Final Exam Review (extended)

15-413: Introduction to Software Engineering

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Hoare Logic

```
{ N > 0, M > 0 }
p := 1
i := N
while (i > 0)
    p := p * M;
    i := i - 1;
{ p = M^N }
```

- Loop invariant?
  - p=M^(N-i) && i >=0
- Variant function?
  - i
- Loop verification condition?
  - INV && i>0 =>
  - p*M=M^(N-(i-1)) && (i-1) >= 0
    - p*M = M^(N-i+1) && i > 0
    - p = M^(N-i) && i > 0

Translation of Temporal Logic

- p = “p holds in the current state”
- A f = “for all paths from the current state” f
- E f = “there exists some path from the current state such that” f
- X f = “in the next state on the path” f
- G f = “in all states along the path” f
- f U g = “along the path there will eventually be a state where” g “and for every state before that” f
- F g = true U g = “along the path there will eventually be a state where” g

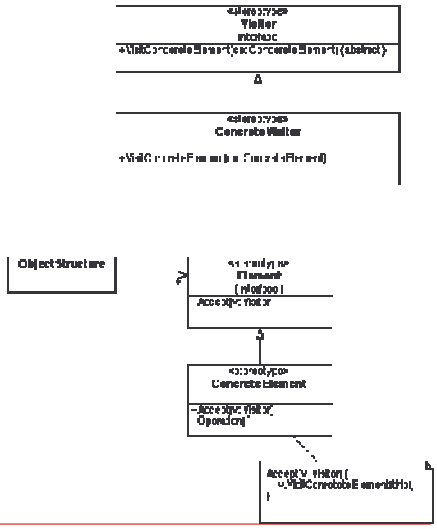
- Examples
  - AG p = “for all paths from the current state, in all states along the path, p holds”
  - EF p = “there exists a path from the current state such that along the path there will eventually be a state where p holds”

Temporal Logic

- Translate these statements into temporal logic
  - No matter what happens, the dike will never overflow at any time
    - AG ~overflow
  - No matter how I use my computer, at any point, there is always something I can do that will eventually shut down
    - AG EF shutdown
  - No matter how I use my computer, at any point, if I press the reset button then the computer will restart immediately afterwards
    - AG (reset => AX restart)

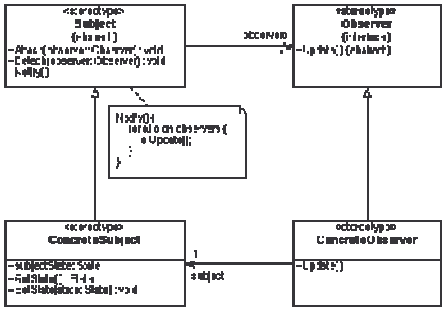
Behavioral: Visitor

- Applicability
  - Structure with many classes
  - Want to perform operations that depend on classes
  - Set of classes is stable
  - Want to define new operations
- Consequences
  - Easy to add new operations
  - Groups related behavior in Visitor
  - Adding new elements is hard
  - Visitor can store state
  - Elements must expose interface



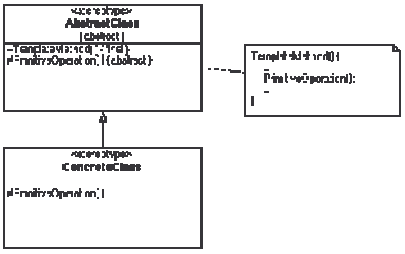
Behavioral: Observer

- Applicability
  - When an abstraction has two aspects, one dependent on the other, and you want to reuse each
  - When change to one object requires changing others, and you don't know how many objects need to be changed
  - When an object should be able to notify others without knowing who they are
- Consequences
  - Loose coupling between subject and observer, enhancing reuse
  - Support for broadcast communication
  - Notification can lead to further updates, causing a cascade effect



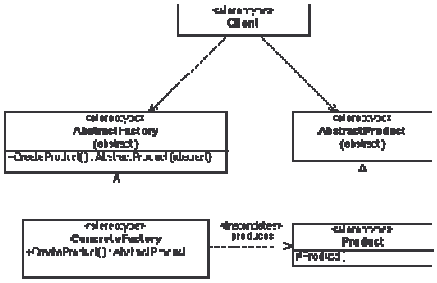
Behavioral: Template Method

- Applicability
  - When an algorithm consists of varying and invariant parts that must be customized
  - When common behavior in subclasses should be factored and localized to avoid code duplication
  - To control subclass extensions to specific operations
- Consequences
  - Code reuse
  - Inverted “Hollywood” control: don’t call us, we’ll call you
  - Ensures the invariant parts of the algorithm are not changed by subclasses

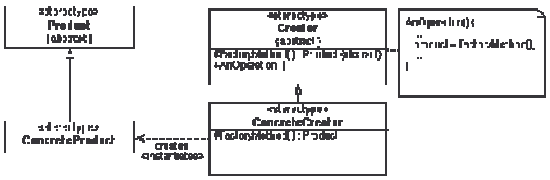


Creational: Abstract factory

- Applicability
  - System should be independent of product creation
  - Want to configure with multiple families of products
  - Want to ensure that a product family is used together
- Consequences
  - Isolates concrete classes
  - Makes it easy to change product families
  - Helps ensure consistent use of family
  - Hard to support new kinds of products



Creational: Factory Method



- Applicability
  - A class can't anticipate the class of objects it must create
  - A class wants its subclasses to specify the objects it creates
- Consequences
  - Provides hooks for subclasses to customize creation behavior
  - Connects parallel class hierarchies

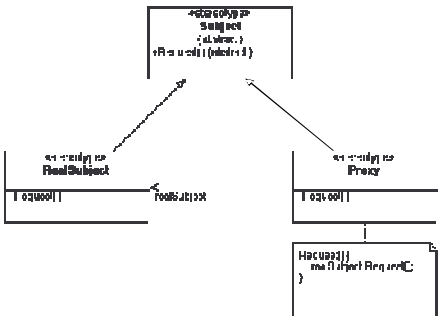
Creational: Singleton

- Applicability
  - There must be exactly one instance of a class
  - When it must be accessible to clients from a well-known place
  - When the sole instance should be extensible by subclassing, with unmodified clients using the subclass
- Consequences
  - Controlled access to sole instance
  - Reduced name space (vs. global variables)
  - Can be refined in subclass or changed to allow multiple instances
  - More flexible than class operations
    - Can change later if you need to

- Implementation
  - Constructor is protected
  - Instance variable is private
  - Public operation returns singleton
    - May lazily create singleton
- Subclassing
  - Instance() method can look up subclass to create in environment

Structural: Proxy

- Applicability
  - Whenever you need a more sophisticated object reference than a simple pointer
    - Local representative for a remote object
    - Create or load expensive object on demand
    - Control access to an object
    - Reference count an object
- Consequences
  - Introduces a level of indirection
    - Hides distribution from client
    - Hides optimizations from client
    - Adds housekeeping tasks



What is an architecture?

- A software architecture is the structure or structures of a system, which comprise elements, their externally-visible properties, and the relationships among them
- But what kinds of structure?
  - *modules*: showing composition/decomposition
  - *runtime*: components at runtime
  - *allocation*: how software is deployed
  - *…*
- Each is the basis of an Architectural View

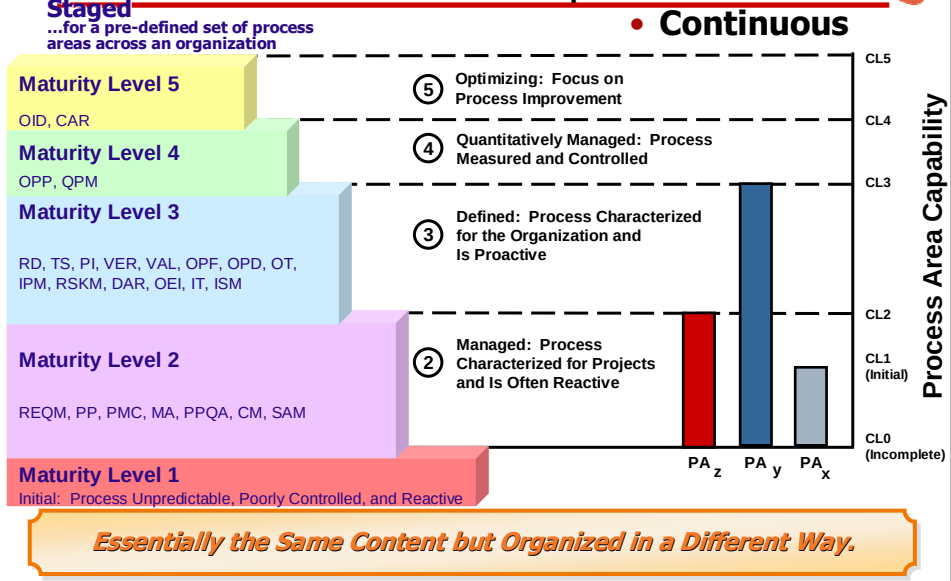
Component-and-Connector (C&C) View

- Decomposition of system into **components**…
  - Components: principal units of run-time computation and data stores
    - Examples: client, server
  - Typically hierarchical
- And **connectors**…
  - Connectors: define an abstraction of the interactions between components
    - Examples: procedure call, pipe, event announce
- Using architectural **styles**…
  - Guide composition of components and connectors
- And **constraints** (or invariants)

What Is Institutionalization?

- Institutionalization involves implementing practices that
  - Ensure processes can be communicated about (they are defined, documented, understood)
  - Ensure the processes are effective, repeatable and lasting
  - Provide needed infrastructure support
  - Enable organizational learning to improve the process

Model Representations



Essentially the Same Content but Organized in a Different Way.

Black-box Testing

- Verify each piece of functionality of the system
  - Black-box: don't look at the code
- Systematic testing
  - Test each use case
  - Test combinations of functionality (bold + italic + font + size)
    - Generally have to sample
  - Test incorrect user input
  - Test each "equivalence class" (similar input/output)
  - Test uncommon cases
    - Generating all error messages
    - Using uncommon functionality
  - Test borderline cases
    - Edges of ranges, overflow inputs, array of size 0 or 1

White-box Testing

- Look at the code (white-box) and try to systematically cause it to fail
- Coverage criteria: a way to be systematic
  - Function coverage
    - Execute each function
  - Statement coverage
    - Most common
  - Edge coverage
    - Take both sides of each branch
  - Path coverage
    - Note: infinite number of paths!
    - Typical compromise: 0-1-many loop iterations
  - Condition coverage
    - Choose a set of predicates
    - Cover each statement with each combination of predicates
  - Exercise data structures
    - Each conceptual state or sequence of states
- Typically cannot reach 100% coverage
  - Especially true of paths, conditions