The University of Iowa

CS:2820 (22C:22) Object-Oriented Software Development

Spring 2015

The Object Model

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The Object Model of Development

- Built on the best ideas from previous technologies
- Influenced by major trends in software engineering:

1. increased focus on programming-in-the-large
2. evolution of high-level programming languages

Object in Object-Oriented Programming Languages

Entity that

- combines features of
  - procedures: performs computations
  - data: stores local state
- is characterized by certain invariants

Essence of OO Programming

- Programs are organized as cooperative collections of objects
- Each object is an instance of some class
- Classes are related via an inheritance relationship

OO Analysis

- Builds a model of the real-world using an object-oriented view
- Examines requirements in terms of classes and objects found in the problem domain

OO Design

- Leads to an object-oriented decomposition
- Uses various notations (e.g., UML diagrams) to express various views of the system being designed:
  - logical (classes and objects) vs. physical structure (modules and processes)
  - static vs. dynamic aspects

OO Software Development

- The products of OO Analysis serve as starting points for OO Design
- The products of OO Design serve as blueprints for an OO implementation

The Object Model of Development

Is built on the synergy among:

- abstraction
- encapsulation
- modularity
- hierarchy
- typing
- concurrency
- persistence

Abstraction

- The process of identifying similarities between objects, situations or processes and ignoring their differences
- A description, or specification, of something that emphasizes some details or properties while ignoring others
- It focuses on the essential characteristics of something relative to a viewer's perspective

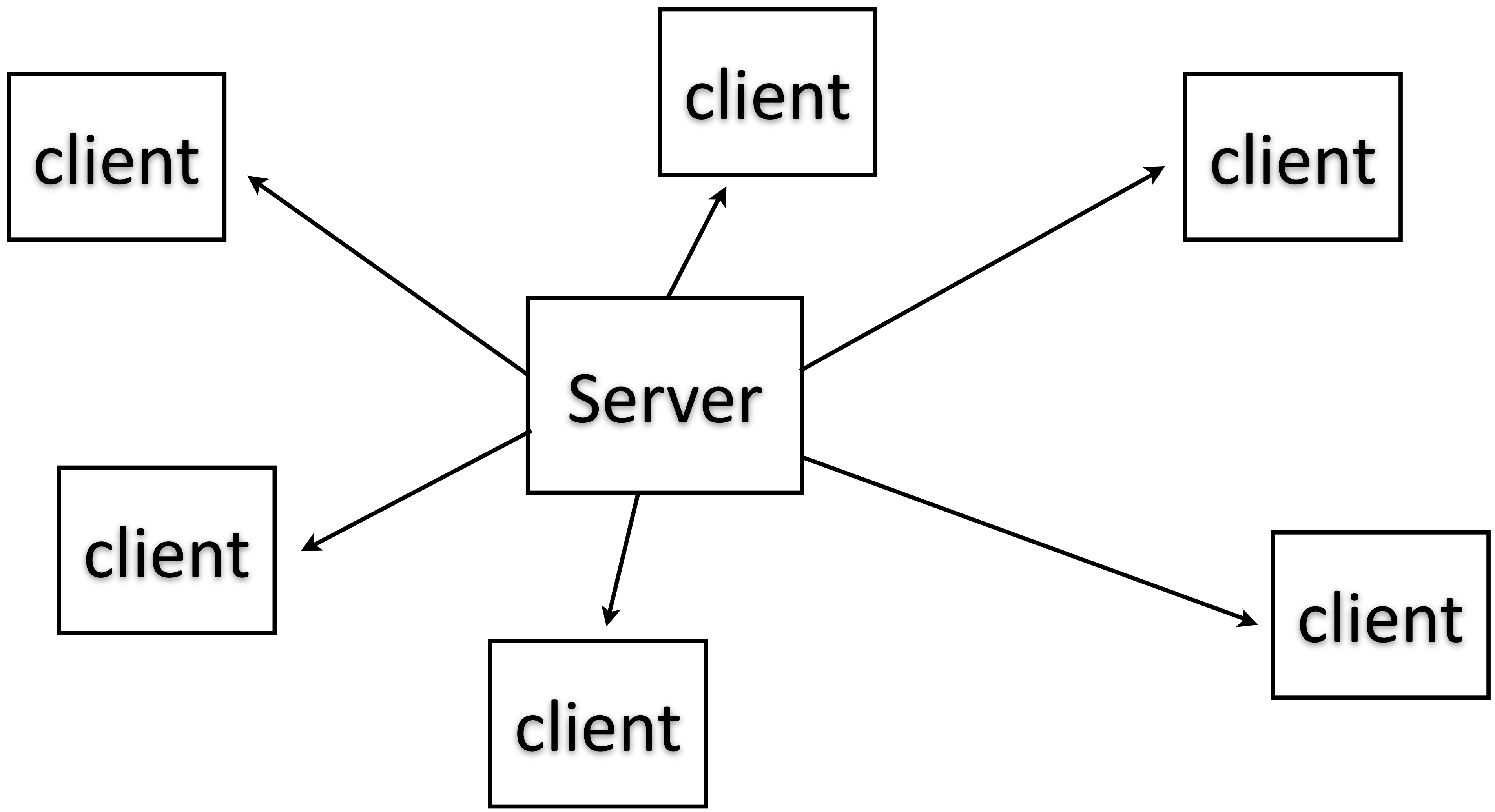
Abstraction

- **Main trait:** it can be understood and analyzed independently on how it is realized
- **Quality:** it is relative to its viewers/users and their current needs

Establishing the right set of abstractions for a problem domain is the main challenge of design

Abstraction in OO Design

- We can characterize the behavior of an object, the server, in terms of the services it provides to other objects, the clients



Abstraction in OO Design

- An object's abstraction defines a contract that
  - other objects depend on and
  - must be honored by the object
- The contract establishes all assumptions a client may make about the behavior of the server

Design by Contract

- Each service (operation) provided by an object has a set of
  - preconditions, to be satisfied by the client when invoking the service
  - postconditions, guaranteed by the server upon completion of the service
  - invariants, properties maintained between operations

Abstraction Examples

- Temperature sensor
- Point on a grid
- Bank account

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Encapsulation

- The abstraction of an object should precede any decisions about its implementation
- Implementation details should not be accessible to clients
- Encapsulation is the process of hiding such details

Encapsulation

- Achieved in OO languages by hiding the internals of an object (attributes and method implementations)
- It greatly facilitates changes that do not impact the abstraction (i.e., the object's contract)
- Leads to a clear separation of concerns (contract vs way to honor it)
- Localizes design decisions likely to change

Encapsulation in OO Languages

Classes of objects described in two parts:

- interface

  captures outside view of the object and its essential behavior

- implementation

  provides a representation of the abstraction and the mechanisms to achieve its behavior

Encapsulation Examples

- Heater Controller
- Point on plane
- Queue

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Modularity

- Modularization divides a software systems into components, modules
- Modules
  - may have connections to other modules
  - but can be compiled separately
  - encapsulate sets of classes and objects
  - have an interface and an implementation

Crucial Point

- Classes and objects define a system's logical structure
- Modules define a system's physical structure
- The two structures are by and large orthogonal

Module Decomposition

- Decomposing a system into module presents challenging design decisions
- There is a tension between the desire to encapsulate abstractions vs need to expose some of them to other modules
- General approach:
  - group together logically related classes and objects and
  - expose only those that are strictly necessary to other modules

Modularity

- Desiderata of module decomposition:
  - Modules
    - designed and implemented independently
    - simple enough to be fully understandable
  - Ability to change a module's implementation without
    - knowing that of other modules
    - affecting their behavior
  - Reuse

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Hierarchy

- A (partial) ordering of abstractions
- Most important hierarchies
  - "is a" relation (class structure)
  - "part of" relation (object structure)

Class Structure

- The "is a" relation we consider is one that relates classes
- Examples

  ☑ A dog is a mammal

  ☑ A dog is a pet

  ☐ Fido is a dog (Fido is not a class)

Class Structure

When a B is an A we also say that

- B is a subclass of A:
  - every instance of B is an instance of A
- B extends (or specializes) A:
  - B has all features and behaviors of A, and possibly more
- B inherits from A:
  - B inherits A's features and behaviors

Class Structure

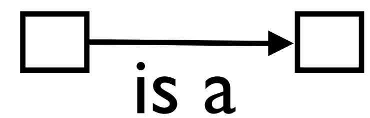
When a B is an A we also say, symmetrically, that

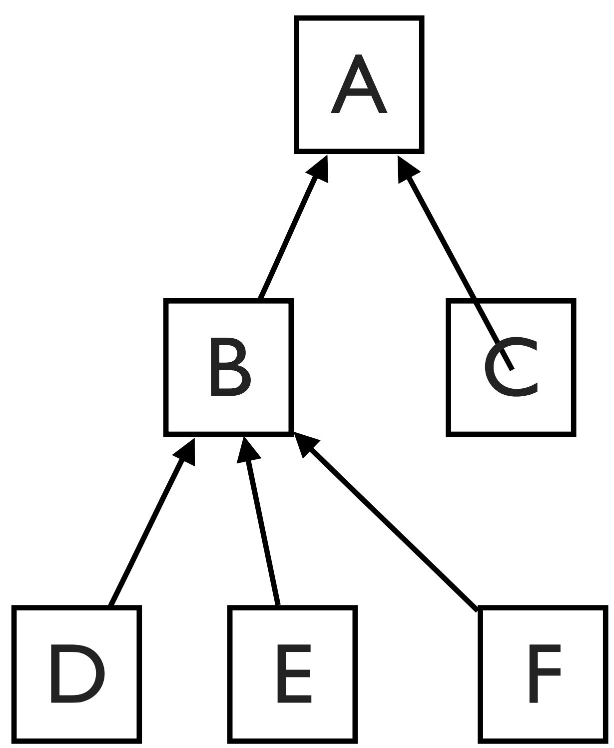
- A is a superclass of B:
  - every instance of B is an instance of A
- A is extended by (or generalizes) B:
  - B has all features and behaviors of A, and possibly more

Inheritance Hierarchies

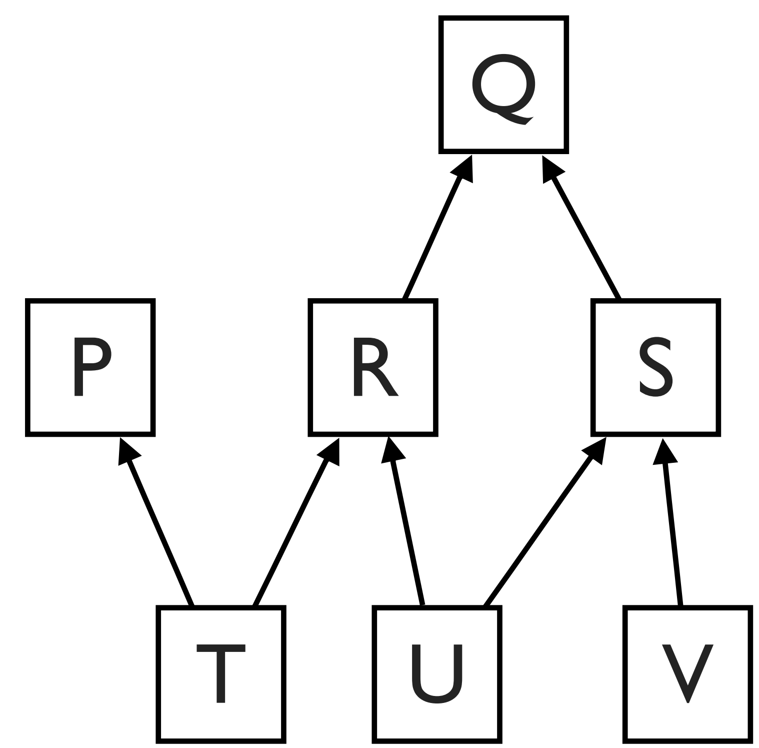
- Single inheritance:
  - each class extends (inherits from) at most one class
  - the hierarchy is a tree, or a forest
- Multiple inheritance:
  - each class extends one or more classes
  - the hierarchy is graph

Inheritance





Single inheritance



Multiple inheritance

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Typing in Programming Languages

- A type is a collection of values with same structural or behavioral properties
  - Ex: integer, string, integer list, integer array, integer and string pair, ...
- The type system of a language
  - imposes a division of values into types
  - defines typing restrictions for each operation (allowed input types, resulting output type)

Types in Programming Languages

- A language is typed if it enforces a type system
- It is untyped otherwise, that is, if it allows operations to be applicable to any values
- Note:
  - Most highly-level languages are typed to some degree (strongly/weakly typed)
  - All assembly languages are untyped

Types in OO Programming Languages

- Every class defines a type, consisting of all objects that are instances of that class
- However, not all types are classes. E.g.:
  - Java's basic types (int, bool, ...)
  - Java's interfaces
  - Traits in Scala

Static vs Dynamic Typing

- Statically typed languages enforce typing restrictions at compile time:
  - the type of each expression denoting a value is determined and checked before running the program
- Dynamically typed languages enforce typing restrictions at run time:
  - types are determined and checked as expressions are evaluated

Static vs Dynamic Typing

- In statically typed languages types are associated to expressions in the source code
  - C++, Java, Scala, ML, Haskell,...
- In dynamically typed languages types are associated to values in memory
  - Python, Ruby, Perl, Javascript, ...

Enhanced Type Systems

- Overloading: same name for different operations
  - E.g.: + for integer addition, string concatenation, list append in Scala
- Subtypes: types extending others
  - E.g.: subclassing in OO languages
- Subtype polymorphism: same name for inherited operations
  - E.g.: inherited methods in OO languages

Enhanced Type Systems

- Parametric types: structured types with components of arbitrary type
  - E.g.: List[X], Array[X], List[(X,Y)] for any types X, Y in Scala
- Parametric polymorphism: generic operations for parametric types
  - E.g.: reverse: (l:List[X]) List[X], head:(l:List[X]) X in Scala