CMSC 433 – Programming Language Technologies and Paradigms  
Spring 2003

Some Design Patterns  
March 11, 2003

Supporting User Commands

• Support execution of Lexi commands
  – GUI doesn’t know
    • who command is sent to
    • command interface

• Complications
  – different commands have different interfaces
  – same command can be invoked in different ways
  – Undo and Redo for some, but not all, commands (print)

Supporting User Commands (cont’d)

• An improved solution
  – create abstract “command” class
  – create action-performing glyph subclass
  – delegate action to command

• Key ideas
  – pass an object, not a function
  – pass context to the command function
  – store command history

Command Objects

An improved solution
  – create abstract “command” class
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Key ideas
  – pass an object, not a function
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  – store command history

Command Pattern

• Name
  – Command or Action or Transaction

• Applicability
  – parameterize objects by actions they perform
  – specify, queue, and execute requests at different times
  – support undo by storing context information
  – support change log for recovery purposes
  – support high-level operations
    • macros

Structure of Command Pattern
**Command Pattern**

- **Consequences:**
  - decouple receiver and executor of requests
    - Lexi example: Different icons can be associated with the same command
  - commands are first class objects
  - easy to support undo and redo
    - command must have method to check whether it’s reversible
    - must add state information
  - can create composite commands
    - Editor macros
  - can extend commands more easily

- **Implementation notes**
  - how much should command do itself?
  - support undo and redo functionality
    - operations must be reversible
    - may need to copy command objects
    - don’t record commands that don’t change state
  - avoid error accumulation in undo process

**Spell-Checking and Hyphenation**

- **Must do textual analysis**
  - multiple operations and implementations
- **Must add new functions and operations easily**
- **Must efficiently handle scattered information and varied implementations**
  - different traversal strategies for stored information
- **Should separate actions from traversal**

**Structure of Iterator Pattern**

**Visitor: Implementing Analyses**

- **Often want to implement multiple analyses on the same kind of object data**
  - Spellchecking and Hyphenating Glyphs
  - Generating code for and analyzing an Abstract Syntax Tree (AST) in a compiler
- **One solution: implement each analysis as a method in each object**
  - Follows idea “objects are responsible for themselves”
  - But many analyses will occlude the object’s main code
  - Result is classes hard to maintain

**Naïve approach (not a visitor)**

- **One method for each analysis**
Use a Visitor

- Alternatively, we can define each analysis as a separate visitor class
  - A visitor encapsulates the operations to be performed on an entire structure, e.g., all elements of a parse tree
- Allows the operations to be specified separately from the structure
  - But doesn’t require putting all of the structure traversal code into each visitor/operation

Sample Visitor class

- NodeVisitor
  - VisitAssignment(AssignmentNode)
  - VisitVariableRef(VariableRefNode)

TypeCheckingVisitor
- VisitAssignment(AssignmentNode)
- VisitVariableRef(VariableRefNode)

CodeGeneratingVisitor
- VisitAssignment(AssignmentNode)
- VisitVariableRef(VariableRefNode)

How to perform traversal?

- Now that we have a visitor class, how do we apply its analysis to the objects of interest?
  - Add accept(visitor) method to each structure class, that will invoke the given visitor on this.
  - Builds on Java’s dynamic dispatch.
  - Use an iteration algorithm (like an Iterator) to call accept() on each relevant object.

Sample visited objects

Visitor pattern

- Name
  - Visitor or double dispatching
- Applicability
  - related objects must support different operations and actual op depends on both the class and the op type
  - distinct and unrelated operations pollute class defs
  - Key: object structure rarely changes, but ops changed often
Visitor Pattern Structure

- Define two class hierarchies
  - one for object structure
    - AST in compiler, Glyphs in Lexi
  - one for each operation family, called visitors
    - One for typechecking, code generation, pretty printing in compiler
    - One for spellchecking or hyphenation in Lexi

Structure of Visitor Pattern

Use of Visitor Pattern in Lexi

Visitor Pattern Consequences

- Adding new operations is easy
  - add new operation subclass with a method for each concrete element class
    - easier than modifying every element class
- Gathers related operations and separates unrelated ones
- Adding new concrete elements is difficult
  - must add a new method to each concrete Visitor subclass
- Allows visiting across class hierarchies
  - Iterator needs a common superclass (i.e. composite pattern)
- Visitor can accumulate state rather than pass it a parameters

Implementing Traversal

- Who is responsible for traversing object structure?
- Plausible answers:
  - visitor
    - But, must replicate traversal code in each concrete visitor
  - object structure
    - Define operation that performs traversal while applying visitor object to each component
  - Iterator
    - Iterator sends message to visitor with current element as arg

Double-dispatch

- Accept code is always trivial
  - Just dynamic dispatch on argument, with runtime type of structure node taking into account in method name
- A way of doing double-dispatch
  - Traversal routine takes two arguments, the visitor and the object to traverse
    - \( o.\text{accept}(a\text{Visitor}) \) will dispatch on the actual identity of \( o \) (the object being considered)
    - \( ...\text{and accept} \) will internally dispatch on the identity of \( a\text{Visitor} \) (the object visiting it).
Using overloading in a visitor

- You can name all of the visitXXX(XXX x) methods just visit(XXX x)
  - Calls to Visit(AssignmentNode n) and Visit(VariableRefNode n) distinguished by compile-time overload resolution

Visitors can forward common behavior

- Useful for composites
  - If subclasses of a particular object all treated the same
  - Can have visit(SubClass) call visit(SuperClass)
- For example
  - visit(BinaryPlusOperatorNode)
    can just forward call to superclass
  - visit(BinaryOperatorNode)

State in a visitor pattern

- A visitor can contain state
  - E.g., the results of typechecking the program so far
    ```java
class TypeCheckingVisitor extends Visitor {
    private TypeMap map;
    void visit(VariableRefNode n) {
        map.add(n, t);
    }
}
```
- Or visitors pass around a separate state object
  - Impacts the type of the Visitor superclass

Traversals

- It's preferred to try to keep traversal separate from the Visitor
  - E.g., use an Iterator
    - Thus traversal and analysis can evolve independently
- But can also do it within node or visitor class. Several solutions here:
  - acceptAndTraverse methods
    - Assumes all visitors have same traversal pattern
      - E.g., visit all nodes in pre-order traversal
  - acceptAndTraverse methods
    - Could provide previsit and postvisit methods to allow for more complicated traversal patterns
      - Still visit every node
      - Can't do out of order traversal
      - In-order traversal requires inVisit method

acceptAndTraverse methods

- accept method could be responsible for traversing children
  - Assumes all visitors have same traversal pattern
    - E.g., visit all nodes in pre-order traversal
  - Could provide previsit and postvisit methods to allow for more complicated traversal patterns
    - Still visit every node
    - Can't do out of order traversal
    - In-order traversal requires inVisit method

Accept and traverse

- Class BinaryPlusOperatorNode
  ```java
  void accept(Visitor v) {
    v.visit(this);
    lhs.accept(v);
    rhs.accept(v);
  }
  ```
Visitor/process methods

- Can have two parallel sets of methods in visitors
  - Visit() methods
  - Process() methods
- Allows finer-grained subtyping of Visitor classes that include traversal
  - Subclass a visitor, and just change the process method
- How it works: the visit() method on a node:
  - Calls process() method of visitor, passing node as an argument
  - Calls accept() on all children of the node (passing the visitor as an argument)

Preorder visitor

- Class PreorderVisitor {
  void visit(BinaryPlusOperatorNode n) {
    process(n);
    n.lhs.accept(this);
    n.rhs.accept(this);
  }
  …
}

Visit/process, continued

- Can define a PreorderVisitor
  - Extend it, and just redefine process method
    - Except for the few cases where something other than preorder traversal is required
- Can define other traversal visitors as well
  - E.g., PostOrderVisitor

Traversal visitors applying an operational visitor

- Define a Preorder traversal visitor
  - Takes an operational visitor as an argument when created
- Perform preorder traversal of structure
  - At each node
    - Have node accept operational visitor
    - Have each child accept traversal visitor

PreorderVisitor with payload

- Class PreorderVisitor {
  Visitor payload;
  void visit(BinaryPlusOperatorNode n) {
    payload.visit(n);
    n.lhs.accept(this);
    n.rhs.accept(this);
  }
  …
}

Pattern hype

- Patterns get a lot of hype and fanatical believers
  - We are going to have a design pattern reading group, and this week we are going to discuss the Singleton Pattern!
- Patterns are sometimes wrong (e.g., double-checked locking) or inappropriate for a particular language or environment
  - Patterns developed for C++ can have very different solutions in Smalltalk or Java