Software Metrics and Problem Detection

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Selected material by Mircea Lungu
Roadmap

> **Software Metrics**
  — Size / Complexity Metrics
  — Quality Metrics

> **Metric-Based Problem Detection**
  — Detecting Outliers
  — Encoding Design Problems

> **Moose**
Measurements

A measurement is a mapping from a domain to a range using mapping rules.

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

In Software: measures = “metrics”
Measurements help you to reason about things using a simplified model rather than the things themselves. (Will these boxes fit in my car?)


The quotation is from Sun Tzu’s “Art of War.” Sun Tzu claims that measurement is the first step towards victory.

The Measurement Process

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

(Victor Basili)

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.

Targets without clear goals will not achieve their goals clearly.
The Goal-Question-Metric method was introduced by Victor Basili. It proposes three steps for finding the correct metrics that should be collected during a program.

The GQM model seems too simple to deserve to be called a model. Still, its usefulness becomes clear when realizing that many metrics programs start not with a goal in mind, but with measuring what is easy to measure and end up with bunch of unrelated and non-conclusive measurements.

This situation was addressed also by Kybourg: “If you have no viable theory in which X enters, you have very little motivation to generate a measure of X”.

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Size Measures

- LOC
- NOM
- NOA
- NOC
- NOP
- ... etc.
The graphic is a *polymetric view* that maps metrics to simple visualizations. This is a “System Complexity View” showing an inheritance hierarchy with NOM (number of methods) mapped to the height of each class node, NOA (number of attributes) to the width, and LOC to the colour (black indicates the most LOC).

Many object-oriented metrics were first defined in the early 90s. See, for example: Chidamber, Kemerer, *A Metrics Suite for Object Oriented Design*. IEEE TSE, 1994.

[http://dx.doi.org/10.1109/32.295895](http://dx.doi.org/10.1109/32.295895)
[http://scgresources.unibe.ch/Literature/SMA/Chid94a-OOMetrics.pdf](http://scgresources.unibe.ch/Literature/SMA/Chid94a-OOMetrics.pdf)
Cyclomatic Complexity (CYCLO)

The number of independent linear paths through a program. (McCabe ’77)

+ Measures minimum effort for testing
*Cyclomatic Complexity* is one of the best-known measures of complexity, which equates complexity with control flow: the more paths through a piece of code, the more complex it is considered to be. This is especially useful for measuring test coverage. (Tests should cover all paths through a program.) CC can be computed by representing control flow as a directed graph, and computing:

\[
CC = E - N + 2
\]

where \( E \) = # edges and \( N \) = # nodes

Weighted Methods per Class (WMC)

The complexity of a class by summing the complexity of its methods, usually using CYCLO. (Chidamber & Kemerer ’94)

+ A proxy for the time and effort required to maintain a class
Intuition: the larger the complexity of a class, the more difficult its maintenance.
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)

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
The visualizations are *class blueprints*. They show five categories of methods and attributes of a single class and their calling/accessing relations. In the first column at the left are *constructors*, followed by *public methods, internal methods* (protected or private), *accessors*, and finally *attributes*.

Here we see that the `weightAndPlaceClasses` and `layout` methods of `ClassDiagramLayouter` are very large, and use many accessors and attributes of `ClassDiagramNode`. The latter has little behavior of its own.
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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
The concept of coupling was introduced in a 1974 article by Stevens, Myers, and Constantine. *Structured Design*. IBM Systems Journal, 1974

http://segresources.unibe.ch/Literature/SMA/Stev74a-StructuredDesign.pdf

https://en.wikipedia.org/wiki/Coupling_(computer_programming)

Here we see that the class Project has both large *fan-in* (clients using it) and *fan-out* (classes it is a client of), so it is highly coupled to much of the system.
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 = 4 / 10 = 0.4
A class is considered to be cohesive using TCC if its methods access many of the same attributes. TCC counts the pairs of methods that access a common attribute.
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Pattern: Study the Exceptional Entities

Problem
— How can you quickly gain insight into complex software?

Solution
— Measure software entities and study the anomalous ones

Steps
— Use simple metrics
— Visualize metrics to get an overview
— Browse the code to get insight into the anomalies
This pattern is from the open-source book, “Object-Oriented Reengineering Patterns”. Like design patterns, reengineering patterns encode knowledge mined from experience with practical problems in real software systems. Instead of encoding design experience, however, these patterns express how to reverse engineer and reengineer legacy software systems.

This particular pattern is useful when you want to obtain an initial overview of a complex object-oriented software system. Since the code base may be very large, it is not feasible to read even a small portion of the code. Instead, by applying simple metrics and visualizing the results, your attention may be drawn to anomalous outliers (i.e., exceptional entities) that will tell you interesting things about the system.

http://scg.unibe.ch/download/oorp/
The Overview Pyramid provides a metrics overview.

Inheritance

Size

Communication
The Overview Pyramid summarizes several common metrics in a single diagram, indicating whether metric values are outliers are not.
The Overview Pyramid provides a metrics overview.
The Overview Pyramid provides a metrics overview.
CALLS = Number of call sites
FANOUT = Sum of all FANOUTS
Coupling Intensity
The Overview Pyramid provides a metrics overview.
ANDC = Average Number of Derived Classes
AHH = Average Hierarchy Height
The Overview Pyramid provides a metrics overview.

<table>
<thead>
<tr>
<th></th>
<th>ANDC</th>
<th></th>
<th>AHH</th>
<th></th>
<th>NOP</th>
<th></th>
<th>NOC</th>
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<td></td>
<td>20.21</td>
<td></td>
<td>9.72</td>
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</tr>
<tr>
<td>NOM</td>
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</tbody>
</table>
The Overview Pyramid provides a metrics overview.
How to obtain the thresholds?

Statistical static analysis of reference systems
Context is important (e.g. programming language)
Lanza and Marinescu advises that you study many software systems and extract statistical rules. The book extracts statistics based on 45 Java systems. Outliers may be signs of poor quality …
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Design Problems and Principles

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
> (Lanza & Marinescu 2002)
God Classes ...

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

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

- **Complexity (WMC)**
- **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

Quantifiers
- FEW
- MANY
- TOP
- HIGH
- ONE THIRD...
Data Classes are dumb data holders

**WOC - Weight Of a Class**

<table>
<thead>
<tr>
<th>Definition</th>
<th>The number of “functional” public methods divided by the total number of public members (Mar02a)</th>
</tr>
</thead>
</table>
Data Classes are dumb data holders

NOPA = #Public Attributes, NOAM = #Accessor Methods
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"Developers spend some half of their time reading code." Do you agree?

... in my case its 90% reading code and 10% writing. So I vote for NO.
development
“We shape our tools and thereafter our tools shape us”

Why ...

• Are
• Slides
• Typically
• Filled
• With
• Bullets?
Click to add title

• Click to add text
Is it not an amazing coincidence how the default template correlates with the way many slides come out?
navigation

query

data
Let’s look at a more technical case. How does a database tool look like?

What does a developer do when presented with a problem in a database with a 1 million rows? The developer typically starts with a query.

Now, how does the same developer approach a problem in a million lines of code? The developer often relies on scrolling. Why?
Now, how does the typical IDE look like? Where is the query box?
If McLuhan is correct, and the evidence suggests that he is, we should be very picky with the kinds of tools that we want to get ourselves exposed to when we deal with software systems.
Moose is a platform for software and data analysis
Moose is a platform for modeling software artifacts to enable software analysis.

Moose has been developed for well over a decade. It is the work of dozens of researchers, and has been the basis of numerous academic and industrial projects.

For a general overview, see:


http://scg.unibe.ch/archive/papers/Nier05cStoryOfMoose.pdf

The system can be freely downloaded:

http://www.moosetechnology.org
Moose provides basic infrastructure for navigation, measuring, querying, and grouping software models. A large number of different tools have been built on top of Moose. The key to Moose’s flexibility is its extensible metamodel. Every tool that builds on Moose is able to extend the metamodel with concepts that it needs, such as history.
Here we see a number of different visualization tools:

System complexity - Clone evolution view
Class blueprint - Topic Correlation Matrix - Distribution Map for topics spread over classes in packages
Hierarchy Evolution view - Ownership Map
Platform for Crafting Analysis Tools

data

loaders

models

analysis

generates

engines
Moose is not only about data analysis now. It also provides a convenient way to build your own tools for analyzing data
MOOSE Hands On!
MOOSE Hands On!

Download MOOSE: http://moosetechnology.org/#install
Download the Moose 6.0 package for your operating system, unpack and launch the executable.
MOOSE Hands On!

Download MOOSE: http://moosetechnology.org/#install

Download Demo Data: https://github.com/scg-unibe-ch/moose-demo-data/
MOOSE Hands On!

https://github.com/scg-unibe-ch/moose-demo-data/
Although it is a git repository, we only need the latest version, so you can simply download the zip and unarchive it on your machine.
Open the Moose Panel
Load the Data
Load the Data

“MSE ↓” Button
Load the Data
Set the root folder
to “moose-demo-data-master” (the one with .mse)
Set the root folder of your model to point to the directory where the sources and .mse file resides. This way Moose will be able to pick up the source code.
Case study

Which @Deprecated classes can I remove?
Try to estimate how long it will take to find all the deprecated classes that can be removed and make a shortlist of the deprecated classes that cannot be removed immediately but should be addressed in the first place.
self select: [:each]
    each isAnnotatedWith: 'Deprecated'
```ruby
self select: [:each | 
  each isAnnotatedWith: 'Deprecated'
]
```

```ruby
self select: [:each | 
  each clientTypes anySatisfy: [:c | 
    c isAnnotatedWith: 'Deprecated'
  ] not ]
```
```plaintext
self select: [:each | each isAnnotatedWith: 'Deprecated']
```

```plaintext
view := RTMondrian new.
view shape ellipse if: [:each | (self includes: each) not] color: Color red.
view nodes: self asSet, ((self flatCollect: #clientTypes) reject: #isStub).
view edges connectFromAll: #clientTypes to: #yourself.
view layout force.
```
self select: [:each | each isAnnotatedWith: 'Deprecated'
view := RTMonldrian new.
view shape ellipse if: [:each | (self includes: each) not] color: Color red.
view nodes: self asSet, ((self flatCollect: #clientTypes) reject: #isStub).
view edges connectFromAll: #clientTypes to: #yourself.
view layout force.
view

/*** The main window of the ArgoUML application. */
/**
public final class ProjectBrowser
    extends JFrame
    implements PropertyChangeListener,
    TargetListener {
/**
/**  * Default width.
/**
    public static final int DEFAULT_COMPONENTWIDTH = 400;
/**
/**  * Default height.
/**
    public static final int
The full tutorial

What you should know!

> What is a metric?
> Why goals are important for choosing metrics?
> Why is the context of the metrics important?
> What is the difference between coupling and cohesion?
> What metrics are present on the overview pyramid?
> What do detection strategies detect?
> Why reading code is bad?
> How does Moose solve the data analysis problems?
Can you answer these questions?

> What metrics are important for measuring some of your projects (bachelor’s thesis project, etc…)?

> What are acceptable ranges of CYCLO for different languages?

> Why is it hard to calculate CYCLO for Smalltalk methods?

> What insights can a class blueprint provide besides ATFD?

> What are the strategies of solving code smells detected by detection strategies?
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