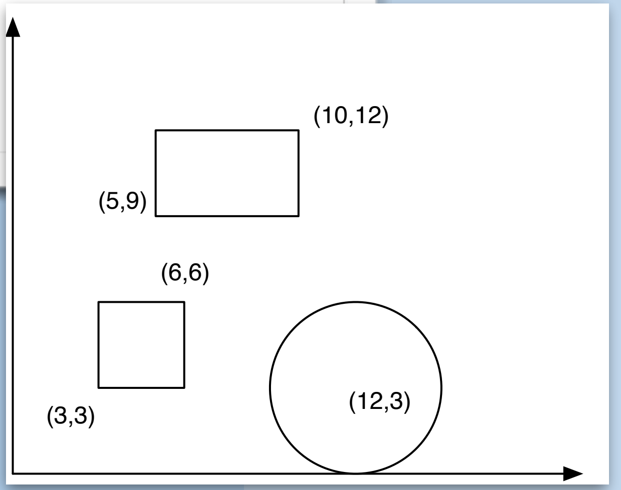
Programming 2
Object-Oriented Programming with Java

Oscar Nierstrasz

```
double size() {
    double total = 0;
    for (Shape shape : shapes) {
        total += shape.size();
    }
    return total;
}
```



P2 — Object-Oriented Programming

Lecturer:	Oscar Nierstrasz
Assistants:	Andrei Chis, Claudio Corrodi Aliaksei Syrel, Mathias Stocker
WWW:	scg.unibe.ch/teaching/p2

Roadmap

> Goals, Schedule
> What is programming all about?
> What is Object-Oriented programming?
> Foundations of OOP
> Why Java?
> Programming tools, version control

Roadmap

- **Goals, Schedule**
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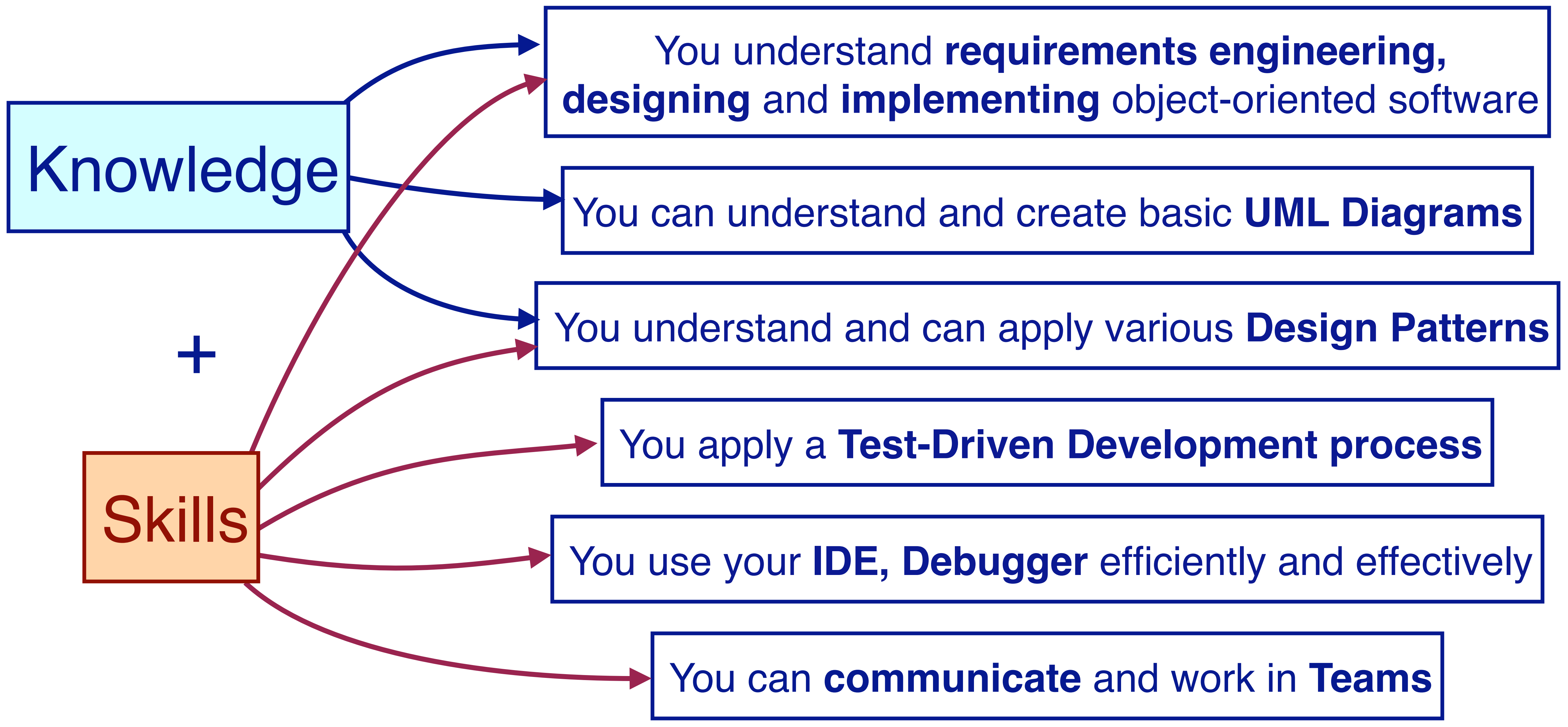
Your Learning Targets



You understand **requirements engineering, designing** and **implementing** object-oriented software

You can understand and create basic **UML Diagrams**

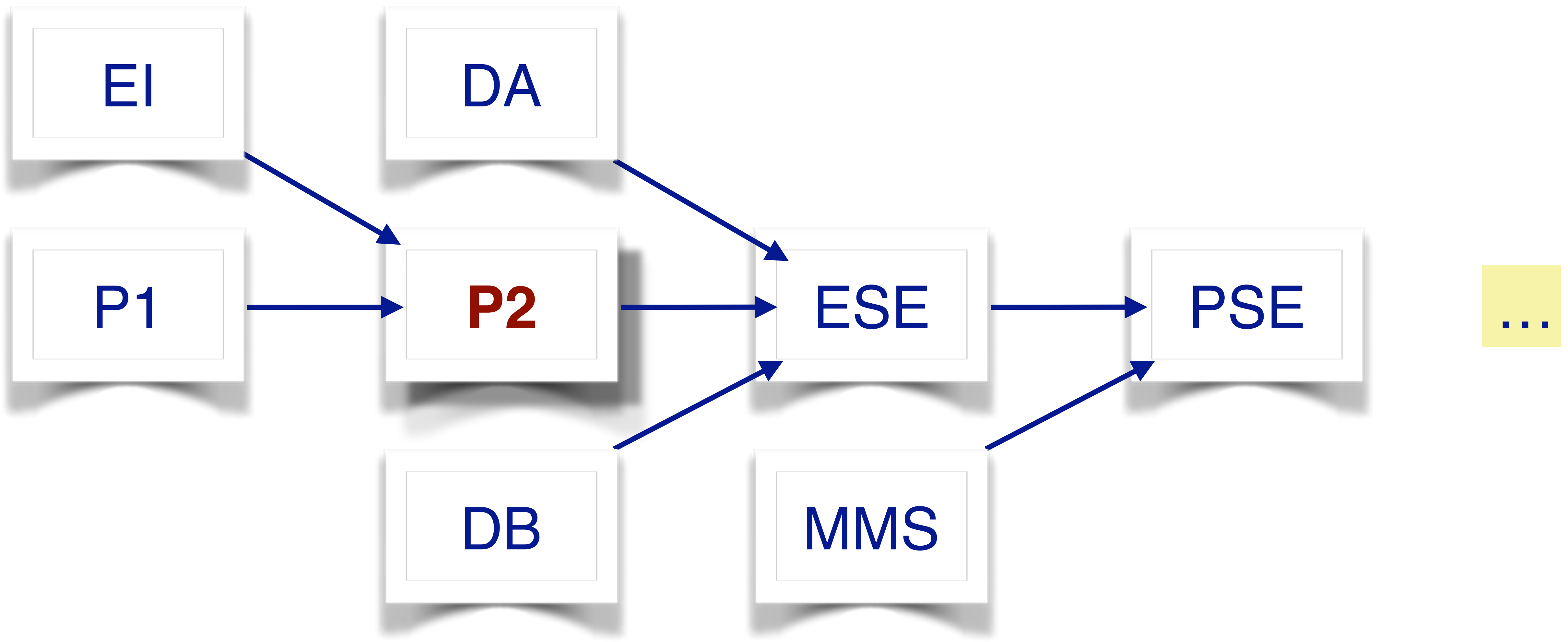
You understand and can apply various **Design Patterns**

You apply a **Test-Driven Development process**

You use your **IDE, Debugger** efficiently and effectively

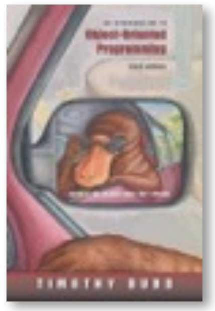
You can **communicate** and work in **Teams**

The Big Picture



Recommended Texts

> ***Java in Nutshell: 6th edition***,
David Flanagan, O'Reilly, 2014.

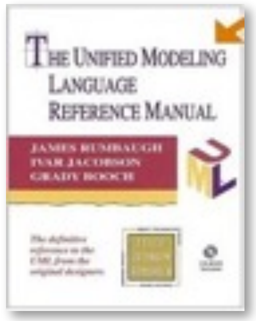


> ***An Introduction to Object-Oriented Programming***,
Timothy Budd, Addison-Wesley, 2004.

> ***Object-Oriented Software Construction***,
Bertrand Meyer,Prentice Hall, 1997.

> ***Object Design - Roles, Responsibilities and Collaborations***,
Rebecca Wirfs-Brock, Alan McKean, Addison-Wesley, 2003.

> ***Design Patterns: Elements of Reusable Object-Oriented Software*****,**
Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides, Addison Wesley, Reading, Mass., 1995.



> ***The Unified Modeling Language Reference Manual*****,**
James Rumbaugh, Ivar Jacobson, Grady Booch, Addison-Wesley, 1999

Schedule

1. Introduction
2. Object-Oriented Design Principles
3. Design by Contract
4. A Testing Framework
5. Debugging and Tools
6. Iterative Development
7. Inheritance and Refactoring
8. GUI Construction
9. Advanced Design Lab
10. Guidelines, Idioms and Patterns
11. A bit of C++
12. A bit of Smalltalk
13. Guest Lecture — Einblicke in die Praxis

This is a note (a hidden slide). You will find some of these scattered around the PDF versions of the slides.

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- **What is programming all about?**
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*What is the **hardest** part of programming?*

What constitutes programming?

- Understanding requirements
- Design
- Testing
- Debugging
- Developing data structures and algorithms
- User interface design
- Profiling and optimization
- Reading code
- Enforcing coding standards
- ...

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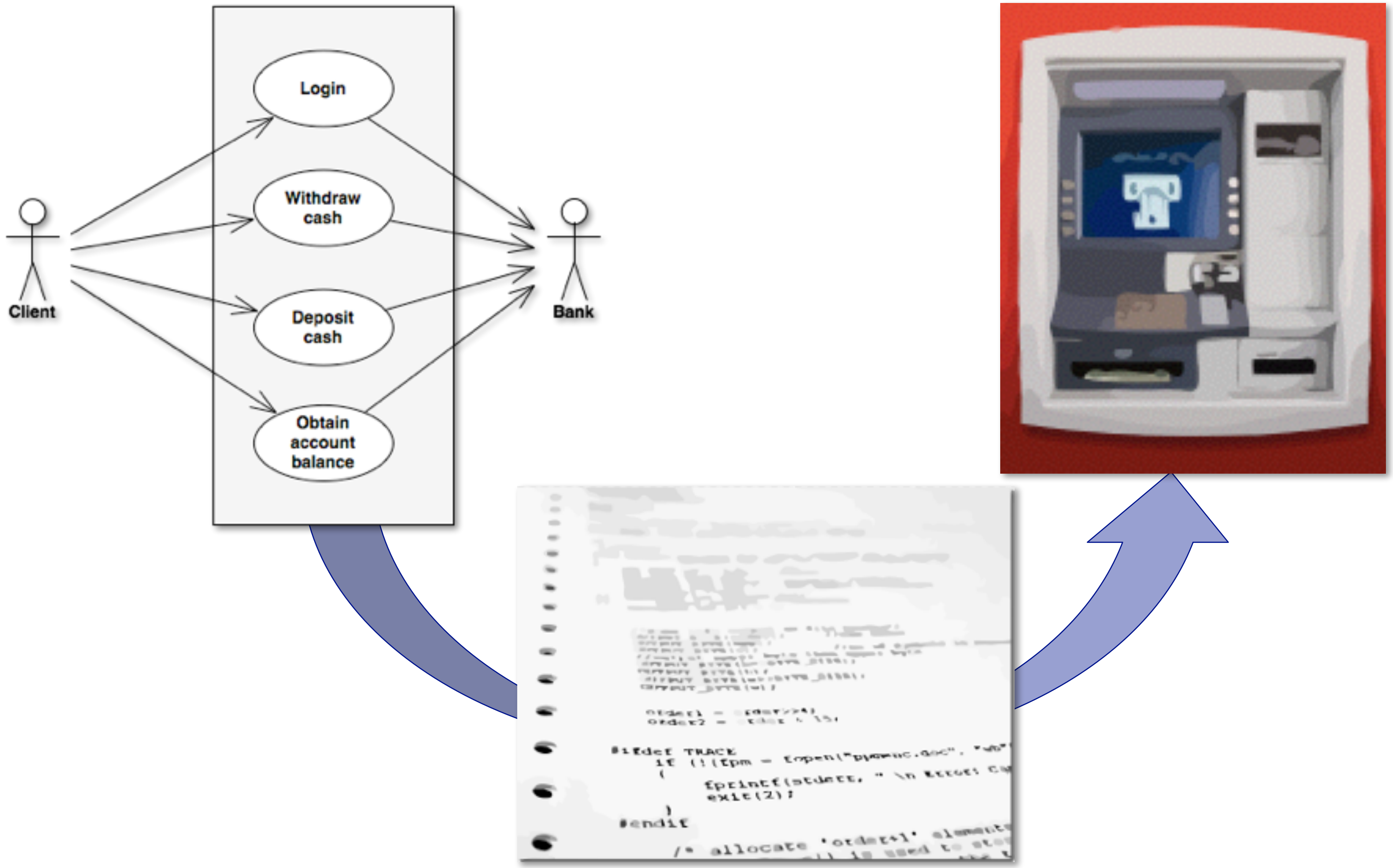
Programming is modeling



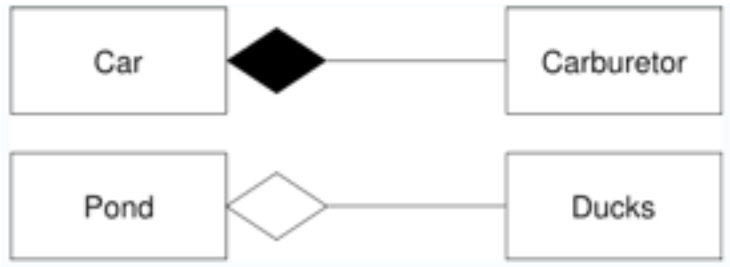
Programs are executable models that are used to achieve some effect in the real world. With a good design, the program code reflects clearly the models as we want them to be.

Programming languages offer us a variety of different tools for expressing executable models. If we pick the right tool, the job is easier.

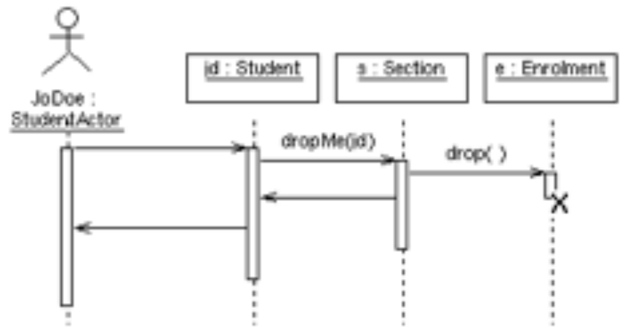
What is Object-Oriented Programming?

Encapsulation — **Abstraction & Information Hiding**

Composition — **Nested Objects**

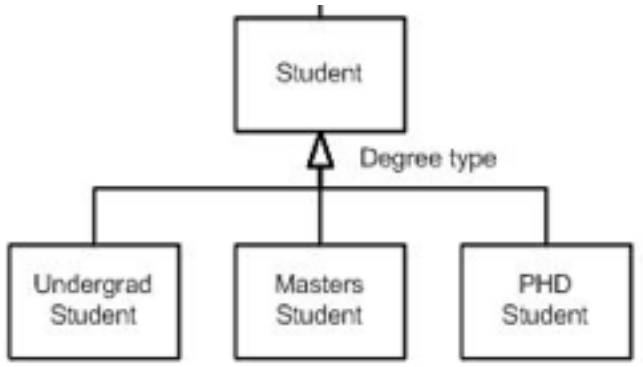


Distribution of Responsibility — ***Separation of concerns (e.g., HTML, CSS)***



Message Passing — ***Delegating responsibility***

Inheritance — ***Conceptual hierarchy, polymorphism and reuse***



Encapsulation means that related entities are bundled together, for example, a Shape object encapsulates data and related operations for shapes.

Abstraction means that we ignore irrelevant details, for example, we abstract from the details of a Shape object and just use its interface (i.e., its operations).

Information hiding means that we hide (forbid access to) the representation behind an abstraction, for example, you may not directly access the state of a Shape but must access it only through its interface.

These three concepts are closely related, but clearly different.

Composition refers to the fact that we can compose complex objects from simpler ones. A Picture may be composed of many shapes.

Distribution of Responsibility means that we *break complex tasks into simpler ones*, and handle them at the *appropriate level of abstraction*, and *close to where the relevant knowledge is*. If you need to resize a shape object, that task should be handled by the shape itself.

Message Passing refers to the idea that you do not “apply procedures to objects”, but that you politely ask them to do something by sending them a message. The object *itself* then decides whether it has a *method* to handle that message.

Inheritance is, simply seen, just a mechanism to share behaviour and state (i.e., methods and instance variables) between a class and its subclasses.

As we shall see, inheritance can be used in object-oriented design for three different, but related purposes:

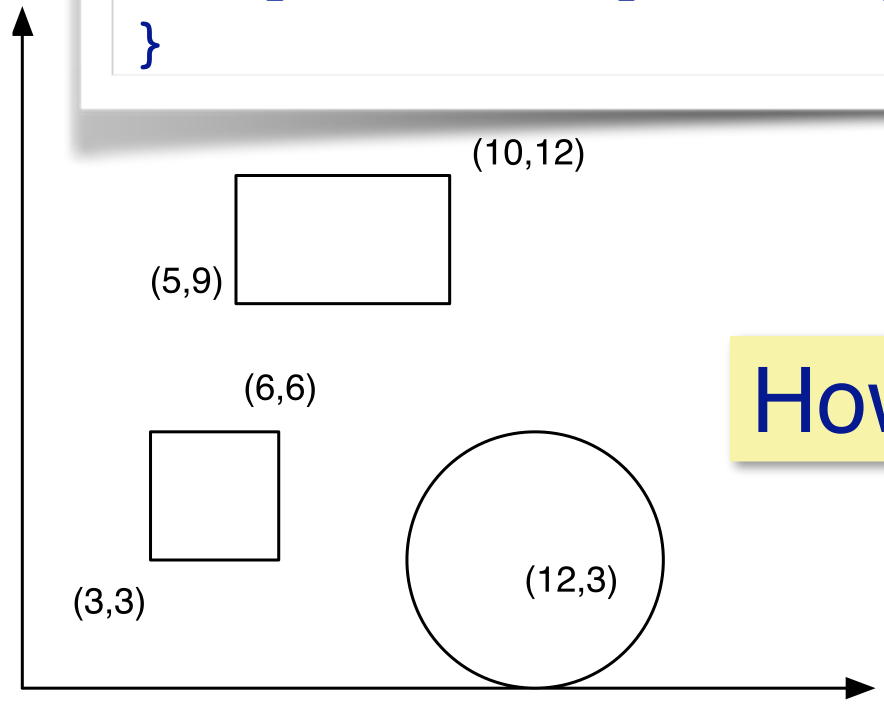
1. Conceptual hierarchy (a Rectangle *is a* Shape)
2. Polymorphism (I can use a rectangle anywhere I expect a shape)
3. Reuse (the Rectangle class reuses everything it inherits from Shape)

In a good object-oriented design, all three of these come together.

Procedural versus OO designs

Problem: compute the total area of a set of geometric shapes

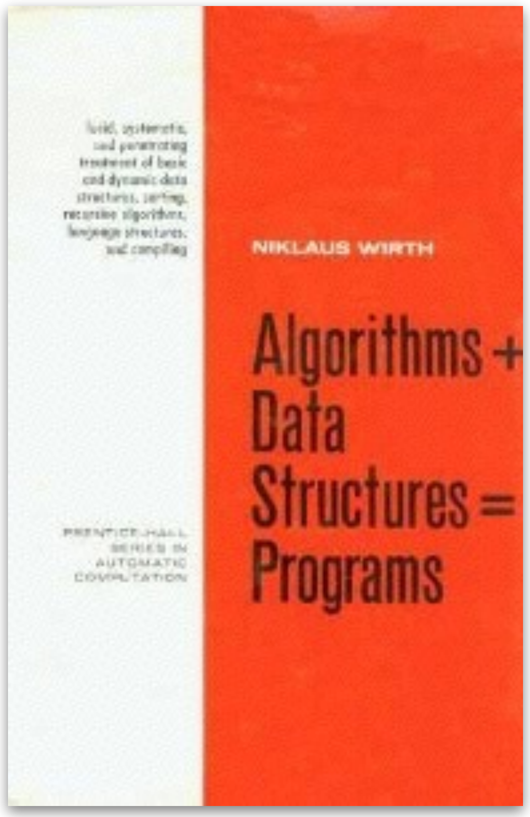
```
public static void main(String[] args) {
   Picture myPicture = new Picture();
   myPicture.add(new Square(3,3,3));         // (x,y,width)
   myPicture.add(new Rectangle(5,9,5,3));    // (x,y,width,height)
   myPicture.add(new Circle(12,3,3));        // (x,y,radius)

   System.out.println("My picture has size " + myPicture.size());
}
```



How to compute the size?

Procedural approach: *centralize* computation

```
double size() {
    double total = 0;
    for (Shape shape : shapes) {
        switch (shape.kind()) {
        case SQUARE:
            Square square = (Square) shape;
            total += square.width * square.width;
            break;
        case RECTANGLE:
            Rectangle rectangle = (Rectangle) shape;
            total += rectangle.width * rectangle.height;
            break;
        case CIRCLE:
            Circle circle = (Circle) shape;
            total += java.lang.Math.PI * circle.radius * circle.radius / 2;
            break;
        }
    }
    return total;
}
```



Here we see a classical procedural design consisting of algorithms and data structures. Squares, Rectangles and Shapes are passive data structures, and algorithms have complete control to manipulate them.

Object-oriented approach: *distribute* computation

```
double size() {
   double total = 0;
   for (Shape shape : shapes) {
      total += shape.size();
   }
   return total;
}
```

```
public class Square extends Shape {
...
   public double size() {
      return width*width;
   }
}
```

What are the advantages and disadvantages of the two solutions?

In the object-oriented design, the responsibility of computing the size of a shape is distributed to the objects with the necessary knowledge to perform the computation. The resulting design is *fundamentally different*.

There are clear tradeoffs between the two approaches. Although OO design has certain advantages, it is not “better” in absolute terms.

Exercise: what are the tradeoffs?

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Object-Oriented Design in a Nutshell

- Identify *minimal* requirements
- Make the requirements *testable*
- Identify objects and their *responsibilities*
- Implement and *test* objects
- Refactor to *simplify* design
- Iterate!

Responsibility-Driven Design

- Objects are responsible to *maintain information and provide services*
- A good design exhibits:
  - *high cohesion* of operations and data within classes
  - *low coupling* between classes and subsystems
- Every method should perform *one, well-defined task:*
  - High level of abstraction — write to an interface, not an implementation

Cohesion refers to the notion that related entities should be close together. This is supported by encapsulation mechanisms, like classes and packages. A good design is cohesive, so that when you have to change something or add new features, then the parts to change can be found together.

Coupling refers to the dependencies between parts of a software system, i.e., what parts call each other, use each other, etc. High coupling is bad because if you change something, it will affect many other parts. A good design exhibits low coupling.

Design by Contract

> Formalize client/server contract as *obligations*
> Class invariant — formalize valid state
> Pre- and post-conditions on all public services
  - —*clarifies responsibilities*
  - —*simplifies design*
  - —*simplifies debugging*

Extreme Programming

Some key practices:

> Simple design
>
> —*Never anticipate functionality that you "might need later"*
>
> Test-driven development
>
> —*Only implement what you test!*
>
> Refactoring
>
> —*Aggressively simplify your design as it evolves*
>
> Pair programming
>
> —*Improve productivity by programming in pairs*

Testing

> Formalize requirements
> Know when you are done
> Simplify debugging
> Enable changes
> Document usage

Code Smells

> Duplicated code
> Long methods
> Large classes
> Public instance variables
> No comments
> Useless comments
> Unreadable code
> …

Refactoring

*"Refactoring is the process of **rewriting** a computer program or other material to improve its structure or readability, while explicitly **keeping its meaning** or behavior."*

— *wikipedia.org*

Common refactoring operations:

> Rename methods, variables and classes
> Redistribute responsibilities
> Factor out helper methods
> Push methods up or down the hierarchy
> Extract class
> …

Design Patterns

> *"a general repeatable solution to a commonly-occurring problem in software design."*

Example

> Adapter — "adapts one interface for a class into one that a client expects."

Patterns:

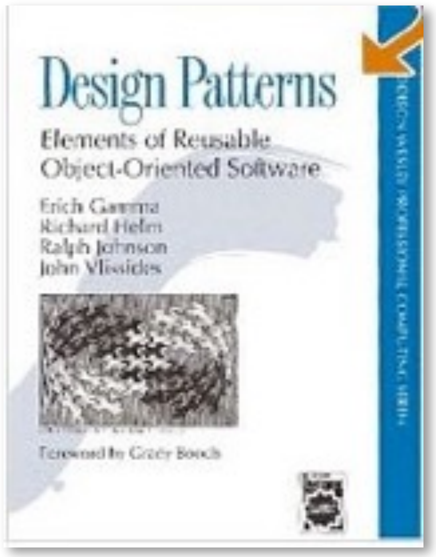
> Document "best practice"
> Introduce standard vocabulary
> Ease transition to OO development

But …

> May increase flexibility at the cost of simplicity

We will see several design patterns during the course, but we'll only look in detail near the end. Most of the design patterns we will see are described in the classic book by the "Gang of Four."

An electronic version is available to students of this course.



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Why Java?

Special characteristics

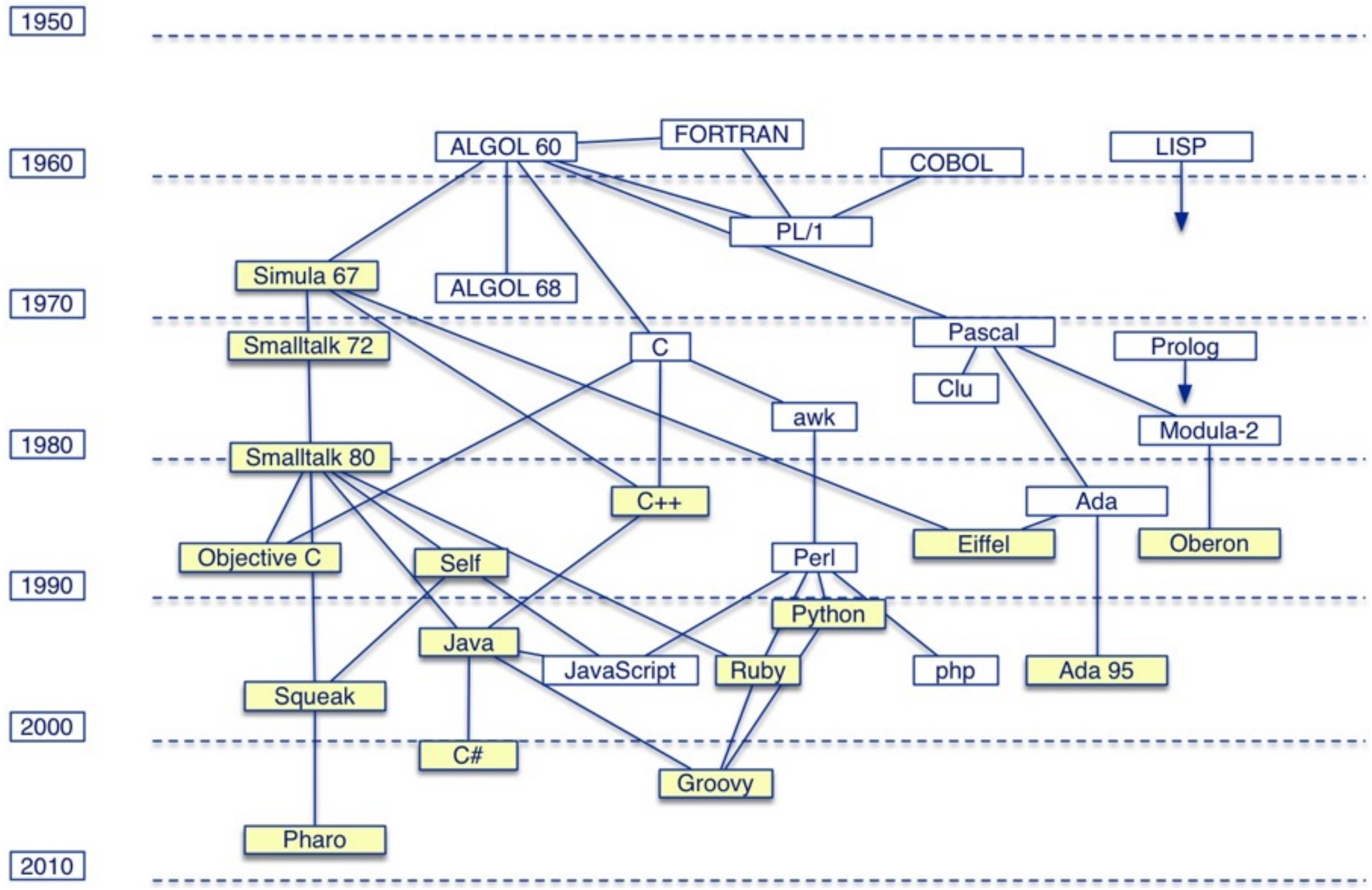
> Resembles C++ minus the complexity
> Clean integration of many features
> Dynamically loaded classes
> Large, standard class library

Simple Object Model

> “Almost everything is an object”
> No pointers
> Garbage collection
> Single inheritance; multiple subtyping
> Static and dynamic type-checking

Few innovations, but reasonably clean, simple and usable.

History


1950
1960
1970
1980
1990
2000
2010
ALGOL 60
FORTRAN
COBOL
LISP
PL/1
Simula 67
ALGOL 68
Smalltalk 72
C
Pascal
Prolog
Clu
awk
Modula-2
Smalltalk 80
C++
Ada
Objective C
Self
Perl
Eiffel
Oberon
Python
Java
JavaScript
Ruby
php
Ada 95
Squeak
C#
Groovy
Pharo

Java adopts much of its syntax from C++, to make it appeal to seasoned C++ programmers, but adopts many language features from Smalltalk, such as single inheritance, implementation based on a virtual machine, and automatic garbage collection.

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Programming Tools

Know your tools!

- IDEs (Integrated Development Environment)— e.g., Eclipse
- Version control system — e.g., svn, git
- Build tools — e.g., maven, ant, make
- Testing framework — e.g., Junit
- Debuggers — e.g., jdb
- Profilers — e.g., java -prof, jip
- Documentation generation — e.g., javadoc

Version Control Systems

A version control system keeps track of multiple file revisions:

> *check-in* and *check-out* of files

> *logging changes* (who, where, when)

> *merge* and *comparison* of versions

> *retrieval* of arbitrary versions

> *"freezing"* of versions as releases

> *reduces storage space* (manages sources files + multiple *"deltas"*)

Version Control

Version control enables you to make radical changes to a software system, with the assurance that ***you can always go back*** to the last working version.

✎ When should you use a version control system?

✔ *Use it whenever you have one available, for even the **smallest project!***

*Version control is as **important** as **testing** in iterative development!*

What you should know!

- ✎ What is meant by “separation of concerns”?
- ✎ Why do real programs change?
- ✎ How does object-oriented programming support incremental development?
- ✎ What is a class invariant?
- ✎ What are coupling and cohesion?
- ✎ How do tests enable change?
- ✎ Why are long methods a bad code smell?

Can you answer these questions?

- ✎ *Why does up-front design increase risk?*
- ✎ *Why do objects "send messages" instead of "calling methods"?*
- ✎ *What are good and bad uses of inheritance?*
- ✎ *What does it mean to "violate encapsulation"?*
- ✎ *Why is strong coupling bad for system evolution?*
- ✎ *How can you transform requirements into tests?*
- ✎ *How would you eliminate duplicated code?*
- ✎ *When is the right time to refactor your code?*