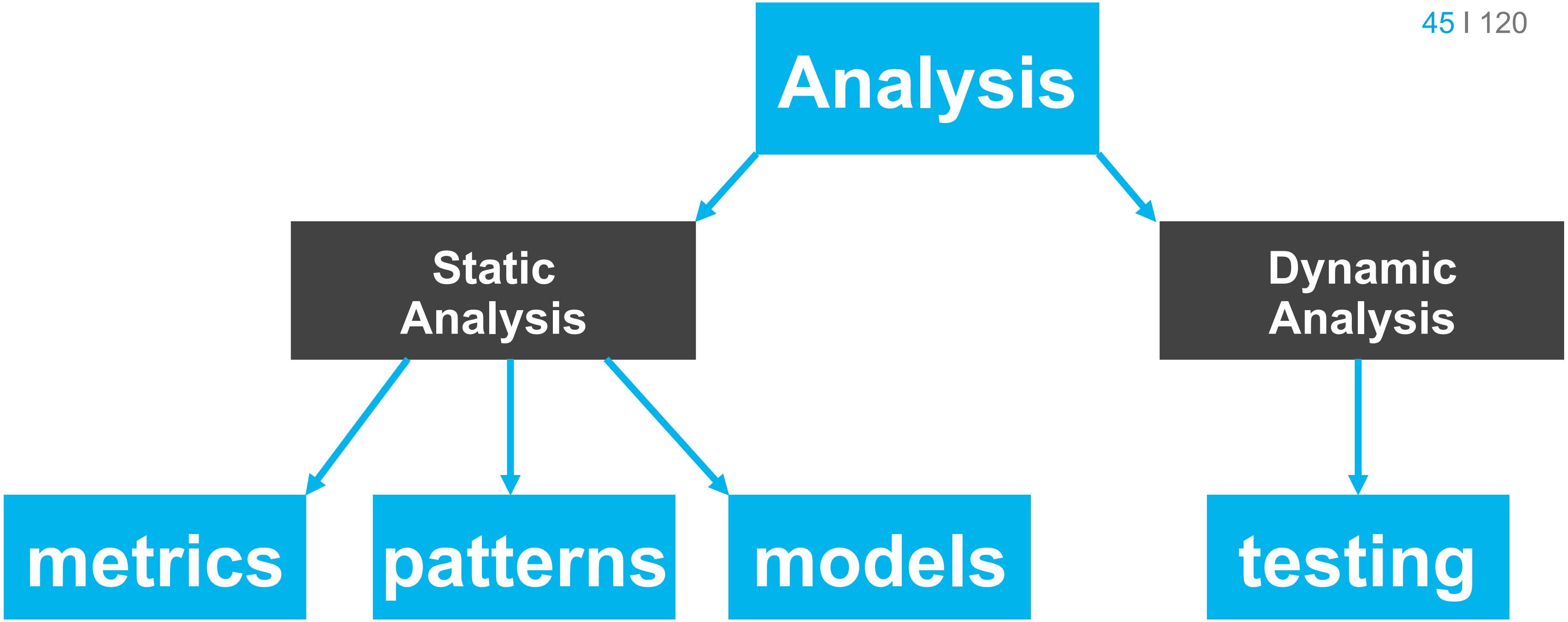
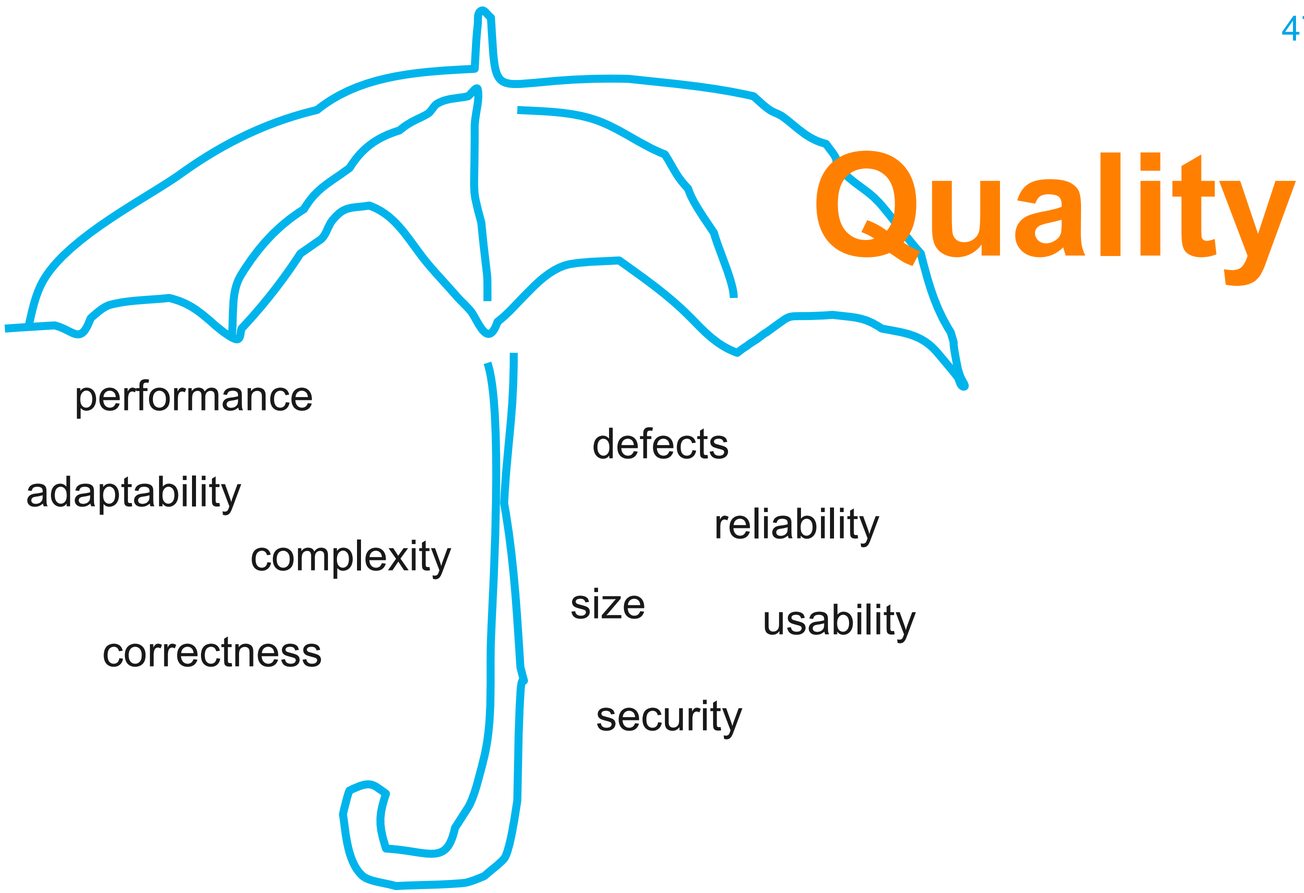
Structure of the lecture

Software Improvement Group

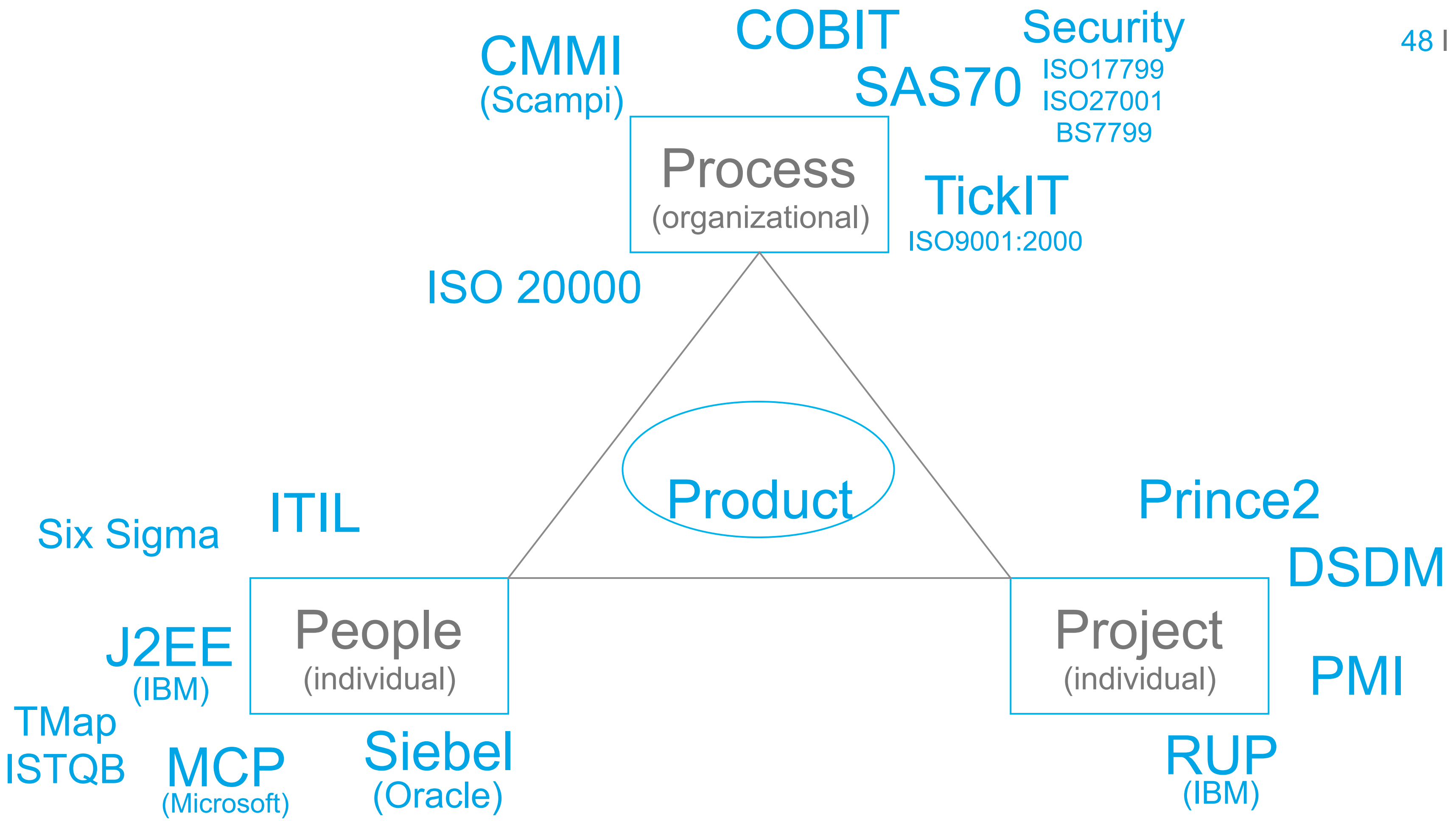


METRICS & QUALITY

Software analysis
What?



The bermuda triangle of software quality



Capability Maturity Model® Integration (CMMI®)

- "… is a process improvement approach that provides organizations with the essential elements of effective processes.." (SEI)
- CMMI for Development (CMMI-DEV), Version 1.2, August 2006.
- consists of 22 process areas with capability or maturity levels.
- CMMI was created and is maintained by a team consisting of members from industry, government, and the Software Engineering Institute (SEI)
- http://www.sei.cmu.edu/cmmi

The Standard CMMI Appraisal Method for Process Improvement (SCAMPI)

- "… is the official SEI method to provide benchmark-quality ratings relative to CMMI models."

Software Quality Process

Software Improvement Group

Software Engineering Institute | Carnegie Mellon

http://sas.sei.cmu.edu/pars/

Organization

Organization Name:	Accenture
Appraisal Sponsor Name:	Jack Ramsay, Marco Spaziani Testa, Maria Angeles Ramirez
Lead Appraiser Name:	John Voss
SEI Partner Name:	Accenture LLP

Model Scope and Appraisal Ratings

Level 2		Level 3		Level 4		Level 5	
Satisfied	REQM	Satisfied	RD	Out of Scope	OPP	Out of Scope	OID
Satisfied	PP	Satisfied	TS	Out of Scope	QPM	Out of Scope	CAR
Satisfied	PMC	Satisfied	PI				
Not Applicable	SAM	Satisfied	VER				
Satisfied	MA	Satisfied	VAL				
Satisfied	PPQA	Satisfied	OPF				
Satisfied	CM	Satisfied	OPD				
		Satisfied	OT				
		Satisfied	IPM				
		Satisfied	RSKM				
		Satisfied	DAR				

Organizational Unit Maturity Level Rating: 3

Additional Information for Appraisals Resulting in Capability or Maturity Level 4 or 5 Ratings:

Software Quality Process

Software Improvement Group

Levels

- L1: Initial
- L2: Managed
- L3: Defined
- L4: Quantitatively Managed
- L5: Optimizing

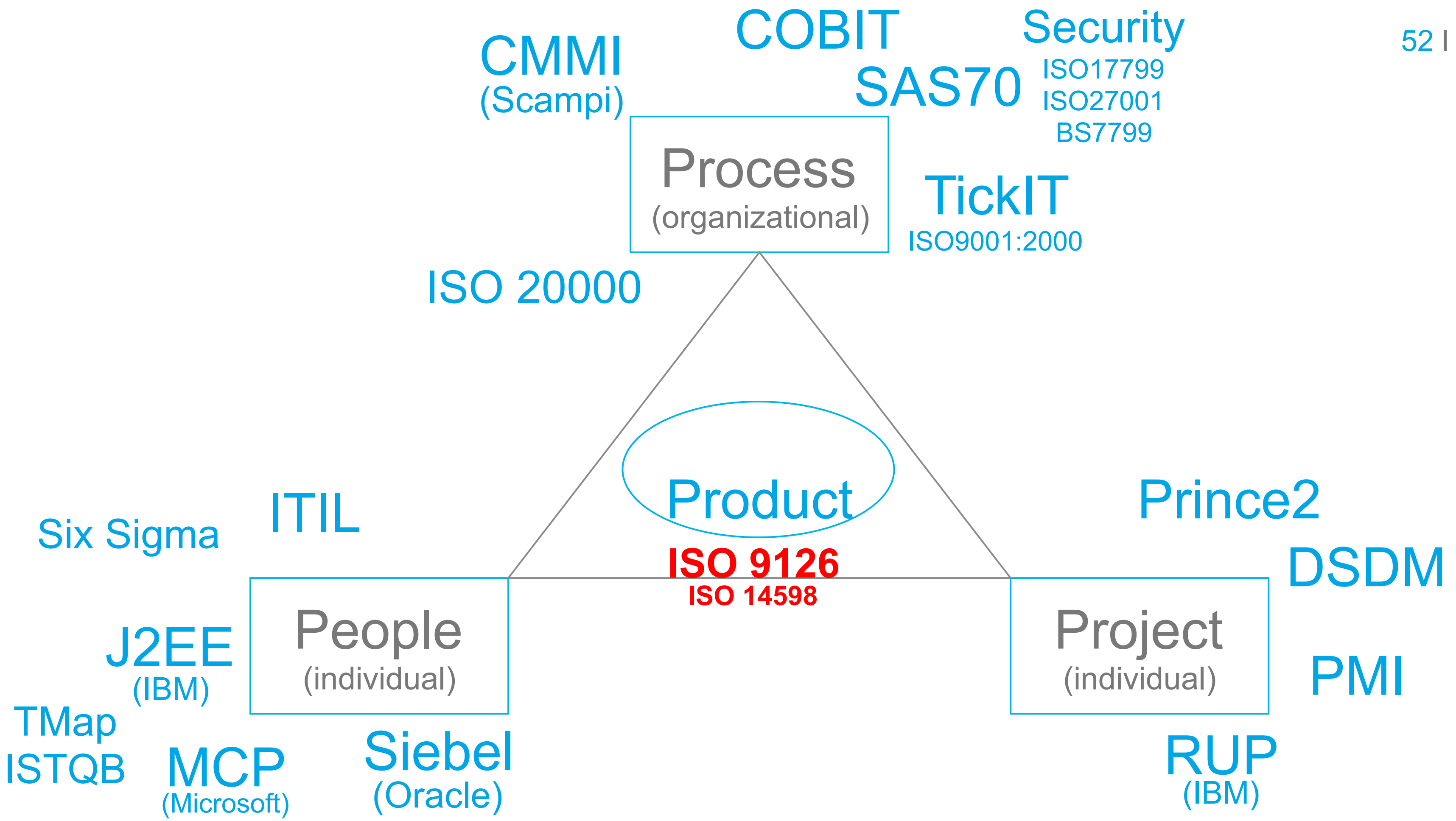
http://www.cmmi.de
(browser)

Process Areas

- Causal Analysis and Resolution
- Configuration Management
- Decision Analysis and Resolution
- Integrated Project Management
- Measurement and Analysis
- Organizational Innovation and Deployment
- Organizational Process Definition
- Organizational Process Focus
- Organizational Process Performance
- Organizational Training
- Product Integration
- Project Monitoring and Control
- CMMI Project Planning
- Process and Product Quality Assurance
- Quantitative Project Management
- Requirements Development
- Requirements Management
- Risk Management
- Supplier Agreement Management
- Technical Solution
- Validation
- Verification

CMMI®

The bermuda triangle of software quality



But …

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What is software quality?

What are the technical and functional aspects of quality?

How can technical and functional quality be measured?

Software product quality standards

Software Improvement Group

ISO/IEC 9126

Software engineering -- Product quality

1. Quality model
2. External metrics
3. Internal metrics
4. Quality in use metrics

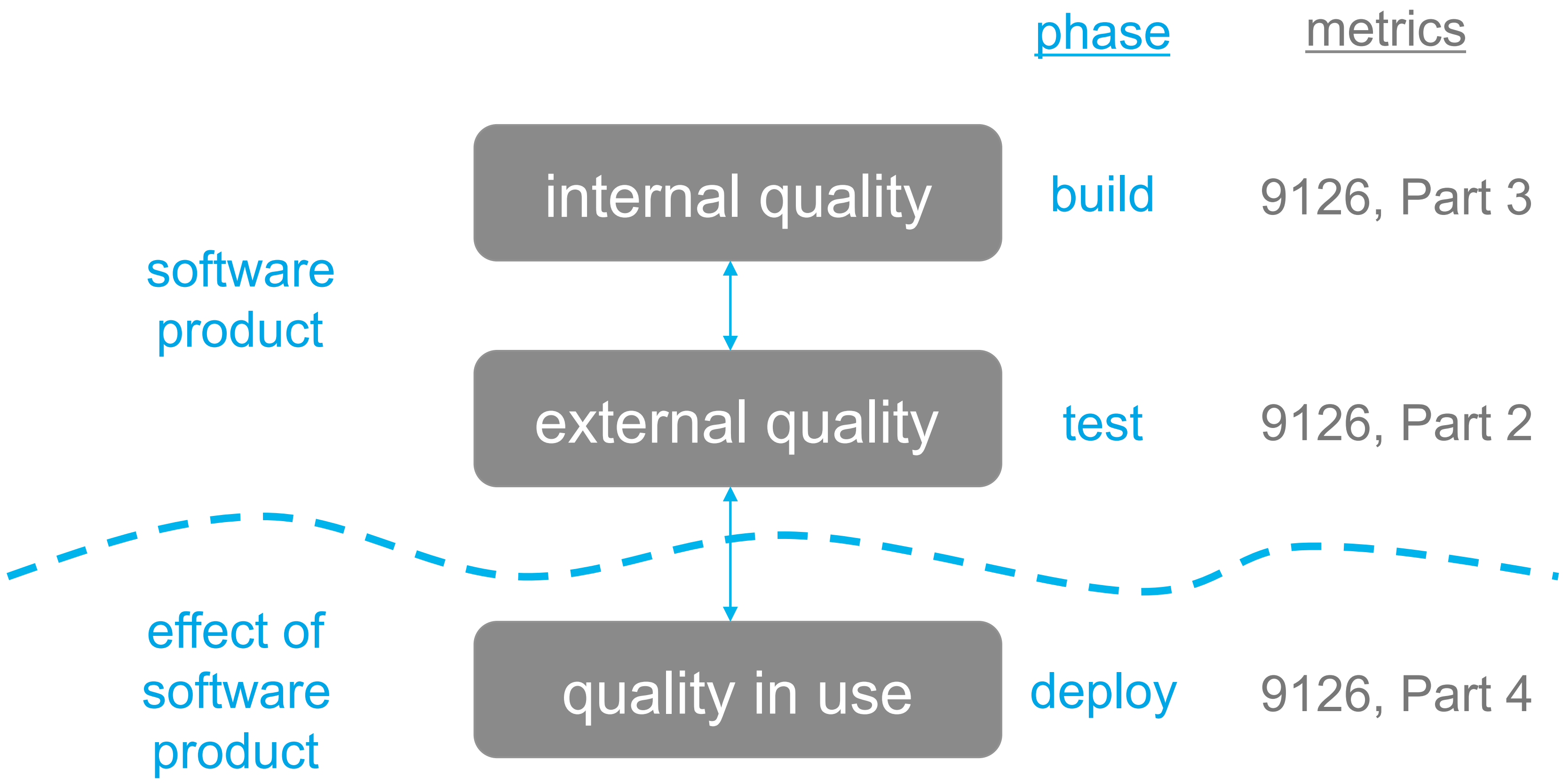
International Organization for Standardization

ISO/IEC 14598

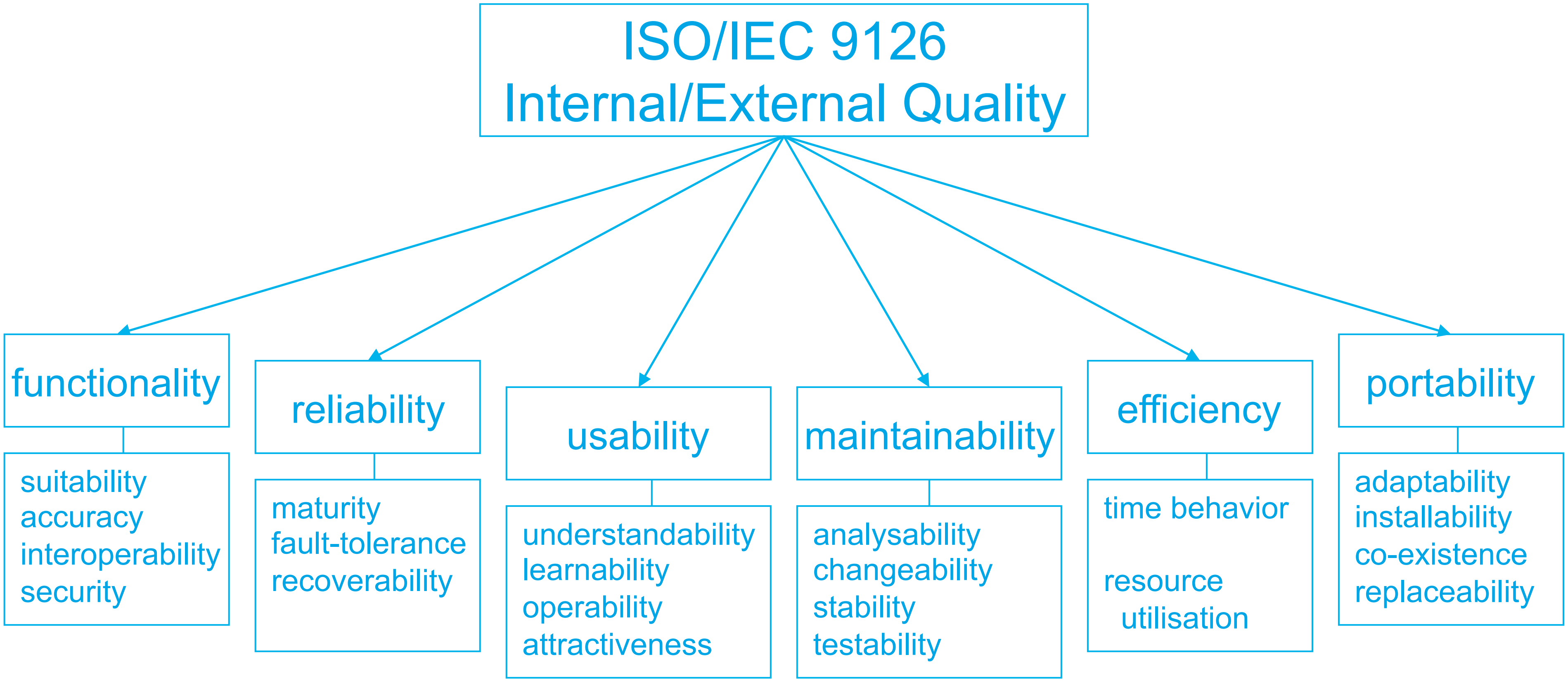
Information technology -- Software product evaluation

1. General overview
2. Planning and management
3. Process for developers
4. Process for acquirers
5. Process for evaluators
6. Documentation of evaluation modules

ISO/IEC 9126, Part 1
Quality perspectives



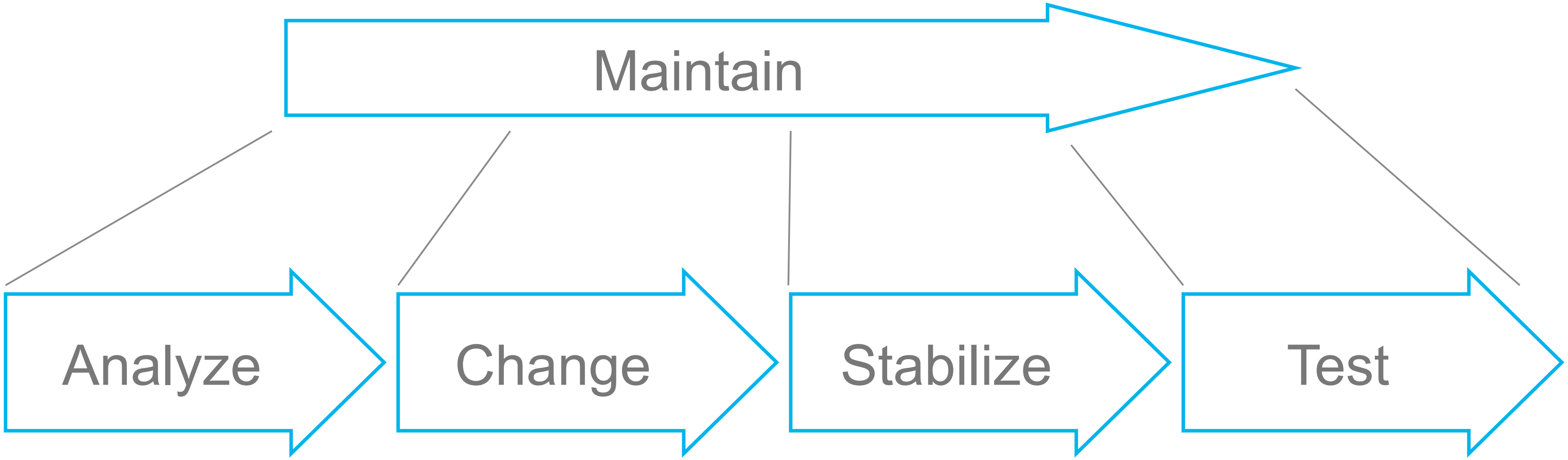
ISO/IEC 9126, Part 1
Product quality model: internal and external



ISO 9126, Part 1
Maintainability (= evolvability)

Maintainability =

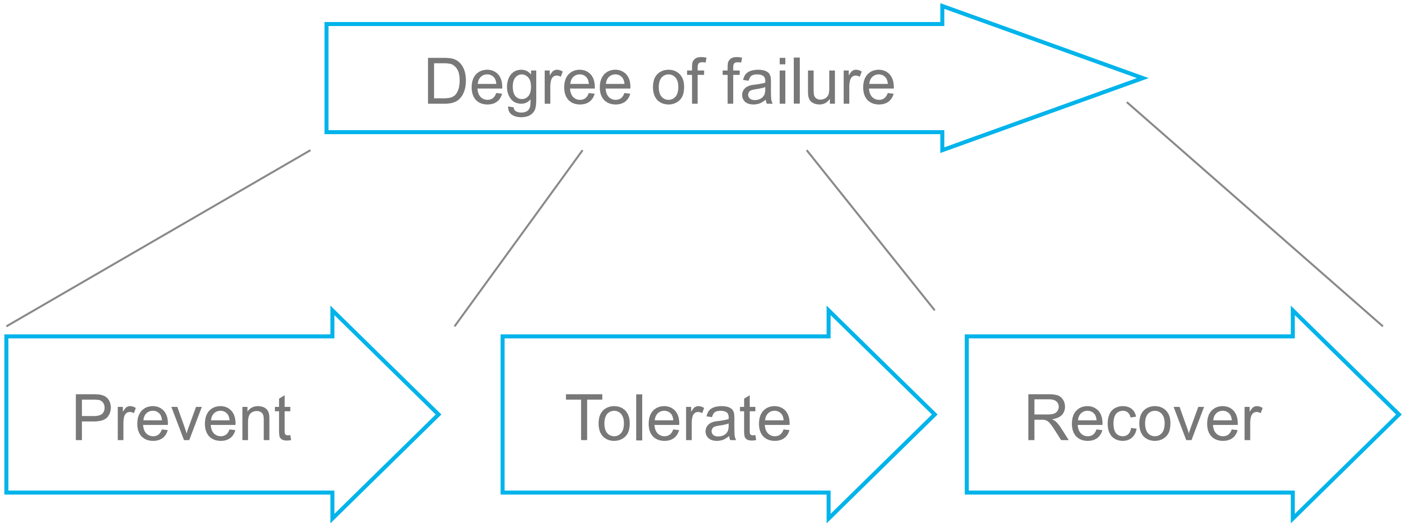
- *Analyzability*: easy to understand where and how to modify?
- *Changeability*: easy to perform modification?
- *Stability*: easy to keep coherent when modifying?
- *Testability*: easy to test after modification?



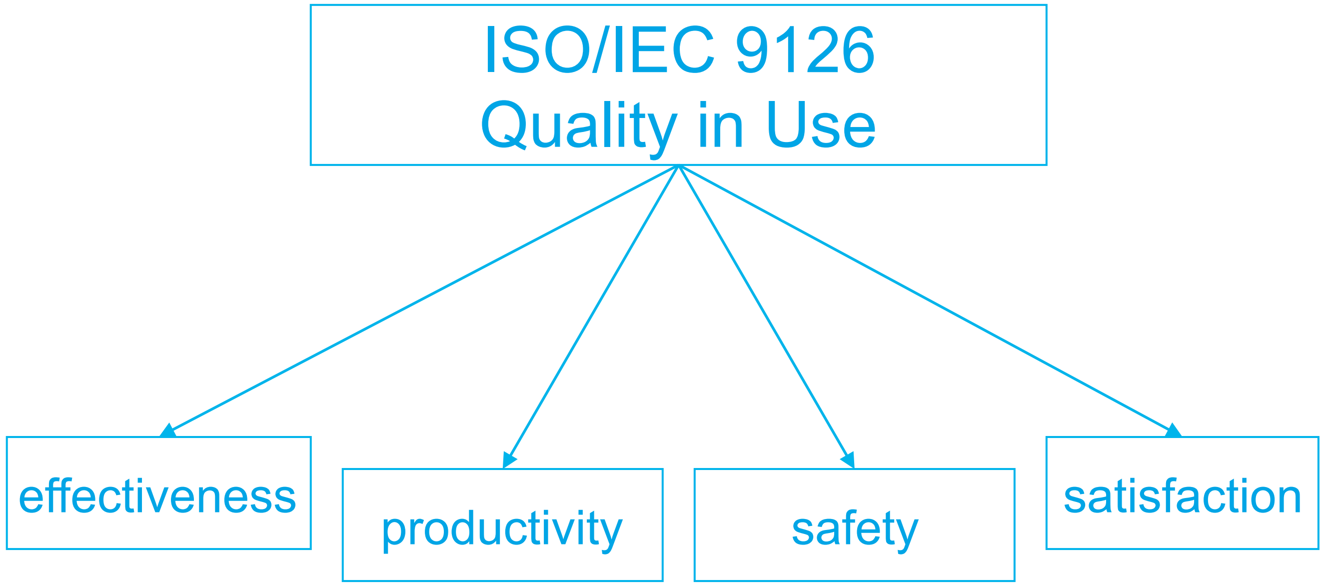
ISO 9126, Part 1
Reliability

Reliability =

- *Maturity*: how much has been done to prevent failures?
- *Fault tolerance*: when failure occurs, is it fatal?
- *Recoverability*: when fatal failure occurs, how much effort to restart?



ISO/IEC 9126, Part 1
Product quality model: quality-in-use



ISO 9126
Part 2,3: metrics

Software Improvement Group

External metrics, e.g.:

- Changeability: “change implementation elapse time”, time between diagnosis and correction
- Testability: “re-test efficiency”, time between correction and conclusion of test

Internal metrics, e.g.:

- Analysability: “activity recording”, ratio between actual and required number of logged data items
- Changeability: “change impact”, number of modifications and problems introduced by them

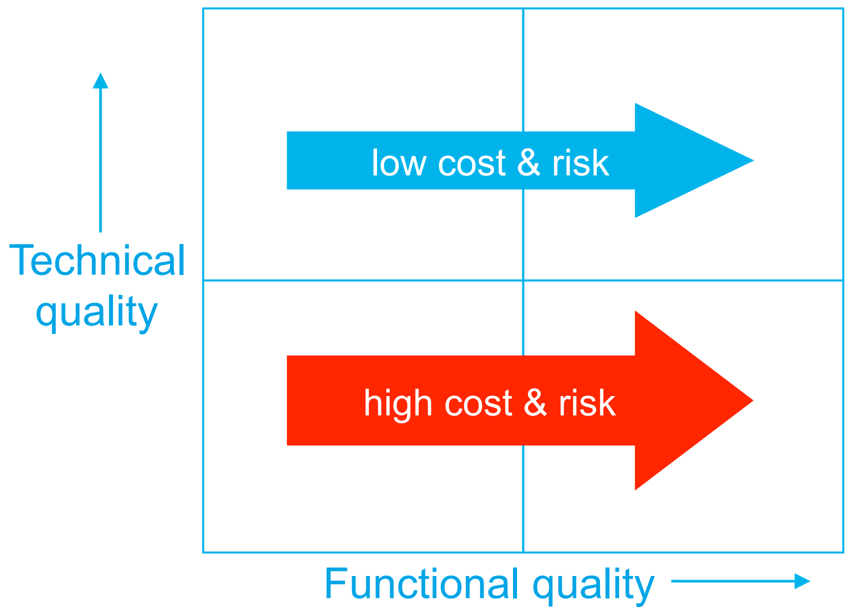
Critique

- Not pure *product* measures, rather *product in its environment*
- Measure *after* the fact
- No clear distinction between functional and technical quality

The issue

- Companies innovate and change
- Software systems need to adapt in the same pace as the business changes
- Software systems that do not adapt lose their value
- The technical quality of software systems is a key element

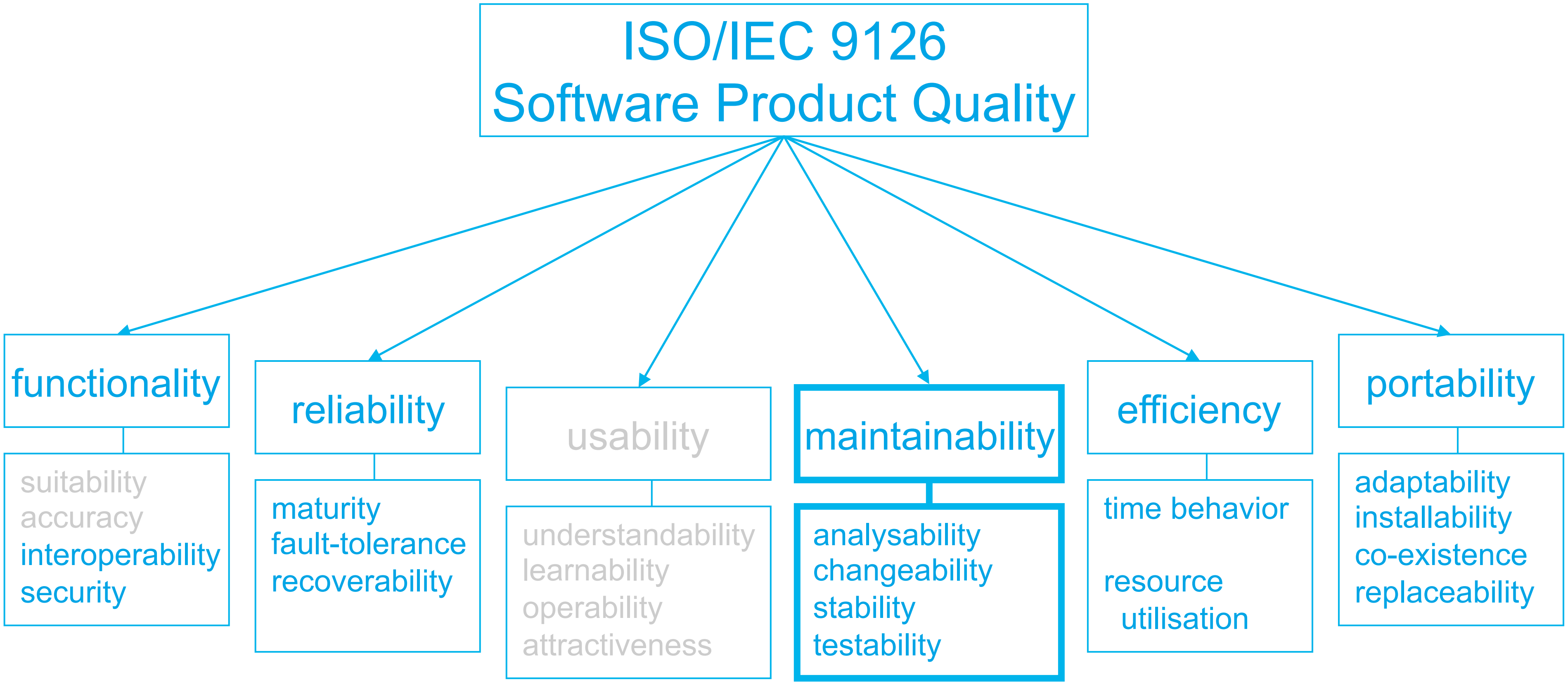
Functional *vs* technical quality



Software with high technical quality can evolve with low cost and risk to keep meeting functional and non-functional requirements.

ISO/IEC 9126, Part 1
Product quality model: technical quality

Software Improvement Group



So …

Software Improvement Group

What is software quality? ✓

What are the functional and technical aspects of quality? ✓

How can technical quality be measured? ?

A Challenge

Software Improvement Group

Use source code metrics to measure technical quality?

Plenty of metrics defined in literature

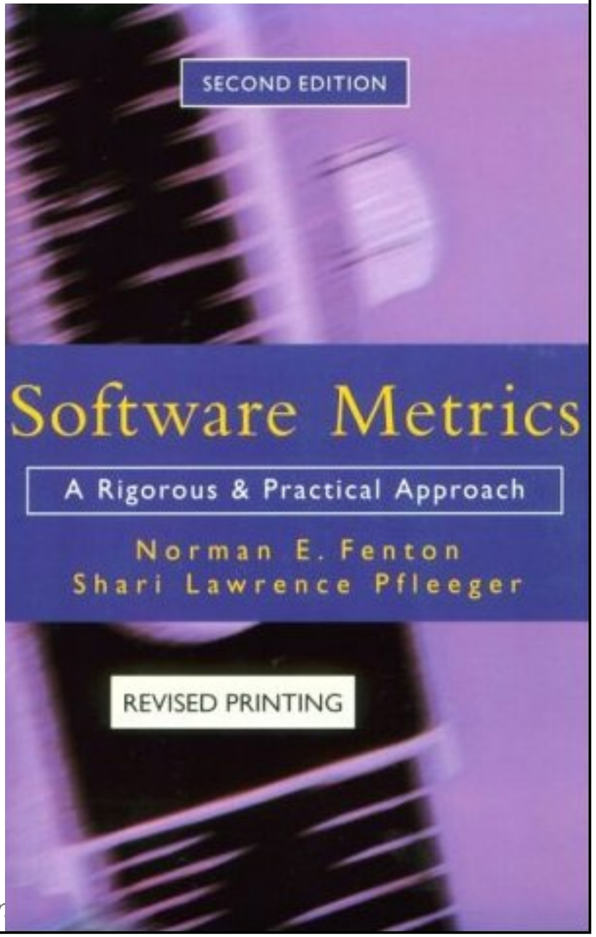
- LOC, cyclomatic complexity, fan in/out, coupling, cohesion, …
- Halstead, Chidamber-Kemener, Shepperd, …

Plenty of tools available

- Variations on Lint, PMD, FindBugs, …
- Coverity, FxCop, Fortify, QA-C, Understand, …
- Integrated into IDEs

But:

- Do they measure technical quality of a system?



Source code metrics
Lines of code (LOC)

Software Improvement Group

- Easy! Or …

- SLOC = Source Lines of Code
  - Physical (≈ newlines)
  - Logical (≈ statements)
- Blank lines, comment lines, lines with only “}”
- Generated *versus* manually written

- Measure effort / productivity: specific to programming language

Source code metrics
Function Point Analysis (FPA)

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- A.J. Albrecht - IBM - 1979
- Objective measure of functional size

- Counted manually
  - IFPUG, Nesma, Cocomo
  - Large error margins

- Backfiring
  - Per language correlated with LOC
  - SPR, QSM

- Problematic, but popular for estimation

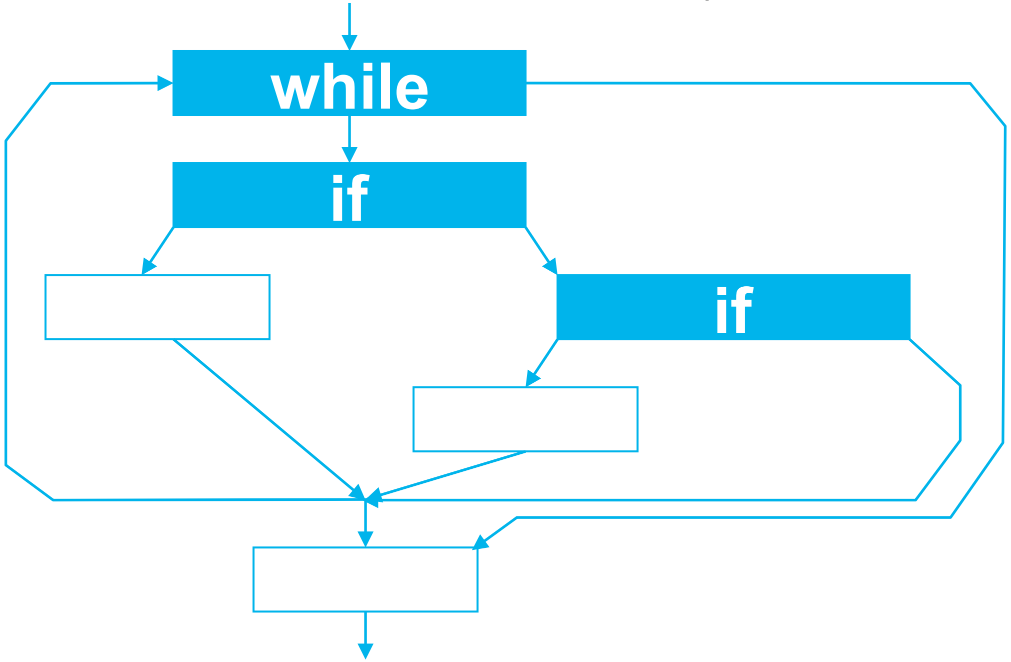
Table 2. Sample Function Point Calculations

Raw Data	Weights		Function Points
1 Input	X 4	=	4
1 Output	X 5	=	5
1 Inquiry	X 4	=	4
1 Data File	X 10	=	10
1 Interface	X 7	=	7

Unadjusted Total			30
Compexity Adjustment			None
Adjusted Function Points			30

Source code metrics
Cyclomatic complexity

- T. McCabe, *IEEE Trans. on Sw Engineering*, 1976
- Accepted in the software community
- Number of independent, non-circular paths per method
- Intuitive: number of decisions made in a method
- 1 + the number of if statements (and while, for, ...)



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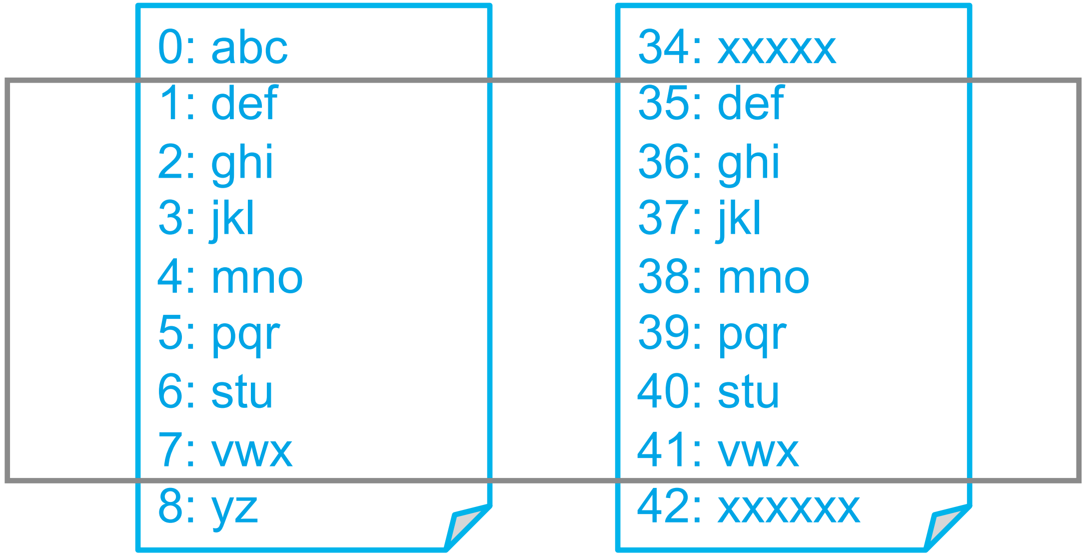
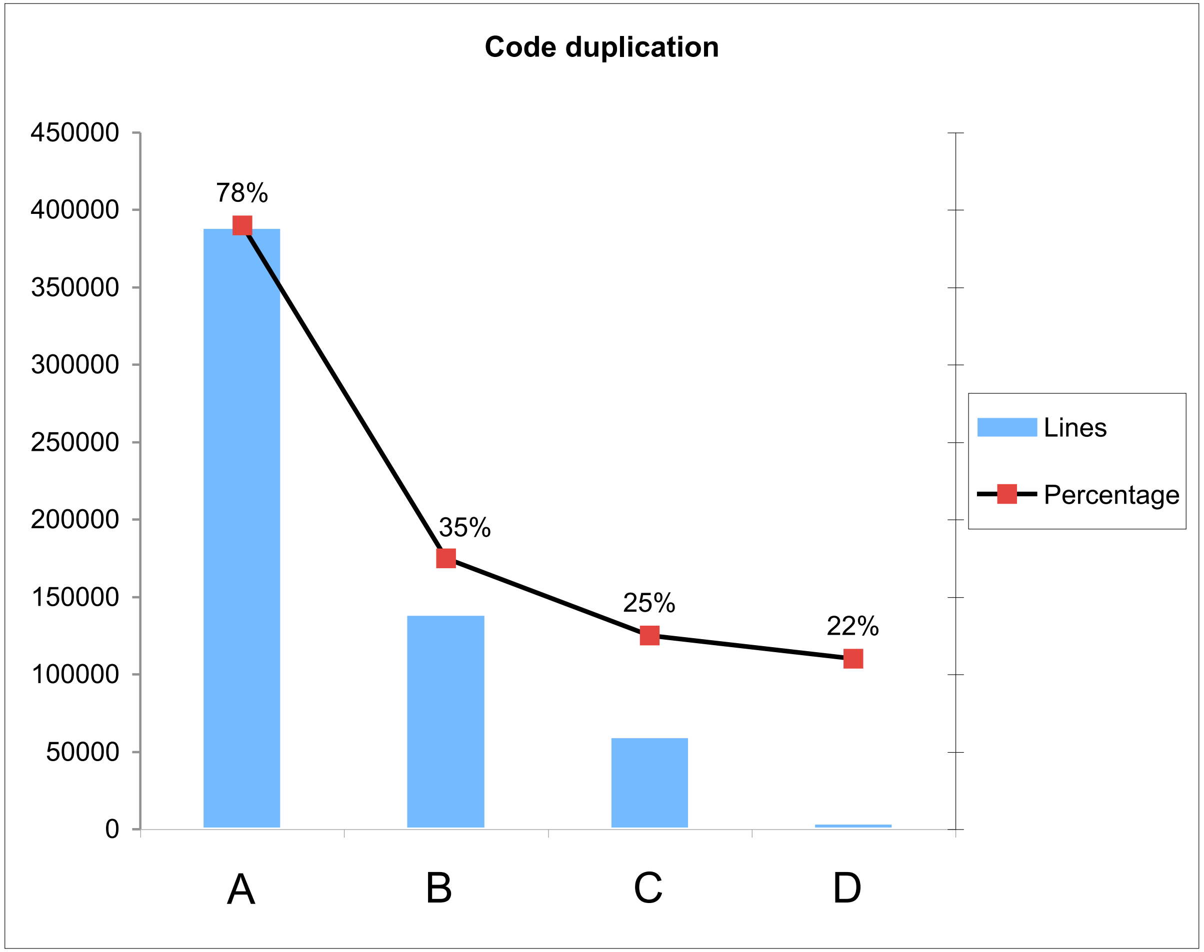
Code duplication measurement



Number of duplicated lines: 14

Code duplication



Source code metrics
Coupling

- Efferent Coupling (Ce)
  - How many classes do I depend on?
- Afferent Coupling (Ca)
  - How many classes depend on me?
- Instability = Ce/(Ca+Ce) $\in$ [0,1]
  - Ratio of efferent *versus* total coupling
  - 0 = very stable = hard to change
  - 1 = very instable = easy to change

Figure 1. Coupling graph

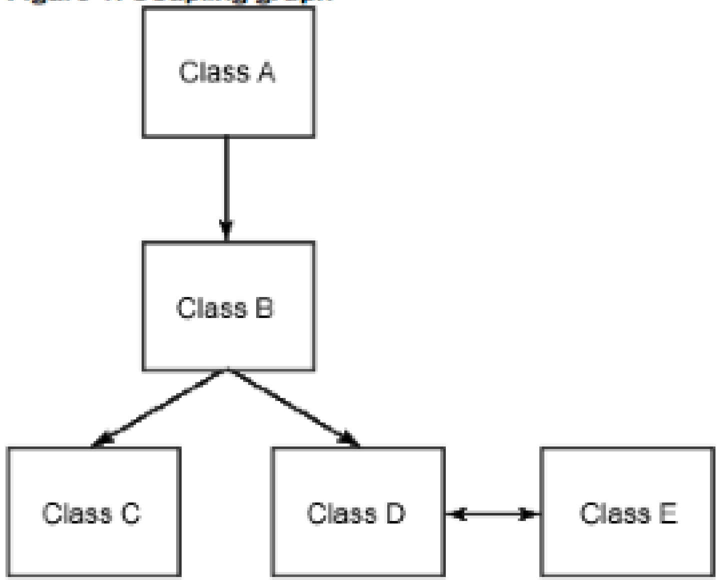


Table 1. Results of compiling a single class

Class to Compile	Other Classes Compiled	Afferent Couplings	Efferent Couplings	Instability Factor
A	B,C,D,E	0	4	1
B	C,D,E	1	3	0.75
C	-	2	0	0
D	E	3	1	0.25
E	D	3	1	0.25

Plethora of software metrics

- Ample definitions in literature
- Ample tools that calculate

Measurement yields data, not information

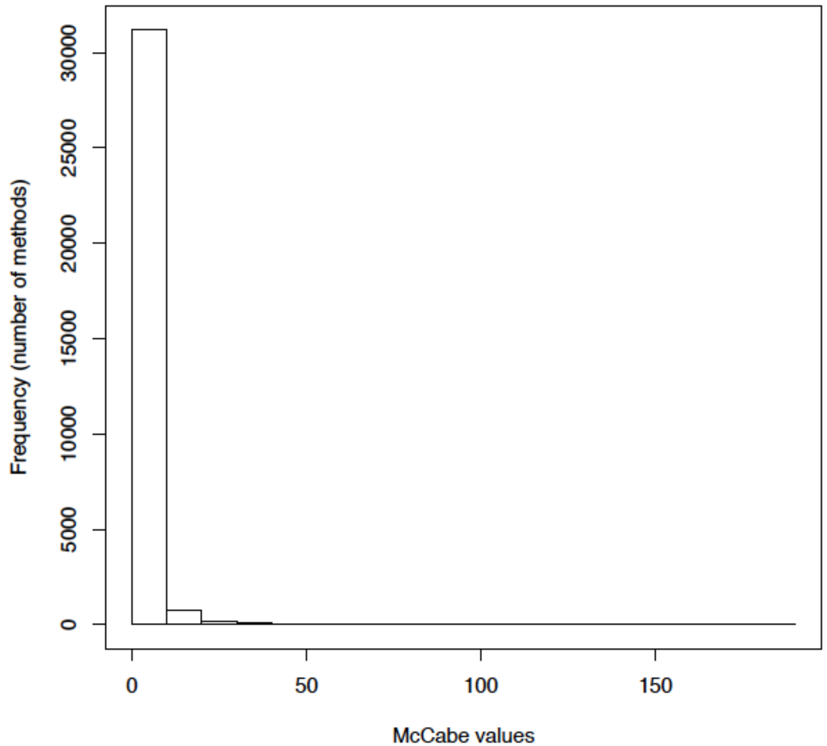
- How to aggregate individual measurement values?
- How to map aggregated values onto quality attributes?
- How to set thresholds?
- How to act on results?

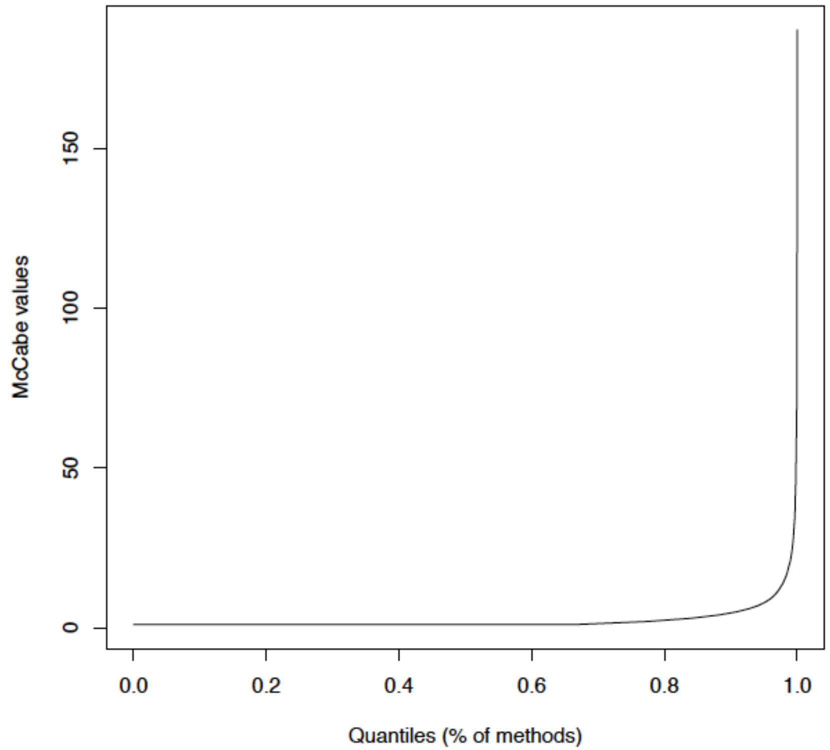
SIG quality model handles these issues in a pragmatic way

The statistical nature of software metrics
Averaging is fundamentally flawed

Average

- Is measure for *central tendency*
- For "symmetric" distributions, such as *normal*. But:



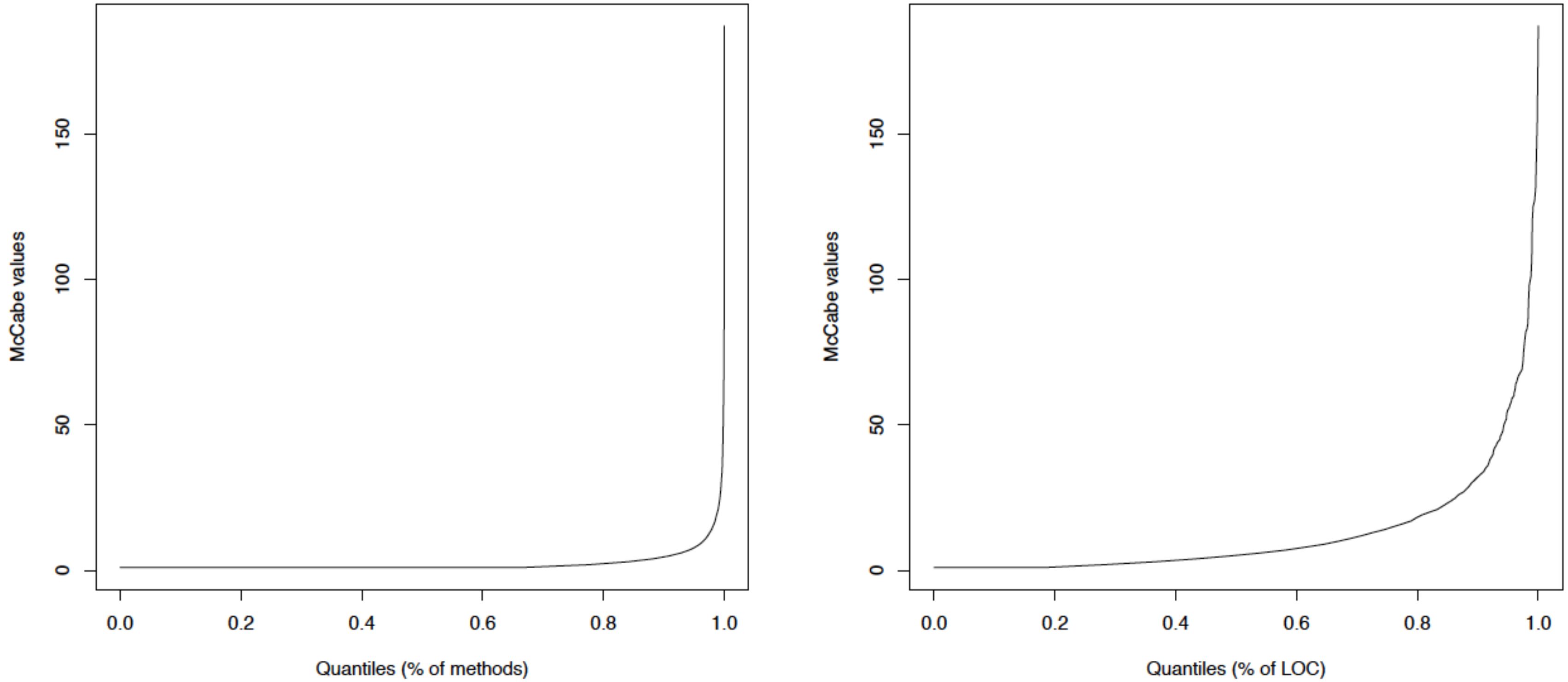


The statistical nature of software metrics
Emphasize area of risk

Software Improvement Group

Exploit a-symmetry

- High-risk code is on the right
- Weighing with LOC



The statistical nature of software metrics
Go where the variation is

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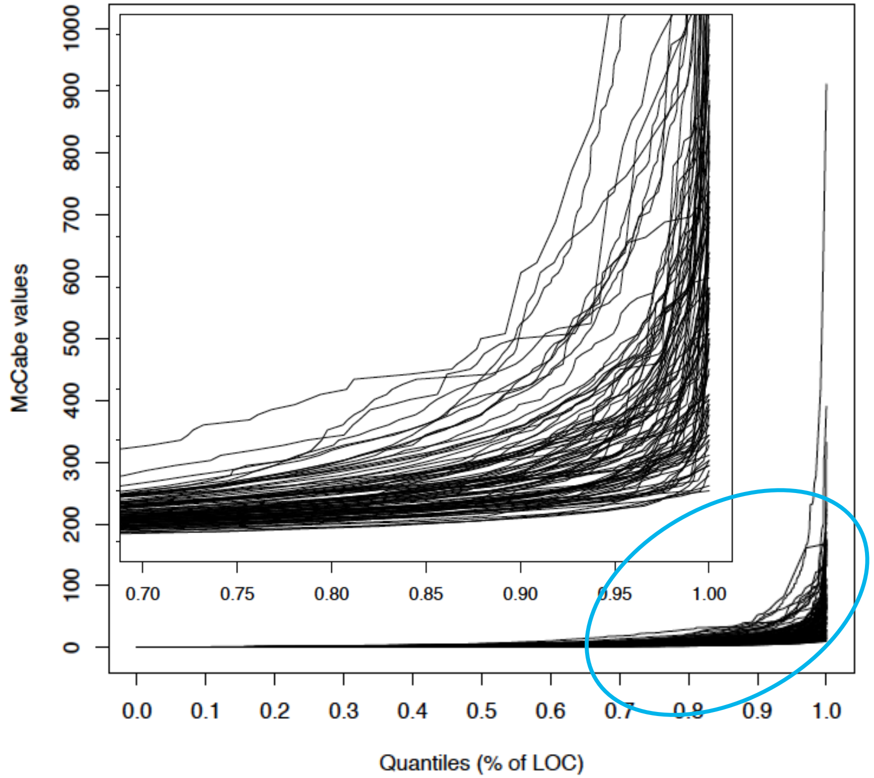

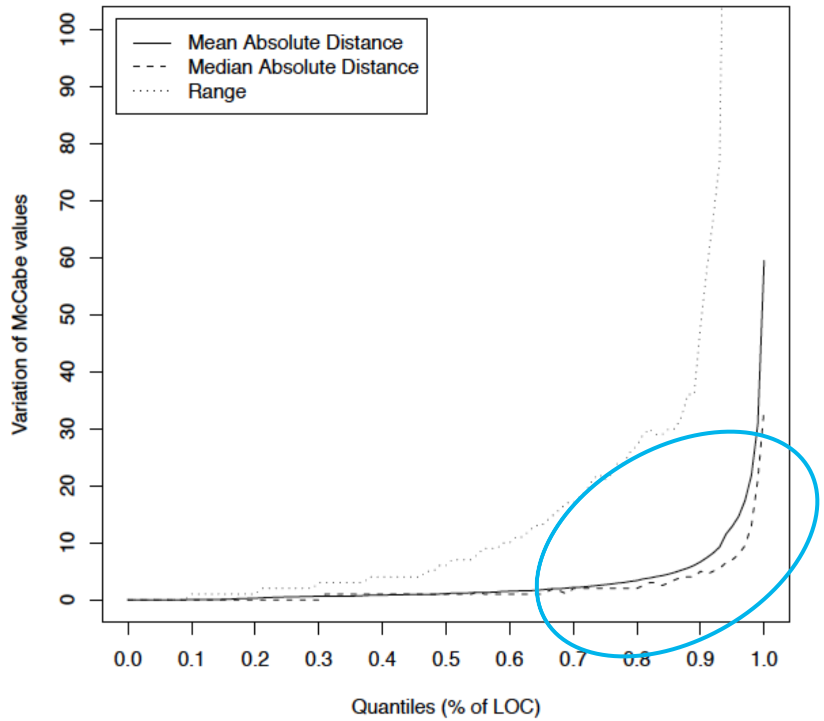

Observe for all:

- Systems are similar in low percentiles. Systems differ in higher percentiles.
- Interesting differences occur mostly above the 70% percentile

The statistical nature of software metrics
Go where the variation is

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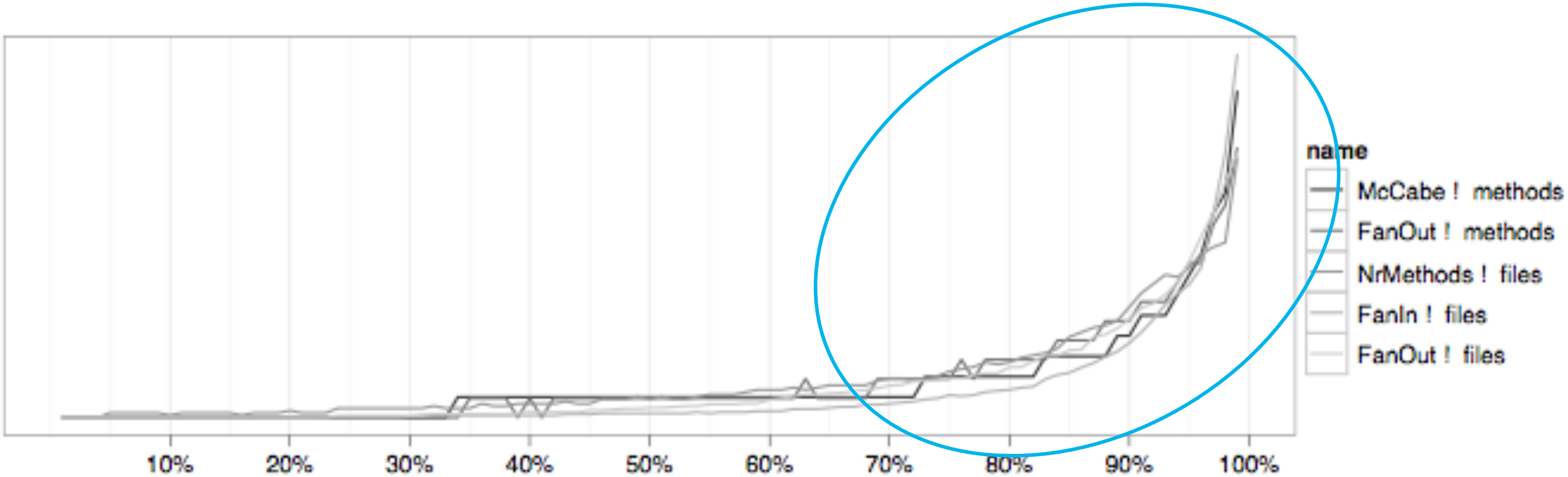
Similar for most source code metrics



SIG Quality Model

Quality profiles

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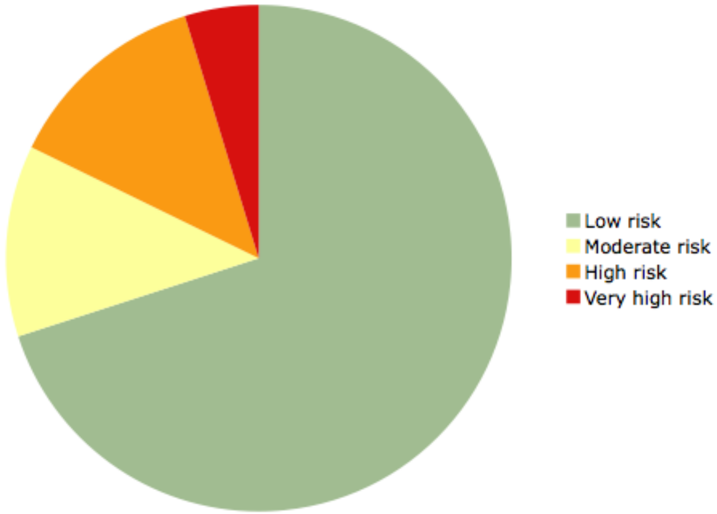
1. Measure source code metrics per method / file / module
2. Summarize distribution of measurement values in "Quality Profiles"



Cyclomatic complexity	Risk category
1 - 10	Low
11 - 20	Moderate
21 - 50	High
> 50	Very high

Sum lines of code per category

Lines of code per risk category			
Low	Moderate	High	Very high
70 %	12 %	13 %	5 %

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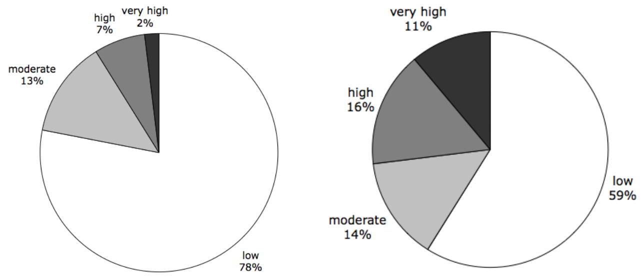
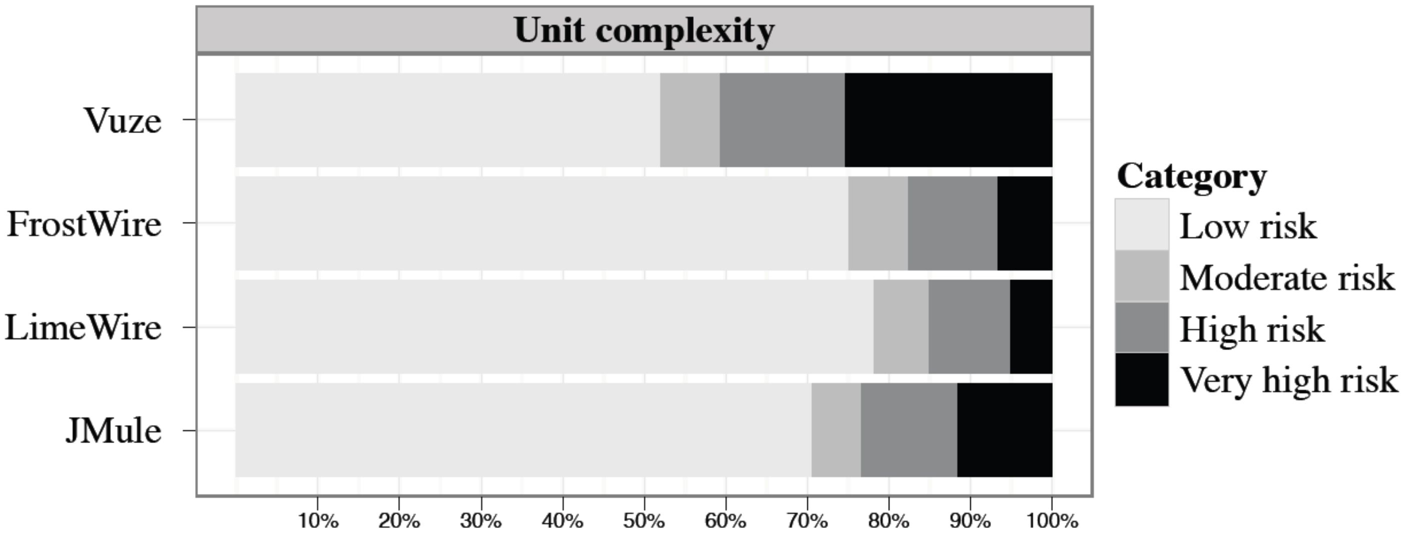
Aggregation by averaging is fundamentally flawed





Quality profiles, in general

Input

- type Input metric = Map item (metric,LOC)

Risk groups

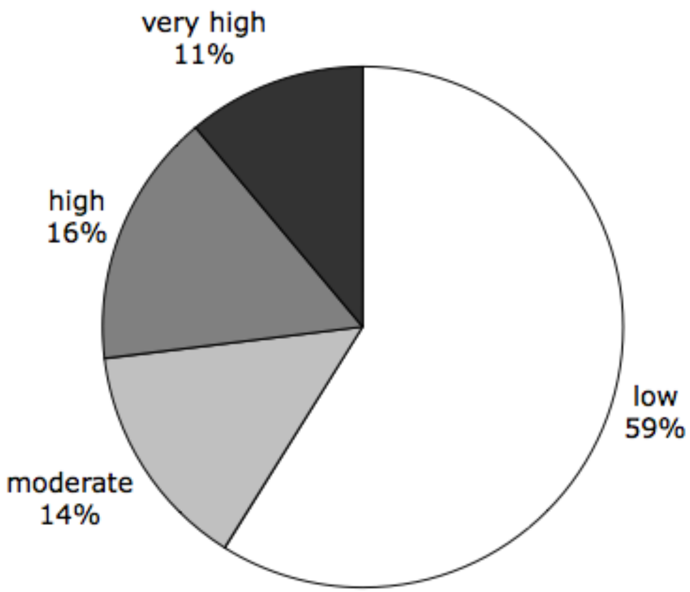
- type Risk = Low | Moderate | High | Very High
- risk :: metric → Risk

Output

- type ProfileAbs = Map Risk LOC
- type Profile = Map Risk Percentage

Aggregation

- profile :: Input metric → Profile



Exercises

Construct quality profile on method level

- Use JavaNCSS to derive LOC, McCabe per file, per method
- Run on your own code, or some OSS project
- Put resulting metrics in a spreadsheet
- Calculate quality profile for McCabe with thresholds 1-10, 11-20, 21-50, 51-..

Establish thresholds for file-level

- What would the risk categories be for file level LOC if we want at most 10% of code in *moderate*, 10% in *high*, and 10% in *very high*?
- Sort files on LOC
- Compute *relative volume* for each file
- Read-off thresholds

SIG Quality Model

How do measurements lead to ratings?

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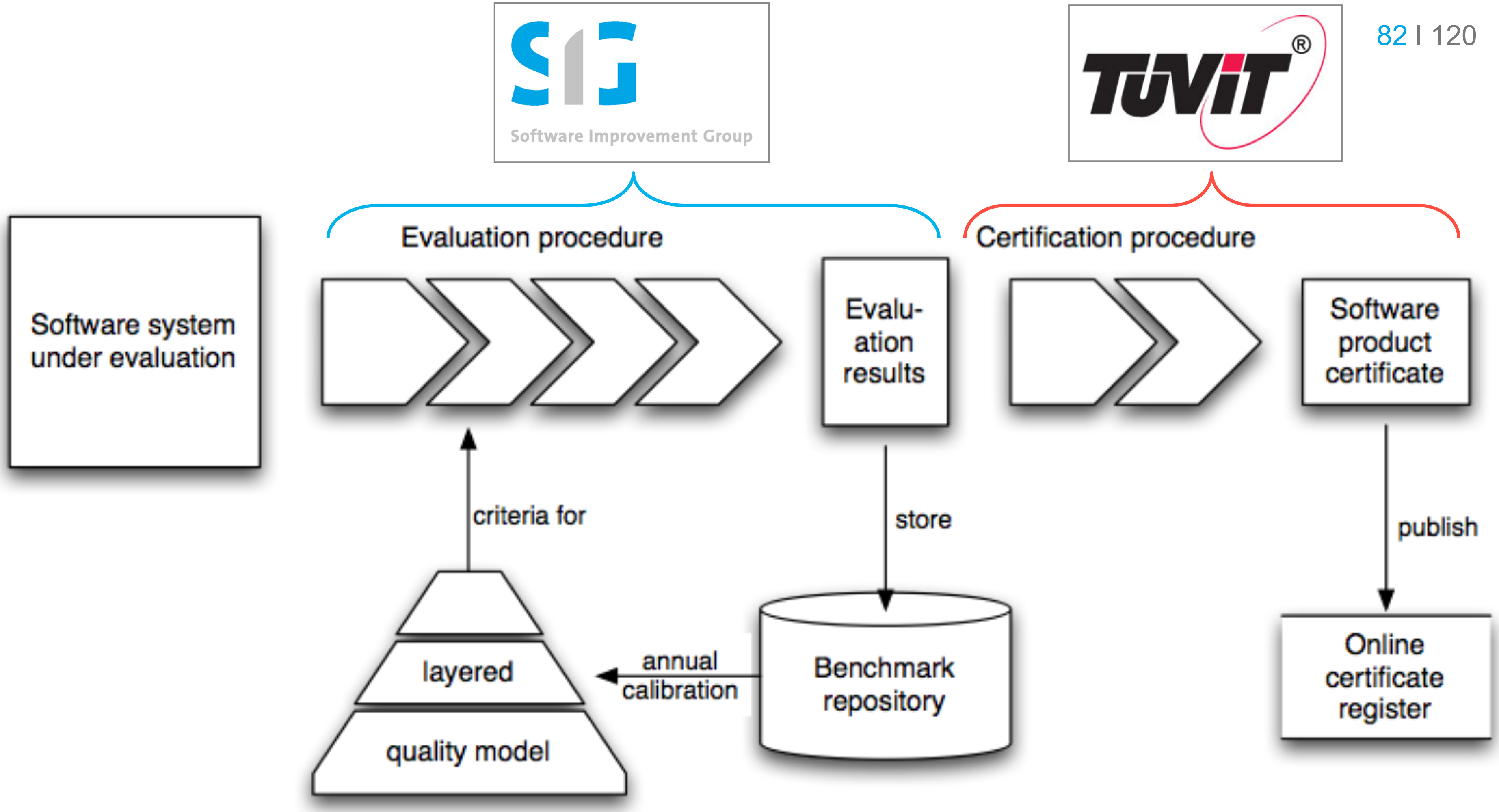
A practical model for measuring maintainability

Heitlager, Kuipers, Visser in QUATIC 2007, IEEE Press

a. Aggregate measurements into "Quality Profiles"
b. Map measurements and quality profiles to ratings for system properties
c. Map ratings for system properties to ratings for ISO/IEC 9126 quality characteristics
d. Map to overall rating of technical quality

SIG Quality Model
Calibration against benchmark



SIG Quality Model
Empirical validation

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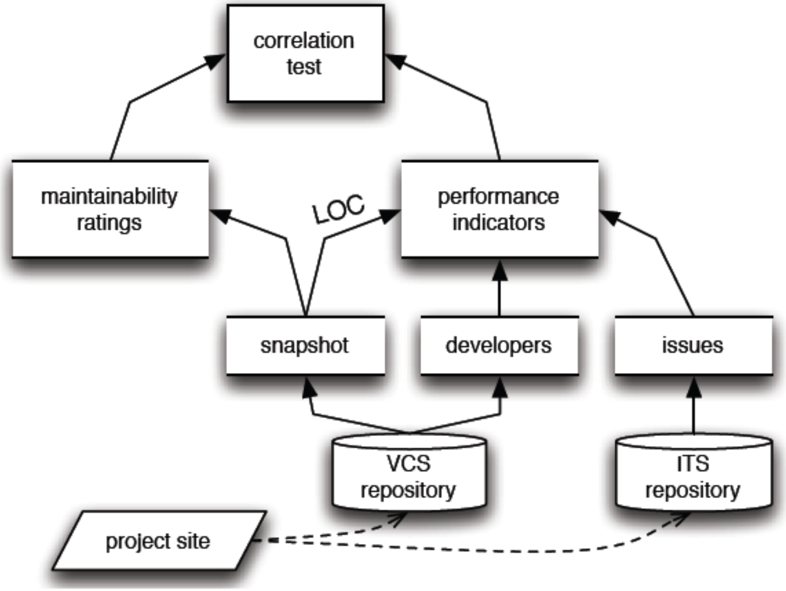
Research

- Data: 16 open source systems (2.5 MLOC)
- Mining issues from issue trackers (50K issues)
- Analyzing source code (150 versions)

- Internal quality: maintainability of source code
- External quality: issue handling

1. Correlation analysis
2. Quantification of impact



- *The Influence of Software Maintainability on Issue Handling*
  MSc thesis, Technical University Delft
- *Indicators of Issue Handling Efficiency and their Relation to Software Maintainability,*
  MSc thesis, University of Amsterdam
- *Faster Defect Resolution with Higher Technical Quality of Software, SQM 2010*

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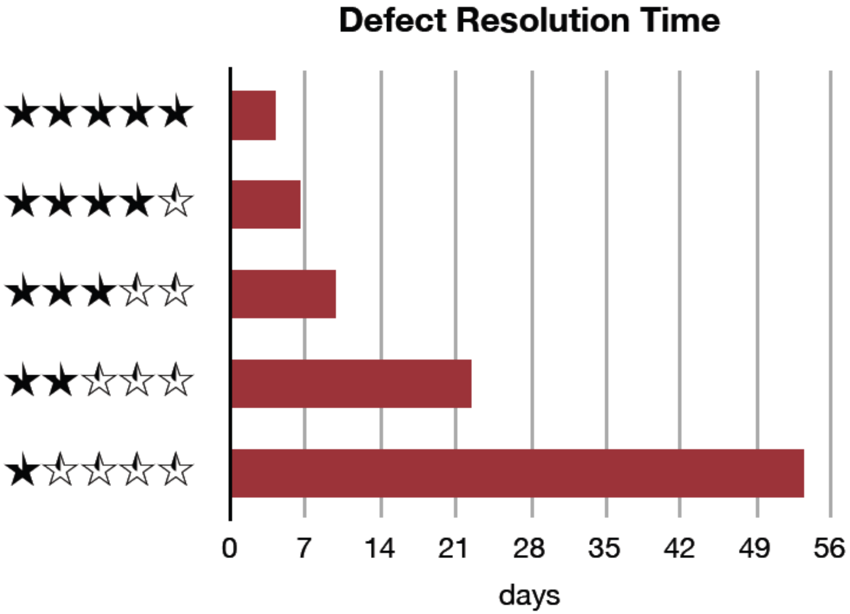
Resolution time for defects and enhancements



- Faster issue resolution with higher quality
- Between 2 stars and 4 stars, resolution speed increases by factors 3.5 and 4.0

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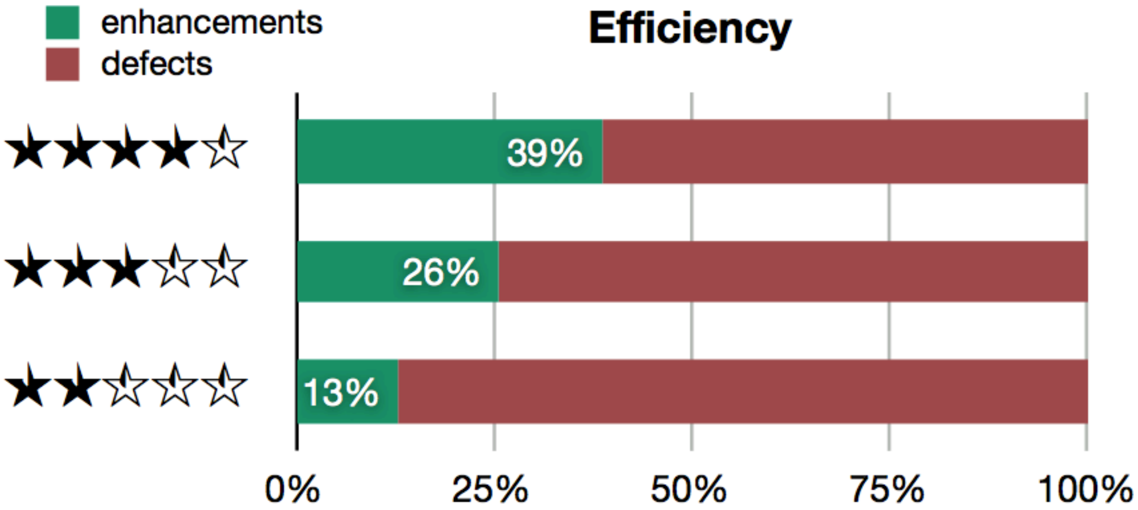
Efficiency (ratio of defects and enhancements)



- More non-corrective maintenance with higher quality
- Efficiency increases with about 13 percent points per quality level

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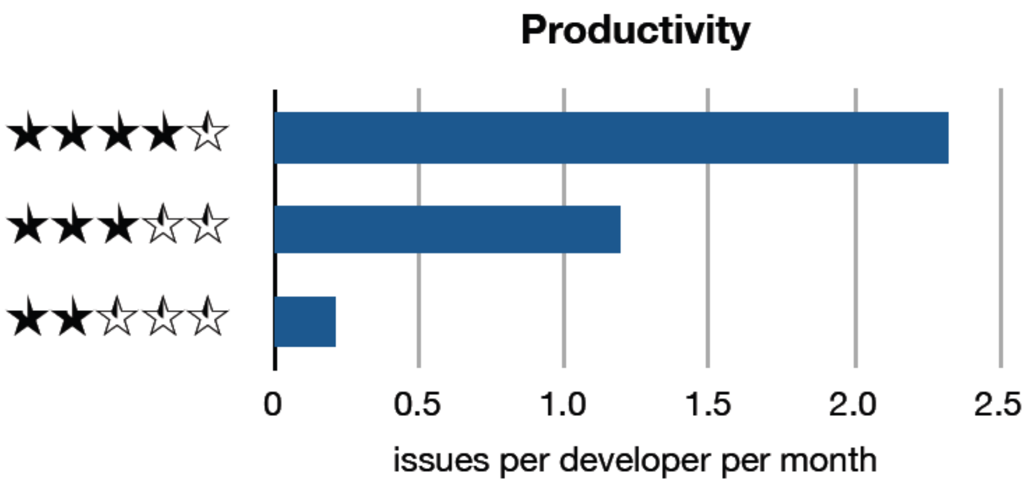
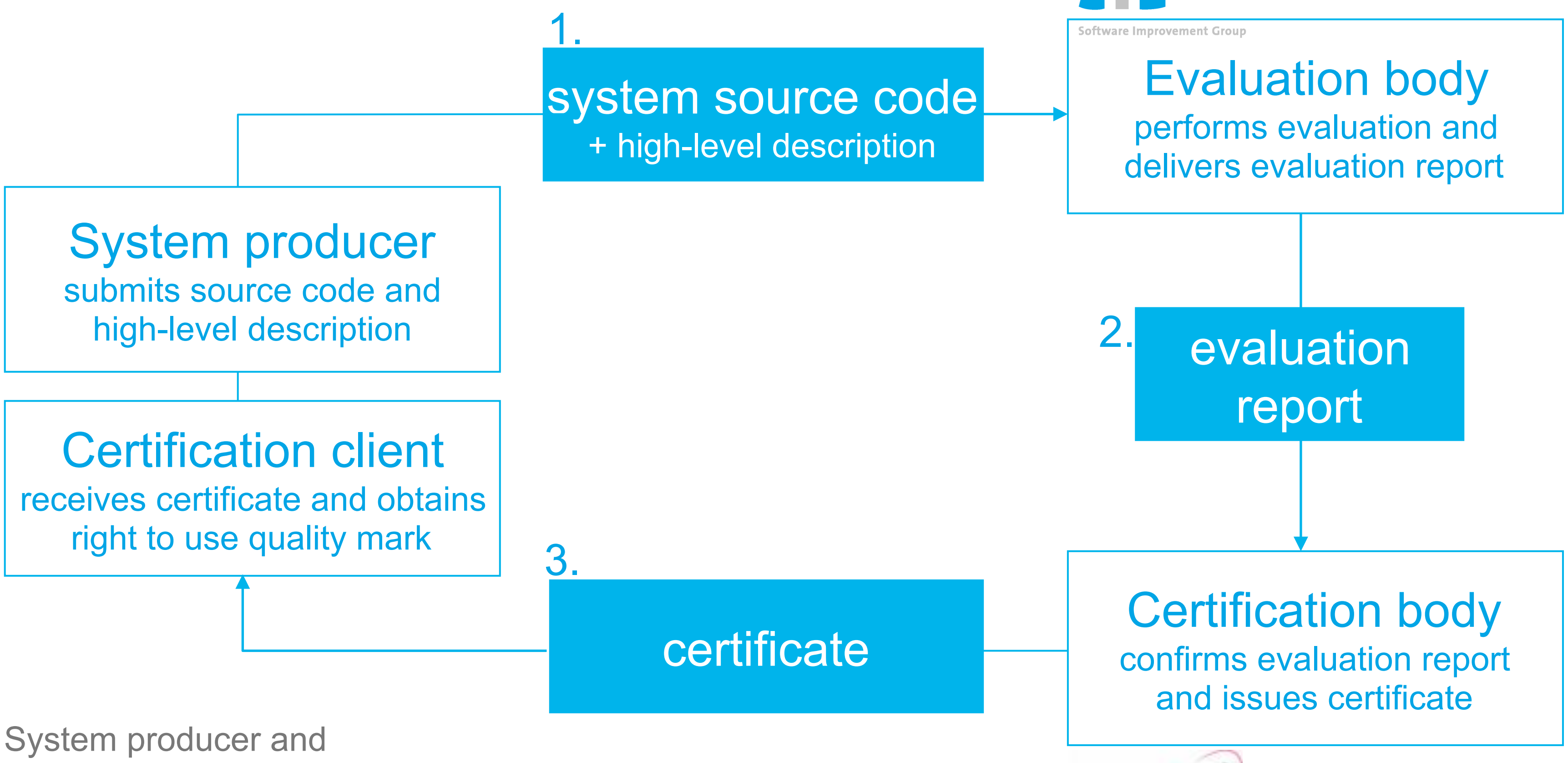
Productivity (resolved issues per developer per month)



- Higher productivity with higher quality
- Between 2 stars and 4 stars, productivity increases by factor 10

Software product certification *by SIG and TÜViT*



System producer and certification client can be the same organization

Evaluation results

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Evaluation report

- Defines scope of the evaluation
- Summarizes measurement results
- Provides ratings (properties, quality, and overall)
- May provide hints for the producer to improve ratings

Certificate

- States conformance to
  SIG/TÜViT Evaluation Criteria
- Confers right to use quality mark
  "TÜViT Trusted Product *Maintainability*"

Main-tainability
TÜViT®
2009 Trusted Product
Voluntary Validation
© 2009 TÜViT GmbH - Member of TÜV NORD Group

Further reading

Software Improvement Group

A pragmatic model for measuring maintainability.
Heitlager, T. Kuipers, J. Visser. QUATIC 2007.

Certification of Technical Quality of Software.
J.P. Correia, J.Visser. OpenCert 2008.

Mapping System Properties to ISO/IEC 9126 Maintainability Characteristics
J.P. Correia, Y. Kanellopoulos, J.Visser. SQM 2009.

Software Risk Assessment service

Assignment

- "Can we scale from 100 to 100,000 customers?"
- "Should we accept delay and cost overrun, or cancel the project?"

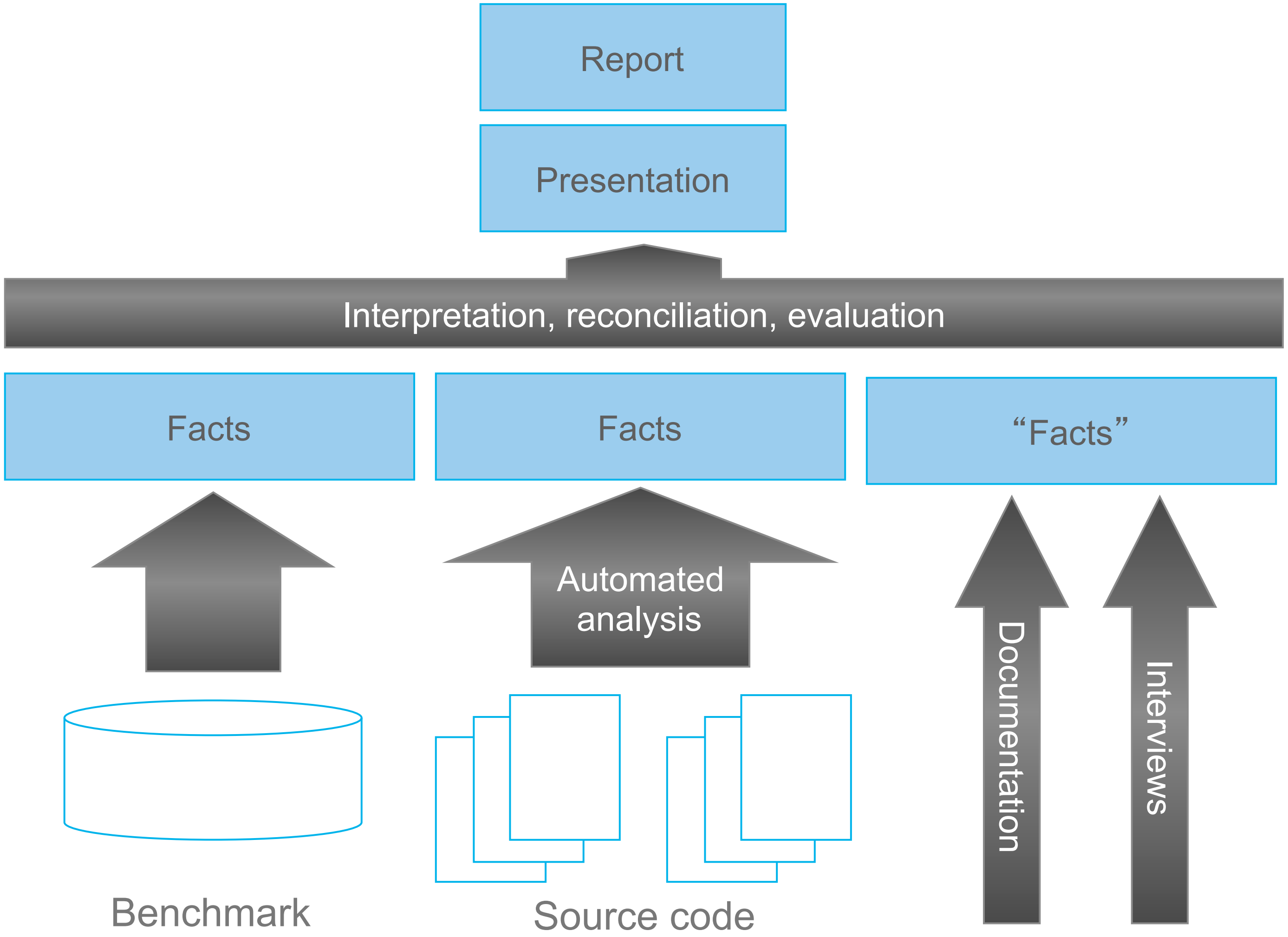
Analysis

- Source code: understanding (reverse engineering) + evaluation (quality)
- Interviews: technical + strategic

Reporting

- Quality judgment using star ratings
- Risk analysis putting quality findings in business perspective
- Recommendations to mitigate risks

Software Risk Assessment



Software Risk Assessment
Example: stagnation before go-live

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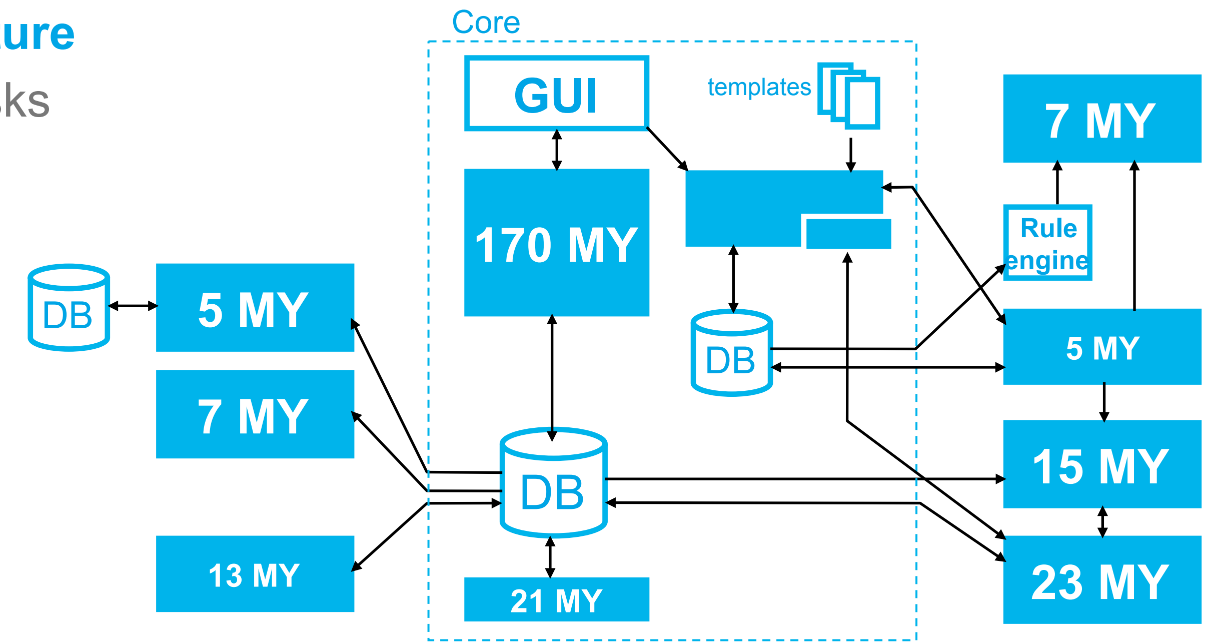
Internal architecture

- Technology risks
- Rebuild value
- Quality



Results

- Insurmountable stability issues, untestable, excessive maintenance burden
- Now: reduce technical complexity, partially automate deployment
- Start planning replacement

Software Monitoring service

Software Improvement Group

Quality roadmap

- "complexity from 2 to 4 stars by 3rd month" in maintenance project
- "final product shall be 4 stars" in development project

Dashboard

- Regular analysis of source code typically once per week
- Shown on dashboard with overviews and drill down possibilities

Consultancy

- Regular reports (presentation and/or written)
- Guard quality agreements, meet quality targets.
- Identify risks and opportunities

Software Monitor
Dashboard

Software Improvement Group

Software Monitor - sig-java

Home | Metrics table | Explanation of metrics | Compare snapshots | Violations | SRA dashboard

	Lines of code /java	McCabe complexity /java	Nr. of methods /java	Nr. of methods /javatest	Nr. of classes /java	Number of asserts /javatest	Severe violations /java
Analyses	99,422	18,146	11,849	8,933	2,101	23,037	6
Monitor	4,206	807	545	408	73	888	5
Monitor2	8,996	1,546	976	570	124	2,095	0
Networks	9,498	1,317	809	282	141	448	24
PLSqlAnalyses	10,587	2,017	1,395	989	183	2,275	6
StudentAnalyses	2,904	505	294	58	63	98	2
Utils	22,977	5,412	3,418	1,361	351	4,711	8
docgen	74,029	14,543	10,992	3,457	1,368	11,183	46

	Nr. of catch blocks /java	Illegal catches /java	Lines /config	Code churn /java	File churn /java
Analyses	232	3	2,746	781	54
Monitor	13	3	34,574	0	0
Monitor2	58	0	43,585	363	11
Networks	50	12	49,776	296	8
PLSqlAnalyses	18	3	238	0	0
StudentAnalyses	18	1	463	232	4
Utils	71	6	1,716	206	9
docgen	134	26	693	29	4

Method length /java | Complexity /java

Top 5 Most complex units /All	
StatementExtractorParse.setEnd(int)	40
StatementExtractorParse.setStart(int)	37
DateConverter.determineMonthNumber(String)	34
QueueMaker.processArgs(String[])	23
CommentRemoverUtils.handleStatusWith(char,char,char)	19

Top 5 Biggest files /All	
PerformGraphTest.java	4,659
Monitor2SqlDaoTest.java	4,155
CobolModelTest.java	3,337
CallGraphMakerTest.java	3,041
MdxAggFactsTableCreatorTest.java	2,173

Top 5 Biggest units /All	
CodeBlockParserTest.testRealCode()	1,267
McCabeCounterTest.testRealCode()	1,208
SybaseParserTest.testFile()	536
software_improvers.util.SQLUtils.$block1	420
LOCMethodsTest.testClientFileHandlers()	401

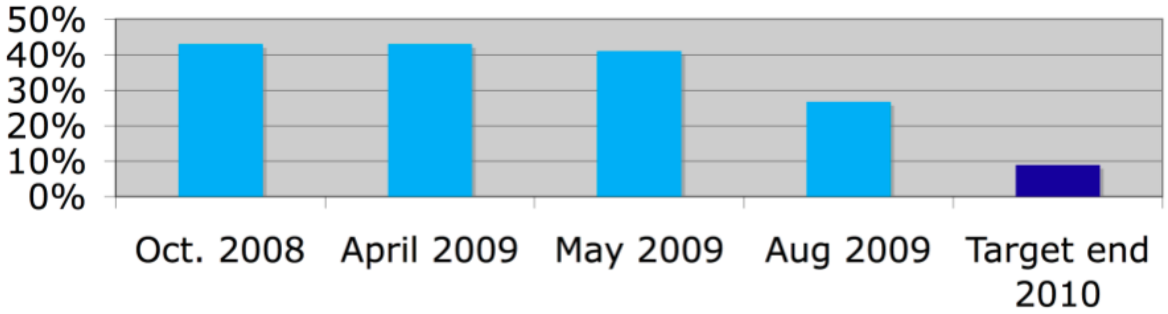
Top 5 Biggest duplicates /java

Top 5 Most frequently changed files /All

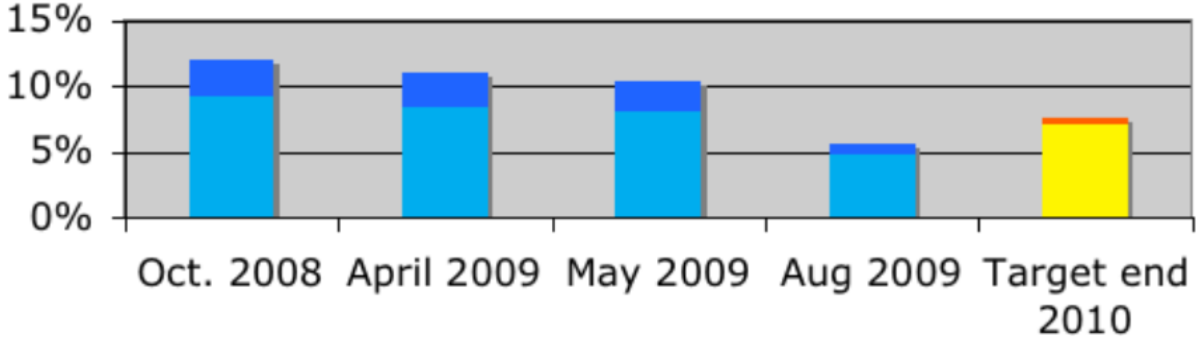
Top 5 Method fan-in /All

Software Monitor
Example: vendor management and roadmap

Duplication



Complexity



From client testimonial:

- "Technical quality: as it improves adding functionality is made easier"
- "As quality was increasing, productivity was going up"

What should you remember (so far) from this lecture?

Software Improvement Group

Testing

- Automated unit testing!

Patterns

- Run tools!

Quality and metrics

- Technical quality matters in the long run
- A few simple metrics are sufficient
- If aggregated in well-chosen, meaningful ways
- The simultaneous use of distinct metrics allows zooming in on root causes