Design Principles

- Data Structures and Algorithms
- Design Goals
- Implementation Goals
- Design Principles
- Design Techniques

Data Structures

- Data Structure - A systematic way of organizing and accessing data.
- In the most general sense, a data structure is a data container into which we can store data.
- However, to access the data in the container, we must follow certain rules …

Abstract Data Types

- The rules that we follow to access data in a data structure is part of the abstract data type (ADT) for that data structure.
- In the object-oriented environment, the ADT also defines what messages the data structure must respond to.

Example - the Simplest Data Structure

- An array is the simplest data structure that almost all programming languages support.
- An array is a data container.
- Rules to access an array:
  - An array has a pre-defined, non-changeable capacity *N*.
    - Example: `int a [] = new a [100];`
  - Elements in the array are indexed by an integer from 0 to *N*-1.
  - When putting data into the array, the index must be in range.
    - Example: `a[3] = 100;`
  - When access data from the array, the index must be in range.
    - Example: `int k = a[3];`

Algorithms

- Algorithm: A step-by-step procedure for performing some tasks in a finite amount of time.
  - This implies that an algorithm should always terminate.
- Algorithms are used with data structures to ensure the rules for the ADT are enforced.

Design Goals

- Using Data Structures and Algorithms to achieve:
  - Correctness: Data structures/Algorithms are designed, at a high level, to **always** work correctly.
  - Efficiency: Data structures/Algorithms should be
    - as fast as possible;
    - use as little resources (e.g. memory) as possible.

Implementation Goal

- The code we write should have the following properties:
  – Robustness
  – Adaptability
  – Reusability

Robustness

- The code should handle all possible inputs (i.e. never "stall", "crash" or "quit").
- The code should recover gracefully from hardware or system failure (e.g. printer out-of-paper, file missing).
- The code should handle gracefully for system limitations (e.g. "out-of-memory" errors).

Adaptability

- Software should facilitate changes over time (in response to changing conditions).
- The code should be able to adapt to unexpected events.
- The "Y2K" problem was a very good counter example that how much it would cost us for lack of adaptability.

Reusability

- Software should facilitate reuse of components in other software systems.
- Example: the user interface code in every office suite can be reused for every component in the suite.

Design Principles

- Abstraction
- Encapsulation
- Modularity and Hierarchy

Abstraction

- Distill a complicated system down to its most fundamental parts.
- Describe these parts in simple and precise language.
- Specify interface but not implementation.
- Example: Abstract Data Types (ADT)
  - Specify types of data stored.
  - Specify operations and parameters.

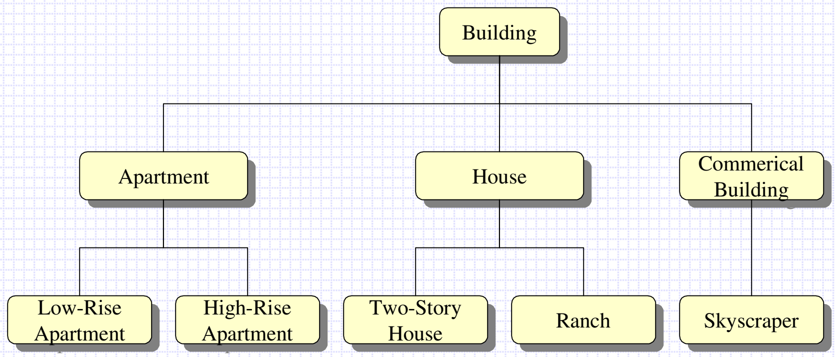
Encapsulation

- Encapsulation = Information Hiding.
- Each software component should implement an abstraction without revealing the internal details of the implementation.
- Example: A stack can be implemented with either an array or a linked list, the user does not need to know about the details in order to use the stack.

Modularity and Hierarchy

- Modularity: Organizing the structures in which the different components are divided into separate functional units.
- Hierarchy: The relationship among the different modules.

Hierarchy Example



Design Techniques

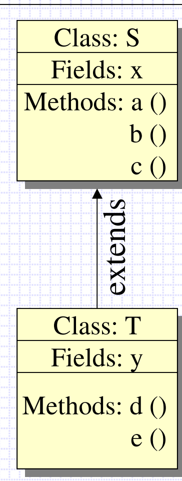
- Interfaces and Typing
- Inheritance and Polymorphism
- Classes and Objects
- Design Patterns

Interfaces and Strong Typing

- All instances of one class have the same interface: a set of messages to which they respond in a prescribed way.
- This is called Application Programming Interface (API) or just short for Interface.
- Strong Typing: All types of parameters passed to methods MUST conform with the interface.
- Type checks of a strong typing language are done at compile time.
- To convert objects among different types, casting must be used.

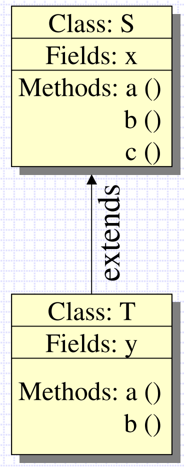
Inheritance

- Subclass inherits all instance variables and methods from superclass.
- Object of Class S has instance variable x.
- Object of Class T has instance variables x and y.
- Object of Class S can respond to methods a, b and c.
- Object of Class T can respond to methods a, b, c, d and e.
- Message: "`o.a ()`" means sending "`a()`" message to object "`o`".



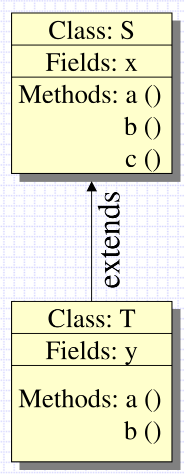
Method Overridden

- Subclass can also change (override) the way how it responds to a message.
- Object of Class T can still respond to methods a, b and c.
- However, the way it responds to the method a and b is different than its superclass.



Polymorphism

- Polymorphism - an object of Class T will respond to the "a ()" message using the overridden implementation, whether it has been typecast to S or not.
- This is also called late binding or dynamic binding as the determination of which implementation to execute is deferred until runtime.
- In Java, methods are dynamically bound by default. Only *final* methods use static binding.



Classes and Objects

- Classes define the behavior of objects.
  - What variables to hold data
  - What messages to respond to
- Objects are the actual actors in application programs
  - They actually hold variables (in memory)
  - They actually respond to messages

Static methods and variables

- The definition of a class is held in a Class object.
- The Class object also holds the static variables and responds to the static methods.
- When we send a message to a static method, we are sending the message to the Class object of that class, not any instance object of that class.

Design Patterns

- A design pattern describes a solution to a "typical" software design problem.
- A pattern provides a general template for a solution that can be applied in many different situations.
- It describes the main elements of a solution in an abstract way that can be specialized for the specific problem at hand.
- Design patterns we will be studying in this course:
  – Adapter (Chapter 4)
  – Iterator (Chapter 5)
  – Position (Chapter 5)
  – Composition (Chapter 7)
  – Comparator (Chapter 7)

Summary

Design Goals	Correctness Efficiency
Implementation Goals	Robustness Adaptability Reusability
Design Principles	Abstraction Encapsulation Modularity
Design Techniques	Interfaces and Typing Inheritance and Polymorphism Classes and Objects Design Patterns