Pattern Language for Adaptive Programming (AP)

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Introduction

Four Patterns

- Structure-shy Traversal
- Selective Visitor
- Structure-shy Object
- Class Graph

On-line information

- $D = www.ccs.neu.edu/research/demeter
- $D is Demeter Home Page
- $SD course home directory
- Lectures are in: $SD/lectures

Summary

- Present ideas of AP at a high-level of abstraction.
- Explain concepts independent of tools and languages.
- Prepare you for homework 1.

Vocabulary

- Pattern: Reusable solution to a problem in a context.
- Class graph = Class diagram: Graph where nodes are classes and edges are relationships between the classes.
- Design pattern book: Gamma, Helm, Johnson, Vlissides: 23 design patterns

Vocabulary

- Visitor pattern: Define behavior for classes without modifying classes.
- Parser: Takes a sequence of tokens and creates a syntax tree or object based on a grammar.
- Grammar: a class graph annotated with concrete syntax.

Overview

- Patterns a useful way to write down experience.
- Use a standard format: Intent, Motivation, Applicability, Solution, Consequences, etc.
- Patterns are connected and refer to each other.
- Extended version at: $D/adaptive-patterns/pattern-lang-conv

Connections

- There are several connections between the AP patterns and other design patterns.
- Class Graph is the basis for Structure-shy Traversal, Selective Visitor and Structure-shy Object.

Structure-shy Traversal

- Intent
  - Succinctly represent a traversal to be performed on objects
  - Commit only to navigation strategy and specify navigation details later

Solve Law of Demeter Dilemma

Small Method Goat

Big Method Goat

Structure-shy Traversal

- Could also be called:
  - Adaptive Traversal
  - Structure-shy Walker
  - Adaptive Visitor (significantly improves the Visitor pattern)

Structure-shy Traversal

- Motivation
  - Noise in objects for specific task
  - Focus on long-term intent
  - Don't want to attach every method to a specific class explicitly. Leads to brittle programs.
  - Small methods problem (example: 80% of methods are two lines long or shorter)

Structure-shy Traversal

- Applicability
  - Need collaboration of at least two classes.
  - In the extreme case, each data member access is done through a succinct traversal specification.
  - Some subgraphs don't have a succinct representation, for example a path in a complete graph. More generally: avoid well connected, dense graphs.

Structure-shy Traversal

- Solution
  - Use succinct subgraph specifications
  - Use succinct path set specifications

Structure-shy Traversal: Solution

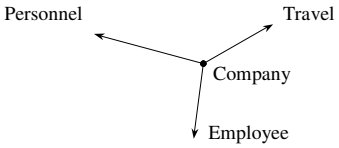
- Traversal Strategy Graphs (Strategies)
  - *First stage*: A strategy is a graph with nodes and edges. Nodes are labeled with nodes of a class graph. Edges mean: all paths.
  - *Second stage*: label edges with constraints excluding edges and nodes in class graph
  - *Third stage*: Encapsulated strategies. Use symbolic elements and map to class graph.

Structure-shy Traversal: Solution

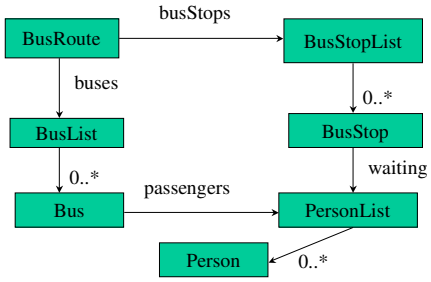
- Traversal Strategy Graphs (Strategies)
  - Simplest useful strategy: One Edge. Possible syntax:
    - from Company to Salary or
    - {Company -> Salary}
  - Line graph. Several edges in a line. Possible syntax:
    - From Company via Employee to Salary
    - {Company -> Employee Employee -> Salary}

Structure-shy Traversal: Solution

- Traversal Strategy Graphs (Strategies)
  - Star graph
    - From Company to {Personnel, Travel, Employee}



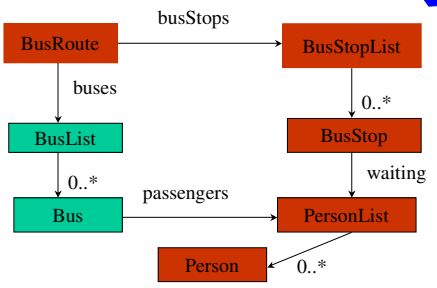
UML Class Diagram



find all persons waiting at any bus stop on a bus route

Traversal Strategy

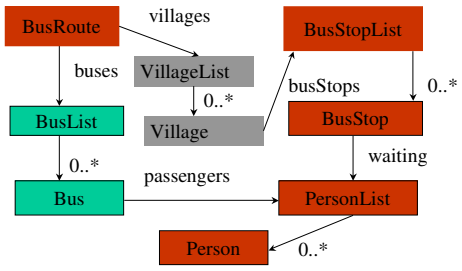
`from` BusRoute `through` BusStop `to` Person



find all persons waiting at any bus stop on a bus route

Robustness of Strategy

`from` BusRoute `through` BusStop `to` Person



Structure-shy Traversal

- Consequences
  - Programs become shorter and more powerful. A paradox. With less work we achieve more. Polya's inventor paradox.
  - Program will adapt to many changes in class structure.

Structure-shy Traversal

- Implementation
  - Many different models for succinct traversal specifications.
  - Best one: Strategies
  - Correct implementation of strategies is tricky. See paper by Lieberherr/Patt-Shamir strategies.ps in my FTP directory.

Structure-shy Traversal

- Known Uses
  - *Adaptive Programming*: Demeter/C++, DemeterJ, Dem/Perl, Dem/CLOS etc.
  - *Databases* (limited use): Structure-shy queries: See Cole Harrison's Master's Thesis (Demeter Home Page)
  - XML: XPath
  - *Artificial Intelligence* (limited use): Minimal ontological commitment

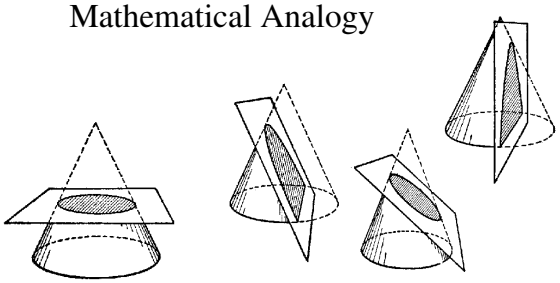
Nature Analogy

same strategy in different class graphs: similar traversals
same seeds in different climates: similar trees

warm climate cold climate

same cone different planes define similar point sets
same strategy different class graphs define similar path sets

Mathematical Analogy



Selective Visitor

- Intent
  - Loosely couple behavior modification to behavior and structure.
  - Would like to write an editing script to modify traversal code instead of modifying the traversal code manually.

Selective Visitor

- Could also be called:
  - Structure-shy Behavior Modification
  - Event-based Coupling
  - Traversal Advice

Selective Visitor

- Motivation:
  - Avoid tangling of code for one behavior with code for other behaviors.
  - Localize code belonging to one behavior.
  - Compose behaviors.
  - Modify the behavior of a traversal call (traversals only traverse).

Selective Visitor

- Applicability:
  - Need to add behavior to a traversal.

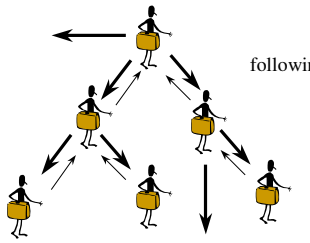
Selective Visitor

- Solution:
  - Use visitor classes and objects.
  - Pass visitor objects as arguments to traversals.
  - Either use naming conventions for visitor methods (e.g., before_A()) or extend object-oriented language (e.g. **before** A, **before** is a new key word).

Selective Visitor

- Solution:
  - before, after methods for nodes and edges in the class graph
  - Activated during traversal as follows:
    - Execute before methods
    - Traverse
    - Execute after methods

Visitor visits objects



following strategy

Visitor collects information in suitcase (variables)

Selective Visitor

- Solution: Focus on what is important.

```
SummingVisitor {
  {{ int total; }}
  init {{ total = 0; }}
  before Salary {{ total = total + host.get_v(); }}
  return {{ total }}
}
```

host is object visited

Code between {{ and }} is Java code

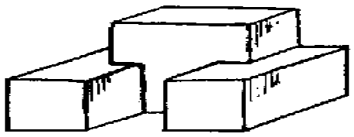
Selective Visitor

- Solution: Use of visitor

```
Company {
  traversal allSalaries(UniversalVisitor) {do S;}
  int sumSalaries()
  {{
    SummingVisitor s = new SummingVisitor();
    this.allSalaries(s);
    return s.get_return_val();
  }}
}
```


Selective Visitor

- Consequences
  - Easy behavior adjustments: Add visitor
  - Reuse of visitors



Selective Visitor

- Consequences: Easy behavior enhancement

```
Company { // enhancements in red
  traversal allSalaries(UniversalVisitor, UniversalVisitor)
    {do S;}
  {{ float averageSalaries() {
    SummingVisitor s = new SummingVisitor();
    CountingVisitor c = new CountingVisitor();
    this.allSalaries(s, c);
    return s.get_return_val() / c.get_return_val();
  } }}
}
```

Writing Programs with Strategies

Example of Adaptive Program

strategy: `from` BusRoute `through` BusStop `to` Person

```
BusRoute {
   traversal waitingPersons(PersonVisitor) {
    through BusStop to Person; } // from is implicit
   int printWaitingPersons() // traversal/visitor weaving instr.
     = waitingPersons(PrintPersonVisitor);
PrintPersonVisitor {
   before Person {{ … }} … }
PersonVisitor {init {{ r = 0 }} … }
```

Extension of Java: keywords: `traversal init through bypassing to before after` etc.

Selective Visitor

- Consequences:
  - Can reuse SummingVisitor and CountingVisitor in other applications.

Selective Visitor

- Implementation
  - Translate to object-oriented language.
  - See DemeterJ, for example.

Selective Visitor

- Known uses
  - Propagation patterns use inlined visitor objects (see AP book).
  - DemeterJ.
  - The Visitor Design Pattern from the design pattern book uses a primitive form of Selective Visitor.

Differences to Visitor pattern

- Focus selectively on important classes. Don't need a method for each traversed class.
- Finer control: not only one accept method but before and after methods for both nodes and edges.

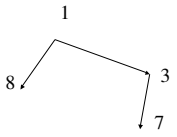
Structure-shy Object

- Intent
  - Make object descriptions for tree objects robust to changes of class structure.
  - Make object descriptions for tree objects independent of class names.

Example

- Tree = "tree" ["left" <left> Tree] ["right" <right> Tree] <n> Node.
- Node = int.

```
tree
  left tree
    8
  right tree
    left tree
      7
    3
  1
```



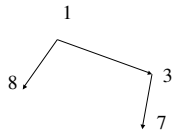

```
new Tree(
  new Tree(null, null, new Node(8)),
  new Tree(
    new Tree(null, null, new Node(7)),
    null,
    new Node(3)),
  new Node(1))
```


Example

- BT = "tree" ["left" <left> BT] ["right" <right> BT] <n> int.

```
tree
  left tree
    8
  right tree
    left tree
      7
    3
  1
```

STILL CORRECT




```
new Tree(
  new Tree(null, null, new Node(8)),
  new Tree(
    new Tree(null, null, new Node(7)),
    null,
    new Node(3)),
  new Node(1))
```

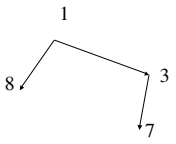
COMPLETELY BROKEN

Flexibility

- There are many ways to clothe a tree!!
- clothing = syntax
- Two goals with clothing:
  - objects look nice
  - avoid ambiguity: two distinct objects must look different

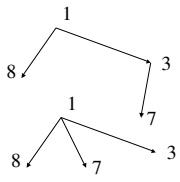
Example

- Tree = "(" <subtrees> TreeList <n> Node ")".
- TreeList ~ {Tree}.
- Node = int.
- ((8) ((7) 3) 1)



Example: bare Tree

- Tree = <subtrees> TreeList <n> Node.
- TreeList ~ {Tree}.
- Node = int.
- 8 7 3 1
- ((8) ((7) 3) 1)
- ((8) (7) (3) 1)



Structure-shy Object

- Could also be called:
  - Object Parsing
  - Grammar
  - Abstract=Concrete Syntax

Structure-shy Object

- Motivation
  - Data maintenance a major problem when class structure changes
  - Tedious updating of constructor calls
  - The creational patterns in the design pattern book also recognize need
  - Concrete syntax is more abstract than abstract syntax!

Structure-shy Object

- Applicability
  - Useful in object-oriented designs of any kind.
  - Especially useful for reading and printing objects in user-friendly notations. Ideal if you control notation.
  - If you see many constructor calls: think of Structure-shy Object.

Structure-shy Object

- Solution
  - Extend the class structure definitions to define the syntax of objects.
  - Each class will define a parse function for reading objects and a print visitor for printing all or parts of an object.

Structure-shy Object

- Solution
  - Start with familiar grammar formalism and change it to make it also a class definition formalism. In the Demeter group we use Wirth's EBNF formalism.
  - Use a parser generator (like YACC or JavaCC) or a generic parser.

Structure-shy Object

Parsers weave sentences into objects

Problem in OO programs: Constructor calls for compound objects are brittle with respect to structure changes.

Solution: Replace constructor calls by calls to a parser. Annotate class diagram to make it a grammar.

Benefit: reduce size of code to define objects, object descriptions are more robust

Correspondence: Sentence defines a family of objects. Adaptive program defines family of object-oriented programs. In both cases, family member is selected by (annotated) class graph.

Structure-shy Object

Run-time weaving: Description

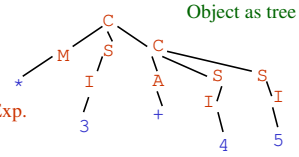
Sentence

* 3 + 4 5

Grammar

Compound=Op <f>Exp <s>Exp.
Simple=Integer.
Exp : Simple | Compound.
Mult="*".
Add="+".
Op : Add|Mult.

Object as tree



Object in linear form (Constructor calls)

C M * S I 3 C A + S I 4 S I 5

SENTENCE IS MORE ROBUST THAN OBJECT

Grammar defined by annotating UML class diagram

Structure-shy Object

- Consequences
  - more robust and shorter object descriptions
  - Need to deal with *unique readability with respect to an efficient parsing algorithm*
  - Can guarantee unique readability by adding more syntax
  - debug class structures by reading objects

Structure-shy Object

- Related patterns
  - Creational patterns in design pattern book.
  - Interpreter pattern uses similar idea but fails to propose it for general object-oriented design.
  - Structure-shy Object useful in conjunction with Prototype pattern.

Structure-shy Object

- Known uses
  - Demeter Tools since 1986, T-gen, applications of YACC, programming language Beta and many more.

Structure-shy Object

- References
  - Chapters 11 and 16 of AP book describe details.
- Exercise
  - Use your favorite grammar notation and modify it to also make it a class graph notation.

Class Graph

- Intent
  - Write class relationships once and reuse them many times.
  - Generate a visitor library from class graph for copying, displaying, printing, checking, comparing and tracing of objects.

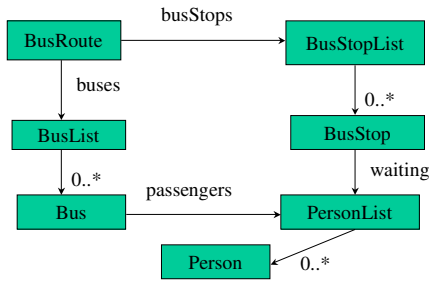
Class Graph

- Could also be called:
  - Class diagram
  - Class dictionary

Class Graph

- Applicability
  - For every application having more than one class.
- Implementation
  - Preferred: Use UML class graph model and notation
  - Use tool to generate visitor library (see DemeterJ).

UML Class Diagram



Class Graph

- Known uses:
  - Almost all object-oriented design methods use some form of class diagram. Only DemeterJ generates visitor library and allows strategies to refer to the class graph.
- References
  - UML class graphs, see UML doc
  - Demeter class graphs, see chapter 6 of AP book

Summary

- State what has been learned: Principles of AP in high-level form.
- How to apply: Do homework one and recognize those patterns in the thousands of lines Java code.

Where to get more information

- Those patterns will be discussed in much more detail.
- AP book covers the concepts.
- UML documentation
- See $D for more information.

Feedback

- Please see me after class or send me email if you have improvements to those patterns.
- lieberherr@ccs.neu.edu