Software Quality Engineering:

Testing, Quality Assurance, and Quantifiable Improvement

Jeff Tian, tian@engr.smu.edu
www.engr.smu.edu/~tian/SQEbook

Chapter 20. Defect Classification and Analysis

- General Types of Defect Analyses.
- ODC: Orthogonal Defect Classification.
- Analysis of ODC Data.

Defect Analysis

- Goal: (actual/potential) defect↓ or quality↑ in current and future products.

- General defect analyses:
  - ▷ Questions: what/where/when/how/why?
  - ▷ Distribution/trend/causal analyses.

- Analyses of classified defect data:
  - ▷ Prior: defect classification.
  - ▷ Use of historical baselines.
  - ▷ Attribute focusing in 1-way and 2-way analyses.
  - ▷ Tree-based defect analysis (Ch.21).

Defect in Quality Data/Models

- Defect data $\subset$ quality measurement data:
  - ▷ As part of direct Q data.
  - ▷ Extracted from defect tracking tools.
  - ▷ Additional (defect classification) data may be available.

- Defect data in quality models:
  - ▷ As results in generalized models (GMs).
  - ▷ As r.v. (response/independent variable) in product specific models (PSMs).
    - semi-customized models $\approx$ GMs,
    - observation-based: r.v. in SRGMs,
    - predictive: r.v. in TBDMs.
    - (SRGMs/TBDMs in Ch.22/21.)

General Defect Analysis

- General defect analyses: Questions
  - ▷ What? identification (and classification).
    - – type, severity, etc.,
    - – even without formal classification.
  - ▷ Where? distribution across location.
  - ▷ When? discovery/observation
    - – what about when injection? harder
    - – pre-release: more data
    - – post-release: more meaningful/sensitive
  - ▷ How/why? related to injection
    - $\Rightarrow$ use in future defect prevention.

- General defect analyses: Types
  - ▷ Distribution by type or area.
  - ▷ Trend over time.
  - ▷ Causal analysis.
  - ▷ Other analysis for classified data.

Defect Analysis: Data Treatment

- Variations of defect data:
  - ▷ Error/fault/failure perspective.
  - ▷ Pre-/post-release.
  - ▷ Unique defect?
  - ▷ Focus here: defect fixes.

- Why defect fixes (DF):
  - ▷ Propagation information.
  - ▷ Close ties to effort (defect fixing).
  - ▷ Pre-release: more meaningful.
    (post release: each failure occurrence.)

Defect Distribution Analysis

- Distribution: what, where, etc.

- What: Distribution over defect types.
  - ▷ Ties to quality views/attributes (Ch.2).
  - ▷ Within specific view: types/sub-types.
  - ▷ Defect types $\Leftarrow$ product's "domain".
  - ▷ IBM example: CUPRIMDSO.

- Important observation:
  - ▷ Skewed distribution, or 80:20 rule
    $\Rightarrow$ importance of risk identification
    for effective quality improvement
  - ▷ Early indicators needed!
    (Cannot wait after defect discoveries.)

Defect Distribution Analysis

Error Type	Description	# of Errors
A	permission denied	2079
B	no such file or directory	14
C	stale NFS file handle	4
D	client denied by server config.	2
E	file does not exist	28631
F	invalid method in request	0
G	invalid URL in req. connection	1
H	mod_mime_magic	1
I	request failed	1
J	script not found or unable to start	27
K	connection reset by peer	0
all types		30760

- Web example: Table 20.1 (p.341)
  - ▷ defect = "error" in web community.
  - ▷ dominance of type E "missing files".
  - ▷ type A: further information needed.
  - ▷ all other types: negligible.

Defect Distribution Analysis

- Further analysis of web example above:
  - ▷ for dominant type E "missing files"
  - ▷ web error distribution by file type
    – Table 20.2 (p.342)
  - ▷ again, skewed distribution!

Type	Errors	%
.gif	12489	43.62
.class	4913	17.16
directory	4425	15.46
.html	3656	12.77
.jpg	1323	4.62
other	394	1.38
All	28631	100

Defect Distribution Analysis

(Table 20.3)

DF=	0	1	2	3	4	5	6
module #	771	174	102	63	31	29	23
%	58.8	13.4	7.9	4.9	2.4	2.2	1.8
DF sum	0	174	204	189	124	145	138
%	0	7.4	8.6	8.0	5.2	6.1	5.8

(Table 20.3 continued...)

DF=	7	8	9	10-19	20-37	all
module #	25	16	7	50	14	1295
%	1.9	1.2	0.5	3.9	1.1	100
DF sum	175	128	63	673	417	2367
%	7.4	5.0	2.7	28.4	17.6	100

- Where: Distribution over locations.
  - ▷ commonly by product areas
    – sub-product/module/procedure/etc.
  - ▷ IBM-LS: Table 20.3 (p.342) above
  - ▷ again, skewed distribution

Defect Distribution Analysis

(Table 20.4)

DF =	0	1	2	3	4	5	6
module #	23	131	112	120	99	94	68
%	2.3	13.2	11.3	12.1	9.9	9.4	6.8
DF sum	0	131	224	360	396	470	408
%	1.67	2.86	4.60	5.06	6.01	5.21	4.47

(Table 20.4 continued...)

DF =	7	8	9	10-19	20-49	>50	all
module #	50	38	32	147	68	13	995
%	5.0	3.8	3.2	14.8	6.8	1.3	100
DF sum	350	304	288	2109	2040	910	7824
%	3.89	3.68	3.07	26.96	26.07	11.63	100

- IBM-NS: Table 20.4 (p.343) above
  – yet another skewed defect distribution

- Extension: distribution by other locators
  – e.g., types of sources or code, etc.

Defect Trend Analysis

- Trend as a continuous function:
  - ▷ Similar to Putnam model (Ch.19)
    – but customized with local data
  - ▷ Other analysis related to SRE
    – defect/effort/reliability curves
    – more in Ch.22 and related references.
  - ▷ Sometimes discrete analysis may be more meaningful (see below).

- Defect dynamics model:
  - ▷ Important variation to trend analysis.
  - ▷ Defect categorized by phase.
  - ▷ Discovery (already done).
  - ▷ Analysis to identify injection phase.

Defect Trend Analysis

Inj. Phase	Removal Phase						
	R	S	D	C	T	P	All
Requirements	10	22	8	0	5	2	47
Specification		10	20	2	0	1	33
Design			52	120	32	5	209
Coding				198	320	46	564
Testing					58	7	65
Post-release						2	2
All	10	32	80	320	415	63	920

- Defect dynamics model: Table 20.5 (p.344)
  - ▷ row: where (phase) injected
  - ▷ column: where (phase) removed/discovered
  - ▷ focus out-of-phase/off-diagonal ones!

Defect Causal Analysis

- Defect causal analyses: Types
  - ▷ Causal relation identified:
    – error-fault vs fault-failure
    – works backwards
  - ▷ Techniques: statistical or logical.

- Root cause analysis (logical):
  - ▷ Human intensive.
  - ▷ Good domain knowledge.
  - ▷ Fault-failure: individual and common.
  - ▷ Error-fault: project-wide effort focused on pervasive problems.

- Statistical causal analysis:
  ≈ risk identification techniques in Ch.21.

ODC: Overview

- Development
  - ▷ Chillarege et al. at IBM
  - ▷ Applications in IBM Labs and several other companies
  - ▷ Recent development and tools

- Key elements of ODC
  - ▷ Aim: tracking/analysis/improve
  - ▷ Approach: classification and analysis
  - ▷ Key attributes of defects
  - ▷ Views: both failure and fault
  - ▷ Applicability: inspection and testing
  - ▷ Analysis: attribute focusing
  - ▷ Need for historical data

ODC: Why?

- Statistical defect models:
  - ▷ Quantitative and objective analyses.
  - ▷ SRGMs (Ch.22), DRM (Ch.19), etc.
  - ▷ Problems: accuracy & timeliness.
- Causal (root cause) analyses:
  - ▷ Qualitative but subjective analyses.
  - ▷ Use in defect prevention.
- Gap and ODC solution:
  - ▷ Bridge the gap between the two.
  - ▷ Systematic scheme used.
  - ▷ Wide applicability.

ODC: Ideas

- Cause-effect relation by type:
  - ▷ Different types of faults.
  - ▷ Causing different failures.
  - ▷ Need defect classification.
  - ▷ Multiple attributes for defects.
- Good measurement:
  - ▷ Orthogonality (independent view).
  - ▷ Consistency across phases.
  - ▷ Uniformity across products.
- ODC process/implementation:
  - ▷ Human classification.
  - ▷ Analysis method and tools.
  - ▷ Feedback results (and followup).

ODC: Theory

- Semantic classification:
  - ▷ defect classes for a product
  - ▷ related-to/explain process
  - ▷ akin to event measurement
  - ▷ sufficient condition:
    - spanning set over process
    - formed by defect attributes

- Classification for cause-effect or views:
  - ▷ cause: type, trigger, etc.
  - ▷ effect: severity, impact, etc.
  - ▷ failure vs fault (internal cause) views
  - ▷ additional causal-analysis-related: source, where/when injected.
  - ▷ sub-population: environment data.

ODC Example: Table 20.6 (p.347)

Label	Name	Possible values or categories & labels
`imp`	impact	c=capability, u=usability, p=performance, r=reliability, in=installation, ma=maint., im=implementation, mi=migration, sec=security, ser=service, std=standard
`trig`	trigger	i=installation, m=migration, s=stress, a=ad-hoc, b=backup, c=communications, f=file i/o, co=coexistence, e=exception, ss=startup/shutdown, hc=h/w config., sc=s/w config., o=normal operation
`sev`	severity	range from 1 (highest) to 4 (lowest) in severity
`wk`	week	week detected, from project start
`ftype`	fix type	s=specification, hld=high-level design, lld=low-level design, c=code, b=build process, o=other product
`act`	action	a=add, d=delete, c=change
`src`	code source	b=base, v=vendor, n=new, c=changed, i=incremental, s=scaffolded, p=previous defect fix
`inj`	phase injected	p=previous release, s=specification, hld=high-level design, lld=low-level design, c=coding, ut=unit test, ft=function test, st=system test, d=customer usage

ODC Attributes: Failure-View

- Defect trigger:
  - ▷ Associated with verification process
    - – similar to test case measurement
    - – collected by testers
  - ▷ Trigger classes
    - – product specific
    - – black box in nature
    - – pre/post-release triggers

- Other attributes:
  - ▷ Impact: e.g., IBM's CUPRIMDSO.
  - ▷ Severity: low-high (e.g., 1-4).
  - ▷ Detection time, etc.

ODC Attributes: Cause/Fault-View

- Defect type:
  - ▷ Associated with development process.
  - ▷ Missing or incorrect.
  - ▷ Collected by developers.
  - ▷ May be adapted for other products.
- Other attributes:
  - ▷ Action: add, delete, change.
  - ▷ Number of lines changed, etc.

ODC Attributes: Cause/Error-View

- Key attributes:
  - ▷ Defect source: vendor/base/new code.
  - ▷ Where injected.
  - ▷ When injected.
- Characteristics:
  - ▷ Associated to additional causal analysis.
  - ▷ (May not be performed.)
  - ▷ Many subjective judgment involved (evolution of ODC philosophy)
- Phase injected: rough "when".

Adapting ODC for Web Error Analysis

- Continuation of web testing/QA study.

- Web error = observed failures, with causes already recorded in access/error logs.

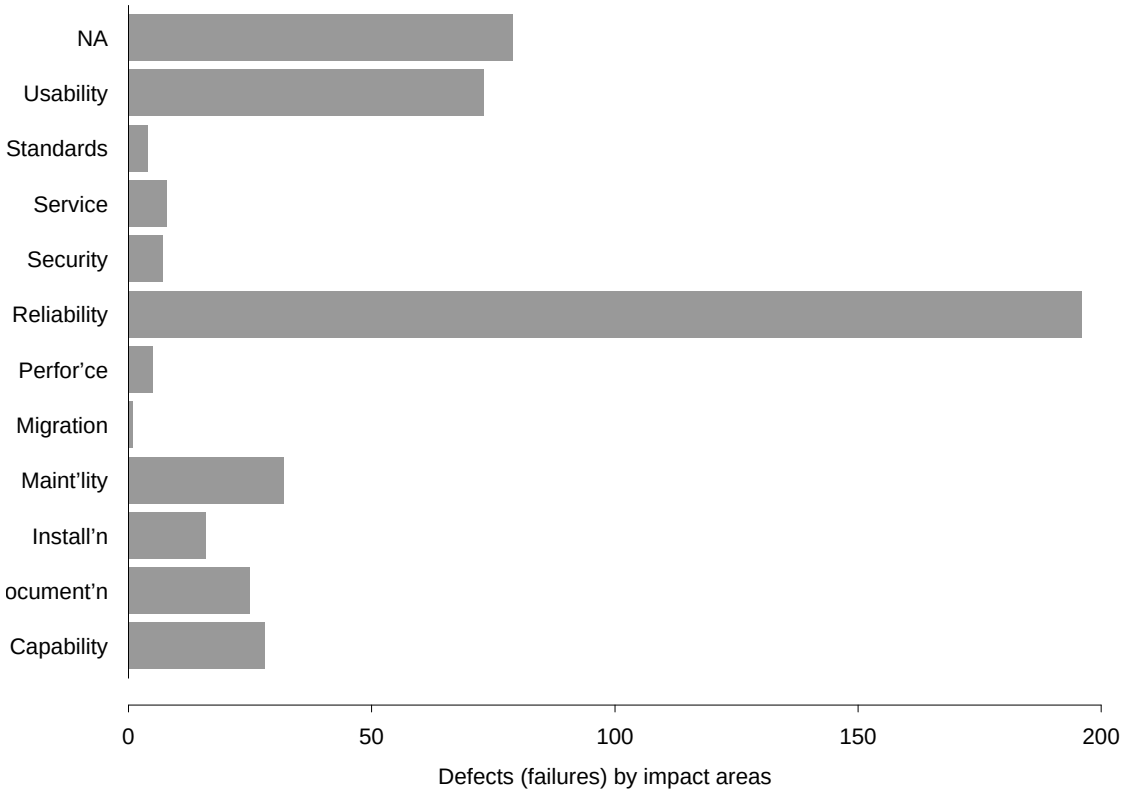
- Key attributes mapped to ODC:
  - ▷ Error type = defect impact.
    - types in Table 20.1 (p.341)
    - response code (4xx) in access logs
  - ▷ Referring page = defect trigger.
    - individual pages with embedded links
    - classified: internal/external/empty
    - focus on internal problems
  - ▷ Missing file type = defect source
    - different fixing actions to follow.

- May include other attributes for different kinds of web sites.

ODC Analysis: Attribute Focusing

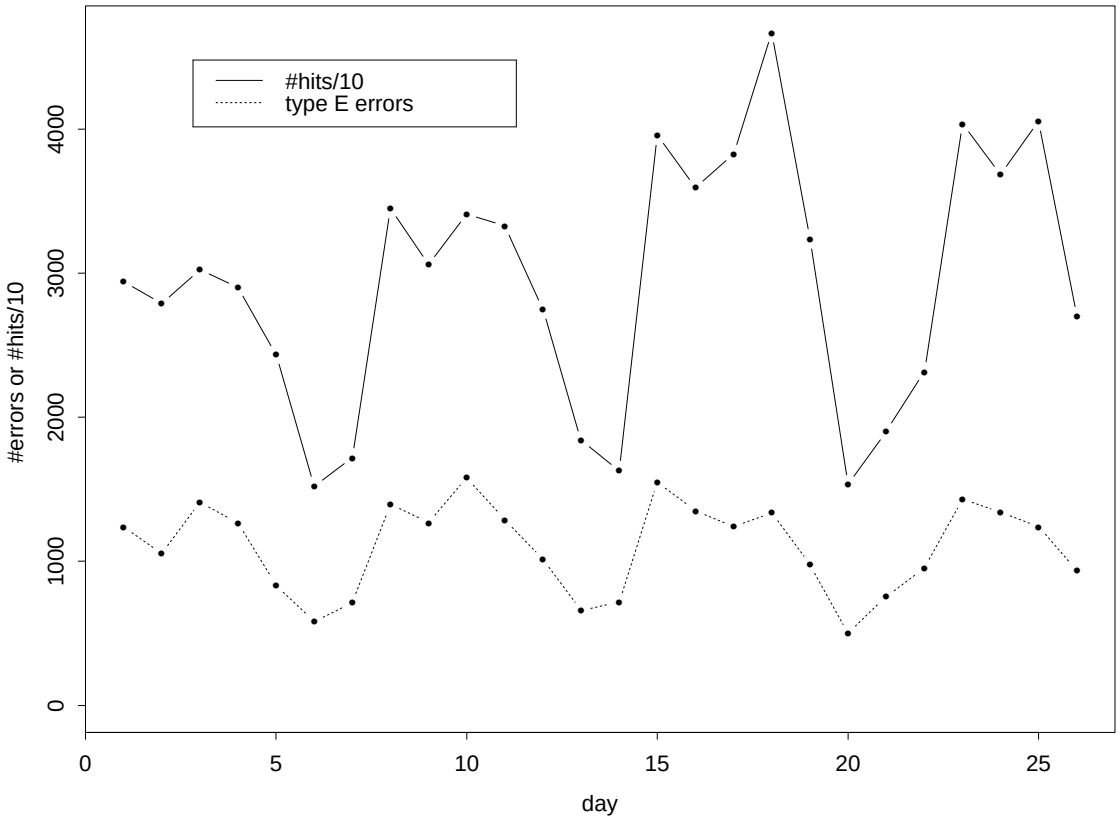
- General characteristics
  - ▷ Graphical in nature
  - ▷ 1-way or 2-way distribution
  - ▷ Phases and progression
  - ▷ Historical data necessary
  - ▷ Focusing on big deviations
- Representation and analysis
  - ▷ 1-way: histograms
  - ▷ 2-way: stack-up vs. multiple graphics
  - ▷ Support with analysis tools

ODC Analysis Examples



- 1-way analysis: Fig 20.1 (p.349)
  - ▷ Defect impact distribution for an IBM product.
  - ▷ Uneven distribution of impact areas! $\Rightarrow$ risk identification and focus.

ODC Analysis Examples



- 1-way analysis: Fig 20.2 (p.350)
  - ▷ web error trend analysis.
  - ▷ context: compare to usage (reliability).
  - ▷ stable operational reliability

ODC Analysis Examples

Impact	Severity			
	1	2	3	4
Capability	2	12	13	1
Documentation	0	1	14	10
Installability	0	6	6	4
Maintainability	0	6	19	7
Migration	0	0	0	1
Performance	1	1	3	0
Reliability	27	96	66	7
Security	1	3	3	0
Service	0	0	4	4
Standards	0	1	2	1
Usability	0	10	44	19

- 2-way analysis: Table 20.7 (p.351)
  - ▷ Defect impact-severity analysis.
  - ▷ IBM product study continued.
  - ▷ Huge contrast: severity of reliability and usability problems!

ODC Process and Implementation

- ODC process:
  - ▷ Human classification
    - – defect type: developers,
    - – defect trigger and effect: testers,
    - – other information: coordinator/other.
  - ▷ Tie to inspection/testing processes.
  - ▷ Analysis: attribute focusing.
  - ▷ Feedback results: graphical.

- Implementation and deployment:
  - ▷ Training of participants.
  - ▷ Data capturing tools.
  - ▷ Centralized analysis.
  - ▷ Usage of analysis results.

Linkage to Other Topics

- Development process
  - ▷ Defect prevention process/techniques.
  - ▷ Inspection and testing.
- Testing and reliability:
  - ▷ Expanded testing measurement
    - – Defects and other information:
    - – Environmental (impact)
    - – Test case (trigger)
    - – Causal (fault)
  - ▷ Reliability modeling for ODC classes