A Simulation Tool to Assess the Performance of Production Systems in Degraded Mode

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Degraded mode

- Degradation of the system performance
- Change in the flow configuration
Degraded mode

- Propagation of system failures
Evaluate the performance of a production system in degraded mode (considering the information related to risks).
Proposed Approach

Descriptive, Static Risk Model

Real System → Structure and behavior → Failures and propagation → Automatic transformation → Dynamic Simulation model → Performance indicators

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Proposed Approach

Real System

Structure and behavior

Failures and propagation

Simulation model

Performance indicators

Modeling

Automatic transformation

Simulation in degraded mode

Describe the production system, its structure, its behavior and its failures and propagation

FIS model (Function, Interaction, Structure)

FIS Modeling – Structure and Behavior

Structuro-functional modeling
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FIS Modeling – Failures and propagation

Dysfunctional modeling
FIS – Modeling of flows

Failure modes:
ModDef1
Modeling of flows

Behavior Mode 1
Validity Conditions: false
Process duration, priority
Input, output information…

Behavior Mode 2
Validity Conditions: True
Process duration, priority
Input, output information…

Failure mode
ModDef1
FIS – Modeling of flows- example

- Pre-disinfected MD
- Rinsing machine
- Staff
- Rinsed MD
- Washers
- Washing
- Washed MD
FIS – Modeling of flows- example

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FIS – Flow modeling
Proposed Approach

Real System

Structure and behavior
 Failures and propagation

Simulation model

Performance indicators

Automatic transformation

Modeling

Simulation in degraded mode

Represent the dynamic behavior of production systems
PTPS (Predicate-Transition, Prioritised, Synchronous Petri Nets)
(capable of satisfying all the requirements of FIS Model)
Set of conversion algorithms
Proposed approach

Real System → Structure and behavior → Failures and propagation → FIS Model

Function view

FIS: Fonction Interaction Structure

Resource View

FIS Model → Automatic transformation → Simulation in degraded Mode

Performance indicators

Simulation Model

PTPS PN
Proposed approach

Real System → Structure and behavior → Failures and propagation → FIS Model → Automatic transformation → PTPS PN → Performance indicators

Function view

Resource View

FIS: Fonction Interaction Structure

Tool for the dynamic simulation and definition of the performance indicators enabling to quantify the performance degradation when a risk occurs

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Composition of the simulation tool

- Event generator
  - Controls the two PN
- Function view
- Resource view
- Simulation clock
  - Updates the simulation clock
- Random number generator
- Data collector
- Performance indicators
Case study: sterilization service from Grenoble Hospital

- Identify the functions and resources of the sterilization service
- Identify the dangerous phenomena and the failure modes that can occur in the sterilization service
- Decompose the identified resources into behavioral modes
Case study: sterilization service from Grenoble Hospital

177 dangerous phenomena

- Prédésinfecter et transférer les DM: 33%
- Rincer les DM: 5%
- Laver les DM: 10%
- Sécher les DM: 2%
- Vérifier et Conditionner les DM: 36%
- Stériliser les DMs: 14%
Case study: sterilization service from Grenoble Hospital

536 Failure modes

- **Pré-désinfecter et transférer les DM**: 19%
- **Rincer les DM**: 40%
- **Sécher les DM**: 27%
- **Laver les DM**: 2%
- **Vérifier et Conditionner les DM**: 9%
- **Stériliser les DMs**: 3%

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Example

- **Washing tunnels**
- **Washers**
- **Dryers**
- **Staff**
- **Autoclaves**

Flowchart:

- **MD P** → Normal (15, 0.5) → **DM R** → 2 modes → **MD W** → Deterministic (40)
- **Staff** → Normal (15, 0.5) → **DM V** → Normal (6, 1.5) → **MDSt** → Deterministic (40)
- **MD C** → Normal (7, 2.1) → **MD D**

Parameters:
- Normal (15, 0.5)
- Normal (6, 1.5)
- Normal (7, 2.1)
- Deterministic (40)
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Function: Washing

Behavior mode ok

Validity condition: false
- Processing time= 20 mins, Priority=1, ...

Degraded mode

Condition de validité: vrai
- Processing Time= 30 mins, Priority=1, ...

Washers

Rinsed MD

Washing Tunnels

Washed MD

Washer failure
Example

MD creation
- Arrival distribution: Triangular (18, 20, 27)
- 120 MD (2 Contaminated by CJD)

Washer failures
- distribution: Binomial (50, 0.7)
- Preemption

<table>
<thead>
<tr>
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<th>Number of non-contaminated MD</th>
<th>Number of contaminated MD</th>
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</thead>
<tbody>
<tr>
<td>Input</td>
<td>118</td>
<td>2</td>
</tr>
<tr>
<td>Output</td>
<td>42</td>
<td>78</td>
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</tbody>
</table>
Some simulation results generated by SIM-RISK

(a) Resource rate of use

(b) Resource MTBF (blue) and MTTR (red)

(c) Mean time spent by medical devices in each function

(d) Percentage of time spent in each mode of behavior of the washing function
Conclusions and Future Issues

• Conclusions
  – Tool enabling to evaluate the performance of a production system, by taking into account the risks, their effects and their propagation
  – Application on a simplified sterilization service

• Future work
  – Improve the usability of the tool
  – Include the detection of failures
  – Include other features, as optimizing performance in degraded mode.
Thank you!

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