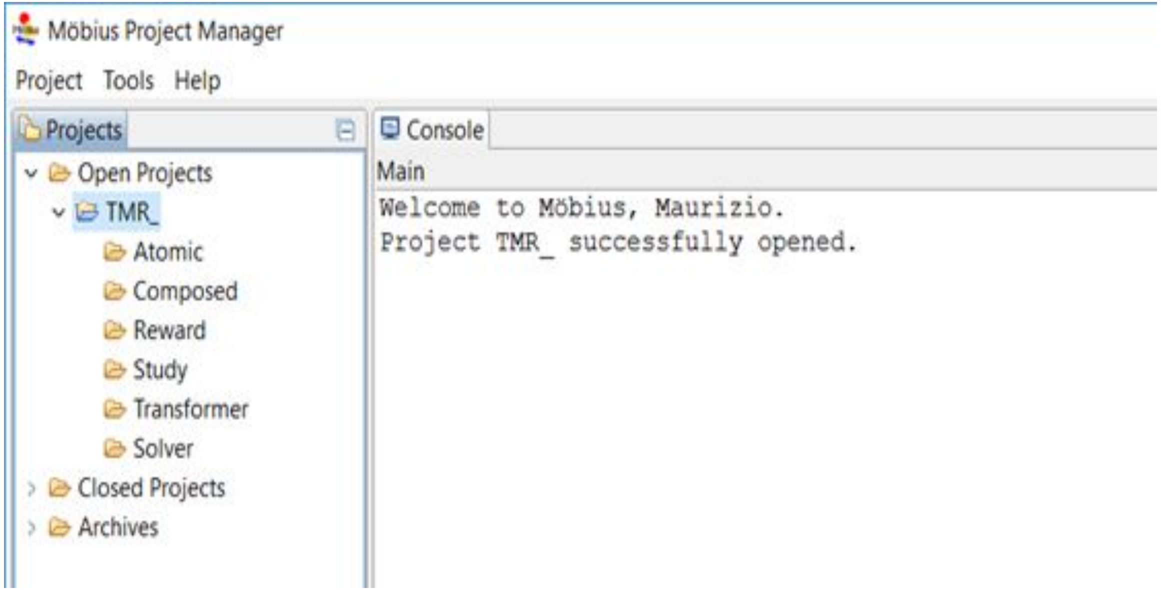
It was originally developed for studying the reliability, availability, and performance of computer and network systems.

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

Möbius Features

- 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

Möbius Features



```
Welcome to Möbius, Maurizio.
Project TMR_ successfully opened.
```

Every project is made of 6 kinds of elements:

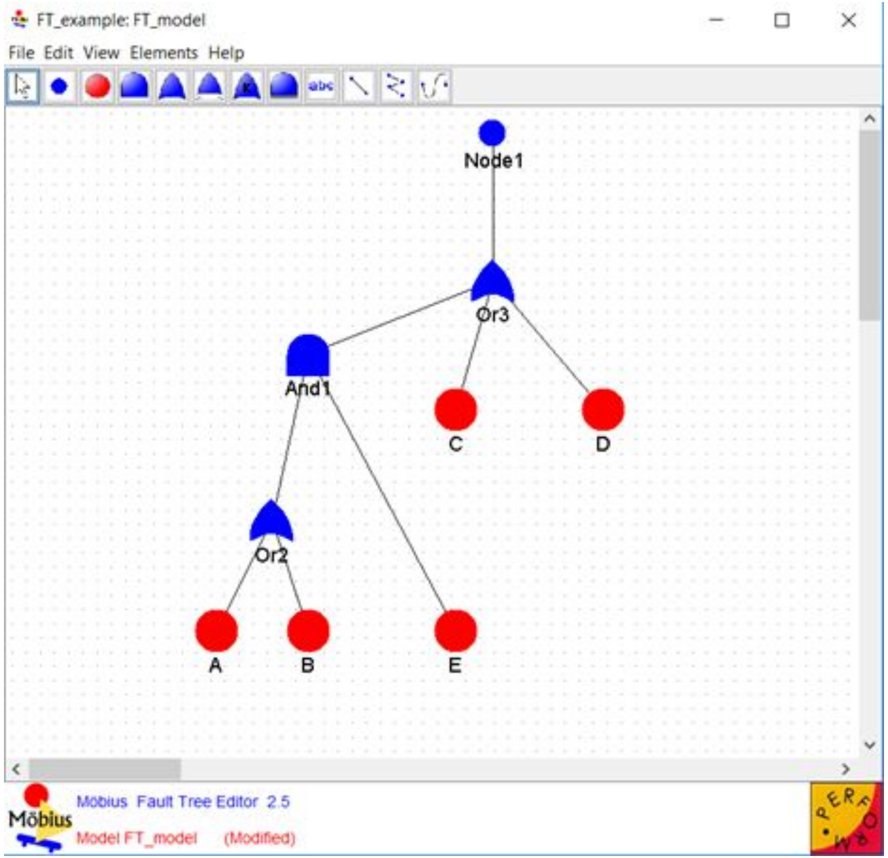
1. **Atomic Model**
2. **Composed Model**
3. **Reward**
4. **Study**
5. **Transformer**
6. **Solver**

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.

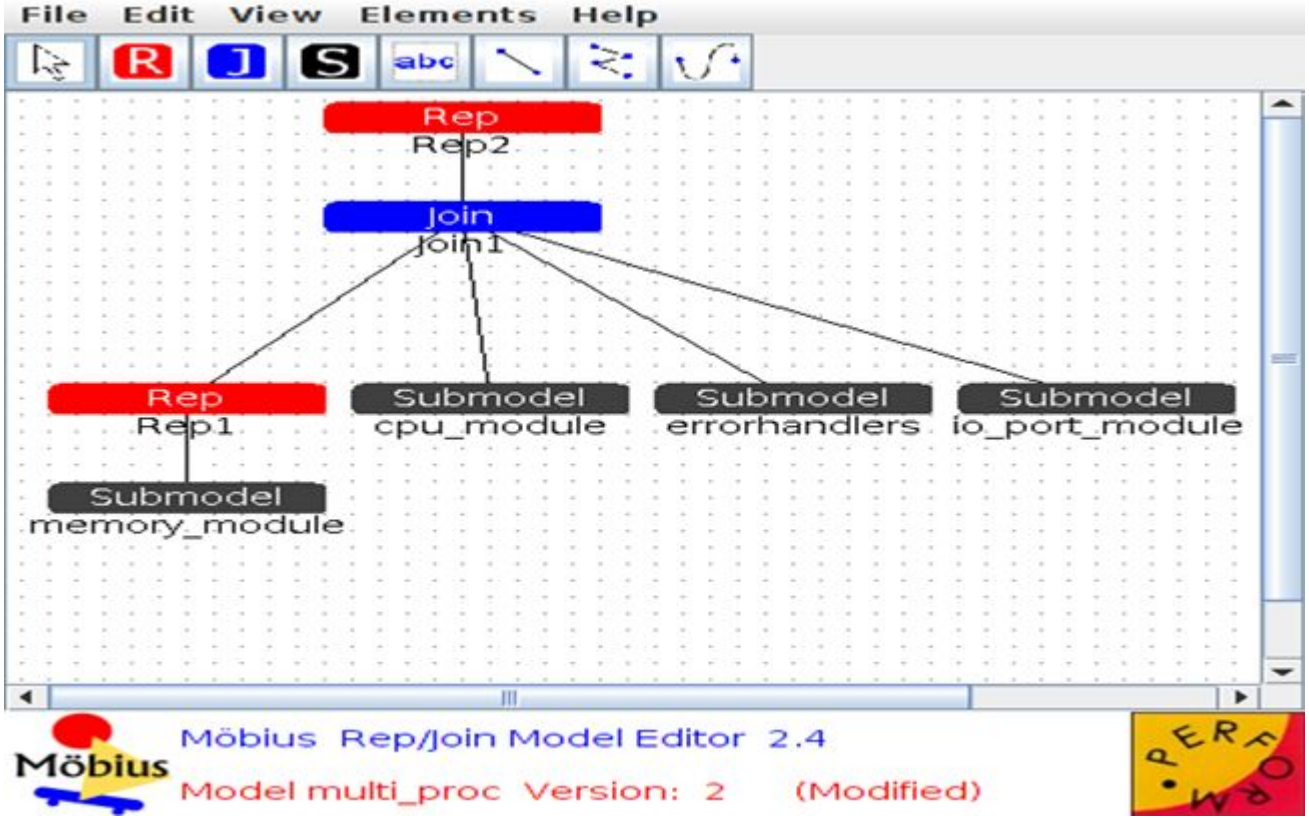

FT_example: FT_model
File Edit View Elements Help
abc
Node1
Or3
And1
C
D
Or2
A
B
E
Möbius
Mobius Fault Tree Editor 2.5
Model FT_model (Modified)
PERFORM

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.

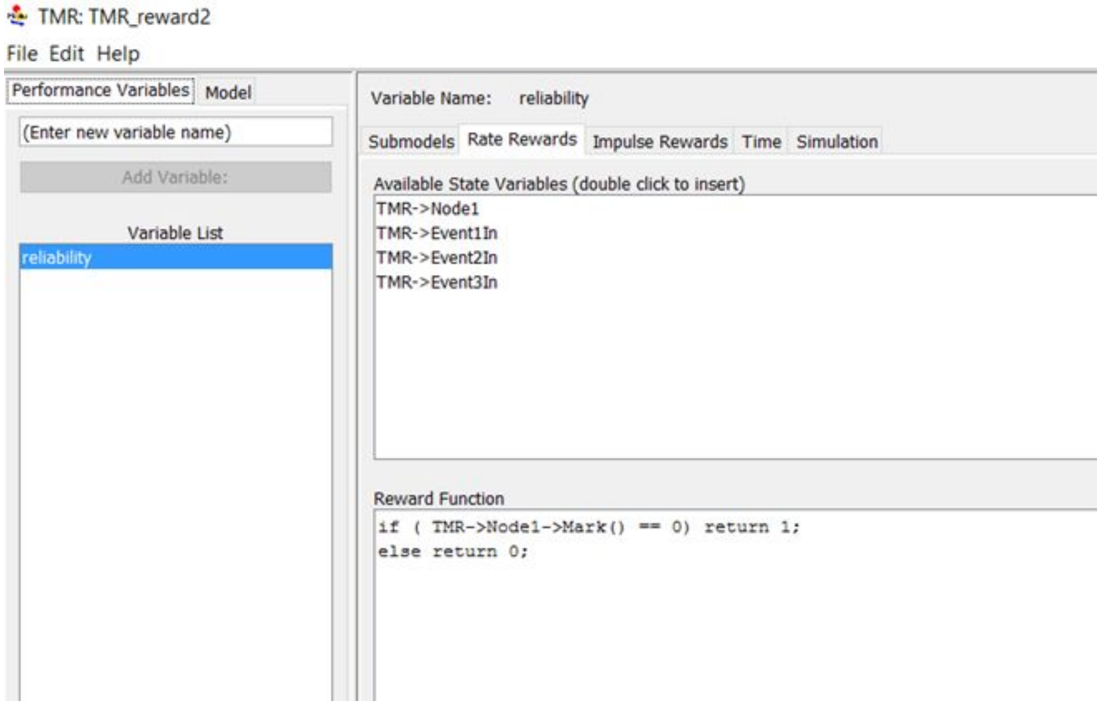
The Rep operator is used to compose copies of a same sub-model.



Möbius Rep/Join Model Editor 2.4

Model multi_proc Version: 2 (Modified)

Reward model 1/2



reliability

Variable Name: reliability

Available State Variables (double click to insert)

TMR->Node1
TMR->Event1In
TMR->Event2In
TMR->Event3In

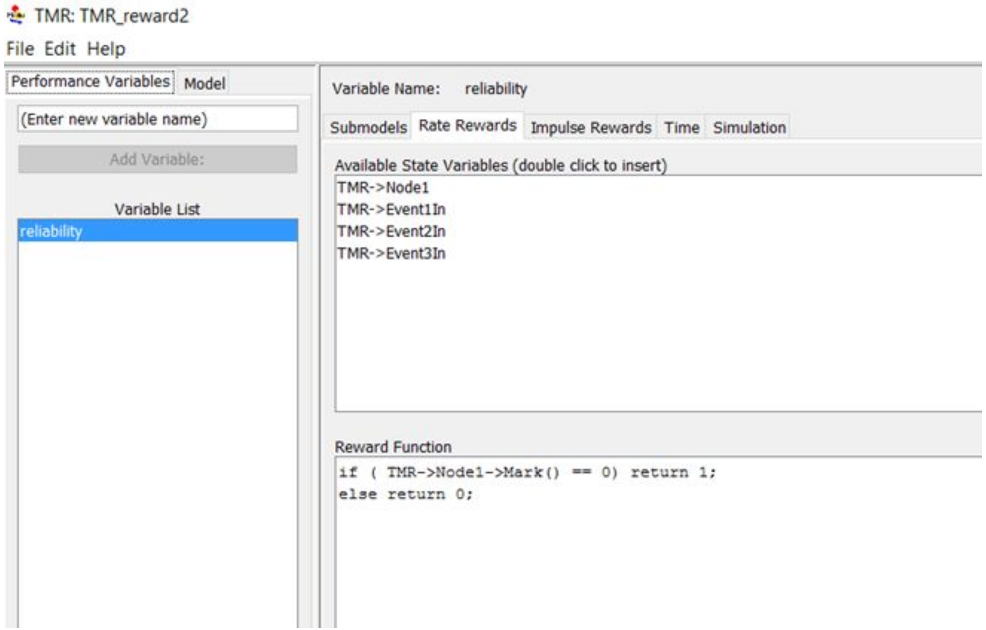
Reward Function

```
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



Variable Name: reliability

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

The values of the RF can be evaluated:

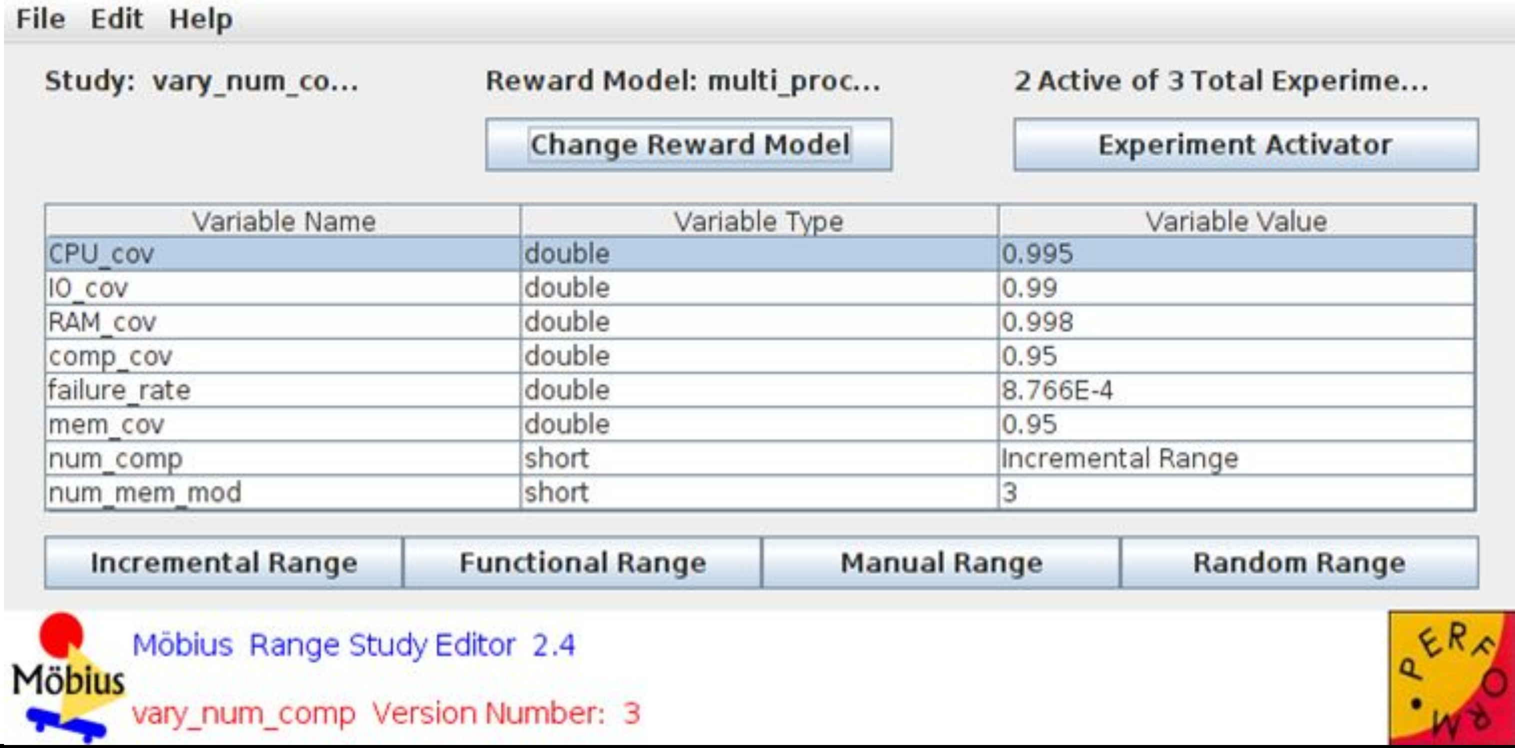
- at specified times (Instant of time PV’s)
- accumulated over a specified interval of time (Interval of time PV’s)
- averaged over a specified interval of time (Time averaged interval of time PV’s)
- or evaluated when the system has reached a steady state (Steady state PV’s)

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.



Study: vary_num_co...

Reward Model: multi_proc...

2 Active of 3 Total Experime...

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

Möbius Range Study Editor 2.4

vary_num_comp Version Number: 3

Solvers

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.

Transformers

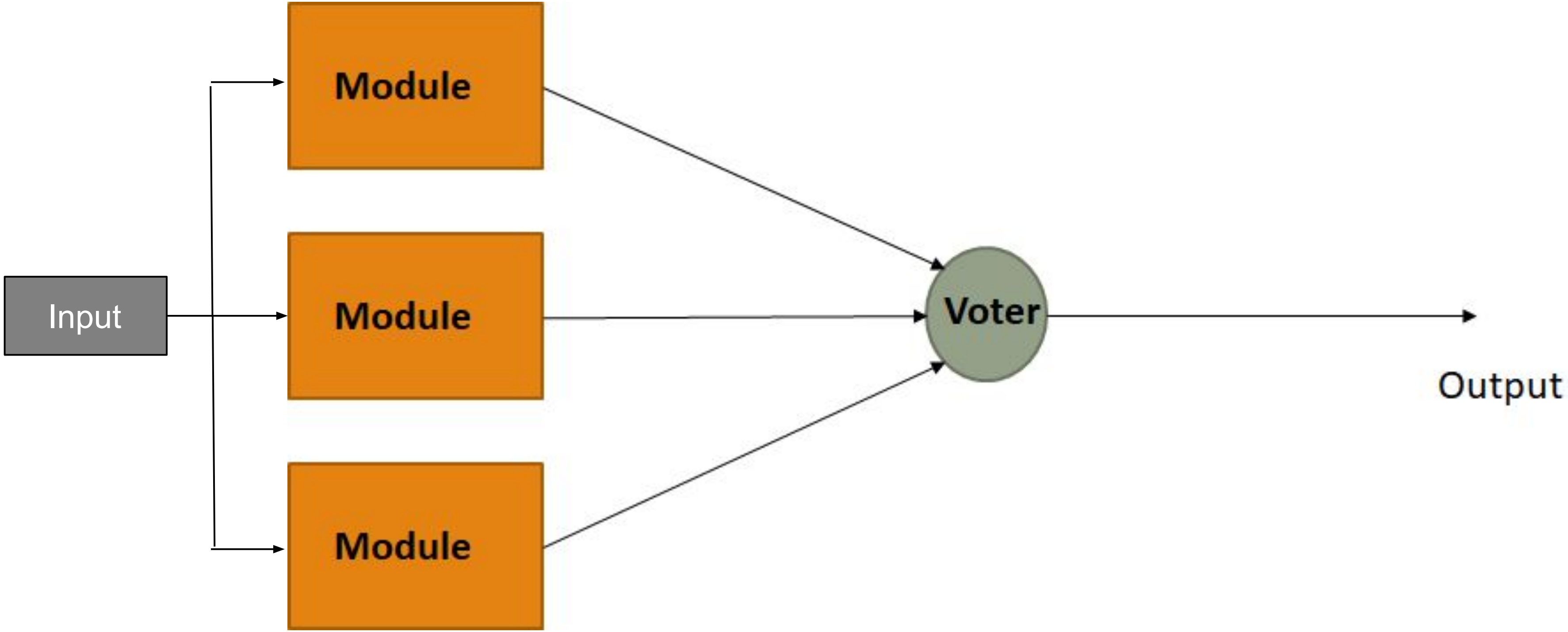
Some of the solution techniques within Möbius, such as the simulator, operate directly on the high-level model representation defined using the Atomic and Composed editors.

There are other solution techniques, which require a different representation of the model as an input.

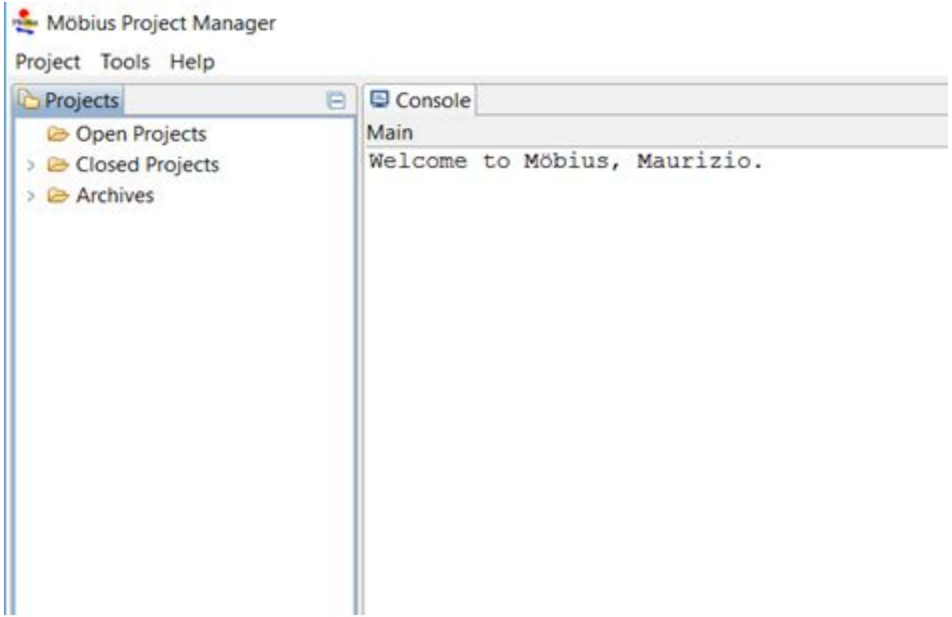
Instead of operating on the high-level model description, numerical solution techniques use a lower-level, state space representation, namely the Markov chain.

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

TMR example



Create a project



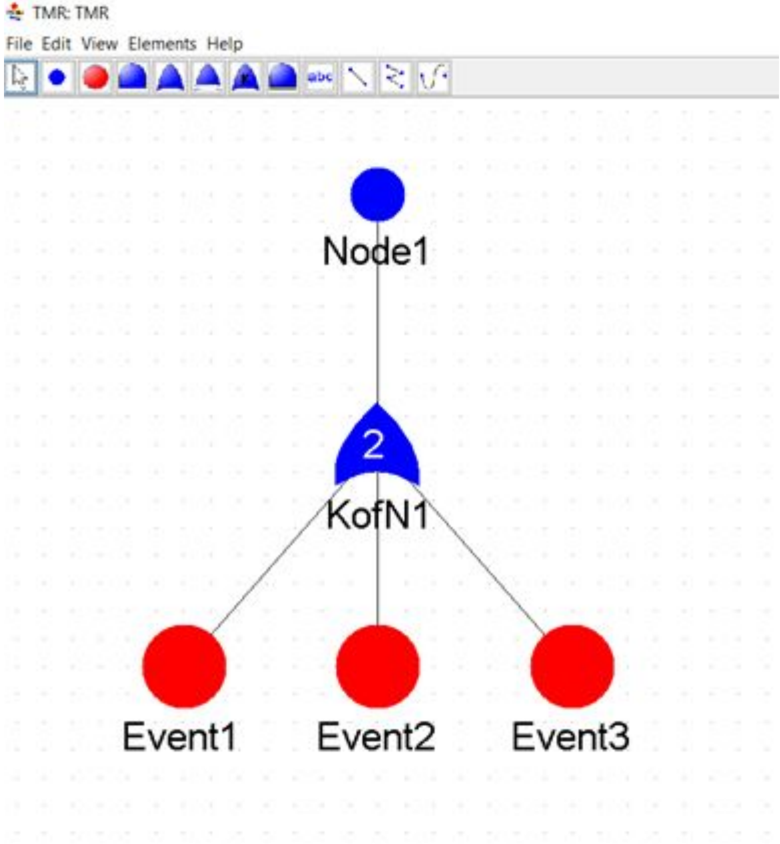
```
Welcome to Möbius, Maurizio.
```

Start with the creation of a new project

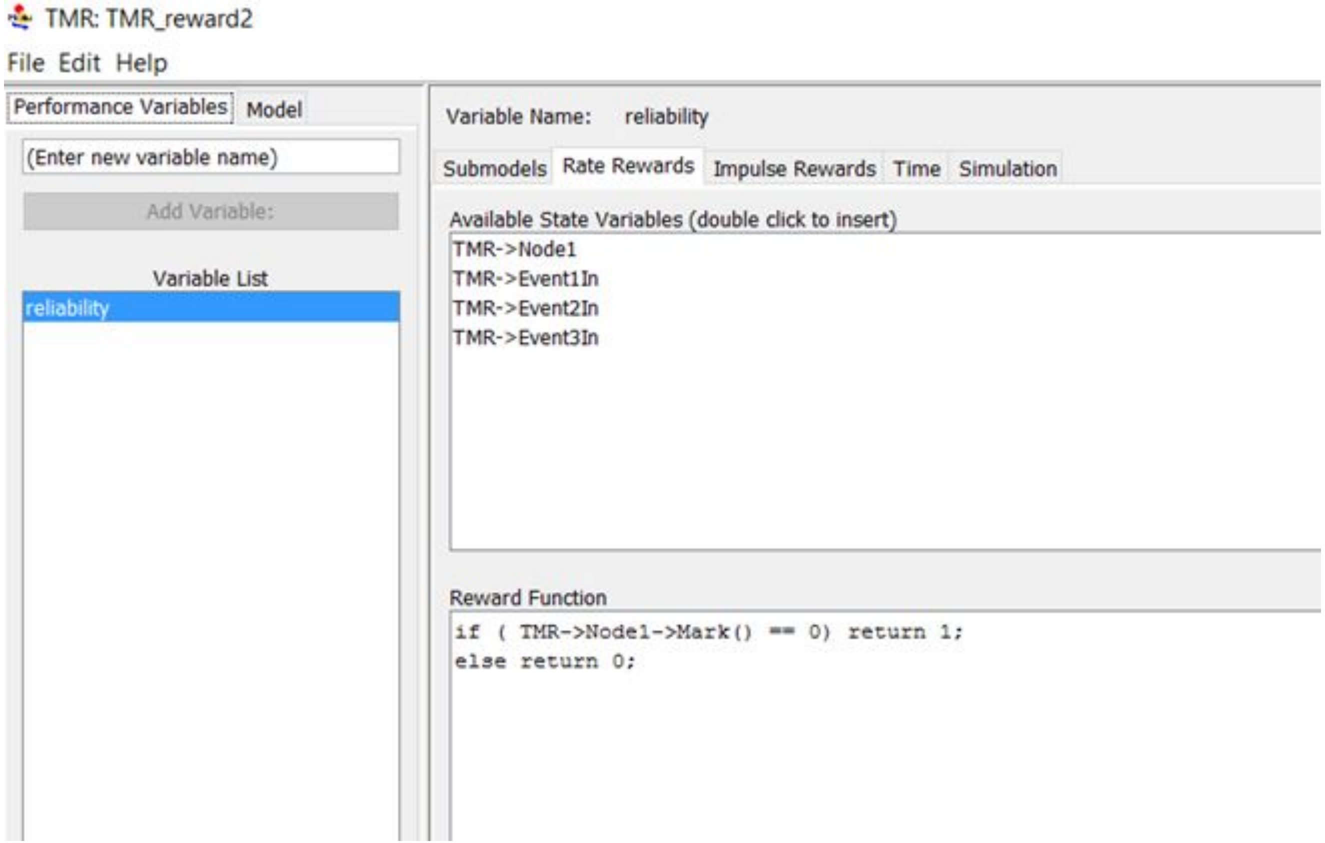
Right click on Open projects-> New project

Enter the project name

Atomic model of TMR



Reward model of TMR 1/2



Variable Name: reliability

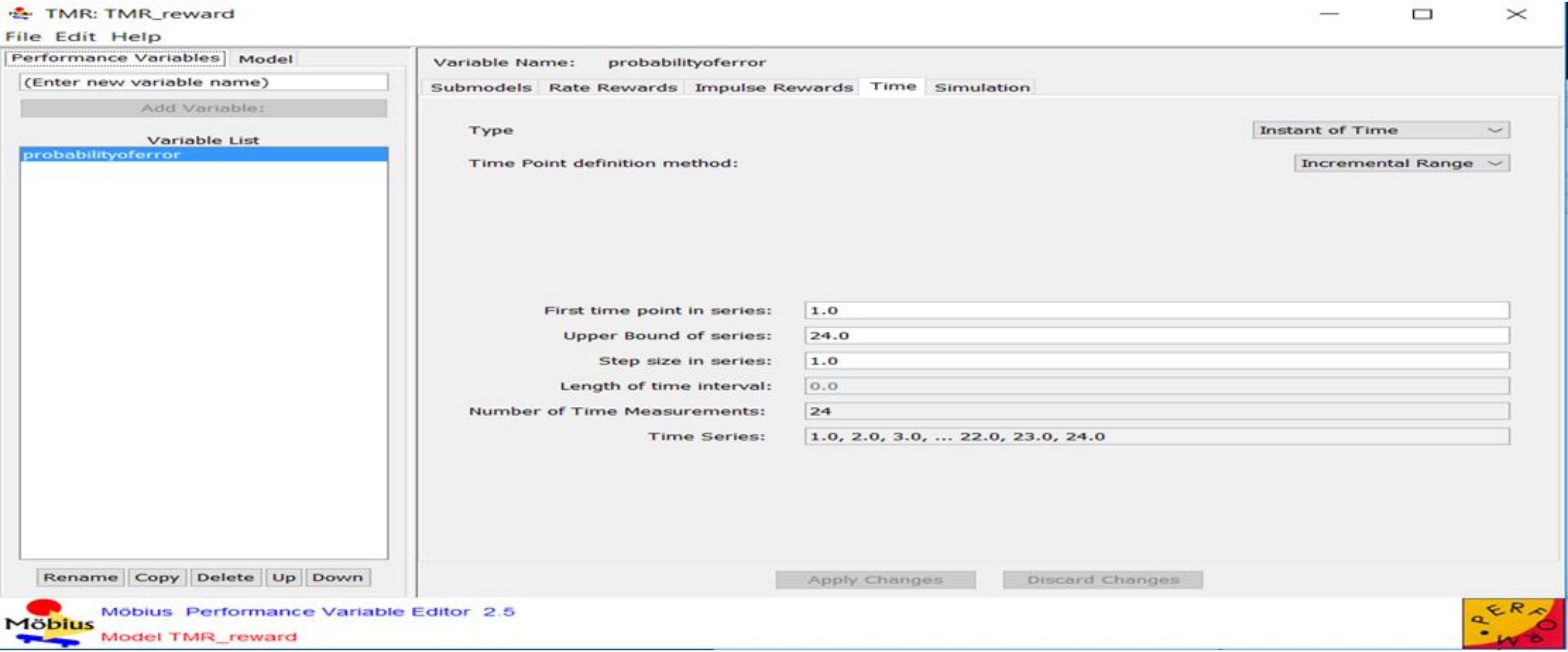
Available State Variables (double click to insert)

TMR->Node1
TMR->Event1In
TMR->Event2In
TMR->Event3In

Reward Function

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

Reward of TMR 2/2



Variable Name: probabilityoferror

Type: Instant of Time

Time Point definition method: Incremental Range

First time point in series: 1.0

Upper Bound of series: 24.0

Step size in series: 1.0

Length of time interval: 0.0

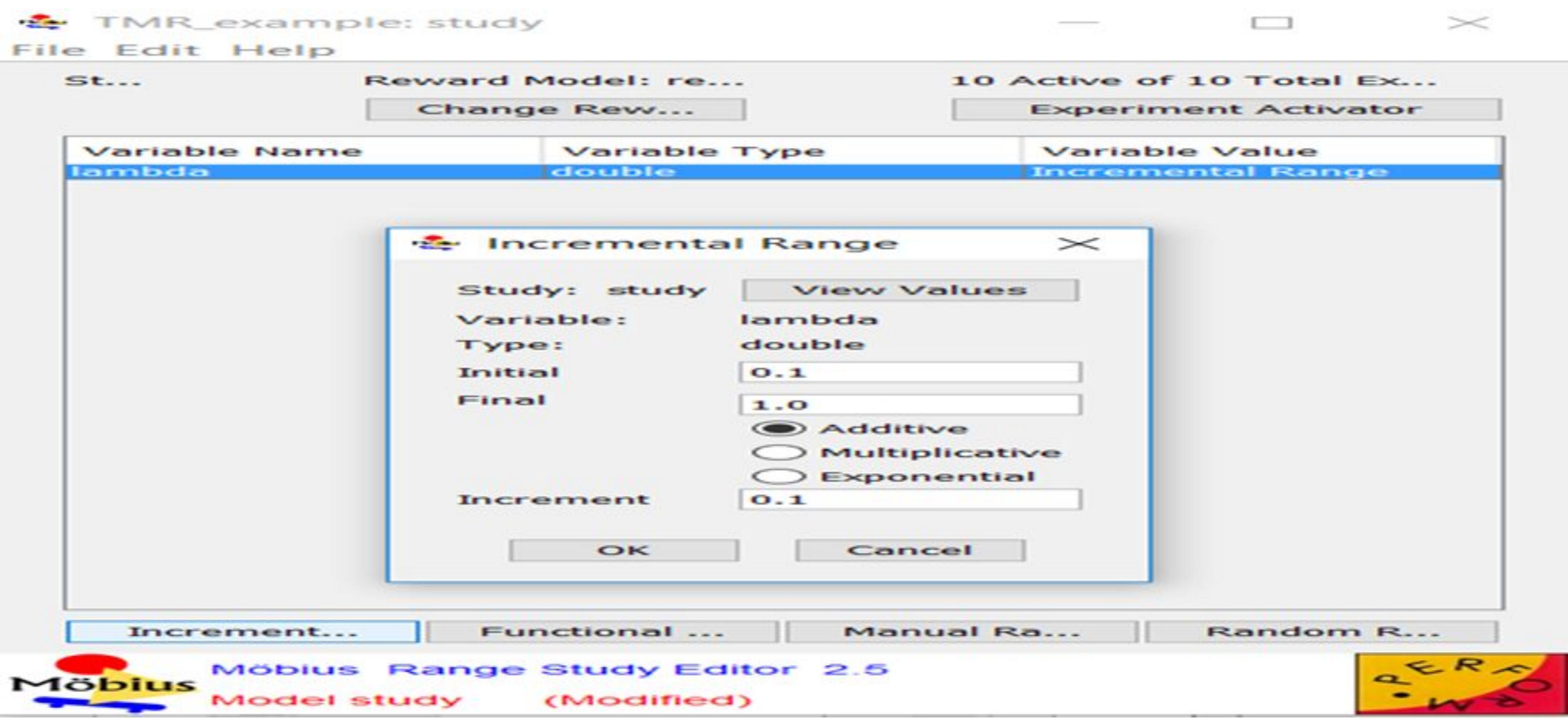
Number of Time Measurements: 24

Time Series: 1.0, 2.0, 3.0, ... 22.0, 23.0, 24.0

Möbius Performance Variable Editor 2.5

Model TMR_reward

Study of TMR



TMR_example: study

St... Reward Model: re... 10 Active of 10 Total Ex...

Variable Name	Variable Type	Variable Value
lambda	double	Incremental Range

Incremental Range

Study: study

Variable: lambda

Type: double

Initial 0.1

Final 1.0

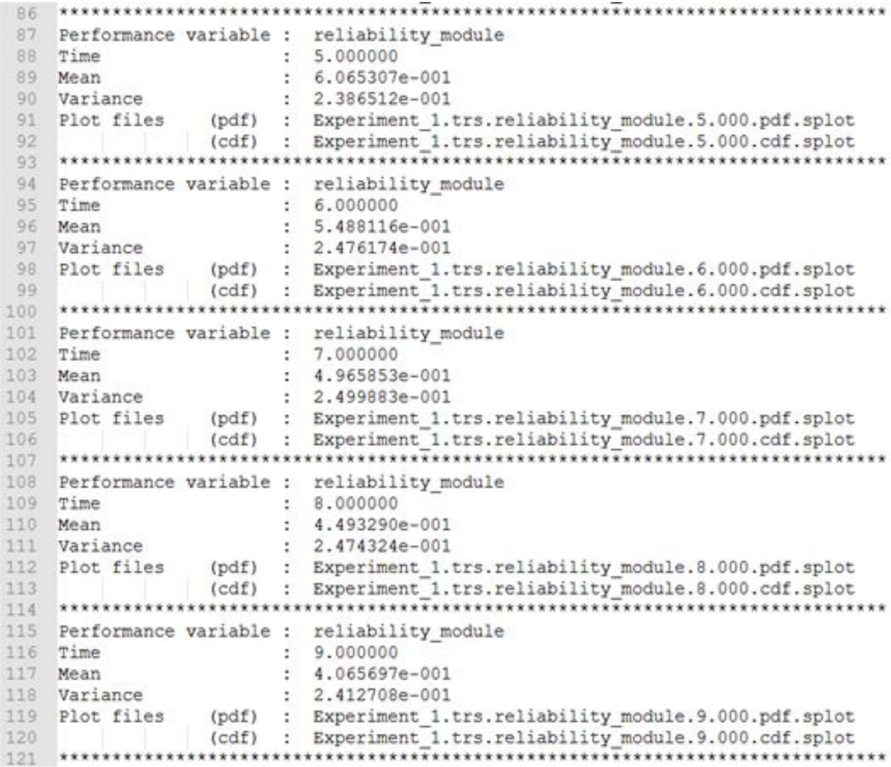
● Additive
○ Multiplicative
○ Exponential

Increment 0.1

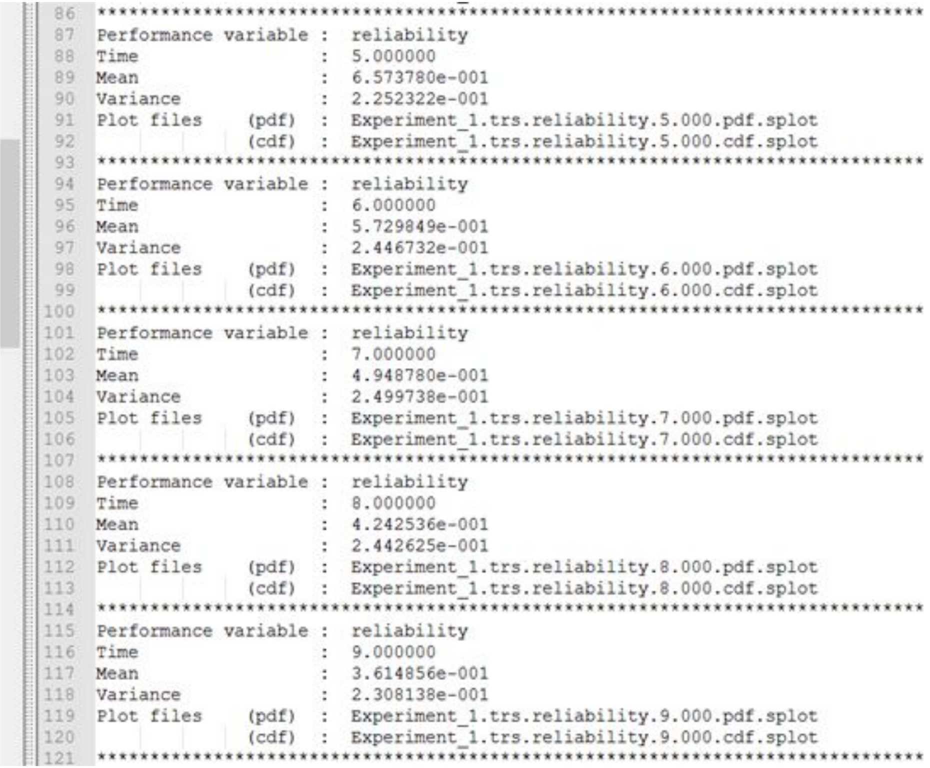
Möbius Range Study Editor 2.5

Model study (Modified)

Analysis of results when λ = 0.1

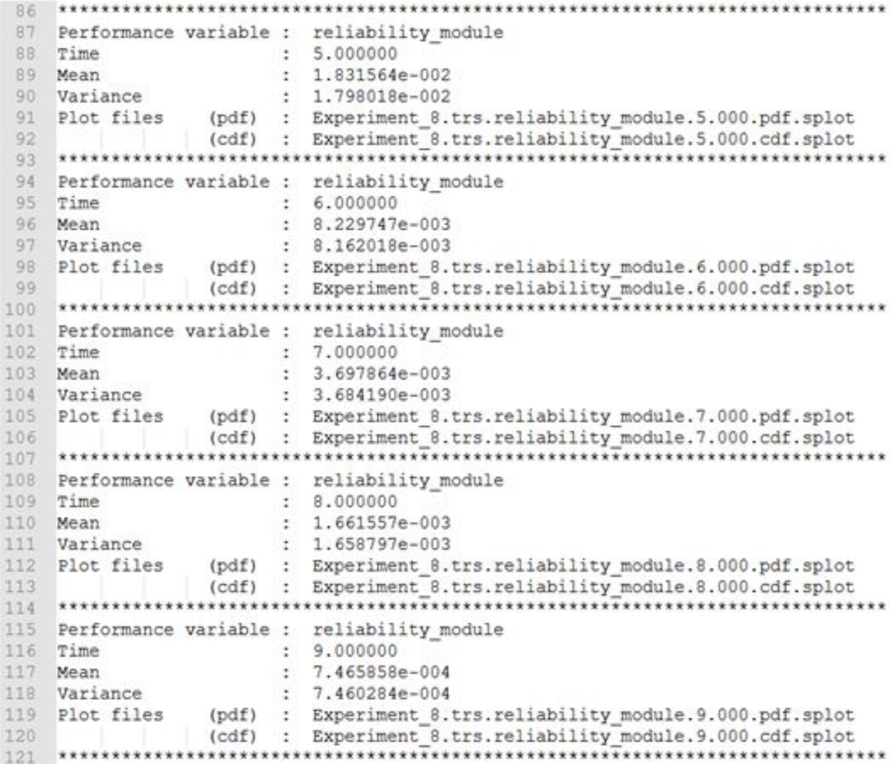


```
**********************************************************************
Performance variable :  reliability_module
Time                 :  5.000000
Mean                 :  6.065307e-001
Variance             :  2.386512e-001
Plot files     (pdf) :  Experiment_1.trs.reliability_module.5.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability_module.5.000.cdf.splot
**********************************************************************
Performance variable :  reliability_module
Time                 :  6.000000
Mean                 :  5.488116e-001
Variance             :  2.476174e-001
Plot files     (pdf) :  Experiment_1.trs.reliability_module.6.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability_module.6.000.cdf.splot
**********************************************************************
Performance variable :  reliability_module
Time                 :  7.000000
Mean                 :  4.965853e-001
Variance             :  2.499883e-001
Plot files     (pdf) :  Experiment_1.trs.reliability_module.7.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability_module.7.000.cdf.splot
**********************************************************************
Performance variable :  reliability_module
Time                 :  8.000000
Mean                 :  4.493290e-001
Variance             :  2.474324e-001
Plot files     (pdf) :  Experiment_1.trs.reliability_module.8.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability_module.8.000.cdf.splot
**********************************************************************
Performance variable :  reliability_module
Time                 :  9.000000
Mean                 :  4.065697e-001
Variance             :  2.412708e-001
Plot files     (pdf) :  Experiment_1.trs.reliability_module.9.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability_module.9.000.cdf.splot
**********************************************************************
```

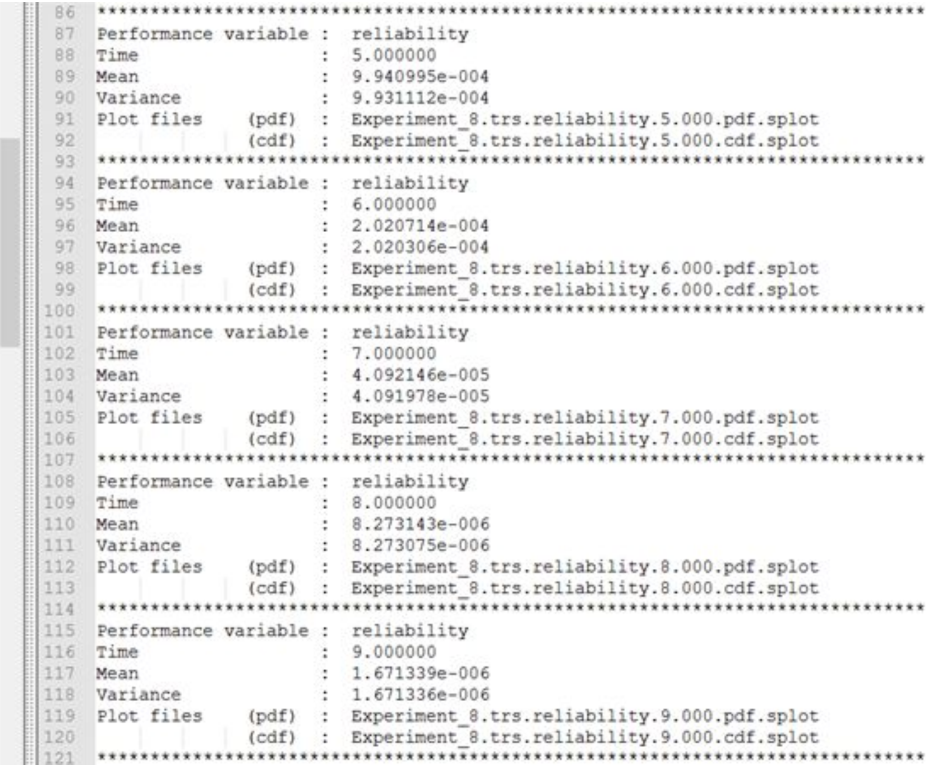


```
**********************************************************************
Performance variable :  reliability
Time                 :  5.000000
Mean                 :  6.573780e-001
Variance             :  2.252322e-001
Plot files     (pdf) :  Experiment_1.trs.reliability.5.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability.5.000.cdf.splot
**********************************************************************
Performance variable :  reliability
Time                 :  6.000000
Mean                 :  5.729849e-001
Variance             :  2.446732e-001
Plot files     (pdf) :  Experiment_1.trs.reliability.6.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability.6.000.cdf.splot
**********************************************************************
Performance variable :  reliability
Time                 :  7.000000
Mean                 :  4.948780e-001
Variance             :  2.499738e-001
Plot files     (pdf) :  Experiment_1.trs.reliability.7.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability.7.000.cdf.splot
**********************************************************************
Performance variable :  reliability
Time                 :  8.000000
Mean                 :  4.242536e-001
Variance             :  2.442625e-001
Plot files     (pdf) :  Experiment_1.trs.reliability.8.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability.8.000.cdf.splot
**********************************************************************
Performance variable :  reliability
Time                 :  9.000000
Mean                 :  3.614856e-001
Variance             :  2.308138e-001
Plot files     (pdf) :  Experiment_1.trs.reliability.9.000.pdf.splot
               (cdf) :  Experiment_1.trs.reliability.9.000.cdf.splot
**********************************************************************
```

Analysis of results when λ = 0.8

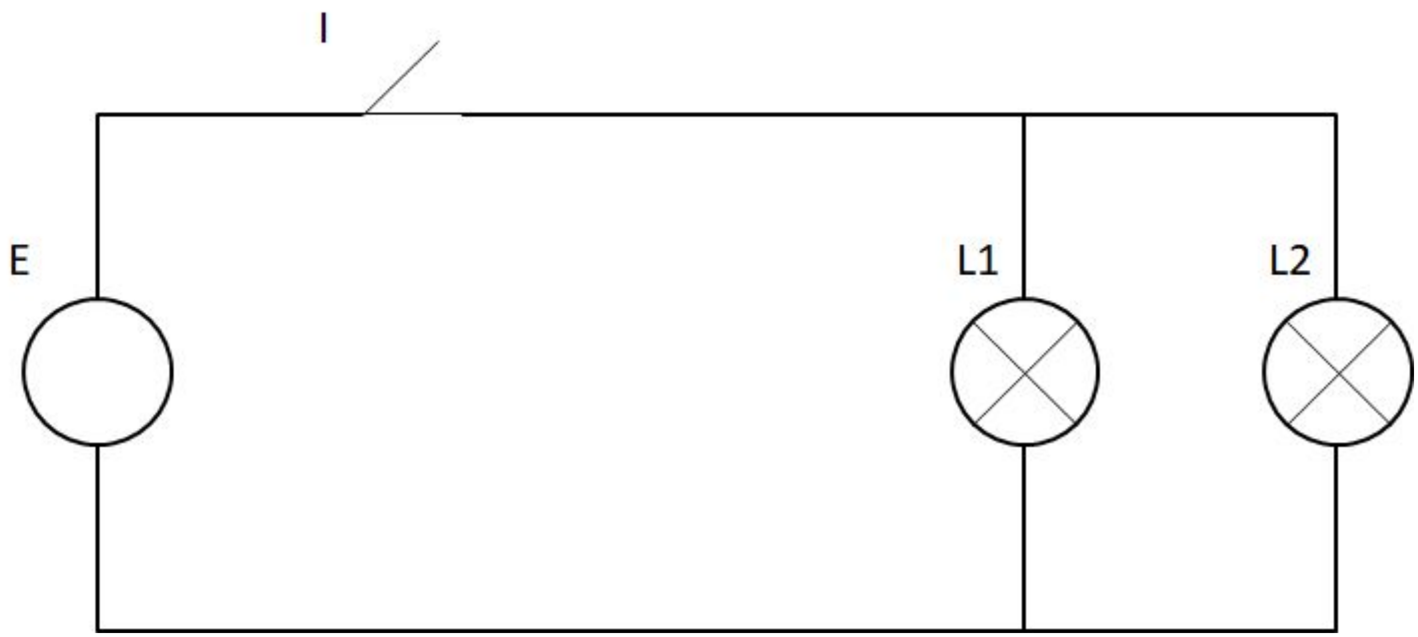


```
******************************************************************************
Performance variable :  reliability_module
Time                 :  5.000000
Mean                 :  1.831564e-002
Variance             :  1.798018e-002
Plot files    (pdf)  :  Experiment_8.trs.reliability_module.5.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability_module.5.000.cdf.splot
******************************************************************************
Performance variable :  reliability_module
Time                 :  6.000000
Mean                 :  8.229747e-003
Variance             :  8.162018e-003
Plot files    (pdf)  :  Experiment_8.trs.reliability_module.6.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability_module.6.000.cdf.splot
******************************************************************************
Performance variable :  reliability_module
Time                 :  7.000000
Mean                 :  3.697864e-003
Variance             :  3.684190e-003
Plot files    (pdf)  :  Experiment_8.trs.reliability_module.7.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability_module.7.000.cdf.splot
******************************************************************************
Performance variable :  reliability_module
Time                 :  8.000000
Mean                 :  1.661557e-003
Variance             :  1.658797e-003
Plot files    (pdf)  :  Experiment_8.trs.reliability_module.8.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability_module.8.000.cdf.splot
******************************************************************************
Performance variable :  reliability_module
Time                 :  9.000000
Mean                 :  7.465858e-004
Variance             :  7.460284e-004
Plot files    (pdf)  :  Experiment_8.trs.reliability_module.9.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability_module.9.000.cdf.splot
******************************************************************************
```



```
******************************************************************************
Performance variable :  reliability
Time                 :  5.000000
Mean                 :  9.940995e-004
Variance             :  9.931112e-004
Plot files    (pdf)  :  Experiment_8.trs.reliability.5.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability.5.000.cdf.splot
******************************************************************************
Performance variable :  reliability
Time                 :  6.000000
Mean                 :  2.020714e-004
Variance             :  2.020306e-004
Plot files    (pdf)  :  Experiment_8.trs.reliability.6.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability.6.000.cdf.splot
******************************************************************************
Performance variable :  reliability
Time                 :  7.000000
Mean                 :  4.092146e-005
Variance             :  4.091978e-005
Plot files    (pdf)  :  Experiment_8.trs.reliability.7.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability.7.000.cdf.splot
******************************************************************************
Performance variable :  reliability
Time                 :  8.000000
Mean                 :  8.273143e-006
Variance             :  8.273075e-006
Plot files    (pdf)  :  Experiment_8.trs.reliability.8.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability.8.000.cdf.splot
******************************************************************************
Performance variable :  reliability
Time                 :  9.000000
Mean                 :  1.671339e-006
Variance             :  1.671336e-006
Plot files    (pdf)  :  Experiment_8.trs.reliability.9.000.pdf.splot
              (cdf)  :  Experiment_8.trs.reliability.9.000.cdf.splot
******************************************************************************
```

Exercise 1



2 lights

1 switch

1 generator

We want to avoid that both lights stop working

Exercise 2

Re-create the TMR without using the K-of-N gate.

Compare the results of the new version with the ones previously shown in these slides.