# Design Engineering

## Overview

- What is design engineering?
- How to do software design?
- Principles, concepts and practices

## Design Engineering

- The process of making decisions about HOW to implement software solutions to meet requirements
- Encompasses the set of concepts, principles, and practices that lead to the development of high-quality systems



## Concepts in Software Design

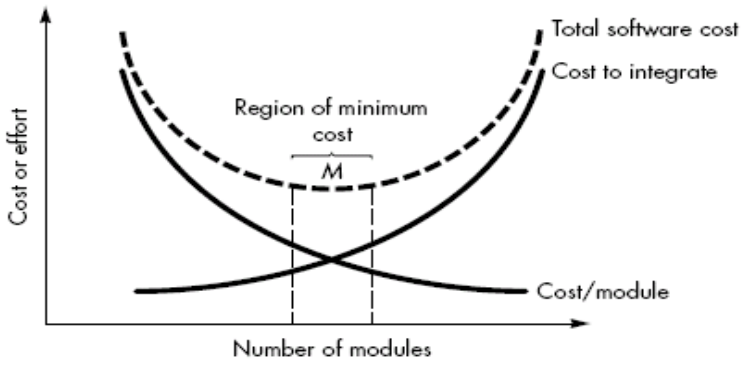
- Modularity
- Cohesion & Coupling
- Information Hiding
- Abstraction & Refinement
- Refactoring

# Modularity

- Software is divided into separately named and addressable components, sometimes called modules, that are integrated to satisfy problem requirements
- Divide-and-conquer



# Modularity and Software Cost



# Cohesion & Coupling

- Cohesion
  - The degree to which the elements of a module belong together
  - A cohesive module performs a single task requiring little interaction with other modules
- Coupling
  - The degree of interdependence between modules
- High cohesion and low coupling



# Information Hiding

- Do not expose internal information of a module unless necessary
  - E.g., private fields, getter & setter methods

# Abstraction & Refinement

- Abstraction
  - To manage the complexity of software,
  - To anticipate detail variations and future changes
- Refinement
  - A top-down design strategy to reveal low-level details from high-level abstraction as design progresses

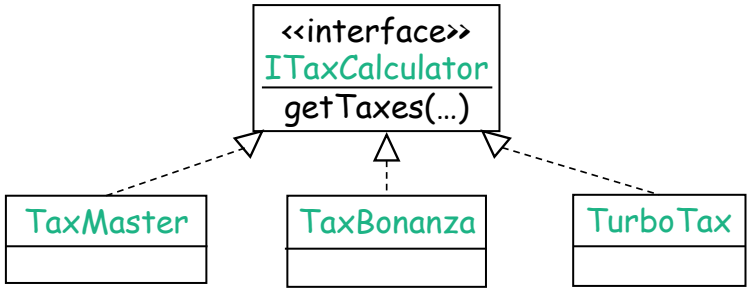


# Abstraction to Reduce Complexity

- We abstract complexity at different levels
  - At the highest level, a solution is stated in broad terms, such as "process sale"
  - At any lower level, a more detailed description of the solution is provided, such as the internal algorithm of the function and data structure

## Abstraction to Anticipate Changes

- Define interfaces to leave implementation details undecided
- Polymorphism






## Refinement

- The process to reveal lower-level details
  - High-level architecture software design
  - Low-level software design
    - Classes & objects
    - Algorithms
    - Data

# Refactoring

"…the process of changing a software system in such a way that it does not alter the external behavior of the code [design] yet improves its internal structure" --Martin Fowler

- Goal: to make software easier to integrate, test, and maintain.



# S.O.L.I.D Principles of OOD

Robert Martin

- S – Single-responsibility principle
- O – Open-closed principle
- L – Liskov substitution principle
- I – Interface segregation principle
- D – Dependency Inversion Principle

# A Running Example

```
class Circle {
    public float radius;

    public Circle(float radius) {
        this.radius = radius;
    }
}

class Square {
    public float length;

    public Square(float length) {
       this.length = length;
    }
}
```



# Single-responsibility principle

Robert Martin

- A class should have only one job.
  - Modularity, high cohesion, low coupling
- Sum up the areas for a list of shapes?

```
class AreaCalculator {
    protected List<Object> shapes;
    public AreaCalculator (List<Object> shapes) {
        this.shapes = shapes;
    }
    public float sumArea() {
        // logic to sum up area of each shape
    }
}
```

# O – Open-closed principle

- Objects or entities should be open for extension, but closed for modification.
- Add a new kind of shape, such as Triangle?

```
interface Shape {
   public float area();
}
class Triangle implements Shape { … }
…
class AreaCalculator {
   protected List<Shape> shapes;
   public float sumArea() {
      float sum = 0;
      for (Shape s : shapes) {   sum += s.area(); }
      …
   } …
}
```



# L - Liskov substitution principle

- Let q(x) be a property provable about objects of x of type T. Then q(y) should be provable for objects y of type S where S is a subtype of T.
- Every subclass/derived class should be substitutable for their base/parent class.

```
class Triangle implements Shape {
   …
   public float area () { return -1;   }
}
```

✗

## I - Interface segregation principle

- A client should never be forced to implement an interface that it doesn't use or clients shouldn't be forced to depend on methods they do not use.
- Interface design

```
interface Shape{
    …
    public int numEdges();
}
```

✗



## D - Dependency Inversion principle

- Entities must depend on abstractions not on concretions. It states that the high level module must not depend on the low level module, but they should depend on abstractions.

```
class AreaCalculator{
    protected Connection con;
    public AreaCalculator(…, MySQLConnection con) {
        …
        this.con = con;
    }
}
```

✗

## Software Design Practices Include:

- Two stages
  - High-level: Architecture design
    - Define major components and their relationship
  - Low-level: Detailed design
    - Decide classes, interfaces, and implementation algorithms for each component



## How to Do Software Design?

- Reuse or modify existing design models
  - High-level: Architectural styles
  - Low-level: Design patterns, Refactorings
- Iterative and evolutionary design
  - Package diagram
  - Detailed class diagram
  - Detailed sequence diagram