CS 247 Midterm Review

ADT Design

- **Best practices**
  - All data members should be <u>private</u>
    - Client accesses data through public methods
    - Derived classes access data through protected methods
  - Use `const` for function parameters whenever possible
  - Accessor methods should be `const`
- **Default arguments**: only trailing parameters can have default values
  - `function (int p1, int p2 = 0, int p3 = 1);`
- **Implicit type conversion**
  - Prohibit by declaring constructor as `explicit`
- **Friends**: can access private members from outside of class
  - Often used for streaming operators
- Operator overloading/special member functions
  - **Default constructor**: generated by compiler if & only if no constructors are declared
  - **Destructor**: compiler default deallocates stack-based members, and calls destructors of member objects
  - **Copy constructor**: compiler default performs <u>shallow copy</u>
  - **Assignment operator**: compiler default performs <u>shallow copy</u>
  - **Equality operator**: no compiler default
  - **istream/ostream operator** (non-member functions): declare as friend
- **Rule of 3**:
  - Destructor, copy constructor, assignment operator
  - If one of these need to be defined, then all of them should be defined
- **Entity-based ADT**
  - Prohibit assignment & copy constructor
  - Prohibit type conversion
  - Compare pointer addresses for equality
  - Mutable
- **Value-based ADT**
  - Implement assignment & copy constructor
  - Implement equality & comparisons

    - Immutable
- **Header guard**: prevent errors when header declarations are included multiple times

    -
      ```
      #ifndef CLASS_H
      #define CLASS_H
      class Class { ...};
      #endif   // Class
      ```
- **Copy-swap idiom**: used to implement exception-safe assignment (e.g. `A = B;`)
    - Create local copy of `B` using copy constructor
    - Swap contents of `A` and new copy of `B`
    - `A` now has the contents of `B`; copy of `B` is deleted by destructor on function return
- **PImpl idiom**: instead of declaring internal workings (private data members) of a class in the public header file, declare in a nested class/struct in a separate file
    - ADT keeps a pointer to the Impl struct

Documentation

- **Interface specification**
    - **Specification fields**: client's view of the object's fields (including private members)
    - Preconditions:
        - **Requires**: can throw exception immediately if preconditions are not satisfied
    - Postconditions:
        - **Modifies**: members that are changed
        - **Ensures**: effects on the changed members (e.g. `this = this@pre + next`)
        - **Throws**: exceptions that may be thrown, and their conditions
        - **Returns**: return value & type
    - Preconditions $\implies$ postconditions
    - Spec A is stronger than spec B (i.e. A $\implies$ B) if & only if:
        - A's preconditions are equal or weaker than B
        - A's postconditions are equal or stronger than B
        - A modifies equal or more objects than B
        - A throws equal or fewer exceptions than B
- **Representation invariant**
    - A predicate in an ADT that must be true at all times
    - Structural invariants
        - e.g. two tree nodes cannot share the same child node; trees cannot have cycles
    - Value invariants

        - e.g. no duplicate data elements; a value cannot be null
    - Should be checked <u>on exit of constructor and mutators</u>
- **Abstraction function**
    - Maps <u>concrete values</u> to <u>abstract values</u> in an ADT

Exceptions & Smart Pointers

- **Assertion**: use to check a certain condition
    - Terminates program immediately without changing its state
- **Exception**:
    - Object representing an error that can be *thrown* and *caught*
    - The call stack is popped/unwinded down to the nearest matching `catch` block
        - Destructors of all stack objects are called
        - i.e. heap objects are only handled properly if they are deleted in a stack object's destructor
- **Smart pointer**:
    - Pointer encapsulated in a stack-based object
    - Heap object is deleted in pointer object's destructor
        - i.e. if exception is raised, heap object is deleted by the pointer's destructor
    - `unique_ptr<T>`: exclusive ownership of referent; ownership can be transferred
    - `shared_ptr<T>`: shared ownership of referent
        - Object is deleted when the # of `shared_ptrs` pointing to it reaches 0
    - `weak_ptr<T>`: same as `shared_ptr`, but doesn't contribute to reference count
        - Need to check if expired, and then convert into `shared_ptr` before dereferencing

RAII Idiom

- **Resource Acquisition is Initialization**: resource management is coupled with lifetime of object
    - Allocate resource in constructor; deallocate resource in destructor
    - `Class (param) :  res_( allocate (param); ) { }`
    - `~Class() { release (res_); }`

UML (Unified Modelling Langauge)

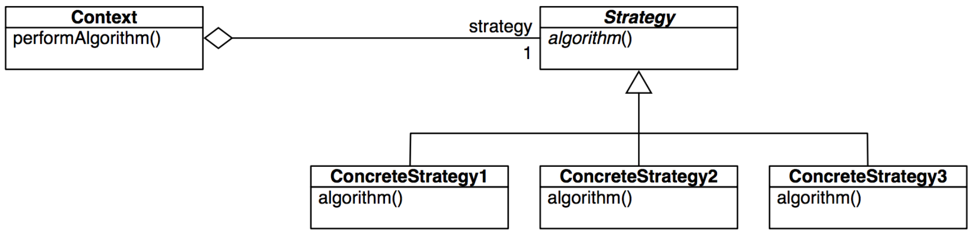
- Attributes
  - `[visibility] name: [type] [multiplicity] = [default value] {property}`
  - e.g. `- playerName: string[1] = ""`
- Operations
  - `[visibility] name (parameter list) : [return type] {property}`
  - e.g. `+ getPlayerName ( playerId : int ) : string const`
  - + public; - private; # protected; static; *pure virtual*
  - `property` = read-only (aka. const), query (aka. accessor), abstract, etc.
- Associations: physical or conceptual links between classes
  - Classes being associated may have role names
  - Navigability: direction of association; e.g. A *has* ($\rightarrow$) B
- Multiplicity: how many objects may fill the attribute/may be linked by an association
  - a = exactly a
  - $m..n$ = between m and n (inclusive)
  - $*$ = many (at least zero)
  - $m..*$ = at least m
- Aggregate: a collection of many members
  - Member can belong to many collections, or exist independently
  - Collection is not responsible for its members
- Composition: a stricter collection of members
  - Member cannot exist without its collection
  - Member belongs to exactly one collection
  - Collection is responsible for its members
- Generalization = inheritance
- **Sequence diagrams**: describe how information is passed between objects (e.g. via function calls), throughout execution of a program
  - Good at showing how different objects collaborate; not good at defining their behaviours precisely

OOP Principles

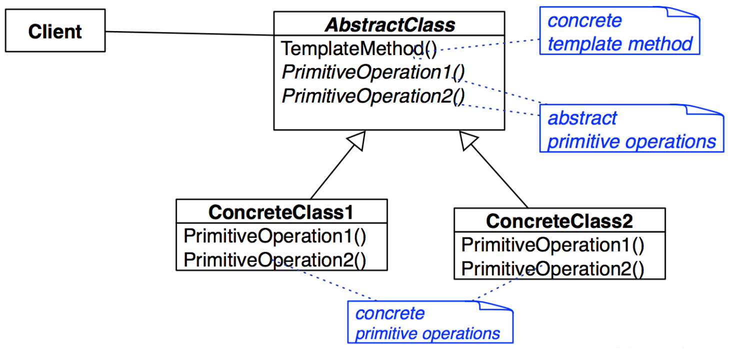
- **Open Closed Principle**
  - Modules should be *open for extension* but *closed for modification*
  - "Program to an interface, not an implementation"
  - e.g. provide an abstract base class (may have default implementation) that can be extended by the client
- **Composition Over Inheritance**
  - Composition = include base class in new subclass as a complex attribute
    - i.e. "has-a" instead of "is-a"
  - Choose inheritance when subtyping, or when base class's original interface is required
  - Choose composition for non-overriding extension or when new required interface is different from original, because the base component can be changed at runtime
  - Composite object can delegate operations to component objects (call the component's corresponding method)
- **Single-Responsibility Principle**
  - Each changeable design decision (responsibility) should be encapsulated in a module
  - An axis of change is an axis of change only if the changes occur; i.e. no need to separate responsibilities if they always change at different times
- **Liskov Substitutability Principle**
  - A derived class must be substitutable for its base class
    - Must accept the same messages (method signatures match the base class)
    - Derived methods must require no more (weaker or same preconditions) and promise no less (stronger or same postconditions) than base class methods
      - Method return types match (or be a subtype) the base class
    - Derived class must preserve properties of base class (e.g. invariant, performance)
- **Law of Demeter**
  - An object should only "talk to its neighbours" (component composition)
  - A method `C::m()` can only call methods of:
    - C
    - C's members
    - m's parameters
    - Any object constructed by A's methods
  - Bad: `game->getPlayer()->getStatus()->getHP();`
  - Good: `game->getPlayerHP();`

Design Patterns

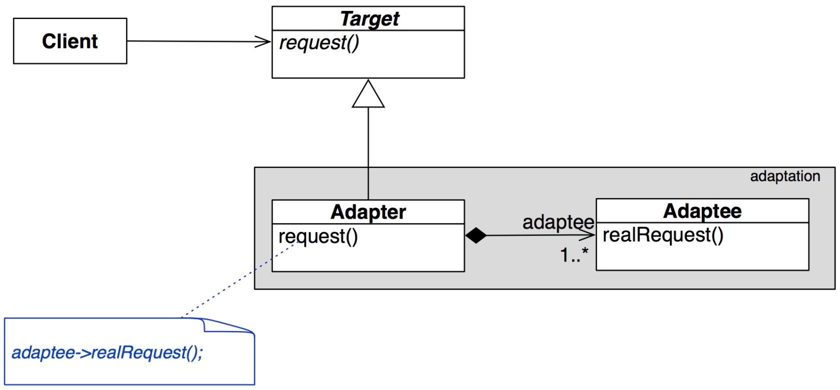
- **Inheritance**
  - Parent class's methods are inherited by child classes
  - Downside: not all subclasses may want to inherit parent behaviour
  - Downside: code duplication
- **Strategy pattern**
  - Allows the implementation of an algorithm/method to be changed at runtime (encapsulation of algorithm)
  - Allows the algorithm to vary independently from clients that use it
  - e.g. data structure holds an instance of base Strategy class, calls the algorithm/method (which is *pure virtual* in base class)
    - Concrete methods with differing behaviour are implemented in Strategy subclasses
    - Strategy can be changed (to other subclasses) at runtime, changing the method's behaviour



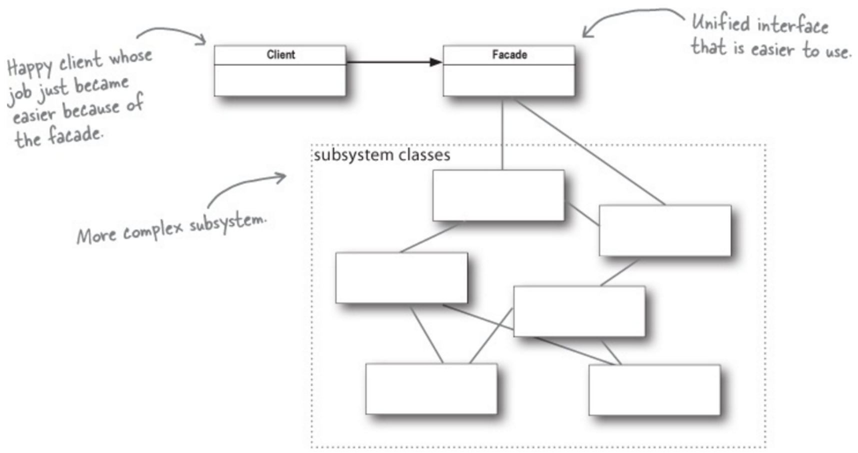
- **Template pattern**
  - **Template method** is a method in a base class that defines code structure but leaves holes to be defined by subclasses
  - Holes are operations defined as *pure virtual* in the base class, but have varying implementations in subclasses



- **Adapter pattern**
  - Adapter maps one interface to another
  - e.g. interface of an existing module does not match with a new module
  - e.g. wrapping an existing data structure interface to create a new data structure

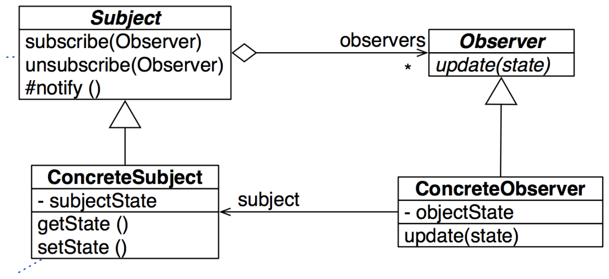


- **Facade pattern**
  - Simplies and unifies classes and interfaces in a subsystem into only a high-level interface and hides individual interfaces within the subsystem
  - Subsystem components and interfaces can be changed without affecting client

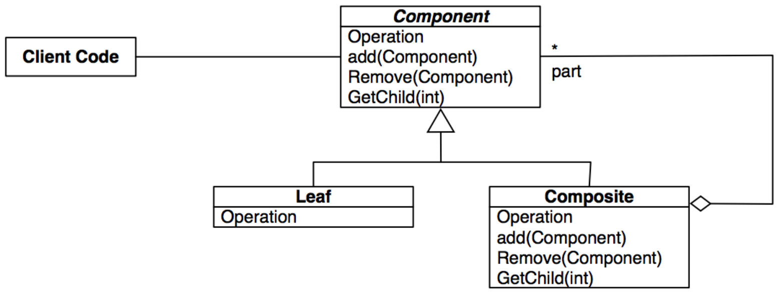

Happy client whose job just became easier because of the facade.
Client
Facade
Unified interface that is easier to use.
subsystem classes
More complex subsystem.

- **Singleton pattern**
  - Ensures only one instance of a class can exist
  - Private constructor; only instantiated through static `getInstance()` method

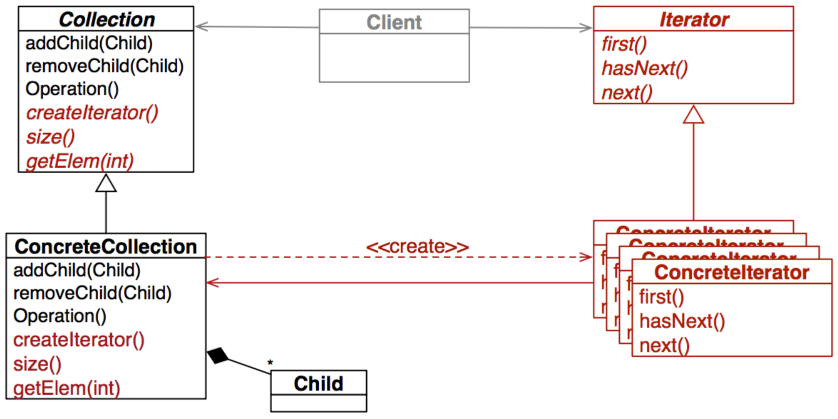
- **Observer pattern**
  - Subject → (one-to-many) Observers
  - Subject can notify all subscribed observers to update
  - Observers can subscribe/unsubscribe at runtime
  - **Push model**: subject pushes state information to observers through `notify(State)`
  - **Pull model**: subject notifies observers, who request information via subject's accessors
  - **Loose coupling**: subjects and observers only know about each other's interfaces, not the concrete classes that implement them



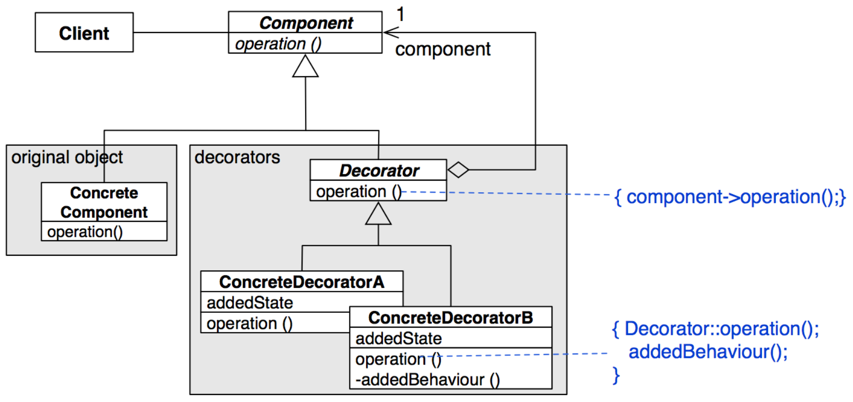
- **MVC pattern**
  - UI code is abstracted into the **view**
    - Composite pattern: all view elements use the same base class (uniform interface)
  - **Controller** translates user input (from the view) into operations on the model
    - Strategy pattern: controller provides the view with a strategy; controller behaviour can be changed by swapping for a different strategy
  - **Model** holds data, state, and application logic
    - Observer pattern: model = subject; views = observers; model sends out notification on state change, triggering views to update accordingly
- **Composite pattern**
  - Components have a <u>uniform interface</u>, and a <u>union of leaf & composite's services</u>
  - Components are organized in a tree structure
  - Set defaults in the base class for leaf-only or component-only operations (override in subclasses)



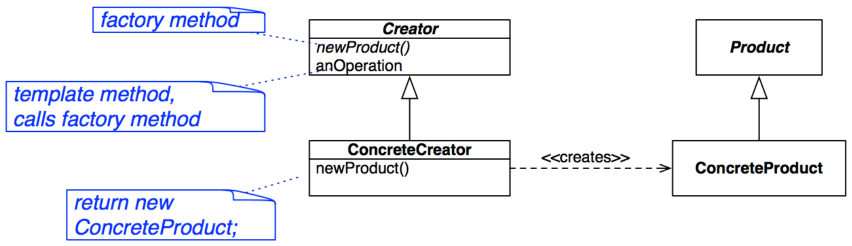
- **Iterator pattern**
  - Allows iteration through the elements of a collection without exposing representation
  - Composite pattern iteration:
    - Traverse tree using DFS (w/ a stack)
    - Define iterator subclasses for both leaf and composite classes



- **Decorator pattern**
  - Allows extra features to be added/removed to an object at runtime, by building wrappers
  - Pass component into decorator to construct the original component w/ added functionality
    - e.g. `Component* comp = new Component(); comp = new Decorator(comp);`



- **Factory pattern**
  - Uses the template pattern (encapsulates object creation)
  - Abstract factory class defines the interface for object creation; concrete factory subclasses decide which object/how to construct



STL (Standard Template Library)

- **STL containers**
  - Sequence containers: contiguous collection of variables; ordered (requires `operator<`)
    - `std::vector`
      - Wrapper around a C-style array (contiguous memory)
      - Reallocation invalidates pointers to elements
    - `std::deque`
      - Push/pop at front *and* back
      - Growing the deque preserves pointers
    - `std::list`
      - Doubly-linked list; no random access
    - `std::forward_list`
      - Singly-linked list; no random access
    - `std::array`
      - Fixed-size vector
  - Container adapters:
    - `std::stack`, `std::queue`, `std::priority_queue`
    - Can specify which container to use (e.g. vector, deque etc.)
    - Has (not inherits) a private container member, to which operations are delegated
    - **Adaptation**: extend a STL container by creating an adapter interface around it (as opposed to inheritance)
    - **Private inheritance**: reuse base class's implementation without supporting its interface
      - Public & protected API of base class are private in the child class
      - Child class is not a subtype; cannot be used polymorphically
      - Similar to adaptation
  - Associative containers:
    - Ordered containers: ordered based on value of key; implemented using BST
      - `std::[multi]map`, `std::[multi]set`
    - Unordered containers: no particular ordering; implemented using hash tables
      - `std::unordered_[multi]map`, `std::unordered_[multi]set`
- **STL iterators**
  - In decreasing hierarchy:
  - **Input/output iterator**: read-only/write-only, each location may only be visited once

    - **Forward iterator**: can visit each location multiple times, can only move foward
    - **Bidirectional iterator**: can iterate forwards and backwards
    - **Random accessor iterator**: allows iterator arithmetic
    - Use `back_inserter`/`front_inserter` to perform `push_back()`/`push_front()` on containers
- **STL algorithms**
    - Use inserters when adding elements to containers (e.g. `std::copy` on vectors)
    - Algorithms don't remove elements; "removed" elements are placed at the back of the container, and an iterator just past the last "valid" element is returned
- **Functors**
    - Overload `operator()` to create function objects
        - e.g. a binary function: `int operator() ( int a, int b) { return a + b; }`
- **Function object adapters**
    - `mem_fun_ref`/`mem_fun`: convert a member function (of the container the algorithm is using) to a function object that can be passed to the algorithm
        - Use `mem_fun_ref` for non-pointers (e.g. `string.length()`)
        - Use `mem_fun` for pointers (e.g. `obj->size()`)

Lambdas

-