Object-Oriented Programming Design and Analysis
Object-Oriented Programming

- First programs: “anything goes”
- 1960s-1970s: structured programming
  - any “computable function” can be achieved by
    - “sequencing” (ordered statements)
    - “selection” (conditions, e.g. if/else)
    - “repetition” (iteration, e.g. for i=0, i<10, i++)
  - "Go To Statement Considered Harmful", Dijkstra
  - Procedural programming: modularity
- 1967 – “objects” first formal appearance in Simula’67
- 1980 – Smalltalk-80: “everything is an object” (including primitive data types such as integers)

The Squares Program (excerpt) written for EDSAC, 1949

http://www.cl.cam.ac.uk/~mr10/edsacposter.pdf

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Object-Oriented Programming
- “Object-oriented programming is a method of implementation in which programs are organized as cooperative collections of objects ...”

Object-Oriented Design
- “Object-oriented design is a method of design encompassing the process of object-oriented decomposition ...” – using object and classes to describe the system

Object-Oriented Analysis
- “Object-oriented analysis is a method of analysis that examines requirements from the perspective of the classes and objects found in the vocabulary of the problem domain”
Geometric abstractions are powerful tools. The floor plan of a building helps both architect and client evaluate spaces, traffic flows, views. Contradictions and omissions become obvious. Scale drawings of mechanical parts and stick-figure models of molecules, although abstractions, serve the same purpose. A geometric reality is captured in a geometric abstraction. The reality of software is not inherently embedded in space. Hence, it has no ready geometric representation in the way that land has maps, silicon chips have diagrams, computers have connectivity schematics.


- **Object Oriented approach allows to use a meaningful abstraction in software design**
  - Looking at a design diagram anyone can have a good guess what the Circle class represents in the Drawing Editor or the Customer class in the Online Banking system

- **Essentially, Object Orientation is the way of describing a system in terms of meaningful abstractions (classes), relationship and interactions between them**

- **Can be used on both Conceptual and Implementation levels**
What are these?
Abstractions

• Cars, of course!

• However, a Fiat Punto and a Buggatti Veron are very different objects, yet we can call both a car and be correct

• Abstractions are generalisations that define certain key characteristics and behaviour

• All cars have
  - 4 wheels, at least a driver seat, an engine

• All cars can
  - move, stop, steer

• All birds have two wings and can fly, all cameras have a lens and can take pictures ...

Classification is the means whereby we order knowledge. In object-oriented design, recognizing the sameness among things allows us to expose the commonality within key abstractions and mechanisms and eventually leads us to smaller applications and simpler architectures.

Object-Oriented Analysis and Design with Applications, Grady Booch, Robert A. Maksimchuk, Michael W. Engel, Bobbi J. Young, Jim Conallen, Kelli A. Houston
Class

- A class represents a key concept within the system
- It encapsulates data and behaviour

Object-oriented approach requires thinking about:
- What classes of objects are present in the problem?
- What behaviour does each class have to provide?
- What should happen when an action is requested of an object?

<table>
<thead>
<tr>
<th>Concept</th>
<th>Data</th>
<th>Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>bank account</td>
<td>balance</td>
<td>debit/credit</td>
</tr>
<tr>
<td>car</td>
<td>speed</td>
<td>move/stop</td>
</tr>
<tr>
<td>message</td>
<td>text</td>
<td>send</td>
</tr>
</tbody>
</table>

Bank Account
- balance
- debit
- credit

Car
- speed
- move
- stop

Message
- text
- send

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Object

- Each class can be used to create multiple *instances*, i.e. *objects* that can contain data and behave according to the class definition

- Bank account no. **12234456** vs Bank account no. **65443221**

- *Credit* 100 EUR, *Debit* 200 EUR

- Given the same data (state) two independent instances of the same class will behave exactly the same: e.g. *crediting* 100 EUR will increase the *current balance* by 100 EUR

- In production (when the software is used) a large number of objects are created, interact with each other, destroyed if no longer needed
Encapsulation

• Classes provide *abstractions*. An object can be used without any knowledge of how it works. This allows to describe the system in manageable concepts.

• All drivers know that a steering wheel makes the car go left if we turn it left and right if we turn it right.

• Most drivers have no idea why/how it works.

• By exposing only WHAT it can do and not HOW, a designer can later improve the steering wheel without changing how the driver interacts with it, e.g. adding power steering or adding play music controls.

• In Object Orientation this approach is called Encapsulation or Information/Data Hiding and is complimentary to Abstraction.
• Suppose class Person has a Name attribute, which defines a full name

• One way to access the Name would be to declare a direct access to the attribute (variable)

• Consider a Change request: we sold the software in France and now need to display the Last Name first

• We can extend our Person class to have two variable and let the display code decide the order

• OR we can keep Name variables hidden from the outside and allow to access via a method

• Compare the change request:
  - in the original case we would need to modify code in ALL cases where the Name is shown
  - in the latter case we only need to make a change to the implementation of the method

```java
class Person
{
    public String FIRST_NAME = "John"
    public String LAST_NAME = "Smith"
}

print Person.FIRST_NAME + Person.LAST_NAME

if (in France)
    print Person.LAST_NAME + Person.FIRST_NAME
else
    print Person.FIRST_NAME + Person.LAST_NAME

class Person
{
    private String FIRST_NAME = "John"
    private String LAST_NAME = "Smith"

    public String Name
    {
        if (in France)
            return Person.LAST_NAME + Person.FIRST_NAME
        else
            return Person.FIRST_NAME + Person.LAST_NAME
    }
}

print Person.NAME
```
Encapsulation and Data Hiding

• Getters/Setters (i.e. Properties) are used to provide controlled access to internal data fields

```java
class Person {
    private String email;
    public String getEmail { return email; }
    public setEmail(String newEmail) {
        if ((newEmail != null) && (newEmail.contains('@')) {
            email = newEmail;
        }
    }
}
```

• They allow to implement constraints checking, e.g. should not be null or should contain be formatted as an email address

• Control concurrent access

• Hide actual data sources (e.g. database)

Startup style development? "We could have getters and setters, but... Life's too short"

a Cambridge software startup, 2012

"You only need to floss the teeth you want to keep"
an old saying

“the point of encapsulation isn't really about hiding the data, but in hiding design decisions, particularly in areas where those decisions may have to change. The internal data representation is one example of this, but not the only one and not always the best one. The protocol used to communicate with an external data store is a good example of encapsulation - one that's more about the messages to that store than it is about any data representation.”

Inheritance

• **Classes can be related**
  - *Superclass AKA base class* (parent) can be *extended/inherited from*
  - *Subclass* (child) can be *extending/deriving/inheriting from*

• **Each Subclass can hold all the data and perform all the actions of the Superclass**

• **Subclass, however, can also**
  - hold additional data
  - perform new actions
  - and/or perform original actions differently

• **Example:**
  - to draw a circle requires to know a point of origin and the radius
  - to draw a triangle requires us know coordinates of its vertexes
  - both can have a fill colour
Polymorphism

- Class inheritance hierarchy allows us to choose the level of abstraction at which we interact with an object:
  - to calculate how much money is in the bank in total, the system needs only one piece of data - the current balance, every account will have the balance and for these purposes there is no difference if it's a savings account or a current account
  - however, the way the balance calculated could be very different (including the rules about interest)
  - Polymorphism allows us to request the same action from objects yet allow for it to be executed in different ways

- Why is it useful? Extensibility! Compare

```java
foreach CurrentAccount in Bank
{
    TotalMoney = TotalMoney + CurrentAccount.balance()
}
foreach SavingsAccount in Bank
{
    TotalMoney = TotalMoney + SavingsAccount.balance()
}
foreach SuperHighInterestAccount in Bank
{
    TotalMoney = TotalMoney + SuperHighInterestAccount.balance()
}
```

- to

```java
foreach Account in Bank
{
    TotalMoney = TotalMoney + Account.balance()
}
```
Polymorphism and Inheritance

- Polymorphism separates the declaration of the functionality from specifics of its implementation
- Polymorphism is one of the key concept of Object Orientation
- Requires a principally different view on the system
- Identifying good key Classes and Inheritance Hierarchy is not simple

Inheritance “IS A” relationship – Subclass “IS A” Superclass
- Coffee IS a Drink, Car IS a Vehicle

Engine, Window, Wheel are NOT Cars

A new quality/feature does NOT equal a new class
Furthermore, Fast, Red, Expensive are Values not Attributes, where the Attributes could actually be Speed, Colour, Price
Abstract Classes

• In our previous example, we used Triangle and Circle classes that extend the Shape class

• In our system, Shape is a conceptual class, i.e. we will never have an actual object which is just a Shape, we will have either a Circle or Triangle

• This makes Shape class Abstract – a class that can not be instantiated

• Abstract classes are a high level “blueprints” for Objects in the system, but to actually make Objects we would need some “concrete” classes

• Abstract classes capture the higher level view of the system
• A purely abstract class that defines only behaviour (not data) is called an Interface

• All WaterCrafts can float on water, but only a Submarine can go under water

• Interfaces help to add specific behaviour to classes

• Typically, a class can only extend one superclass but it can and often will “implement” multiple interfaces
Object Orientation Summary

• Object Oriented approach allows us to understand the requirements and design a solution on the conceptual level

• It allows us to design and build extensible solutions, addressing the key challenge of software engineering – building for change

• To achieve this it offers us encapsulation, inheritance, polymorphism

• Terminology
  - Object is an Instance of a Class
  - Class, Subclass, Superclass
  - Inheritance, Polymorphism
  - Abstract Classes, Interfaces

• It allows us to communicate ideas and concepts in a clear consistent way to all team members

• It works across all stages of the software development process from Analysis to Maintenance via Design and Implementation