On the Effect of Using SysML Requirement Diagrams to Comprehend Requirements: Results from Two Controlled Experiments

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Results at a glance

Using requirements diagrams from SysML increases comprehension and does not change the time
SysML reuses a subset of the UML2 (UML4SysML), and defines its own extensions. Therefore SysML includes nine diagrams instead of the thirteen diagrams from the UML 2.0, making it a smaller language that is easier to learn and apply.
SysML vs. UML

• Extensions and / or changes with respect to the UML:

• Reuse and Extension of the UML:
  SysML reuses the UML and makes changes without altering the language, the more extended with new diagrams;

• Package:
  the package is the basic unit of partitioning in the specification, i.e. packages share model elements into logical groups;

• Stratification:
  each package is treated as an extension to the UML model layer;
SysML is defined on a modular basis. We can distinguish between elements of the Structural Model (Structure) used to describe the structure of the system, elements of the Behavioral Model (Behavior) used to describe the functions of the system, and other model elements that relate to both (structural and behavioral).
Example of a requirement diagram

Example requirement diagram:

- **Mission Statement**
  - **Id**: "MS.5"
  - **Text**: "The client would like to explore the viability of developing and deploying a large number of extremely simple water distillers, of a common design which is both economical to build, and adaptable to use the variety of energy sources anticipated in remote areas. This project addresses the design and analysis of this water distiller system."

- **Simple Distiller**
  - **Id**: "MS.5.1"
  - **Text**: "The client would like ... extremely simple water distillers... economical ... and adaptable."

- **Project Scope (1)**
  - **Id**: "MS.5.2"
  - **Text**: "This project addresses the design and analysis of this water distiller system."
Requirements diagram and Use Cases

```
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economical Distiller</td>
<td>The client would like to explore the viability of developing and deploying a large number of extremely simple water distillers, of a common design which is both economical to build, and adaptable to the variety of energy sources anticipated in remote areas. This project addresses the design and analysis of this water distiller system.</td>
</tr>
<tr>
<td>Simple Distiller</td>
<td>The client would like extremely simple water distillers, economical and adaptable.</td>
</tr>
<tr>
<td>Project Scope</td>
<td>This project addresses the design and analysis of this water distiller system.</td>
</tr>
</tbody>
</table>

Use Cases:
- Distiller
  - Operate Distiller
  - Tend Heat Source
  - Tend Water Source
```
Example of a requirement diagram

```
req [Package] Mission Statement [deriving system requirement from mission]

```

```
<<requirement>>
Safe Drinking Water

Id = "MS.1"
Text = "The client is a humanitarian organization dedicated to the purpose of providing safe drinking water to the broadest possible spectrum of people, especially in impoverished parts of the world where it is not readily available. For purposes of this project, we will assume that cost effectively supplying a sustainable long-term source of pure water in remote, impoverished areas is of paramount importance."

<<deriveReqt>>
Purification
Id = "DS.5"
Text = "The distiller shall purify water so that it is safe to drink"

<<deriveReqt>>
Simple Distiller
Id = "MS.5.1"
Text = "The client would like ... extremely simple water distillers... economical ... and adaptable."

<<deriveReqt>>
Not a Filter
Id = "MS.4"
Text = "Initial studies have indicated that filter-based approaches to water purification are not sustainable, because of the limited effective lifetime of low cost viral grade filters, and the high logistical cost of maintaining a ready supply of replacement filters in remote areas."

<<rationale>>
The requirement for the distiller to purify water needs to be explicitly stated. This provides a single starting point for performance analysis.

<<external document>>
Clean Water Study Report
```

Experiment design – hypotheses

• Goal
  — Analyze **SysML requirement diagrams**
  — for the purpose of **evaluating requirements comprehensibility**
  — with respect to correctness of **comprehension** and **time** to accomplish a comprehension task
  — from the point of view of the **requirements analyst and the developer**
  — in the context of students in Computer Science/Software Engineering.

• Hypotheses
  — Hn0: *The mean value of the comprehension for the RD factor is the same as the mean value of the comprehension variable for the NORD factor.*
  — Hn1: *The mean value of the comprehension for the RD factor is the same as the mean value of the comprehension variable for the NORD factor.*
Experiment objects

Class diagram

Use case diagram

Requirements diagram

Requirements specification

- Intruder Emergency Response
  - Intrusion Detection and False Alarm Rate: ESS must provide intrusion detection and
    the frequency of false alarms. It must ensure the detection of intrusions in the
    perimeter (Perimeter Detection), interior (Internal Detection) and entry-exit (Entry-
    Exit Detection) area of the place where the system is present/installed.

- Fire Detection and False Alarm Rate
  ESS must ensure fire detection and must take note of false alarms (frequency).
The experiment was done at University of Basilicata (24) and Chalmers | University of Gothenburg (63 students)
Data collection: Example question

7. The maximum acceleration of a car is strongly connected to (one or more answers may be correct)
☐ Engine power
☐ Car noise
☐ The number of the cylinders of the engine
☐ The space for the occupants inside the car
☐ The maximum speed

How much do you trust your answer?
☐ Unsure  ☐ Not sure enough  ☐ Sure Enough  ☐ Sure  ☐ Very Sure

How do you assess the question?
☐ Very difficult  ☐ Difficult  ☐ On average  ☐ Simple  ☐ Very simple

What is the “main” source of information used to answer the question?
☐ Previous Knowledge  ☐ Requirements List  ☐ Internet  ☐ Use Cases  ☐ Use Case Diagram  ☐ Requirement Diagrams

• Pre-experiment questionnaire
• Comprehension test
• Post-experiment questionnaire
Results (hypothesis testing)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Dependent Variable</th>
<th>#obs for RD</th>
<th>#obs for NORD</th>
<th>p-value</th>
<th>Statistical Power</th>
<th>β-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-UBAS</td>
<td>Comprehension</td>
<td>24</td>
<td>24</td>
<td>YES (&lt; 0.001)</td>
<td>0.949</td>
<td>0.051</td>
</tr>
<tr>
<td></td>
<td>Completion time</td>
<td>24</td>
<td>24</td>
<td>NO (0.556)</td>
<td>0.068</td>
<td>0.932</td>
</tr>
<tr>
<td>R1-UGOT</td>
<td>Comprehension</td>
<td>63</td>
<td>63</td>
<td>YES (&lt; 0.001)</td>
<td>0.881</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>Completion time</td>
<td>59</td>
<td>56</td>
<td>NO (0.805)</td>
<td>0.064</td>
<td>0.936</td>
</tr>
</tbody>
</table>

- The effect on comprehension is significant
  - Size of the effect: 24% and 32% improvement in comprehension
Results (information source)

- What is the main source of information used to answer the question?
  - 1. Previous Knowledge
  - 2. Requirements List
  - 3. Internet
  - 4. Use Cases
  - 5. Use Case Diagram
  - 6. Requirement Diagrams

- Requirements diagrams seem to be useful (and used)
Conclusions

• Summary
  — Using requirements diagrams increases comprehension and does not affect speed

• Practical implications
  — Lower number of defects
  — Higher design costs (additional effort to create requirements)
  — Modelled requirements are more expressive