Focus of our paper

PROBLEM
- How to select a subset of options/variants from the variability model $VP_1 = \{V_1, v_2, v_3..V_n\}$ for a new product $(P_i)$?
- Complex variability models

OUR SOLUTION
- Apply Multi-Criteria Decision-Making (MCDM) for ranking variants
Overview

- Introduction
- Usage scenario
- MCDM approaches for SPLs
- Conclusion

Multi-Criteria Decision-Making (MCDM)

- **What**: Structuring and solving the decision-making problem involving multiple criteria
- **How**: MCDM approaches are based on mathematical models
- **Actors**: Human decision-maker (e.g. an application engineer)
- **Output**: Ranking of options
Proposed usage scenario: Selecting variants of a variation point (VP1) for a new product

- Actors: Application engineer et al.
- Step 1: Application engineer initiates instantiation of VP1
- Step 2: He/she collects criteria (e.g. Price, Usability, Reliability etc.) that are quality concerns for the product
- Step 3: Execute a MCDM approach
- Step 4: The MCDM approach ranks variants (e.g. V3: rank1, Vn: rank2)
- Step 5: Select variants with a good rank
- Step 6: Performs sensitivity analysis for checking robustness of decisions
Weighted Sum model (WSM)

Suppose, \( n \) options and \( m \) criteria

\[
A_i^{WSM} - \text{score} = \sum_{j=1}^{m} W_j a_{ij} \quad \text{for } i = 1, 2, 3, \ldots, n. \quad (\text{Eq.1})
\]

\[
\sum_{j=1}^{m} W_j = 1 \quad (\text{Eq.2})
\]

How to resolve connectivity?

WSM example: Get criteria and weights

<table>
<thead>
<tr>
<th></th>
<th>Reliability (( w_1 = 0.35 ))</th>
<th>Price (( w_2 = 0.25 ))</th>
<th>Usability (( w_3 = 0.30 ))</th>
<th>Performance (( w_4 = 0.10 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option1: Power Line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option2: Ethernet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option3: Wireless</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option4: Satellite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WSM example: Collect assessments

<table>
<thead>
<tr>
<th></th>
<th>Reliability (w1 =0.35)</th>
<th>Price (w2 =0.25)</th>
<th>Usability (w3 =0.30)</th>
<th>Performance (w4 =0.10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option1: Power Line</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Option2: Ethernet</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Option3: Wireless</td>
<td>--</td>
<td>Supports strongly</td>
<td>Hinders</td>
<td>0</td>
</tr>
<tr>
<td>Option4: Satellite</td>
<td>++</td>
<td>--</td>
<td>+</td>
<td>No affect</td>
</tr>
</tbody>
</table>

- Collect assessments from stakeholders

We used these assessments from QOC [MacLean et al. 1991]

WSM example: Perform ranking

<table>
<thead>
<tr>
<th></th>
<th>Reliability (w1 =0.35)</th>
<th>Price (w2 =0.25)</th>
<th>Usability (w3 =0.30)</th>
<th>Performance (w4 =0.10)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option1: Power Line</td>
<td>2*0.35</td>
<td>1*0.25</td>
<td>0*0.30=0</td>
<td>1*0.10=0.10</td>
<td>1.05 (Rank 1)</td>
</tr>
<tr>
<td>Option2: Ethernet</td>
<td>-1*0.35</td>
<td>2*0.25 =-0.50</td>
<td>-1*0.30 =-0.30</td>
<td>0*0.10 =0</td>
<td>-0.15 (Rank 3)</td>
</tr>
<tr>
<td>Option3: Wireless</td>
<td>-2*0.35</td>
<td>-2*0.25 =-0.50</td>
<td>-1*0.30 =-0.30</td>
<td>0*0.10 =0</td>
<td>-1.50 (Rank 4)</td>
</tr>
<tr>
<td>Option4: Satellite</td>
<td>2*0.35</td>
<td>2*0.25 =-0.50</td>
<td>1*0.30 = 0.30</td>
<td>0*0.10 =0</td>
<td>0.50 (Rank 2)</td>
</tr>
</tbody>
</table>

- Replace with: "++" -> "2", "+" ->"1", "," -> "", "−" -> "-2"
- Calculate the performance of each option
WSM evaluation

Advantages
- Simple
- Scalable
- Collaboration between stakeholders

Disadvantages
- No support for calculating weights
- Lack of theoretical basis for weights (e.g. what does it mean if I change weight by 20%?)

Good solution with,
- With expert stakeholders
- Repetitive instantiation of variation points

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  - Weighted Product Model (WPM)
- Analytic Hierarchy Process (AHP)
- Physical Programming (PP)
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Weighted Product Model (WPM)

\[ A_i^{WSM} \cdot \text{score} = \prod_{j=1}^{m} a_{ij}^{wj} \]

- Similar to WSM, with few changes
  - instead of “sum”, “product” is used
  - weight is in the power
- WPM not commonly used technique
- Advantages and disadvantages same as WSM

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Analytic Hierarchy Process (AHP)

1. Calculation of weights
   - Pairwise comparison for criteria
     - E.g. Reliability is twice as important as price
   - Eigenvector for pairwise comparison matrix
2. Relative importance of options
   - Pairwise comparison of options for each criteria
     - E.g. Under Reliability, PowerLine is twice as important as Ethernet
   - Calculate eigenvectors
3. Performance of options
   Multiply eigenvectors from 1 and 2.

AHP Evaluation

Advantages
- Support for calculation of weights
- More accurate results than WSM
- Better collaboration than WSM

Disadvantages
- Time consuming when there are large number of options and criteria

Adoptions
- Criteria calculation can be combined with WSM
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Physical Programming (PP)

\[ F_a = \log \left( \frac{1}{m} \sum_{i} F_a(F_i(x)) \right) \]

- Criteria should be expressed as individual utility functions
- The individual utility functions take general forms such as smaller is better, larger is better, range is better etc.
- Degree of preferences for Criteria. E.g. for Price, ideal =100 USD, desirable = 120 USD, tolerable = 130 USD, undesirable =170 USD, highly undesirable = 200USD.
- Weights calculated by the algorithm
PP evaluation

Advantages
- Strong mathematical basis
- Accurate ranking
- Weights are calculated by the approach itself
- Scalable

Disadvantages
- Difficulty to construct utility functions
- Less collaboration than WSM & AHP

Conclusion

- Different MCDM approaches have different strengths
  - Supporting a set of approaches for SPLs
- **Future research:**
  - How to manage constraint dependencies?
  - Sensitivity analysis for different approaches
  - Empirical evaluation
  - Multi-criteria optimization for tuning criteria (Reliability vs Price)
Managing Requirements Knowledge book

- Editors: Walid Maalej and Anil Thurimela
- MaRK workshop series (2008-2011)
- Will be published by the end of 2012 from Springer
- Topics
  - Identifying Requirements Knowledge (e.g. Theory, guidelines)
  - Representing Requirements Knowledge for Reuse (e.g. ontologies, patterns)
  - Sharing Requirements Knowledge (e.g. global projects, agile, stakeholder analysis)
  - Reasoning about Requirements (e.g. first order logic)
  - Intelligent Tool Support (e.g. recommendation systems, experience-based tools, RMF)

Expert feedback

- How would MCDM techniques be helpful for resolving variability?
- Would MCDM approaches help engineers/stakeholders in your organization for selecting variants?
- Do you see any specific problems in using MCDM techniques for SPLs? For that do you suggest any further adoptions?
- How important is the research on MCDM for SPLs
  1. Very Important
  2. Important
  3. OK
  4. Less important
  5. Not important at all
Conclusion

- SPLs could benefit from MCDM approaches
- Discussion only limited WSM, WPM, AHP & PP
- No single MCDM approach that is good for all situations
  - We focus on supporting a set of approaches