

Coupling

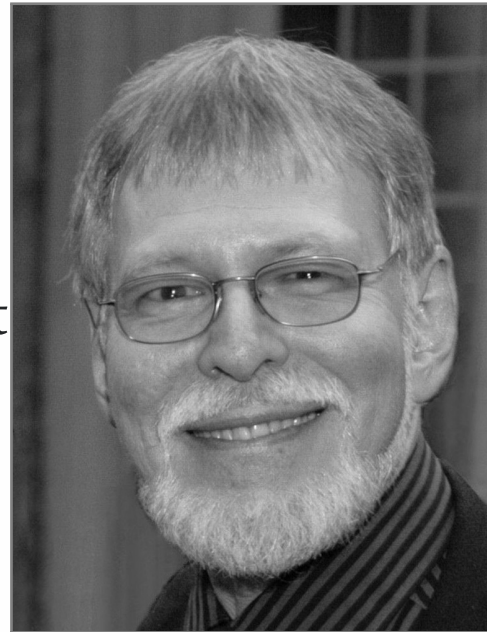
YEGOR BUGAYENKO

Lecture #6 out of 24

80 minutes

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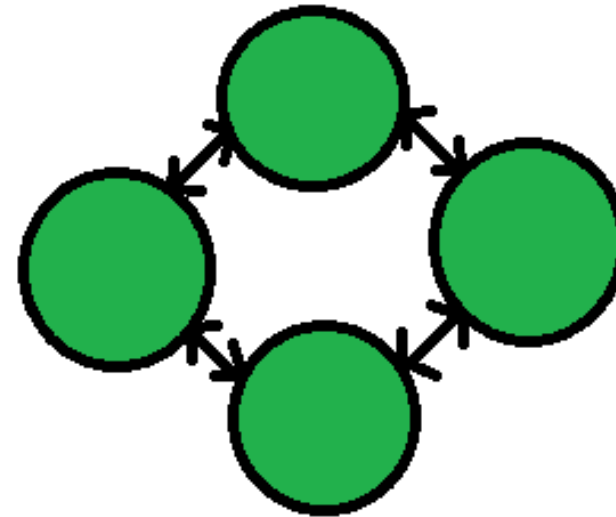
“The fewer and simpler the connections between modules, the easier it is to understand each module without reference to other modules.”

— Wayne P. Stevens, Glenford J. Myers, and Larry L. Constantine, *Structured Design*, IBM Systems Journal 13.2 (1974)



Tight coupling:

1. More Interdependency
2. More coordination
3. More information flow



Loose coupling:

1. Less Interdependency
2. Less coordination
3. Less information flow

Source: <https://www.geeksforgeeks.org/coupling-in-java/>

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“Coupling is the measure of the strength of association established by a connection from one module to another. Strong coupling complicates a system since a module is harder to understand, change, or correct by itself if it is highly interrelated with other modules. Complexity can be reduced by designing systems with the weakest possible coupling between modules.”

— Wayne P. Stevens, Glenford J. Myers, and Larry L. Constantine, *Structured Design*, IBM Systems Journal 13.2 (1974)



Source: <https://www.javatpoint.com/software-engineering-coupling-and-cohesion>

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“The degree of coupling established by a particular connection is a function of several factors, and thus it is difficult to establish a simple index of coupling. Coupling depends (1) on how complicated the connection is, (2) on whether the connection refers to the module itself or something inside it, and (3) on what is being sent or received.”

— Wayne P. Stevens, Glenford J. Myers, and Larry L. Constantine, *Structured Design*, IBM Systems Journal 13.2 (1974)



Source: <https://nordicapis.com/the-difference-between-tight-coupling-and-loose-coupling/>

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“Coupling Between Objects (CBO) — for a class is a count of the number of other classes to which it is coupled.”

— Shyam R. Chidamber and Chris F. Kemerer, *A Metrics Suite for Object Oriented Design*, IEEE Transactions on Software Engineering, 20.6, 1994

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“Direct Class Coupling (DCC) — this metric is a count of the different number of classes that a class is directly related to. The metric includes classes that are directly related by attribute declarations and message passing (parameters) in methods.”

— Jagdish Bansiya and Carl G. Davis, *A Hierarchical Model for Object-Oriented Design Quality Assessment*, IEEE Transactions on Software Engineering, 28.1, 2002

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“The biggest problems come from uncontrolled coupling at the upper levels. I don’t worry about the number of modules coupled together, but I look at the pattern of dependency relationship between the modules.”

— Martin Fowler, *Reducing Coupling*, IEEE Software, 2001

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“Low-to-medium fan-out means having a given class use a low-to-medium number of other classes. High fan-out (more than about seven) indicates that a class uses a large number of other classes and may therefore be overly complex. High fan-in refers to having a high number of classes that use a given class. High fan-in implies that a system has been designed to make good use of utility classes at the lower levels in the system.”

— Steven McConnell, *Code Complete*, 2004

Fan-in = number of ingoing dependencies
Fan-out = number of outgoing dependencies



Heuristic: a high fan-in/fan-out indicates a high complexity

(c) Natalia Kokash, Leiden Institute of Advanced Computer Science

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An Evolutionary Study of Fan-in and Fan-out Metrics in OSS

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Abstract— Excessive coupling between object-oriented classes is widely acknowledged as a maintenance problem that can result in a higher propensity for faults in systems and a ‘rotted up’ future problem. The aim of this paper is to explore the relationship between ‘fan-in’ and ‘fan-out’ coupling metrics over multiple versions of open-source software. More specifically, we explore the relationship between the two metrics to determine patterns of growth in each over the course of time. The HAWK tool was used to extract the two metrics from five open-source systems. Two questions were posed for each system. First, what are the characteristics of classes exhibiting the highest fan-in values? Second, do fan-in and fan-out increase in corresponding and consistent amounts over time? Results show a wide range of traits in the classes to explain both high and low levels of fan-in and fan-out. We also found evidence of certain ‘key’ classes (with both high fan-in and fan-out) and ‘client’ and ‘server’-type classes with just high fan-out and fan-in, respectively. We provide an explanation of the composition and existence of such classes as well as for disproportionate increases in each of the two metrics over time.

Keywords— coupling, fans, fan-in, fan-out, package.

I. INTRODUCTION

Excessive class coupling has often been related to the propensity for faults in software [5]. It is widely believed in the Object-Oriented (OO) community that excessive coupling between classes creates a level of complexity that can complicate subsequent maintenance and represents a ‘rotted up’ maintenance problem. In practice, a class that is highly coupled to many other classes is an ideal candidate for re-engineering or removal from the system to mitigate both current and potential future problems. A problem that immediately arises however for the developer when considering re-engineering of classes with high coupling is: ‘Do those classes have prohibitively large dependencies?’ If so, then are those coupling dependencies ‘incoming’ or ‘outgoing’ dependencies? In theory, it is more difficult to modify a target class with high incoming and low outgoing coupling, since the former requires detailed and careful scrutiny of each of the many ‘incoming’ dependent classes and the possible side-effects of change.

In this paper, we investigate versions of five Open Source Systems (OSS) focusing on two well-known coupling metrics ‘fan-in’ (i.e., incoming coupling) and ‘fan-out’ (i.e., outgoing coupling). We used an automated tool to extract each of the coupling metrics from those five systems. The research questions we explore are first, is it the case that classes with large incoming coupling naturally have low outgoing coupling and second, does this relationship worsen over time? In other words, does the potential maintenance problem become worse in terms of fan-in and fan-out values?

II. MOTIVATION AND RELATED WORK

The research in this paper is motivated by a number of factors. Firstly, previous research [15] has shown that there is a trade-off between coupling types – in particular, that between coupling through imported packages and the introduction of ‘internal-to-the-package’ coupling. In this paper, we explore the potential characteristics and trade-offs between fan-in and fan-out metrics over time. Second, we would always expect potentially problematic classes to be re-engineered by developers through techniques such as refactoring [9]; however, the practical realities of limited time and resources at their disposal means that only when classes exhibit particularly bad ‘smells’ (e.g. excessive coupling) [9] are they dealt with. In this paper, we explore, over time, whether smells given by too much coupling do become ‘smellier’ and, if so, in what proportions. Finally, the research is motivated by previous research [16] which showed that the fan-in and fan-out metrics tended to be relatively small for classes removed from a system. In other words, classes with either high fan-in and/or fan-out may be difficult to move or remove from a system. This question has inspired further examination of trends in the two metrics presented.

In terms of related work, the research presented relates to areas of software evolution, coupling metrics and the use of OSS [8]. In terms of software evolution, the laws of Lehman [2] provide the backdrop for many past evolutionary studies. Evolution has also been the subject of simulation studies [18] and this has allowed OSS evolution to be studied in a contrasting way to that empirically. The research presented in this paper delves into specific evolutionary coupling features

“We also found evidence of certain ‘key’ classes (with both high fan-in and fan-out) and ‘client’ and ‘server’-type classes with just high fan-out and fan-in, respectively.”

— A. Mubarak et al., *An Evolutionary Study of Fan-in and Fan-out Metrics in OSS*, Proceedings of the 4th International Conference on Research Challenges in Information Science (RCIS), 2010

Fan-out, as a metric, is supported by a few tools:

- Checkstyle for Java
- CCCC for C++, C, and Java
- module-coupling-metrics for Python

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“Afferent coupling (denoted by **Ca**) is a metric that indicates the total number of other projects/boundaries that are dependent upon it. Efferent coupling (denoted by **Ce**) is another metric that is the verse of Afferent Coupling. It is the total number of projects that a given project depends on. Instability another metric that is a ratio: $I = Ce / (Ce + Ca)$. This metric is a ratio between 0 and 1. With 0 meaning it's totally stable and 1 meaning it's unstable.”

— Derek Comartin, Write Stable Code using Coupling Metrics, 2021

Types of Coupling (some of them)

- Content Coupling is when one module modifies or relies on the internal workings of another module (e.g., accessing local data of another module).
- Global Coupling is when two modules share the same global data (e.g., a global variable).
- External Coupling occurs when two modules share an externally imposed data format, communication protocol, or device interface.
- Control Coupling is one module controlling the flow of another, by passing it information on what to do (e.g., passing a what-to-do flag).
- Stamp Coupling is when modules share a composite data structure and use only a part of it, possibly a different part (e.g., passing a whole record to a function that only needs one field of it).
- Data Coupling is when modules share data through, for example, parameters. Each datum is an elementary piece, and these are the only data shared (e.g., passing an integer to a function that computes a square root).
- Message Coupling can be achieved by state decentralization (as in objects) and component communication is done via parameters or message passing (see Message passing).
- Subclass Coupling describes the relationship between a child and its parent. The child is connected to its parent, but the parent isn't connected to the child.
- Temporal Coupling is when two actions are bundled together into one module just because they happen to occur at the same time.

Source:

[https://wiki.edunitas.com/IT/en/114-10/Coupling-\(computer-programming\)_1430_eduNitas.html](https://wiki.edunitas.com/IT/en/114-10/Coupling-(computer-programming)_1430_eduNitas.html)

Fear of Decoupling

```
1 interface Money {
2     double cents();
3 }
4
5 void send(Money m) {
6     double c = m.cents();
7     // Send them over via the API...
8 }
9
10 class OneDollar implements Money {
11     @Override
12     double cents() {
13         return 100.0d;
14     }
15 }
```

```
1 class EmployeeHourlyRate
2     implements Money {
3     @Override
4     double cents() {
5         // Fetch the exchange rate;
6         // Update the database;
7         // Calculate the hourly rate;
8         // Return the value.
9     }
10 }
```

“Polymorphism makes software more fragile ... to make it more robust!”

Temporal Coupling

Tight coupling (**not good**):

```
1 List<String> list =  
2   new LinkedList<>();  
3 Foo.append(list, "Jeff");  
4 Foo.append(list, "Walter");  
5 return list;
```

Loose coupling (**good**):

```
1 return Foo.with(  
2   Foo.with(  
3     new LinkedList<>(),  
4     "Jeff"  
5   ),  
6   "Walter"  
7 );
```

<https://www.yegor256.com/2015/12/08/temporal-coupling-between-method-calls.html>

Distance of Coupling

```
1 class Temperature {  
2     private int t;  
3     public String toString() {  
4         return String.format("%d F",this.t);  
5     }  
6 }  
7  
8 Temperature x = new Temperature();  
9 String txt = x.toString();  
10 String[] parts = txt.split(" ");  
11 int t = Integer.parseInt(parts[0]);
```

“The larger the number (or the mean of all numbers), the worse the design: in good design we are not supposed to take something out of a method and then do some complex processing. The distance metric will tell us exactly that: how many times, and by how much, we violated the principle of loose coupling.”

<https://www.yegor256.com/2020/10/27/distance-of-coupling.html>

Read this:

Structured Design, Wayne P. Stevens, et al., IBM Systems Journal, 13.2, 1974

A Hierarchical Model for Object-Oriented Design Quality Assessment, Jagdish Bansiya et al., IEEE Transactions on Software Engineering, 28.1, 2002

An Overview of Various Object Oriented Metrics, Brij Mohan Goel et al., International Journal of Information Technology & Systems, 2.1, 2014

Analysing the Contribution of Coupling Metrics for the Development and Management of Process Architectures, Daniel Braunnagel et al., ECIS, 2015

New Metric: the Distance of Coupling (2020)

Fear of Decoupling (2018)

Reflection Means Hidden Coupling (2022)