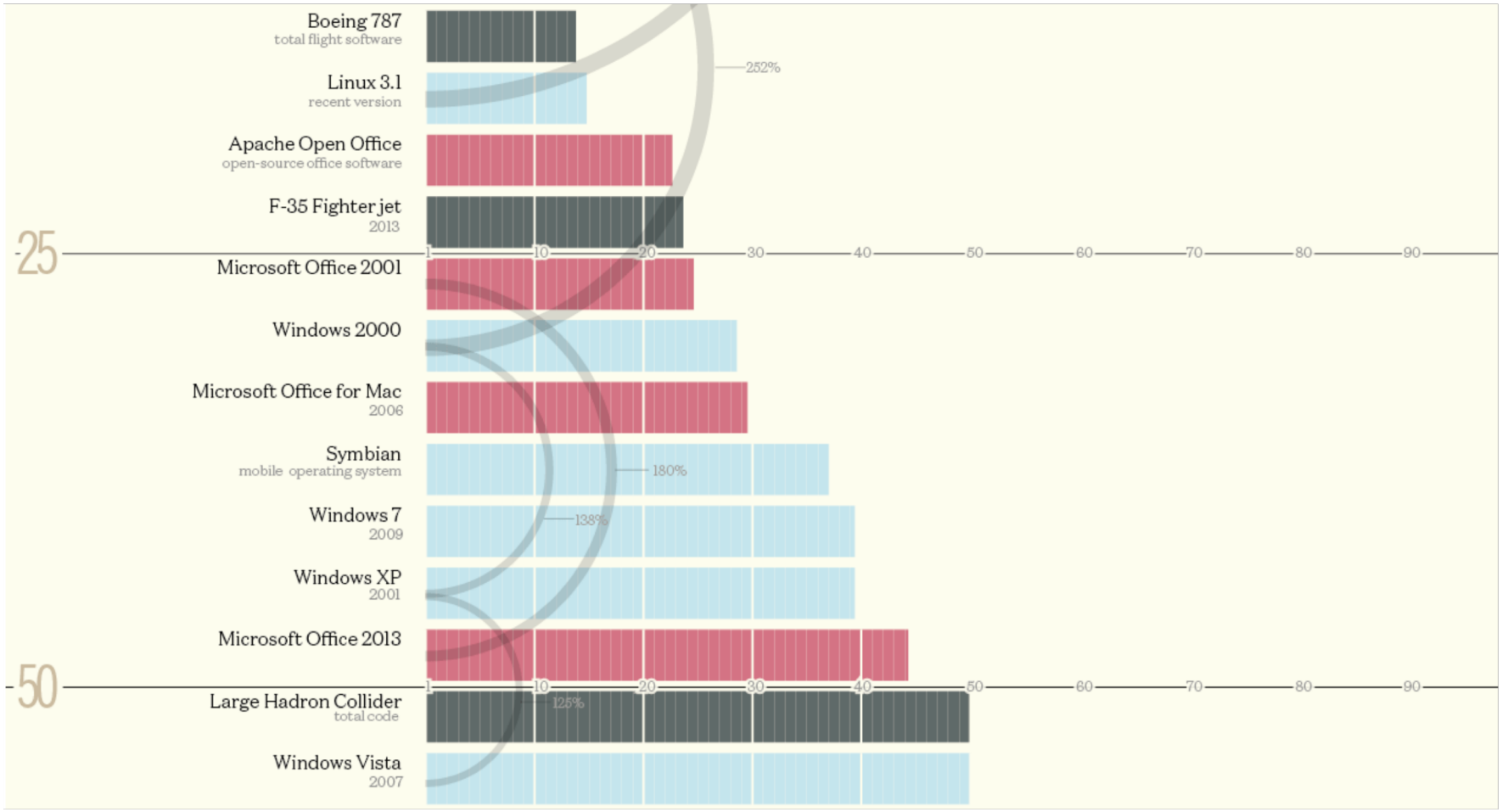
Introduction to Object Oriented Programming

Università di Modena e Reggio Emilia

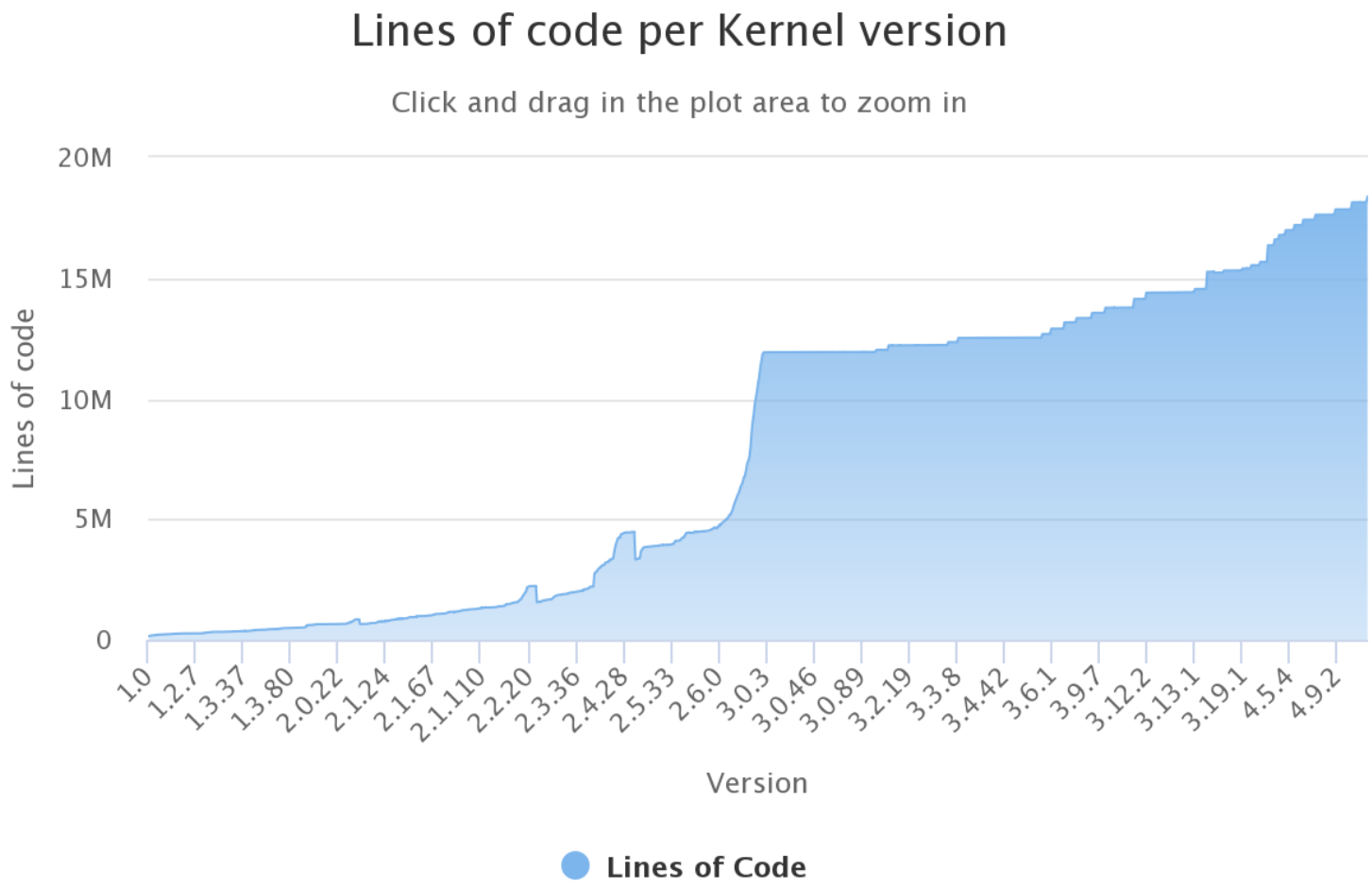
Prof. Nicola Bicocchi (nicola.bicocchi@unimore.it)

Software Size

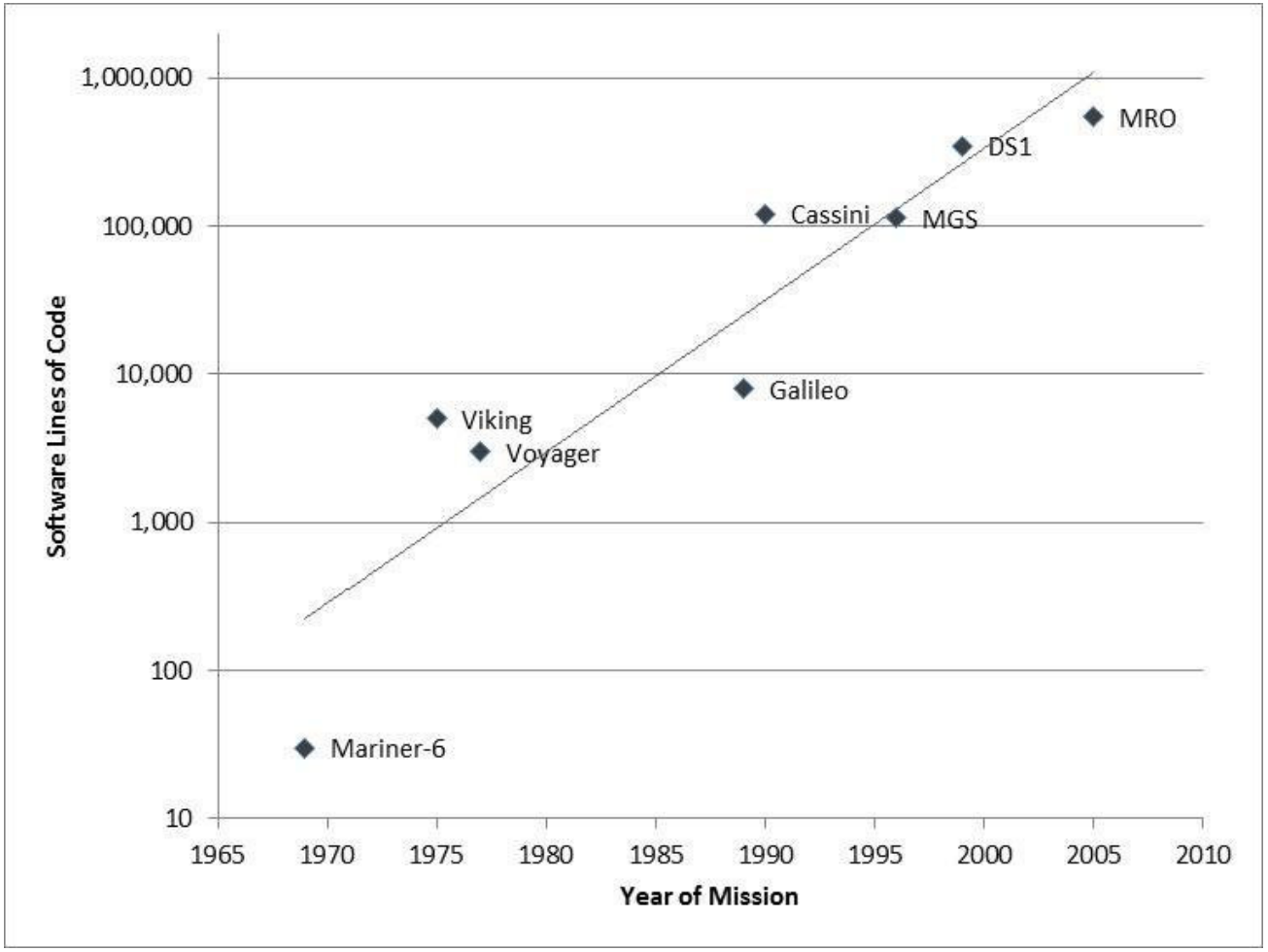


* http://www.informationisbeautiful.net/visualizations/million-lines-of-code/

Software Size



Software Size



Why OOP?

Why OOP?

- Procedural programming languages (e.g., Pascal, C) are not suitable for building large software infrastructures
- OOP addresses this issue and reduces development and maintenance costs for large and complex software projects

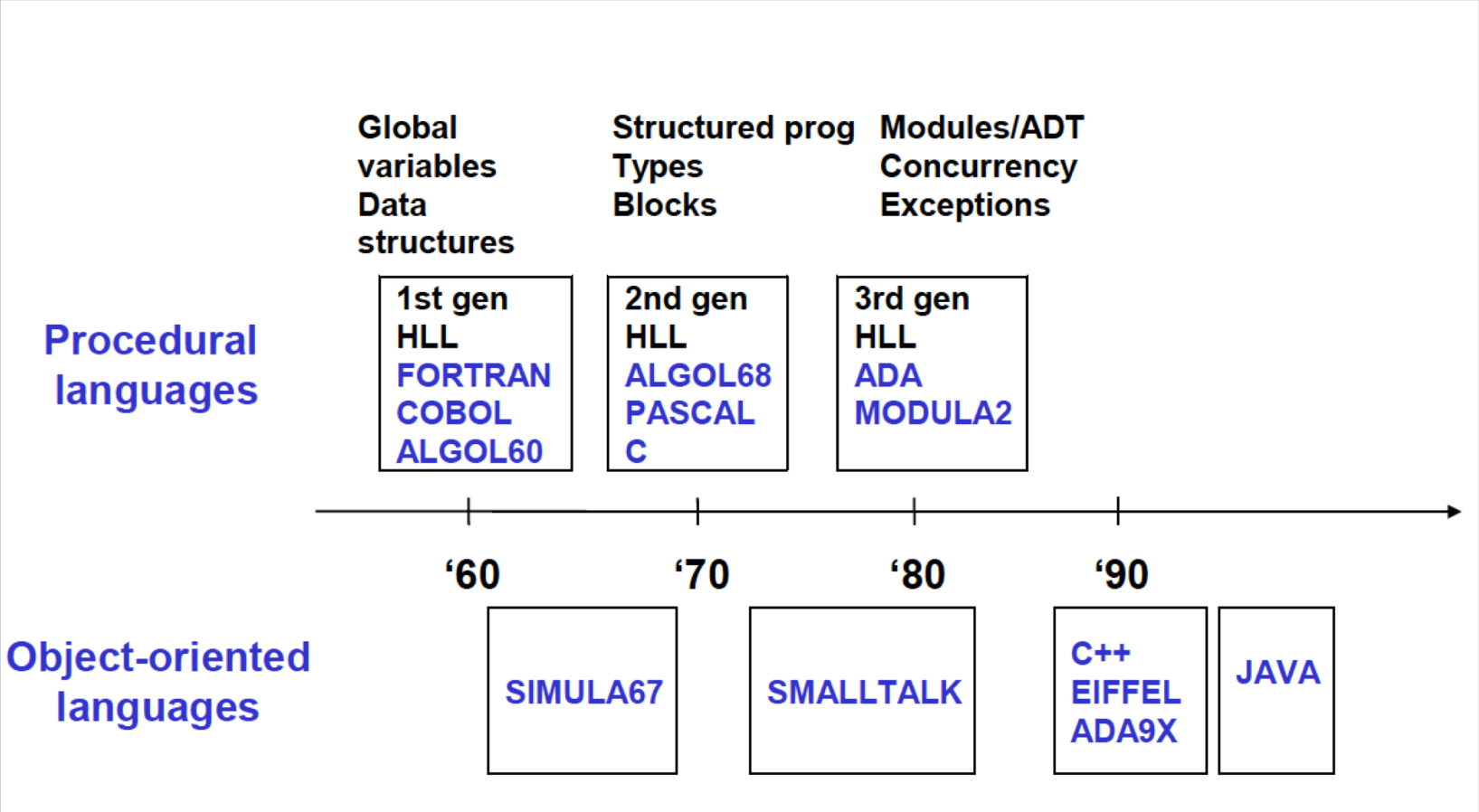
Errors / 1K SLOC

- **Industry Average**
  - 25 errors / 1K SLOC
- **Corporate Applications**
  - 5 errors / 1K SLOC
- **Cleanroom development technique**
  - 0.5 errors / 1K SLOC

Software crisis (1970)

- The causes of the software crisis were linked to the **overall complexity of hardware and the software development process**. The crisis manifested itself in several ways:
  - Projects running over-budget
  - Projects running over-time
  - Software was inefficient
  - Software was difficult to maintain

Languages Timeline



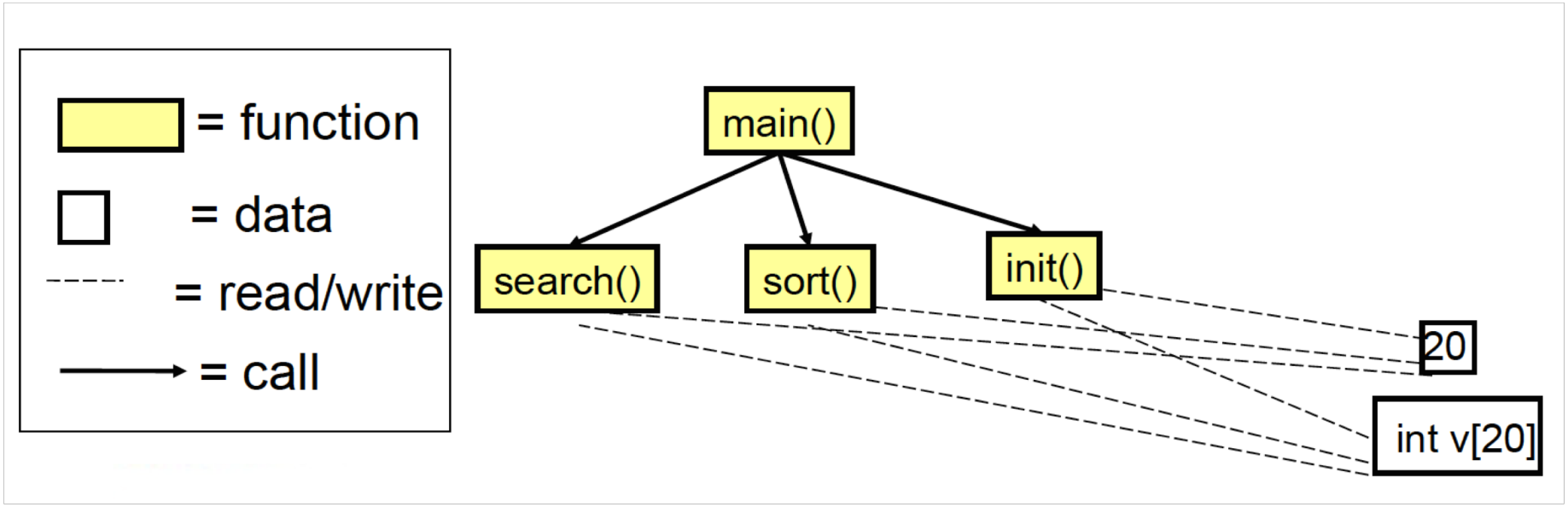
OOP Goal

- Build software being secure, re-usable, flexible, documentable, extensible
- Instead of focusing on algorithms, optimization and efficiency, OOP focus on programming techniques
- OOP considers software as a set of well-defined entities containing both data and functions

Procedural Programming

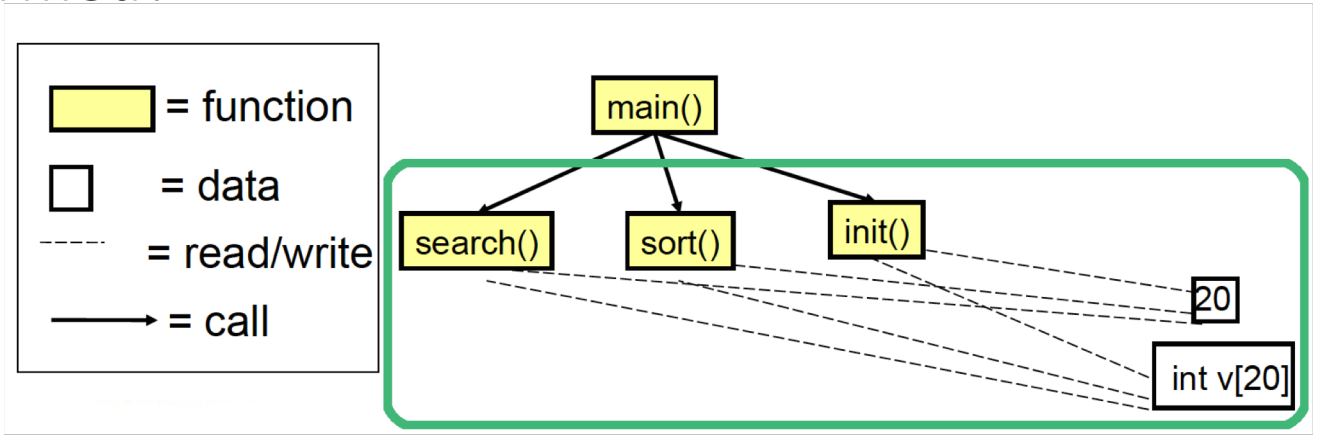
```
int vect[20];
int i;

void sort()         { /* sort */ }
int search(int n)   { /* search */ }
void init()         { /* init */ }

void main() {
    init();
    sort();
    search(13);
}
```

Modules and relationships



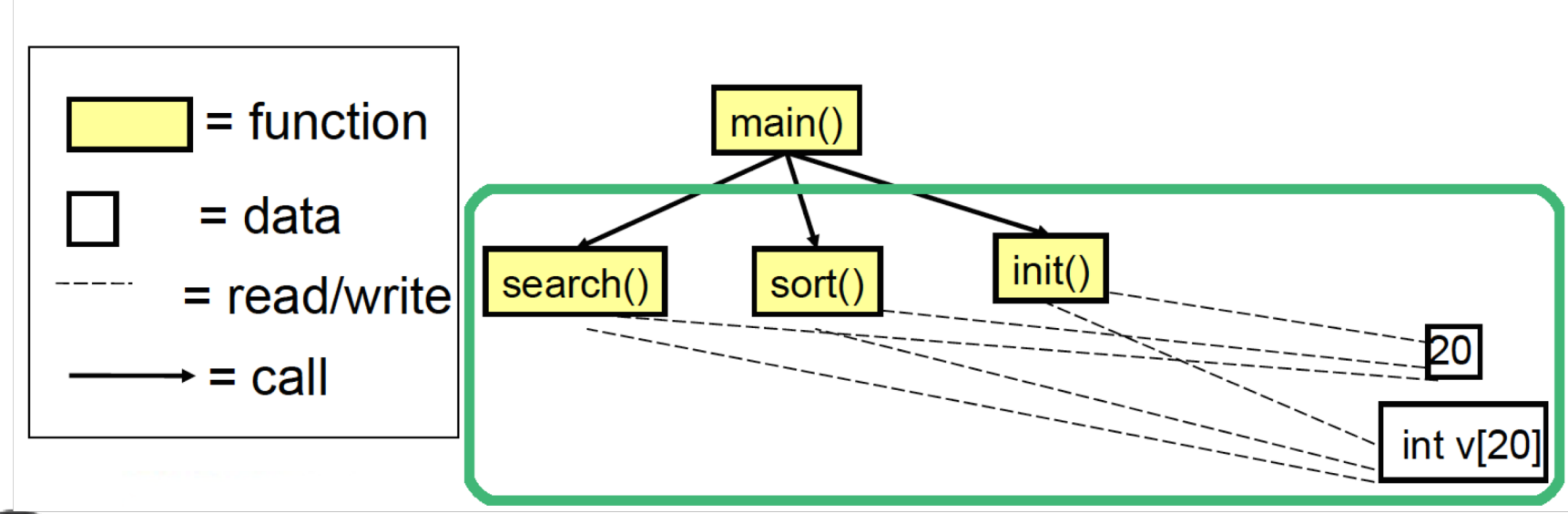
Issues

- There is no clear relationship between:
  - Vectors (int vect[20])
  - Operations on vectors (search, sort, init)
- There is no control over size:
  - for (i=0; i<=20; i++) { vect[i]=0; };
- Initialization
  - Actually performed?



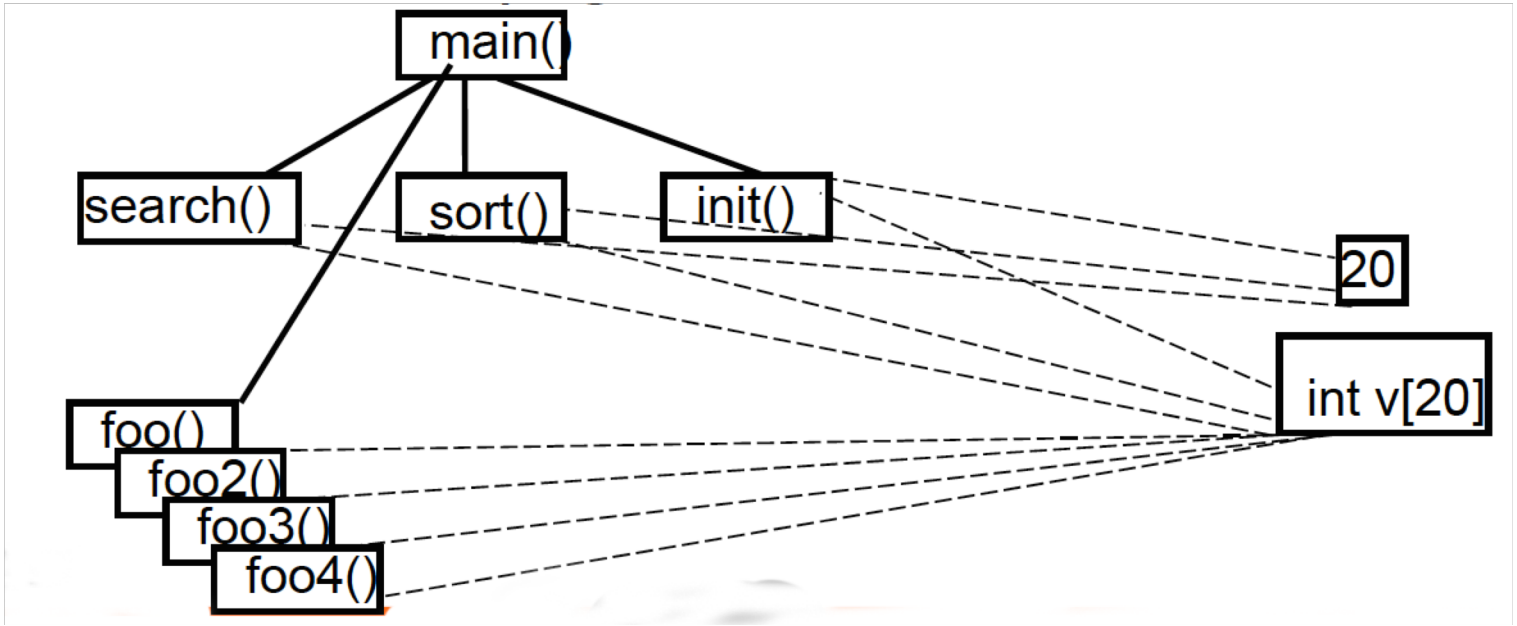
Issues

- It’s not possible to consider a vector as a primitive concept
- Data and functions are not modularized



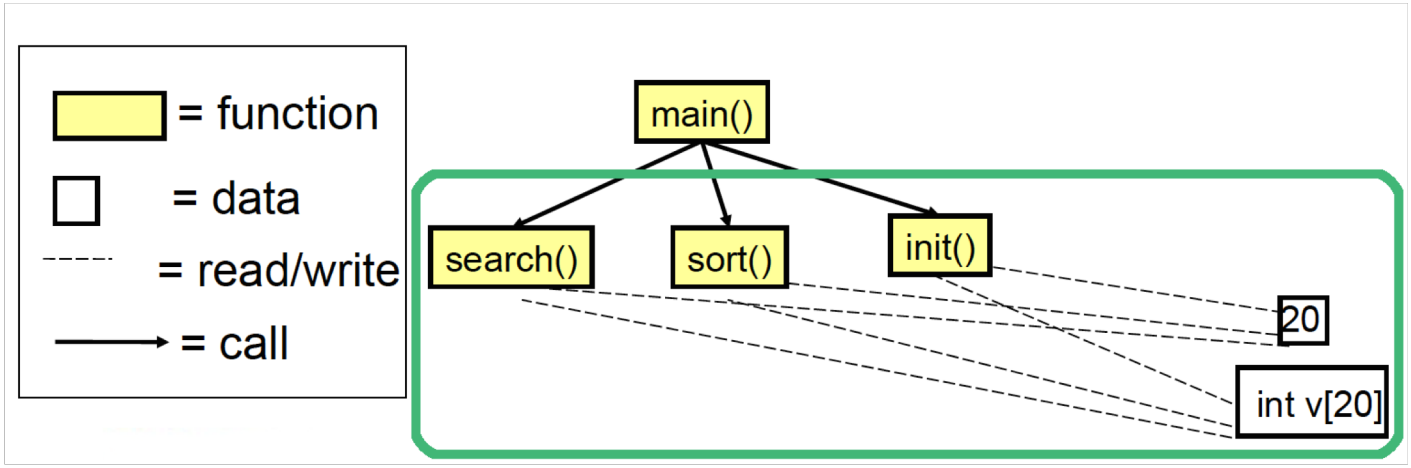
Issues, the long run

- External functions can read/write vector's data, leading to a **growing number of relationships**
- Source code becomes **difficult to understand and maintain**
- **Spaghetti Code**



Issues

- **Reuse of code limited**
  - Data and procedures (functions) are separate. This makes it complex to reuse existing code in other projects
- **Data protection limited**
  - Unprotected data accessible from vast portions of the source code. After a certain stage, debug becomes a nightmare!
- **Unsuitable for decomposition**
  - Large scale projects require large scale working force (many teams). Unprotected data, separate from functions makes it hard to decompose



Object-Oriented approach

```
class Vector {
    // internal data
    private int v[20];

    // external interface
    public MyVector() {
        /* init */
        for(int i=0; i<20; i++) v[i]=0;
    }

    public sort()         { /*sort*/ }
    public search(int c) { /*search*/ }
}
```

Object-Oriented approach

```
MyVector v1 = new MyVector();
MyVector v2 = new MyVector();

v1.sort();
v1.search(22);

v1++;              // Error: not an integer
v1.v[2] = 47;  // Error: v[] is encapsulated
```

An engineering approach

- Client-Server model
- OOP implies a paradigm shift
  - Do not uses functions for processing data entities
  - Ask entities to deliver services

operation(object, params)

For example:

insert(vector, element)

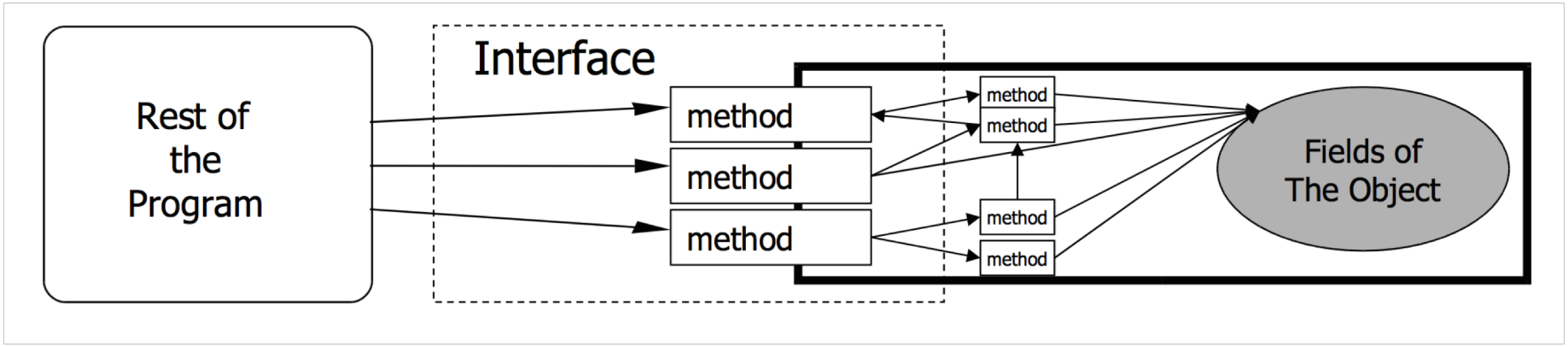
object.operation(params)

For example:

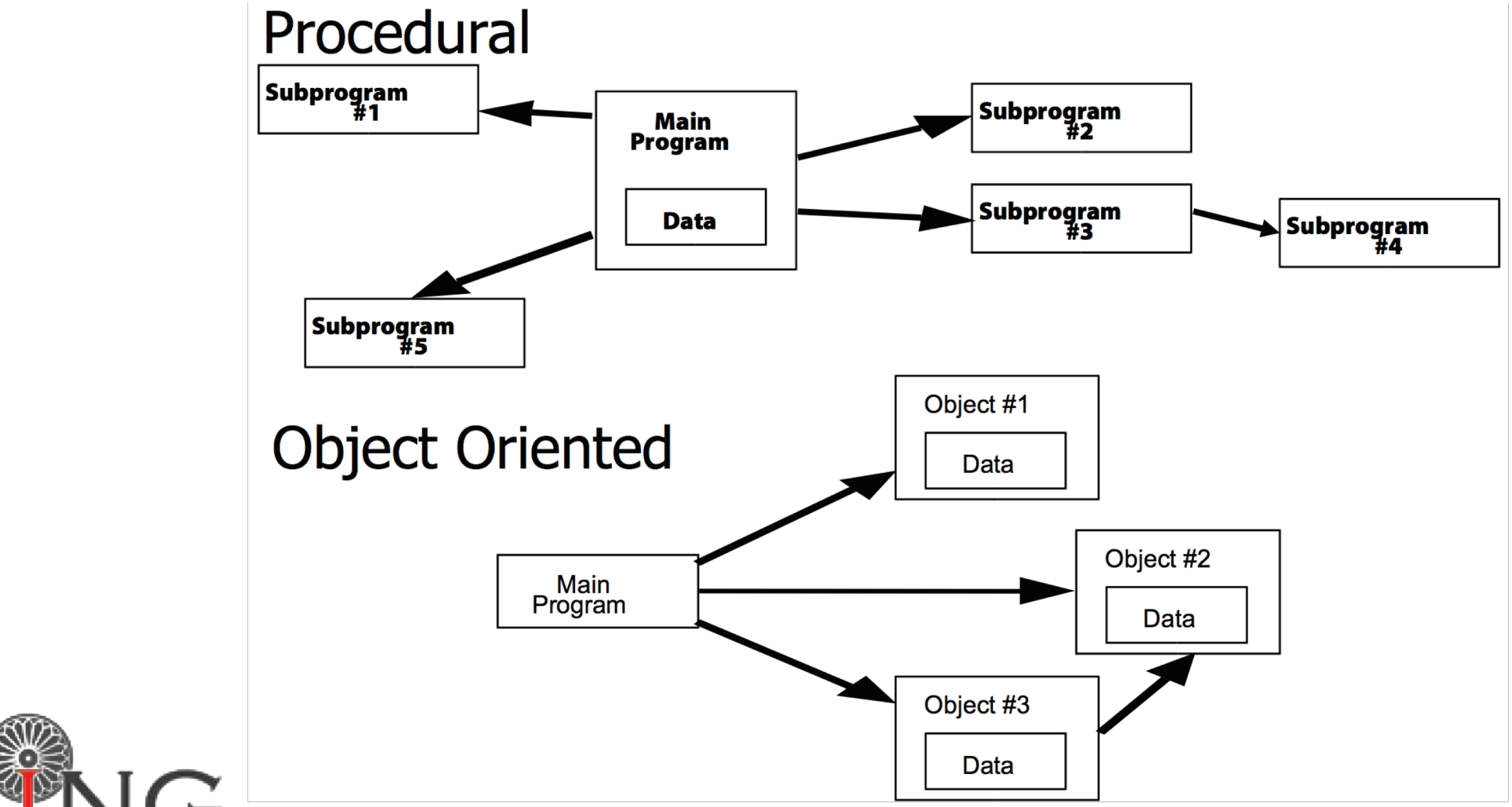
vector.insert(element)

An engineering approach

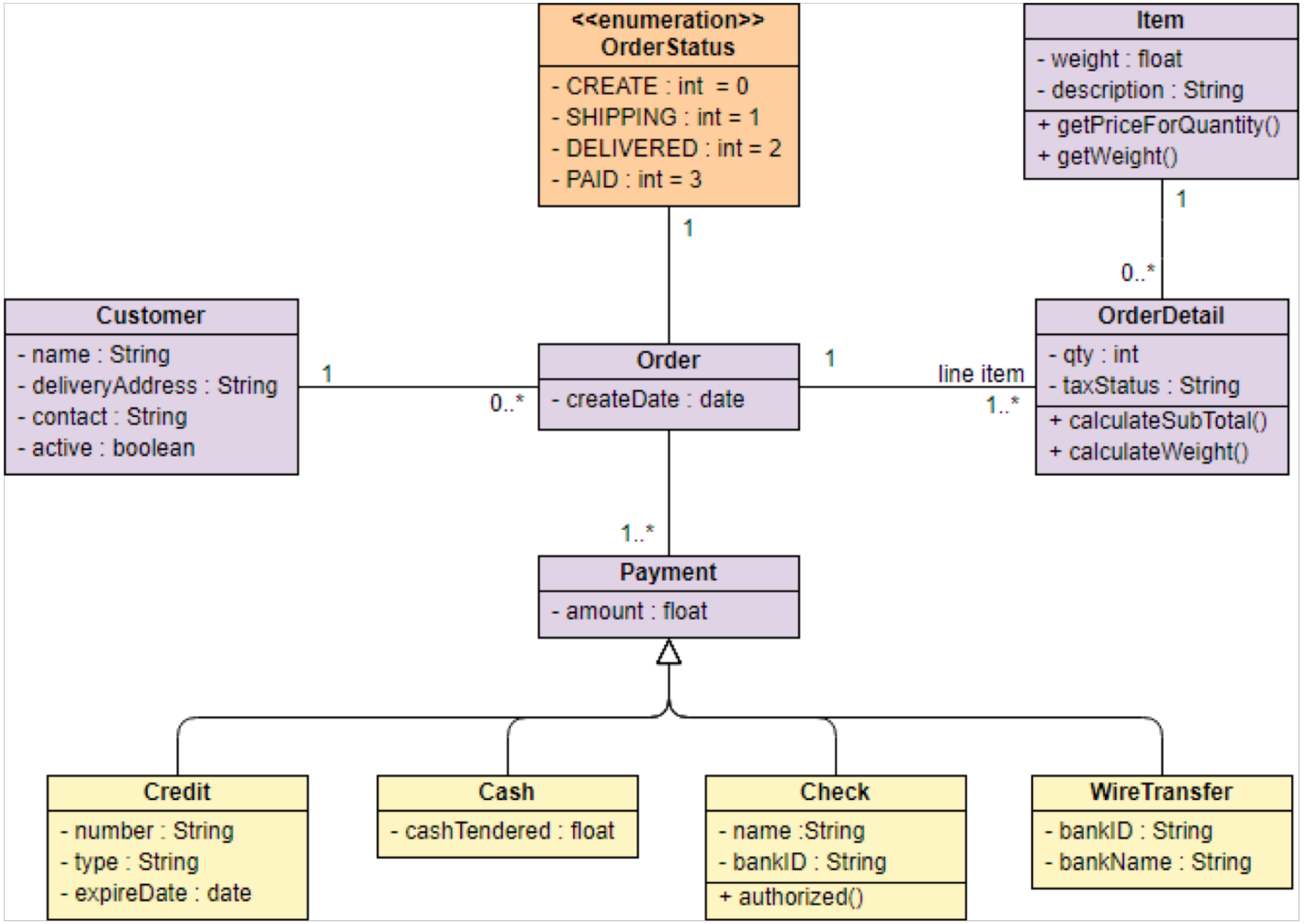
- Given a system, we have to:
  - Identify the components
  - Define component interfaces
  - Define how components interact each other through their interfaces
  - Minimize relationships among components



An engineering approach

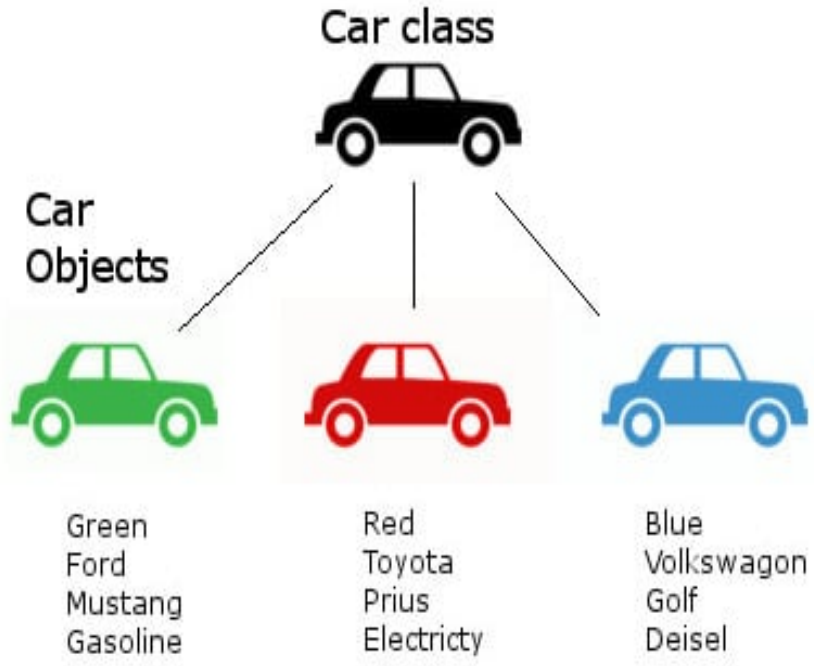


An engineering approach



Class and object

```
public class Car {
      String color;
      String brand;
      String model;
      String fuel;

      public Car(color, brand, model, fuel) {
            this.color = color;
            this.brand = brand;
            this.model = model;
            this.fuel = fuel;
      }
      /* ... */
}

Car c1 = new Car(Green, Ford, Mustang, Gasoline);
Car c2 = new Car(Red, Toyota, Prius, Electricity);
Car c3 = new Car(Blue, VW, Golf, Diesel);
```



Class and object

- Class (the description of object structure, i.e. type):
  - Data (ATTRIBUTES or FIELDS)
  - Functions (METHODS or OPERATIONS)
  - Creation methods (CONSTRUCTORS)
- Object (class instance)
  - Identity
  - State

Class and object

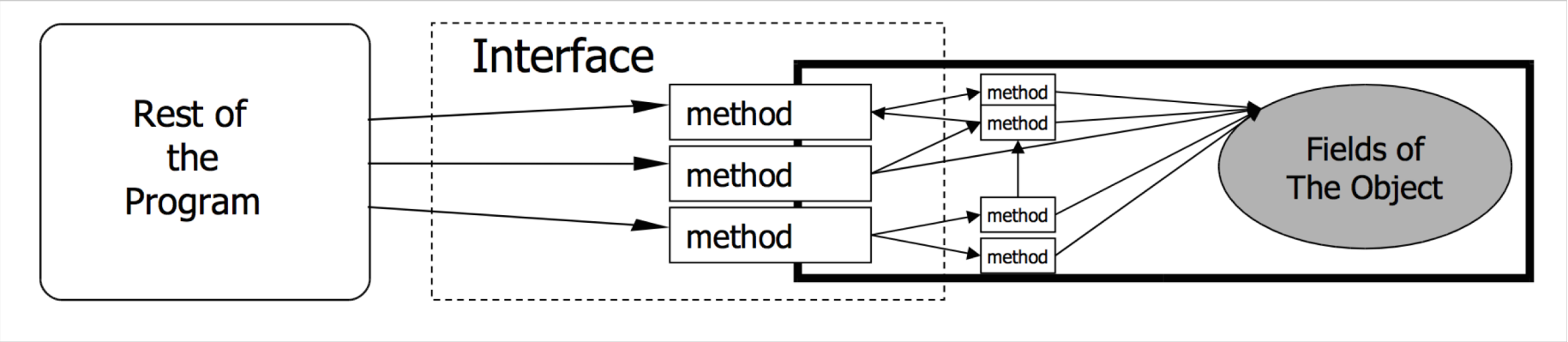
- A class is like a type definition. No data is allocated until an object is created from the class
- The creation of an object is called instantiation. The created object is often called an instance
- No limit to the number of objects that can be created from a class
- Each object is independent. Changing one object doesn't change the others

OOP Key Features

- Encapsulation
- Inheritance
- Polymorphism

Encapsulation

- Each object “wraps” code and data
- Each object handles its own data
- Other objects can use the object’s interface to require services



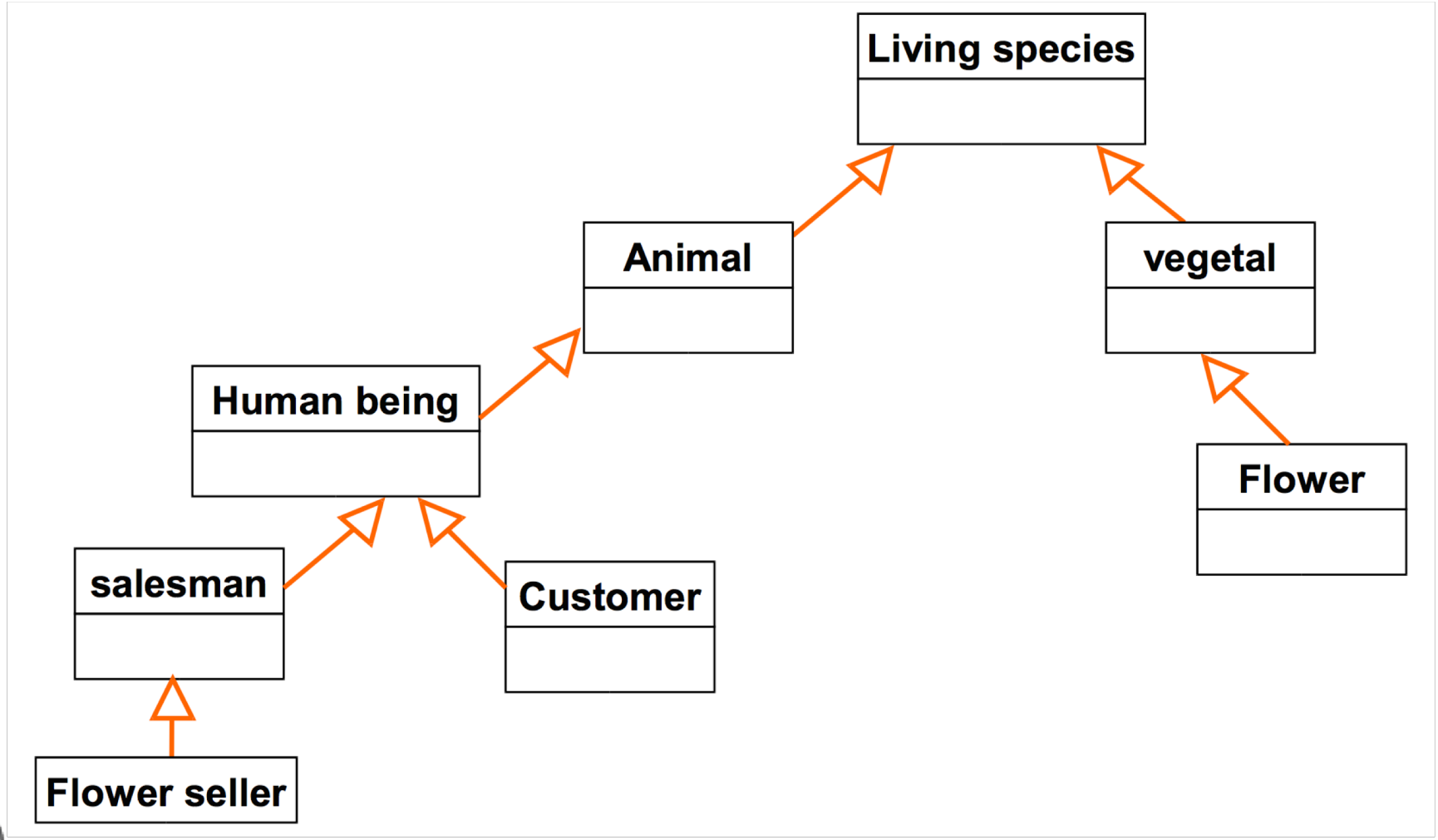
Encapsulation

```
class MyVector {
    // internal data (encapsulated data)
    private int v[20];

    // external interface (methods)
    public MyVector() {
        for(int i=0; i<20; i++) v[i]=0;
    }

    public sort()         { /*sort*/ }
    public search(int c) { /*search*/ }
}
```

Inheritance

- A class can derive from another class by extending it
- The derived class inherits variables and methods of the base class. The child class adds its own variables and methods
- Simplify the code reuse, build relations among classes

Inheritance



Inheritance

```
public class LivingSpecies {
  private boolean isAlive;
}

public class Animal extends LivingSpecies {
  . . .
}

public class HumanBeing extends Animal {
  . . .
}
```

Polymorphism

- Same requests for a method may lead to different behaviors depending on:
  - The actual object performing the operation (e.g., base class vs derived class)
  - Type of parameters passed as argument
  - Execution context

Polymorphism

```
class MyVector {
    // internal data (encapsulated data)
    private int v[20];

    public MyVector() {
        for(int i=0; i<20; i++) v[i]=0;
    }

    public MyVector(int[] v) {
        for(int i=0; i<20; i++) this.v[i]=v[i];
    }


    public sort()         { /*sort*/ }
    public search(int c) { /*search*/ }
}
```

Advantages of OOP

- Simplify the process of building software in a cooperative manner:
  - Different people developing different classes (on the same project!)
- Simplify code management
  - Bugs on object data are easy to spot. Since data are not visible from the outside, errors mostly occurs in the object handling the data
  - Changes on a specific class do not impact other classes (unless the interface is not modified)
- Support incremental design and development
  - Define new classes by extending the exsisting ones

Costs of OOP

- Needs a Object Oriented way of thinking
- Complex design (e.g., Which classes?, How many classes?)
- Benefits only occur in large programs
  - Programs < 100 lines, spaghetti is understandable and faster to write
  - Programs > 1K lines, spaghetti is incomprehensible, probably doesn't work, not maintainable