Software Quality Engineering:

Testing, Quality Assurance, and Quantifiable Improvement

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Chapter 19. Quality Models and Measurements

- Types of Quality Assessment Models.
- Comparing Quality Assessment Models.
- Data Requirements and Measurement
- Measurement and Model Selection.

QA Data and Analysis

- Generic testing process:
  - ▷ Test planning and preparation.
  - ▷ Execution and measurement.
  - ▷ Test data analysis and followup.
  - ▷ Related data ⇒ quality ⇒ decisions
- Other QA activities:
  - ▷ Similar general process.
  - ▷ Data from QA/other sources (Ch.18).
  - ▷ Models used in analysis and followup:
    - – provide timely feedback/assessment
    - – prediction, anticipating/planning
    - – corrective actions ⇒ improvement

QA Models and Measures

- General approach
  - ▷ Adapt GQM-paradigm.
  - ▷ Quality: basic concept and ideas.
  - ▷ Compare models ⇒ taxonomy.
  - ▷ Data requirements ⇒ measurements.
  - ▷ Practical selection steps.
  - ▷ Illustrative examples.

- Quality attributes and definitions:
  - ▷ Q models: data ⇒ quality
  - ▷ Correctness vs. other attributes
  - ▷ Our definition/restriction:
    being defect-free or of low-defect
  - ▷ Examples: reliability, safety,
    defect count/density/distribution/etc.

Quality Analysis

- Analysis and modeling:
  - ▷ Quality models: data ⇒ quality
    – a.k.a. quality assessment models or quality evaluation models
  - ▷ Various models needed
  - ▷ Assessment, prediction, control
  - ▷ Management decisions
  - ▷ Problematic areas for actions
  - ▷ Process improvement

- Measurement data needed
  - ▷ Direct quality measurements: success/failure (& defect info)
  - ▷ Indirect quality measurements:
    – activities/internal/environmental.
  - ▷ Indirect but early quality indicators.
  - ▷ All described in Chapter 18.

Quality Models

- Practical issues:
  - ▷ Applicability vs. appl. environment
  - ▷ Goal/Usefulness: information/results?
  - ▷ Data: measurement data required
  - ▷ Cost of models and related data

- Type of quality models
  - ▷ Generalized: averages or trends
    - – overall, segmented, and dynamic
  - ▷ Product-specific:
    - – semi-customized: product history
    - – observation-based: observations
    - – measurement-driven: predictive
  - ▷ Model taxonomy: Fig 19.1 (p.324).
  - ▷ Relating to issues above

Generalized Models: Overall

- Key characteristics
  - ▷ Industrial averages/patterns
    $\Rightarrow$ (single) rough estimate.
  - ▷ Most widely applicable.
  - ▷ Low cost of use.

- Examples: Defect density.
  - ▷ Estimate total defect with sizing model.
  - ▷ Variation: QI in IBM
    (counting in-field unique defect only)

- Non-quantitative overall models:
  - ▷ As extension to quantitative models.
  - ▷ Examples: 80:20 rule, and other general observations.

Generalized Models: Segmented

- Key characteristics:
  - ▷ Estimates via product segmentation.
  - ▷ Model: segment → quality.
  - ▷ Multiple estimates provided.
- Examples:
  - ▷ Table 19.1 (p.326): reliability levels.
  - ▷ Segmented defect density model (derived from previous overall model)
- Other applications.
  - ▷ Commonly used in software estimation.
  - ▷ Example: COCOMO models.

Generalized Models: Dynamic

- Key characteristics:
  - ▷ Overall/average trend over time.
  - ▷ Often expressed as a mathematical function or an empirical curve.

- Example: Putnam
  - ▷ Rayleigh curve for failure rate r:

$$r = 2Bate^{-at^2}$$

  - ▷ Other variations in literature.
  - ▷ Similar: reliability growth trend.

- Combined models possible, e.g., segmented dynamic models.

Product-Specific Models (PSM)

- Product-specific models (PSMs):
  - ▷ Product-specific info. used
    (vs. none used in generalized models)
  - ▷ Better accuracy/usefulness at cost ↑
  - ▷ Three types:
    - semi-customized
    - observation-based
    - measurement-driven predictive

- Connection to generalized models (GMs):
  - ▷ Customize GMs to PSMs with new/refined models and additional data.
  - ▷ Generalize PSMs to GMs with empirical evidence and general patterns.
  - ▷ Illustrated in Fig 19.1 (p.324).

PSM: Semi-Customized

- Semi-customized models:
  - ▷ Project level model based on history.
  - ▷ Data captured by phase.
  - ▷ Both projections and actual.
  - ▷ Linear extrapolation.
  - ▷ Example: DRM in Table 19.2 (p.327)

- Related examples:
  - ▷ Defect dynamics model in Ch.20, as extension to DRM above.
  - ▷ ODC defect analyses in Ch.20:
    - 1-way distribution/trend analysis
    - 2-way analysis of interaction.

PSM: Observation-Based

- Observation-based models:
  - ▷ Detailed observations and modeling
  - ▷ Software reliability growth models
  - ▷ Other reliability/safety models

- Model characteristics
  - ▷ Focus on the effect/observations
  - ▷ Assumptions about the causes
  - ▷ Assessment-centric
  - ▷ Example: Goel-Okumoto NHPP SRGM
    - functional relation: $m(t) = N(1-e^{-bt})$
    - observed failures over time
    - curve fitting
    - reliability assessment/prediction
    - management decisions: exit criteria

PSM: Predictive

- Measurement-driven predictive models
  - ▷ Establish predictive relations
  - ▷ Modeling techniques:
    regression, TBM, NN, OSR etc.
  - ▷ Risk assessment and management

- Model characteristics:
  - ▷ Response: chief concern
  - ▷ Predictors: observable/controllable
  - ▷ Linkage quantification
  - ▷ Example: Table 19.3 (p.329)
    - – tree-based defect modeling
    - – substantially different high-risk areas
    - – identification and remedial actions

Model Summary and Application

- Summary: Table 19.4 (p.329)
  - ▷ Primary results/usefulness.
  - ▷ Applicability.

- Model generalization or customization in connection with model applications.

- Applications:
  - ▷ ¬ data ⇒ GMs as early choices.
  - ▷ Data arrival ⇒ phase in PSMs:
    - special case: historical data
      ⇒ semi-customized models early.
  - ▷ Model customization within.
  - ▷ Model generalization: data out.

Relating Models to Measurements

- Data required by quality models
  - ▷ Direct quality measurements
    – to be assessed/predicted/controlled
  - ▷ Indirect quality measurements
    – means to achieve the goal
    – environmental, activity, product-internal
  - ▷ All data covered in Chapter 18.
  - ▷ Data requirement by models:
    summarized in Table 19.5 (p.331)

- Data requirement of GMs:
  - ▷ Quality averages/patterns: $\overline{Q}$
  - ▷ No measurements from current project

Relating Models to Measurements

- Data requirement of PSMs:
  - ▷ All use direct quality measurements: Q
    - related to other measurements: M
    - as relations: $Q \sim M$
    - or as functions: $Q = f(M)$
  - ▷ Measurement-driven models:
    - M = all measurements
  - ▷ Semi-customized models:
    - M = environmental measurements
  - ▷ Observation-based models:
    - M = activity measurements
  - ▷ Various other secondary uses

- Can also be examined from the direction of measurements-models forward links.

- Relating models to measurements:
  Fig 19.3 (p.332) – chapter summarized.

Model/Measurement Selection

- Customize GQM into 3-steps
- Step 1: Quality goals
  - ▷ Restricted, not general goals
- Step 2: Quality models
  - ▷ Model characteristics/taxonomy
  - ▷ Model applicability/usefulness
  - ▷ Data requirement/affordability
- Step 3: Quality measurements
  - ▷ Model-measurements relations
  - ▷ Detailed model information

Selection Example A

- Goal: rough quality estimates

- Situation 1:
  - ▷ No product specific data
  - ▷ Industrial averages/patterns
  - ▷ Commercial tools: SLIM etc.
  - ▷ Product planning stage
  - ▷ Defect profile in lifecycle
  - ▷ Use generalized models

- Situation 2:
  - ▷ Data from related products
  - ▷ DRM for legacy products
  - ▷ ODC profile for IBM products
  - ▷ Semi-customized models

Selection Example B

- Goal: customer-view of quality in system testing

- Quality model:
  - ▷ SRGMs: info. about reliability
  - ▷ Assessment: customer-view
  - ▷ Prediction: project management
  - ▷ Decisions: exit criteria
  - ▷ Affordability: data and modeling

- Quality measurements:
  - ▷ Reliability: failure-free operation for a given time under a specific environment
  - ▷ Result: success/failure measurement
  - ▷ Time measurement: reflect activity
  - ▷ Fig 19.4 (p.335): time = transactions
  - ▷ Environment: implicitly assumed

Selection Example C

- Goal: testing process/quality improvement
- Quality model: Fig 19.5 (p.336)
  - ▷ Inadequacy of SRGMs
  - ▷ TBRM: improvement focus
    - – what's wrong: risk identification
    - – what to do: remedial actions
  - ▷ Affordability: data and modeling
- Quality measurements:
  - ▷ Result: success/failure measurement
  - ▷ Timing info.: time-domain analysis
  - ▷ Input state: input-domain analysis
  - ▷ Data attributes: Table 19.6 (p.336)

Summary and Perspectives

- Practical need for quality measurement and model selection

- Viable approach
  - ▷ Model characteristics ⇒ taxonomy
  - ▷ Model data requirement:
    different types of quality measurements
  - ▷ Selection steps: customized GQM
  - ▷ Viability: examples

- Perspective and future work:
  - ▷ Refined taxonomy
  - ▷ Relating models to measurements:
    – more details and specific info.
  - ▷ Lifecycle activities and support
  - ▷ Automation?