

# Konzepte objektorientierter Programmierung

**Prof. Dr. Peter Müller**  
Software Component Technology

Wintersemester 05/06

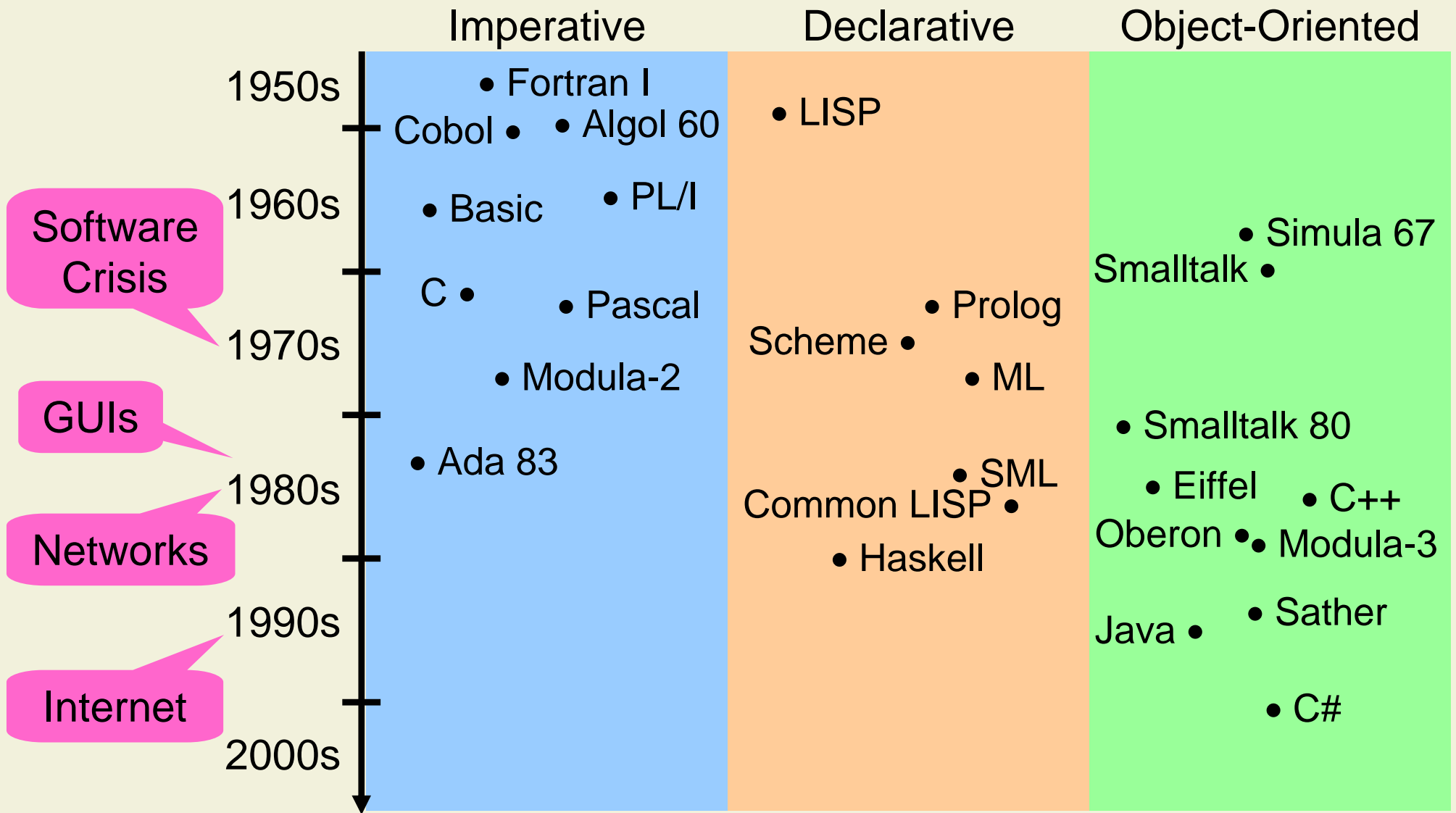
**ETH**

Eidgenössische Technische Hochschule Zürich  
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# Programming Paradigms

- Definition of *Paradigm*:  
*A theoretical framework of a scientific discipline consisting of concepts, methods, techniques, theories, and standards.*
- Imperative / procedural
  - we ask “how”
- Declarative (functional, logic)
  - we ask “what”
- Object-oriented
  - we ask “who”

# History of Programming Languages



# Agenda for Today

## 1. Introduction

- 1.1 Requirements
- 1.2 Concepts
- 1.3 Course Outline

## Objectives

- Motivation for object-oriented programming
- Distinction between core concepts, language concepts, and language constructs

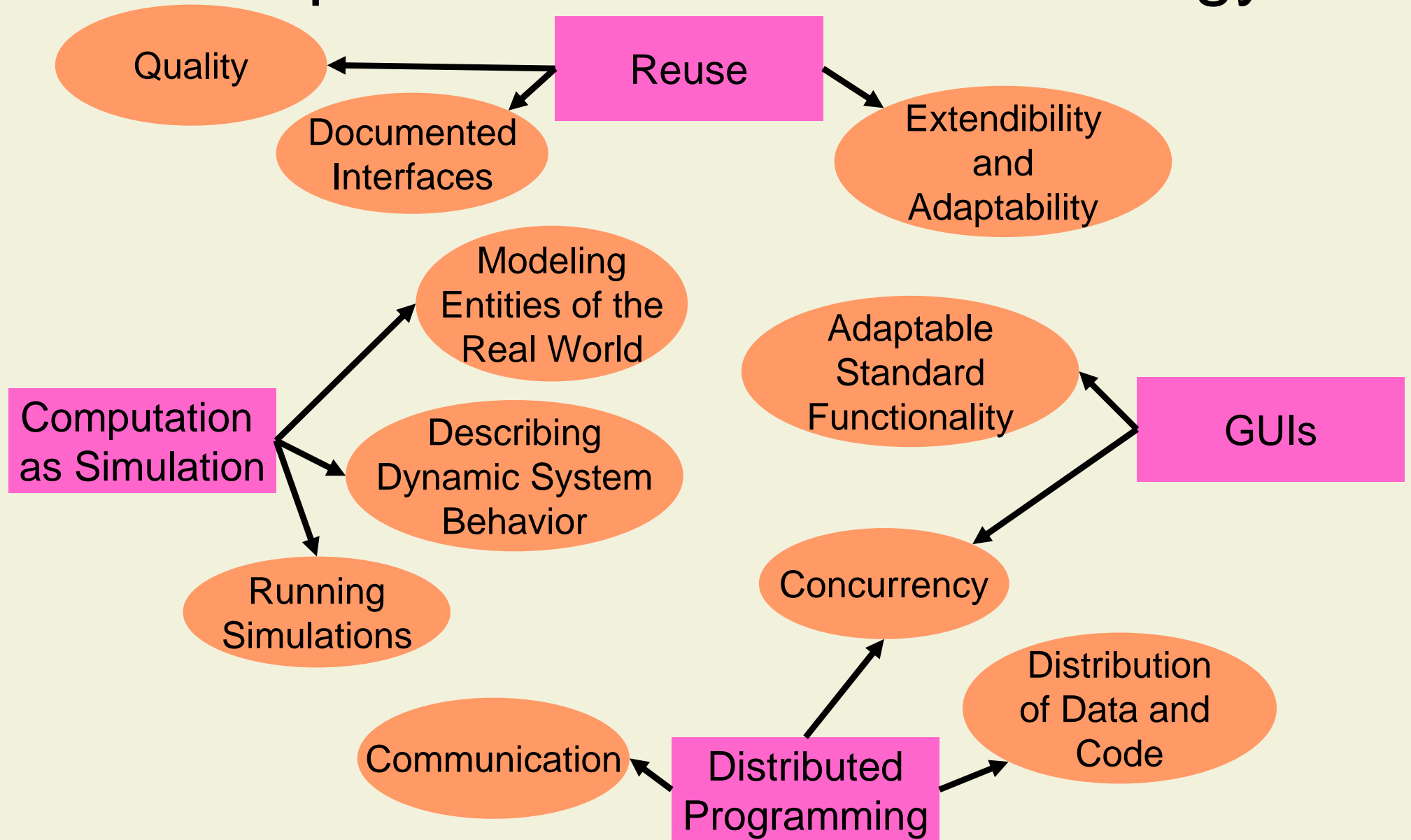
# 1. Introduction

## 1.1 Requirements

## 1.2 Concepts

## 1.3 Course Outline

# New Requirements in SW-Technology



# Example: Reusing Imperative Programs

- Scenario: University Administration System
  - Models students and professors
  - Stores one record for each student and each professor in a repository
  - Procedure printAll prints all records in the repository

# An Implementation in C

```
typedef struct {  
    char *name;  
    char *room;  
    char *institute;  
} Professor;
```

```
typedef struct {  
    char *name;  
    int  reg_num;  
} Student;
```

```
void printStudent( Student *s )  
{ ... }
```

```
void printProf( Professor *p )  
{ ... }
```



# An Implementation in C (cont'd)

```
typedef struct {  
    enum { STU,PROF } kind;  
    union {  
        Student *s;  
        Professor *p;  
    } u;  
} Person;
```

```
typedef Person **List;
```

```
void printAll( List l ) {  
    int i;  
    for ( i=0; l[ i ] != NULL; i++ )  
        switch ( l[ i ] -> kind ) {  
            case STU:  
                printStudent( l[ i ] -> u.s );  
                break;  
            case PROF:  
                printProf( l[ i ] -> u.p );  
                break;  
        }  
}
```

# Extending and Adapting the Program

- Scenario: University Administration System
  - Models students and professors
  - Stores one record for each student and each professor in a repository
  - Procedure printAll prints all records in the repository
- Extension: Add assistants to system
  - Add record and print function for assistants
  - Reuse old code for repository and printing

# Step 1: Add Record and Print Function

```
typedef struct {  
    char *name;  
    char *room;  
    char *institute;  
} Professor;
```

```
typedef struct {  
    char *name;  
    int  reg_num;  
} Student;
```

```
typedef struct {  
    char *name;  
    char PhD_student; /* 'y', 'n' */  
} Assistant;
```

```
void printStudent( Student *s )  
    { ... }
```

```
void printProf( Professor *p )  
    { ... }
```

```
void printAssi( Assistant *a )  
    { ... }
```

## Step 2: Reuse Code for Repository

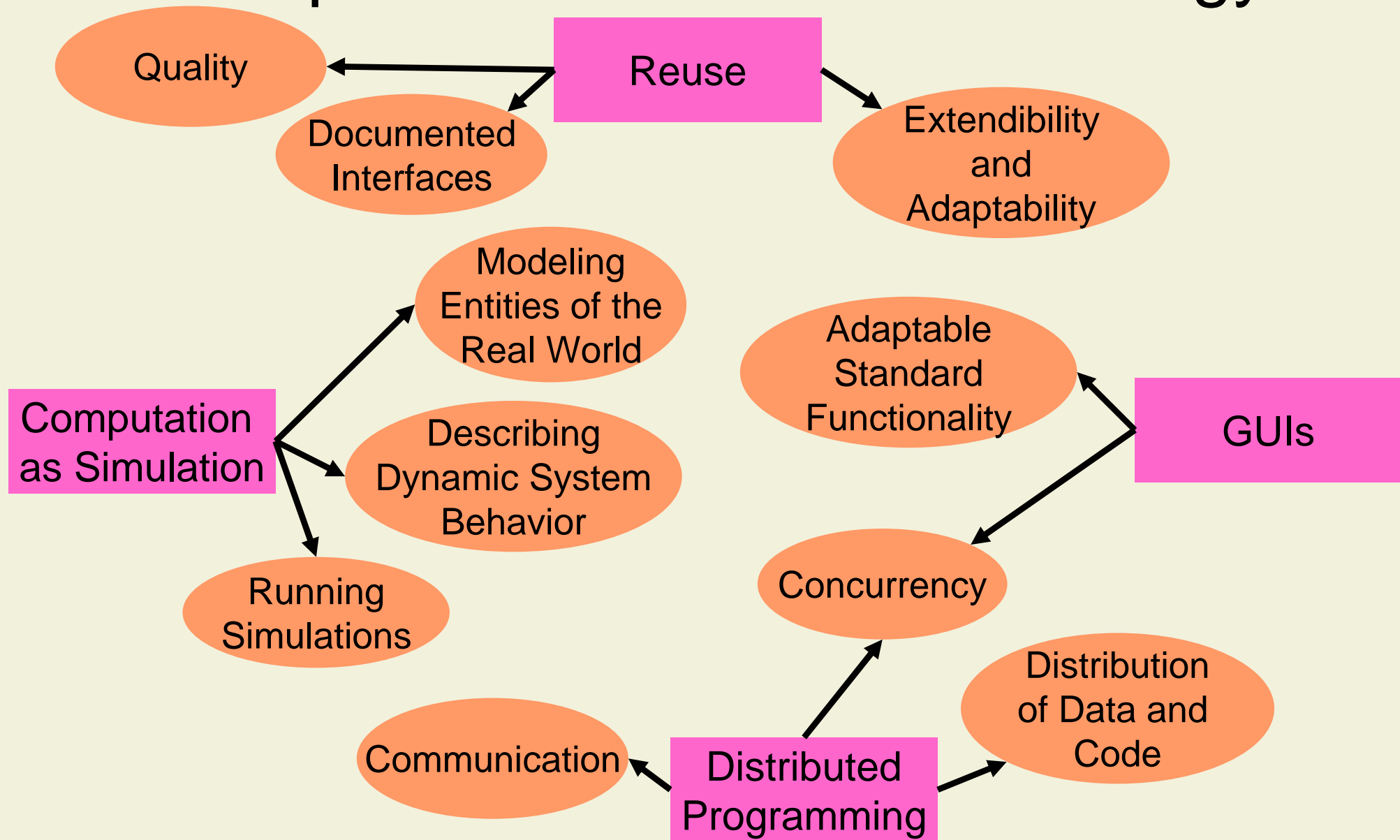
```
typedef struct {  
    enum { STU,PROF,ASSI } kind;  
    union {  
        Student *s;  
        Professor *p;  
        Assistant *a;  
    } u;  
} Person;  
  
typedef Person **List;
```

```
void printAll( List l ) {  
    int i;  
    for ( i=0; l[ i ] != NULL; i++ )  
        switch ( l[ i ] -> kind ) {  
            case STU:  
                printStudent( l[ i ] -> u.s );  
                break;  
            case PROF:  
                printProf( l[ i ] -> u.p );  
                break;  
            case ASSI:  
                printAssi( l[ i ] -> u.a );  
                break;  
        }  
}
```

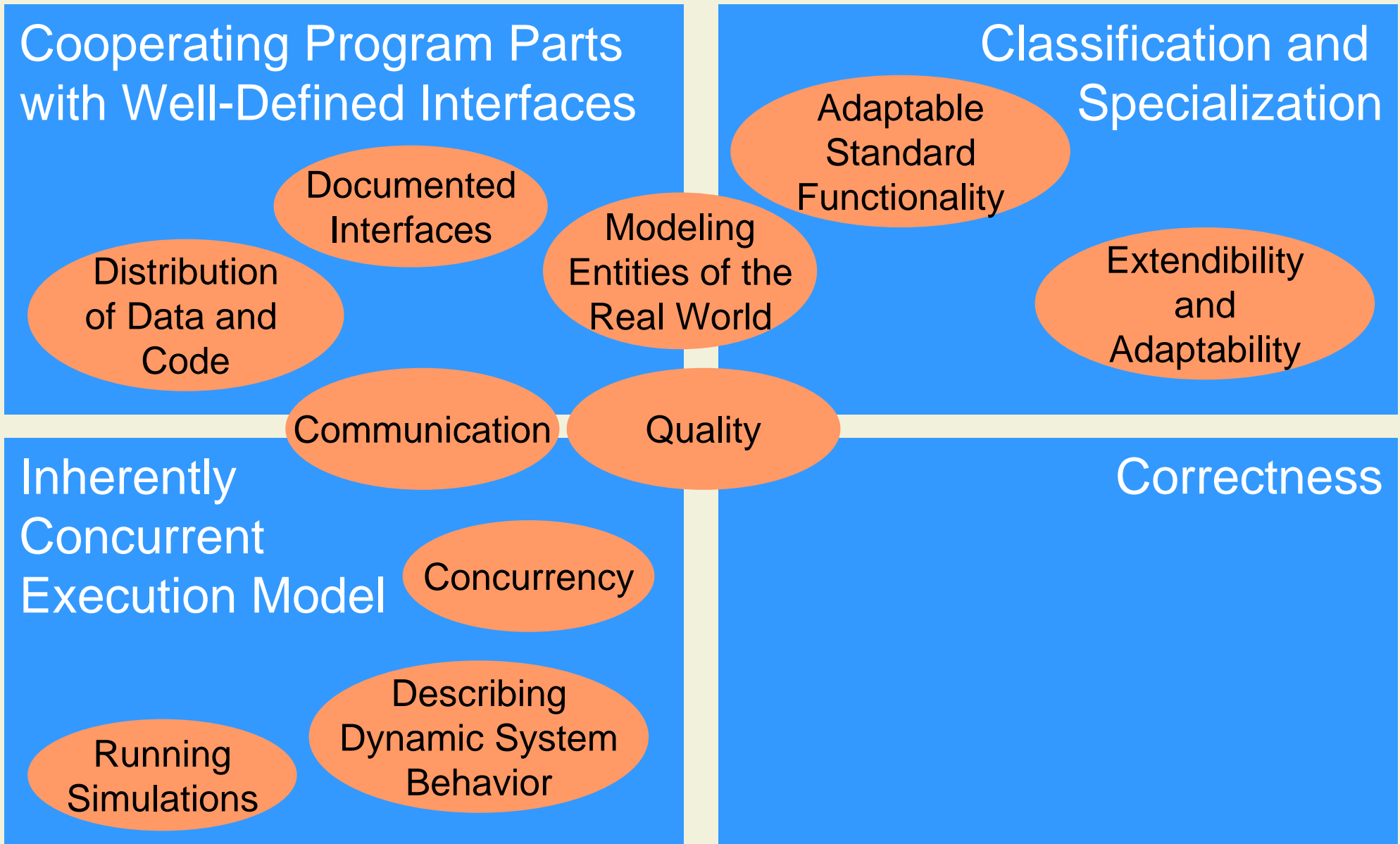
# Reuse in Imperative Languages

- No explicit language support for extension and adaptation
- Adaptation usually requires modification of reused code
- Copy-and-paste reuse
  - Code duplication
  - Difficult to maintain
  - Error-prone

# New Requirements in SW-Technology



# Core Requirements



# From Requirements to Concepts

What are the concepts of a programming paradigm

- That allow one to express **concurrency** naturally?
- That structure programs into **cooperating program parts with well-defined interfaces**?
- That are able to express **classification and specialization** of program parts without modifying reused code?
- That facilitate the development of **correct programs**?



# 1. Introduction

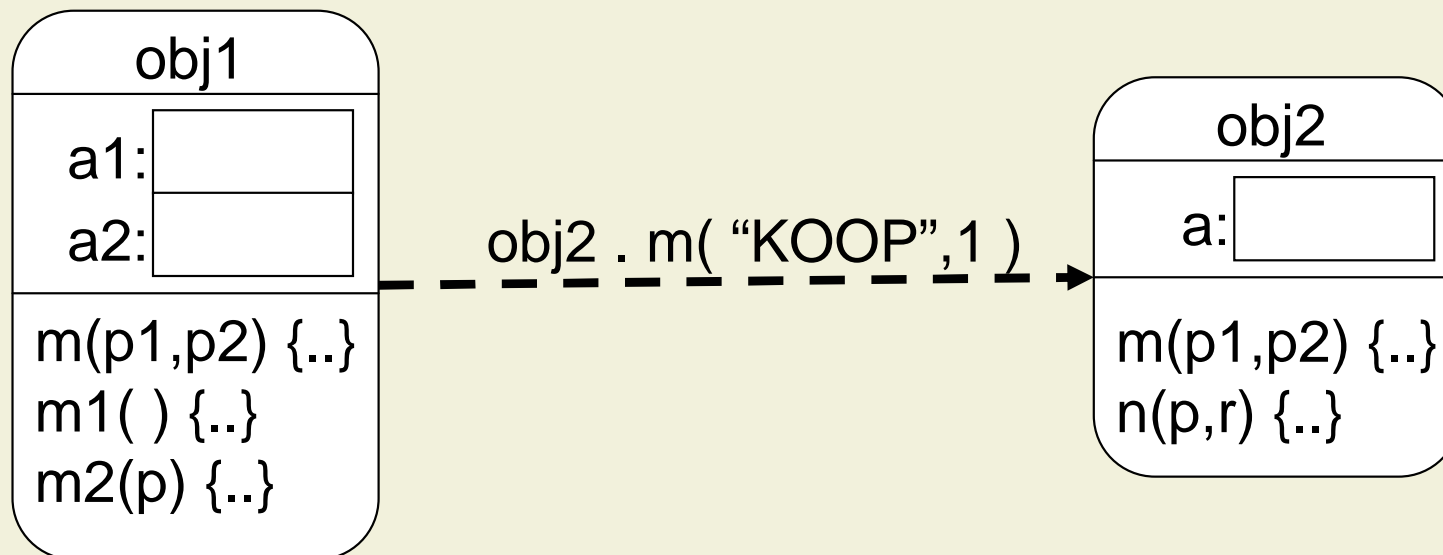
1.1 Requirements

**1.2 Concepts**

1.3 Course Outline

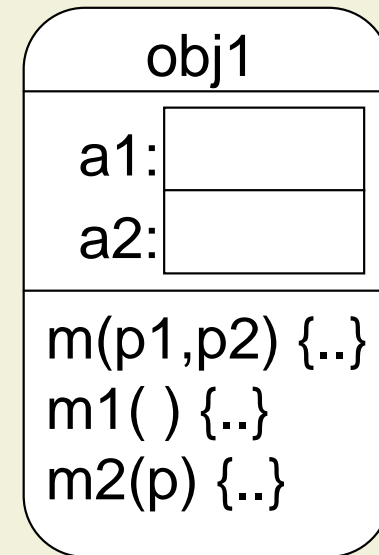
# The Object Model

- A software system is a set of cooperating objects
- Objects have state and processing ability
- Objects exchange messages



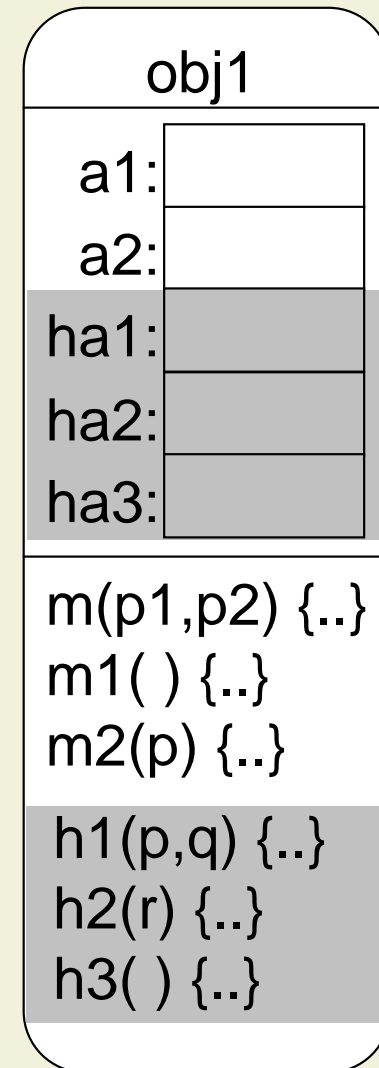
# Interfaces and Encapsulation

- Objects have well-defined interfaces
  - Publicly accessible attributes
  - Publicly accessible methods
- Implementation is hidden behind interface
  - Encapsulation
  - Information hiding
- Interfaces are the basis for describing behavior



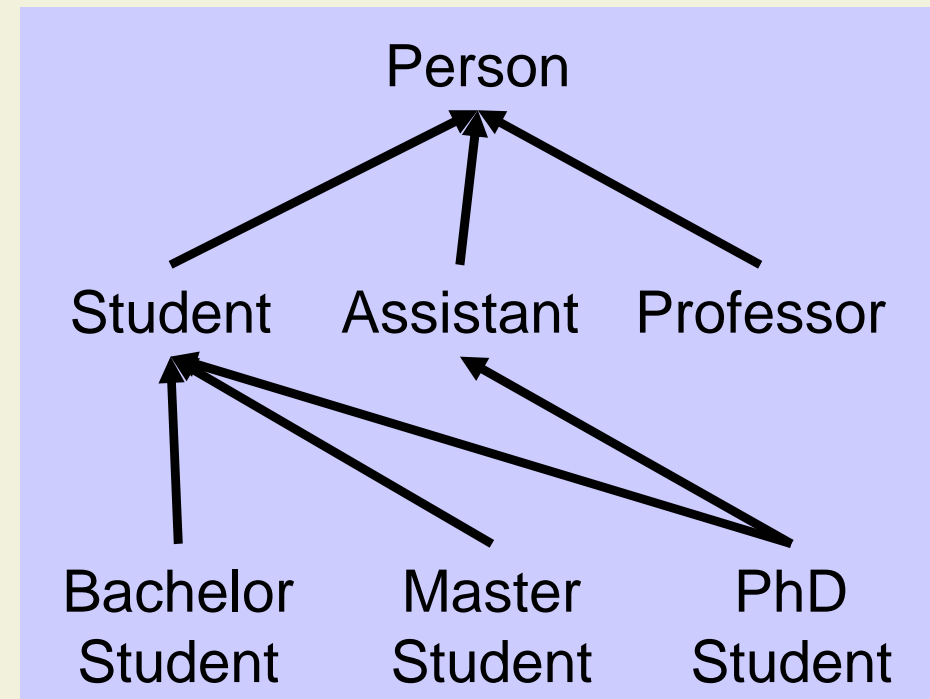
# Interfaces and Encapsulation

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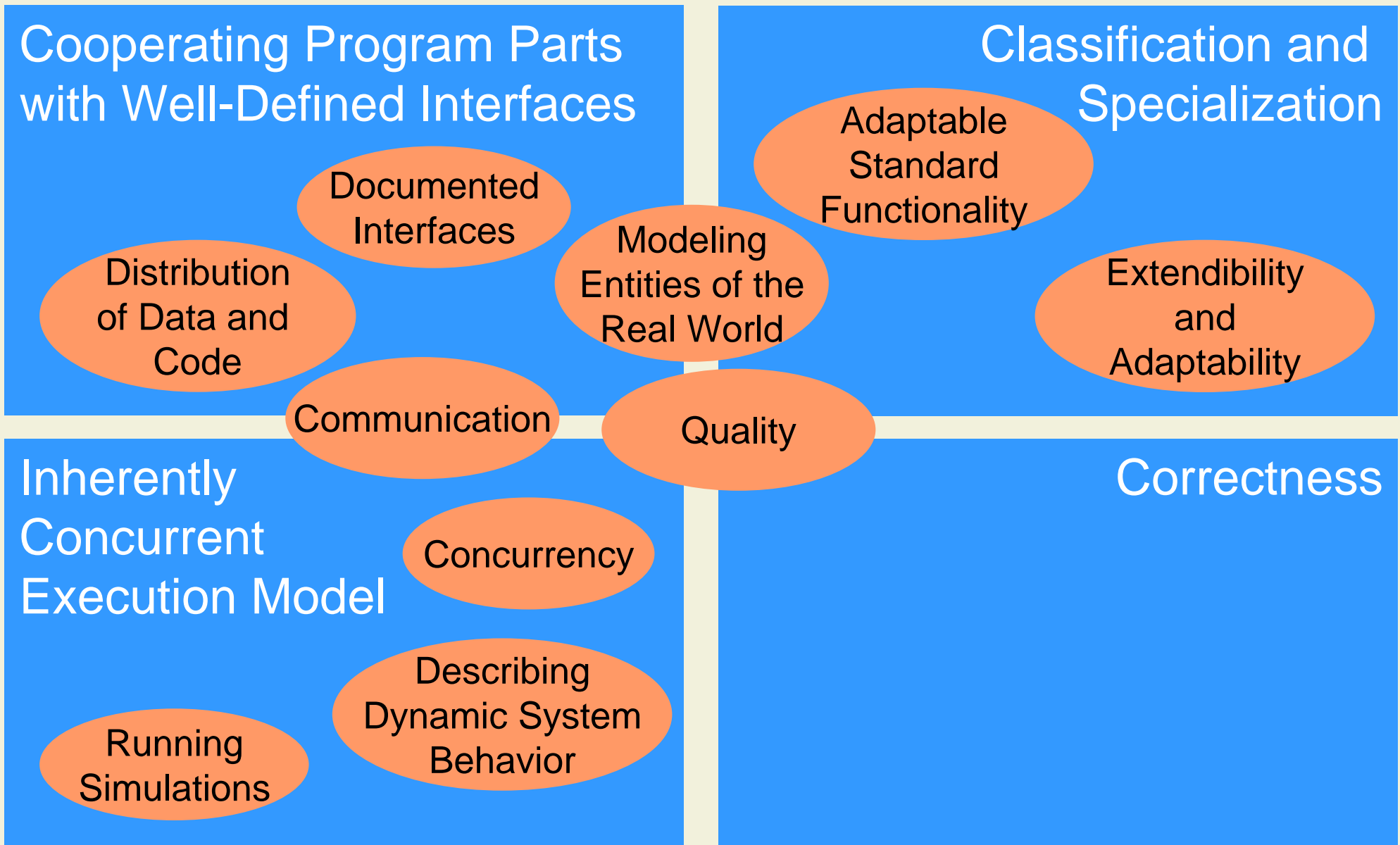


# Classification and Polymorphism

- **Classification:**  
Hierarchical structuring of objects
- Objects belong to different classes simultaneously
- **Substitution principle:**  
Subtype objects can be used wherever supertype objects are expected



# Meeting the Requirements



# Meeting the Requirements

## Cooperating Program Parts with Well-Defined Interfaces

- Objects (data + code)
- Interfaces
- Encapsulation

## Classification and Specialization

- Classification, subtyping
- Polymorphism
- Substitution principle

## Inherently Concurrent Execution Model

- Active objects
- Message passing

## Correctness

- Interfaces
- Encapsulation
- Simple, powerful concepts

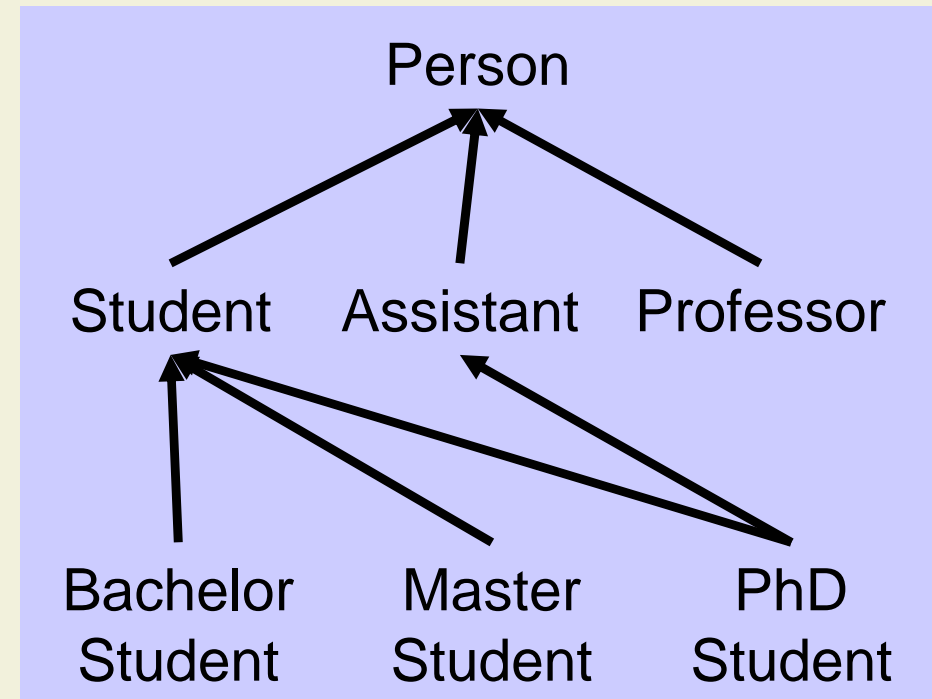
# Core Concepts: Summary

- Core concepts of the OO-paradigm
  - Object model
  - Interfaces and encapsulation
  - Classification and polymorphism
- Core concepts are **abstract concepts** to meet the new requirements
- To apply the core concepts we need ways to **express them in programs**
- **Language concepts** enable and facilitate the application of the core concepts



# Example: Dynamic Method Binding

- Classification and polymorphism
  - Algorithms that work with supertype objects can be used with subtype objects
  - Subclass objects are specialized
- Dynamic binding: Method implementation is selected at runtime, depending on the type of the receiver object



```
void printAll( Person[ ] l ) {  
    for (int i=0; l[ i ] != null; i++)  
        l[ i ] . print( );  
}
```

# OO-Concepts and Imperative Languages

- What we have seen so far
  - New concepts are needed to meet **new requirements**
  - **Core concepts** serve this purpose
  - **Language concepts** are needed to express core concepts in programs
- Open questions
  - Why do we need **OO-programming languages**?
  - Can't we use the language concepts as **guidelines** when writing imperative programs?
- Let's do an experiment ...
  - Writing object-oriented programs in C

# Types and Objects

- Declare types

```
typedef char*          String;  
typedef struct sPerson Person;
```

- Declare records with
  - Attributes
  - Methods  
(function pointers)

```
struct sPerson {  
    String name;  
    void   ( *print )( Person* );  
    String ( *lastName )( Person* );  
};
```

# Methods and Constructors

- Define methods

```
void printPerson( Person *this ) {  
    printf("Name: %s\n", this->name);  
}
```

```
String LN_Person( Person *this )  
{ ... }
```

- Define constructors

```
Person *PersonC( String n ) {  
    Person *this = (Person *)  
                  malloc( sizeof( Person ) );  
    this-> name      = n;  
    this-> print     = printPerson;  
    this-> lastName  = LN_Person;  
    return this;  
}
```

# Using the “Object”

- Declaration
- Use constructors, attributes, and methods

```
struct sPerson {  
    String name;  
    void   ( *print )( Person* );  
    String ( *lastName )( Person* );  
};
```

```
Person *p;  
p = PersonC( “Werner Dietl“ );  
p->name = p->lastName( p );  
p->print( p );
```

# Inheritance and Specialization

- Copy code
- Adapt function signatures
- Define specialized methods

```
typedef struct sStudent Student;  
struct sStudent {  
    String name;  
    void  ( *print )( Student* );  
    String ( *lastName )( Student* );  
    int reg_num;  
};
```

```
void printStudent( Student *this ) {  
    printf("Name: %s\n", this->name);  
    printf("No: %d\n", this->reg_num);  
}
```

# Inheritance and Specialization (cont'd)

- Reuse LN\_Person for Student
- View Student as Person (cast)

```
Student *StudentC( String n, int r ) {  
    Student *this = (Student *)  
        malloc( sizeof( Student ) );  
  
    this -> name      = n;  
    this -> print     = printStudent;  
  
    this -> lastName  =  
        (String (*)(Student*)) LN_Person;  
    this -> reg_num   = r;  
  
    return this;  
}
```

# Subclassing and Dynamic Binding

- Student has all attributes and methods of Person
- Casts are necessary
- Array I can contain Person and Student objects
- Methods are selected dynamically

```
Student *s;  
Person *p;  
s = StudentC( "Werner Dietl" );  
p = (Person *) s;  
p -> name = p -> lastName( p );  
p -> print( p );
```

```
void printAll( Person **I ) {  
    int i;  
    for ( i=0; I[ i ] != NULL; i++ )  
        I[ i ] -> print( I[ i ] );  
}
```



# Discussion of the C Solution: Pros

- We can express **objects**, **attributes**, **methods**, **constructors**, and **dynamic method binding**
- By imitating OO-programming, the union in Person and the switch statement in printAll became dispensable
- The behavior of reused code (Person, printAll) can be **adapted** (to introduce Student) **without changing the implementation**

# Discussion of the C Solution: Cons

- Inheritance has to be replaced by **code duplication**
- Subclassing can be simulated, but it requires
  - Casts, which is **not type safe**
  - **Same memory layout** of super and subclasses (same attributes and function pointers in same order), which is **extremely error-prone**
- Appropriate language support is needed to apply object-oriented concepts

# A Java Solution

```
class Person {  
    String  name;  
    void    print( ) {  
        System.out.println("Name: " +  
            name);  
    }  
    String  lastName( ) { ... }  
    Person( String n )    { name = n; }  
}
```

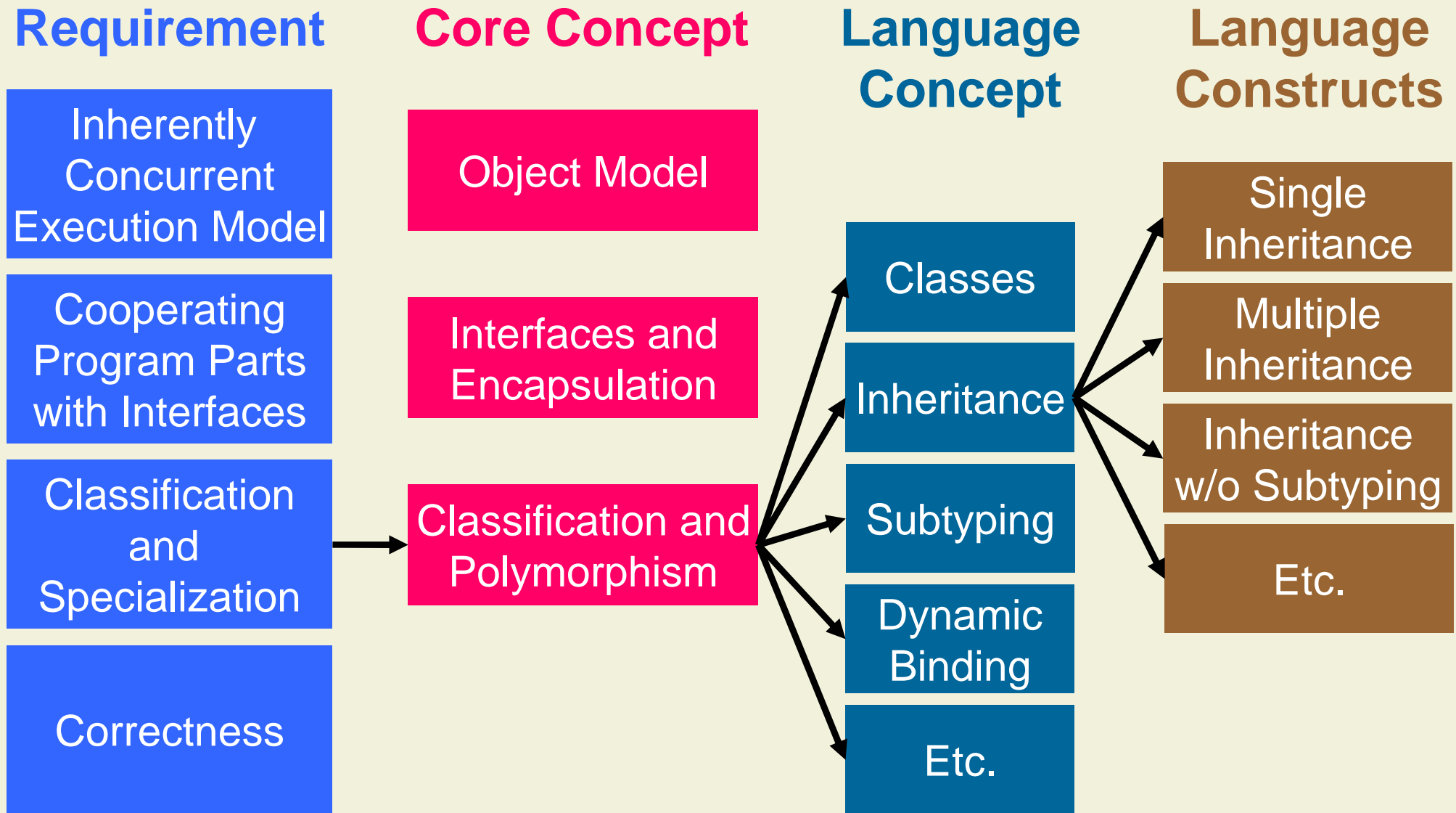
```
void printAll( Person[ ] l ) {  
    for (int i=0; l[ i ] != null; i++)  
        l[ i ].print( );  
}
```

```
class Student extends Person {  
    int    reg_num;  
    void    print( ) {  
        super.print();  
        System.out.println("No: " +  
            reg_num);  
    }  
    Student( String n, int i ) {  
        super( n );  
        reg_num = i;  
    }  
}
```

# Discussion of the Java Solution

- The Java solution uses
  - **Inheritance** to avoid code duplication
  - **Subtyping** to express classification
  - **Overriding** to specialize methods
  - **Dynamic binding** to adapt reused algorithms
- Java supports the OO-language concepts
- The Java solution
  - Is simpler and smaller
  - Easier to maintain (no duplicate code)
  - Type safe

# Concepts: Summary



# 1. Introduction

1.1 Requirements

1.2 Concepts

**1.3 Course Outline**

# After this Course, you should be able

- To understand the core concepts
- To compare OO-languages
- To understand the language concepts
- To learn new languages faster
- To apply language concepts correctly
- To write better object-oriented programs

# Approach

- We discuss the
  - **Concepts** of  
as opposed to languages, implementations, etc.
  - **Object-Oriented**  
as opposed to imperative, declarative
  - **Programming**  
as opposed to analysis, design, etc.
- We try to be language-independent
  - However, Java is used for examples and exercises
- We look at code and analyze programs



# Course Outline (tentative)

2. Core and Basic Language Concepts
3. Reusable Components
4. Frameworks
5. Information Hiding and Encapsulation
6. Object Structures and Aliasing
7. Static Safety and Extended Typing
8. Concurrency and Threads
9. Remote Method Invocation
10. Reflection and Dynamic Class Loading
11. Behavioral Interface Specifications
12. Extended Static Checking

Classification and  
Polymorphism

Interfaces and  
Encapsulation

Object Model

Correctness

# Using this Course

- Master Program:  
This course is a **Fokusfach** for the Major in Software Engineering
- Diploma Program:  
This course is a **Specialized Course** (Vertiefungsfach)

# Related Courses

- Software Architecture (SS)
- Object-Oriented Software Construction (Meyer, SS)
- Trusted Components (Meyer, WS)
- Semantik von Programmiersprachen (Müller, WS)
- Verteilte Systeme (Mattern, Alonso, Wattenhofer, WS)
- C++ Templates and Generic Programming (Zueff, WS)

# Related Seminars

- Specification and Verification of Object-Oriented Software (Kröning, Müller, WS)
- FATS Formal Approaches to Software (Abrial, Basin, Kröning, Meyer, Müller)

# Literature

- Poetzsch-Heffter, Arnd: Konzepte objektorientierter Programmierung. Springer-Verlag, 2000
- Budd, Timothy: An Introduction to Object-Oriented Programming. Addison-Wesley, 1991
- Meyer, Bertrand: Object-Oriented Software-Construction (2<sup>nd</sup> edition). Prentice Hall, 1997
- Horstmann, Cay S. and Cornell, Gary: Core Java, Band 1 – Grundlagen. Markt+Technik, 2003
- See course web page for a comprehensive list