CS 247 Midterm Review

ADT Design

- **Best practices**
  - All data members should be private
    - 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 shallow copy
  - **Assignment operator**: compiler default performs shallow copy
  - **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)

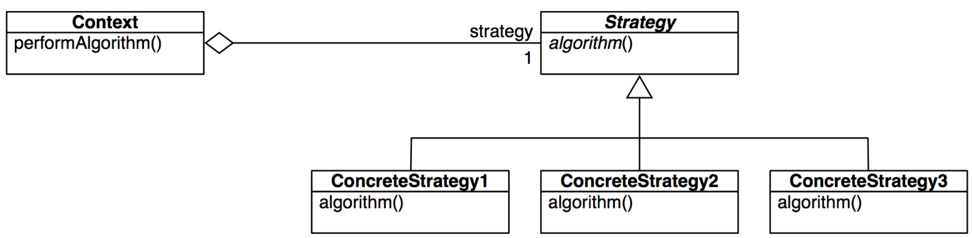
- Attributes
  - `[visibility] name: [type] [multiplicity] = [default value] {property}`
  - e.g. `- playerName: string[1] = ""`
- Operations
  - `[visibility] name (parameter list) : [return type] {property}`
  - e.g. `+ getPlayerName ( playerId : int ) : string const`
  - + public; - private; # protected; 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

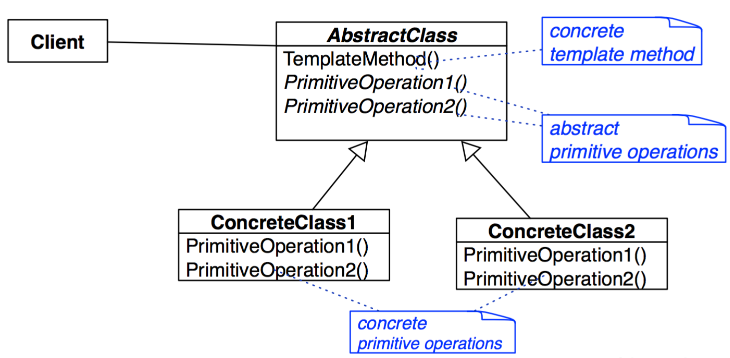
- **Open Closed Principle**
  - Modules should be *open for extension* but *closed for modification*
  - "Program to an interface, not an implementation"
  - e.g. provide an abstract base class (may have default implementation) that can be extended by the client
- **Composition Over Inheritance**
  - 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

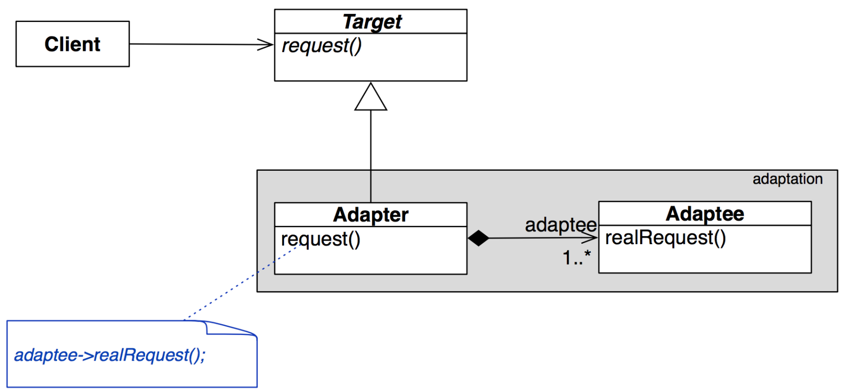
- **Inheritance**
  - Parent class's methods are inherited by child classes
  - Downside: not all subclasses may want to inherit parent behaviour
  - Downside: code duplication
- **Strategy pattern**
  - Allows the implementation of an algorithm/method to be changed at runtime (encapsulation of algorithm)
  - 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



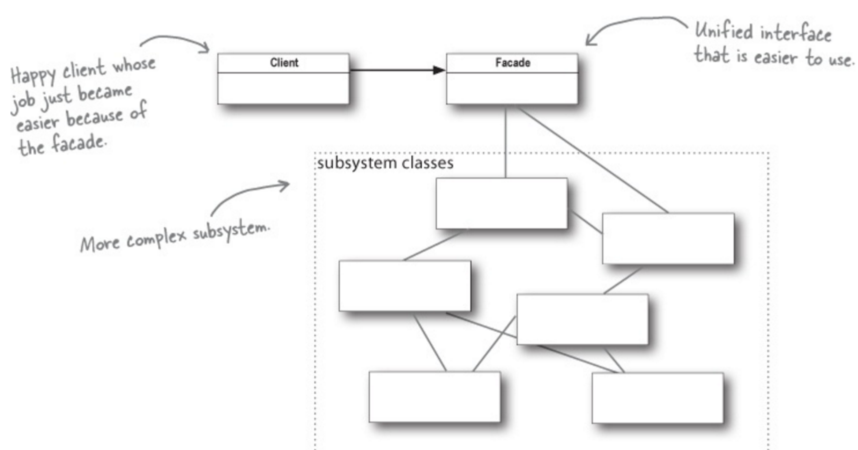
- **Template pattern**
  - **Template method** is a method in a base class that defines code structure but leaves holes to be defined by subclasses
  - Holes are operations defined as *pure virtual* in the base class, but have varying implementations in subclasses



- **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

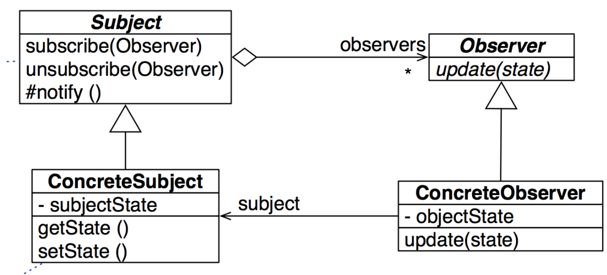


- **Facade pattern**
  - Simplies and unifies classes and interfaces in a subsystem into only a high-level interface and hides individual interfaces within the subsystem
  - Subsystem components and interfaces can be changed without affecting client

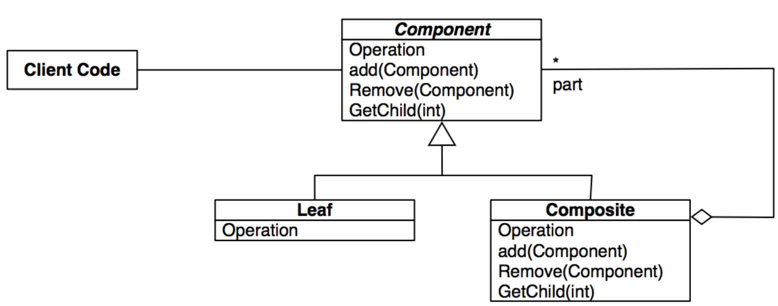


- **Singleton pattern**
  - Ensures only one instance of a class can exist
  - Private constructor; only instantiated through static `getInstance()` method

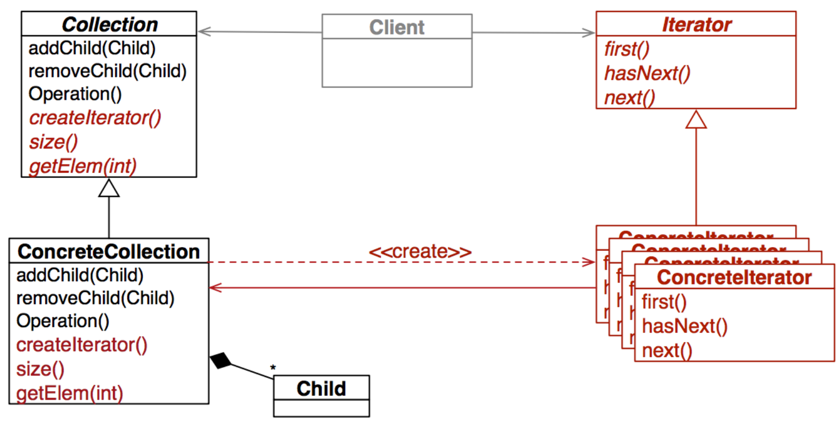
- **Observer pattern**
  - Subject → (one-to-many) Observers
  - Subject can notify all subscribed observers to update
  - Observers can subscribe/unsubscribe at runtime
  - **Push model**: subject pushes state information to observers through `notify(State)`
  - **Pull model**: subject notifies observers, 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



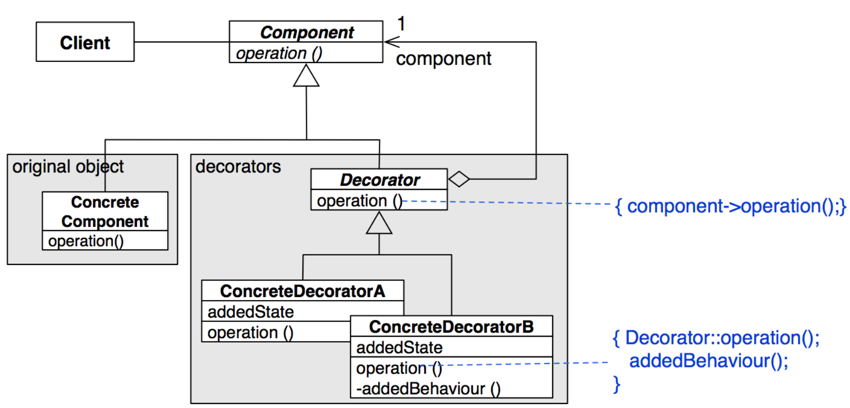
- **MVC pattern**
  - UI code is abstracted into the **view**
    - Composite pattern: all view elements use the same base class (uniform interface)
  - **Controller** translates user input (from the view) into operations on the model
    - Strategy pattern: controller provides the view with a strategy; 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)



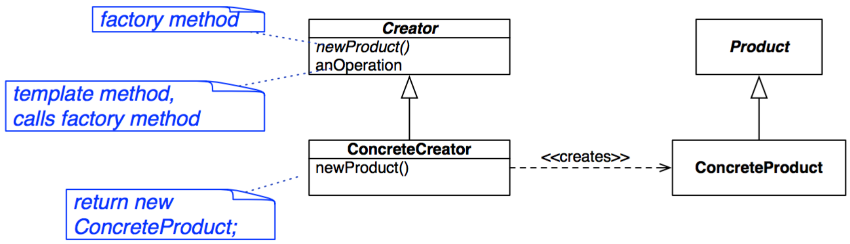
- **Iterator pattern**
  - Allows iteration through the elements of a collection without exposing representation
  - Composite pattern iteration:
    - Traverse tree using DFS (w/ a stack)
    - Define iterator subclasses for both leaf and composite classes



- **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)