TCC and LCC

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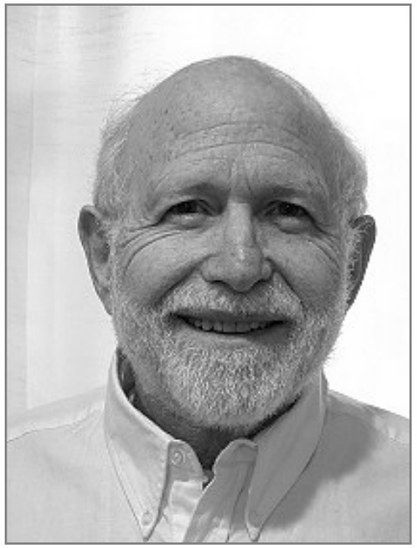
Lecture #8 out of 24
80 minutes

"Module cohesion may be conceptualized as the cement that holds the processing elements of a module together. In a sense, a high degree of module cohesion is an indication of close approximation of inherent problem structure."

— Edward Yourdon and Larry Constantine, *Structured Design: Fundamentals of a Discipline of Computer Program and Systems Design*, Prentice Hall, 1979



“We define two measures of class cohesion based on the direct and indirect connections of method pairs: TCC and LCC.”

— James M. Bieman and Byung-Kyoo Kang, *Cohesion and Reuse in an Object-Oriented System*, Proceedings of the Symposium on Software Reusability (SSR), 1995

Tight and Loose Class Cohesion (TCC+LCC)

```
1  class Rectangle
2    int x, y, w, h;
3    int area()
4      return w * h;
5    int move(int dx, dy)
6      x += dx; y += dy;
7    int resize(int dx, dy)
8      w += dx; h += dy;
9    bool fit()
10     return w < 100
11       && x < 100;
```

Max possible connections (NP):
$N \times (N-1)/2 = 4 \times 3/2 = 6$

Directly connected ($\mathrm{NDC} = 4$):
area+fit, area+resize, move+fit, resize+fit

Indirectly connected ($\mathrm{NIC} = 2$):
area+move, move+resize

$\mathrm{TCC} = \mathrm{NDC}/\mathrm{NP} = 4/6 = 0.66$
$\mathrm{LCC} = (\mathrm{NDC}+\mathrm{NIC})/\mathrm{NP} = 6/6 = 1.00$

Cohesion and Reuse in an Object-Oriented System*

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Abstract

We define and apply two new measures of object-oriented class cohesion to a reasonably large C++ system. We find that most of the classes are quite cohesive, but that the classes that are reused more frequently via inheritance exhibit clearly lower cohesion.

1 Introduction

Software developers aim for systems with high cohesion and low coupling. The value of these goals has not been validated empirically [6]. Rather, they have been justified on the basis of intuition. The amount of reuse — the number of times that a component is reused — is an indicator of reusability. Of course, other factors such as the usefulness of a component are also components of reusability.

Cohesion refers to the "relatedness" of module components. A highly cohesive component is one with one basic function. It should be difficult to split a cohesive component into two or more components. A cohesion scale that ranges from the least desirable category—*coincidental cohesion*—to the most desirable—*functional cohesion* [7]. To apply this cohesion model to classes in object-oriented software, we need to add a new classification, *data cohesion* [5].

Bieman and Ott developed a set of functional cohesion measures based on program slices [2]. These measures apply only to individual functions; their application to entire classes is not obvious. Chidamber and Kemerer developed a Lack of Cohesion in Methods (LCOM) measure for object-oriented software [3]. LCOM is effective at identifying the most non-cohesive classes, but it is not effective at distinguishing between partially cohesive classes. LCOM indicates lack of cohesion only when, compared pairwise, fewer than half of the paired methods use the same instance variables.

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Cohesion measures that are sensitive to small changes are needed in order to evaluate the relationship between cohesion and reuse. In this paper, we develop sensitive class cohesion measures and apply them to a reasonably large C++ system. We evaluate the relationship between class cohesion and private reuse in this system.

2 Class Cohesion

The components of a class are the instance variables and methods defined in the class plus those that are inherited. A method and an instance variable are related by the way that an instance variable is used by the method. Two methods are related (connected) through instance variable(s) if both methods use the instance variable(s). Class cohesion is defined in terms of the relative number of connected methods in the class.

2.1 Relations between Class Components

Individual methods are tied together via two mechanisms. One mechanism, *MIV relations*, involves communication between methods through shared instance variables. The other mechanism, *call relations*, involves the sending of messages directly (or indirectly) from one method to another.

An *MIV* relation is created when two or more class methods read or write to the same class instance variable. We treat shared instance variables as glue that binds the class methods together.

Instance variables used by the server may also used indirectly by the client when one method invokes another through message passing. Thus, a *call* relation can be reflected by the MIV relation; two methods with a call-relation are also connected through the instance variables used by both methods. One method uses the instance variable(s) directly and the other uses the instance variable(s) indirectly through the call relation. There is no MIV relation when a server method neither writes nor reads instance variables. Call relations can not always be determined statically, due to dynamic binding in object-oriented software. However, we have observed very few cases where dynamic binding affects class cohesion.

Figure 1 shows a C++ class *Stack* and Figure 2(a) shows the MIV relations among class components of *Stack* in Figure 1. A link between a rectangle and an oval indicates that the method corresponding to the

“If a class is designed in ad hoc manner and unrelated components are included in the class, the class represents more than one concept and does not model an entity. The cohesion value of such a class is likely to be less than 0.5.”

— James M. Bieman and Byung-Kyoo Kang, *Cohesion and Reuse in an Object-Oriented System*, Proceedings of the Symposium on Software Reusability (SSR), 1995

“Cohesion refers to how closely all the routines in a class or all the code in a routine support a central purpose—how focused the class is. The ideas of abstraction and cohesion are closely related—a class interface that presents a good abstraction usually has strong cohesion.”

— Steven McConnell, *Code Complete*, 2004

Abstraction

- Color: red
- Weight: 120g
- Price: $0.99

```
var file = {
  path: '/tmp/data.txt',
  read: function() { ... },
  write: function(txt) { ... }
}
```

The slide is taken from the "Pain of OOP" (2023) course.

Inheritance vs. Cohesion

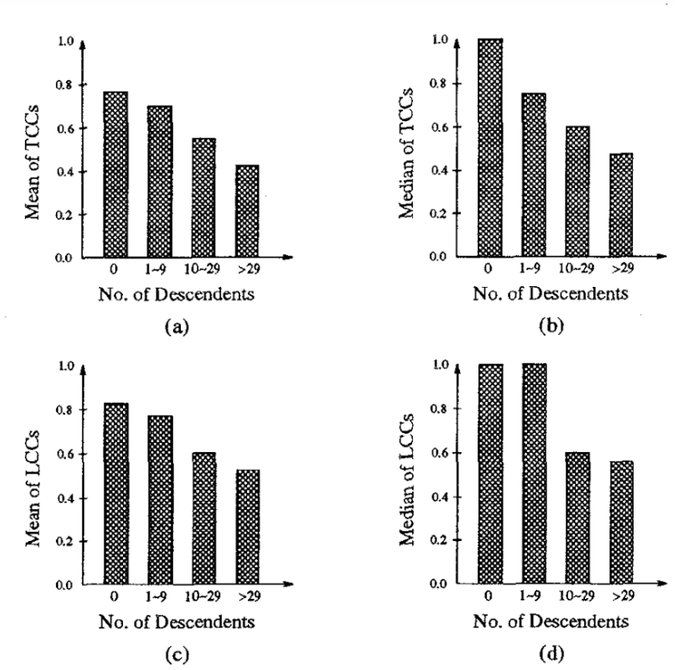

Figure 3: Number of descendents and Class Cohesion

"Our results show that the classes that are heavily reused via inheritance exhibit lower cohesion. We expected to find that the most reused classes would be the most cohesive ones." — James M. Bieman and Byung-Kyoo Kang

Inheritance is Code Reuse

```
1  class Manuscript {
2    protected String body;
3    void print(Console console) {
4      console.println(this.body);
5    }
6  }
7  class Article
8    extends Manuscript {
9    void submit(Conference cnf) {
10     cnf.send(this.body);
11   }
12 }
```

"The `Article` copies method `print()` and attribute body from the `Manuscript`, as if it's not a living organism, but rather a dead one from which we inherit its parts."

"Implementation inheritance was created as a mechanism for code reuse. It doesn't fit into OOP at all."

Source: Inheritance Is a Procedural Technique for Code Reuse (2016)

Composition over Inheritance

```
class Manuscript
  protected String body;
  void print(Console console)
    console.println(this.body);

class Article
  extends Manuscript
  void submit(Conference cnf)
    cnf.send(this.body);
```

```
class Manuscript
  protected String body;
  void print(Console console)
    console.println(this.body);

class Article
  Manuscript manuscript;
  Article(Manuscript m)
    this.manuscript = m;
  void submit(Conference cnf)
    cnf.send(this.body);
```

Wikipedia: https://en.wikipedia.org/wiki/Composition_over_inheritance

TCC+LCC can be calculated by a few tools:

- jPeek for Java
- C++ — don't know
- Python — don't know
- JavaScript — don't know
- C# — don't know

Read this:

Cohesion and Reuse in an Object-Oriented System, James M. Bieman and Byung-Kyoo Kang, Proceedings of the Symposium on Software Reusability (SSR), 1995

Code Complete, Steven McConnell, 2004

Structured Design: Fundamentals of a Discipline of Computer Program and Systems Design, Edward Yourdon and Larry Constantine, Prentice Hall, 1979

Inheritance Is a Procedural Technique for Code Reuse (2016)