CSE 403
Lecture 8

UML Class Diagrams

Thanks to Marty Stepp, Michael Ernst, and other past instructors of CSE 403
http://www.cs.washington.edu/403/

How do we design classes?

• class identification from project spec / requirements
  – nouns are potential classes, objects, fields
  – verbs are potential methods or responsibilities of a class

• CRC card exercises
  – write down classes' names on index cards
  – next to each class, list the following:
    • **responsibilities**: problems to be solved; short verb phrases
    • **collaborators**: other classes that are sent messages by this class
      (asymmetric)

• UML
  – class diagrams (today)
  – sequence diagrams
  – ...
• **Unified Modeling Language (UML):** depicts an OO system
  – programming languages are not abstract enough for OO design
  – UML is an open standard; lots of companies use it
    • many programmers either know UML or a "UML-like" variant

• UML is ...
  – a *descriptive* language: rigid formal syntax (like programming)
  – a *prescriptive* language: shaped by usage and convention

  – UML has a rigid syntax, but some don't follow it religiously
  – it's okay to omit things from UML diagrams if they aren't needed by team/supervisor/instructor
### Diagram of one class

- **class name** in top of box
  - write `<interface>` on top of interfaces' names
  - use *italics* for an *abstract class* name

- **attributes**
  - should include all fields of the object
  - also includes derived "properties"

- **operations / methods**
  - may omit trivial (get/set) methods
    - but don't omit any methods from an interface!
  - should not include inherited methods

### Example Diagrams

- **Rectangle**
  - width: int
  - height: int
  - area: double
  - Rectangle(width: int, height: int)
  - distance(r: Rectangle): double

- **Student**
  - name: String
  - id: int
  - totalStudents: int
  - #getId(): int
  - getName(): String
  - getEmailAddress(): String
  - getTotalStudents(): int
Class attributes

- attributes (fields, instance variables)
  - visibility name : type [count] = defaultValue

- visibility: + public
  # protected
  - private
  ~ package (default)
  / derived

- underline static attributes

- derived attribute: not stored, but can be computed from other attribute values

- attribute example:
  - balance : double = 0.00
Class operations / methods

- operations / methods
  - visibility name (parameters) : returnType
  
  - underline static methods
  
  - parameter types listed as (name: type)
  
  - omit returnType on constructors and when return is void

- method example:
  
  + distance(p1: Point, p2: Point): double
Inheritance relationships

- Hierarchies drawn top-down with arrows pointing upward to parent.

- Line/arrow styles differ based on parent:
  - **class**: solid, black arrow
  - **abstract class**: solid, white arrow
  - **interface**: dashed, white arrow

- We often don't draw trivial / obvious relationships, such as drawing the class Object as a parent.
Associational relationships

1. multiplicity  (how many are used)
   - *  ⇒ 0, 1, or more
   - 1  ⇒ 1 exactly
   - 2..4  ⇒ between 2 and 4, inclusive
   - 3..*  ⇒ 3 or more

2. name  (what relationship the objects have)
3. navigability  (direction)
Multiplicity

• one-to-one
  – each student must have exactly one ID card

![Diagram showing one-to-one relationship between Student and IDCard]

• one-to-many
  – a RectangleList can contain 0, 1, 2, ... rectangles

![Diagram showing one-to-many relationship between Rectangle and RectangleList]
**Association types**

- **aggregation**: "is part of"
  - clear white diamond

- **composition**: "is entirely made of"
  - stronger version of aggregation
  - the parts live and die with the whole
  - black diamond

- **dependency**: "uses temporarily"
  - dotted line or arrow
  - often is an implementation detail, not an intrinsic part of that object's state
Class design exercise

• Consider this Texas Hold 'em poker game system:
  – 2 to 8 human or computer players
  – Each player has a name and stack of chips
  – Computer players have a difficulty setting: easy, medium, hard
  – Summary of each hand:
    • Dealer collects ante from appropriate players, shuffles the deck, and deals each player a hand of 2 cards from the deck.
    • A betting round occurs, followed by dealing 3 shared cards from the deck.
    • As shared cards are dealt, more betting rounds occur, where each player can fold, check, or raise.
    • At the end of a round, if more than one player is remaining, players' hands are compared, and the best hand wins the pot of all chips bet.

– What classes are in this system? What are their responsibilities? Which classes collaborate?
– Draw a class diagram for this system. Include relationships between classes (generalization and associational).
Class diagrams show the responsibilities and relationships of each class, but not behavior.
Class diag. pros/cons

• Class diagrams are great for:
  – discovering related data and attributes
  – getting a quick picture of the important entities in a system
  – seeing whether you have too few/many classes
  – seeing whether the relationships between objects are too complex, too many in number, simple enough, etc.
  – spotting dependencies between one class/object and another

• Not so great for:
  – discovering algorithmic (not data-driven) behavior
  – finding the flow of steps for objects to solve a given problem
  – understanding the app's overall control flow (event-driven? web-based? sequential? etc.)
Qualities of modular software

- decomposable
  - can be broken down into pieces

- composable
  - pieces are useful and can be combined

- understandable
  - one piece can be examined in isolation

- has continuity
  - reqs. change affects few modules

- protected / safe
  - an error affects few other modules
Heuristics 2 quick reference

- **Heuristic 2.1**: All data should be hidden within its class.
- **Heuristic 2.2**: Users of a class must be dependent on its public interface, but a class should not be dependent on its users.
- **Heuristic 2.3**: Minimize the number of messages in the protocol of a class.
- **Heuristic 2.4**: Implement a minimal public interface that all classes understand.
- **Heuristic 2.5**: Do not put implementation details such as common-code private functions into the public interface of a class.
- **Heuristic 2.6**: Do not clutter the public interface of a class with items that users of that class are not able to use or are not interested in using.
- **Heuristic 2.7**: Classes should only exhibit nil or export coupling with other classes, that is, a class should only use operations in the public interface of another class or have nothing to do with that class.
- **Heuristic 2.8**: A class should capture one and only one key abstraction.
- **Heuristic 2.9**: Keep related data and behavior in one place.
- **Heuristic 2.10**: Spin off non-related behavior into another class (i.e., non-communicating behavior).
- **Heuristic 2.11**: Be sure the abstractions that you model are classes and not simply the roles objects play.

• **public interface**: visible data/behavior of an object
  – can be seen and executed externally

• **private implementation**: internal data/methods in an object
  – helps implement the public interface; cannot be directly accessed

• **client**: code that uses your class/subsystem

  – Example: *radio*
    • public interface is the speaker, volume buttons, station dial
    • private implementation is the guts of the radio; the transistors, capacitors, frequencies, etc. that user should not see
Poker design question 1

- Poker **Deck** class stores a list of cards; the game needs to be able to shuffle and draw the top card.

  - We give the **Deck** class the following methods:
    
    `add(Card), add(index, Card), getCard(int), indexOf(Card), remove(index), shuffle(), drawTopCard(), etc.`

  - What's wrong with this design?

  - **Heuristic 2.3**: Minimize the # of messages in the protocol of a class.
  - **Heuristic 2.5**: Do not put implementation details such as common-code private functions into the public interface of a class.
  - **Heuristic 2.6**: Do not clutter the public interface of a class with items that users of that class are not able to use or are not interested in using.
Minimizing public interface

- Make a method private unless it needs to be public.

- Supply getters (not setters) for fields if you can get away with it.
  - example: Card object with rank and suit (get-only)

- In a class that stores a data structure, don't replicate that structure's entire API; only expose the parts clients need.
  - example: If PokerGame has an inner set of Players, supply just an iterator or a getPlayerByName(String) method

- Use a Java interface with only the needed methods, and then refer to your class by the interface type in client code.
Proposed fields in various poker classes:

- A Hand stores 2 cards and the Player whose hand it is.
- A Player stores his/her Hand, last bet, a reference to the other Players in the game, and a Deck reference to draw cards.
- The PokerGame stores an array of all Players, the Deck, and an array of all players' last bets.

What's wrong with this design?
Cohesion and coupling

- **cohesion**: how complete and related things are in a class  
  *(a good thing)*

- **coupling**: when classes connect to / depend on each other  
  *(too much can be a bad thing)*

- **Heuristic 2.7**: Classes should only exhibit nil or export coupling with other classes; that is, a class should only use operations in the public interface of another class or have nothing to do with that class.
  
  - (in other words, minimize unnecessary coupling)
Reducing coupling

- combine 2 classes if they don't represent a whole abstraction
  • example: Bet and PlayRound

- make a coupled class an inner class
  • example: list and list iterator; binary tree and tree node
  • example: GUI window frame and event listeners

- provide simpler communication between subsystems
  • example: provide methods (newGame, reset, ...) in PokerGame so that clients do not need to manually refresh the players, bets, etc.
**Heuristics 3 quick reference**

- **Heuristic 3.1:** Distribute system intelligence horizontally as uniformly as possible, that is, the top-level classes in a design should share the work uniformly.
- **Heuristic 3.2:** Do not create **god classes**/objects in your system. Be very suspicious of a class whose name contains Driver, Manager, System, or Subsystem.
- **Heuristic 3.3:** Beware of classes that have many accessor methods defined in their public interface.
- **Heuristic 3.4:** Beware of classes that have too much **noncommunicating behavior**.
- **Heuristic 3.5:** In applications that consist of an object-oriented model interacting with a user interface, the **model** should never be dependent on the interface.
- **Heuristic 3.6:** Model the real world whenever possible.
- **Heuristic 3.7:** Eliminate irrelevant classes from your design.
- **Heuristic 3.8:** Eliminate classes that are outside the system.
- **Heuristic 3.9:** Do not turn an operation into a class. Be suspicious of any class whose name is a verb or is derived from a verb, especially those that have only one piece of meaningful behavior (don't count set, get, print).
- **Heuristic 3.10:** **Agent classes** are often placed in the analysis model of an application. During design time, many agents are found to be irrelevant and should be removed.

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Poker design question 3

- Our PokerGame class:
  - stores all the players
  - stores an array of cards representing the card deck
  - stores all bets and money
  - does the logic for each betting round
  - performs the AI for each computer player's moves

- What's wrong with this design?
God classes

- **god class**: a class that hoards too much of the data or functionality of a system.

- **Heuristic 2.8**: A class should capture one and only one key abstraction.

- **Heuristic 3.2**: Do not create god classes/objects in your system. Be very suspicious of a class whose name contains Driver, Manager, System, or Subsystem.

- **Heuristic 3.4**: Beware of classes that have too much non-communicating behavior, that is, methods that operate on a proper subset of the data members of a class. God classes often exhibit much non-communicating behavior.
Each new game round, the `PokerGame` wants to deal cards to each player. During the game, players draw additional cards.

- We will create a `Dealer` class that the `PokerGame` asks to deal the cards to every player.

- Player objects will store a reference to the `Dealer`. During the game, they will talk to the dealer to draw their cards. The `Dealer` will notify the Game once all players have drawn.

- What's wrong with this design?
Poker design question 5

– Cards belong to one of four suits. So we have created classes Club, Diamond, Heart, Spade class to represent each suit.

– In each game round, one player is the dealer and one is the first better. Also each turn there is a next better waiting. So we have created classes Dealer, NextBetter, FirstBetter.

– Every game has several betting rounds, each round consisting of several bets. So we have created classes Bet and CurrentBettingRound.

– What's wrong with this design?
Proliferation of classes

• proliferation of classes: too many classes that are too small in size/scope; makes the system hard to use, debug, maintain
  – Heuristic 2.11: Be sure the abstractions that you model are classes and not simply the roles objects play.
  
  – Heuristic 3.7: Eliminate irrelevant classes from your design.
    • often have only data and get/set methods; or only methods, no real data
  
  – Heuristic 3.8: Eliminate classes that are outside the system.
    • don’t model a Blender just because your company sells blenders; don’t necessarily model a User just because the system is used by somebody
  
  – Heuristic 3.9: Do not turn an operation into a class.
    • Be suspicious of any class whose name is a verb, especially those that have only one piece of meaningful behavior. Move the behavior to another class.
A player may bet only as much $ as they have; and if a prior player has made a "call", the current player cannot raise.

- Where should these policies be enforced?

- **Design 1:** Player class remembers whether that player is in the game, what that player's current bet is, whether it is his turn, etc.
  - Player checks whether a "call" has been made.
  - Player checks whether he/she has enough to make a given bet.

- **Design 2:**
  - PokerGame class remembers who is in the game.
  - Betting class remembers every player's current bets, checks $.
  - Dealer class remembers whose turn it is.
- **Heuristic 2.9**: Keep related data and behavior in one place.
  - avoids having to change two places when one change is needed

- **Heuristic 3.3**: Beware of classes that have many accessor methods ... [This] implies that related data and behavior are not being kept in one place.
  - "policy" behavior should be where that policy is enforced/enacted