Empirical Estimates of Software Availability in Deployed Systems

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Motivation

- A key software engineering objective is to improve quality via practices and tools supporting requirements, design, implementation, verification, and maintenance
- Needs of a user: reliability, maintainability, availability, backward compatibility, cost, and features
- Primary objectives
  - Can we measure quality *in vivo*?
  - Is the common wisdom about software quality correct?

Outline

- Quality for communications
- Ways to observe and estimate quality *in vivo*
- Questions
  - How to measure software reliability and availability?
  - Does hardware or software have more impact on quality?
  - Which part of the life-cycle affects quality the most?
- Discussion

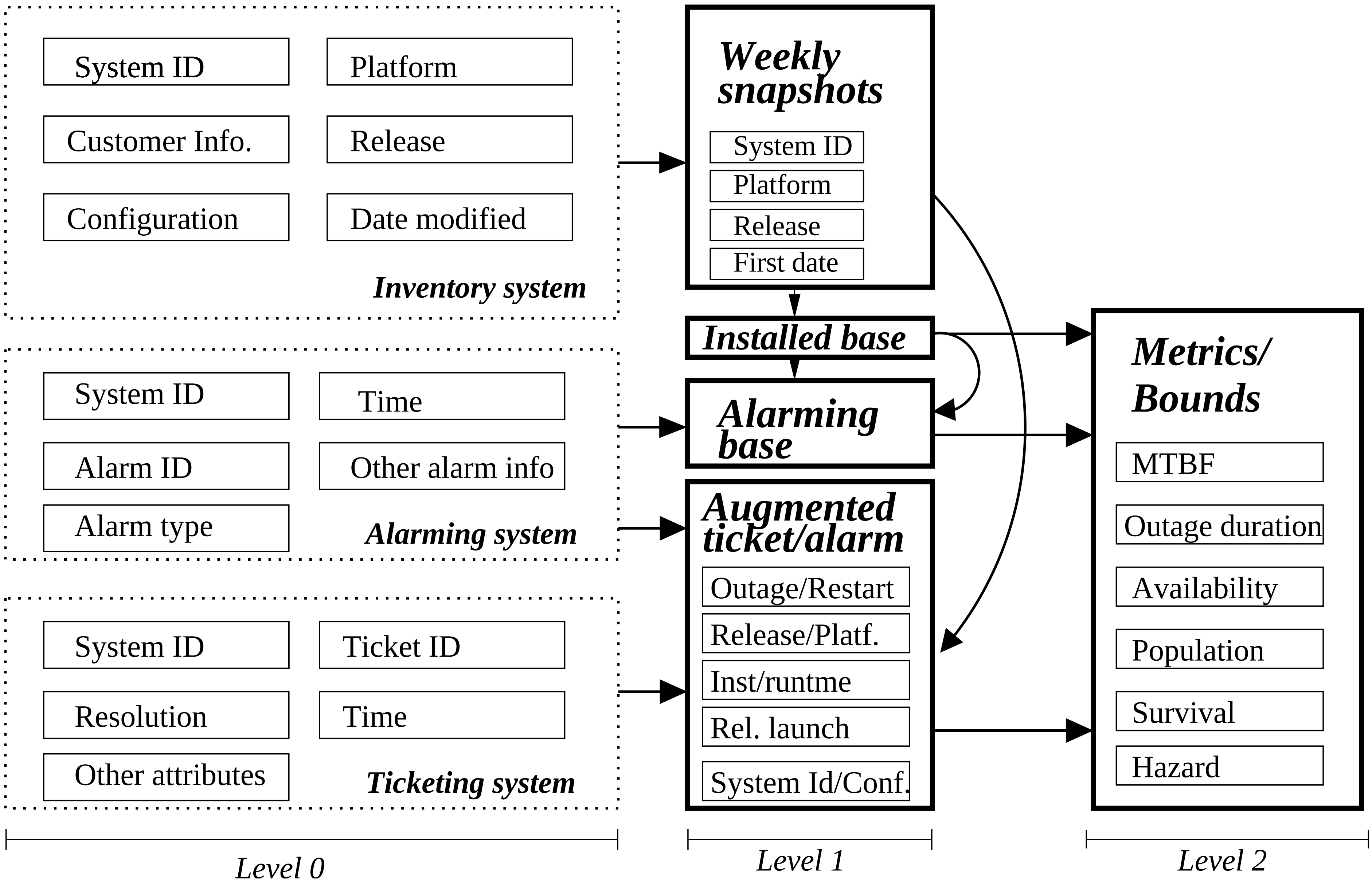
Common Approaches

- Measuring quality
  - Theoretical models [16]
  - Simulations (*in silico*)
  - Observing indirectly (test runs, SW defects)
  - **Observing directly** *in vivo* via recorded user/system actions (not opinion surveys)
    - More realistic
    - More accurate
    - Provides higher level of confidence
    - *In vivo* research is more suited to observe an overall effect than *in vitro* research
    - More relevant

Communications Quality [6]

- Context: military and commercial communication systems, 1960-present
- Goals: system outage, loss of service, degradation of service
  - Downtime of 2 hours over 40 yr, later “5 nines” (or 5 min per year)
  - Degradation of service, e.g., $< .01\%$ calls mishandled
  - Faults per line per time unit, e.g., errors per 100 subscribers per year
  - MTBF for service or equipment, e.g, exchange MTBF, % subscribers with $MTBF > X$
  - Duplication levels, e.g., standby HW for systems with > 64 subscribers

Observing *in vivo* — architecture



Observing *in vivo* — sources

- Service tickets
  - Represent requests for action to remedy adverse events: outages, software and hardware issues, and other requests
  - Manual input: not always accurate
  - Some issues may be unreported
- Software alarms
  - Complete and detailed list for the systems set to generate them
  - Irrelevant events are included, e.g, experimental, misconfigured systems that are not in production use at the time
- Inventory
  - Type, size, configuration, install date for each release
- **Link between deployment dates and tickets/alarms**

Issues with commonly available data and published analyses

- Present
  - Problem reports by month (hopefully grouped by release)
  - Sales by month (except for freely downloadable SW)
- Absent
  - No link between install time and problem report $\Longrightarrow$ no way to get accurate estimates of hazard trends
  - No complete list of software outages $\Longrightarrow$ no way to get rough estimates of the underlying rate

Data Remedies

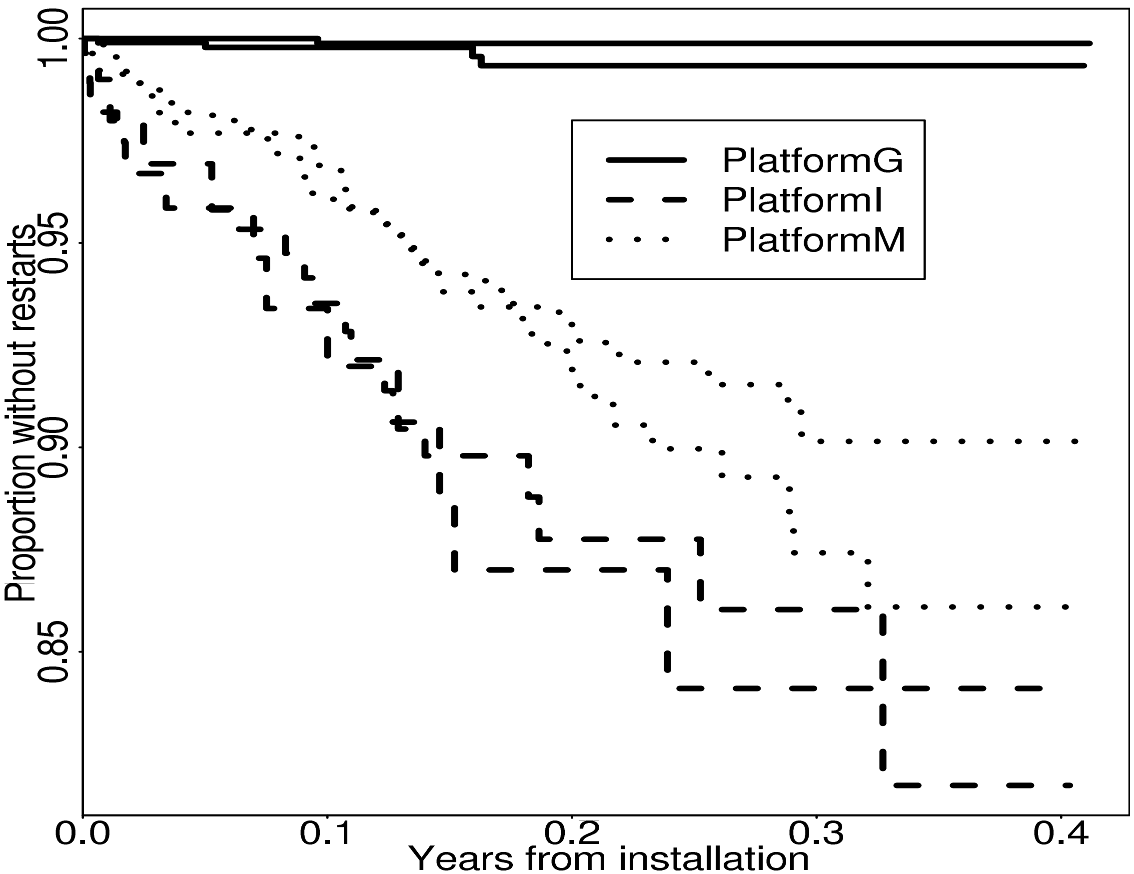
- Only present state of inventory is kept $\Longrightarrow$ collect snapshots to reconstruct history
- The accounting aggregation (by solution) is different from service (by system) or production (by release/patch) aggregation $\Longrightarrow$ remap to the finest common aggregation
- Missing data
  - Systems observed for different periods $\Longrightarrow$ use survival curves
  - Reporting bias $\Longrightarrow$ divide into groups according to service levels and practices
- Quantity of interest not measured $\Longrightarrow$ design measures for upper and lower bounds

Naive reliability estimates

- Naive estimate: $\frac{\text{calendar time} \times \text{installed base}}{\text{\# software restarts}}$
- Naive+ estimate: $\frac{\text{runtime} | \text{simplex systems}}{\text{\# restarts} | \text{simplex}}$
- Alarming syst. estimate: $\frac{\text{runtime} | \text{simplex,generating alarms}}{\text{\# restarts} | \text{simplex}}$

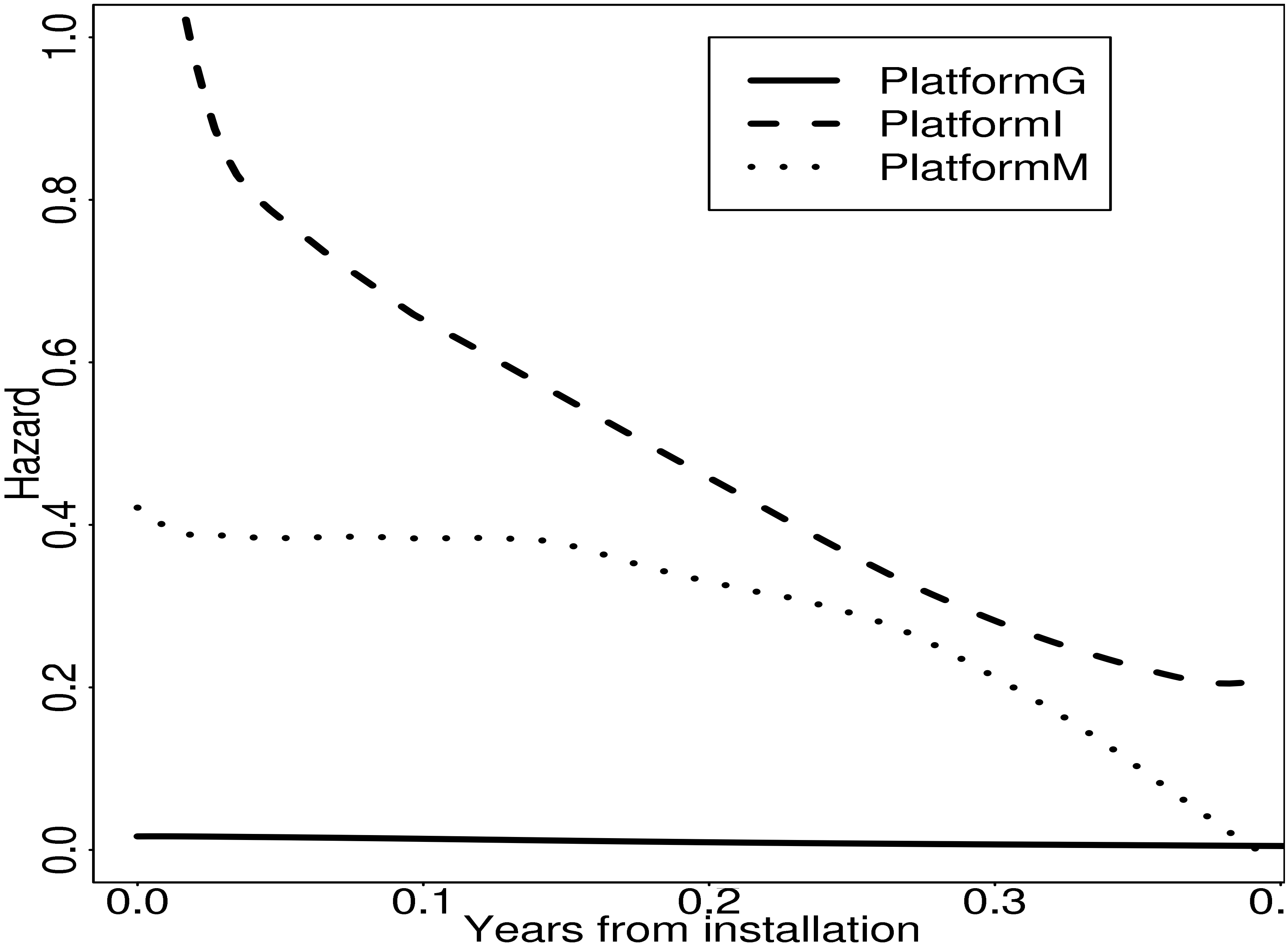
	Naive	Naive+	Alarming
Systems	80000	1011	761
Restarts	14000	32	32
Period	.5	.25	.25
MTBF (years)	3	7.9	5.9

What affects restart rates?

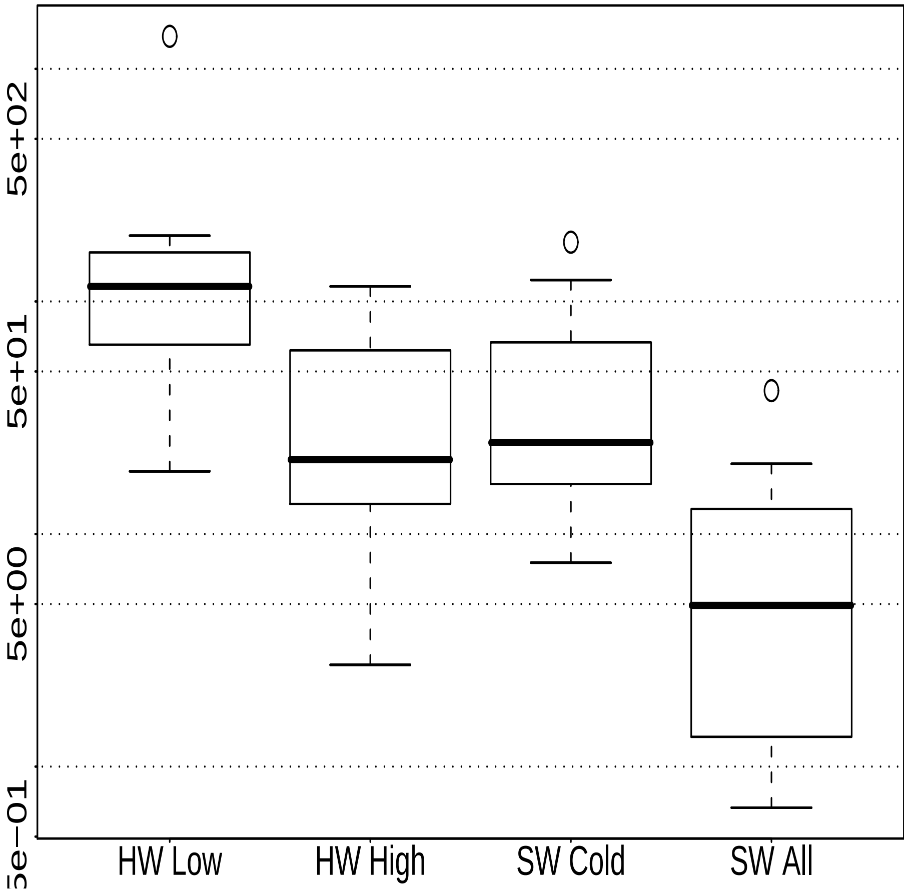


- Kaplan-Meier estimates of the survival curves for three platforms and two releases
- Differences between releases dwarfed by differences among platforms [8]

Hazard function



Hardware vs Software



- Limitations
  - Durations of SW Warm, SW Cold, HW differ by orders of magnitude
  - Warm rst. don't drop calls
  - High/Critical cfg. may by unaffected
  - HW-High ultra conservative
  - Variability for each estimate may be high

- Distribution of MTBF for 15 platform/release combinations

More detailed information $\Longrightarrow$ new insights

- New insights gleaned via support systems — cross-linking development, support, and sales databases
- Navigate numerous pitfalls of missing, biased, irrelevant data, bound the quantity of interest
- Results become an integral part of development practices — continuous feedback on production changes/improvements
- Action hints
  - Maintenance — the most important quality improvement activity
  - Software tends to be a bigger reliability issue with a few exceptions

Thank You.

Limitations

- Different characteristics of the project including numbers of customers, application domain, software size, quality requirements are likely to affect most of the presented values
- Many projects may not have as detailed and homogeneous service repositories

Methodology: Validation

- Interview a sample of individuals operating and maintaining relevant systems
  - Go over recent cases the person was involved with
    - to illustrate the practices (what is the nature of the work item, why you got it, who reviewed it)
    - to understand/validate the meaning of attribute values: (when was the work done, for what purpose, by whom)
    - to gather additional data: effort spent, information exchange with other project participants
    - to add experimental/task specific questions
- Augment data via relevant models [8, 11, 1, 12]
- Validate and clean retrieved and modeled data
- Iterate

Methodology: Existing Models

- Predicting the quality of a patch [12]
- Work coordination:
  - What parts of the code can be independently maintained [13]
  - Who are the experts to contact about any section of the code [10]
  - How to measure organizational dependencies [4]
- Effort: estimate MR effort and benchmark practices
  - What makes some changes hard [5]
  - What practices and tools work [1, 2, 3]
  - How OSS and Commercial practices differ [9]
- Project models
  - Release schedule [14]
  - Release readiness criteria [7]
  - Consumer perceived quality [15, 8]

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Abstract

We consider empirical evaluation of the availability of the deployed software. Evaluation of real systems is more realistic, more accurate, and provides higher level of confidence than simulations, testing, or models. We process and model information gathered from a variety of operational and service support systems to obtain estimates of software reliability and availability. The three principal quantities are the total runtime, the number of outages, and the duration of outages. We consider methods to assess the quality of information in customer support systems, discuss advantages and disadvantages of various sources, consider methods to deal with missing data, and ways to construct bounds on measures that are not directly available. We propose a method to assess empirically software availability and reliability based on information from operational customer support and inventory systems and use a case study of a large communications system to investigate factors affecting software reliability. We find large variations among platforms and releases and find the failure rate to vary over time.

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Audris Mockus is interested in quantifying, modeling, and improving software development. He designs data mining methods to summarize and augment software change data, interactive visualization techniques to inspect, present, and control the development process, and statistical models and optimization techniques to understand the relationships among people, organizations, and characteristics of a software product. Audris Mockus received B.S. and M.S. in Applied Mathematics from Moscow Institute of Physics and Technology in 1988. In 1991 he received M.S. and in 1994 he received Ph.D. in Statistics from Carnegie Mellon University. He works in the Software Technology Research Department of Avaya Labs. Previously he worked in the Software Production Research Department of Bell Labs.