Semi-automated Test Planning for e-ID Systems by Using Requirements Clustering

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What is this presentation about?

- Acceptance testing of e-ID systems
- Multi-viewpoint requirements engineering
- Optimization of test plans using clustering
Development Process

1. Strategy
2. Planning
3. Procurement
4. Implementation
5. Production
6. Approval
7. Operations

Political will

ICAO and national requirements

System architecture

Components requirements

Solution architecture

System integration test plan

System integration test

Components or unit test

Qualification

System (site) acceptance test

Factory (site) acceptance test/qualification

Interoperability/conformance test

Service level control

Issuing Authority

Zulieferer

Kunde

Berater

Zulieferer

System Integrator

Component Supplier

Line of responsibility

Line of responsibility
What is the problem?

- **Reference Model for Open Distributed Processing (RM-ODP)** [ISO]
- Desired overlappings in the requirements
  - Redundant test cases
  - Repeating testing steps
  - Inefficient testing

- **Solution idea:**
  1. Identify overlappings (similarities)
  2. Choose representatives, ignore others at first
  3. Compute an efficient order of requirements to be tested
  4. Create and execute test cases → out of scope
### Example

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYC135M</td>
<td>The authorizing officer SHALL sign the printed application and notify the</td>
</tr>
<tr>
<td>SYC480M</td>
<td>Personalization SHALL personalize the e-passport chip electrically.</td>
</tr>
<tr>
<td>SYC545M</td>
<td>An old e-passport of the recipient that is still valid MUST be cancelled.</td>
</tr>
<tr>
<td>SYE310M</td>
<td>An authorizing officer SHALL authorize the application after all necessary</td>
</tr>
<tr>
<td>SYE330M</td>
<td>The e-passport issue system SHALL automatically generate a production order</td>
</tr>
<tr>
<td>SYE390M</td>
<td>The blank e-passport SHALL be personalized electrically, that means the signed data is stored into the contactless chip of the e-passport in a secure procedure.</td>
</tr>
<tr>
<td>SYE5610M</td>
<td>after application, the current applicant's passport or e-passport SHALL be cancelled.</td>
</tr>
<tr>
<td>SYI250M</td>
<td>after authorization, the e-passport issue system SHALL generate a production order from the passport application and the identity information.</td>
</tr>
</tbody>
</table>

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**Computational**

**Enterprise**

**Information**

---

**Order!**

**Eliminate!**
• Related work
  ➢ functional decomposition [Hsia88, Yaung92, Otaiby05, Madhavji07]
  ➢ remodularization [Wiggerts97]
  ➢ incremental delivery [Hsia92, Hsia96]
  ➢ feature modeling [Chen05]
  ➢ requirements reuse [Lopez02]

• Testing not handled yet extensively!
  ➢ Scenario analysis [Hsia97]
  ➢ Abstraction for impact analysis [Goldin]
Questions of Clustering

• What are the artifacts to be clustered? 
  
  Informal textual requirement descriptions

• How is similarity between two artifacts measured? 
  
  • Distance measures
  • Association coefficients
  • Probabilistic similarity

• Which algorithm should be used for clustering of artifacts? 
  
  • Hierarchical algorithms
  • Partitional algorithms
Our Process

- **Annotation**
  - Annotation correct?
    - Yes
    - No (Improve Annotation)

- **Clustering**
  - Clusters useful?
    - Yes
    - No (Improve Clustering)

- **Test Plan Specification**
  - Desired reduction reached?
    - Yes
    - No (Improve TP Specification)
### Annotation

<table>
<thead>
<tr>
<th>Id</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYC545M</td>
<td>An old e-passport of the recipient that is still valid SHALL be cancelled. Delivery SHALL notify the passport life-cycle management about the cancellation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Id</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYC545M-1</td>
<td>An old e-passport of the recipient that is still valid SHALL be cancelled.</td>
</tr>
<tr>
<td>SYC545M-2</td>
<td>Delivery SHALL notify the passport life-cycle management about the cancellation.</td>
</tr>
</tbody>
</table>

---

**Linguistic analysis**

```
(S
  (NP (NN Delivery)) Actor
  (VP (MD shall)) Process
  (VP (VB notify)
    (NP (DT the) (JJ passport) (JJ life-cycle)
      (NN management))
    (PP (IN about)
      (NP (DT the)
        (NN cancellation))))
( . . ))
```

<table>
<thead>
<tr>
<th>Id</th>
<th>Actor</th>
<th>Process</th>
<th>Direct Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYC545M-2</td>
<td>Delivery</td>
<td>notify</td>
<td>the passport life-cycle management</td>
</tr>
</tbody>
</table>
Annotation – Controlled Language

[CONDITIONS] → [ACTOR] → [SHOULD] → [MAY] → [OBJECT]

- **SHALL**
  - PROVIDE <whom?>
  - THE ABILITY TO <process>
  - BE ABLE TO <process>

[Rup07]
### Partitional Clustering

#### Similarity function

\[ s(r_1, r_2) = \begin{cases} 
3 & \text{(if Actor, Process and direct Object are same)} \\
2 & \text{(if Actor and Process are same)} \\
1 & \text{(if Actor is the same)} \\
0 & \text{(otherwise)} 
\end{cases} \]

- \( C_{A1} \), \( C_{A3} \), \( C_{S4} \), \( C_{S5} \), \( C_{R6} \), \( C_{R7} \)

#### Representative

<table>
<thead>
<tr>
<th>Id</th>
<th>Actor</th>
<th>Process</th>
<th>Direct Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYC535M</td>
<td>The recipient</td>
<td>provide</td>
<td>his ID card and the receipt</td>
</tr>
<tr>
<td>SYE430M-2</td>
<td>The recipient</td>
<td>provide</td>
<td>his ID card and the receipt</td>
</tr>
<tr>
<td>SYE430M-3</td>
<td>the recipient</td>
<td>provide</td>
<td>his current e-passport</td>
</tr>
<tr>
<td>SYE630M</td>
<td>the recipient</td>
<td>provide</td>
<td>his receipt and his ID card</td>
</tr>
<tr>
<td>SYE640M</td>
<td>the recipient</td>
<td>provide</td>
<td>his receipt and his ID card</td>
</tr>
</tbody>
</table>
### Test Plan Specification 1/2

1. **Test activity**: Requirement to be tested  
   **Test step**: Action1  
   **Test step**: Action2  
   ...  

2. **Test activity**: Requirement to be tested  
   **Test step**: Action1  
   **Test step**: ActionX \( r_2 \)  
   **Test step**: Action2 \( r_1 \)  
   ...  

3. **Test activity**: Requirement to be tested  
   **Assert**: Rule1 \( r_2 \)  
   **Test step**: Action1  
   **Test step**: ActionX  
   **Test step**: Action2 \( r_1 \)  
   **Assert**: State1 \( r_2 \)  
   ...  

---

**Heuristic**

- \( C_{A1} \)
- \( C_{A3} \)
- \( C_{S4} \)
- \( C_{R6} \)
- \( C_{R7} \)

**Pattern 1**

- **Action**: Subject  
  **Condition**: Operator  
  **verb**: Subject  
  **Object**: ...  

**Pattern 2**

- **Action**: Subject  
  **verb**: Object  
  **State/Rule**: \( r_1 \)  
  **State/Rule**: \( r_2 \)  
  **State/Rule**: ...  

---

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# Test Plan Specification 2/2

## Test Plan

<table>
<thead>
<tr>
<th>Activity</th>
<th>ID</th>
<th>Actor</th>
<th>Process</th>
<th>Direct Object / Adjective</th>
<th>Acceptance criteria</th>
<th>valid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test step</td>
<td>AC62</td>
<td>recipient</td>
<td>provide</td>
<td>his bill and his ID card</td>
<td>( \text{exec}(AC62) \land \text{valid}(ST65) \land \text{valid}(ST87) )</td>
<td></td>
</tr>
<tr>
<td>Assert</td>
<td>ST65</td>
<td>bill</td>
<td>be</td>
<td>paid</td>
<td>Is bill paid?</td>
<td></td>
</tr>
<tr>
<td>Assert</td>
<td>ST87</td>
<td>ID card</td>
<td>be</td>
<td>valid</td>
<td>Is ID card valid?</td>
<td></td>
</tr>
<tr>
<td>Test step</td>
<td>AC103</td>
<td>officer</td>
<td>authorize</td>
<td>application</td>
<td>( \text{exec}(AC10) \land \text{valid}(ST36) )</td>
<td></td>
</tr>
<tr>
<td>Assert</td>
<td>ST36</td>
<td>application</td>
<td>be</td>
<td>signed</td>
<td>Is application signed?</td>
<td></td>
</tr>
<tr>
<td>Test step</td>
<td>AC265</td>
<td>officer</td>
<td>personalize</td>
<td>e-passport</td>
<td>( \text{exec}(AC26) \land \text{valid}(RL56) )</td>
<td></td>
</tr>
<tr>
<td>Assert</td>
<td>RL56</td>
<td>e-passport</td>
<td>conform</td>
<td>ICAO</td>
<td>Does e-passport conform to ICAO?</td>
<td></td>
</tr>
</tbody>
</table>

**Total**

\[ \bigwedge_{id \in \{ID\}} \text{valid}(id) \]
## Tool Support

<table>
<thead>
<tr>
<th>Activity</th>
<th>Degree of automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annotation</td>
<td></td>
</tr>
<tr>
<td>• Splitting</td>
<td>high</td>
</tr>
<tr>
<td>• Syntactical analysis</td>
<td></td>
</tr>
<tr>
<td>Clustering</td>
<td>high</td>
</tr>
<tr>
<td>• Coarse grained</td>
<td></td>
</tr>
<tr>
<td>• Fine grained</td>
<td></td>
</tr>
<tr>
<td>Test plan specification</td>
<td>medium</td>
</tr>
<tr>
<td>• Pattern matching</td>
<td></td>
</tr>
</tbody>
</table>

Prototype implemented

![Diagram](attachment://diagram.png)
### Case Study

#### Statistics on analyzed requirements

<table>
<thead>
<tr>
<th>Viewpoints</th>
<th># of Req.</th>
<th>Action</th>
<th>State</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprise</td>
<td>103</td>
<td>84</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Information</td>
<td>61</td>
<td>25</td>
<td>29</td>
<td>7</td>
</tr>
<tr>
<td>Computation</td>
<td>141</td>
<td>89</td>
<td>39</td>
<td>13</td>
</tr>
<tr>
<td>Engineering</td>
<td>67</td>
<td>27</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>Technology</td>
<td>33</td>
<td>0</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>405</strong></td>
<td><strong>300</strong></td>
<td><strong>72</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

#### Number of requirements in clusters

<table>
<thead>
<tr>
<th>Viewpoints</th>
<th>Enrolment</th>
<th>Personalization</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>final</td>
<td>initial</td>
</tr>
<tr>
<td>Enterprise</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Information</td>
<td>0</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Computation</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Engineering</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Technology</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
<td><strong>34</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

#### Performance of steps in milliseconds

<table>
<thead>
<tr>
<th># of Req.</th>
<th>Annotation</th>
<th>Similarity</th>
<th>Clustering</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>4.594</td>
<td>&lt;1</td>
<td>103</td>
</tr>
<tr>
<td>50</td>
<td>19.938</td>
<td>9</td>
<td>1.534</td>
</tr>
<tr>
<td>100</td>
<td>35.797</td>
<td>15</td>
<td>4.602</td>
</tr>
<tr>
<td>400</td>
<td>141.859</td>
<td>31</td>
<td>55.198</td>
</tr>
</tbody>
</table>

Detected similarities: 73  
Threshold: 2

After applying heuristics

After applying patterns
Conclusion

• Overlappings and timing relations can be detected
  – Linguistic analysis
  – Clustering

• Important: What is the target?

• Efficient test planning possible
  – Eliminating overlappings in test plans
  – Ordering related requirements in test plans

• Tools for particular tasks available

• Lessons learned for specifying requirements
  – No passive voice
  – Use atomic sentences
• Baris Güldali, Holger Funke, Michael Jahnich, Stefan Sauer, Gregor Engels:  
  **Semi-automated Test Planning for e-ID Systems by Using Requirements Clustering.**  

• Baris Güldali, Stefan Sauer, Peter Winkelhane, Michael Jahnich, Holger Funke:  
  **Pattern-based Generation of Test Plans for Open Distributed Processing Systems.**  
Thank you for your attention

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