UNIVERSITÄT BERN

Software Metrics and Problem Detection

Mircea Lungu

Roadmap

- **Measurements**
- Software Metrics
  - Size / Complexity Metrics
  - Quality Metrics
  - Schedule / Cost
- Metric-Based Problem Detection
  - Detecting Outliers
  - Encoding Design Problems
- Discussion

Measurements

Estimation of quantity owes its existence to Measurement
Calculation to Estimation of quantity
Balancing of chances to Calculation
and Victory to Balancing of chances.

Measurements

A measurement is a mapping

- domain
- range
- rules

A measure is a numerical value or a symbol assigned during mapping

In Software:
measurements = **metrics**

*Estimation of quantity owes its existence to Measurement
Calculation to Estimation of quantity
Balancing of chances to Calculation
and Victory to Balancing of chances.*

Measurement Scales

- > Nominal
- > Ordinal
- > Interval
- > Ratio
- > Absolute

- > Analysis should take scales into account!!

Estimation of quantity owes its existence to Measurement
Calculation to Estimation of quantity
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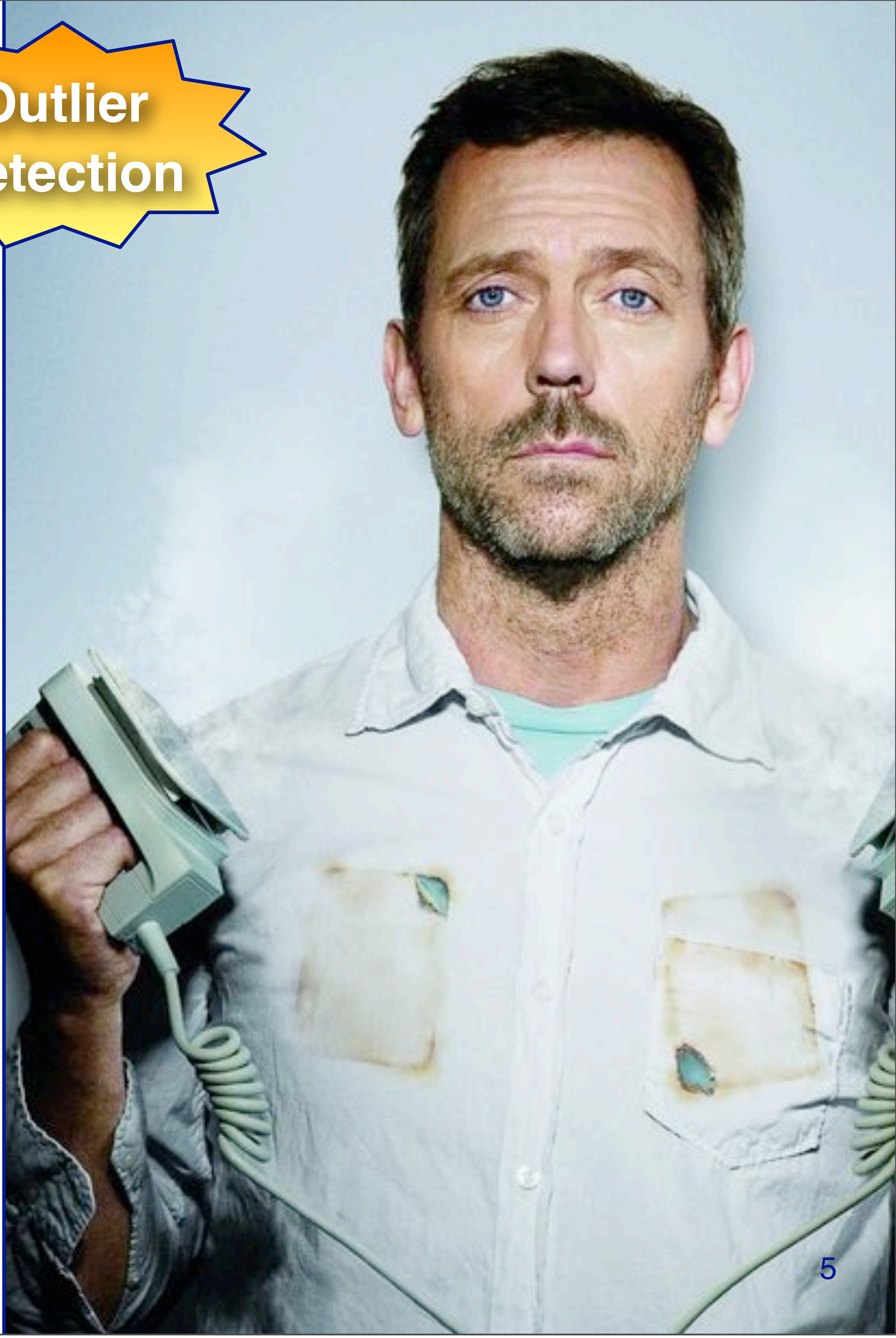
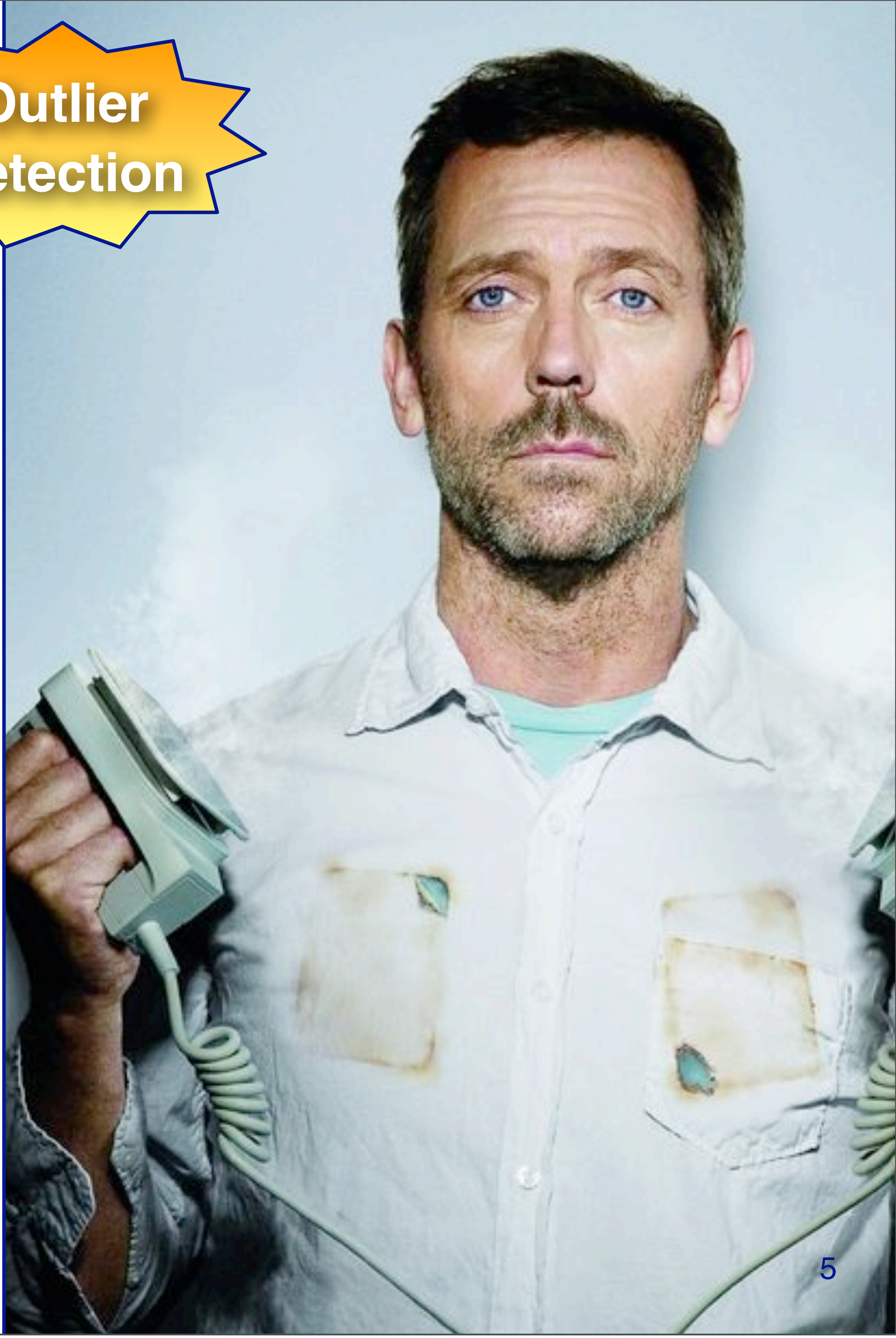
Outlier Detection



Medical Markers are used in diagnositcs based on statistical data

Outlier Detection

> Potassium Levels
> Red Blood Cell Count
> Glucose Levels
> etc.



- What do you do when you want to digitize and make public 5 million books but can not because of copyright?

Synthesis

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Google Measures N-gram Frequencies

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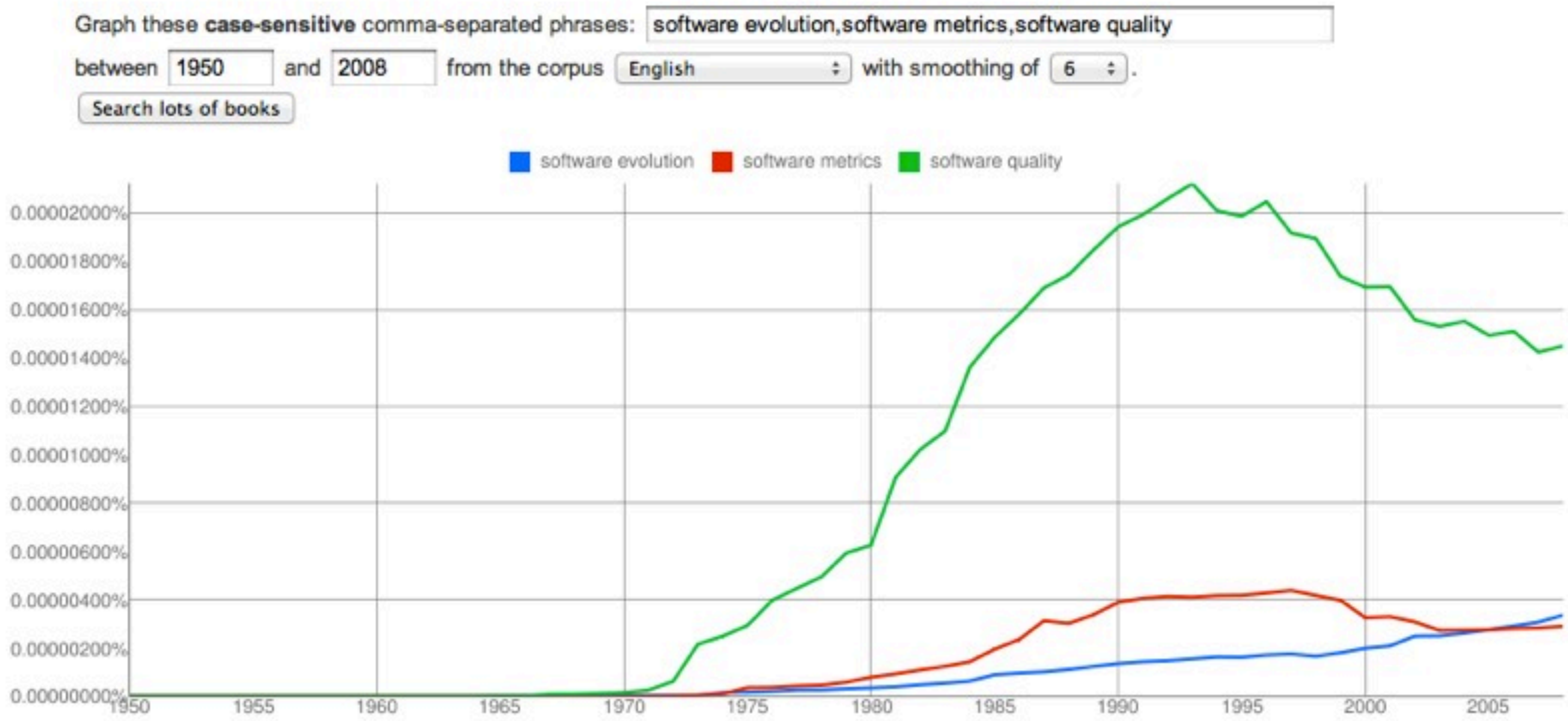

Graph these **case-sensitive** comma-separated phrases: software evolution,software metrics,software quality

between 1950 and 2008 from the corpus English with smoothing of 6.

Search lots of books

Can you assess unknown code without reading it?

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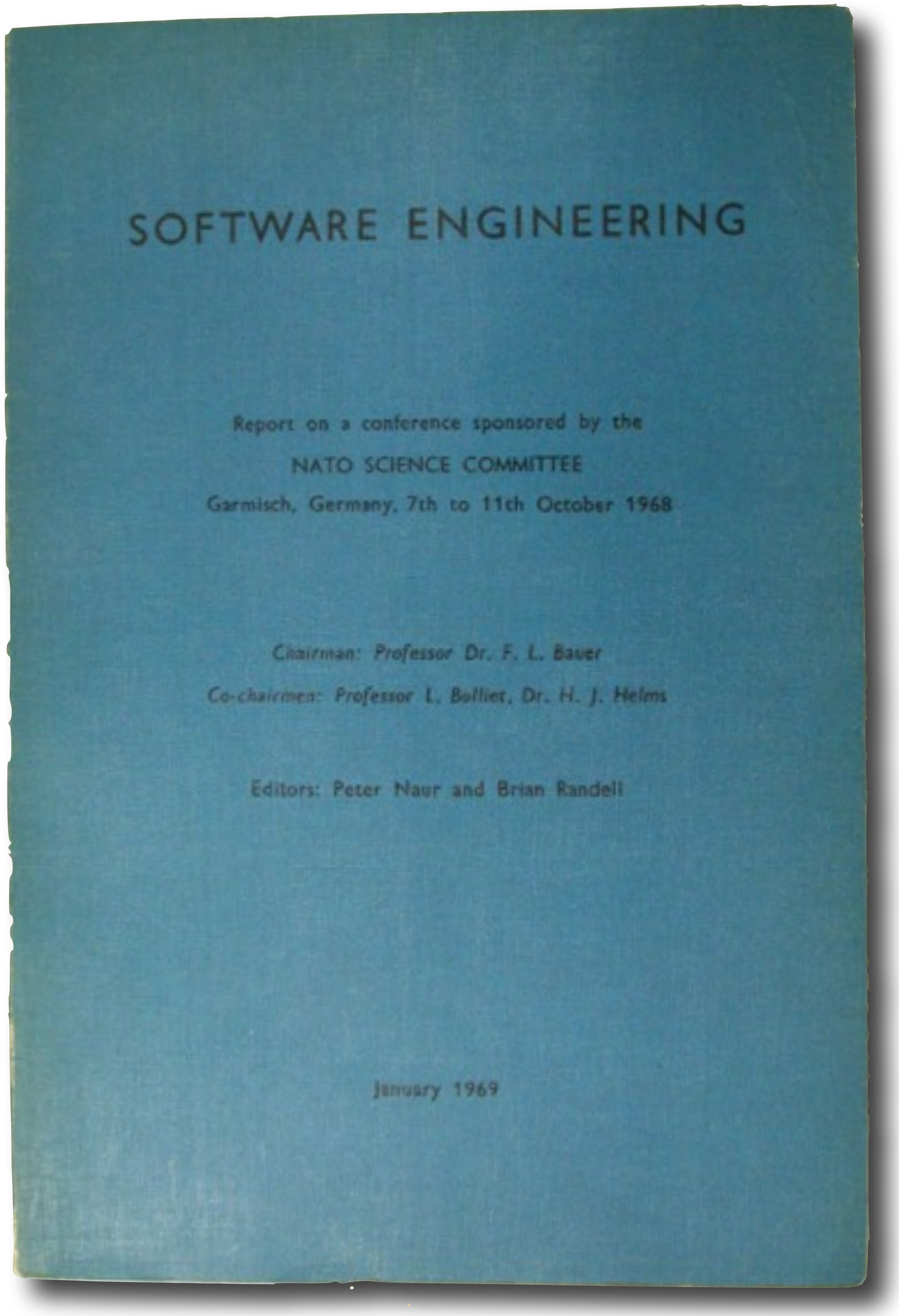

SOFTWARE ENGINEERING

Report on a conference sponsored by the

NATO SCIENCE COMMITTEE

Garmisch, Germany, 7th to 11th October 1968

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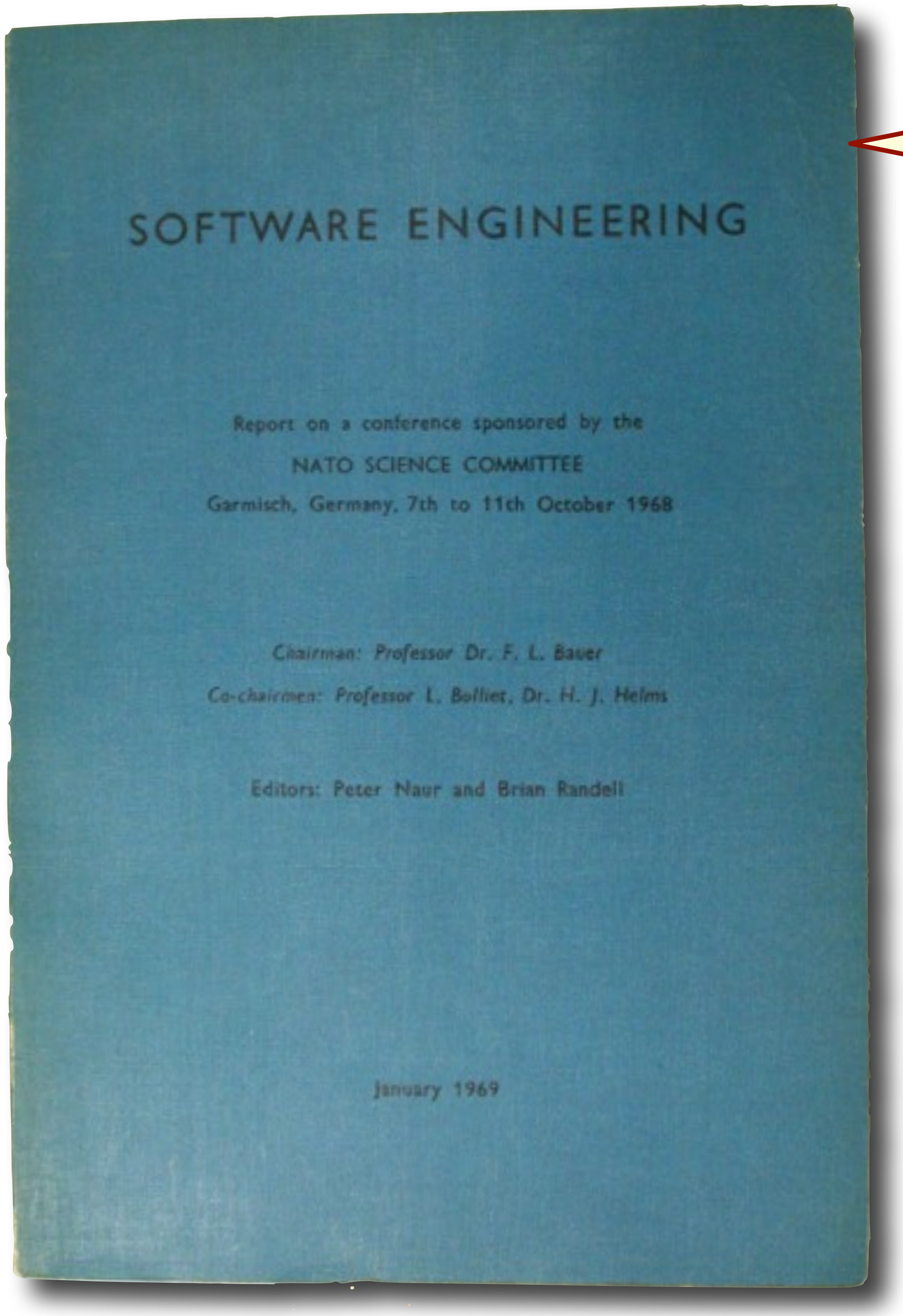
Editors: Peter Naur and Brian Randell

January 1969



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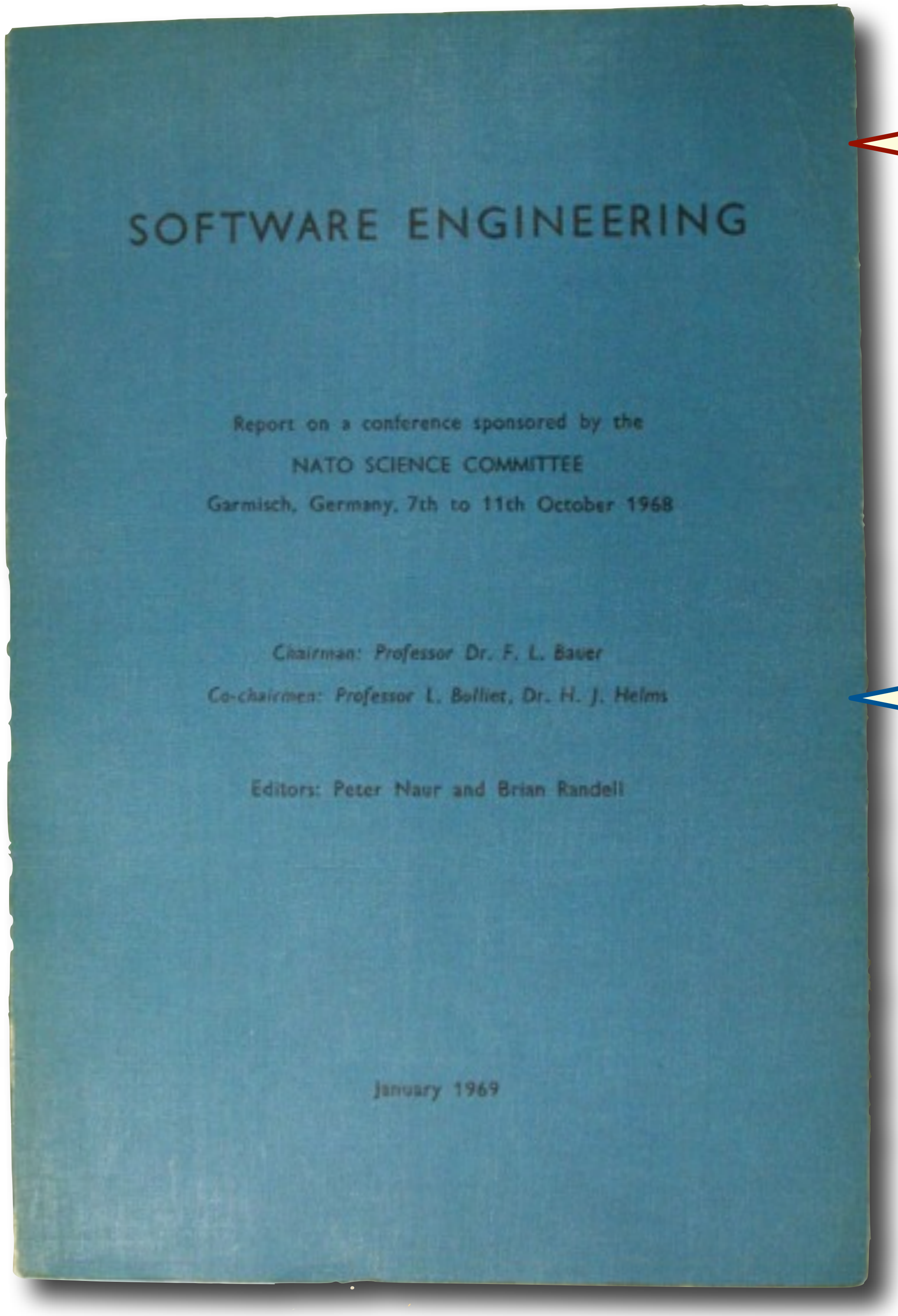
Fraser:
One of the problems that is central to the software production process is to identify the nature of progress and **to find some way of measuring it**.



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One of the problems that is central to the software production process is to identify the nature of progress and **to find some way of measuring it**.

McIlroy:
In programming efforts [...] clarity and style seem to count for nothing — the only thing that counts is whether the program works when put in place. It seems to me that it is important that we should **impose these types of aesthetic standards**.

Roadmap

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The Measurement Process

Targets without clear goals will not achieve their goals clearly.

Gilb’s Principle

The Measurement Process

The Goal-Question-Metric model proposes three steps to finding the correct metrics.

(Victor Basili)

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(Victor Basili)

Targets without clear goals will not achieve their goals clearly.

Gilb's Principle

1) Establish the **goals** of your maintenance or development project.

2) Derive, for each goal, **questions** that allow you to verify its accomplishment.

3) Find what should be **measured** in order to quantify the answer to the questions.

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Size Measures

LOC

NOM

NOA

NOC

NOP

... etc.

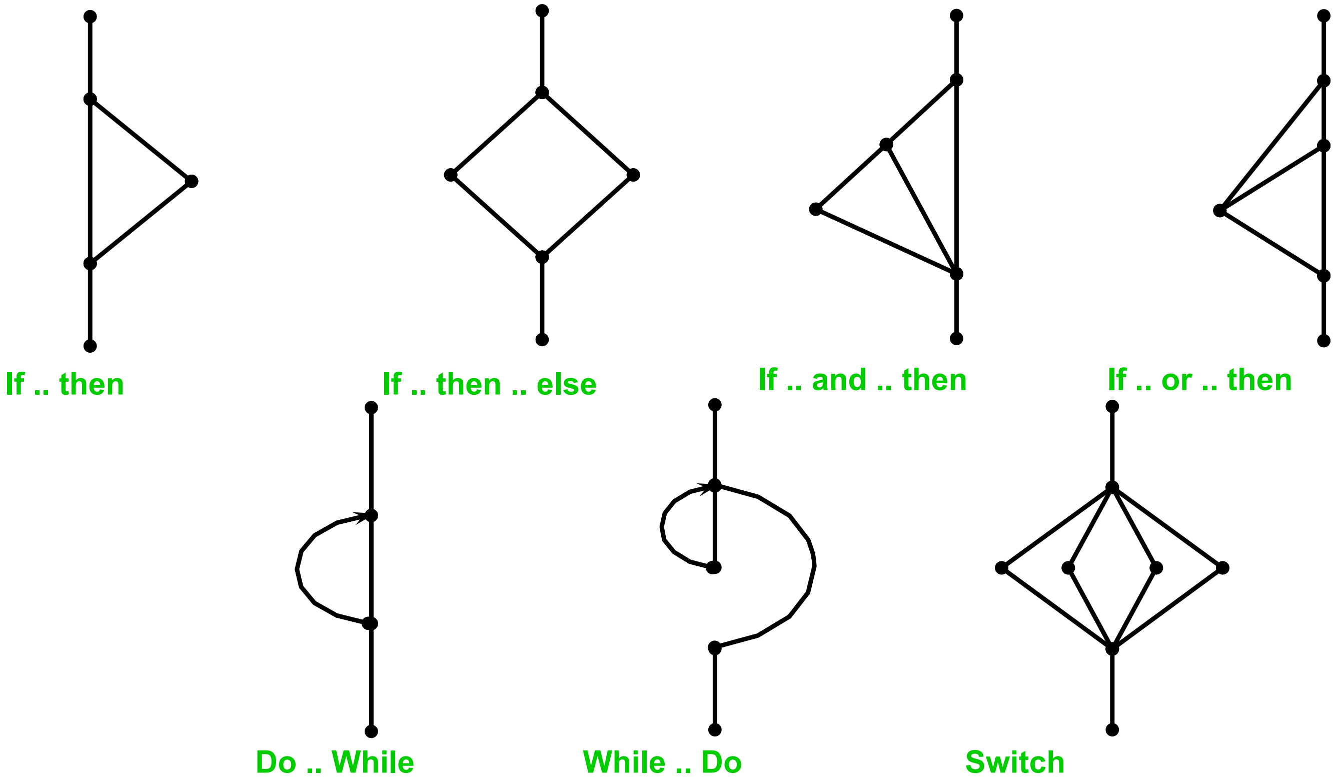
Lorenz, Kidd, 1994
Chidamber, Kemerer, 1994

Cyclomatic Complexity (CYCLO)

The number of independent linear paths through a program.

(McCabe ’77)

+ Measures minimum effort for testing



Weighted Methods per Class (WMC)

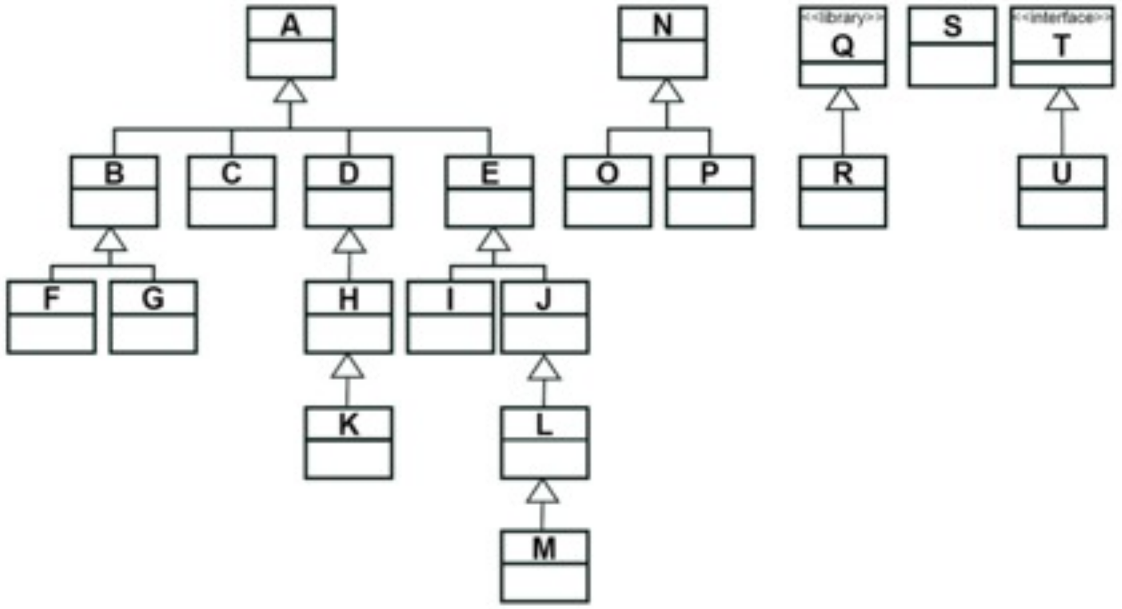
The complexity of a class by summing the complexity of its methods, usually using CYCLO.

(Chidamber & Kemerer ’94)

Synthesis

+ A proxy for the time and effort required to maintain a class

Depth of Inheritance Tree (DIT)

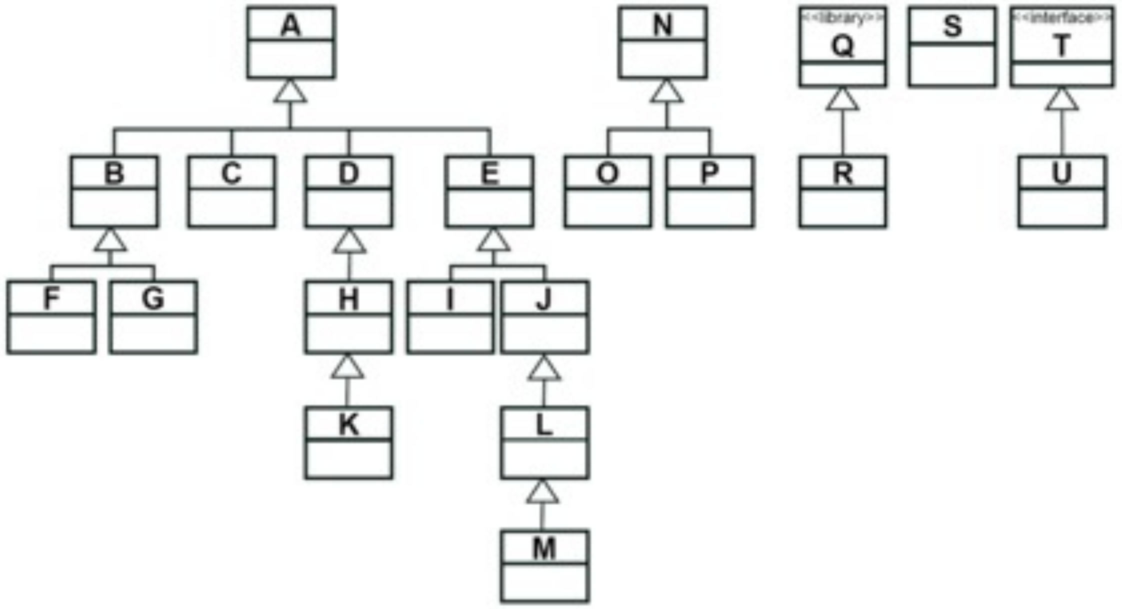


Depth of Inheritance Tree (DIT)

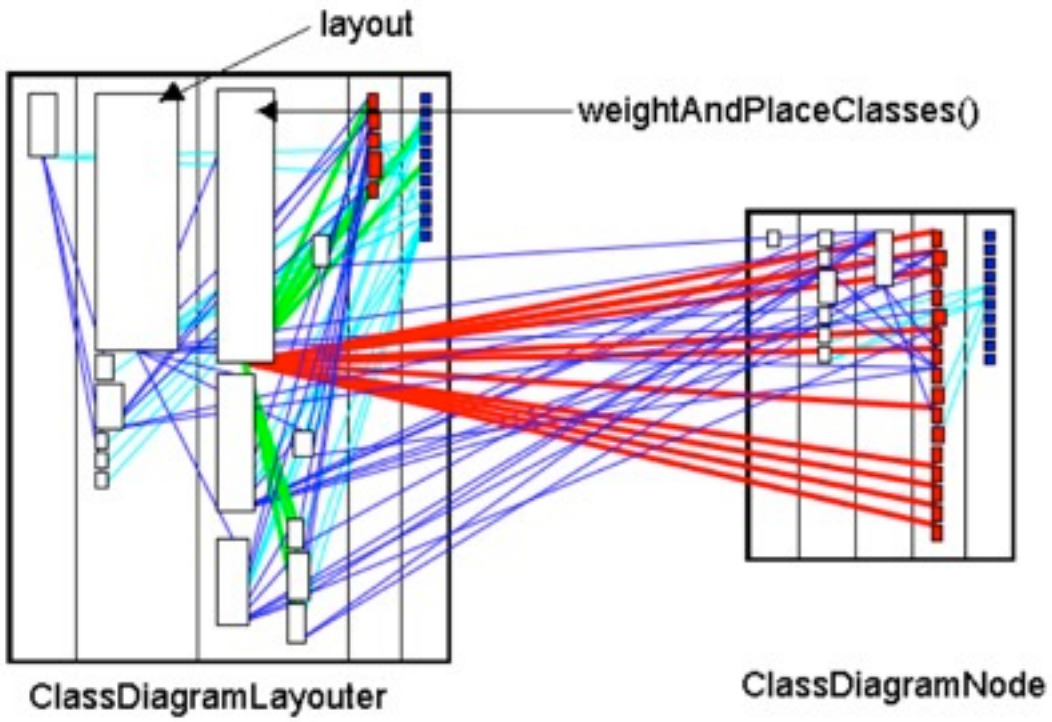
The maximum depth level of a class in a hierarchy.

(Chidamber & Kemerer ’94)

+ Inheritance depth is a good proxy for complexity



Access To Foreign Data (ATFD)



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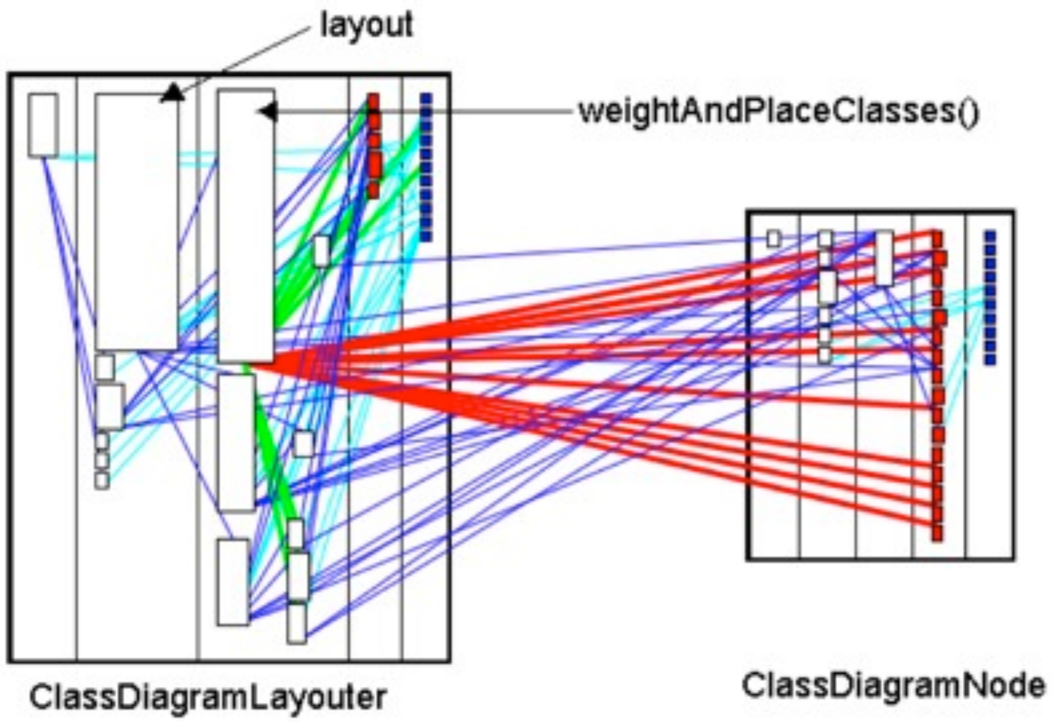
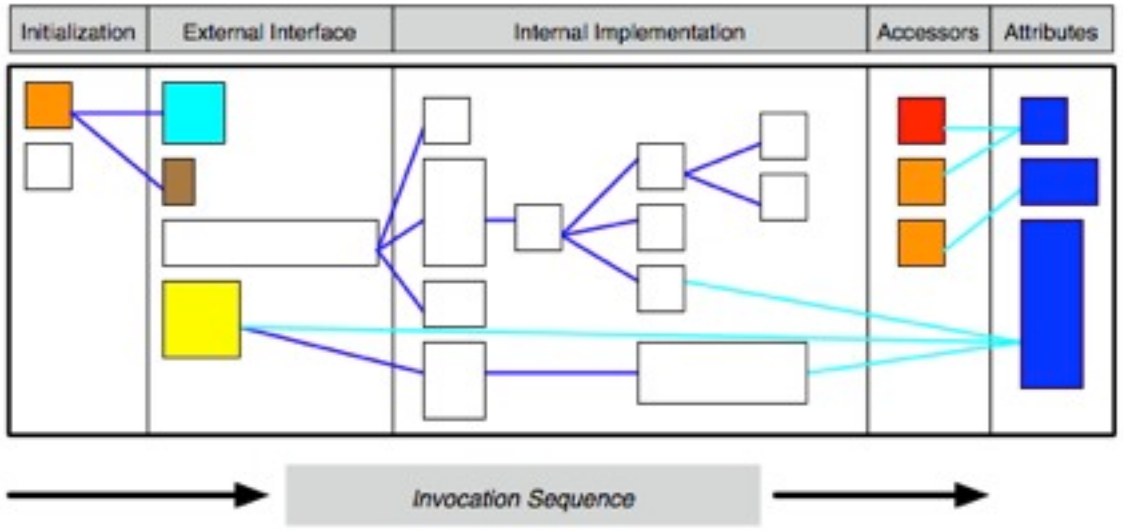
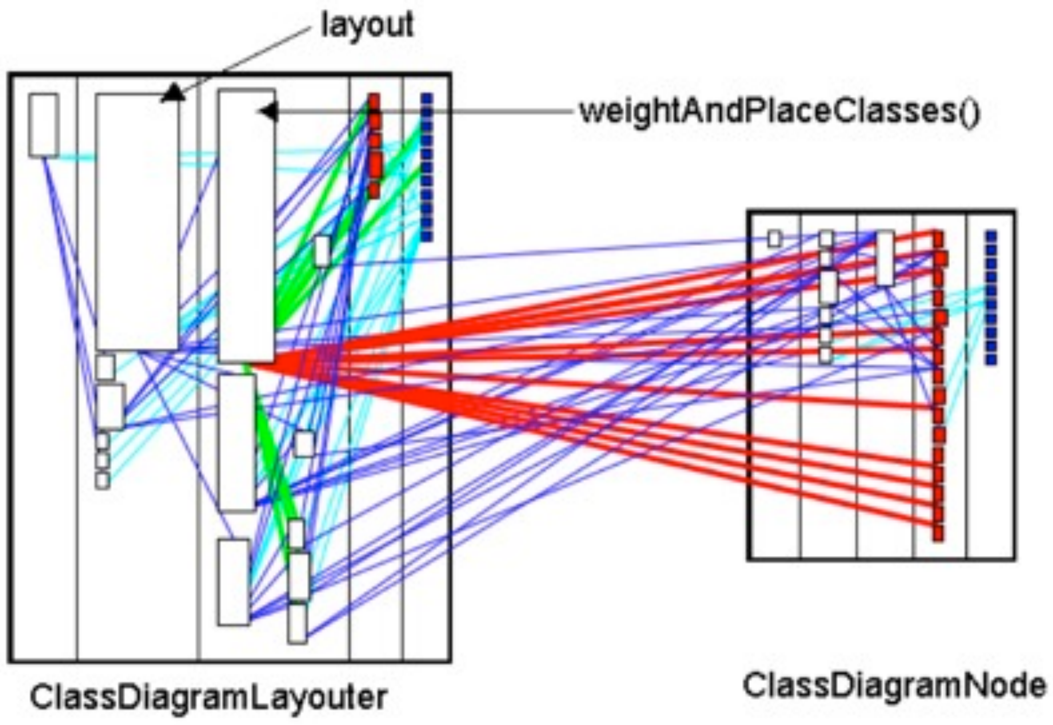




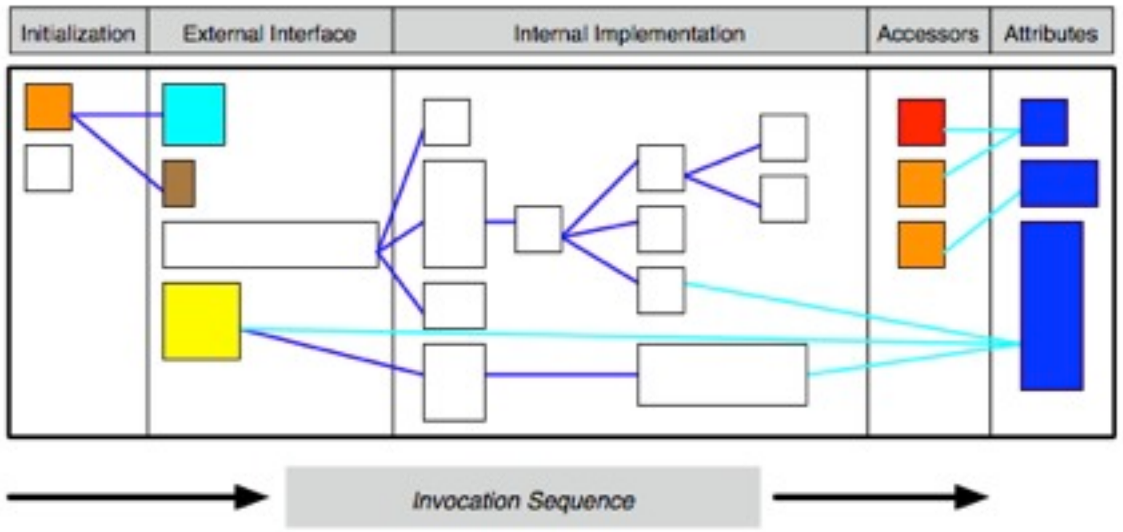
Access To Foreign Data (ATFD)

ATFD counts how many attributes from other classes are accessed directly from a given class.

(Lanza & Marinescu ’06)



+ ATFD summarizes the interaction of a class with its environment



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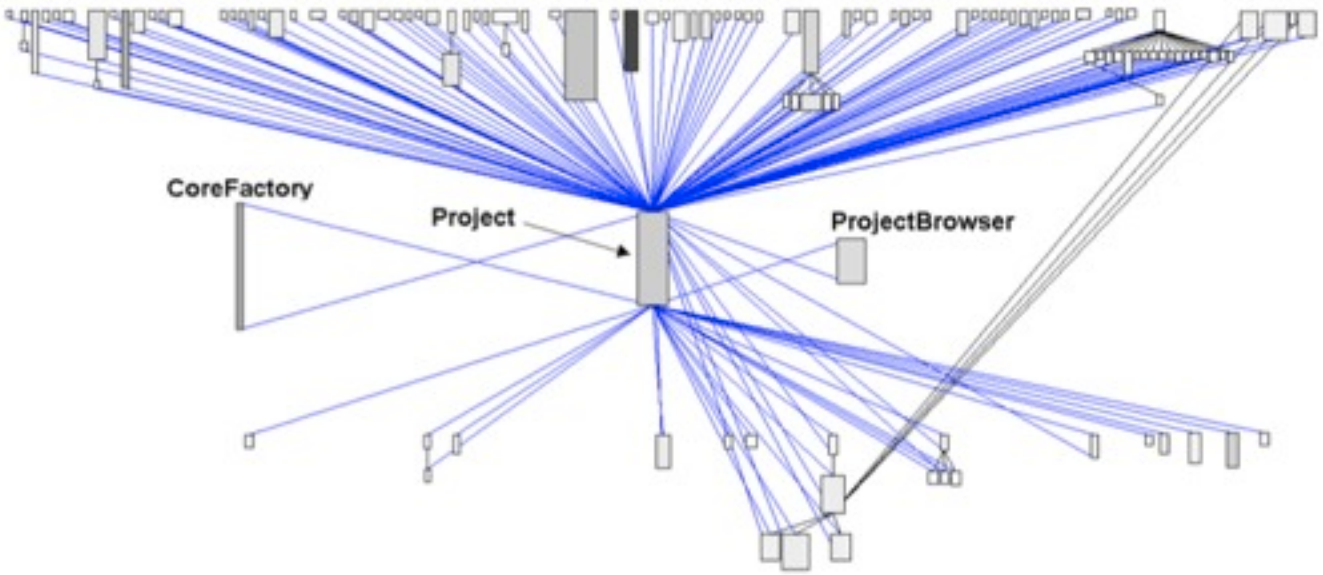
Coupling Between Object Classes (CBO)

CBO for a class is the number of other classes to which it is coupled.

(Chidamber & Kemerer ’94)



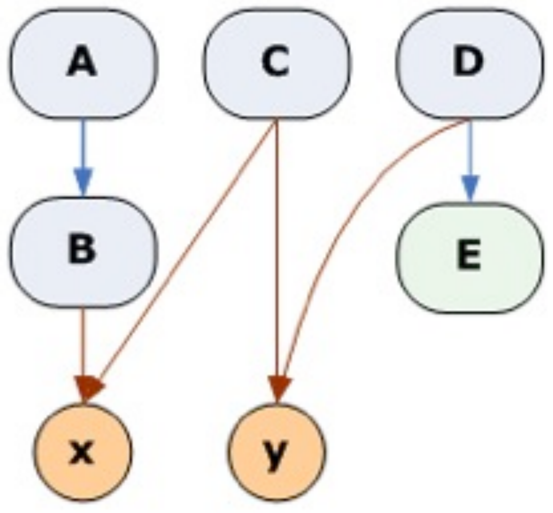
+ Meant to assess modular design and reuse

Tight Class Cohesion (TCC)

TCC counts the relative number of method-pairs that access attributes of the class in common.

(Bieman & Kang, 95)

+ Can lead to improvement action



TCC = 2 / 10 = 0.2

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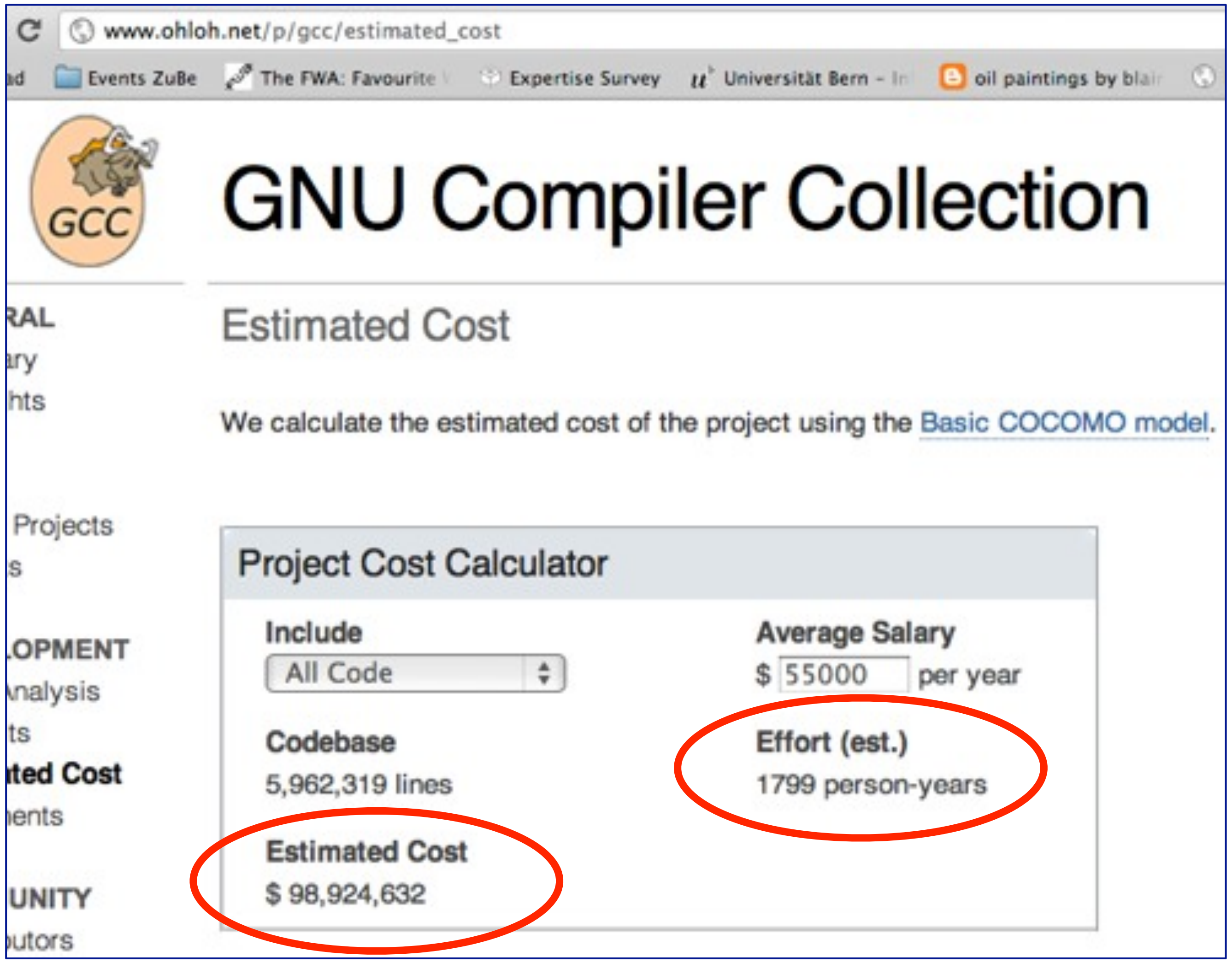


GNU Compiler Collection

Estimated Cost

We calculate the estimated cost of the project using the Basic COCOMO model.

Project Cost Calculator

Include
All Code

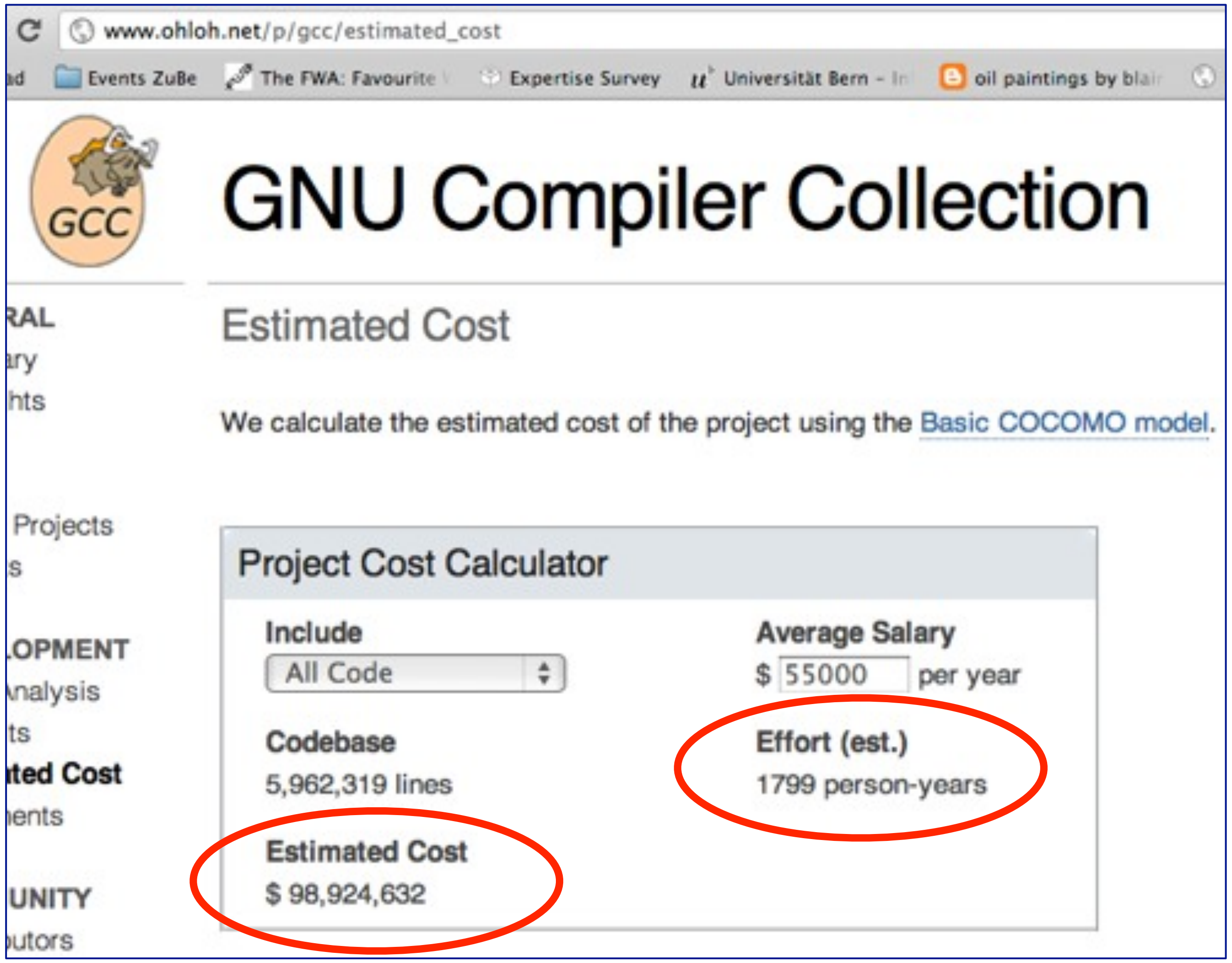
Average Salary
$ 55000 per year

Codebase
5,962,319 lines

Effort (est.)
1799 person-years

Estimated Cost
$ 98,924,632

Man-Month/Year



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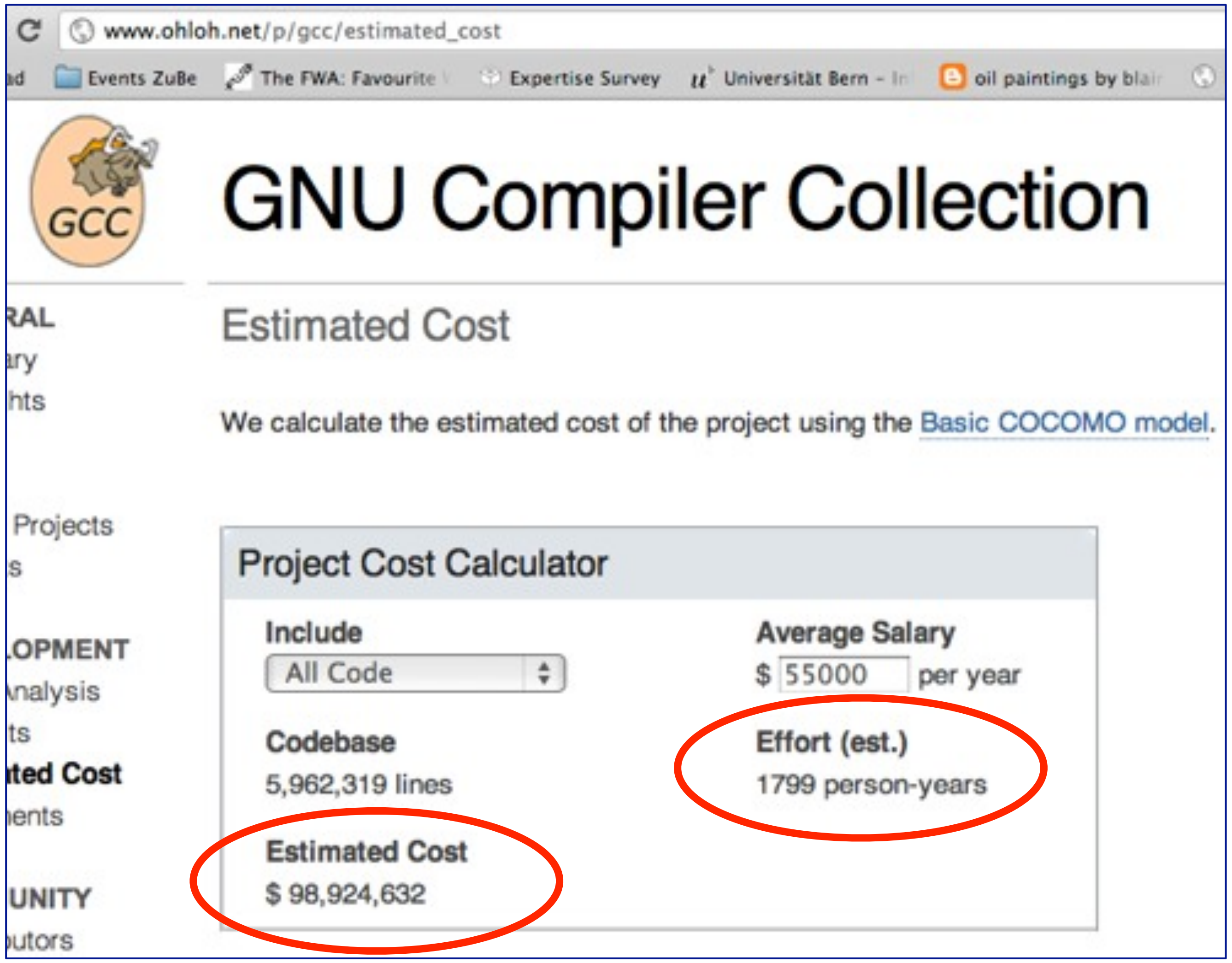
Estimated Cost: $ 98,924,632

Man-Month/Year

The amount of work performed by an average developer in a month/year.



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Function Point (FP)

FP is a unit of measurement to express the amount of functionality an information system provides to a user.

- Risks hiding the internal functions (algorithms)

By star5112

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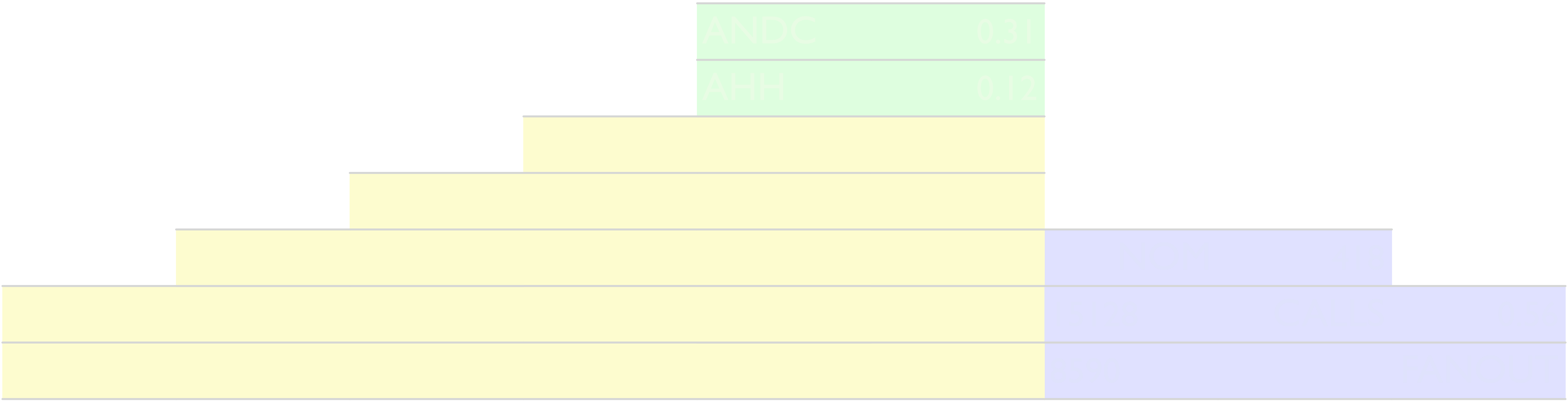
The Overview Pyramid provides a metrics overview.

Lanza, Marinescu
2006

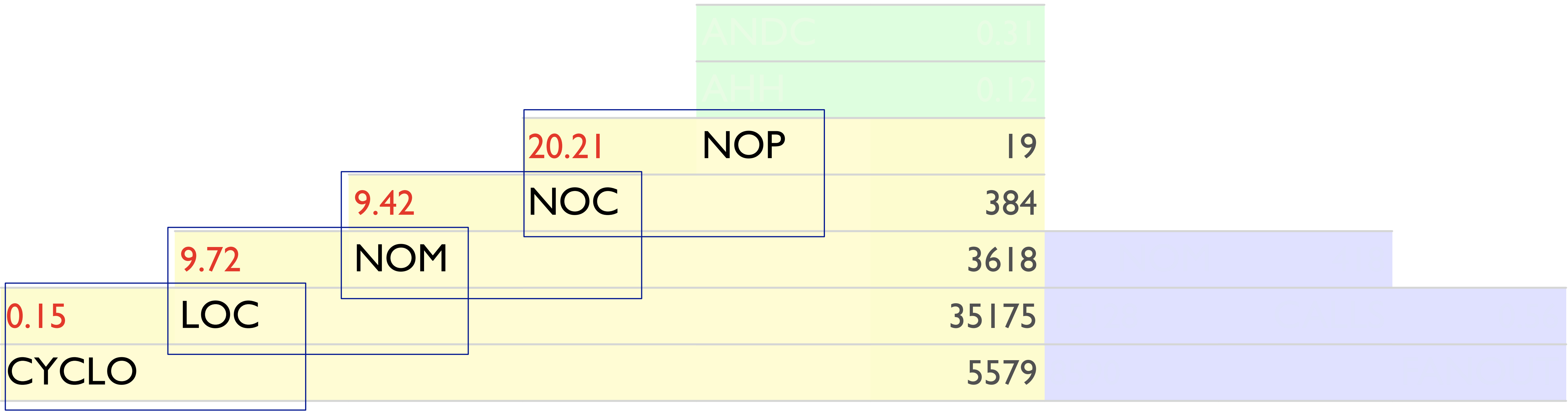
Inheritance



Size

Communication

The Overview Pyramid provides a metrics overview.



	ANDC	0.31
	AHH	0.12
20.21	NOP	19
9.42	NOC	384
9.72	NOM	3618
0.15	LOC	35175
	CYCLO	5579

Size

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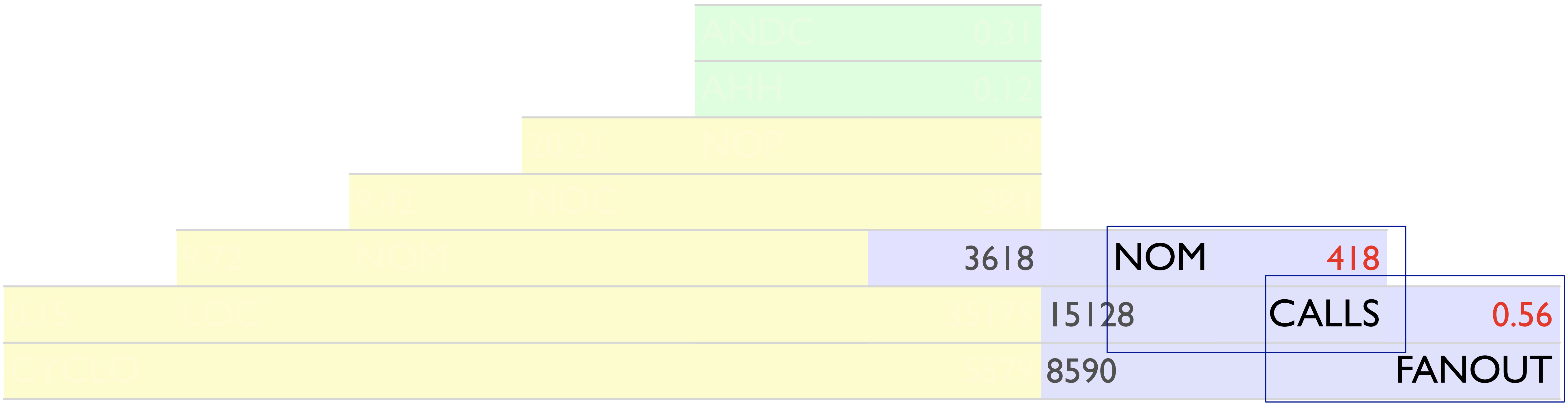

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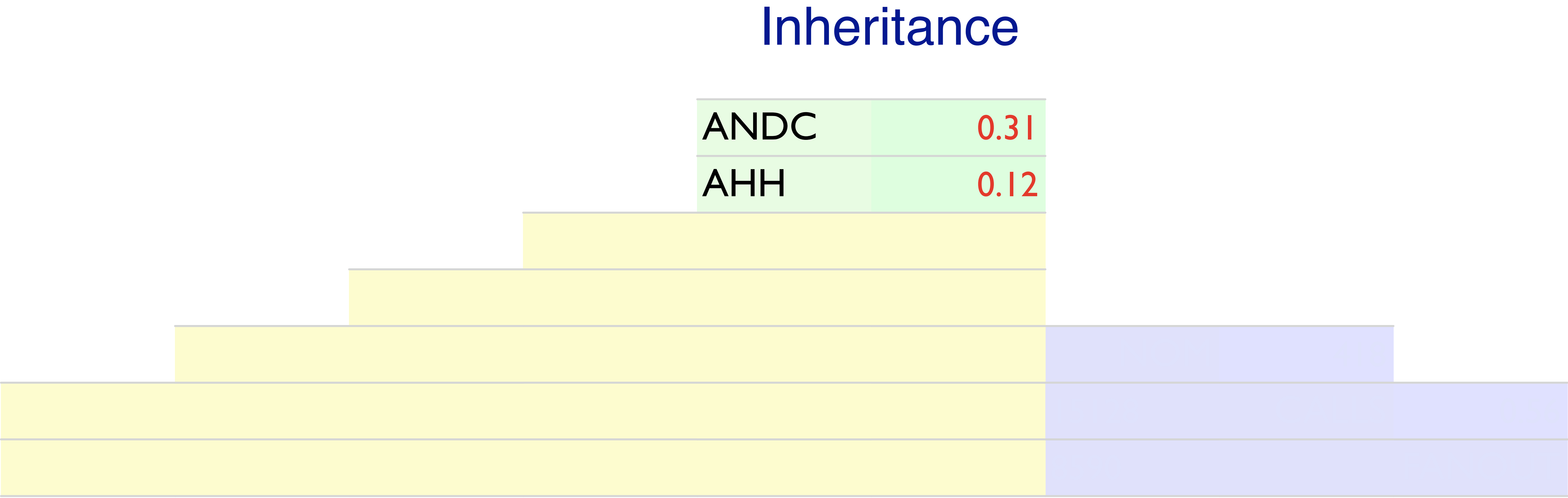

Inheritance

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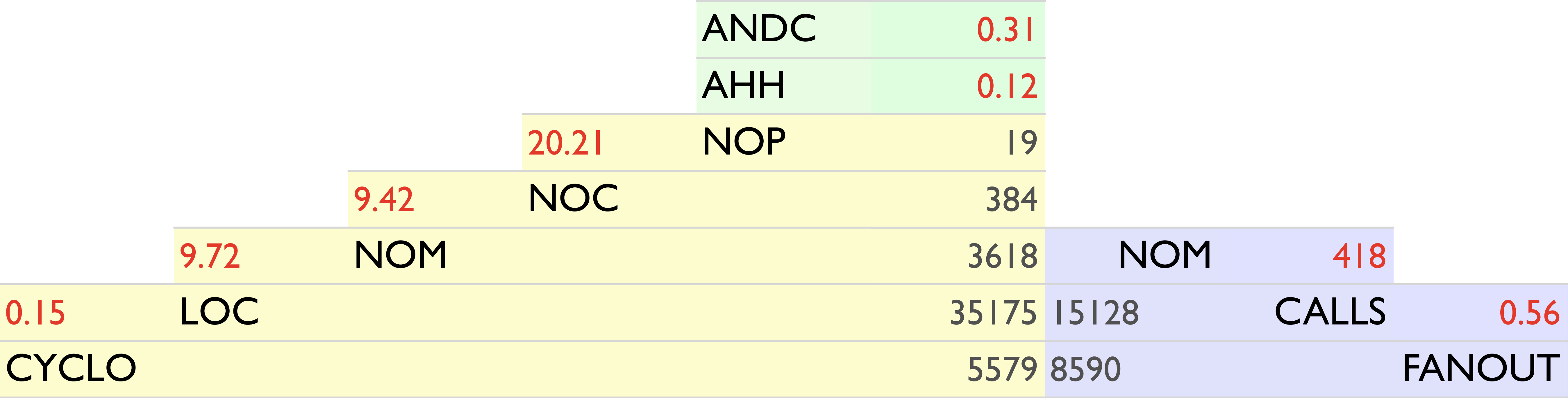

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0.15	LOC				35175	15128	CALLS	0.56
CYCLO					5579	8590		FANOUT

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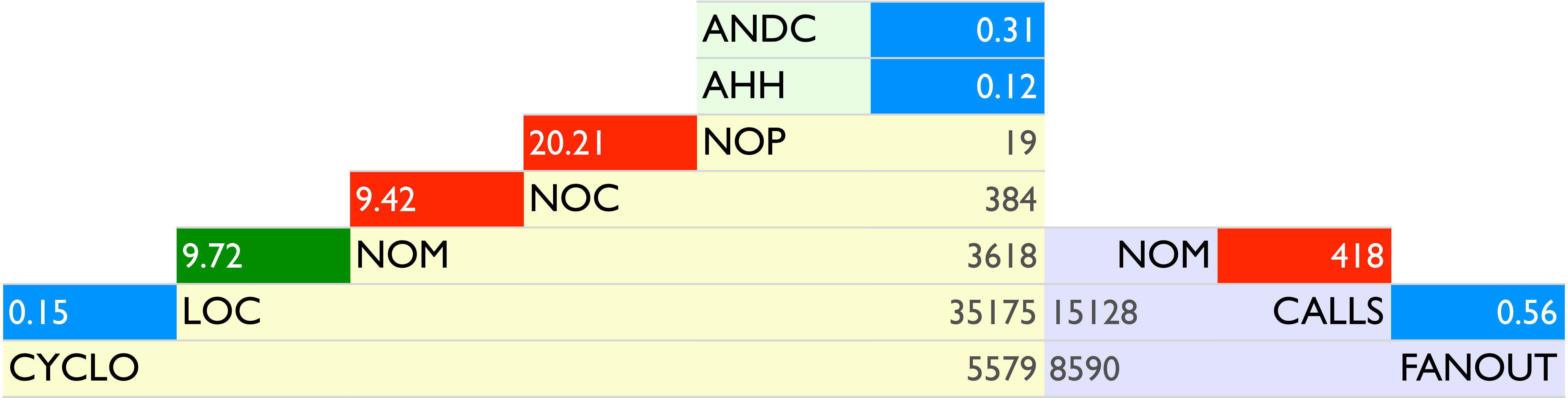

				ANDC	🟦 0.31			
				AHH	🟦 0.12			
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		🟥 9.42	NOC		384			
	🟩 9.72	NOM			3618	NOM	🟥 418	
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🟥 close to high

🟩 close to average

🟦 close to low

The Overview Pyramid provides a metrics overview.

Outlier Detection

close to high

close to average

close to low

How to obtain the thresholds?

	Java			C++		
	LOW	AVG	HIGH	LOW	AVG	HIGH
CYCLO/LOC	0.16	0.20	0.24	0.20	0.25	0.30
LOC/NOM	7	10	13	5	10	16
NOM/NOC	4	7	10	4	9	15
...						

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By statistical static analysis of many systems

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By statistical static analysis of many systems

Context is important (e.g. programming language)

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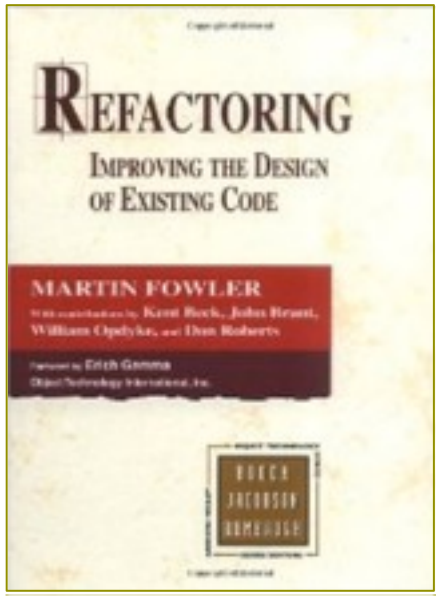
Design Problems and Principles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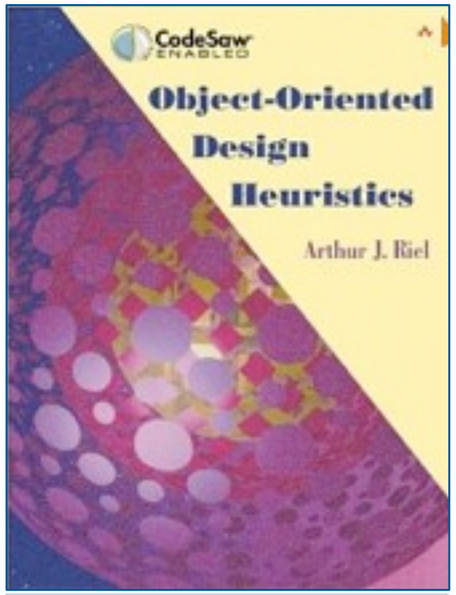
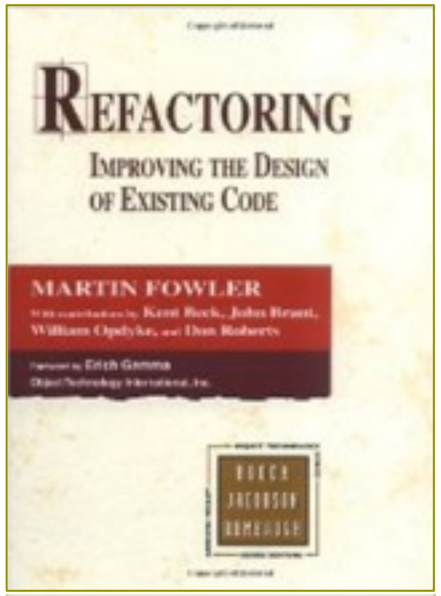
MARTIN FOWLER
With contributions by Kent Beck, John Brant, William Opdyke, and Don Roberts
Foreword by Erich Gamma
BOOCH JACOBSON RUMBAUGH



Design Problems and Principles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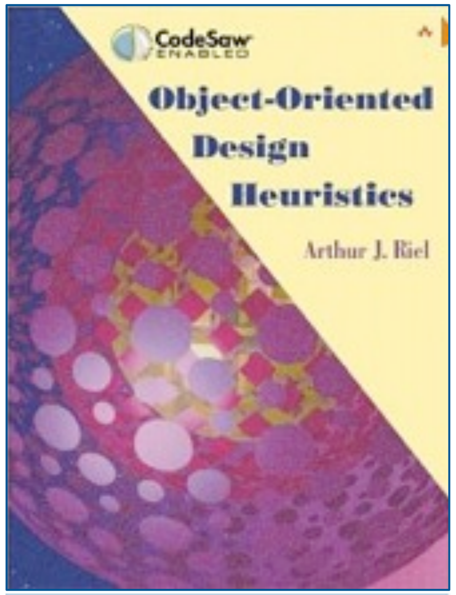
Bad Smells

Comments

Switch Statement

Shotgun Surgery

...



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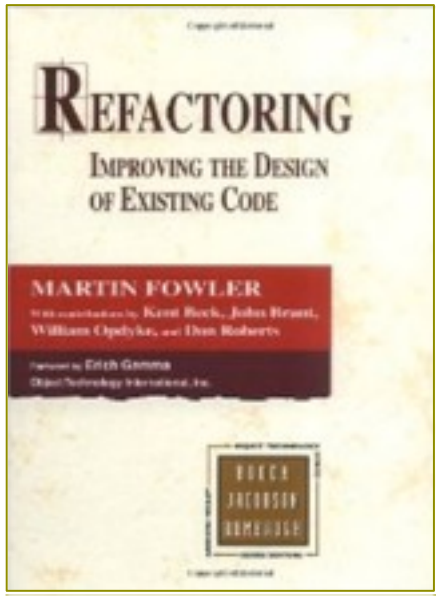

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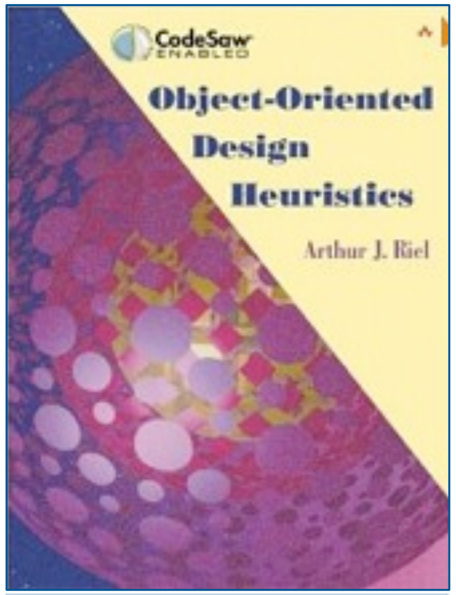


Design Heuristics

Encapsulation

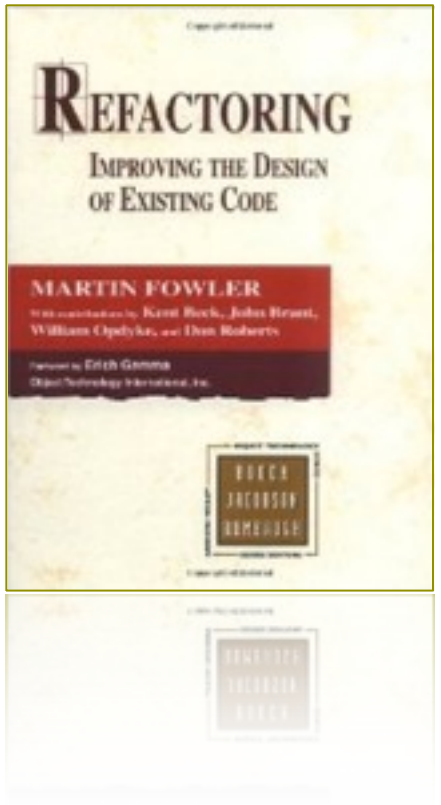
Minimize Coupling

Class Coherence

Inheritance Depth

...

Design Problems and Principles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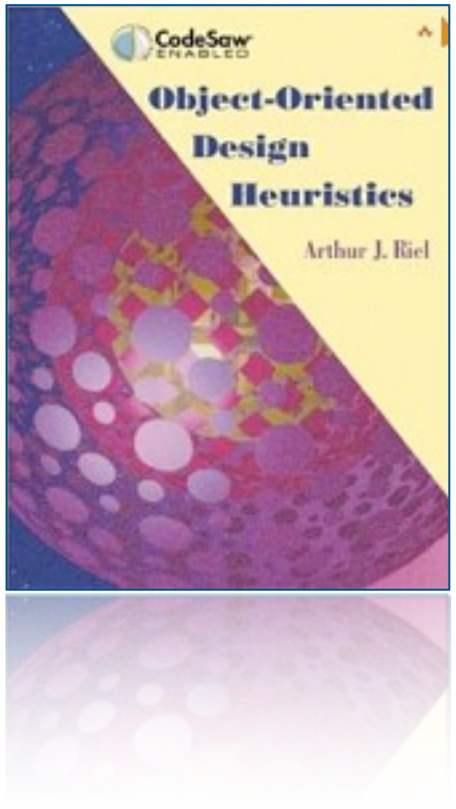

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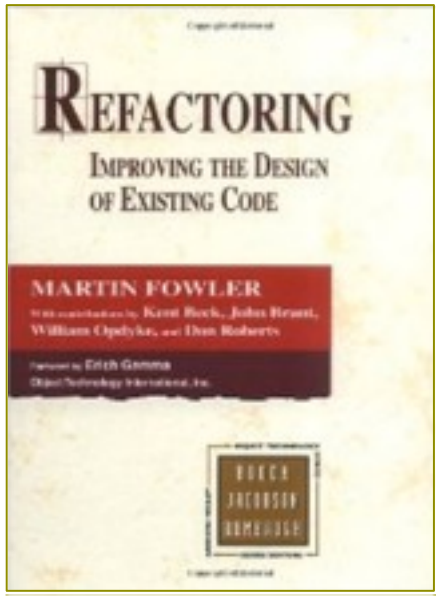
Design principles come in prose - how to measure them?

Design Problems and Principles



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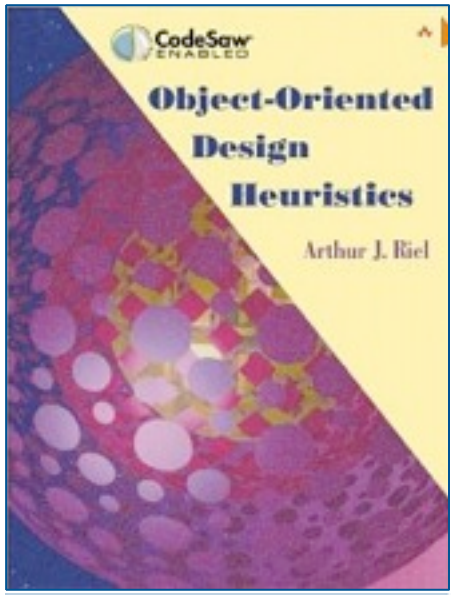


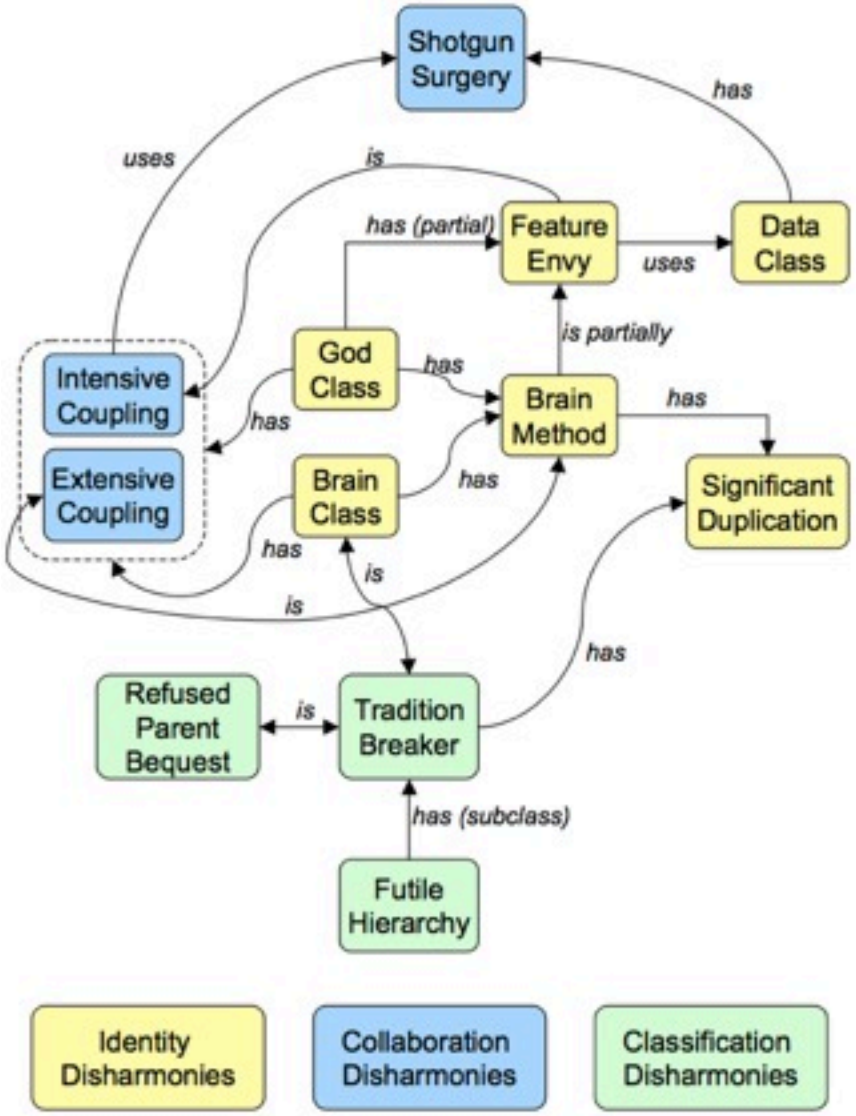
Design Heuristics
Encapsulation
Minimize Coupling
Class Coherence
Inheritance Depth
...

Design principles come in prose - how to measure them?

Rarely a single metric is sufficient >>> Detection Strategies

Detection Strategies...

... are metric based queries
for detecting design problems
(Marinescu 2002)



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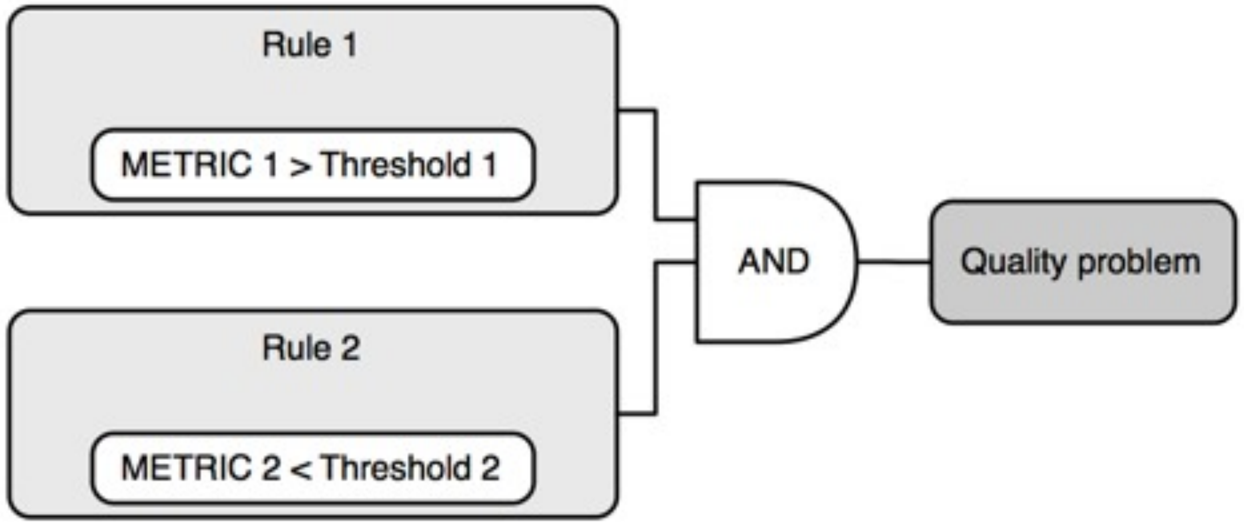
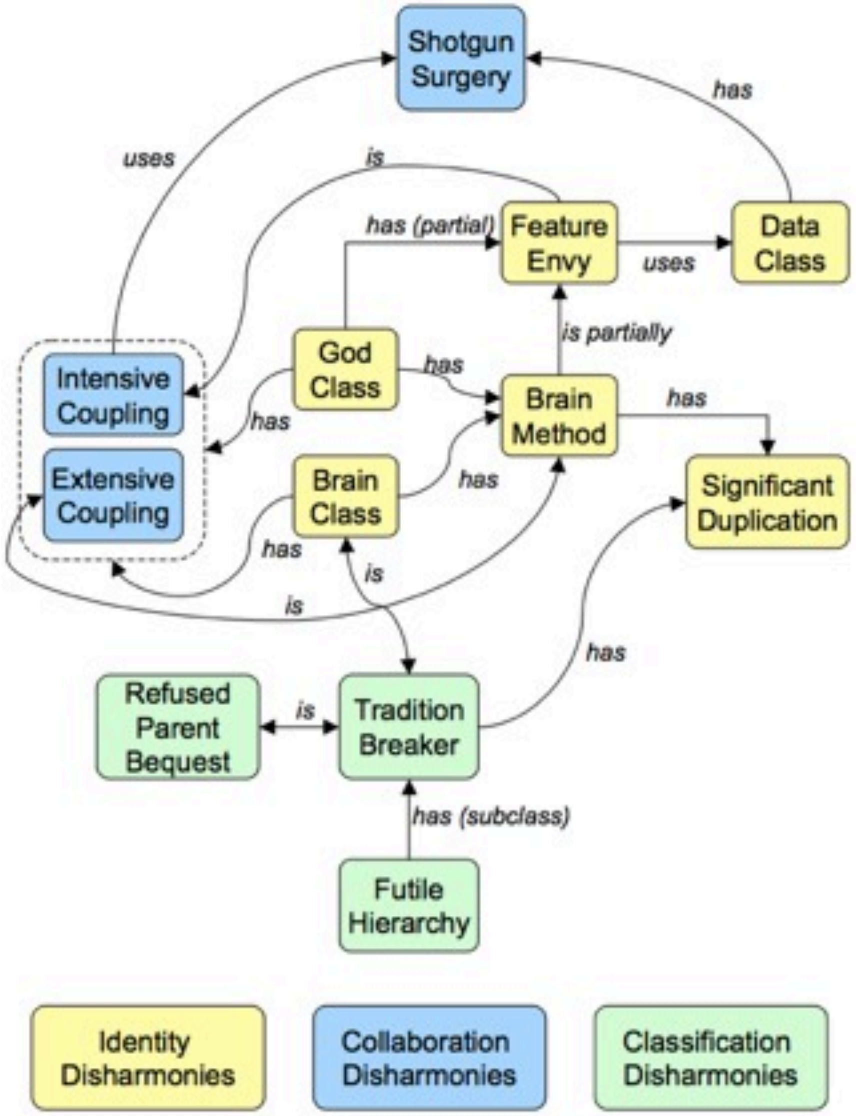
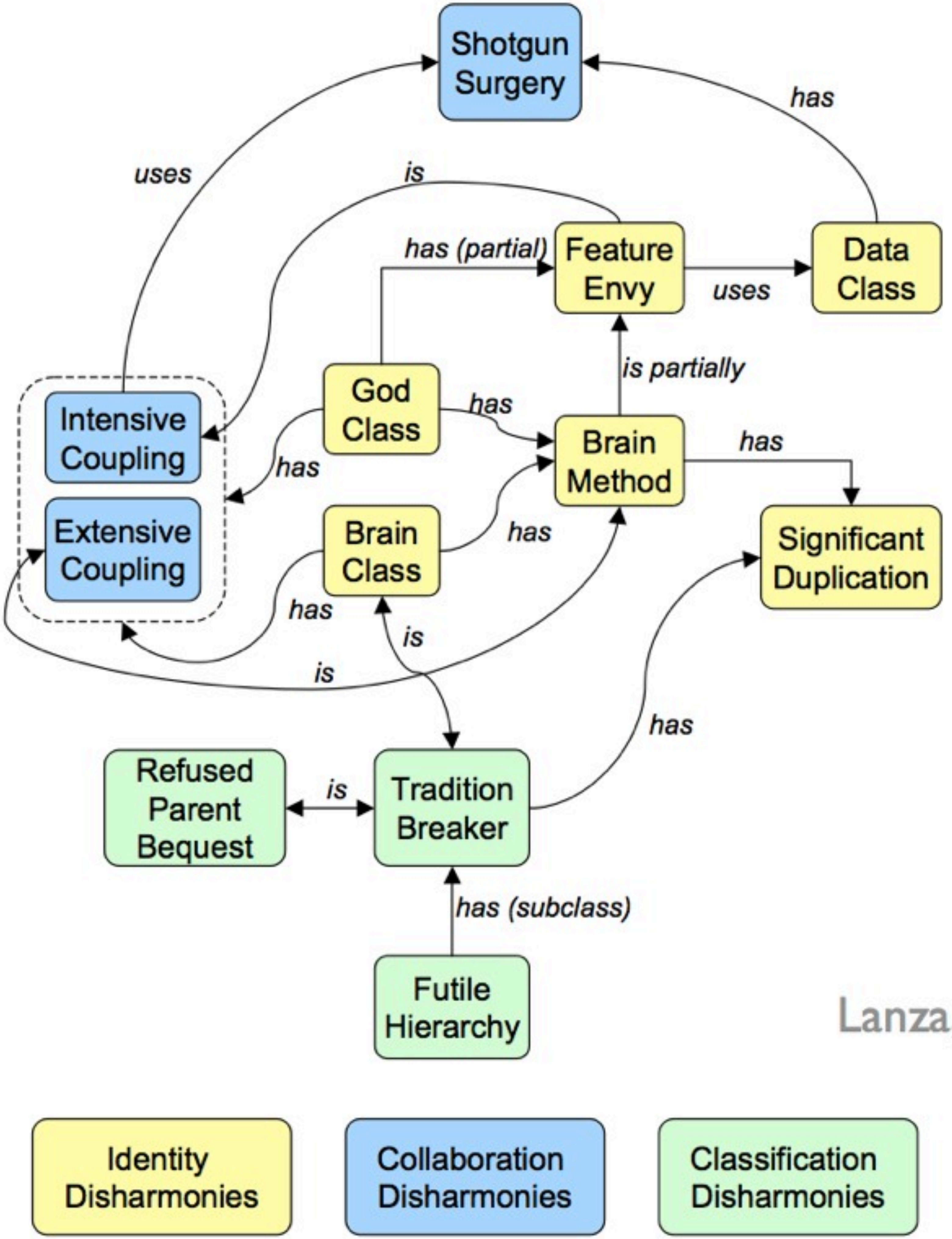




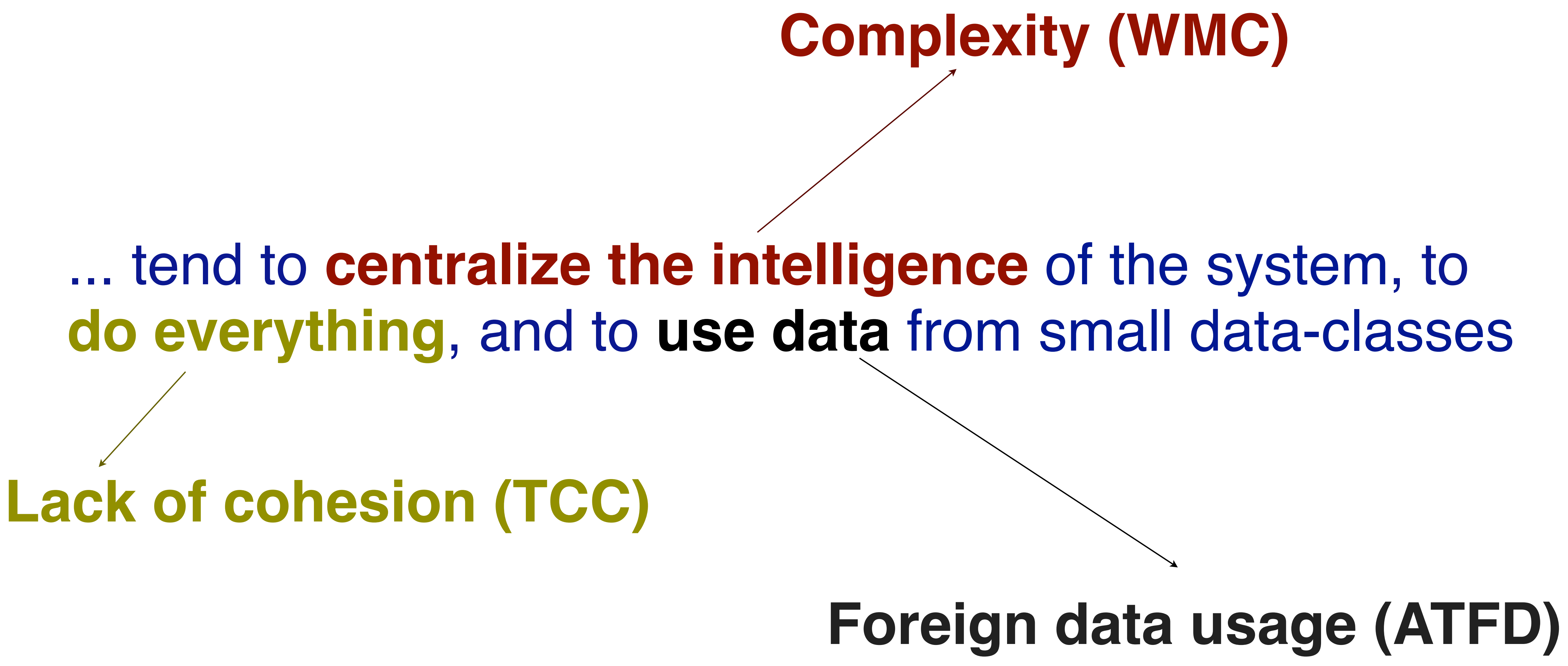


Lanza, Marinescu 2006

God Classes ...

... tend to **centralize the intelligence** of the system, to **do everything**, and to **use data** from small data-classes

God Classes ...



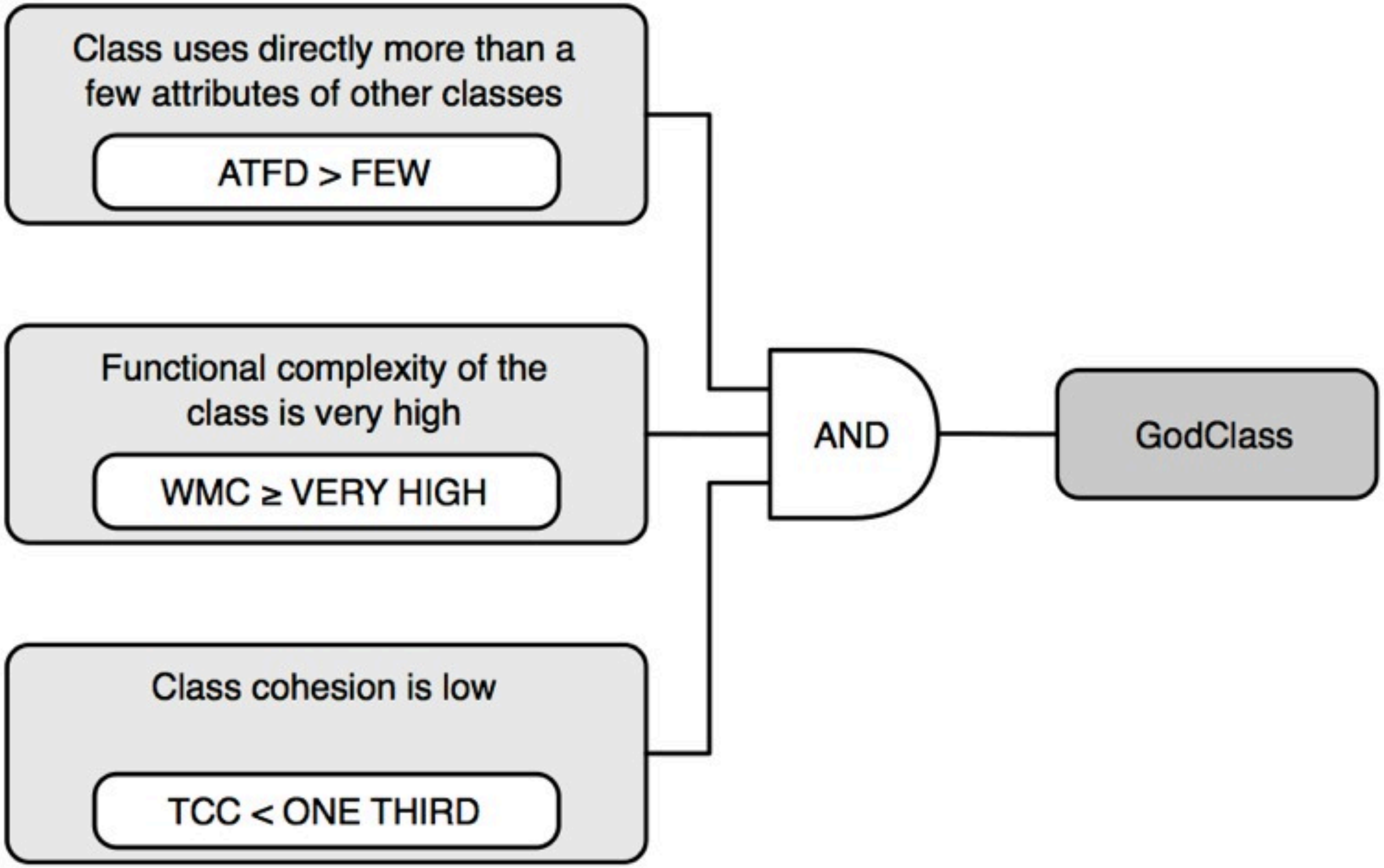
Complexity (WMC)

... tend to **centralize the intelligence** of the system, to **do everything**, and to **use data** from small data-classes

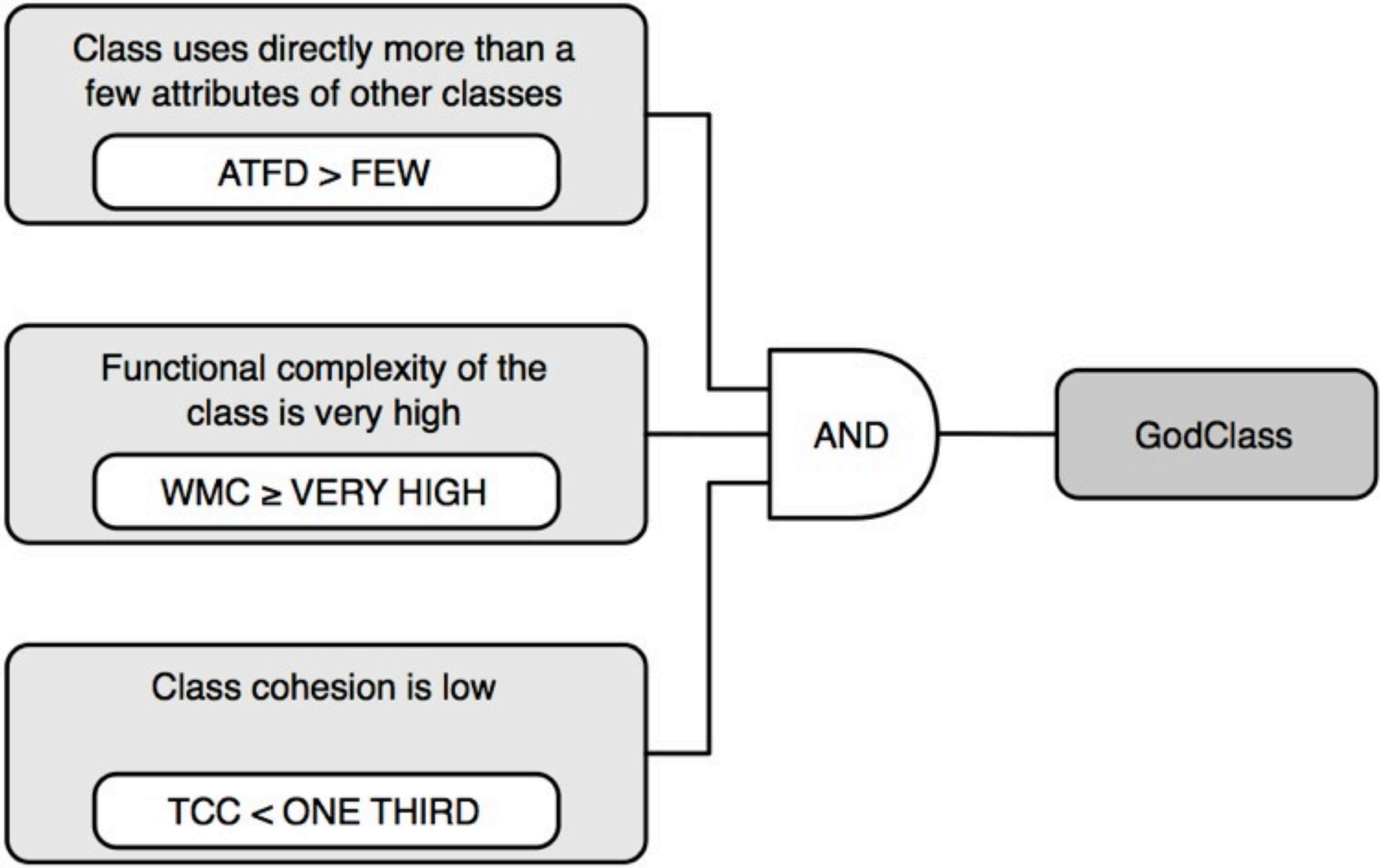
Lack of cohesion (TCC)

Foreign data usage (ATFD)

God Classes


Class uses directly more than a few attributes of other classes
ATFD > FEW
Functional complexity of the class is very high
WMC ≥ VERY HIGH
Class cohesion is low
TCC < ONE THIRD
AND
GodClass

God Classes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WMC ≥ VERY HIGH
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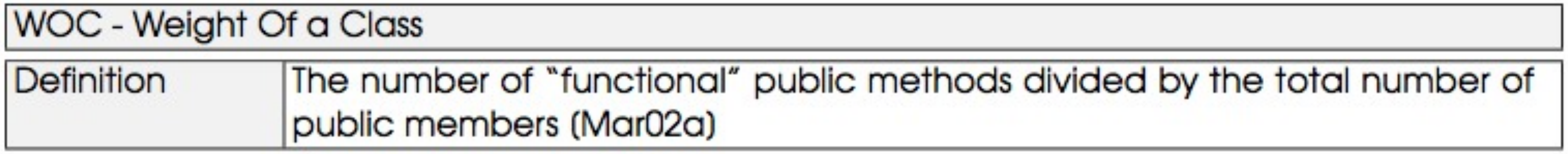
TCC < ONE THIRD
AND
GodClass

Quantifiers

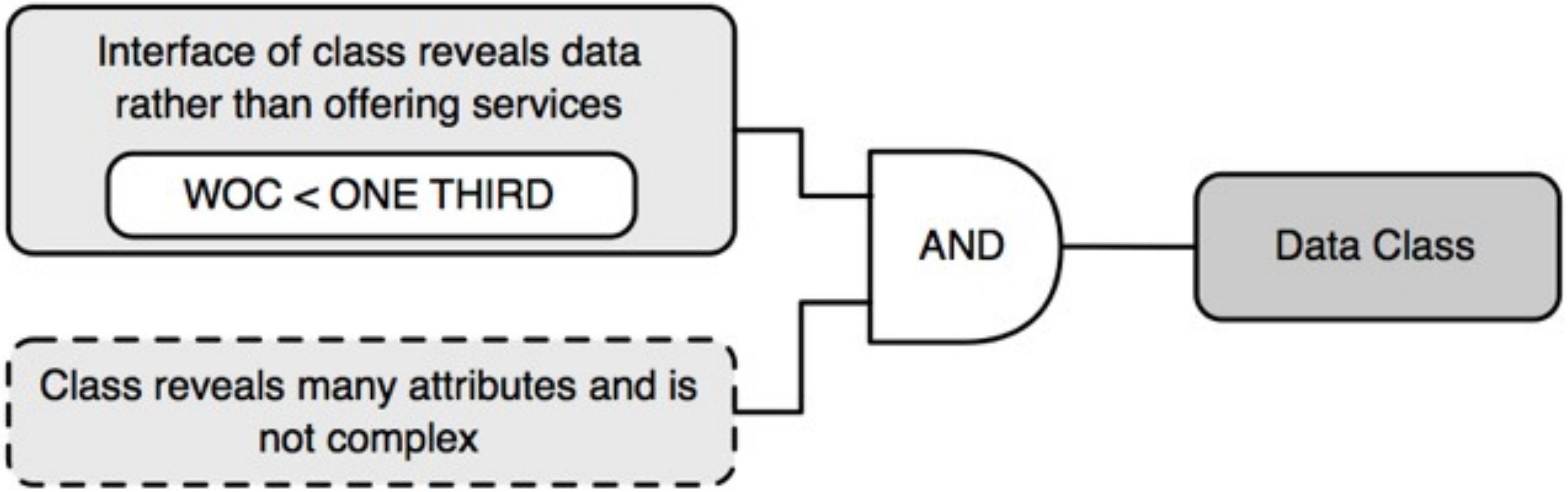
- FEW
- MANY
- TOP
- HIGH
- ONE THIRD ...

Data Classes are dumb data holders



WOC - Weight Of a Class	
Definition	The number of “functional” public methods divided by the total number of public members (Mar02a)

Data Classes are dumb data holders



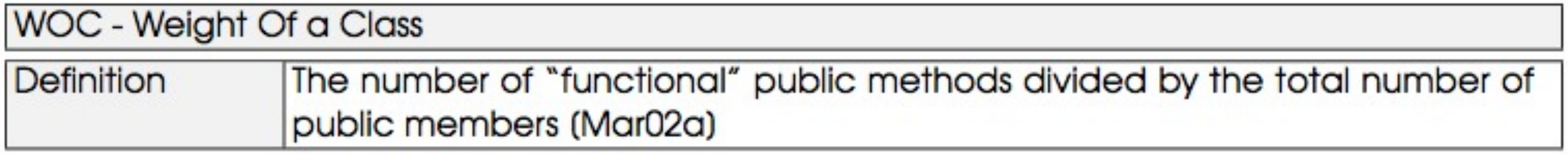
Interface of class reveals data rather than offering services

WOC < ONE THIRD

Class reveals many attributes and is not complex

AND

Data Class



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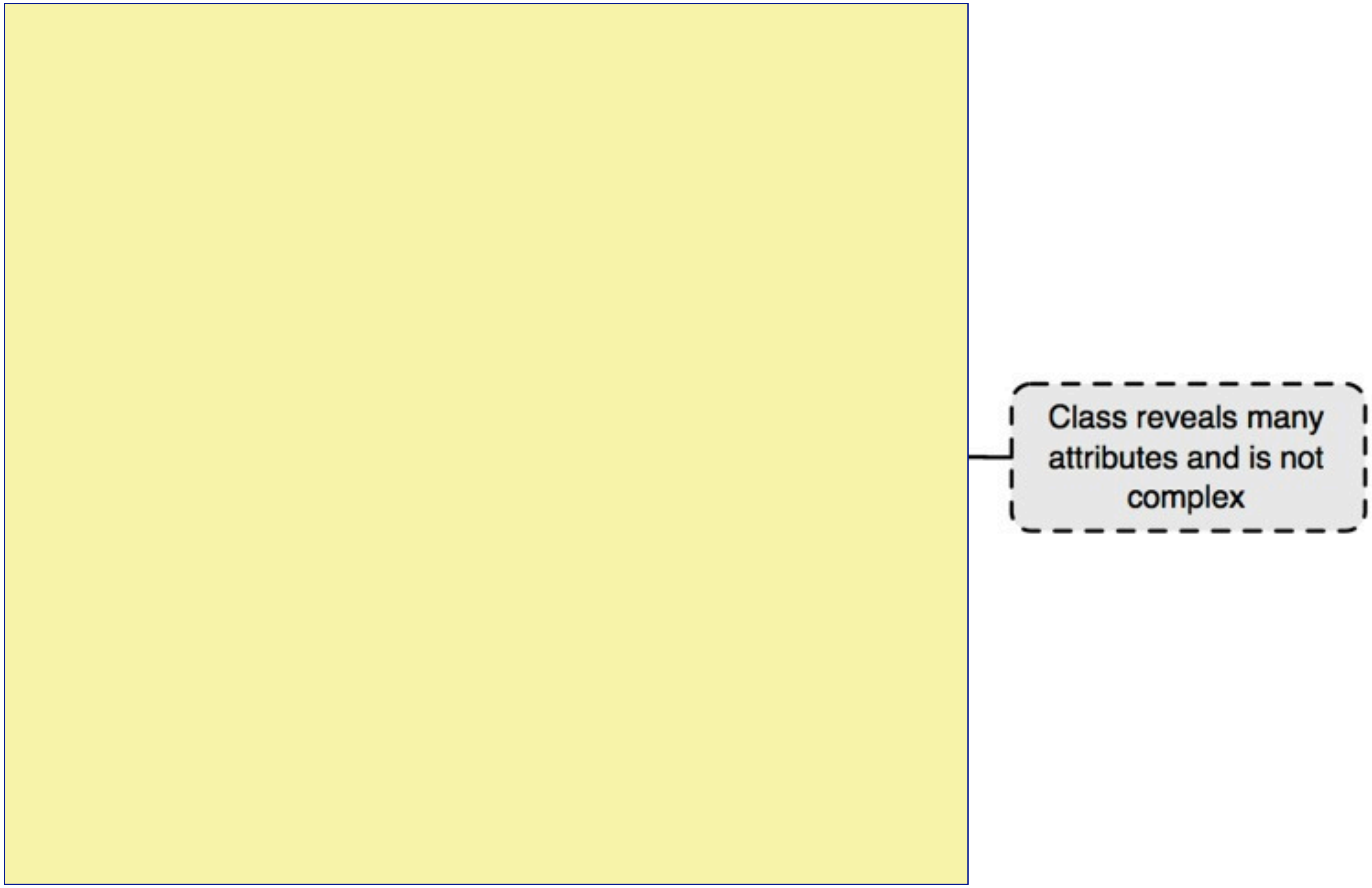
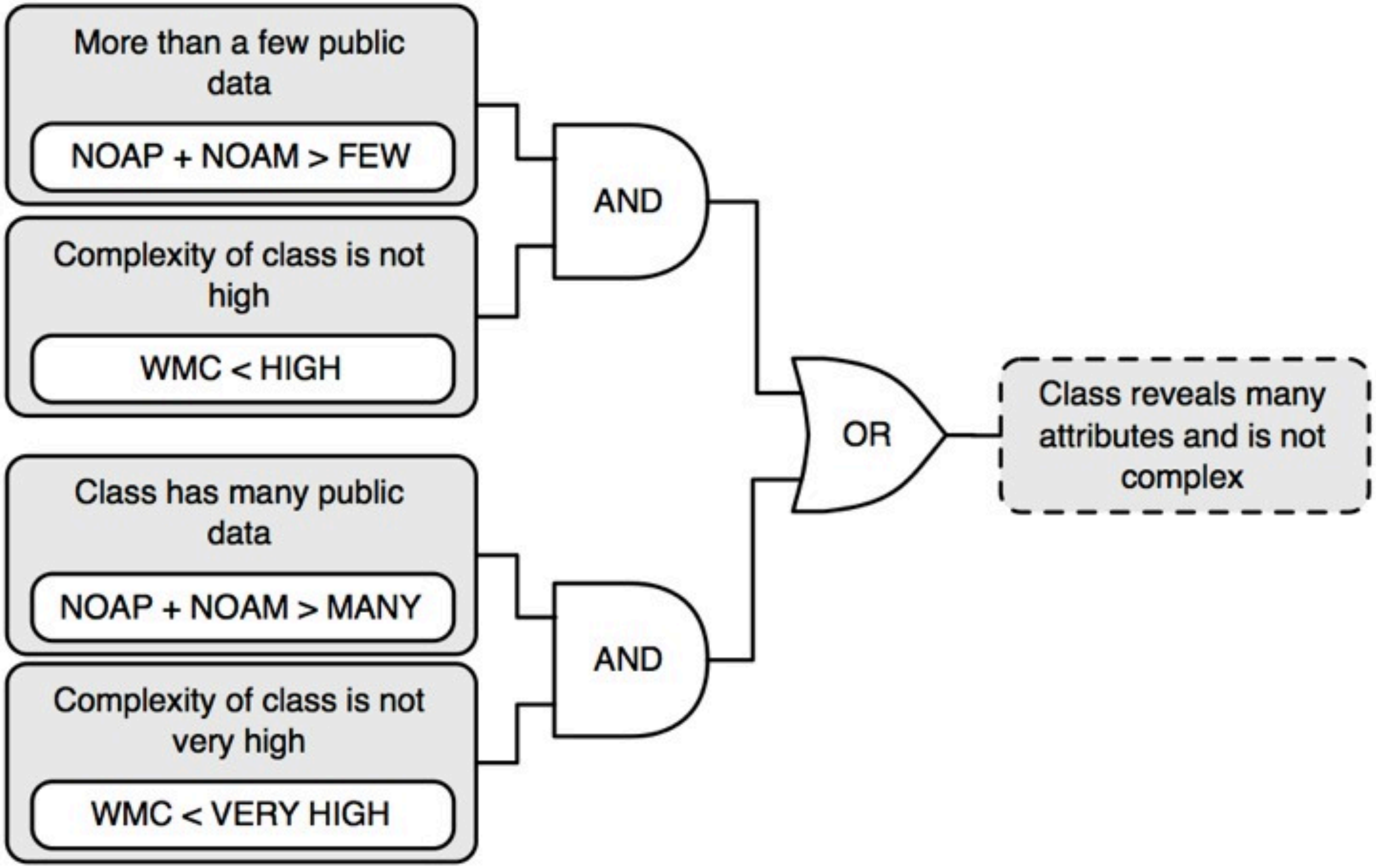


Class reveals many attributes and is not complex

NOAP = #Public Attributes,
NOAM = #Accessor Methods

Data Classes are dumb data holders


More than a few public data
NOAP + NOAM > FEW
Complexity of class is not high
WMC < HIGH
AND
Class has many public data
NOAP + NOAM > MANY
Complexity of class is not very high
WMC < VERY HIGH
AND
OR
Class reveals many attributes and is not complex

NOAP = #Public Attributes,
NOAM = #Accessor Methods

Feature Envy is ...

Feature Envy is ...

This one you find in the Lanza-Marinescu Book!

Roadmap

> Measurements

> Software Metrics

- Size / Complexity Metrics
- Quality Metrics
- Schedule / Cost

> Metric-based Problem Detection

- Detecting Outliers
- Encoding Design Problems

> **Discussion**

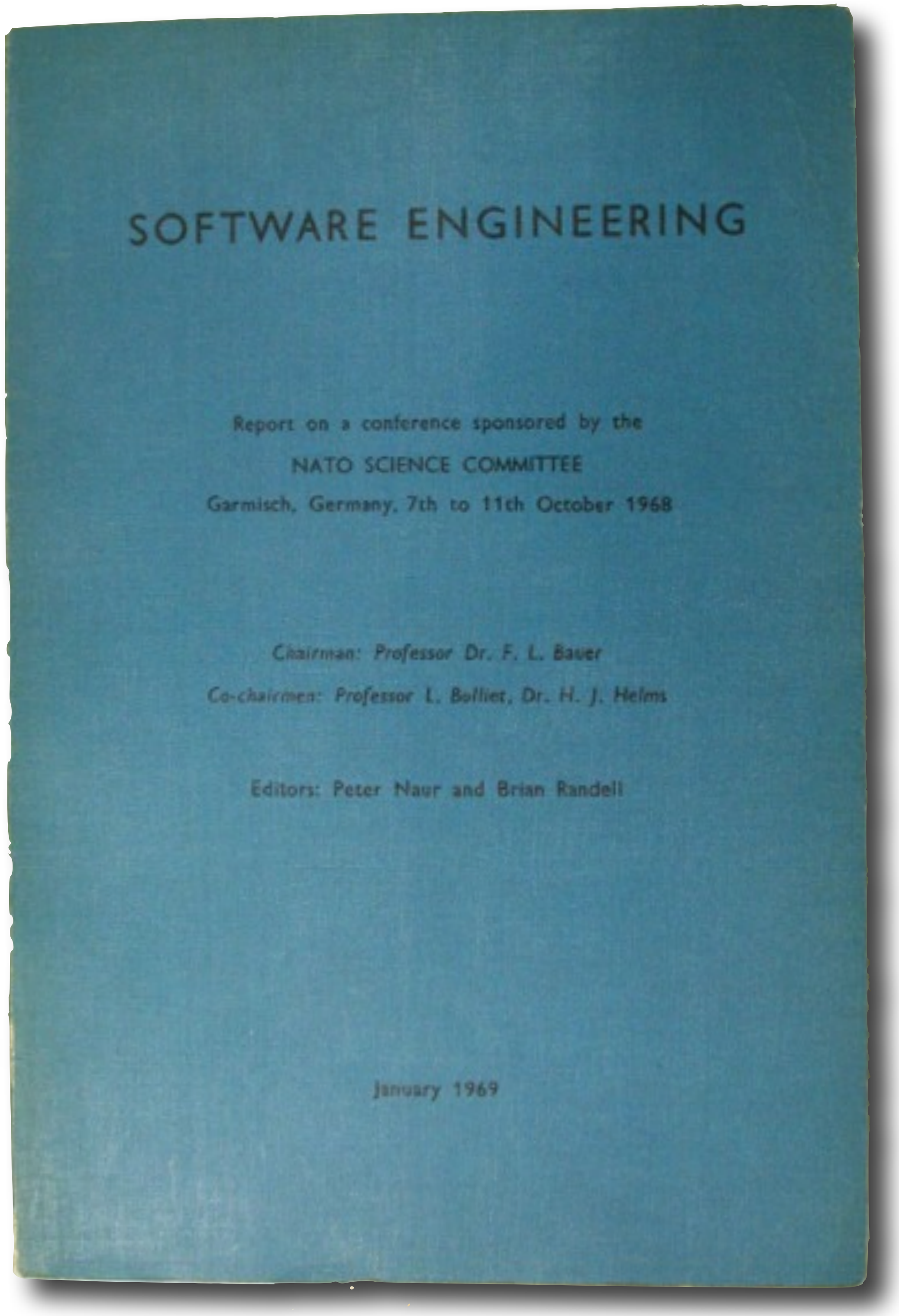
Empirical Analysis

Empirical Analysis

- Basil et al. showed that DIT, RFC, NOC, CBO were correlated with faulty classes

- D’Ambros et al. showed that design flaws correlate with software defects

- There is need for more ...



SOFTWARE ENGINEERING

Report on a conference sponsored by the
NATO SCIENCE COMMITTEE
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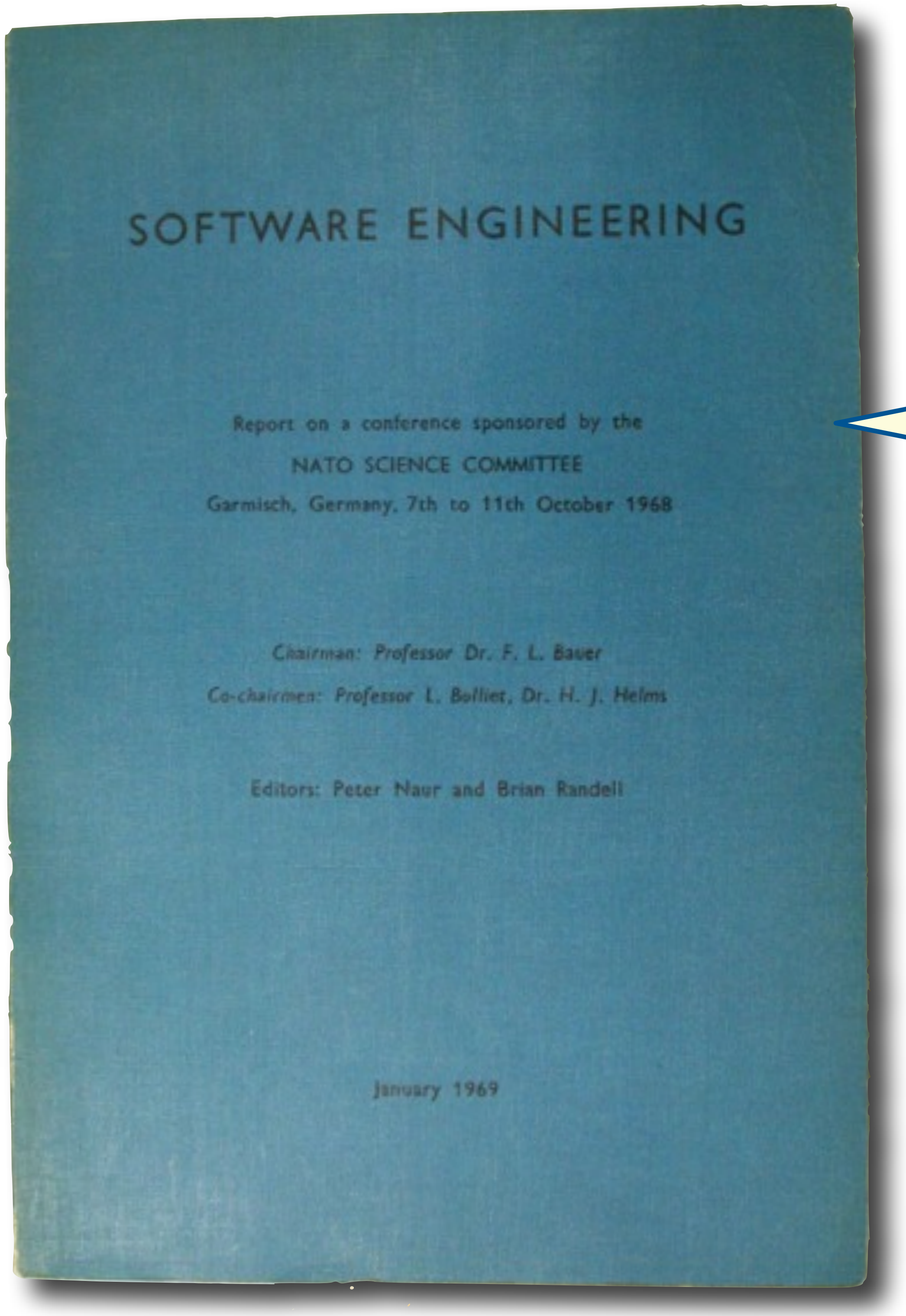
Editors: Peter Naur and Brian Randell

January 1969



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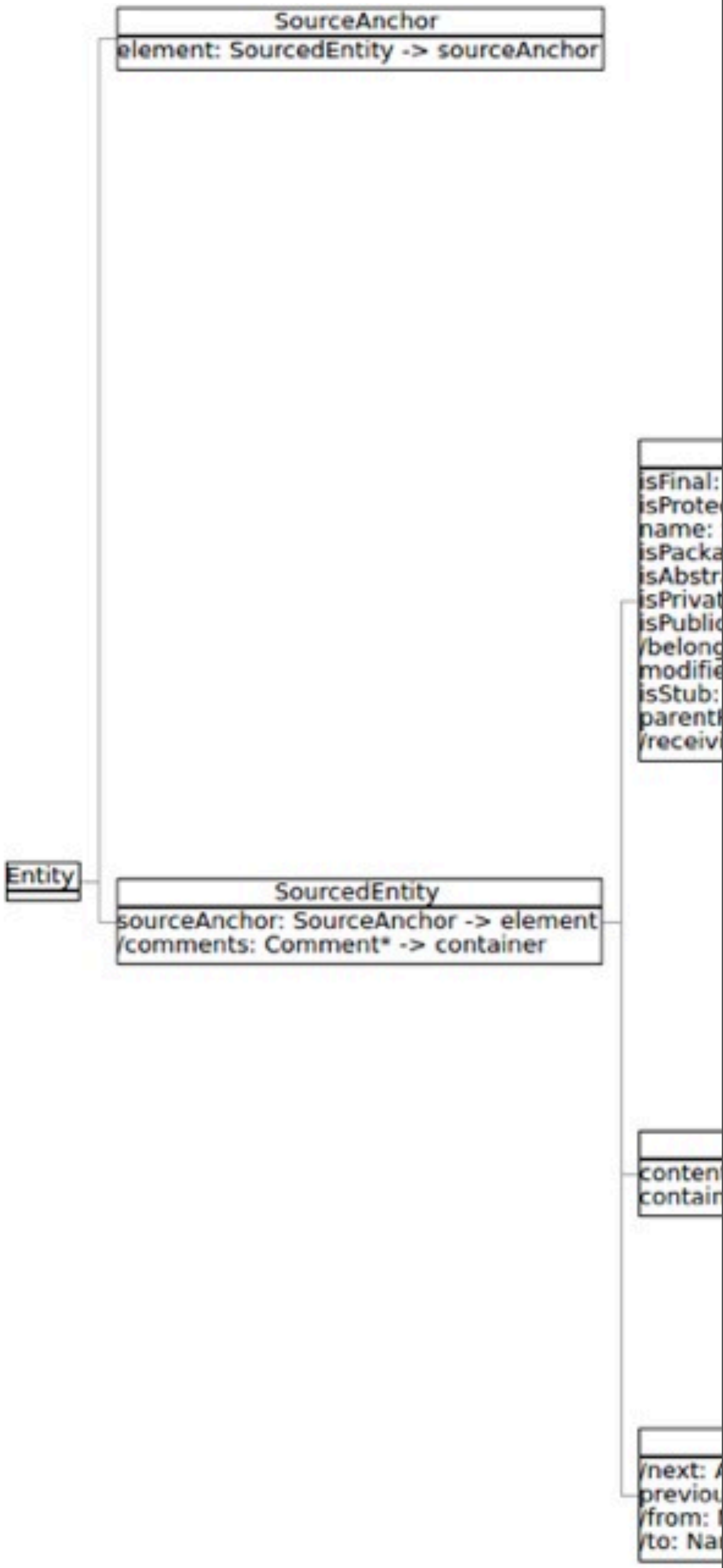
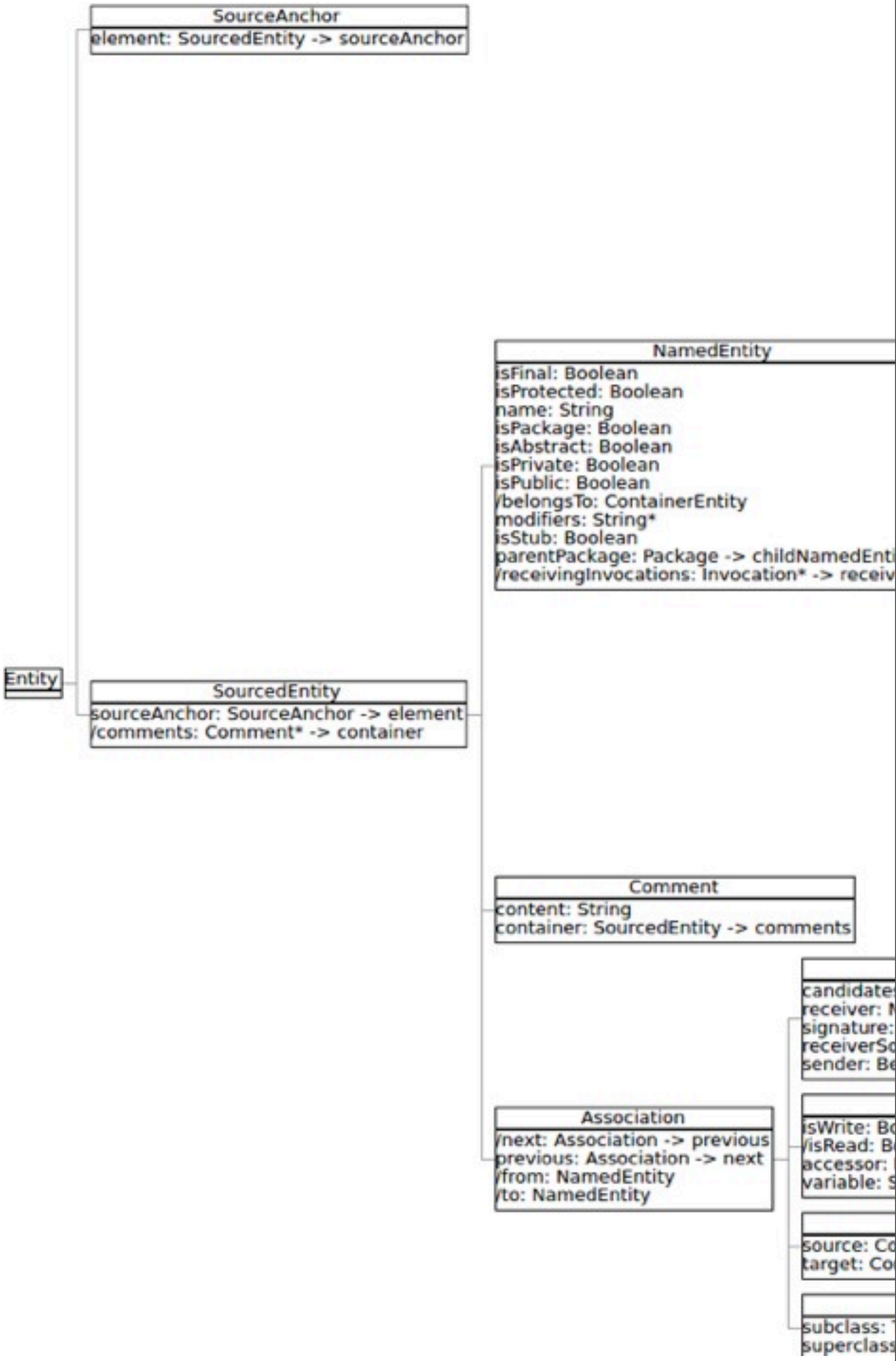
January 1969

McClure:
I know of one organisation that attempts to apply time and motion standards to the output of programmers. They judge a programmer by the amount of code he produces. This is guaranteed to produce insipid code — code which does the right thing but which is twice as long as necessary.

FAMIX 3.0

- Meta-model
- Core - independent of programming language
- Implemented in Moose





Entity

SourceAnchor
element: SourcedEntity -> sourceAnchor

SourcedEntity
sourceAnchor: SourceAnchor -> element
/comments: Comment* -> container

NamedEntity
isFinal: Boolean
isProtected: Boolean
name: String
isPackage: Boolean
isAbstract: Boolean
isPrivate: Boolean
isPublic: Boolean
/belongsTo: ContainerEntity
modifiers: String*
isStub: Boolean
parentPackage: Package -> childNamedEnti
/receivingInvocations: Invocation* -> receiv

Comment
content: String
container: SourcedEntity -> comments

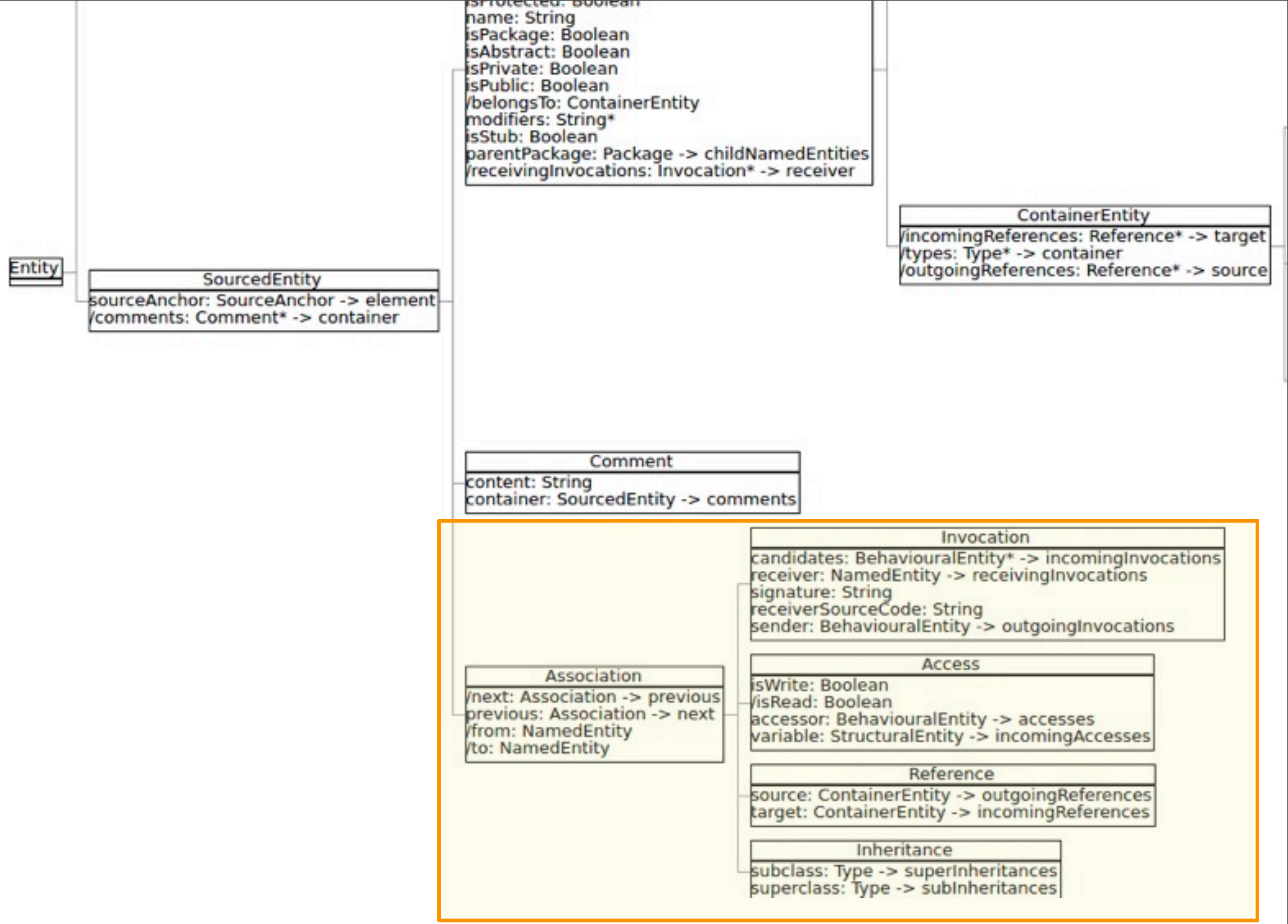
Association
/next: Association -> previous
previous: Association -> next
/from: NamedEntity
/to: NamedEntity

candidate
receiver:
signature:
receiverSo
sender: Be

isWrite: Bo
/isRead: Be
accessor:
variable: S

source: Co
target: Co

subclass:
superclass



isProtected: Boolean
name: String
isPackage: Boolean
isAbstract: Boolean
isPrivate: Boolean
isPublic: Boolean
/belongsTo: ContainerEntity
modifiers: String*
isStub: Boolean
parentPackage: Package -> childNamedEntities
/receivingInvocations: Invocation* -> receiver

ContainerEntity
/incomingReferences: Reference* -> target
/types: Type* -> container
/outgoingReferences: Reference* -> source

Entity

SourcedEntity
sourceAnchor: SourceAnchor -> element
/comments: Comment* -> container

Comment
content: String
container: SourcedEntity -> comments

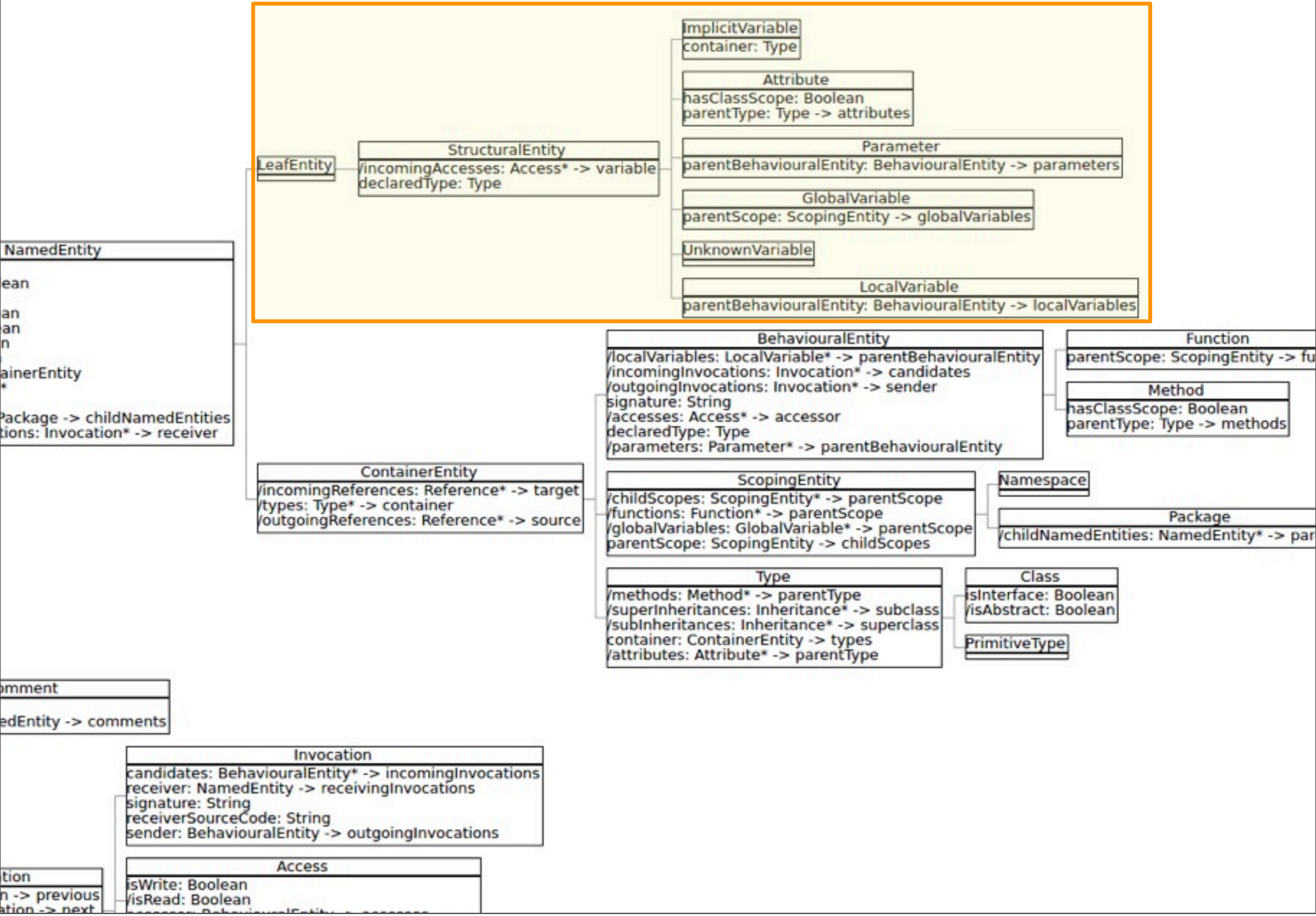
Invocation
candidates: BehaviouralEntity* -> incomingInvocations
receiver: NamedEntity -> receivingInvocations
signature: String
receiverSourceCode: String
sender: BehaviouralEntity -> outgoingInvocations

Association
/next: Association -> previous
previous: Association -> next
/from: NamedEntity
/to: NamedEntity

Access
isWrite: Boolean
/isRead: Boolean
accessor: BehaviouralEntity -> accesses
variable: StructuralEntity -> incomingAccesses

Reference
source: ContainerEntity -> outgoingReferences
target: ContainerEntity -> incomingReferences

Inheritance
subclass: Type -> superInheritances
superclass: Type -> subInheritances



LeafEntity

StructuralEntity
/incomingAccesses: Access* -> variable
declaredType: Type

ImplicitVariable
container: Type

Attribute
hasClassScope: Boolean
parentType: Type -> attributes

Parameter
parentBehaviouralEntity: BehaviouralEntity -> parameters

GlobalVariable
parentScope: ScopingEntity -> globalVariables

UnknownVariable

LocalVariable
parentBehaviouralEntity: BehaviouralEntity -> localVariables

NamedEntity
ean
an
an
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ainerEntity
*
Package -> childNamedEntities
tions: Invocation* -> receiver

BehaviouralEntity
/localVariables: LocalVariable* -> parentBehaviouralEntity
/incomingInvocations: Invocation* -> candidates
/outgoingInvocations: Invocation* -> sender
signature: String
/accesses: Access* -> accessor
declaredType: Type
/parameters: Parameter* -> parentBehaviouralEntity

Function
parentScope: ScopingEntity -> fu

Method
hasClassScope: Boolean
parentType: Type -> methods

ContainerEntity
/incomingReferences: Reference* -> target
/types: Type* -> container
/outgoingReferences: Reference* -> source

ScopingEntity
/childScopes: ScopingEntity* -> parentScope
/functions: Function* -> parentScope
/globalVariables: GlobalVariable* -> parentScope
parentScope: ScopingEntity -> childScopes

Namespace

Package
/childNamedEntities: NamedEntity* -> par

Type
/methods: Method* -> parentType
/superInheritances: Inheritance* -> subclass
/subInheritances: Inheritance* -> superclass
container: ContainerEntity -> types
/attributes: Attribute* -> parentType

Class
isInterface: Boolean
/isAbstract: Boolean

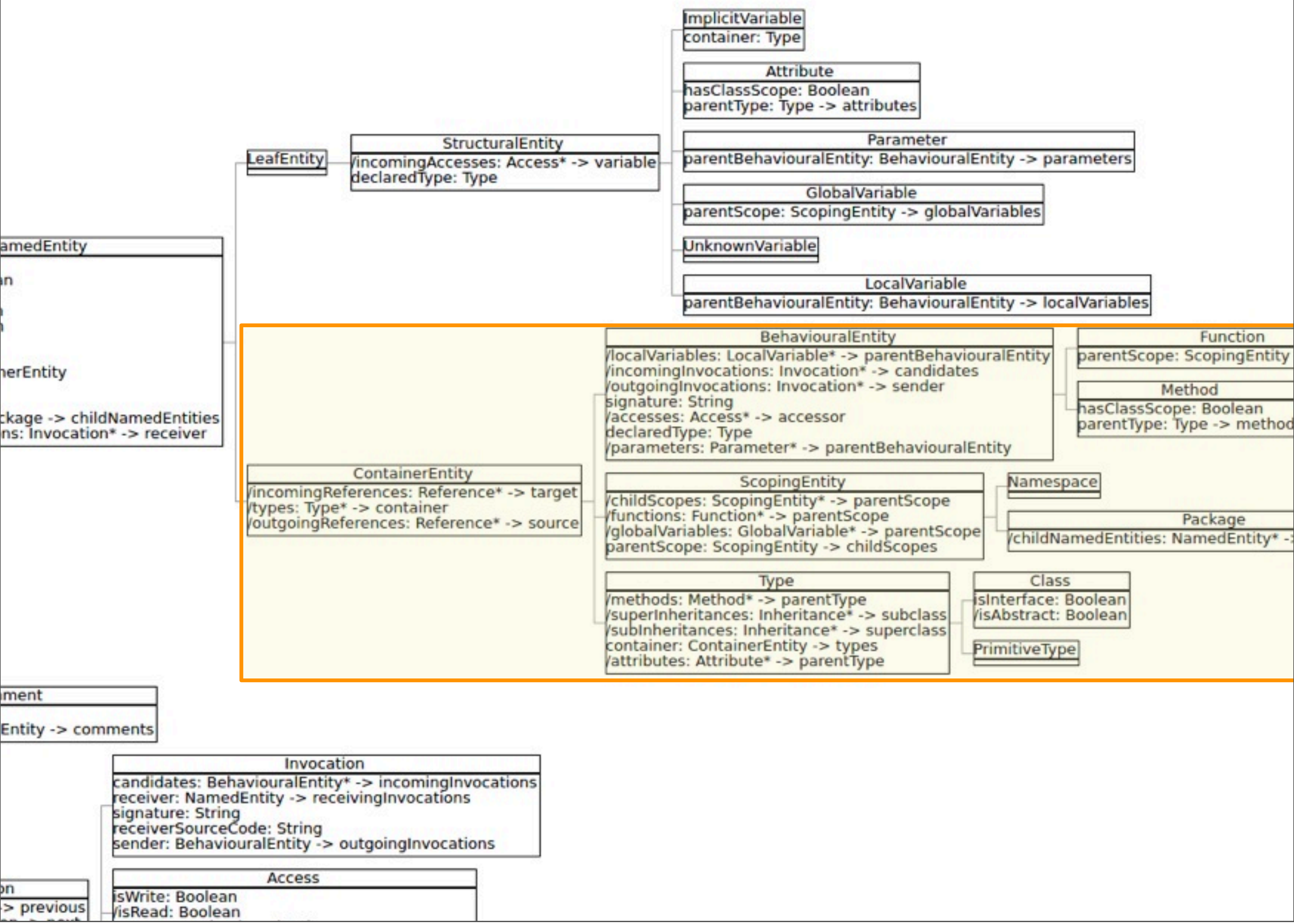
PrimitiveType

omment
edEntity -> comments

Invocation
candidates: BehaviouralEntity* -> incomingInvocations
receiver: NamedEntity -> receivingInvocations
signature: String
receiverSourceCode: String
sender: BehaviouralEntity -> outgoingInvocations

tion
n -> previous
ation -> next

Access
isWrite: Boolean
/isRead: Boolean



ImplicitVariable
container: Type

Attribute
hasClassScope: Boolean
parentType: Type -> attributes

LeafEntity

StructuralEntity
/incomingAccesses: Access* -> variable
declaredType: Type

Parameter
parentBehaviouralEntity: BehaviouralEntity -> parameters

GlobalVariable
parentScope: ScopingEntity -> globalVariables

UnknownVariable

LocalVariable
parentBehaviouralEntity: BehaviouralEntity -> localVariables

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ckage -> childNamedEntities
ns: Invocation* -> receiver

BehaviouralEntity
/localVariables: LocalVariable* -> parentBehaviouralEntity
/incomingInvocations: Invocation* -> candidates
/outgoingInvocations: Invocation* -> sender
signature: String
/accesses: Access* -> accessor
declaredType: Type
/parameters: Parameter* -> parentBehaviouralEntity

Function
parentScope: ScopingEntity

Method
hasClassScope: Boolean
parentType: Type -> method

ContainerEntity
/incomingReferences: Reference* -> target
/types: Type* -> container
/outgoingReferences: Reference* -> source

ScopingEntity
/childScopes: ScopingEntity* -> parentScope
/functions: Function* -> parentScope
/globalVariables: GlobalVariable* -> parentScope
parentScope: ScopingEntity -> childScopes

Namespace

Package
/childNamedEntities: NamedEntity* ->

Type
/methods: Method* -> parentType
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Class
isInterface: Boolean
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PrimitiveType

ment
Entity -> comments

Invocation
candidates: BehaviouralEntity* -> incomingInvocations
receiver: NamedEntity -> receivingInvocations
signature: String
receiverSourceCode: String
sender: BehaviouralEntity -> outgoingInvocations

on
-> previous

Access
isWrite: Boolean
/isRead: Boolean

What you should know!

- Software metrics are measurements
- Every scale allows certain operations and analyses
- Detection strategies are queries for design problem detection
- The Goal Question Metric model has three phases
- Bad smells encode bad OO practices
- Design heuristics encode good OO practices

Can you answer these questions?

- How do you compute TCC for a given class?
- Can you explain how the God Class detection strategy works?
- Can you list several of the elements of the FAMIX meta-model?
- What are three metrics appropriate for OO systems but not be appropriate for procedural systems?
- Can you give examples of three bad smells?
- Why are comments a bad smell? But switch clauses?
- Can you give examples of three design heuristics?

Further Reading

> *Cohesion and Reuse in Object Oriented Systems*, by Bieman & Kang
> *OOMIP* by Lanza and Marinescu (Sections 5.3 - 5.5)
> http://sourcemaking.com/refactoring/bad-smells-in-code
> http://scg.unibe.ch/staff/mircea/sde/60-design-heuristics