CSE 403
Lecture 8

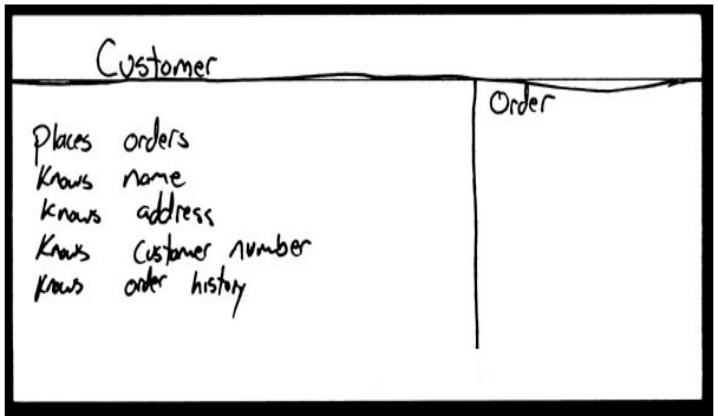
UML Class Diagrams

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

See also: Object-Oriented Design Heuristics by Arthur J. Riel (Addison-Wesley Professional, 1996), ISBN-13: 978-0-201-63385-6

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
  - ...



Introduction to UML

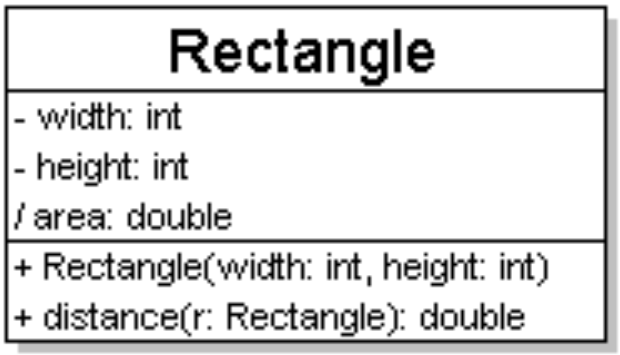
- **Unified Modeling Language (UML)**: depicts an OO system
  - programming languages are not abstract enough for OO design
  - UML is an open standard; lots of companies use it
    - many programmers either know UML or a "UML-like" variant

- 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

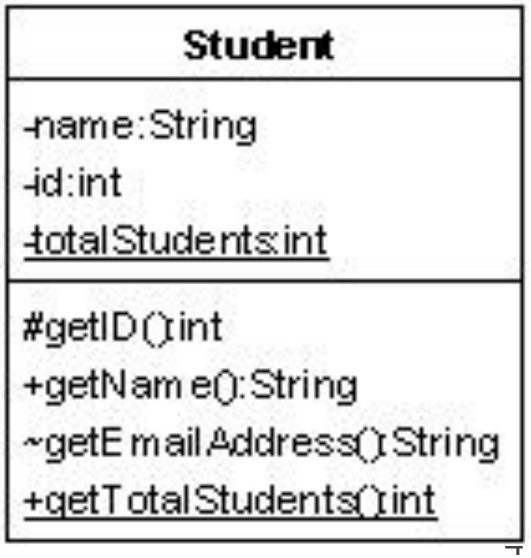
Diagram of one class

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



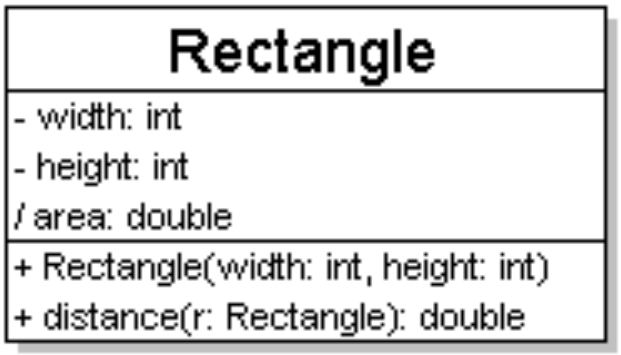
- **attributes**
  - should include all fields of the object
  - also includes derived "properties"

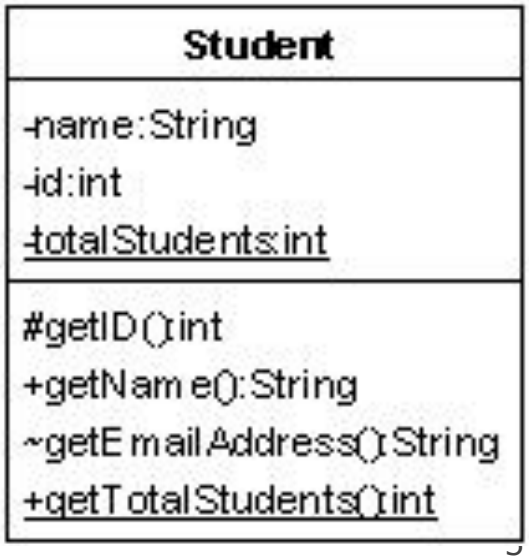
- **operations** / methods
  - may omit trivial (get/set) methods
    - but don't omit any methods from an interface!
  - should not include inherited methods



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

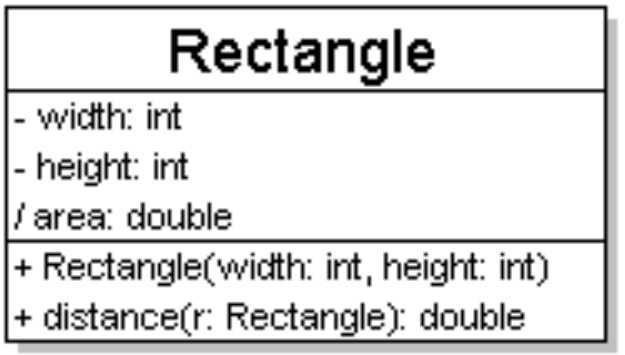


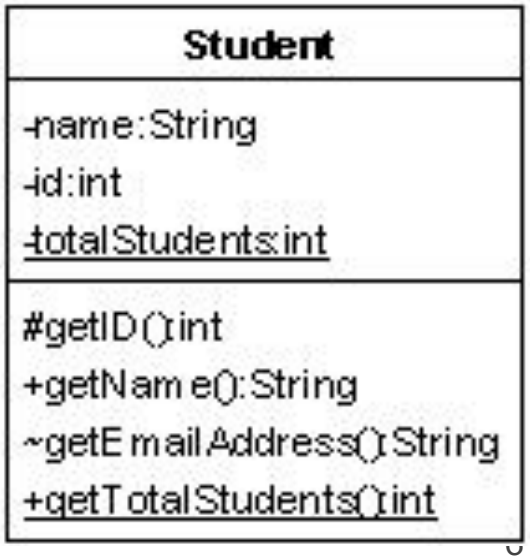


Class operations / methods

- 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



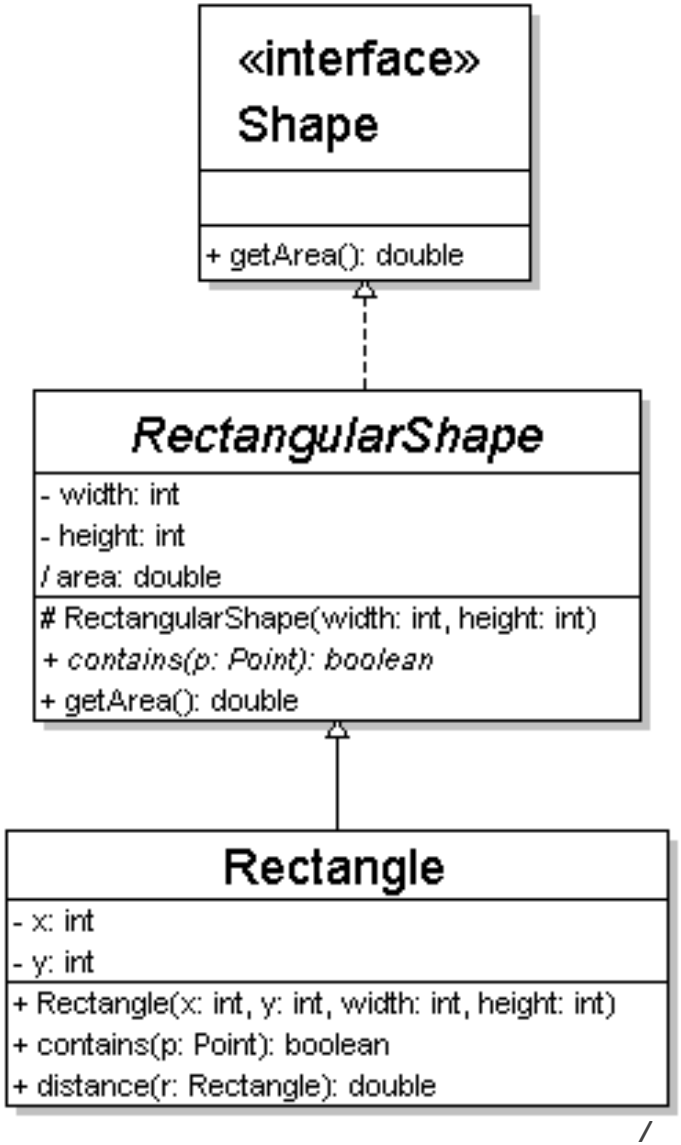


Inheritance relationships

- hierarchies drawn top-down with arrows pointing upward to parent

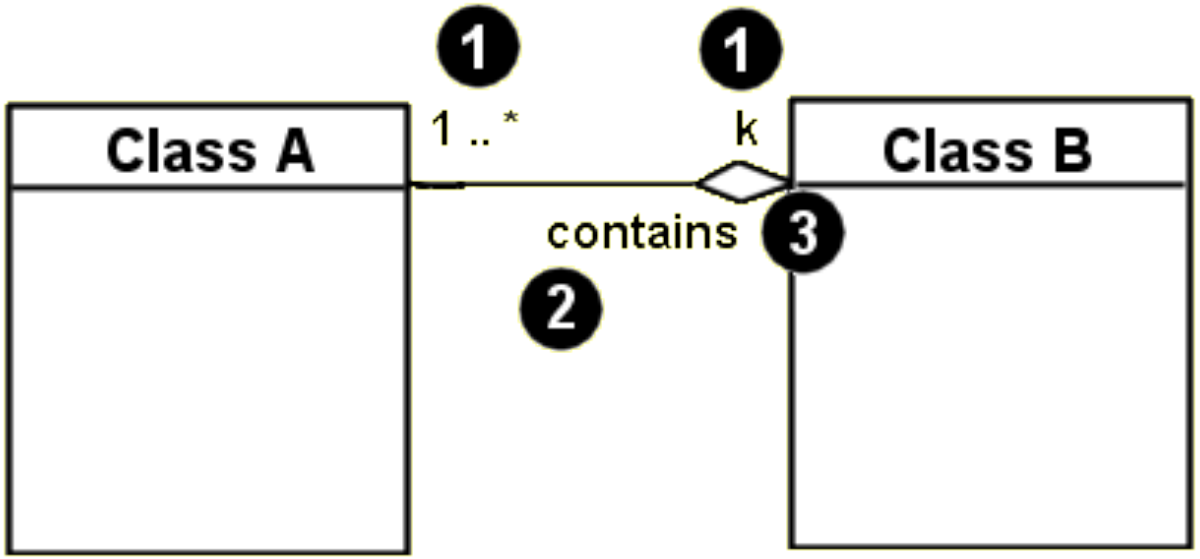
- line/arrow styles differ based on parent:
  - *class* : solid, black arrow
  - *abstract class* : solid, white arrow
  - *interface* : dashed, white arrow

- we often don't draw trivial / obvious relationships, such as drawing the class `Object` as a parent



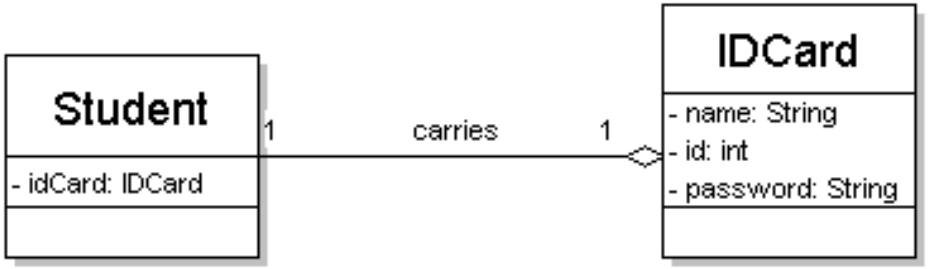
Associational relationships

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)

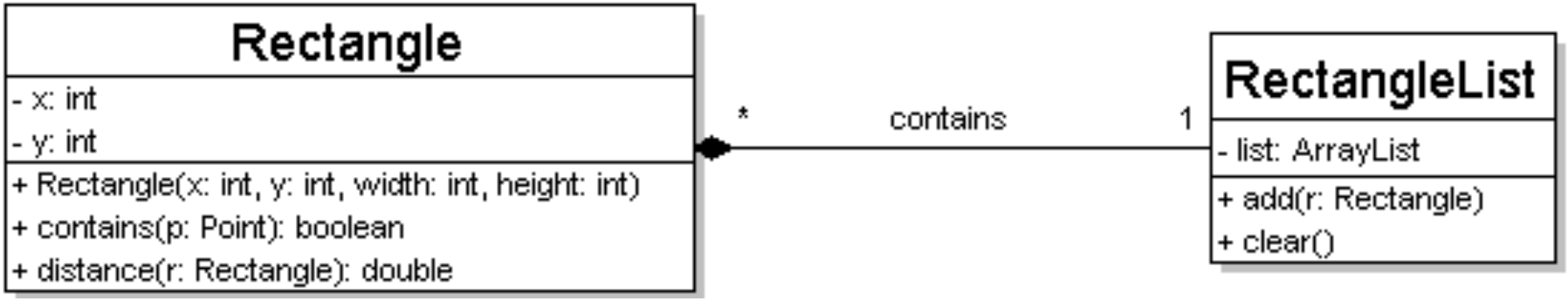


Multiplicity

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

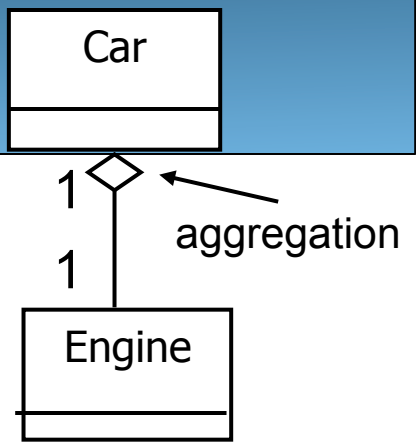


- one-to-many
  - a RectangleList can contain 0, 1, 2, ... rectangles

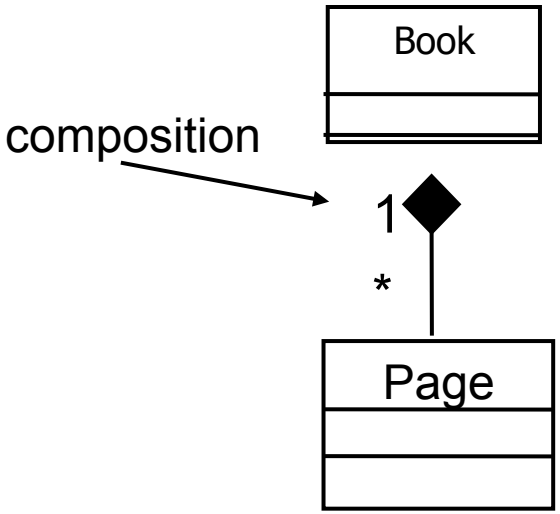


Association types

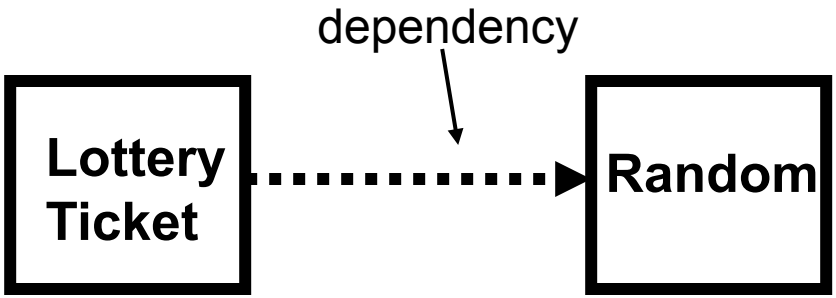
- **aggregation**: "is part of"
  - clear white diamond



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



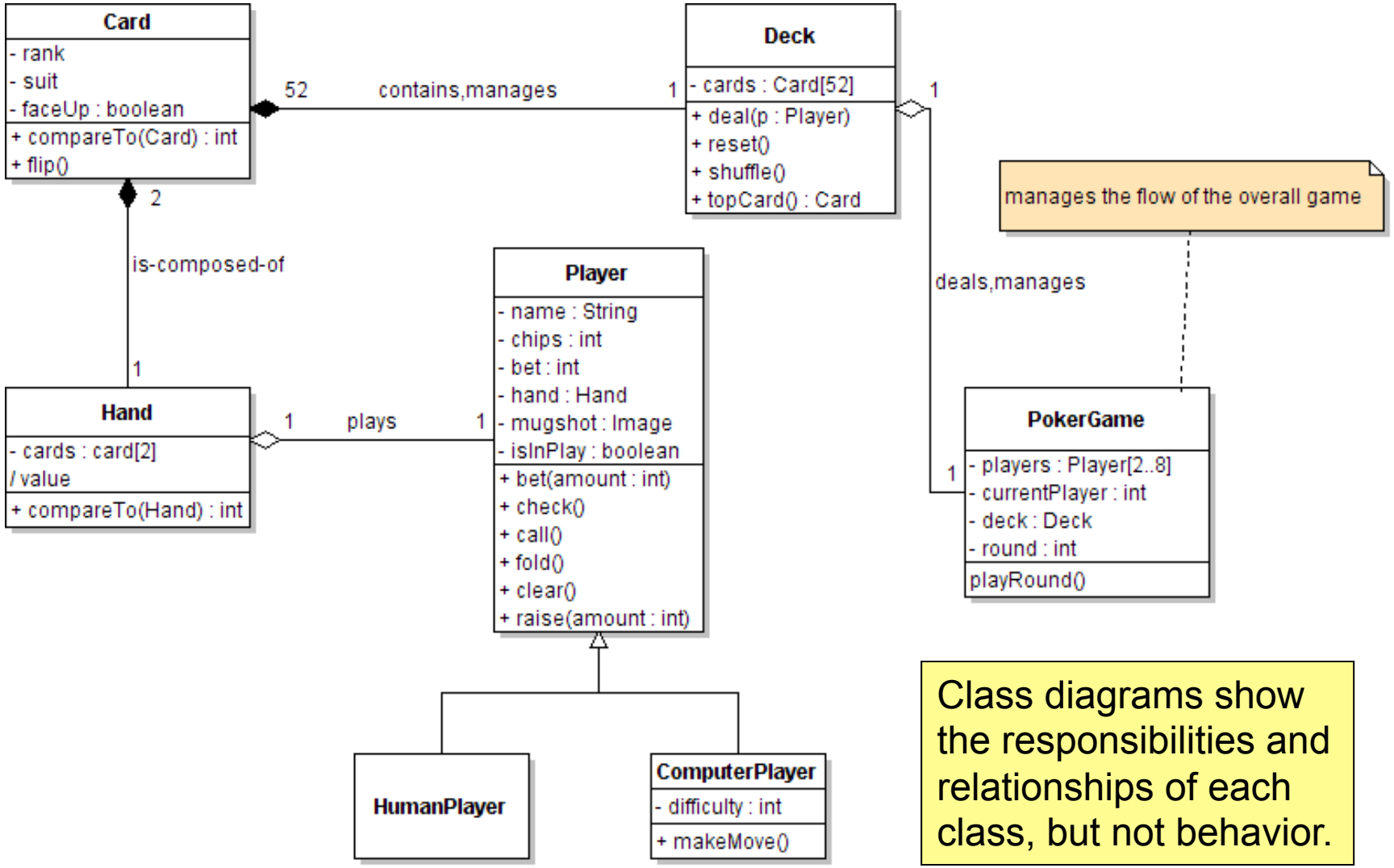
- **dependency**: "uses temporarily"
  - dotted line or arrow
  - often is an implementation detail, not an intrinsic part of that object's state



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).

Poker class diagram



Class diagrams show the responsibilities and relationships of each class, but not behavior.

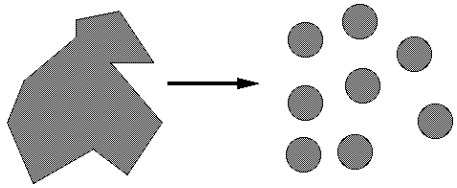
Class diag. pros/cons

- 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

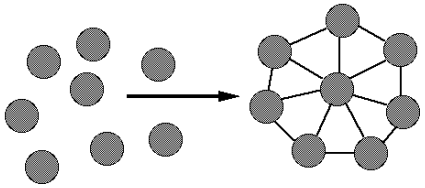
- Not so great for:
  - discovering algorithmic (not data-driven) behavior
  - finding the flow of steps for objects to solve a given problem
  - understanding the app's overall control flow (event-driven? web-based? sequential? etc.)

Qualities of modular software

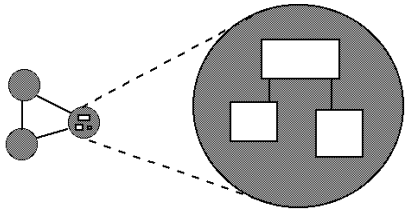
- decomposable
  - can be broken down into pieces



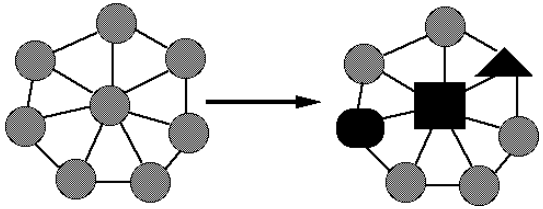
- composable
  - pieces are useful and can be combined



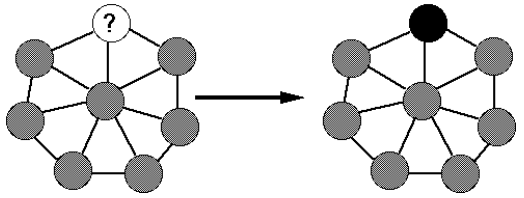
- understandable
  - one piece can be examined in isolation



- 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.
- from Object-Oriented Design Heuristics by Arthur J. Riel (Addison-Wesley Professional, 1996), ISBN-13: 978-0-201-63385-6

Interface/implementation

- **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.

Poker design question 2

- 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 `Player`s in the game, and a `Deck` reference to draw cards.
  - The `PokerGame` stores an array of all `Player`s, 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

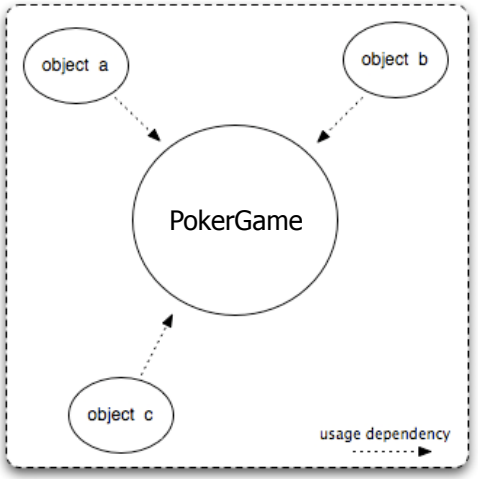
- **Heuristic 3.1**: Distribute system intelligence horizontally as uniformly as possible, that is, the top-level classes in a design should share the work uniformly.
- **Heuristic 3.2**: Do not create **god classes**/objects in your system. Be very suspicious of a class whose name contains Driver, Manager, 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.

- from Object-Oriented Design Heuristics by Arthur J. Riel (Addison-Wesley Professional, 1996), ISBN-13: 978-0-201-63385-6

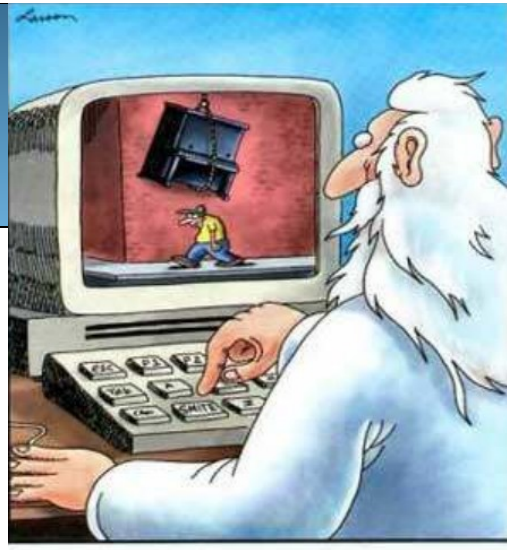
Poker design question 3

- 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?



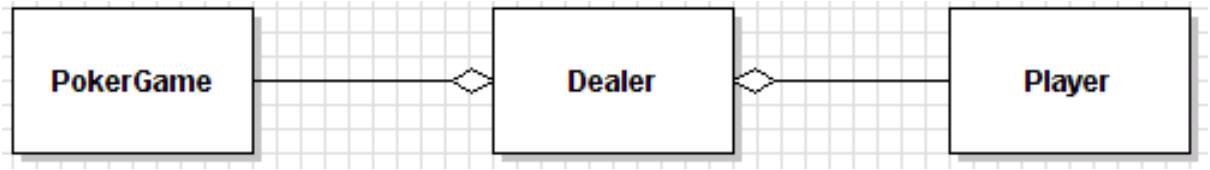
God classes


God at His computer

- **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.

Poker design question 4

- 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.

Poker design question 6

- 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.

Related data and behavior

- **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