A Quantitative Approach to Architecture-Based Product Line Development

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Overview

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• Critical Barriers to Architectural Consensus
  – Inconsistent stakeholder views
  – Conflicting stakeholder goals
  – Lack of objective measures of trade-offs
  – No measure of consensus
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Introduction

• Quantitative Architectural Consensus (QAC)
  – Provides objective measures to quantify degree of consensus achieved for a product line given specific architectural choices.
  – Provides greater visibility into the architecting process by quantifying architectural choices based on strategic cost-benefit goals and provides feedback concerning financial viability of architectural choices.
  – Provides an objective measure that may be used with the Win-Win technology.
Architecting Using WinWin

- Identify stakeholders
- Identify Win conditions
- Resolve conflicts
- Establish
  - objectives
  - constraints
  - alternatives
- Evaluate…
  - integrated with COCOMO II
- Make architectural choices

Boehm’s WinWin Spiral Model
Motivation

Win-Win provides most of what is available in current practice to objectify architectural decision-making. It doesn’t provide:

– a quantification of the degree of consensus,
– objective measure of product-line cost-benefit

for any given architectural choice relative to the degree of consensus of the architecting team.
Critical Barriers to Architectural Consensus

- Inconsistency among stakeholders views
- Conflicting stakeholders goals
- Lack of objective measures to quantify costs and benefits of a product line given specific architectural choices
- No objective measure of “consensus” with respect to architectural choices
Inconsistency Among Stakeholder Views

• Primarily related to technical issues
• This barrier must be resolved initially and revisited throughout the architecting process.
• If an undetected inconsistency among views exists any architectural consensus reached subsequently will be flawed.
• This is a result of basing decisions on incorrect assumptions implicit or explicit in inconsistent views.
Conflicting Stakeholder Goals

- technological issues (preferences or aversion for OO technologies)
- business case issues (bounding the domain of the product line to achieve maximum cost-benefit)
- organizational issues (who will bear the cost of domain engineering and core asset development)
Lack of Objective Measures

- Architectural trade-offs are multidimensional requiring a additional comparative measurement
- Objective measures are required to identify when favorite solutions are no longer working
- goal resolution among stakeholders may drive the solution away from desired outcomes relative to the cost structure constraints
No Measure of Consensus

- WinWin technology supports achieving consensus through resolution of conflict concerning:
  - systems and software objectives
  - relative to constraints
  - by comparing alternatives

Consensus is not measured. Are decisions resulting from groupthink, dominant personalities, or sound reasoning and convergence of expert opinions.
Critical Barriers

Object Oriented technology is wrong for this system...

I don’t have $$ in my project budget for product line development

Should we use COTS for this system?

COTS   Component-X   Component-X'

There are inconsistencies in the specifications for this system!

How will we know we’ve reached a consensus?
Quantitative Architectural Consensus (QAC)

- QAC formulates the problem as a given set of products (with respect to a macro architectural structure) and a weight associated with each product.
- The maximum cost savings is computed with regard to the distribution of the products across the product line.
- The domain boundary of the product line is characterized in the attribute space of the products and evaluated given the reuse, reengineering and/or COTS integration strategy employed.
QAC Measurement Steps

- **STEP 1:** Architectural alternatives are evaluated using a MAX/MIN matrix strategy. Matrices characterizing reusable assets according to their degree of core commonality and extent of domain variability are iterated until an ideal solution is identified.

- **STEP 2:** The recommended solutions of stakeholders weighted given the architectural objectives which are mapped to architectural alternatives.

- **STEP 3:** Architectural choices are made by consensus agreement among domain experts and stakeholders. Pre and post decision positions are measured for consensual distance.
Step 1: Cost as a Function of Reuse Goals

The greater the concentration attributes by segment, and assets by products, the higher the leveraging of cost through product-line reuse.
Step 1: Cost as a Function of Reuse Goals

Cost is decreased by reuse of core commonality

• Core commonality is focused towards market segments based on desired product attributes
• Products may be a member of more than one market segment
• Products may have many product attributes

Cost is increased by modifications based on domain variability

• Domain variability is increased by the number of candidate assets that are applied minimally across products in the product line
• Architectural configurations are based on an optimization of candidate asset use across the product line
STEP 2: Apply Ball Algorithm

- The goal is to converge on an architectural choice.
- The architect’s preferences are expressed in terms of some norm of the attribute space.
- The architects are assumed to have an ideal product in the space.
- The architects will converge on consensus as they approach choices closest to the ideal.
- Maximize subject to the number of attributes considered.

\[
\text{Maximize} Z = \sum_{j=1}^{n} p_j \delta_j
\]

- Index the domain experts alternatives, denote the number of experts that agree and the position of the ideal product in the attribute space.
- Index the existing alternatives relative to the ideal. Associate each architect with a norm.
- The complexity of this algorithm is evaluated for Euclidean norms and is found to be NP-hard, but polynomially solvable when the dimensions of the attribute space is fixed.
Step 3: Measure of Consensus

The consensual distance is the sum of the distance of the architectural choice from the ideal. The effectiveness of the process is the delta between the original preferences and the revised preferences relative to the ideal.

\[ I = \left( \sum P \right) \rho^k \]
Quantitative Architectural Consensus (QAC) approach augments Win-Win with objective measurements of architectural decision-making. QAC provides:

- a quantification of the degree of consensus,
- objective measure of product-line cost-benefit

for any given architectural choice relative to the degree of consensus of the architecting team.