Code Metrics

CS6.401 Software Engineering

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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!!

Definition from: Norman Fenton, Software Measurement: A Necessary Scientific Basis, IEEE TSE, March 1994

What is measurement?

Measurement is defined as the ***process*** *by which* ***numbers or symbols are assigned*** *to* ***attributes of entities*** *in the real world in such a way as to* ***describe them*** *according to clearly* ***defined rules***

Definition from: Norman Fenton, Software Measurement: A Necessary Scientific Basis, IEEE TSE, March 1994

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

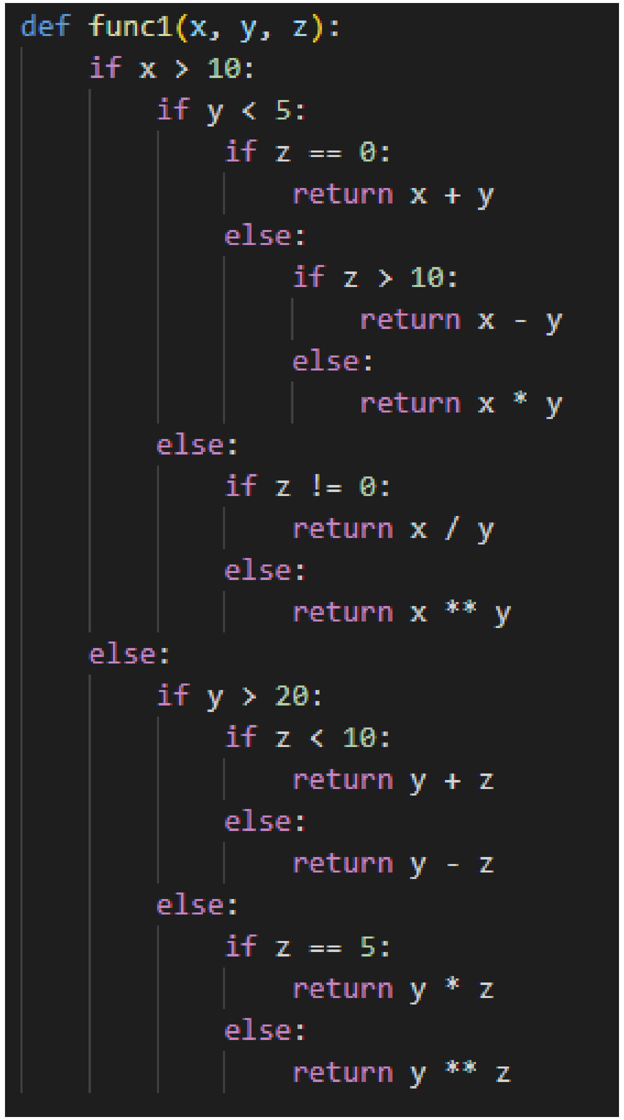
- Lines of Code (LOC)
  - Easiest but effective indicator of complexity
  - Small modules have low defect rates as opposed to large ones

- Cyclomatic Complexity
  - Developed by Thomas McCabe, 1976
  - Allows to measure the complexity with respect to control flow of the code

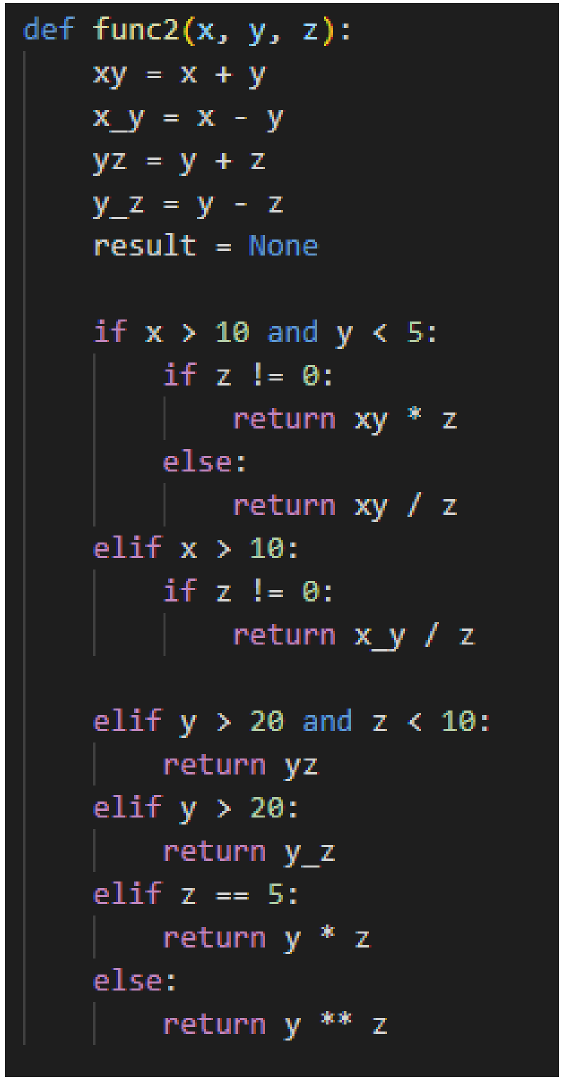
- Halstead Software Science Metrics
  - Developed by Halstead, 1977
  - Measures complexity in terms of the amount of information in source code

- There are also object oriented metrics (Chidamber and Kemerer 1994, Li and Henry 1993)

Which is more complex?



```
def func1(x, y, z):
    if x > 10:
        if y < 5:
            if z == 0:
                return x + y
            else:
                if z > 10:
                    return x - y
                else:
                    return x * y
        else:
            if z != 0:
                return x / y
            else:
                return x ** y
    else:
        if y > 20:
            if z < 10:
                return y + z
            else:
                return y - z
        else:
            if z == 5:
                return y * z
            else:
                return y ** z
```



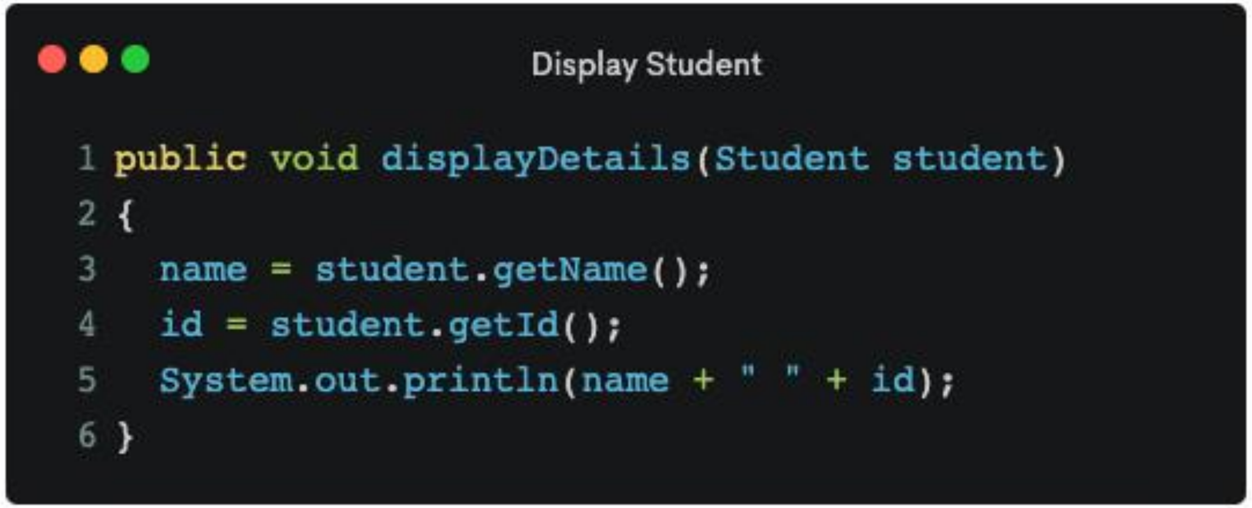
```
def func2(x, y, z):
    xy = x + y
    x_y = x - y
    yz = y + z
    y_z = y - z
    result = None

    if x > 10 and y < 5:
        if z != 0:
            return xy * z
        else:
            return xy / z
    elif x > 10:
        if z != 0:
            return x_y / z

    elif y > 20 and z < 10:
        return yz
    elif y > 20:
        return y_z
    elif z == 5:
        return y * z
    else:
        return y ** z
```

Cyclomatic Complexity

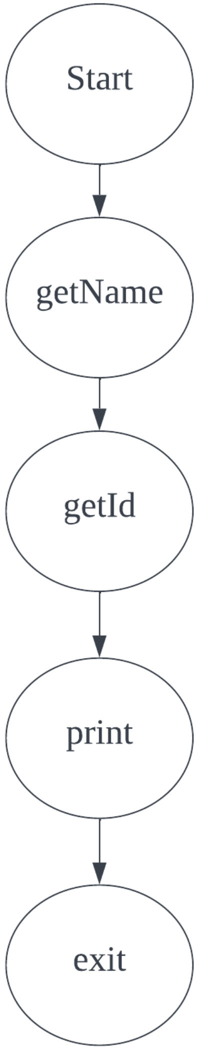
- Count of the number of linearly independent paths in a program
- Has a big impact on testing – test cases needs to cover the different paths
- Uses the control flow graph, G of the given program – Approach based on graph theory
- V(G) = e – n + 2p
  - e = Number of edges
  - n = Number of nodes
  -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

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

Cyclomatic Complexity - Simple Example

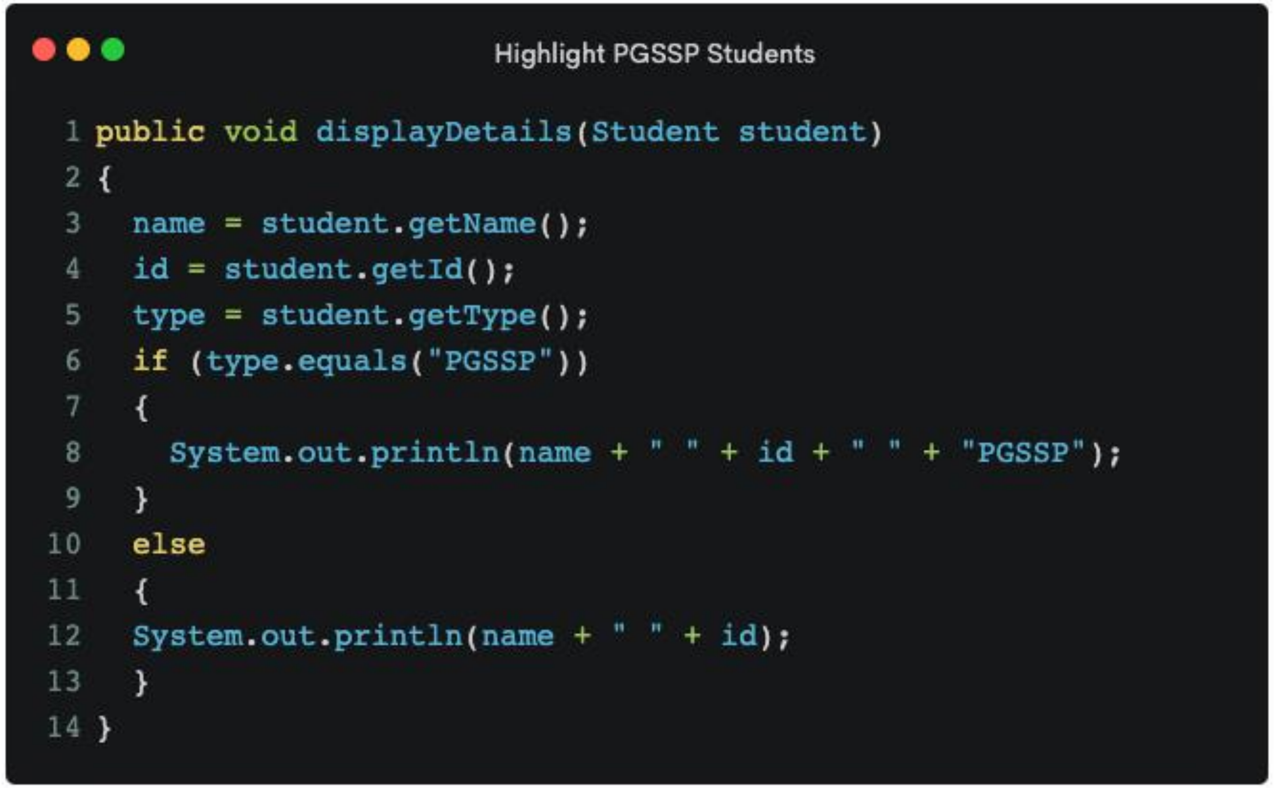


```java
public void displayDetails(Student student)
{
  name = student.getName();
  id = student.getId();
  System.out.println(name + " " + id);
}
```



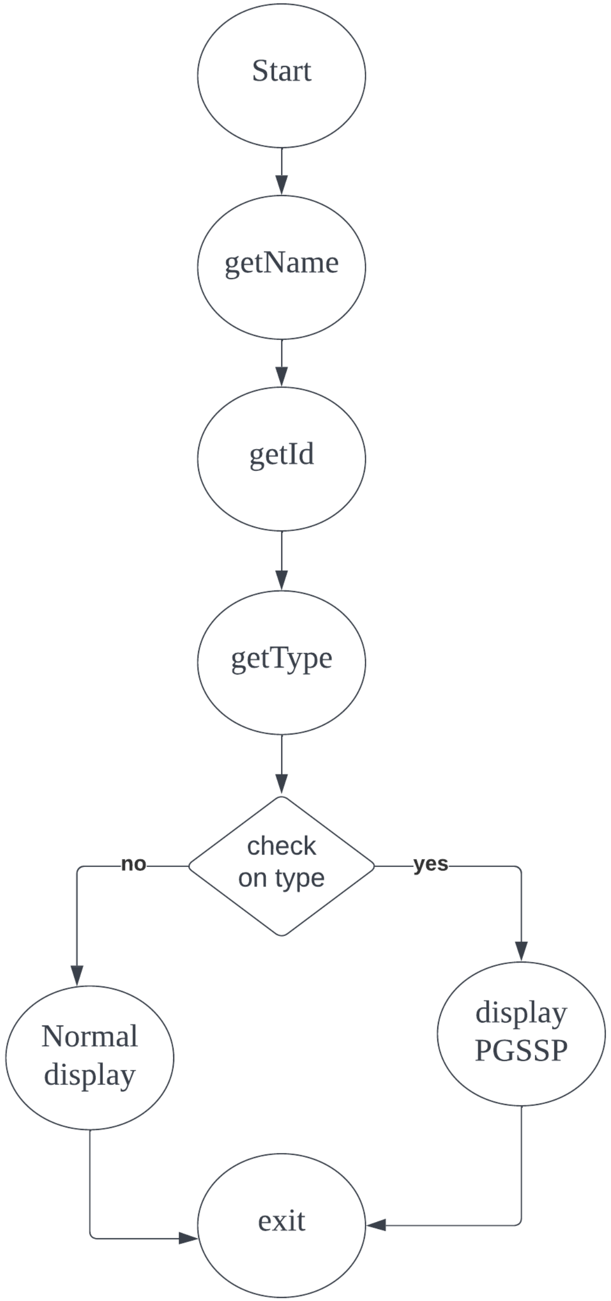
$$\text{Complexity} = 4 - 5 + 2*1$$
$$= 1$$

Cyclomatic Complexity - Another Example



Highlight PGSSP Students

```
public void displayDetails(Student student)
{
  name = student.getName();
  id = student.getId();
  type = student.getType();
  if (type.equals("PGSSP"))
  {
    System.out.println(name + " " + id + " " + "PGSSP");
  }
  else
  {
  System.out.println(name + " " + id);
  }
}
```



Complexity = 8 – 8 + 2*1
= 2

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

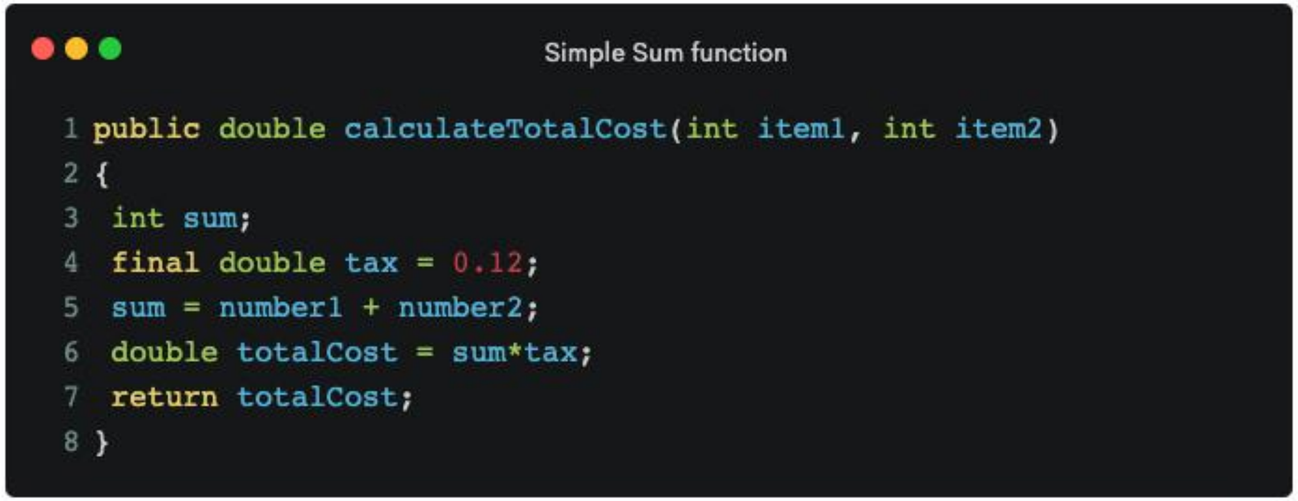
  n1 -> number of distinct operators (+, -, *, while, for, (), {}, function calls, etc.)
  n2 -> number of distinct operands (variables, method names, etc.)
  N1 -> total number of occurrence of operators
  N2 -> total number of occurrence of operands

- The above observations are combined to provide different metrics

Halstead Software Science Metrics

- Vocabulary, n = n1 + n2
- Program length N = N1 + N2
- Volume, V = $N\log_2 (n)$

….



Simple Sum function

```
public double calculateTotalCost(int item1, int item2)
{
 int sum;
 final double tax = 0.12;
 sum = number1 + number2;
 double totalCost = sum*tax;
 return totalCost;
}
```

Operators (+, *, =, double, int, final, return, {, }, (,)), n1 = **11**

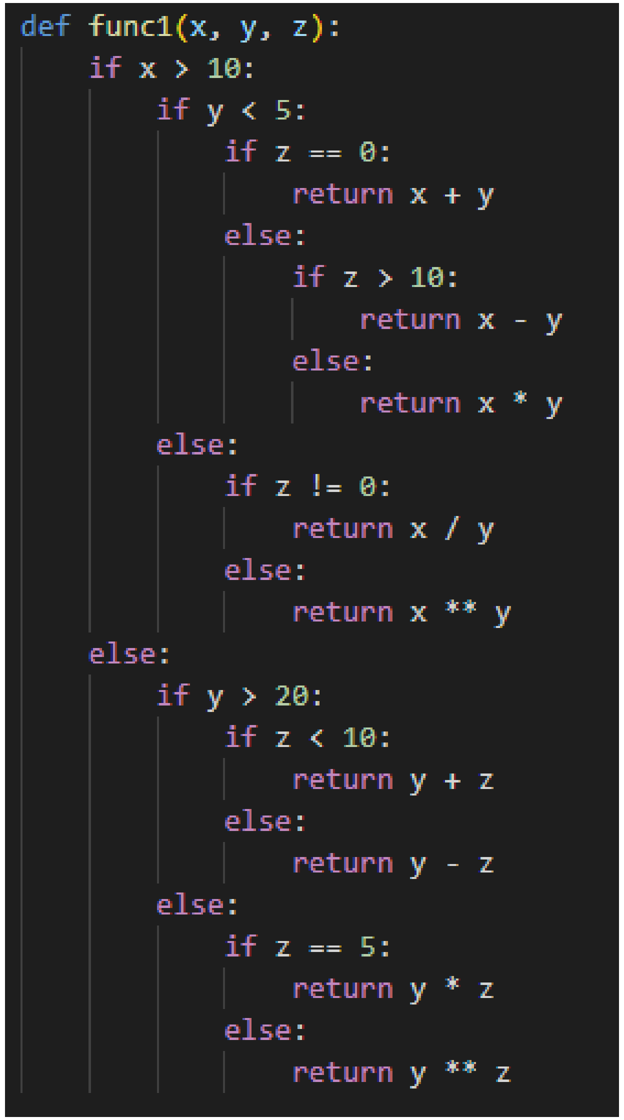
Operands (calculateTotalCost, item1, item2, sum, tax, number1, number 2, totalCost) = **8**

N1 - (1, 1, 3, 3, 3, 1, 1,1,1,1,1) = **17**

n = 19, N = 28, V = 28log(19) = 35.80

N2 – (1, 1, 1, 2, 2, 1, 1, 2) = **11**

Which is more complex?



```python
def func1(x, y, z):
    if x > 10:
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            else:
                if z > 10:
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                else:
                    return x * y
        else:
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            else:
                return x ** y
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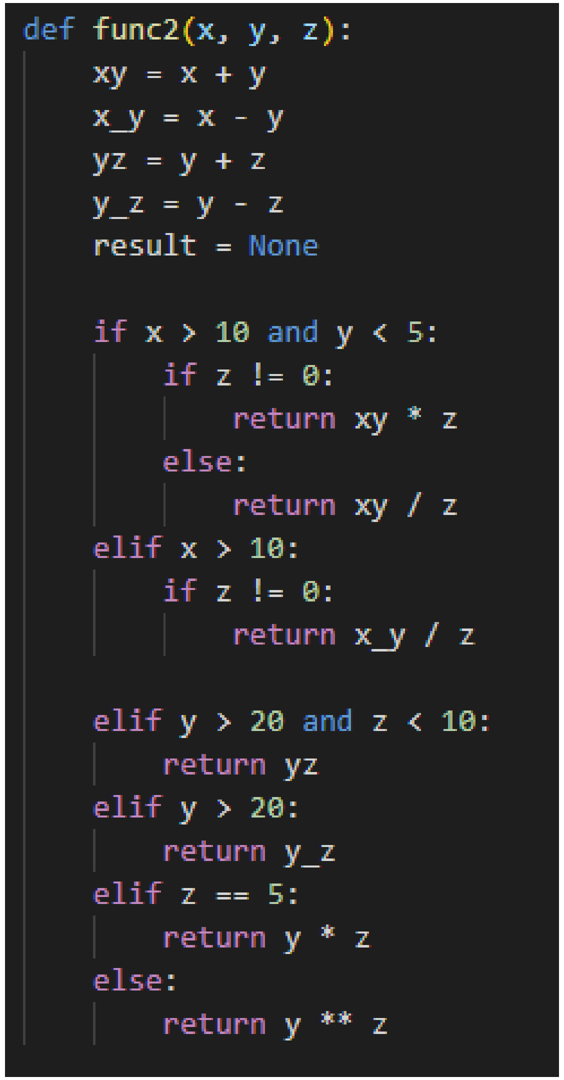

```python
def func2(x, y, z):
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```

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

Image source: medium, google images

Thank You

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