

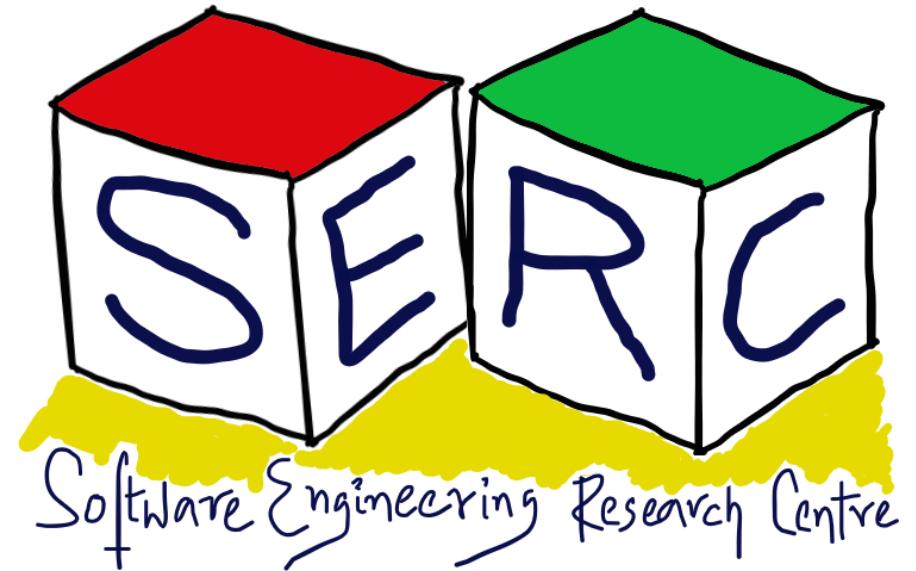
Code Smells and Code Metrics

CS6.401 Software Engineering

Dr. Karthik Vaidhyanathan

karthik.vaidhyanathan@iiit.ac.in

<https://karthikvaidhyanathan.com>



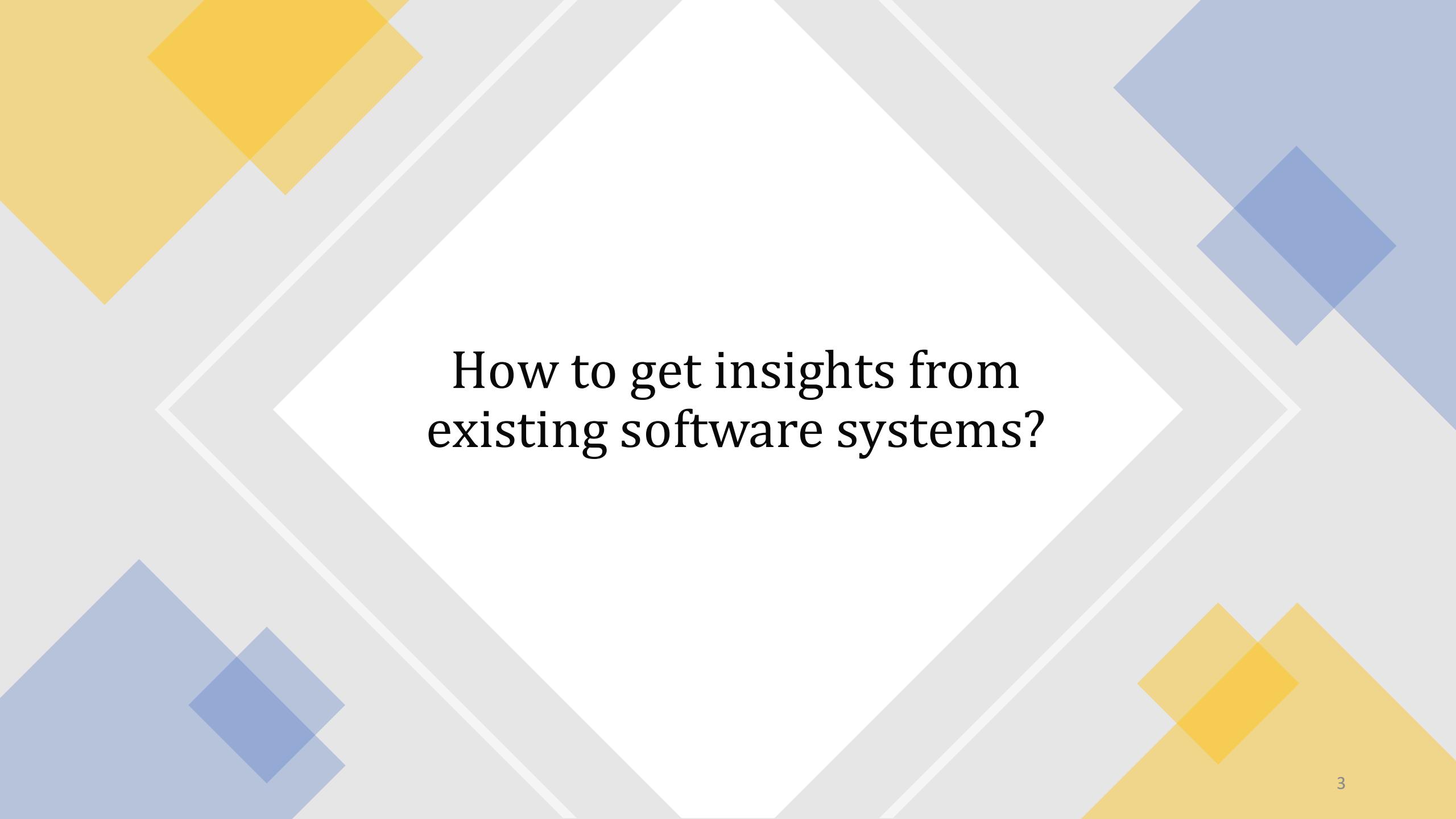
Acknowledgements

The materials used in this presentation have been gathered/adapted/generate from various sources as well as based on my own experiences and knowledge

-- Karthik Vaidhyanathan

Sources:

1. Refactoring, Improving the design of existing code, Martin Fowler et al., 2000
2. Various research articles that have been duly cited



How to get insights from
existing software systems?

Mining Software Repositories

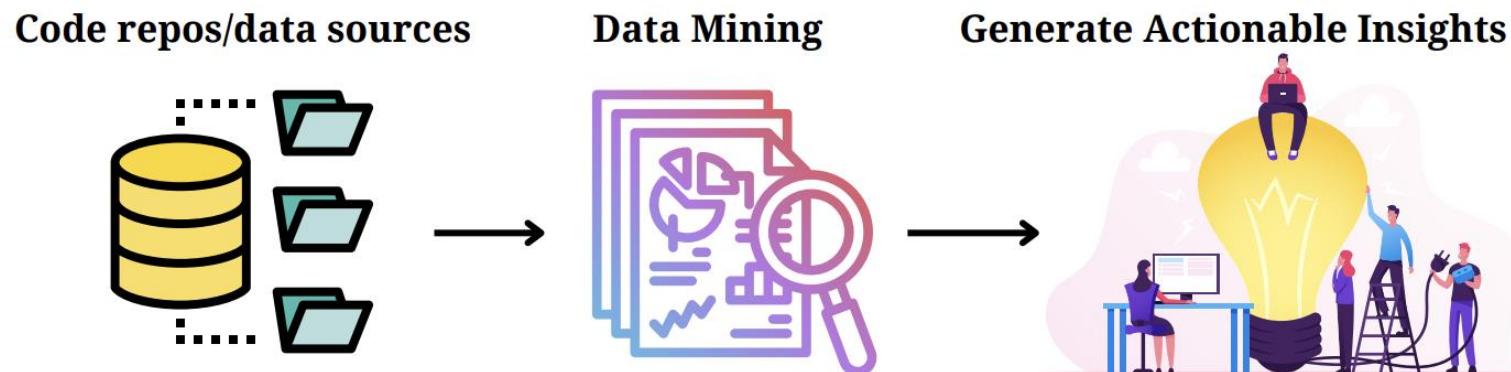
*The MSR field **analyzes rich data available in software repositories** to extract useful and **actionable information** about software projects and systems – msrconf.org*

- Large amount of artefacts are generated in the software development process
- These data are available from various sources
 - Version control systems (SVN, Mercurial,..)
 - Q&A Forums (Stackoverflow, Stackexchange, etc.)
 - Bug repositories (BugZilla, Jira)
 - Code repositories (Github, Gitlab, etc.)
 - Crash reports, log files, execution traces, etc.

Mining Software Repositories

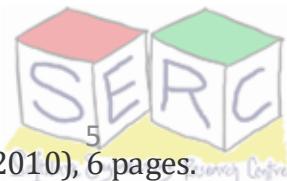
Repositories are great sources of unbiased data on how a product came to be - something that's very valuable and hard to find.

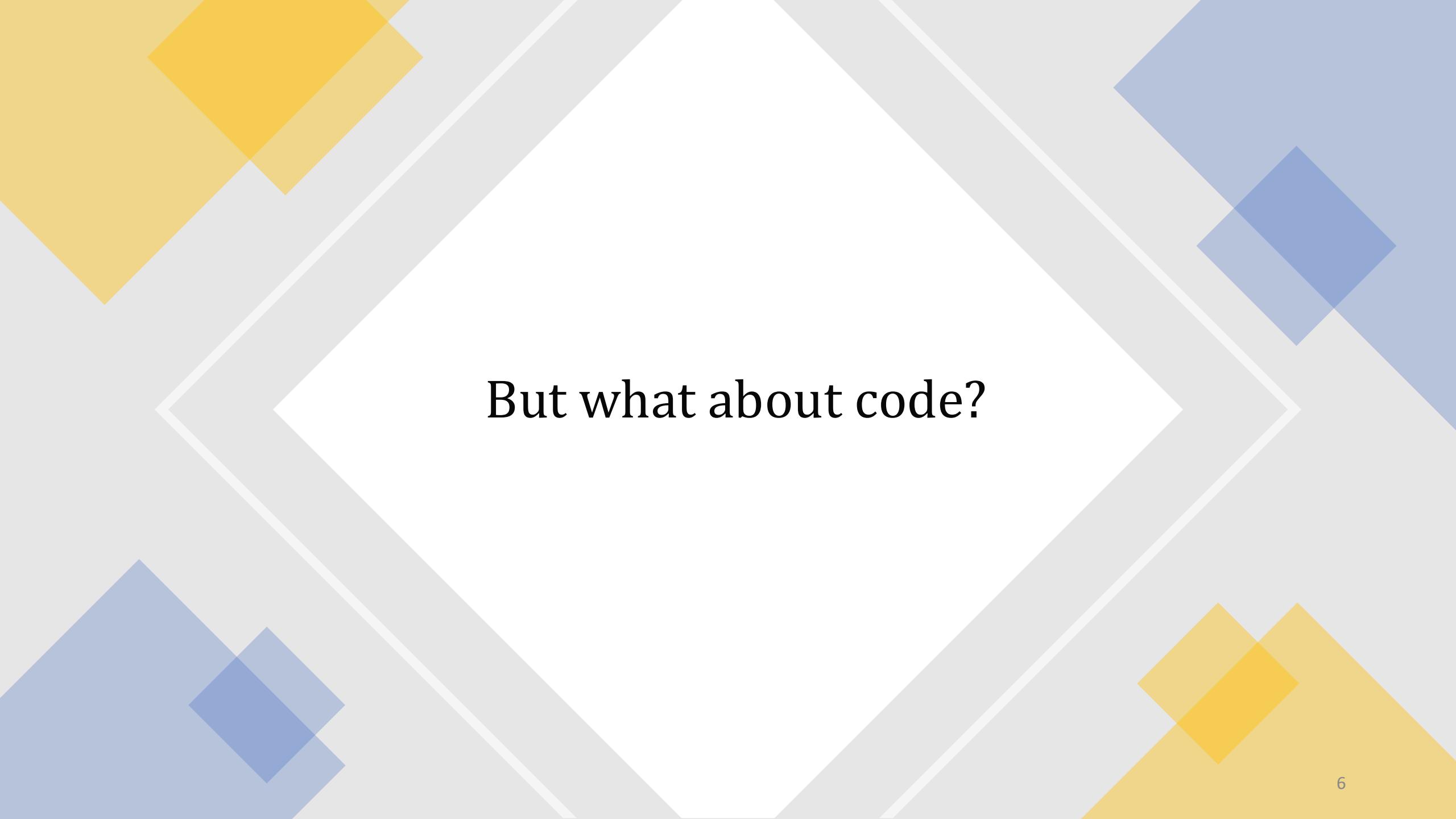
-- Andreas Zeller



<https://2026.msrconf.org/>

- Generate insights on best practices (eg: Sources of technical debt)
- Develop approaches for automated code completions, bug localization,..
- ...





But what about code?

Code can also Smell

Code smell serves an indication that there is deeper problem in the system

- Code smells are only hints – not necessarily a problem!
- Look for bad smells – definitely needs a refactoring!
- But is there some list that could be used? Or common ones?



Some Examples

Code Smells – Long Method



Course Enrolment Scenario

```
1 public boolean enrolmentHandler(String studentId, String studentName, String courseId,
2                                 String courseName, String paymentId)
3 {
4     boolean status = false;
5     // check payment status
6     // check if prerequisites are satisfied
7     // check if student has added the course
8     // add student to the course
9     return status;
10 }
```

Expand the comments to code – that's a very long method!!

Long Method - Refactoring



Course Enrolment Scenario

```
1 public boolean enrolmentHandler(String studentId, String studentName, String courseId,
2                                 String courseName, String paymentId)
3 {
4     boolean enrolStatus = false;
5     paymentStatus = checkPayment(studentId, courseId);
6     prerequisiteStatus = checkPrerequisite(studentId, courseId);
7     addDropStatus = checkAddDrop(studentId, courseId);
8     hasFreeSeats = seatsAvailability(courseId);
9     enrolStatus = enrolStudent(paymentStatus, prerequisiteStatus, addDropStatus, hasFreeSeats);
10    return enrolStatus;
11 }
```

What changes do you notice? – Any comments ? Can we do better?

Code Smells - Long Method

Longer a procedure, more difficult it is to understand

Context: A method has to perform a series of computations to accomplish a functionality

Problem: All the computations are written in its entirety inside one method making the method long - Too many lines of code!!

Suggested Refactoring: Any method longer than 20 lines (even 10+) is worth inspecting

Decompose the method into smaller methods -> Extract Method

This may result in other smells, which can call for further refactoring – parameter list

Code Smells – Long Parameter List



Course Enrolment Scenario

```
1 public boolean enrolmentHandler(String studentId, String studentName, String courseId,
2                                 String courseName, String paymentId)
3 {
4     boolean enrolStatus = false;
5     paymentStatus = checkPayment(studentId, courseId);
6     prerequisiteStatus = checkPrerequisite(studentId, courseId);
7     addDropStatus = checkAddDrop(studentId, courseId);
8     hasFreeSeats = seatsAvailability(courseId);
9     enrolStatus = enrolStudent(paymentStatus, prerequisiteStatus, addDropStatus, hasFreeSeats);
10    return enrolStatus;
11 }
```

See the number of parameters that are taken as input by enrolmentHandler

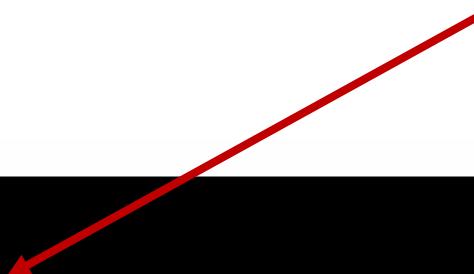
Long Parameter List – Refactoring

Check parameters



Course Enrolment Scenario

```
1 public boolean enrolmentHandler(Student student, Course course, String paymentId)
2 {
3     boolean enrolStatus = false;
4     studentId = student.getStudentId();
5     courseId = course.get courseId();
6     paymentStatus = checkPayment(studentId, courseId);
7     prerequisiteStatus = checkPrerequisite(studentId, courseId);
8     addDropStatus = checkAddDrop(studentId);
9     hasFreeSeats = seatsAvailability(courseId);
10    enrolStatus = enrolStudent(paymentStatus, prerequisiteStatus, addDropStatus, hasFreeSeats);
11    return enrolStatus;
12 }
```



The parameters are now respective objects, can we do further?

Code Smells - Long Parameter List

Try to have not more than 4 parameters – Not a Golden rule

Context: A method has to perform a series of computations to accomplish a functionality and it takes in lot of parameters

Problem: Hard to understand and the calling function/method needs to place the parameters in right positions, attracts adding of even more parameters!!

Suggested Refactoring: Multiple ways

- Replace parameter with method (call inside)
- Preserve whole object
- Introduce parameter object (if data items are related and no logical object exists)

Long parameter can indicate other smells (eg: long methods, data clumps, primitive obsession)

Code Smells – Primitive Obsession



Make Payment Scenario

```
1 protected String makePayment(String StudentId, String studentName, String studentType,  
2 int semester, int numberOfCourses)  
3 {  
4     //calculate payment considering all different parameters  
5     //logic to make payment  
6     return paymentId;  
7 }
```

Overuse of primitive types

Primitive Obsession – Refactoring

Check type of parameters



Make Payment Scenario

```
1 protected String makePayment(Student student,
2 int semester, int numberOfCourses)
3 {
4     //calculate payment considering all different parameters
5     //logic to make payment
6     return paymentId;
7 }
```

We can do further, can we?

Code Smells – Primitive Obsession

Over use of primitive data types instead of objects

Context: A method has to perform a series of computations to accomplish a functionality and it takes in lot of parameters of primitive types

Problem: Having too many primitive types may lead to long parameters and can contribute to code duplication and type mismatches

Suggested Refactoring: Multiple ways

- Replace data value with object
- If there are group of fields (extract class)
- If there are fields that belong to object (Introduce parameter object)

Primitive obsession can lead to other smells (eg: long methods, data clumps, long Methods, etc.)

Code Smells – Switch Statements (Conditional Complexity)

```
Course Enrolment Scenario

1 public boolean checkEnrollmentEligibility(Course course, Student
2 student)
3 {
4     if (course.requiresPrerequisites())
5     {
6         if (student.getStudentType() == "PhD")
7         {
8             if (course.getCourseType() == "advanced")
9             {
10                 return true;
11             }
12         }
13     else if (student.getStudentType() == "PGSSP")
14     {
15         //logic to check if the master student has eligibility
16     }
17     else if /*something more*/
18     {
19         /*logic for other student followed by another else*/
20     }
21 }
22 return false;
23 }
24 }
```

Too many conditions!! Can we do better?

Switch Statements (Conditional Complexity) - Refactoring



Course Enrolment Scenario

```
1 public boolean checkEnrollmentEligibility(Course course, Student
2 student)
3 {
4     if (course.requiresPrerequisites())
5     {
6         if(student.hasEligibility(course))
7         {
8             return true;
9         }
10    return false;
11 }
12 return false;
13 }
```



PGSSP Class inherited from Student

```
1 class PGSSP extends Student
2 {
3     /*
4      member variables and functions
5     */
6     @override
7     public boolean hasEligibility(course)
8     {
9         //logic to check eligibility in a course for
10    PGSSP
11 }
12 }
```

Leveraging inheritance and polymorphism, we can do this for different types of student

Code Smells – Conditional Complexity

Complex set of switch or sequence of if conditions. When nesting goes too far!!

Context: A Single class has some operations and it requires editing multiple times when changes are made outside the class

Problem: Having too many conditional operations or switch makes it harder to understand, and high probability of breaking, testing also becomes difficult

Suggested Refactoring: Multiple ways

- Introduce polymorphism
- Extract and move – Group things that need to be together, move to introduce polymorphism
- If there is only few cases that affect single method – use extract method
[Polymorphism can become overkill]

Code Smells – Divergent Change



Instructor Class

```
1 class Instructor
2 {
3     public String instructorId;
4     public String instructorName;
5     public List<Course>
6         courseOfferings;
7     //there can be inherited variables
8     public Instructor
9         (instructorId, instructorName)
10    {
11        //logic to add an instructor
12    }
13    // Other functions can go here
14    public boolean assignCourses
15        (Course course)
16    {
17        //logic to add course to offering
18    }
19 }
```



Course Class

```
1 class Course
2 {
3     public String courseId;
4     public String courseName;
5     public List<Instructor>
6         instructorList;
7     //There can be more variables
8     public Course
9         (courseId, courseName)
10    {
11        //logic to add a course
12    }
13    // Other functions can go here
14    public boolean assignInstructor
15        (Instructor instructor)
16    {
17        //logic to add instructor to
18        course
19 }
```

What could be some issue here with respect to instructor class?

Divergent Change - Refactoring



```
CourseManager Class

1 class CourseManager
2 {
3     private int courseCount;
4     private int unAssignedCourses;
5
6     //There can be more variables
7     // Other functions can go here
8     public boolean assignCourses
9         (Course course,Instructor instructor)
10    {
11        //logic to add course to add to list
12    }
13 }
```

Extract class and put the functionalities in one place so that one change does not impact others

Code Smells – Divergent Change

One change should not result in changes in "n" other places within a class

Context: A class has a method to perform an operation which is affected by changes happening in another method in same or different class

Problem: Impacts maintainability and results in a scenario where one needs to know everything. Also affects the testability and understandability

Suggested Refactoring: Multiple ways

- Extract Class – Put everything that changes together into one class
- Extract method – Check if the operations that change can be wrapped into a single method

Code Smells – Feature Envy

Student Class

```
1 class Student
2 {
3     public String studentId;
4     public String studentName;
5     protected String fullAddress;
6     private Address address;
7     public String zipCode;
8     /*There may be other inherited
9      variables */
10    /* other getters can be
11       added here */
12    public getFullAddress()
13    {
14        return address.getLine1() +
15            " " + address.getLine2() +
16            " " + address.getCity() +
17            "\n" + address.getState() +
18            "\n" +
19        address.getZipCode();
20    }
21 }
```

Address Class

```
1 class Address
2 {
3     public String line1;
4     public String line2;
5     public String city;
6     public String state;
7     public String zipCode;
8     /*There may be other inherited
9      variables */
10    /* getters for each
11       variables */
12    public String getCity()
13    {
14        return this.city;
15    }
16
17    public String getLine1()
18    {
19        return this.line1;
20    }
21 }
```

One class depending too much on functions from another class – Envious!!

Feature Envy - Refactoring

```
●●● Address Class  
1 class Address  
2 {  
3     public String line1;  
4     public String line2;  
5     public String city;  
6     public String state;  
7     public String zipCode;  
8     /*There may be other inherited  
9      variables */  
10    public String getLine1()  
11    {  
12        return this.line1;  
13    }  
14    /* getters for each  
15     variables */  
16    public String getFullAddress()  
17    {  
18        return this.getLine1() +  
19            " " + this.getLine2() +  
20            " " + this.getCity() +  
21            "\n" + this.getState() +  
22            "\n" + this.getZipCode();  
23    }  
24 }
```

Move the method to the class so that the single responsibility principle is also ensured

Code Smells – Feature Envy

Method in a class is envious of features offered by other classes

Context: A class has a method that needs to perform operations for which it depends on multiple data and operations in another class(es)

Problem: Causes coupling between different classes affecting extensibility and changeability. Testing also becomes challenging

Suggested Refactoring: Multiple ways

- Move method – moving the method to where it belongs
- Extract and move method – When only part of the method has too much dependency

Code Smells – Speculative Generality



Course Class

```
abstract Class Course
{
    public String courseId;
    public String courseName;
    /* Other variables */
}
```



BouquetElective Class

```
Class BouquetElective extends Course
{
    /* some functions for enrollment */
}
```

Sometimes we over design and
overcomplicate things and
speculate !!



SystemElective Class

```
Class SystemElective extends Course
{
    /* some functions for enrollment */
}
```

Do we even need an inheritance at the point

Speculative Generality - Refactoring



Course Class

```
Class Course
{
    public String courseId;
    public String courseName;
    public String courseType;

    public Course (String courseId, String courseName)
    {
        //add Course
    }
    /* Other getters and setters*/
}
```

Refactoring by Collapsing the hierarchy

Code Smells – Speculative Generality

Code created with speculation that something will be required in future and never implemented

Context: Classes have been built after extending classes creating inheritance relationship but never used or features have been planned but not implemented

Problem: Unwanted complexity affecting understandability. Can lead to some implementations in the child classes resulting in unwanted behaviour. Can be spotted when the only use of a class is some test cases.

Suggested Refactoring: Multiple ways

- Collapse Hierarchy – Remove abstract classes not doing much
- Use Inline Class – Remove unnecessary delegation
- Remove unused parameters
- Rename methods to be in line with context

Five Main Categories Of Smells

- **Bloaters** – Too many things packed, keeps accumulating
(eg: Long Method, primitive obsession)
- **Object Oriented Abusers** – Incorrect use of OO principle or even incomplete
(eg: Conditional complexity)
- **Change Preventers** – Changing one causes change in others
(eg: Divergent Change)
- **Dispensables** – Code whose absence won't make a difference, but presence could!
(eg: Speculative Generality)
- **Couplers** – Creates too much coupling between classes
(eg: Feature Envy)

Quick Reference Cards

Smell Name	Short Description	Suggested Refactoring
Duplicated Code	Same code in more than one place	Extract Method, pull up field,..
Long Method	Too many things in one method	Extract Method, Decompose conditionals, Parameter objects,..
Large Class	One class is doing too much	Extract class, extract sub classes. Extract interface,..
Long Parameter List	Never ending list of parameters	Parameter object, Extract Method,..
Divergent Change	Too many changes in one class for different reasons	Extract class,..
Shotgun Surgery	One change => too many changes	Move Method, Move field, Inline class,..
Feature Envy	Interested in methods of another class	Extract Method, Move Method
Data Clumps	Same data items together in many places	Extract Class, Parameter Object, ..
Primitive Obsession	Using too many primitive data types	Extract class, Introduce parameter Object,..
Switch Statements	Complex switch statements, conditionals,..	Replace with explicit method, Replace conditional with polymorphism,..
Parallel Inheritance hierarchies	Requiring parallel subclasses creation	Move Method and Move field,..

Smell Name	Short Description	Refactoring
Lazy Class	Not doing much, exists there!	Collapse hierarchy,..
Speculative Generality	No use in the current context than test	Inline class, Collapse hierarchy,..
Temporary Field	Having instance variables not used much	Extract class for unused variables,..
Message Chains	Ask to one object which leads to next...	Hide Delegate, extract method and move method,..
Middle Man	Lots of delegations happening	Remove Middle Man, Inline Method, Replace delegate with inheritance,..
Inappropriate Hierarchy	Too much private information shared between classes	Extract class, hide delegate, Extract class, ..
Alternative Classes different Interface	Two classes having similar methods Using different interface	Move method, extract superclass,..
Incomplete Library Class	Modifying library class can be impossible	Introduce local extension, foreign method,..
Data Class	Classes with just some data fields	Move method, Extract method,..
Refused Bequest	Subclasses don't need everything	Push down method, Push down field,..
Comments	Too much of comments is also bad	Rename method, Extract method,..

Refactoring - Best Practices

- Understand code well before refactoring
 - What you think might be a problem may not be a problem!
- Create tests and ensure the tests work just like before or even better
- Keep refactoring small and commit often – Take small steps, test and repeat
- The scope of refactoring needs to be defined clearly
 - Sometimes it can end in a loop
 - To do notes can be always useful
- It always helps when there are more eyes [Also for project!!]



Refactoring – Some Tools

- There is no single best tool that are available – Use your intuition along with existing tools
- IDEs provide a lot of support – Refactor menu (In IntelliJ IDEA)
- SonarLint – Like spellchecker for code, detects smells, checks for any possible issues (available for IDE's like IntelliJ, Eclipse, etc.)
- SonarQube – It's a server, given a repo it finds the list of code smells

LLMs for refactoring!!

Give me a small example of java code refactoring



Sure! Here's a small example of Java code refactoring to improve readability and maintainability.

Original Code:

java

Copy

```
public class Greeting {  
    public static void main(String[] args) {  
        String name = "John";  
        int hour = 14;  
  
        if (hour >= 0 && hour < 12) {  
            System.out.println("Good morning, " + name + "!");  
        } else if (hour >= 12 && hour < 18) {  
            System.out.println("Good afternoon, " + name + "!");  
        } else {  
            System.out.println("Good evening, " + name + "!");  
        }  
    }  
}
```

Key Improvements:

1. Extracted Methods:

- The logic for determining the greeting (`getGreeting`) and checking the time of day (`isMorning`, `isAfternoon`) is moved into separate methods. This makes the code more modular and easier to test.

2. Constants:

- The default name `"John"` is stored in a constant (`DEFAULT_NAME`), making it easier to change and reuse.

3. Readability:

- The `main` method is now cleaner and focuses on high-level logic, while the details are handled in helper methods.

4. Reusability:

- The `getGreeting` method can now be reused in other parts of the program if needed.

This refactoring makes the code more maintainable, easier to understand, and ready for future extensions. Let me know if you'd like further clarification or another example!

Refactored Code:

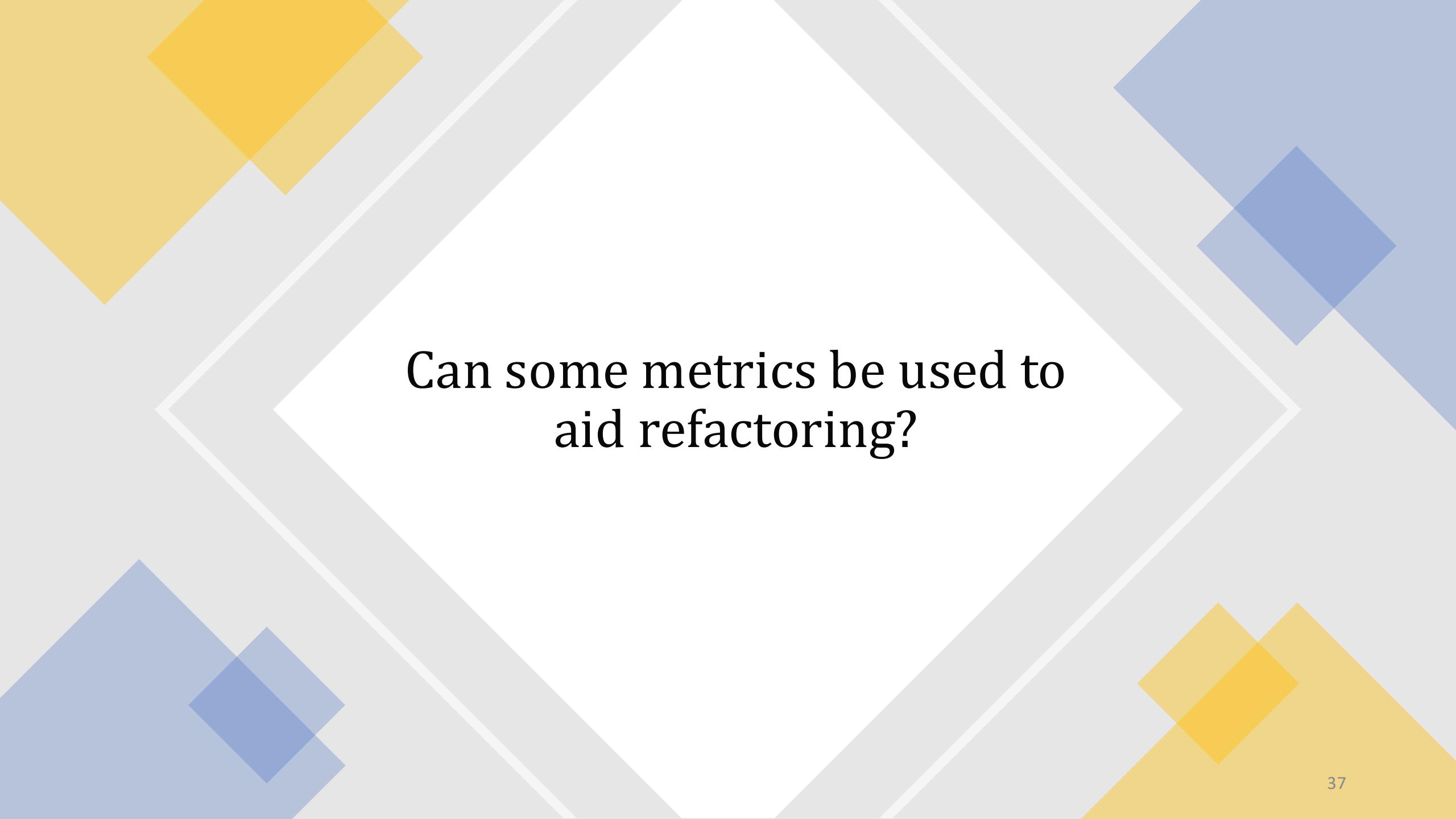
java

```
public class Greeting {  
    private static final String DEFAULT_NAME = "John";  
  
    public static void main(String[] args) {  
        String name = DEFAULT_NAME;  
        int hour = 14;  
  
        String greeting = getGreeting(hour);  
        System.out.println(greeting + ", " + name + "!");  
    }  
  
    private static String getGreeting(int hour) {  
        if (isMorning(hour)) {  
            return "Good morning";  
        } else if (isAfternoon(hour)) {  
            return "Good afternoon";  
        } else {  
            return "Good evening";  
        }  
    }  
  
    private static boolean isMorning(int hour) {  
        return hour >= 0 && hour < 12;  
    }  
  
    private static boolean isAfternoon(int hour) {  
        return hour >= 12 && hour < 18;  
    }  
}
```

Copy

Feel free to use but with





Can some metrics be used to aid refactoring?

Code Complexity

The ratio of time spent reading versus writing is well over 10 to 1

--Robert C Martin

- Code over time has tendency to accumulate complexity
- Greater or larger functionality should not have direct impact on code complexity
- Unnecessary complexity affects maintainability, time to market, understandability and testability

How to manage it? – Start measuring it!!



What is measurement?

- Entity: can be an Object (person) or event (journey)
- Attribute: Feature of property of entity (height, blood pressure, etc.)
- Two types of measurement:
 - Direct measurement: measurement of attribute
 - Indirect measurement: Measurement of attribute involves measurement of some other attribute (eg: BMI)
- Uses of measurement – Assessment or Prediction

Measurement In terms of Software

- Carried out throughout the software development process
- Measurements can be performed at different levels
 - Completed Product (reliability, performance, etc.)
 - Development Process (time, man hours, etc.)
 - Source Code (lines of code, cyclomatic complexity, etc.)
- Source code metrics focus on measuring the source code of a system
 - Allows to measure complexity of code
 - Improve quality of code and thereby overall software
 - Used for lot of applications (defect prediction, fault localizations, refactoring, testing, etc.)

Commonly Used Source Code Metrics

- Lines of Code (LOC)
 - Easiest but effective indicator of complexity
 - Small modules have low defect rates as opposed to large ones
- Cyclomatic Complexity
 - Developed by Thomas McCabe, 1976
 - Allows to measure the complexity with respect to control flow of the code
- Halstead Software Science Metrics
 - Developed by Halstead, 1977
 - Measures complexity in terms of the amount of information in source code
- There are also object oriented metrics (Chidamber and Kemerer 1994, Li and Henry 1993)

Cyclomatic Complexity

- Count of the number of linearly independent paths in a program
- Has a big impact on testing – test cases needs to cover the different paths
- Uses the control flow graph, G of the given program – Approach based on graph theory
- $V(G) = e - n + 2p$
 - e = Number of edges
 - n = Number of nodes
 - p = Connected components

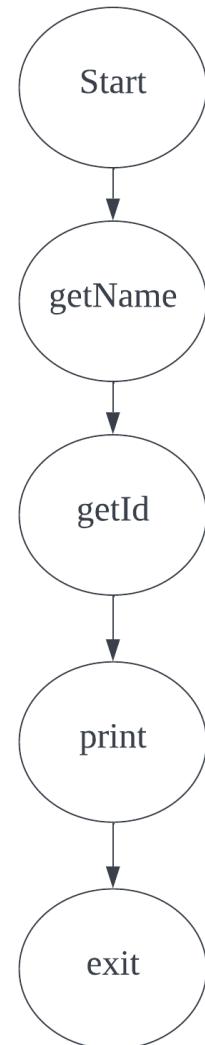
In practice the number boils down to 1 (base) + number of decision points

Cyclomatic Complexity - Simple Example

Display Student

```
1 public void displayDetails(Student student)
2 {
3     name = student.getName();
4     id = student.getId();
5     System.out.println(name + " " + id);
6 }
```

$$\begin{aligned}\text{Complexity} &= 4 - 5 + 2*1 \\ &= 1\end{aligned}$$



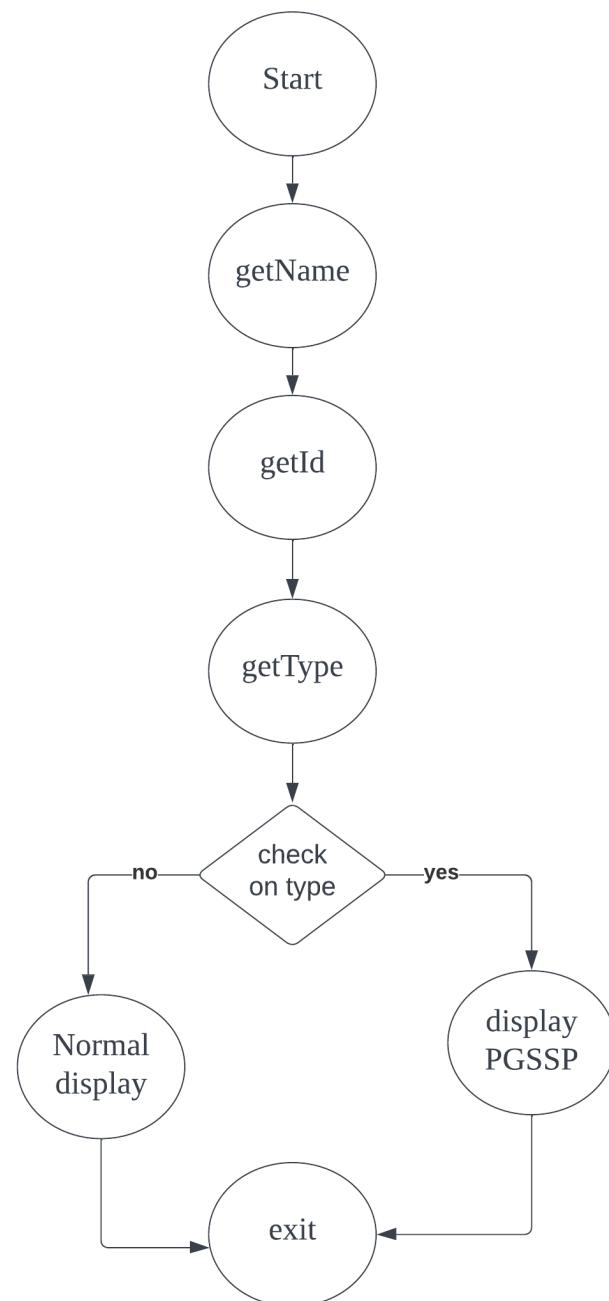
Cyclomatic Complexity - Another Example

● ● ●

Highlight PGSSP Students

```
1 public void displayDetails(Student student)
2 {
3     name = student.getName();
4     id = student.getId();
5     type = student.getType();
6     if (type.equals("PGSSP"))
7     {
8         System.out.println(name + " " + id + " " + "PGSSP");
9     }
10    else
11    {
12        System.out.println(name + " " + id);
13    }
14 }
```

$$\begin{aligned}\text{Complexity} &= 8 - 8 + 2*1 \\ &= 2\end{aligned}$$



Halstead Software Science Metrics

- Considers program as a collection of tokens
- Tokens: Operators or operands
- The metrics makes use of the occurrence of operators and operands in a program to reason about complexity

$n_1 \rightarrow$ number of distinct operators (+, -, *, while, for, (), {}, function calls, etc.)

$n_2 \rightarrow$ number of distinct operands (variables, method names, etc.)

$N_1 \rightarrow$ total number of occurrence of operators

$N_2 \rightarrow$ total number of occurrence of operands

- The above observations are combined to provide different metrics

Halstead Software Science Metrics

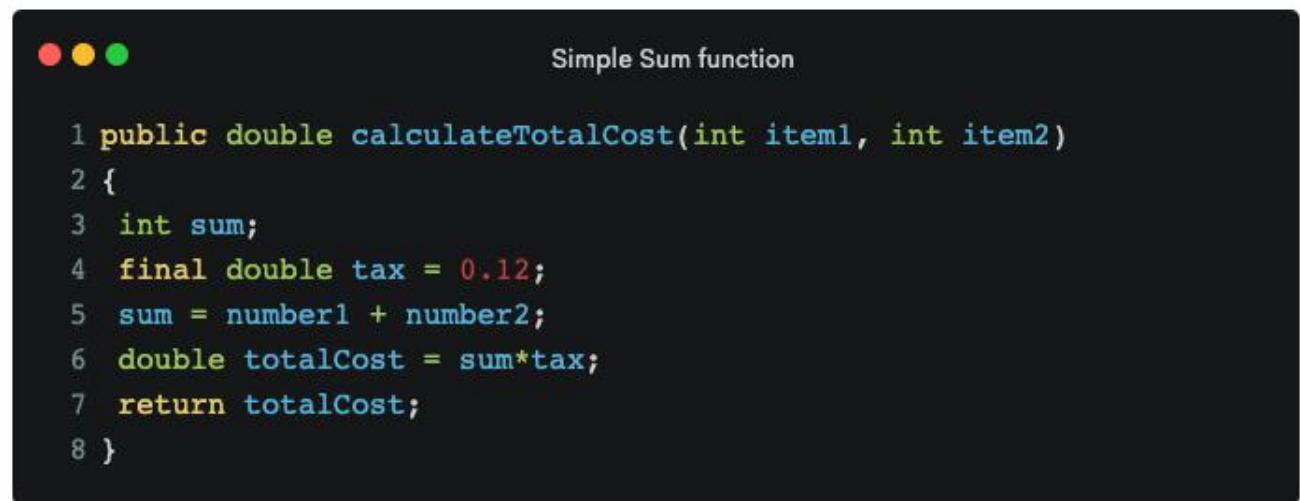
- Vocabulary, $n = n_1 + n_2$
 - Program length $N = N_1 + N_2$
 - Volume, $V = N \log_2 (n)$
-

Operators (+, *, =, double, int,
final, return, {}, (),), $n_1 = 11$

Operands (calculateTotalCost, item1, item2, sum, tax, number1, number 2, totalCost) = **8**

$N_1 - (1, 1, 3, 3, 3, 1, 1, 1, 1, 1) = 17$ **$n = 19, N = 28, V = 28 \log(19) = 35.80$**

$N_2 - (1, 1, 1, 2, 2, 1, 1, 2) = 11$



The screenshot shows a Java code editor with a dark theme. At the top, there are three colored circles (red, yellow, green). To the right, it says "Simple Sum function". The code itself is:

```
1 public double calculateTotalCost(int item1, int item2)
2 {
3     int sum;
4     final double tax = 0.12;
5     sum = number1 + number2;
6     double totalCost = sum*tax;
7     return totalCost;
8 }
```

Six OO Metrics – Chidamber and Kemerer

- Weighted Methods per Class
- Depth of Inheritance Tree
- Number of Children of a Class
- Coupling Between Object Classes
- Response for a Class
- Lack of Cohesion on Methods

Thank You



Course website: [karthikv1392.github.io/cs6401_se](https://karthikvaidhyanathan.github.io/cs6401_se)

Email: karthik.vaidhyanathan@iiit.ac.in

Web: <https://karthikvaidhyanathan.com>

X: [@karthi_ishere](https://twitter.com/@karthi_ishere)

