I don’t think object-oriented programming is a structuring paradigm that meets my standards of elegance.

Edsger W. Dijkstra

OBJECT-ORIENTED PROGRAMMING

Class and Object

Lecture #1

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Programming concepts

- Structured programming
  - Data structures (array, record)
  - Program flow structures (sequence, selection, iteration)
  - Subroutines (macros, procedures, functions)
- Modular programming
  - Separation of concerns
  - Definition of interfaces (declaration, implementation)
  - Improvement of maintainability
- Object-oriented programming
  - Objects (data fields + methods) and their interactions
  - Object-oriented techniques (**abstraction, information hiding, encapsulation, inheritance, polymorphism**)
  - **Improvement of code reuse**

Object orientation

- How to deal with complexity?
  - Abstraction
- How to define the scope of data inside data structures (objects)?
  - Encapsulation
- How to protect parts of the program from extensive modification based on design changes?
  - Information hiding
- How to reuse existing code with little or no modification?
  - Subtyping and inheritance
- How to work with variables (objects) using different types?
  - Polymorphism

Abstraction

- Simplifying complex reality by modeling objects appropriate to the problem
- An abstraction focuses on the outside view of an object and separates an object's behavior from its implementation

Abstract data types

- Mathematical model for a **class** of data structures (**objects**) that have similar behavior
- Abstract data types simplify the description of abstract algorithms
  - In programming languages usually implemented as data types, data structures, modules
- **One of the formalizing concept of object-oriented programming**

Abstract data types in object-oriented programming

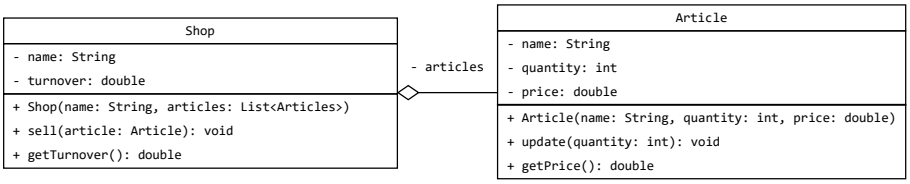
- **Class**
  - Defines abstract characteristics of things (objects)
  - It includes **properties** (data fields) and **capabilities** (functions and procedures)
- **Object**
  - One version (exemplar) of the class with concrete version of properties

Object example: Analysis

- Example: Let's have a shop that sales articles and keeps the track of total turnover
- What data structure do we need?
  - Shop
    - Properties: name, list of articles, total turnover
    - Capabilities: create new shop, sell article, get total turnover
  - Article
    - Properties: name, quantity, price
    - Capabilities: create new item, update article quantity (after sale), get price
- How to represent list of articles?
  - Dynamic data structures, e.g. linked list

Object example: Design

- For the design we will use UML
- We design two classes with following characteristics, behaviors and interactions



- Data fields inside classes are bound and can be maintained only by the object of that class itself (**encapsulation**)

What are software objects?

- Building blocks of software systems
  - A program is a collection of interacting objects
  - Objects cooperate to complete a task
  - To do this, they communicate by sending “messages” to each other
- Objects model **tangible** things
  - A shop
  - An article
- Objects model **conceptual** things
  - An inventory
  - An order
- Objects model **processes**
  - Calculating sales report for the shop owner
  - Sorting articles in the stock
- Objects have
  - **Capabilities**: what they can do, how they behave
  - **Properties**: features that describe them

Objects capabilities (behavior)

- Objects' **capabilities** allow them to perform specific actions
- Capabilities are also called **behaviors** and can be
  - **Constructors**: establish initial state of object's properties
  - **Commands**: change object's properties
  - **Queries**: provide responses based on object's properties
- Example: shops are capable of performing specific actions
  - **Constructor**: be created
  - **Commands**: sell article
  - **Queries**: get total turnover
- Implement capabilities as **methods**
  - Functions and procedures bound to the class

Object properties (state)

- **Properties** determine how an object acts
- Properties can be
  - **Attributes**: things that help describe an object
  - **Components**: things that are "part of" an object
  - **Associations**: things an object knows about, but are not part of that object
- **State**: collection of all an object's properties (changes if any property changes)
  - Some properties do not change, e.g., name of the article
  - Others do, e.g., quantity of the article
- Example: properties of shop
  - **Attributes**: name, total turnover
  - **Components**: articles
  - **Associations**: e.g. a shop can be associated with a chain of shops
- Implement properties as **instance variables**
  - Variables bound to the class

Object instantiation

- **Object instantiation** creates an object instance of a class
  - **Constructor** is the first message: creates the instance

```
Shop grocery = new Shop("Grocery", articles);
```

- Reserved word **`new`** makes a new object instance, and call its constructor
  - Full name of constructor is given after **`new`**; since constructors have same name as their classes, this specifies the class to instantiate
- Statements defined in constructor are executed when the constructor is called

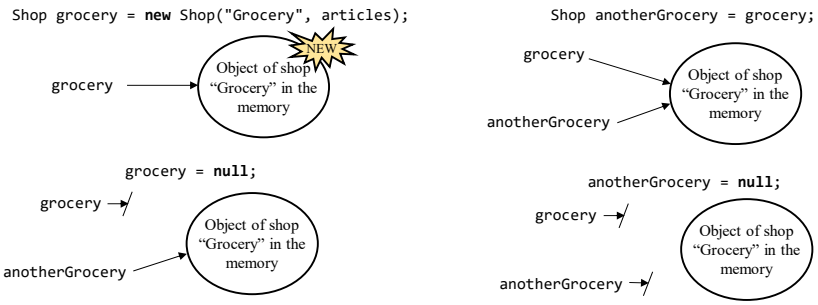
Constructor

- **Constructor** is a special method that is called whenever a class is instantiated (created)
  - Another object sends a message that calls a constructor
  - A constructor is the first message an object receives and cannot be called subsequently
  - **Establishes initial state of properties** for the object instance
  - Constructor has always the same name as class and has no return type
- If you do not define any constructors for a class, the default constructor is called
  - Default constructor will initialize each instance variable to its default value
  - This is not a good idea – always write your own constructor for each class and always give each instance variable a value

Constructors overloading

- It's common to **overload** constructors
  - Define multiple constructors which differ in number and/or types of parameters
- The compiler determines which constructor to call based on the number and the type of arguments in a call statement

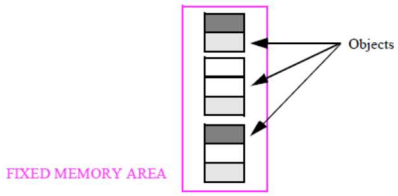
Memory management



- Remember, you are always working with references!
- There are three commonly found modes of memory management
  - **Static**
  - **Stack-based**
  - **Free (heap-based)**

Static memory mode

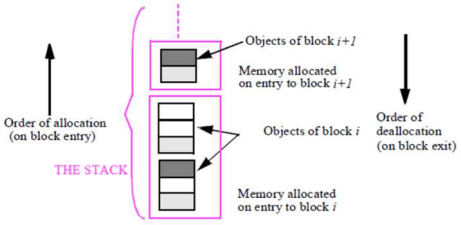
- An entity may become attached to at most one run-time object during the entire execution of the software
  - Allocate space for all objects (and attach them to the corresponding entities) once and for all, at program loading time or at the beginning of execution



- Problems
  - Recursion is permitted
  - Cannot use dynamic data structures

Stack-based mode

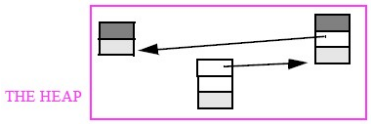
- An entity may at run-time become attached to several objects in succession, and the run-time mechanisms allocate and deallocate these objects in last-in, first-out order
  - When an object is deallocated, the corresponding entity becomes attached again to the object to which it was previously attached, if any



- Problem
  - Still cannot use dynamic data structures

Free (heap-based) mode

- An entity may become successively attached to any number of objects; the pattern of object creations is usually not predictable at compile time
  - The free mode allows us to create the sophisticated dynamic data structures

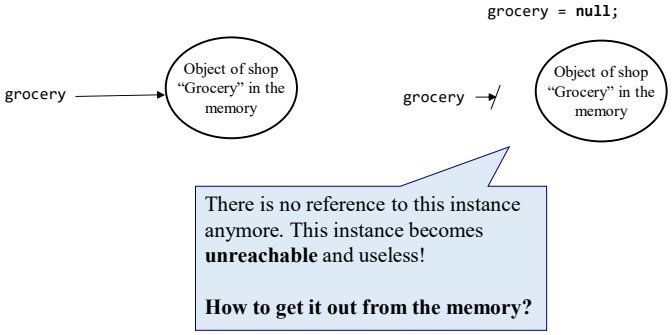


Space reclamation

- The ability to create objects dynamically, raises the question of what to do when an object becomes unused
  - Is it possible to reclaim its memory space, so as to use it again for one or more new objects in later creation instructions?
- Static mode
  - No problem with deallocation of objects
- Stack-based mode
  - Block-structured language make things particularly simple: object allocation occurs at the same time for all entities declared in a given block, allowing the use of a single stack for a whole program (remember local variables in C language)
- Free mode
  - The pattern of object creation is unknown at compile time it is not possible to predict when a given object may become useless
  - For example in C language programmers are forced to use `malloc()` and `free()` to allocate and deallocate the memory

Reachability problem

- We can easily get an unreachable problem after detachment of the reference



Memory management problem in object-oriented model

- The problem of memory management arises from the unpredictability of the operations which affect the set of reachable instances: creation and detachment
  - Such a prediction is possible in some cases, for data structures managed in a strictly controlled way (e.g. remember linked list in C language)
- Three general attitudes are possible as to objects that become unreachable
  - **Casual approach** – Ignore the problem and hope that there will be enough memory to accommodate all objects, reachable or not (hardly usable!)
  - **Manual reclamation** – Ask developers to include in every application an algorithm that looks for unreachable objects, and give them mechanisms to free the corresponding memory (e.g. C++ with command **`delete`**)
  - **Automatic garbage collection** – Include in the development environment (as part of the so-called runtime system) automatic mechanisms that will detect and reclaim unreachable objects (e.g. Java, C#)

Take care about memory

- "*I say a big NO! Leaving an unreferenced object around is BAD PROGRAMMING. Object pointers ARE like ordinary pointers – if you [allocate an object] you should be responsible for it, and free it when its finished with (didn't your mother always tell you to put your toys away when you'd finished with them?).*" (I. Stephenson, 1991)

- "*An object-oriented program without automatic memory management is roughly the same as a pressure cooker without a safety valve: sooner or later the thing is sure to blow up!*" (M. Schweitzer, L. Strether, 1993)