

# Análise de Sensibilidade de Modelos Hierárquicos para Computação em Nuvem

Rubens de Souza Matos Júnior  
Orientador: Prof. Paulo Maciel

# Agenda

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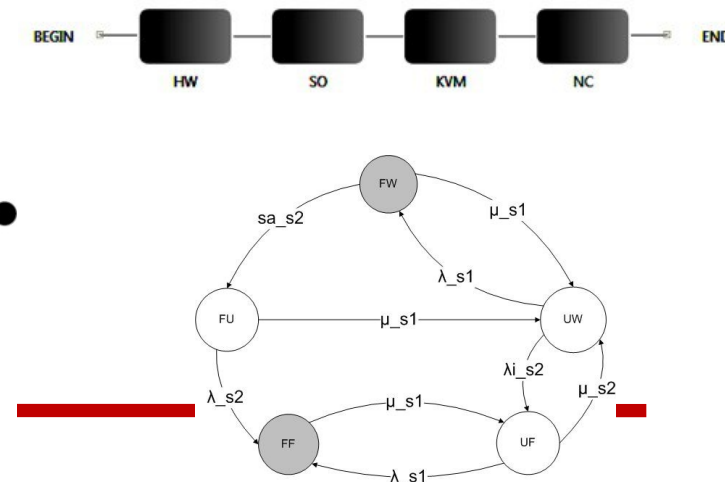
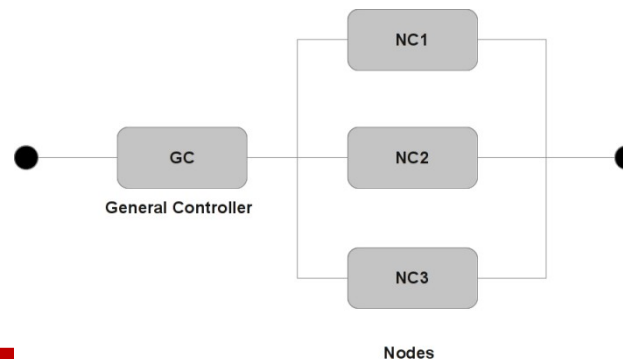
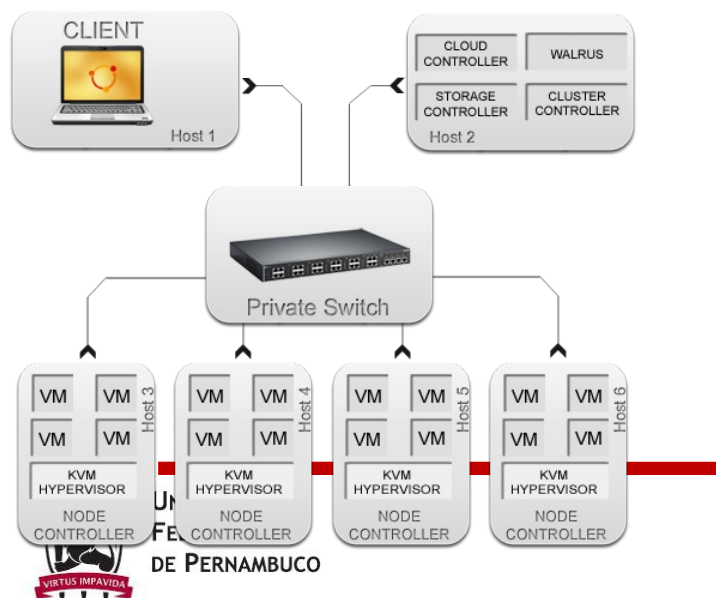
- Motivação
- Objetivos
- Estudo de caso: A.S. em modelos de Mobile Cloud
- Resultados
- Próximos passos



# Motivação



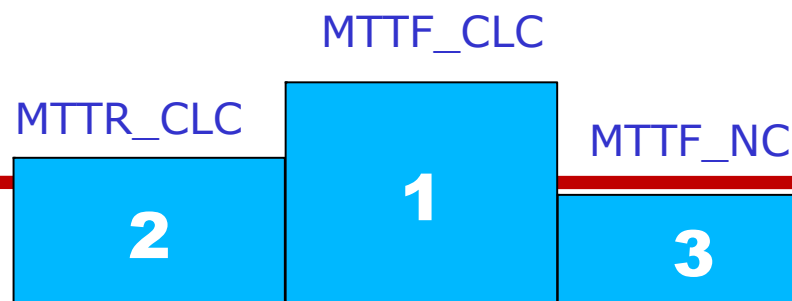
- Computação em nuvem é usada/almejada por várias empresas
- Como propor melhorias de desempenho/dependabilidade para sistemas complexos tais como as nuvens computacionais?
  - Muitos componentes de hardware e software
  - Modelos hierárquicos facilitam a descrição desses sistemas e o tratamento de largeness e stiffness.



# Motivação



- Análise de sensibilidade:
  - Métodos para verificar o quanto as mudanças nos parâmetros de entrada irão afetar as saídas (resultados) de um sistema/modelo.
  - Técnica essencial para **detecção de “gargalos”** de desempenho/dependabilidade
    - Variação dos parâmetros, um por vez
    - Análise diferencial
    - Análise de correlação/regressão
    - Design of Experiments: Full-factorial, 2k-Factorial, ...



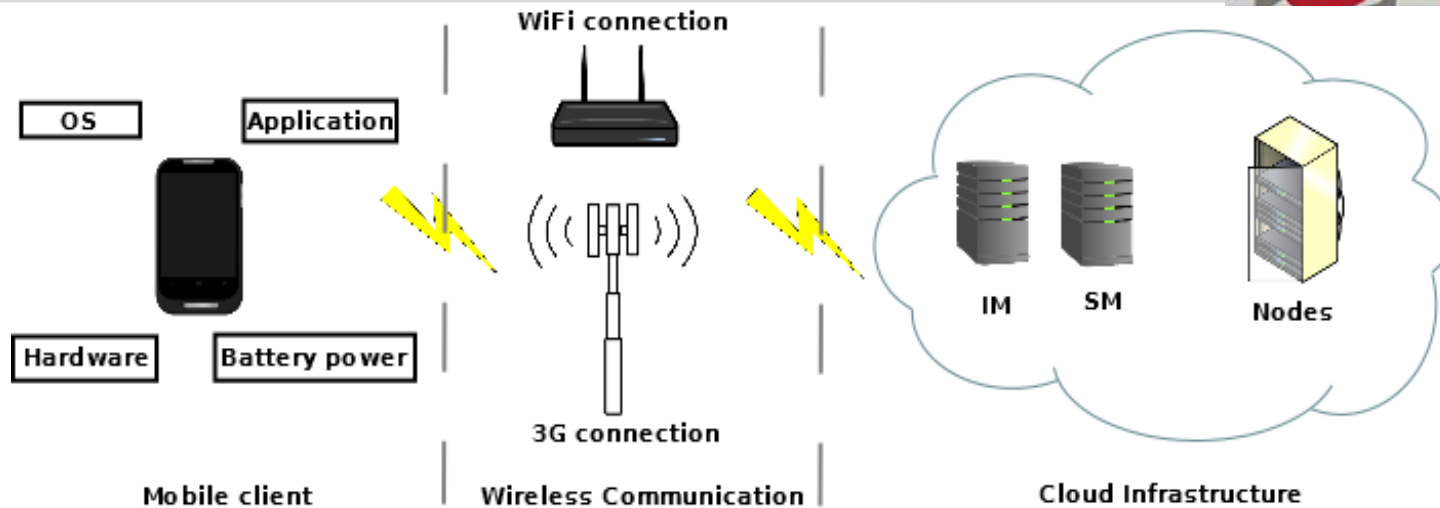
# Objetivos



- Principais objetivos:
  - Criação de **modelos** abrangendo **nível de aplicação e de infraestrutura** (Software executando em IaaS)
  - Prover **métodos e ferramentas** para **análise de sensibilidade** automatizada dos modelos hierárquicos
  - Incorporação de métodos de **A.S. em algoritmos de otimização** de infraestruturas/serviços de nuvem

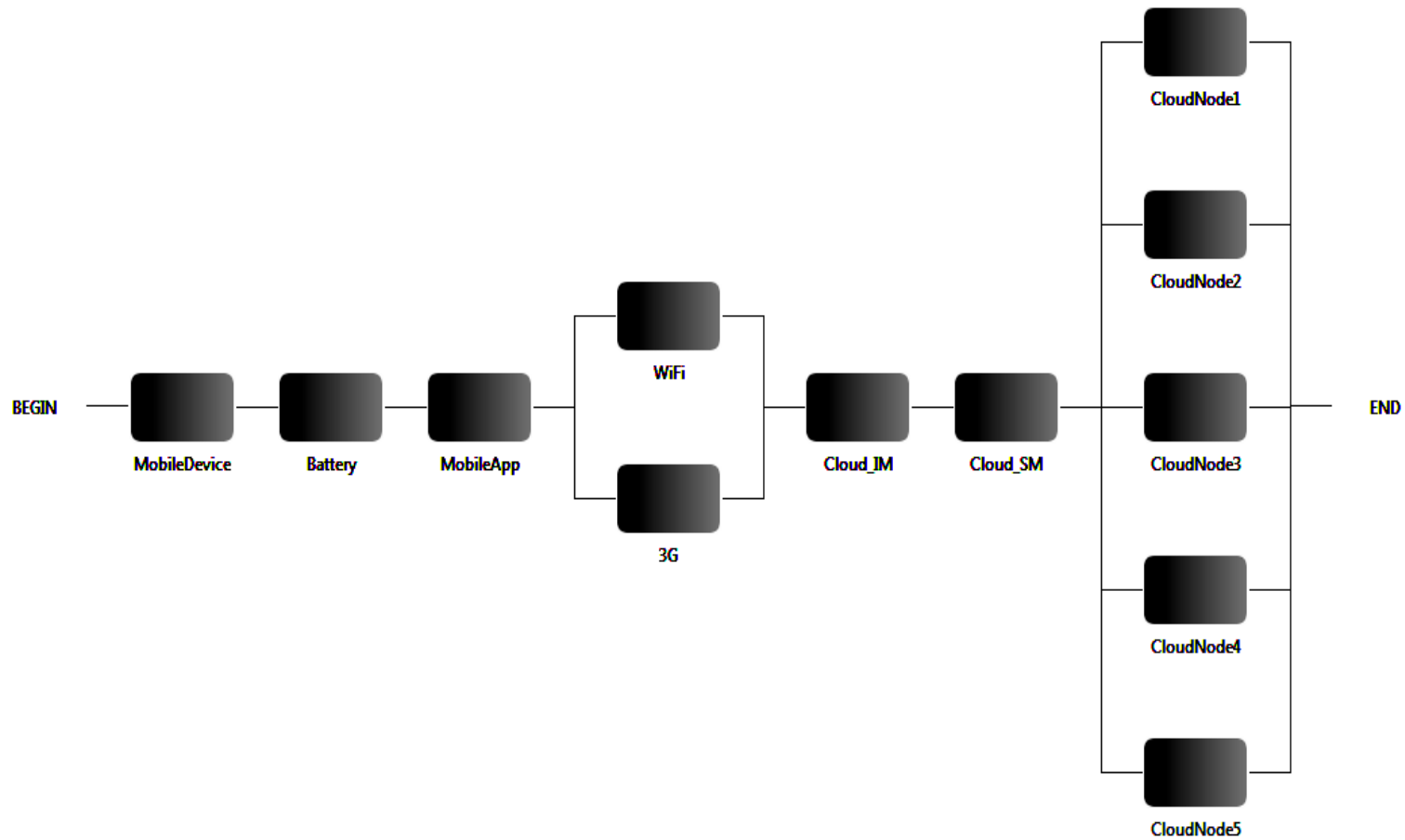


# A.S. em modelos de mobile cloud

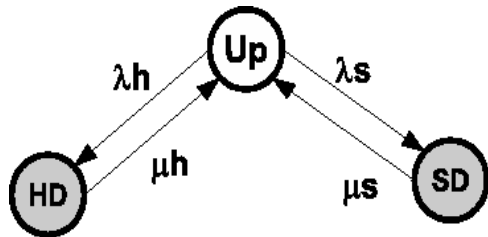


- **Modelos de disponibilidade** para sistemas de mobile cloud
  - Falha/reparo de **hardware, rede e software**
  - **Descarga da bateria** do dispositivo móvel
  - Atualizações do **software**
  - **Fatores de cobertura** das falhas

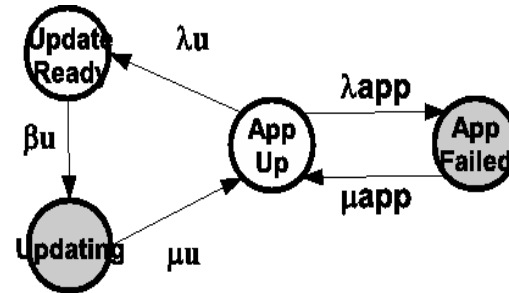
# Modelo RBD



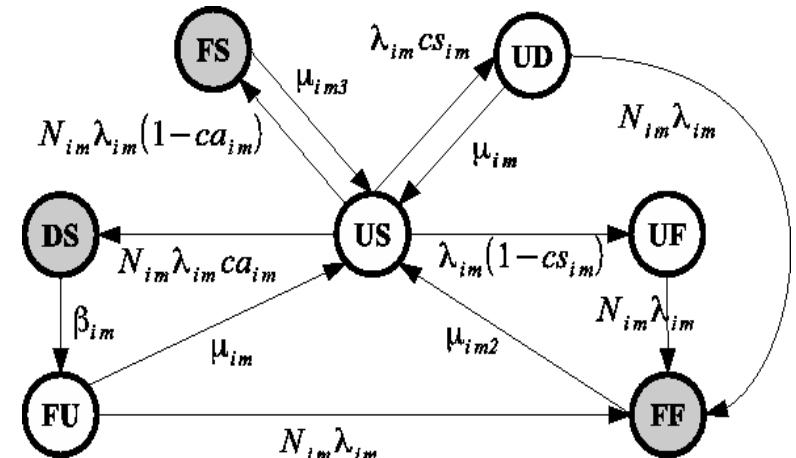
# Modelos CTMC



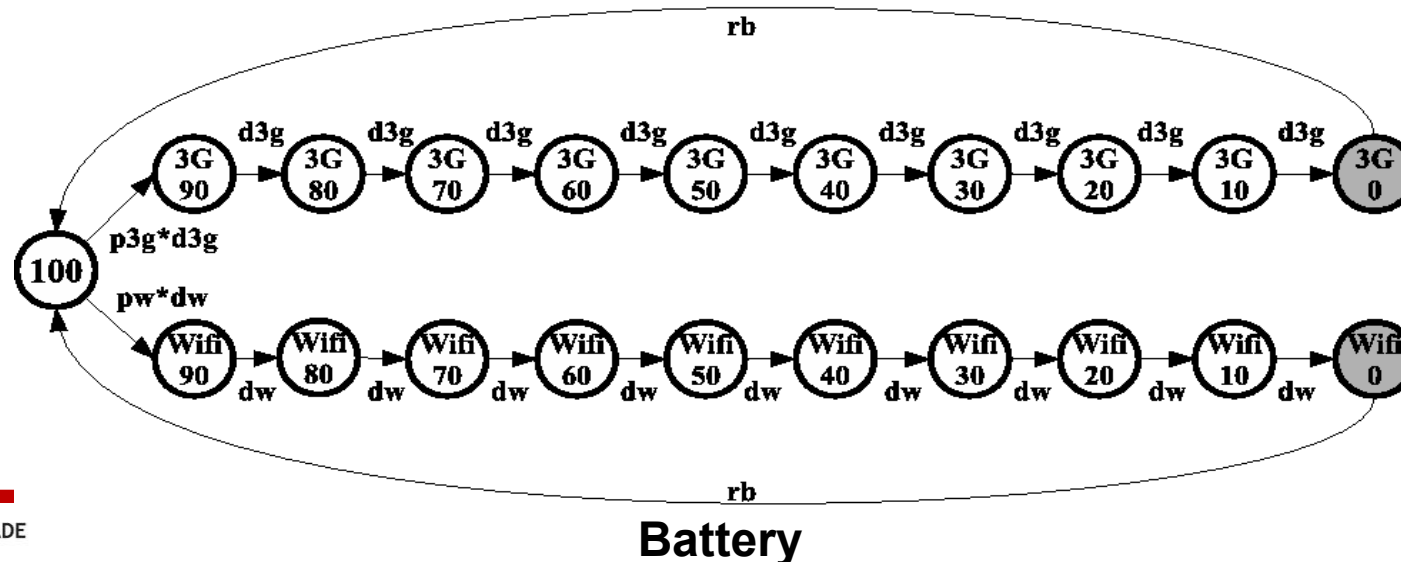
Mobile Device



Mobile Application



Infrastructure Manager



Battery



# Equações fechadas



$$A_{System} = A_{MobileDev} \times A_{Battery} \times A_{MobileApp} \\ \times (1 - (1 - A_{WiFi}) \times (1 - A_{3G})) \times A_{IM} \times A_{SM} \times (1 - (1 - A_{Node})^5)$$

$$A_{MobileDev} = \frac{(\mu_{ah} \times \mu_{as})}{(\lambda_{as} \times \mu_{ah} + (\lambda_{ah} + \mu_{ah}) \times \mu_{as})}$$

$$A_{WiFi} = \frac{\mu_{wifi}}{\lambda_{wifi} + \mu_{wifi}}$$

$$A_{3G} = \frac{\mu_{3g}}{\lambda_{3g} + \mu_{3g}}$$

$$A_{MobileApp} = \frac{((\beta_u + \lambda_u) \times \mu_{app} \times \mu_u)}{(\beta_u \times \lambda_u \times \mu_{app} + \lambda_u \times \mu_{app} \times \mu_u + \beta_u \times (\lambda_{app} + \mu_{app}) \times \mu_u)}$$



# Equações fechadas



$$A_{Battery} = \frac{((1 + 9 \times p3g + 9 \times pw) \times rb)}{(d3g \times p3g + dw \times pw + rb + 9 \times (p3g + pw) \times rb)}$$

$$A_{CloudIM} = \frac{(\beta_{im}(N_{im}(1 + N_{im} + ca_{im}N_{im})\lambda_{im} + (1 - cs_{im} + N_{im})\mu_{im})\mu_{im2}\mu_{im3})}{((-1 + ca_{im})N_{im}^2\beta_{im}\lambda_{im}(N_{im}\lambda_{im} + \mu_{im})\mu_{im2} - ((1 - cs_{im})\beta_{im}\mu_{im}\mu_{im2} + ca_{im}N_{im}^3\lambda_{im}^2(\beta_{im} + \mu_{im2}) + N_{im}\beta_{im}(\mu_{im}\mu_{im2} + \lambda_{im}(\mu_{im} - cs_{im}\mu_{im} + \mu_{im2}))) + N_{im}^2\lambda_{im}(ca_{im}\mu_{im}\mu_{im2} + \beta_{im}(\lambda_{im} + \mu_{im2} + ca_{im}\mu_{im2})))\mu_{im3}} \quad (12)$$

$$A_{Node} = \frac{\mu_{node}}{\lambda_{node} + \mu_{node}}$$



# Sumarização de resultados



## Derivadas parciais

Parameter	$ SS(A) $
$CS_{sm}$	0.006242686368
$ca_{sm}$	0.005679147263
$CS_{im}$	0.003946053118
$ca_{im}$	0.003579911742
$rb$	0.002173576439

## Diferença percentual

Parameter	$ S(A) $
$N_{sm}$	0.0068660546
$rb$	0.0058528304
$N_{im}$	0.003583039
$ca_{sm}$	0.0026962696
$CS_{sm}$	0.0026128065

## Análise de DoE

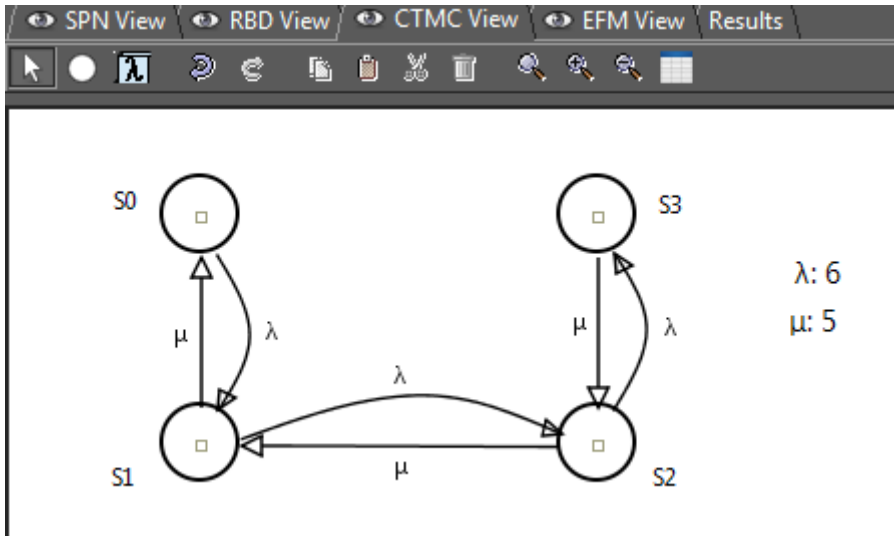
Parameter	Effect
$rb$	0.010521
$ca_{sm}$	0.007525
$N_{sm}$	-0.006857
$\mu_{sm2}$	0.004468
$\lambda_{sm}$	-0.004225

Os parâmetros que aparecem entre os **5 primeiros** do ranking em pelo menos **2 dos 3 métodos** são:

- $ca_{sm}$  ● **Fator de cobertura** da falha do servidor primário no **Storage Manager**
- $CS_{sm}$  ● **Fator de cobertura** da falha do servidor secundário no **Storage Manager**
- $N_{sm}$  ● **Número** necessário de **Storage Managers** ativos
- ' ● Taxa de **substituição da bateria** do dispositivo móvel



# Implementação no Mercury



Sensitivity analysis of CTMC

Type of sensitivity index  
 Scaled  Unscaled

Type of ranking  
 Ordered  Unordered

Measure of interest  
Item 1

Parameter of interest  
Item 1

Sensitivity with respect to lambda  
State S0: 1.7257847752049897  
State S1: 0.7257830220549935  
State S2: -0.274218431307747  
State S3: -1.2742186767372679

Sensitivity with respect to mu  
State S0: -1.7257847710093839  
State S1: -0.7257830210454719  
State S2: 0.274218429783088  
State S3: 1.274218674878748

Run Close

# Validando com o Mathematica



```
ClearAll["Global`*"];
S0 = 1; S1 = 2; S2 = 3; S3 = 4;
p0 = {1, 0, 0, 0};
mat = SparseArray[{{S0, S1} -> λ, {S1, S2} -> λ, {S2, S3} -> λ, {S3, S2} -> μ, {S2, S1} -> μ, {S1, S0} -> μ}];
(matQ = Transpose[SetDiagonal[Transpose[mat]]]) // MatrixForm
(prob = ProbStationary[Transpose[matQ]]) // FullSimplify
probS0 := prob[[S0]]; probS1 := prob[[S1]]; probS2 := prob[[S2]]; probS3 := prob[[S3]];
sensS0mu = D[probS0, μ] * (μ / probS0);
sensS1mu = D[probS1, μ] * (μ / probS1);
sensS2mu = D[probS2, μ] * (μ / probS2);
sensS3mu = D[probS3, μ] * (μ / probS3);
sensS0lambda = D[probS0, λ] * (λ / probS0);
sensS1lambda = D[probS1, λ] * (λ / probS1);
sensS2lambda = D[probS2, λ] * (λ / probS2);
sensS3lambda = D[probS3, λ] * (λ / probS3);
μ := 5;
λ := 6;
Print["Sensitivity with respect to lambda"]
N[sensS0lambda, 6]
N[sensS1lambda, 6]
N[sensS2lambda, 6]
N[sensS3lambda, 6]
Print["Sensitivity with respect to mu"]
N[sensS0mu, 6]
N[sensS1mu, 6]
N[sensS2mu, 6]
N[sensS3mu, 6]
```

Derivadas parciais das equações fechadas



# Validando com o Mathematica



Wolfram Mathematica | STUDENT EDITION

Out[378]/MatrixForm=

$$\begin{pmatrix} -\lambda & \lambda & 0 & 0 \\ \mu & -\lambda - \mu & \lambda & 0 \\ 0 & \mu & -\lambda - \mu & \lambda \\ 0 & 0 & \mu & -\mu \end{pmatrix}$$

$$\text{Out[377]= } \left\{ \frac{\mu^3}{(\lambda + \mu)(\lambda^2 + \mu^2)}, \frac{\lambda \mu^2}{(\lambda + \mu)(\lambda^2 + \mu^2)}, \frac{\lambda^2 \mu}{(\lambda + \mu)(\lambda^2 + \mu^2)}, \frac{\lambda^3}{(\lambda + \mu)(\lambda^2 + \mu^2)} \right\}$$

Sensitivity with respect to lambda

Out[393]= -1.72578

Out[394]= -0.725782

Out[395]= 0.274218

Out[396]= 1.27422

Sensitivity with respect to mu

Out[398]= 1.72578

Out[399]= 0.725782

Out[400]= -0.274218

Out[401]= -1.27422

Sensitivity analysis of CTMC

Type of sensitivity index

Scaled  Unscaled

Type of ranking

Ordered  Unordered

Measure of interest

Item 1

Parameter of interest

Item 1

Sensitivity with respect to lambda

State S0: -1.7257801494566996

State S1: -0.725781830401081

State S2: 0.27421678120417864

State S3: 1.2742165473484495

Sensitivity with respect to mu

State S0: 1.7257801452610968

State S1: 0.7257818293915602

State S2: -0.27421677967952085

State S3: -1.2742165454899308

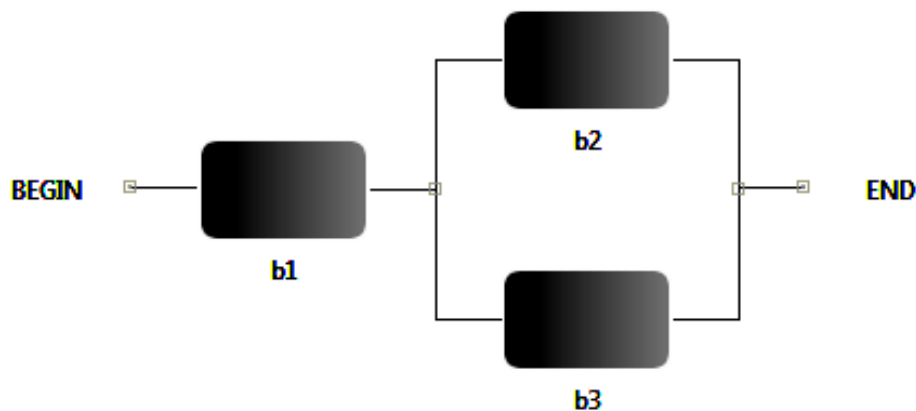
Run

Close



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# Implementação para RBD



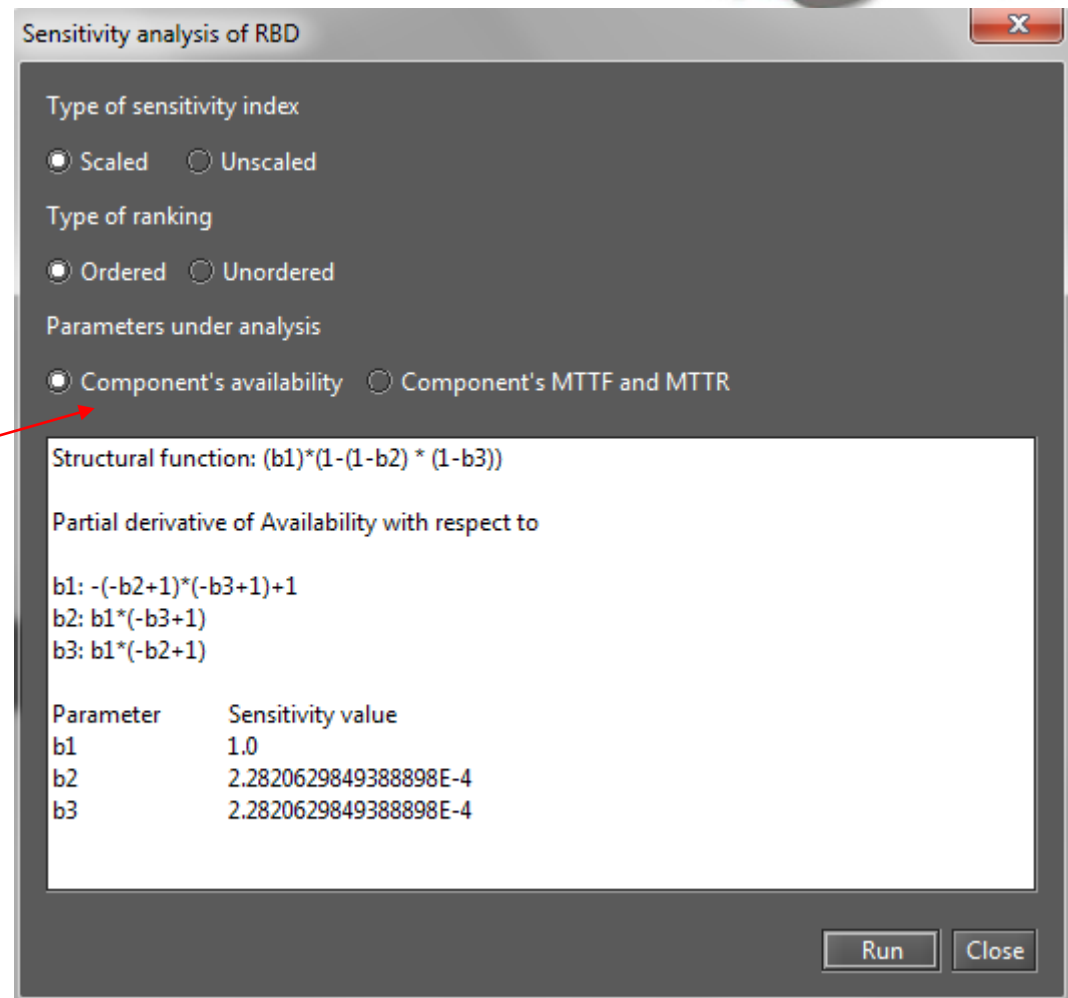
Block Name:	<input type="text" value="b1"/>		
Parameters Type:	<input type="text" value="Time"/>	State:	<input type="text" value="Default"/>
<b>Parameters</b>			
Failure Time	<input type="text" value="4380.0"/>		
Repair Time	<input type="text" value="2.0"/>		
Price (\$)	<input type="text" value="0.0"/>		

Block Name:	<input type="text" value="b2"/>		
Parameters Type:	<input type="text" value="Time"/>	State:	<input type="text" value="Default"/>
<b>Parameters</b>			
Failure Time	<input type="text" value="8760.0"/>		
Repair Time	<input type="text" value="2.0"/>		
Price (\$)	<input type="text" value="0.0"/>		

# Implementação para RBD

A análise pode ser feita em relação a:

- Disponibilidade de cada bloco
- MTTFs e MTTRs



Sensitivity analysis of RBD

Type of sensitivity index  
 Scaled  Unscaled

Type of ranking  
 Ordered  Unordered

Parameters under analysis  
 Component's availability  Component's MTTF and MTTR

Structural function:  $(b1) * (1 - (1 - b2) * (1 - b3))$

Partial derivative of Availability with respect to

b1:  $-(-b2+1)*(-b3+1)+1$   
b2:  $b1*(-b3+1)$   
b3:  $b1*(-b2+1)$

Parameter	Sensitivity value
b1	1.0
b2	2.2820629849388898E-4
b3	2.2820629849388898E-4

Run Close



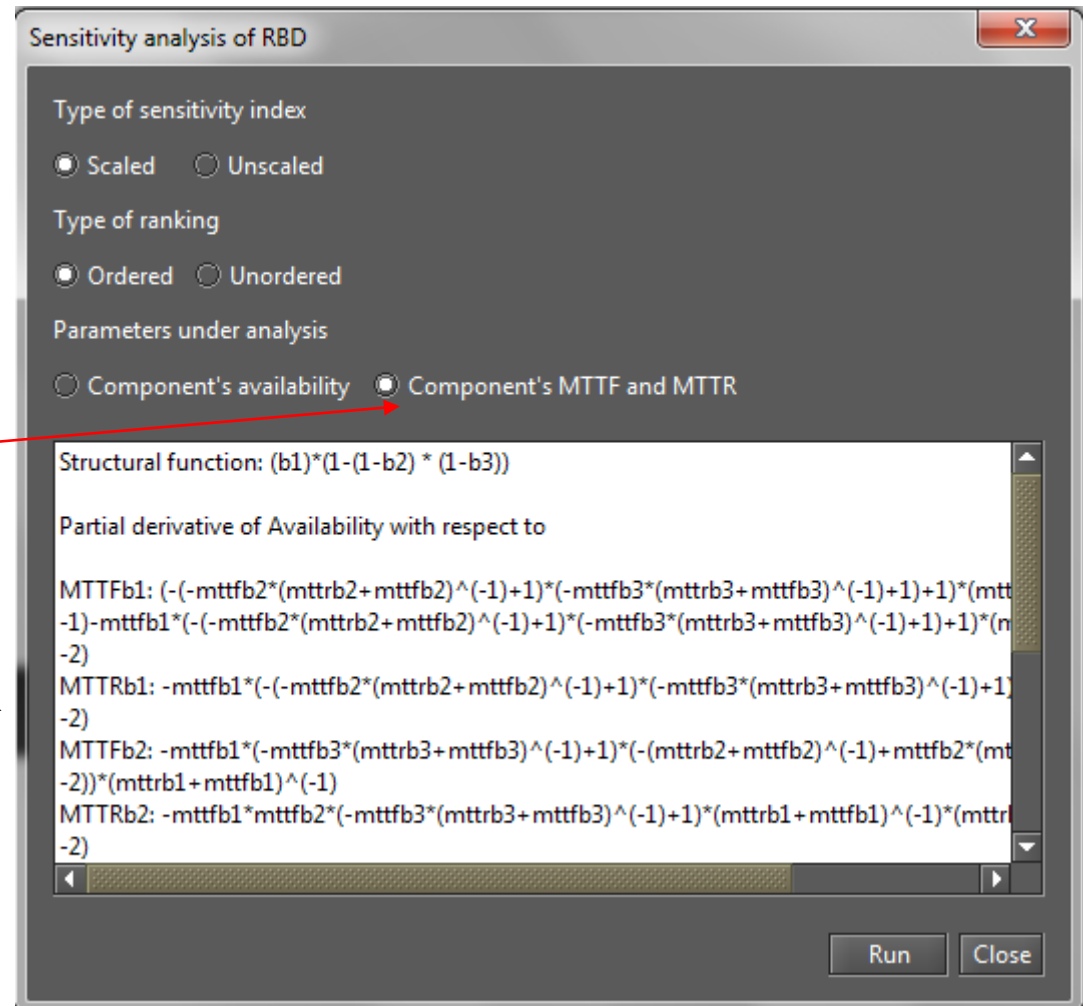
# Implementação para RBD

A análise pode ser feita em relação a:

- Disponibilidade de cada bloco
- MTTFs e MTTRs

Nomenclatura temporária: →

- MTTFb1
- MTTRb1
- ...



Sensitivity analysis of RBD

Type of sensitivity index  
 Scaled  Unscaled

Type of ranking  
 Ordered  Unordered

Parameters under analysis  
 Component's availability  Component's MTTF and MTTR

Structural function:  $(b1) * (1 - (1 - b2) * (1 - b3))$

Partial derivative of Availability with respect to

MTTFb1:  $(-(-mttfb2 * (mtrrb2 + mttfb2)^{-1} + 1) * (-mttfb3 * (mtrrb3 + mttfb3)^{-1} + 1) + 1) * (mtrrb1 + mttfb1)^{-1} - mttfb1 * (-(-mttfb2 * (mtrrb2 + mttfb2)^{-1} + 1) * (-mttfb3 * (mtrrb3 + mttfb3)^{-1} + 1) + 1) * (mtrrb1 + mttfb1)^{-1}$

MTTRb1:  $-mttfb1 * (-(-mttfb2 * (mtrrb2 + mttfb2)^{-1} + 1) * (-mttfb3 * (mtrrb3 + mttfb3)^{-1} + 1) + 1) * (mtrrb1 + mttfb1)^{-1}$

MTTFb2:  $-mttfb1 * (-mttfb3 * (mtrrb3 + mttfb3)^{-1} + 1) * (-mtrrb2 + mttfb2)^{-1} + mttfb2 * (mtrrb2 + mttfb2)^{-1} * (mtrrb1 + mttfb1)^{-1}$

MTTRb2:  $-mttfb1 * mttfb2 * (-mttfb3 * (mtrrb3 + mttfb3)^{-1} + 1) * (mtrrb1 + mttfb1)^{-1} * (mtrrb2 + mttfb2)^{-1}$

Run Close

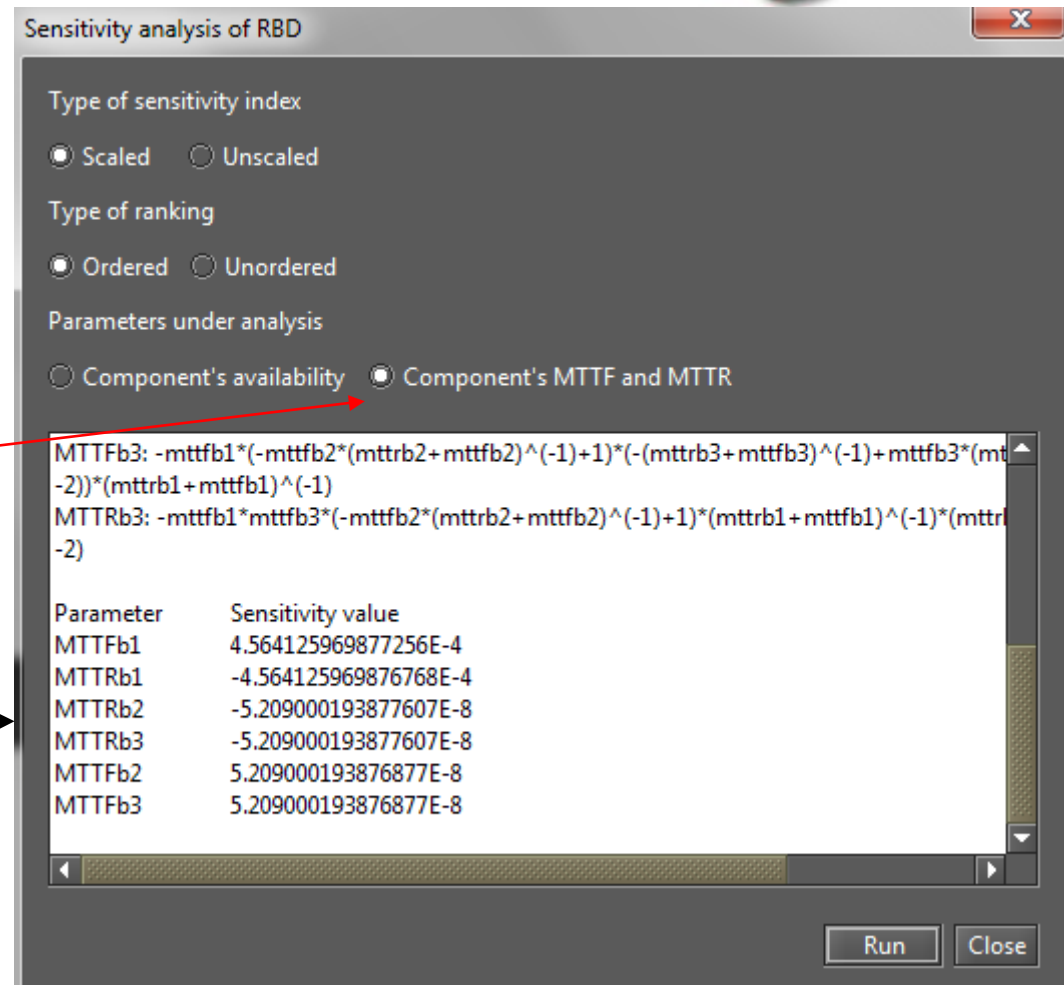
# Implementação para RBD

A análise pode ser feita em relação a:

- Disponibilidade de cada bloco
- MTTFs e MTTRs

Nomenclatura temporária:

- MTTFb1
- MTTRb1
- ...



The screenshot shows a dialog box titled "Sensitivity analysis of RBD". It contains several options for configuring the analysis:

- Type of sensitivity index:  Scaled,  Unscaled
- Type of ranking:  Ordered,  Unordered
- Parameters under analysis:  Component's availability,  Component's MTTF and MTTR

Below these options, there is a text area containing mathematical formulas for MTTFb3 and MTTRb3. A red arrow points from the text "Component's MTTF and MTTR" to this area.

MTTFb3:  $-mttfb1 * (-mttfb2 * (mtrb2 + mttfb2)^{-1} + 1) * (-mtrb3 + mttfb3)^{-1} + mttfb3 * (mtrb1 + mttfb1)^{-1} * (-2)$

MTTRb3:  $-mttfb1 * mttfb3 * (-mttfb2 * (mtrb2 + mttfb2)^{-1} + 1) * (mtrb1 + mttfb1)^{-1} * (mtrb1 + mttfb1)^{-1} * (-2)$

Below the formulas is a table with two columns: "Parameter" and "Sensitivity value".

Parameter	Sensitivity value
MTTFb1	4.564125969877256E-4
MTTRb1	-4.564125969876768E-4
MTTRb2	-5.209000193877607E-8
MTTRb3	-5.209000193877607E-8
MTTFb2	5.209000193876877E-8
MTTFb3	5.209000193876877E-8

At the bottom right of the dialog box are "Run" and "Close" buttons.

# Próximos passos

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- Incluir funções de A.S. para probabilidades transientes (em andamento)
- Testar o uso de A.S. para otimização baseada no GRASP (em andamento)
- Estudo de caso com modelos de desempenho de web services na nuvem
- Experimentos para validar os resultados de alguns estudos de caso

