Goal-centric traceability for managing Non-Functional Requirements

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Introduction

- **Motivation**
  - NFRs are important, but not considered well
    - Due to difficulties in tracing interdependencies
    - Due to difficulties in determining tradeoffs

- **Research goal**
  - Introduce GCT approach to managing NFRs
    - Represent it with SIG*
    - Grasp impacts
      - When changes to functional requirements are occurred

*SIG = Softgoal Interdependency Graph
Background (1/2)

- Softgoal Interdependency Graph (SIG)

[ Example of the SIG ]

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Probabilistic network model

- One of Information Retrieval (IR) techniques

# Model assumption
- Relevance relationship between a document and a user’s query cannot be determined with certainty

\[ pr(q) = \sum_i pr(q \mid t_i) pr(t_i) \]

\[ pr(d_j) = \sum_i pr(d_j \mid t_i) pr(t_i) \]

\[ pr(d_j \mid t_i) = \frac{freq(d_j, t_i)}{\sum_k freq(d_j, t_k)} \]
Overall approach

- Goal-Centric Traceability (GCT)

1. Construct SIG*
   - Goal Modeling
   - Maintain SIG

2. Link Retrieval
   - User Evaluation
   - Impact Detection

3. Contribution Re-analysis
   - Goal Re-evaluation

4. Impact Evaluation
   - Decision Making
   - Decision

SIG* → NFRs in SE, Kluwer Academic, 2000

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Goal modeling

- Construct SIG
  - Ice Breaker system

[One of nine SIGs representing NFRs of availability, cost, performance and so on]
Impact detection (1/2)

- **Link retrieval** (with the tool)
  - Use of a probabilistic network model for runtime link gen.
    - between UML class & sequence diagram and NFRs
    - With the threshold satisfying
      
      \[ \text{"maximize } \text{Recall} + \text{Precision, where recall} > 85\% \text{"}. \]
      
      (Training set was used to select the threshold values)

- Recall = \( \frac{\text{Number of relevant documents retrieved}}{\text{Number of relevant documents}} \)

- Precision = \( \frac{\text{Number of relevant documents retrieved}}{\text{Total number of documents retrieved}} \)
Experimental evaluation (to measure the effectiveness of the IR)

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Training Set</th>
<th>Full data set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.015</td>
<td>0.02</td>
</tr>
<tr>
<td>Actual</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Retrieved</td>
<td>226</td>
<td>205</td>
</tr>
<tr>
<td>Correctly retrieved</td>
<td>87</td>
<td>86</td>
</tr>
</tbody>
</table>

| Recall | 0.9667 | 0.9556 | 0.8889 | 0.8667 | 0.8444 | 0.7778 | 0.8724 |
| Precision | 0.3850 | 0.4195 | 0.4210 | 0.4333 | 0.4935 | 0.5185 | 0.5133 |
| Objective Function (Recall + Precision) | 1.3517 | 1.3751 | 1.3099 | 1.3000 | Recall < 85% | Recall < 85% |

- About 14 returned-links related to each query
- About 50% links were discarded by a user
Goal analysis

Goal re-evaluation

- Determine if the goal can be fulfilled
  - By operationalizations after changes

# Two symbols
(Additionally introduced)

↑ : strengthens
↓ : weakens

[ SIG prior to change ]

[ SIG showing change impact ]
### Impact detection
(with the sequence diagram “Predict freezing conditions”)

<table>
<thead>
<tr>
<th>Operationalization</th>
<th>Directly Related Goal</th>
<th>SIG Type</th>
<th>Probability of link to “Road Sensor” class</th>
<th>Probability of link to “Road” class</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track truck within 50m of actual location</td>
<td>Real-time tracking of dispatched trucks</td>
<td>Performance</td>
<td>0.11176</td>
<td></td>
<td>Reject</td>
</tr>
<tr>
<td>Remove road sections</td>
<td>Modify map</td>
<td>Extensibility</td>
<td>0.07669</td>
<td>0.14333</td>
<td>Maybe</td>
</tr>
<tr>
<td><strong>Analyze freezing conditions</strong></td>
<td><strong>Real time processing</strong></td>
<td>Performance</td>
<td>0.05795</td>
<td>0.10857</td>
<td><strong>Accept</strong></td>
</tr>
<tr>
<td>Add new road sections</td>
<td>Modify map</td>
<td>Extensibility</td>
<td>0.05752</td>
<td>0.10750</td>
<td>Maybe</td>
</tr>
<tr>
<td>Monitoring of road conditions</td>
<td>Road safety</td>
<td>Safety</td>
<td></td>
<td>0.05286</td>
<td><strong>Accept</strong></td>
</tr>
<tr>
<td>Display de-iced sections of route</td>
<td>Onboard directions</td>
<td>Usability</td>
<td>0.04967</td>
<td>0.06786</td>
<td>Maybe</td>
</tr>
<tr>
<td>Record road freezing events</td>
<td><strong>Accurate weather predictions</strong></td>
<td>Accuracy</td>
<td>0.04510</td>
<td>0.08036</td>
<td><strong>Accept</strong></td>
</tr>
<tr>
<td>Broadcast road conditions to contacts</td>
<td>Monitoring of road conditions</td>
<td>Safety</td>
<td></td>
<td>0.03964</td>
<td>Maybe</td>
</tr>
<tr>
<td>Update truck status &lt; 1 minute.</td>
<td>Real time communication through onboard computer</td>
<td>Performance</td>
<td>0.03725</td>
<td></td>
<td>Reject</td>
</tr>
<tr>
<td>Remove weather station</td>
<td>Network of weather stations</td>
<td>Extensibility</td>
<td></td>
<td>0.02714</td>
<td>Reject</td>
</tr>
<tr>
<td><strong>Assign roads to sensors</strong></td>
<td><strong>Modify road sensors</strong></td>
<td>Extensibility</td>
<td></td>
<td>0.02571</td>
<td><strong>Accept</strong></td>
</tr>
</tbody>
</table>

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Case study (2/2)

Impact evaluation

- Impacted goal and subgoal
- Impacted operationalization

New Notation

↑ Enhanced ability to fulfill goal
↓ Decreased ability to fulfill goal

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Conclusion

❖ Contribution
  ▪ Provide developers with means
    • Of notifying the impact of functional change upon NFRs
    • With tools to mitigate a user’s link filtering effort
  ▪ Show the feasibility of dynamic link retrievals
    • For NFRs

❖ Future work
  ▪ Improve both recall and precision metrics
  ▪ Analyze additional SIG types
Discussion

⚠️ Limitation

- Low precision rate of the link retrieval method
  - But no one found the silver bullet to it yet.
- Insufficient explanation about building SIG
  - Just referenced another paper
  - But the root cause comes from the SIG itself
- Ambiguous targeting to the functional model
  - Source code is not directly considered with links
    - Instead, just referenced other tools