Sensitivity Analysis for a Scenario Based Reliability Prediction Model

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The Reliability Prediction Approach

requirements, reliability and usage profile

elicit & annotate

scenarios (MSCs)

synthesize & map

implied scenarios

evolve

analyse & predict

architecture behaviour model

[Image]
Annotated bMSC

- Annotate with component reliabilities
  - Could provide message- and timeline-level reliabilities instead

- Message interpreted as invocation of functionality in message recipient C
  - Assume $P(\text{success}) = R_C$
  - Assume success not dependent on time
  - Assume failures are independent across invocations
Annotated hMSC

- Annotate with operational profile

Flowchart:
- Initialise
- Register
- Analysis
- Stop

Initialise:
- Sensor
- Database
- Control
- Actuator
- Start

Register:
- Sensor
- Database
- Control
- Actuator
- Pressure

Analysis:
- Sensor
- Database
- Control
- Actuator
- Query
- Data
- Command

Stop:
- Sensor
- Database
- Control
- Actuator
- Stop
Synthesis of LTS for Architecture Model

ArchitectureModel = (Database || Sensor || Control || Actuator).
Implied Scenarios

- Traces exhibited by synthesised architecture but not by MSC specification
- Implied scenarios are “gaps” in the MSC specification and should be detected and validated
- Gap in the MSC specification: Positive Scenarios
- Gap in the synthesized architecture: Negative Scenarios
  1. Constraints built
  2. Compose with architecture model
  3. Re-calculate prediction
A Negative Scenario

Control should never Query before Sensor supplies Pressure

Constrain the architecture (with an LTS) to prevent the scenario from occurring.
The Sensitivity Analysis
Sensitivity Analysis of the System Reliability

- As a function of:
  - Component reliability
  - Transition probability
- Implied scenario impact
- As a function of scenario executions
Component Reliability Sensitivity I

- Identify components with greatest impact on the software reliability

- Method:
  - Vary one component reliability and fix the others
  - Transition probabilities remain unchanged
Component Reliability Sensitivity II

Architecture Model

System Reliability (%) vs. Components Reliability (%)

- Control
- Sensor
- Actuator
- Database
Component Reliability
Sensitivity III

- Analysis:
  - Database has greatest impact on the system reliability. Why?
    - Number of requests the component processes?
    - What about Sensor?
  - Higher probability of transition to a scenario has a higher influence on the components’ sensitivity of the reliability.
Transition Probability Sensitivity I

- Find out if scenario transitions significantly influence our prediction technique. If so, which?

- **Method:**
  - Take splitting transitions, vary one of them and normalize the others
  - Components reliability remain unchanged
Transition Probability Sensitivity II

Architecture Model

![Graph showing transition probability sensitivity](image-url)
Transition Probability Sensitivity III

- **Analysis:**
  - Outgoing transitions of scenario *Terminate* have higher impact on the system reliability
  - Higher chances to reach *End* scenario:
    - Lower probability of returning to *Initialize*
    - Fewer chances for the system failure
Implied Scenario Impact I

- Prevent previously identified negative implied scenario from happening
- Analyse the impact on the previous sensitivity analysis results:
  - For the components reliability
  - For the transition probability
Implied Scenario Impact II

Constrained Model

![Graph showing system reliability (%) vs. component reliability (%) with different line types for Control, Sensor, Actuator, and Database.](image-url)
Implied Scenario Impact III

Constrained Model

- TerEnd Transition
- RegReg Transition

Graph:
- Y-axis: System Reliability (%)
- X-axis: Transition Probability (%)
- Graph shows the relationship between system reliability and transition probability.
System reliability increases in both analyses, e.g.:

- *Database* results shifted on average 69%
- *TerEnd* results shifted on average 36%
System Reliability as a Function of Scenario Execution I

- Analyse the overall behaviour of the system reliability for the architecture model and the constrained model.
- Based on Cheung definition for failure:

\[ E = P^n \left( N_1; F \right) \]

- \( E \) = probability of reaching Fault state
- \( P \) = stochastic matrix with all the states in the LTS
- \( P^n(i,j) \) = probability that starting from state \( i \), the chain reaches state \( j \) at or before the \( nth \) step

- System reliability \((R) = 1 - E\)
System Reliability as a Function of Scenario Execution II

Architecture versus Constrained Model

![Diagram showing system reliability as a function of scenario execution frequency. The graph compares architecture and constrained models. The x-axis represents the frequency of scenario executions ranging from 1 to 1000, and the y-axis represents system reliability in percentages, ranging from 100 to 55. The graph includes two lines: one for architecture and one for constrained, with the architecture line showing a steeper decline.]
The greater the scenario executions, the greater the difference between architecture and constrained models.

Reliability in the constrained model stabilizes after around 70 interactions compared to 300 of the architecture model.
Related Work

- **Analytical**
  - Mathematical Function to derive sensitivity analysis
  - Cheung; and Siegrist

- **Experimental**
  - Results obtained through measurement
  - Yacoub et.al.
Future Work

- Further understand and investigate effects of implied scenarios

Ongoing work:
- Integration with Model-Driven Architecture (MDA)
- Experimenting with PRISM probabilistic model for reliability computation
- Validate with large case study!
Conclusion

- Reliability prediction technique based on scenarios consider:
  - Component structure exhibited in the scenarios
  - Concurrent nature of component-based systems

- Sensitivity analysis:
  - Component reliabilities and transition probabilities
  - Influence of implied scenarios
Questions?

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