# Object Oriented Software Metrics

## Lecture 3

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# Outline

- Motivation and how the quality of software can be measured
- Control Flow Graphs (CFG)
- McCabe's Cyclomatic Complexity Metrix
- CK Metrics
- Metrics guidelines
- Tools

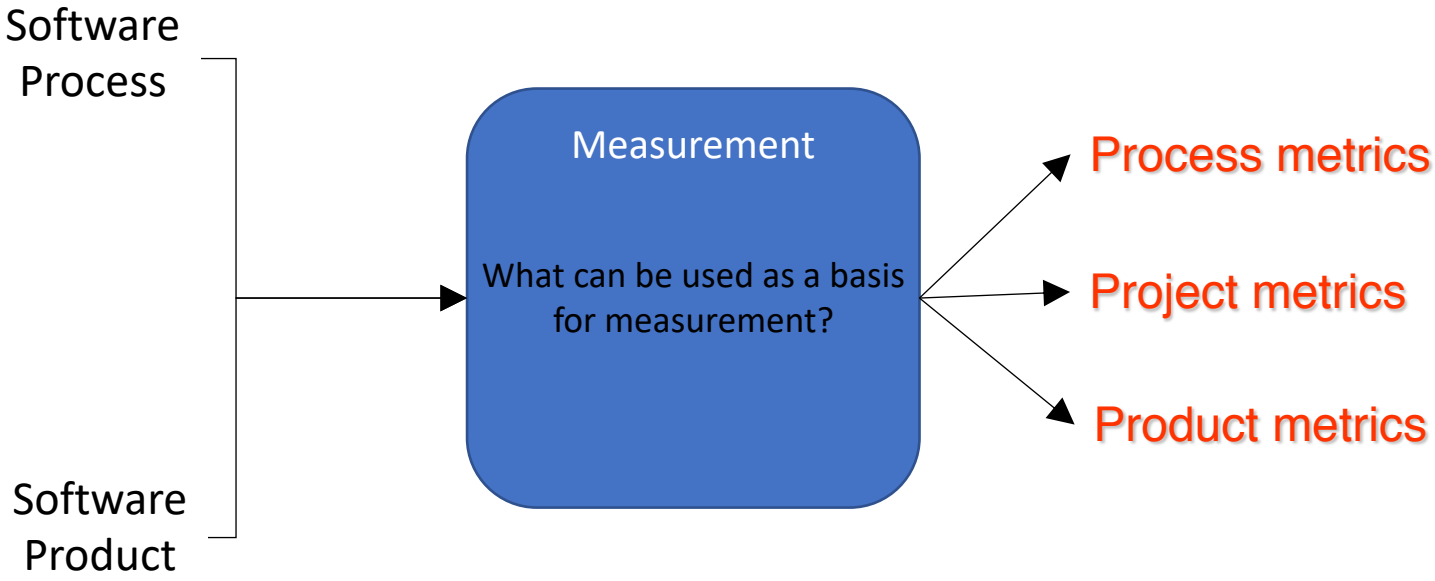
# Motivation for Metrics

- Estimate the cost & schedule of future projects
- Evaluate the productivity impacts of new tools and techniques
- Establish productivity trends over time
- Improve software quality
- Forecast future staffing needs
- Anticipate and reduce future maintenance needs

# Definitions

- *Measure* - quantitative indication of extent, amount, dimension, capacity, or size of some attribute of a product or process.
- *Metric* - quantitative measure of degree to which a system, component or process possesses a given attribute.
- *Indicator* - combination of metrics that provide insight into the software process or project or product itself.

# How can Quality be Measured?



# How can Quality be Measured?

- To define what can be used as a basis for measurement, Bassili proposed a top-down goal oriented framework for software metrics:
  - Step 1. Develop a set of Goals
  - Step 2. Develop a set of questions that characterise the goals
  - Step 3. Specify the Metrics needed to answer the questions
  - Step 4. Develop Mechanisms for data Collection and Analysis
  - Step 5. Collect Validate and Analyse the Data.
  - Step 6. Analyse in a Post Mortem Fashion
  - Step 7. Provide Feedback to Stakeholders

Basili, Victor R. *Software modeling and measurement: the Goal/Question/Metric paradigm*. 1992.

# Control Flow Graph (CFG)

- A representation, using **graph** notation, of all paths that might be traversed through a program during its execution.
- Nodes are basic blocks in a program code
- Edges represent possible flow of control from the end of one block to the beginning of the other
- There may be multiple incoming/outgoing edges for each block

# How to draw CFG

1. Identify methods in a class

```
public void collisionDetector() {
    dts = computeDTS();
    dfo = computeDFP();
    breaking = false;
    airbagactive = false;
    alarmon = false;

    while(accelerating) {
        dts = computeDTS();
        dfo = computeDFP();

        if(dts < 10) {
            alarmon = true;
        }

        if(dts == dfo) {
            airbagactive = true;
        }
        else {
            airbagactive =false;
        }
    }

    printstatus();

}
```

# How to draw CFG

2. Divide the intermediate code of each method into basic blocks. A basic block is a piece of straight line code, i.e. there are no jumps in or out of the middle of a block.

```
public void collisionDetector() {
    dts = computeDTS();
    dfo = computeDFP();
    breaking = false;
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        if(dts == dfo) {
            airbagactive = true;
        }
        else {
            airbagactive =false;
        }
    }

    printstatus();

}
```
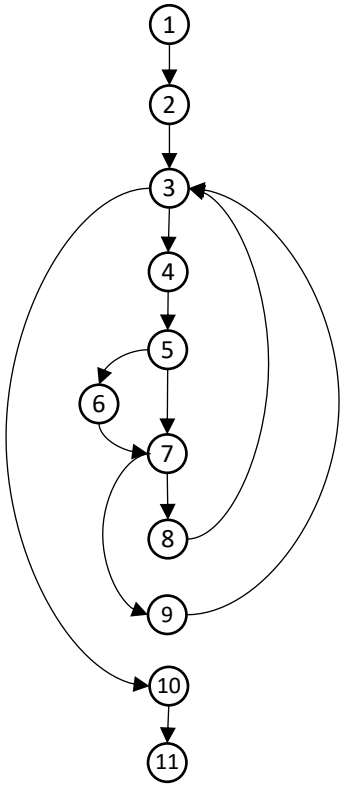

# How to draw CFG

3. Add labels to the following:
   - start of the method
   - each block
   - decision points
   - end of the method

```
(1) public void collisionDetector() {
        dts = computeDTS();
        dfo = computeDFP();
(2)     breaking = false;
        airbagactive = false;
        alarmon = false;

(3)     while(accelerating) {
(4)         dts = computeDTS();
            dfo = computeDFP();

(5)         if(dts < 10) {
(6)             alarmon = true;
            }

(7)         if(dts == dfo) {
(8)             airbagactive = true;
            }
            else {
(9)             airbagactive =false;
            }
        }

(10)    printstatus();

(11) }
```

# How to draw CFG

4. Generate a control flow graph of how to move from the first node to the last node

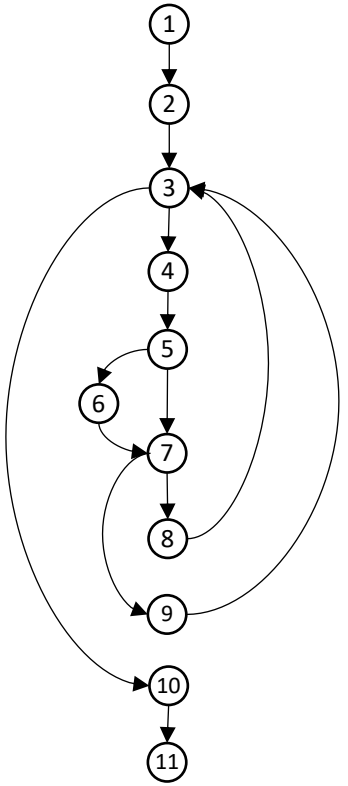



```
1  public void collisionDetector() {
       dts = computeDTS();
       dfo = computeDFP();
2      breaking = false;
       airbagactive = false;
       alarmon = false;

3      while(accelerating) {
4          dts = computeDTS();
           dfo = computeDFP();

5          if(dts < 10) {
6              alarmon = true;
           }

7          if(dts == dfo) {
8              airbagactive = true;
           }
           else {
9              airbagactive =false;
           }
       }

10     printstatus();

11 }
```

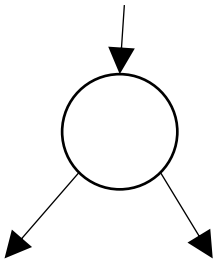
# How to draw CFG

- An edge from one node to another node exists if execution of the statement representing the first node can result in transfer of control to the other node.

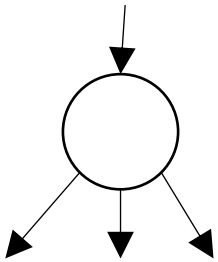
- The graph is complete if there is a path from every other node to the last node



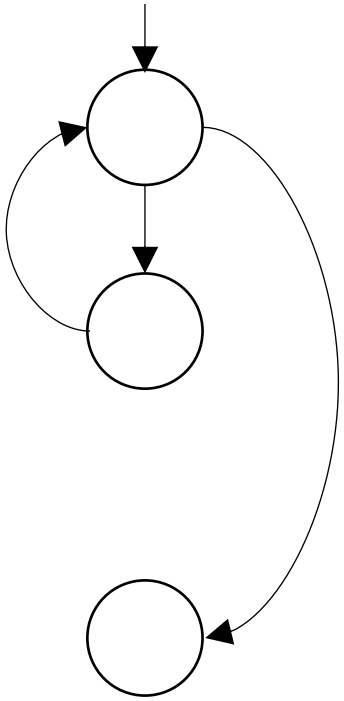
# How to draw CFG



if



case



while

# How to draw CFG

Exercise: Draw the control flow graph of a for loop

# McCabe's Cyclomatic Metric

Given a control flow graph G, where the cyclomatic complexity is represented by $V(G)$, then:

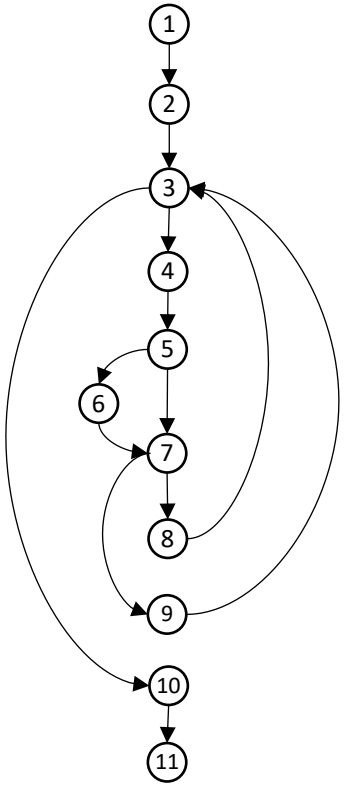
$$V(G) = E - N + 2$$

$N$ is the number of nodes in G

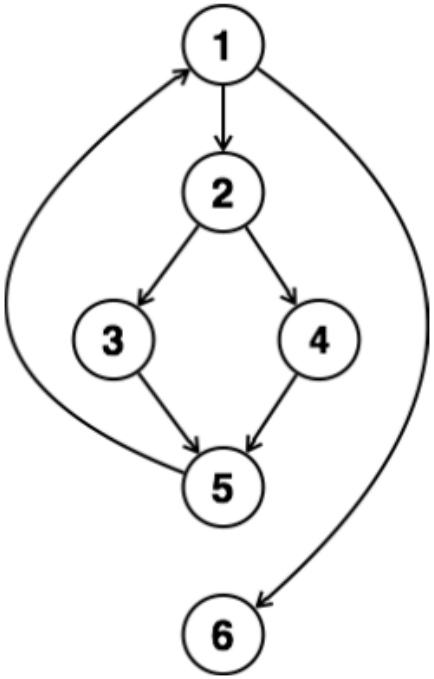
$E$ is the number of edges in G

# McCabe's Cyclomatic Metric

Cyclomatic complexity
V(G) = 13 – 11+2 = 4



# McCabe's Cyclomatic Metric




What is Cyclomatic Complexity of the CFG?

# McCabe's Cyclomatic Metric

- rule of thumb:
  - begin restructuring your code with the component with highest V(G)

| V(G) | Risk |
|---|---|
| 1 – 10 | easy program, low risk |
| 11 – 20 | complex program, tolerable risk |
| 21 – 50 | complex program, high risk |
| >50 | impossible to test, extremely high risk |

# McCabe's Cyclomatic Metric

- Advantages
  - easy to compute (parser)
  - empirical studies: good correlation between cyclomatic complexity and understandability
- Disdvantages
  - only control flow
  - no data flow
  - may be inappropriate for OO programs (trivial functions)

# CK Metrics

- In 1994, Shyam Chidamber and Chris Kemerer defined six simple metrics for object-oriented programs.
  - Since then this work has been extended to over 300 metrics.

S. R. Chidamber and C. F. Kemerer, "A metrics suite for object oriented design," in *IEEE Transactions on Software Engineering*, vol. 20, no. 6, pp. 476-493, Jun 1994.

# CK Metrics: Objectives

- **WMC** Weighted Methods Per Class
- **DIT** Depth of Inheritance Tree
- **NOC** Number of Children
- **CBO** Coupling between Object Classes
- **RFC** Response for a Class
- **LCOM** Lack of Cohesion of Methods

S. R. Chidamber and C. F. Kemerer, "A metrics suite for object oriented design," in *IEEE Transactions on Software Engineering*, vol. 20, no. 6, pp. 476-493, Jun 1994.

# Weighted methods per class (WMC)

- This is the sum of the complexities of methods in a class

$$WMC = \sum_{i=1}^{n} c_i$$

- $c_i$ is the *complexity* of each method $M_i$ of the class
- Complexity is the McCabe complexity of the method
- Smaller values are better
- WMC is a predictor of how much TIME and EFFORT is required to develop and to maintain the class.
- The objective is to achieve **low** WMC

# Depth of inheritance tree (DIT)

- DIT is the length of the path from the node to the root of the tree

The greater values of DIT :

a) The greater the number of methods (NOM) it is likely to inherit, making more **COMPLEX** to predict its behaviour

b) The greater the potential **RE-USE** of inherited methods

c) Small values of DIT in most of the system's classes may be an indicator that designers are forsaking **RE-USABILITY** for simplicity of **UNDERSTANDING**.

d) The objective is to achieve the appropriate **trade-off** in DIT

# Number of children (NOC)

- For any class in the inheritance tree, NOC is the number of *immediate* children of the class (the number of direct subclasses)

The greater values of NOC:

a) the greater is the **RE-USE**
b) The greater is the probability of **improper abstraction** of the parent class,
c) The greater the requirements of method's **TESTING** in that class.
d) Small values of NOC, may be an indicator of lack of communication between different class designers.
e) The objective is to achieve the appropriate **trade-off** in NOC

# Coupling between Object classes (CBO)

- For a class, C, the CBO metric is the number of other classes to which the class is coupled
- A class, X, is coupled to class C if
  - X operates on (affects) C or
  - C operates on X

Small values of CBO :

- Improve **MODULARITY** and promote **ENCAPSULATION**
- Indicates independence in the class, making easier its **RE-USE**
- Makes easier to **MAINTAIN** and to **TEST** a class.
- The objective is to achieve **low** CBO

# Response for class (RFC)

- It is the number of methods of the class plus the number of methods called by any of those methods.
- Normally RFC is calculated up to the first method call level, and not through the transitive closure of all method calls.
- Smaller numbers are better
  - Larger numbers indicate increased complexity and debugging difficulties. **TESTING** and **MAINTANACE** of the Class becomes more **COMPLEX**
- The objective is to achieve **low** RFC

# Lack of cohesion metric (LCOM)

- Counts the sets of methods in a class that are **not** related through the sharing of some of the class's fields.
  - Step 1: Consider all pairs of a class's methods.
  - Step 2: Check if the pair share common fields.
    - In some of these pairs both methods access at least one common field of the class, while in other pairs the two methods to not share any common field accesses.
  - Step 3: The lack of cohesion in methods is then calculated by subtracting from the number of method pairs that don't share a field access the number of method pairs that do

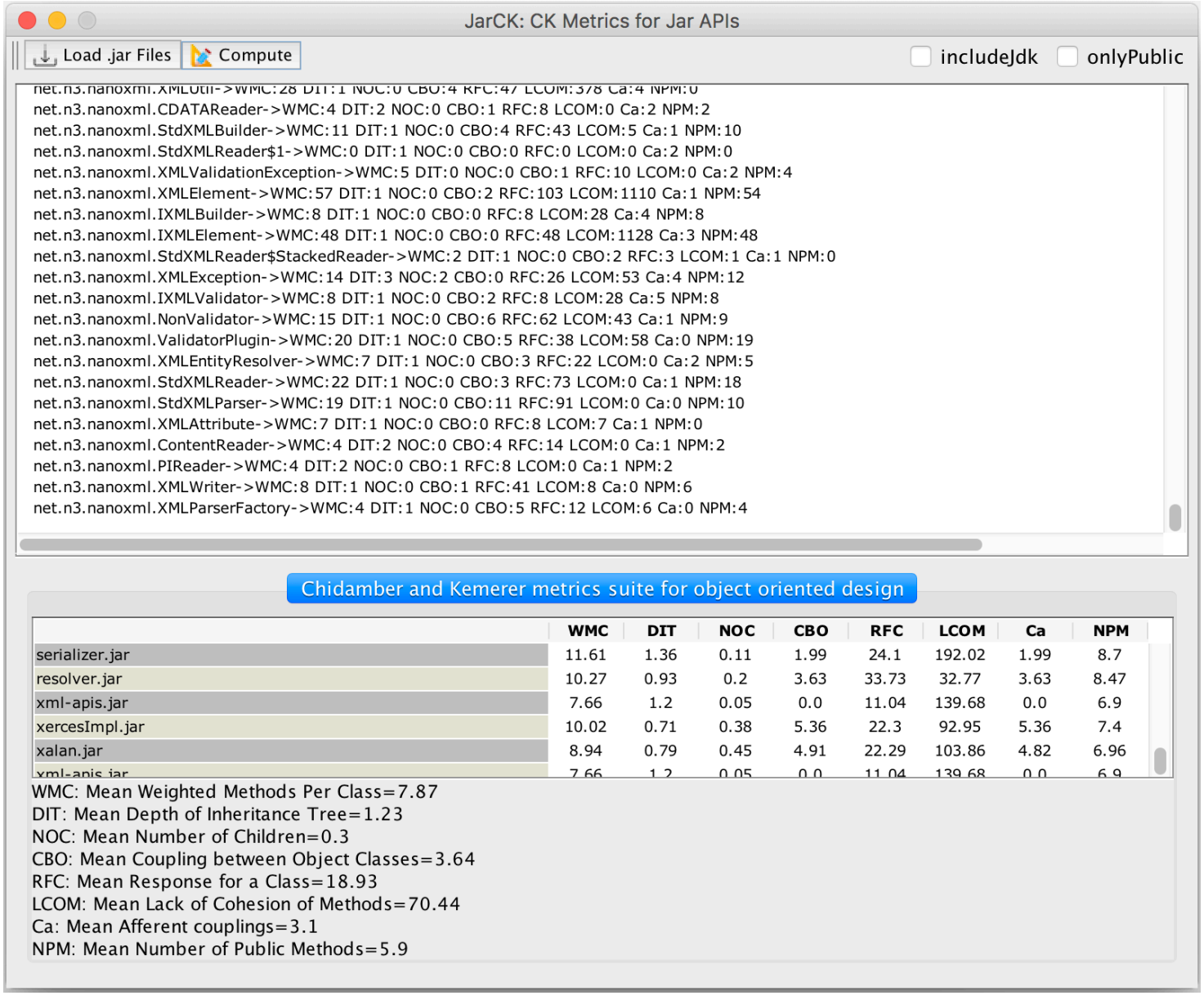
# Lack of cohesion metric (LCOM)

- A measure of the “tightness” of the code
- Greater values of LCOM:
  - Increases **COMPLEXITY**
  - Does not promotes **ENCAPSULATION** and implies classes should probably be split into two or more subclasses
- Helps to identified low-quality design
- The objective is to achieve **low** LCOM

# CK Metrics: Guidelines

| METRIC | GOAL | LEVEL | COMPLEXITY (To develop, to test and to maintain) | RE-USABILITY | ENCAPSULATION, MODULARITY |
|---|---|---|---|---|---|
| WMC | Low | ▼ | ▼ | ▲ | |
| DIT | Trade-off | ▼ | ▼ | ▼ | |
| | | ▲ | ▲ | ▲ | |
| NOC | Trade-off | ▼ | ▼ | ▼ | |
| | | ▲ | ▲ | ▲ | |
| CBO | Low | ▼ | ▼ | | ▲ |
| RFC | Low | ▼ | ▼ | | |
| LCOM | Low | ▼ | ▼ | | ▲ |

# JarCK




| | WMC | DIT | NOC | CBO | RFC | LCOM | Ca | NPM |
|---|---|---|---|---|---|---|---|---|
| serializer.jar | 11.61 | 1.36 | 0.11 | 1.99 | 24.1 | 192.02 | 1.99 | 8.7 |
| resolver.jar | 10.27 | 0.93 | 0.2 | 3.63 | 33.73 | 32.77 | 3.63 | 8.47 |
| xml-apis.jar | 7.66 | 1.2 | 0.05 | 0.0 | 11.04 | 139.68 | 0.0 | 6.9 |
| xercesImpl.jar | 10.02 | 0.71 | 0.38 | 5.36 | 22.3 | 92.95 | 5.36 | 7.4 |
| xalan.jar | 8.94 | 0.79 | 0.45 | 4.91 | 22.29 | 103.86 | 4.82 | 6.96 |
| xml-apis.jar | 7.66 | 1.2 | 0.05 | 0.0 | 11.04 | 139.68 | 0.0 | 6.9 |

# Workshop 1

- Software Metrics(5 Marks)