# 2.6 Product Analytics

The product analytics model specifies analyses that substantiate the degree to which a product can be expected to satisfy behavioral quality criteria specified in the product requirements model. This model has four elements: product quality metrics, product observability and introspection, formal methods and models, and root cause analyses. These elements provide quantitative and qualitative analyses, and support comparative analyses of alternative versions, of a product model.

This model supports the applied analytics aspect of the product verification model as an additional basis beyond directed reviews and normative testing for determining the quality of the software product as it is being built. Its intent is both to influence how the product is built and to set customer expectations concerning what is known and what will remain uncertain concerning the behavioral quality of the product in use. Secondarily, it is meant to reduce reliance on and resultant cost of reviews and testing as the means for determining component and product quality.

Analytic methods are chosen based on how the various quality factors relate to the product. Methods may be quantitative or qualitative, objective or subjective, and theoretically or empirically based. Each analytic method can be characterized by the information it uses and the accuracy of its associated quality factor predictions. Methods may differ in relevance or application depending on the nature of the subject matter for the product being built.

Analyses can be used to understand how changes in the problem or solution would affect various quality factors. Secondarily, it specifies the quality factor tradeoffs associated with considered alternative resolutions of problem-solution uncertainties. These results, in turn, inform the focus of other product verification efforts— reviews and testing of product model elements and instances. The results of these analyses, along with the empirical results obtained through product element reviews and product verification efforts, provides a unified basis for confidence in the behavioral quality of a specific product version or subset realization and how alternative realizations compare.

## **Product Quality Metrics**

The product quality metrics element specifies analyses of the product in terms of the degree to which a particular design realization will satisfy quality criteria. The product requirements model specifies and prioritizes product quality objectives to be met and evaluated for feasibility as part of the design rationale element of the product design model.

Achieving an expected level of behavioral quality in a product entails making tradeoffs among quality factors. The means to predict and then objectively measure the factors that software will exhibit in operation are limited. However, exploiting the means that exist helps reduce the need to make changes after deployment to fix quality deficiencies that are better discovered and corrected during development.

[As a simple example of how qualities can interact, a product might be specified as needing high usability, moderate performance, and moderately high security. In this example, security demands may somewhat reduce usability; similarly, security and usability expectations may together modestly reduce performance. If usability and security goals are projected to be satisfied in the resulting product but performance is projected to be unacceptable, either some aspect of the usability or security goals that impact performance might need to be relaxed; alternatively, options for reducing functionality or improving how performance is achieved would need to be explored.]

The properties that a product is expected to exhibit and the relative importance of each are specified in the product requirements model. How these are to be met and the effects of both enabling and inhibiting dependencies among these properties are specified in the product design model. The analytics model supports evaluating the degree to which the product, both as being built and then as built, can be expected to satisfy the prescribed quality criteria, both in theory and relative to the actual operational environment as specified in the product environment model.

Each of the specified quality factors are defined more precisely in terms of the acceptable range of values associated with each and how they are to be measured (quantitatively and/or qualitatively) and how quality factors interact, in particular how

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changes targeting one factor affect others. Each quality factor represents a facet of the quality space, corresponding to some distinguished property of the envisioned product. Within the overall quality space, each facet can be defined and measured independently but any changes to the product can affect multiple facets. Understanding the relationships among quality factors is a key aspect of product analytics, providing the basis for adjusting the quality of the product as a whole.

The attainable satisfaction of a factor may be constrained by behavioral limitations of the operational platform on which the product is deployed. In addition, the degree of importance of a quality factor may be localized within a product, differing in different portions of a solution and accommodating different tradeoffs with other factors.

Failure to satisfy even less significant factors may result in a product that fails to meet customer expectations. Similarly, a failure to address such less important factors in product requirements should be identified as a discrepancy to be resolved (even if only to confirm that it is adequately addressed without changes in the product).

### Quality Factor Tradeoff Analysis

A multi-dimensional analysis can be used in identifying tradeoffs needed to obtain a satisficing (achievable best-fit-to-needs) balance among the various interacting quality factors. This entails determining the acceptable limits that each quality factor needs to meet relative to its importance in overall product quality. Alternative resolutions of the overall quality space are analyzed in terms of how various qualities interact and the cost to realize different combinations of quality factor measures.

[A "radar" chart [www.wikipedia.org/wiki/Radar\_chart] may be a useful form for depicting various alternative combinations of quality factor tradeoffs for a given product. Each of the (e.g., 4) major quality factors are exhibited as an axis in the chart, with the elements of each factor shown as embedded levels within that axis. *{include a figure showing a notional example of such a chart}* The content of a quality factors tradeoff chart is obtained based on instances of the acceptable range of values for each factor of interest, weighted according to the relative importance of the factor to the overall behavioral quality of the product. (Each factor for a given product chart is represented

by its projected value proportional to its possible (or acceptable) minimum and maximum values depicted by its axis. The relative importance of a subordinate factor can be represented by, for example, the width of its axis relative to that of other factor axes or by relative color shading.) By comparing tradeoff charts for different combinations of quality factors, a subjective determination can be made as to which combinations of factor tradeoffs are worth comparative empirical analyses of the product versions corresponding to those alternative quality tradeoffs.]

*{what are the effects/side-effects of a quality tradeoff? what emergent behaviors are likely and what changes would affect those?}* 

- quantitative & qualitative models of system/product behavior: how can objectivity of qualitative measures be improved based on a diversity of subjective experience?
- sensitivity-based characterizations of behavioral qualities: which are more or less significant for a product? how do different factors interact?
- implementation-level considerations: what are the relative contributions of the various design-specified components in achieving (or impeding) particular quality criteria?

# **Product Observability and Introspection**

The product observability and introspection element specifies the means to empirically analyze behavioral quality based on observed product behavior. Analyses of behavioral quality factors require a means to gather data corresponding to the behavior of the product in operation. Some data about a product are associated with the externally observable behavior of the product and can be collected by users (e.g., related to usability) and software operating external to the operational product itself. Other data require instrumentation of the product's realization for observability (monitoring and control) of the product's operation.

Instrumentation of a product may be specified as part of the operational behavior of the product in development, in support of its evaluation but excluded from deployed

versions. The detriment of development-time instrumentation (and to a more limited degree, external monitoring, due to competition for computing resources) is that it can reduce the degree to which some qualities (e.g., performance) are accurately represented in measurements on which product metrics are based.

Limited instrumentation (e.g., event logging) may be included in a deployed product for purposes of auditing for deviations from expected behavior (e.g., to identify any undetected defects such as inefficient operations or safety, security, or data anomalies) or for dynamic tracking and adaptation of critical behavioral quality factors (e.g., performance under load). Such instrumentation can provide improved understanding of the product's actual behavior, how well the product accommodates user/operator interactions, detection of degraded hardware operation for timely remediation, or the product's ability to introspectively profile and explain its behavior.

### Formal Methods and Models

The formal methods and models element specifies theory- and experience-based models for predicting behavioral quality factors. Formal mathematical models of certain behavioral properties, primarily in particular areas of performance and dependability, have been developed and improved since the 1970's. For a product that conforms to the assumptions on which a particular method and associated model is based, developers can obtain a better understanding of how to design and implement a product that will satisfy the quality factors corresponding to properties of interest. Such understanding should then be confirmed through developmental review and testing toward tuning of product properties or have adjustments made to the model to ensure a proper fit between the predicted and actual quality measures.

Lacking a formal model for predicting satisfaction of a quality factor objective, subjective experience-based models, correlating particular practices to particular quality outcomes (e.g., aspects of usability), can be informative in comparative evaluations of feasible design alternatives.

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## **Root Cause Analyses**

The root cause analyses element specifies the means to expose the causes of observed software defects in the product, both to correct the immediate cause and also to institute developmental and review criteria for avoiding or discovering other similar flaws. Such analyses may be supported by examination of relevant elements of the product model as well as anomaly testing that will help localize the source of a discovered defect.

This element should also support discovery and revision or removal of nominally excluded product capabilities, particularly in the evaluation of elements being considered for reuse from other sources. Regression testing can be used to ensure both that expected behavior has not been compromised by unrelated changes but also that unspecified behavior (e.g., prohibited communications) continues to be excluded as the product evolves.

# **Alternative Products Evaluation**

The elements of this model, as the medium for projecting the approximate behavioral quality of a product, subset, or component assembly, supports identifying and comparatively evaluating alternatives—representing differences in either the problem (requirements and environment models) or its solution (design and components models)—to determine how these differ in satisfying specified quality criteria. Particular analytic methods can be applied to each alternative to identify potential differences in effects on quality:

- Subjective observer (developer or user) evaluations of achieving quality criteria
- Theory-based formal models that support predicting specific quality factors (e.g., aspects of performance or dependability)
- The collection, visualization, and analysis of empirical measures of quality factors (e.g., by instrumentation of product realizations)
- The degree to which alternatives differ in achieving fit to factor weighting preferences, considering tradeoffs among interacting factors

- Identifying the component(s) and module(s) (i.e., implementations) that most affect each behavioral quality factor, considering effects on related factors, as a means of supporting analyses of alternatives in product design
- The degree to which alternative computational platforms will support the product (problem-solution) alternative that best fits specified behavioral quality criteria