A Case Study of “Gang of Four” (GoF) Patterns : Part 7

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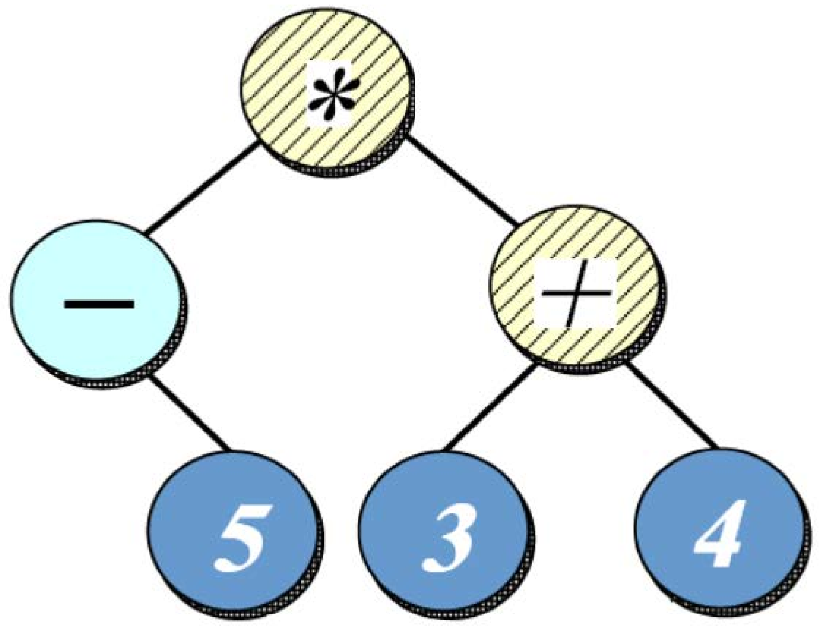
Topics Covered in this Part of the Module

- Describe the object-oriented (OO) expression tree case study
- Evaluate the limitations with algorithmic design techniques
- Present an OO design for the expression tree processing app
- Summarize the patterns in the expression tree design
- Explore patterns for
  - Tree structure & access
  - Tree creation
  - Tree traversal




```
for (auto iter = expr_tree.begin();
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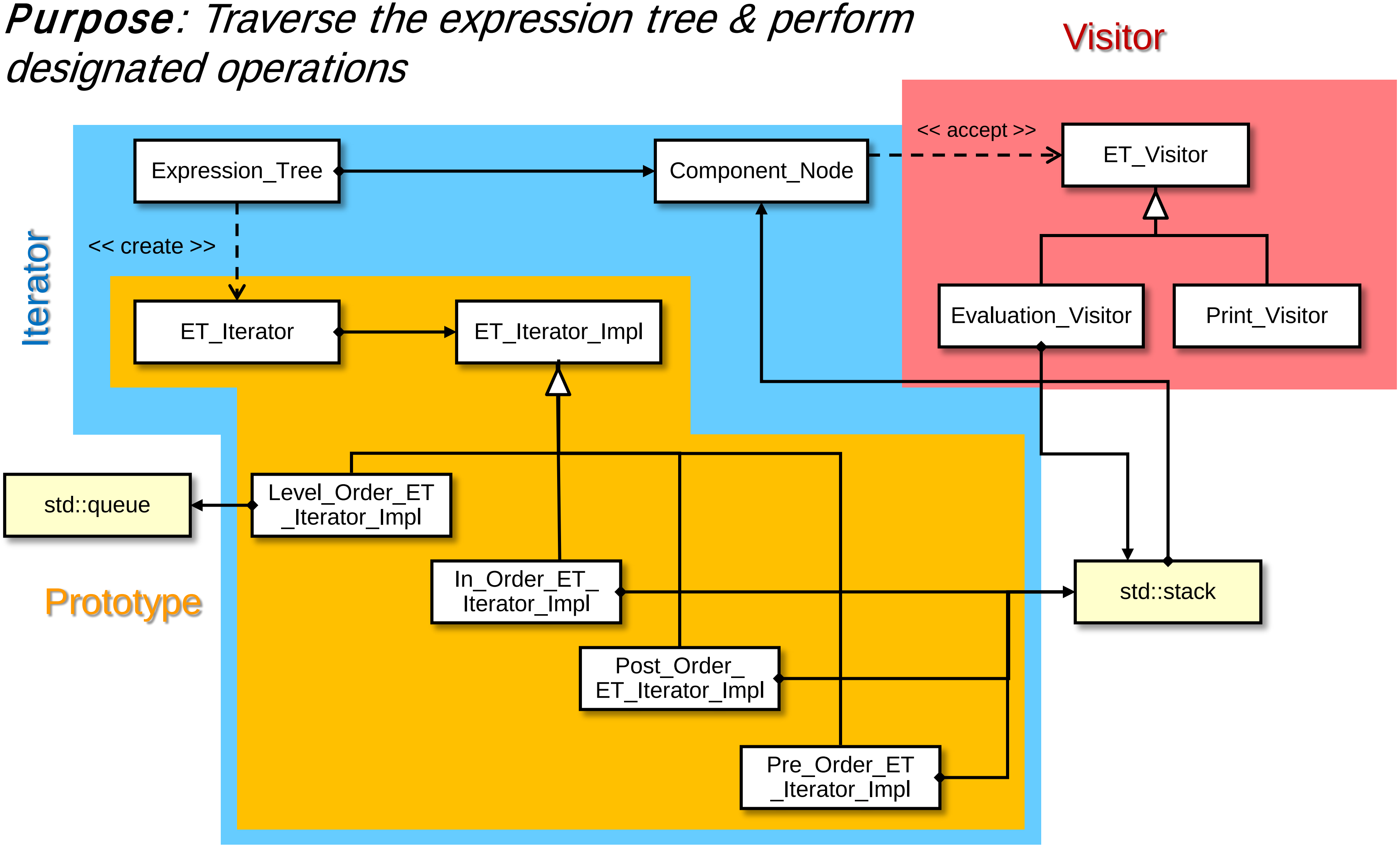
 (*iter).accept(print_visitor);
```

Overview of Tree Traversal Patterns

***Purpose**: Traverse the expression tree & perform designated operations*

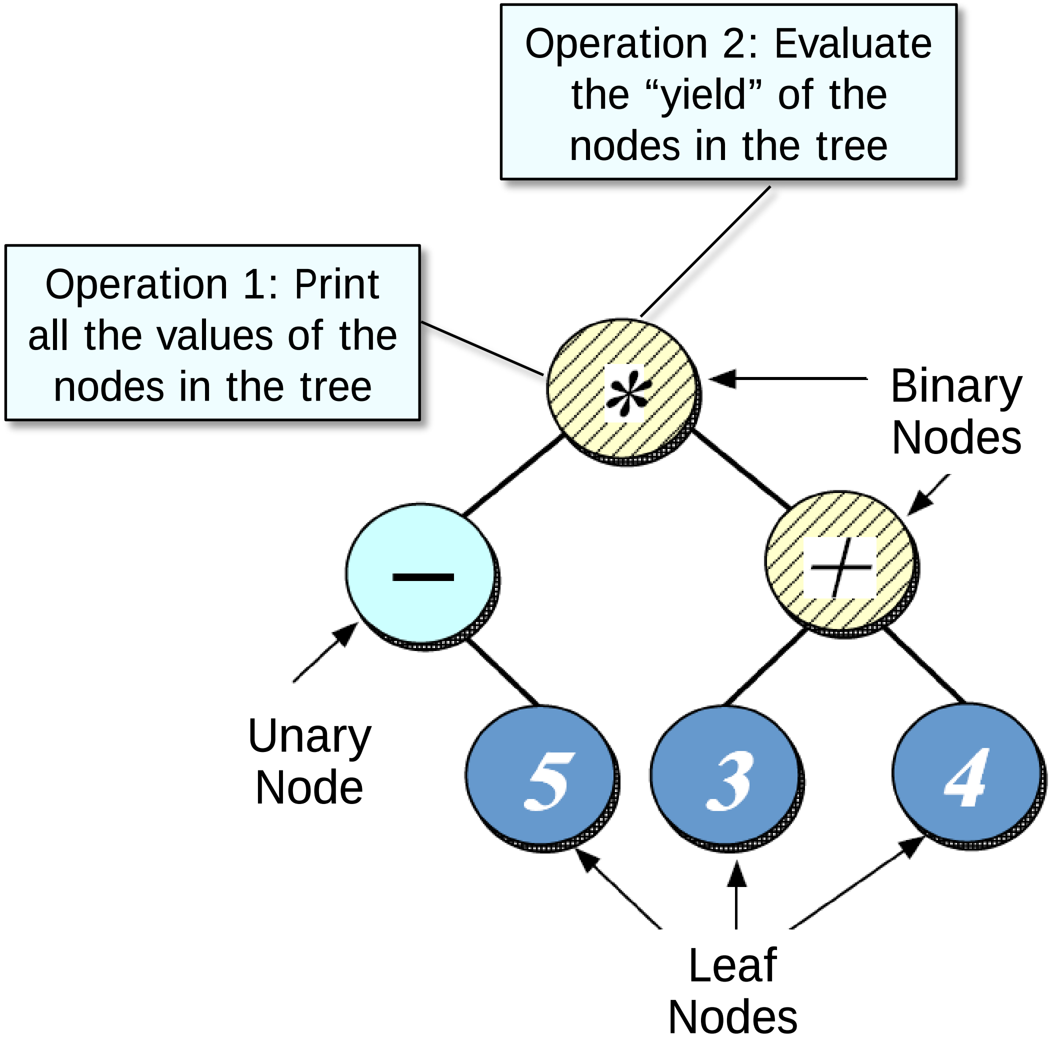


Patterns decouple expression tree structure from operations performed on it

Problem: Extensible Expression Tree Operations

Goals

- Create a framework for performing operations that affect nodes in a tree



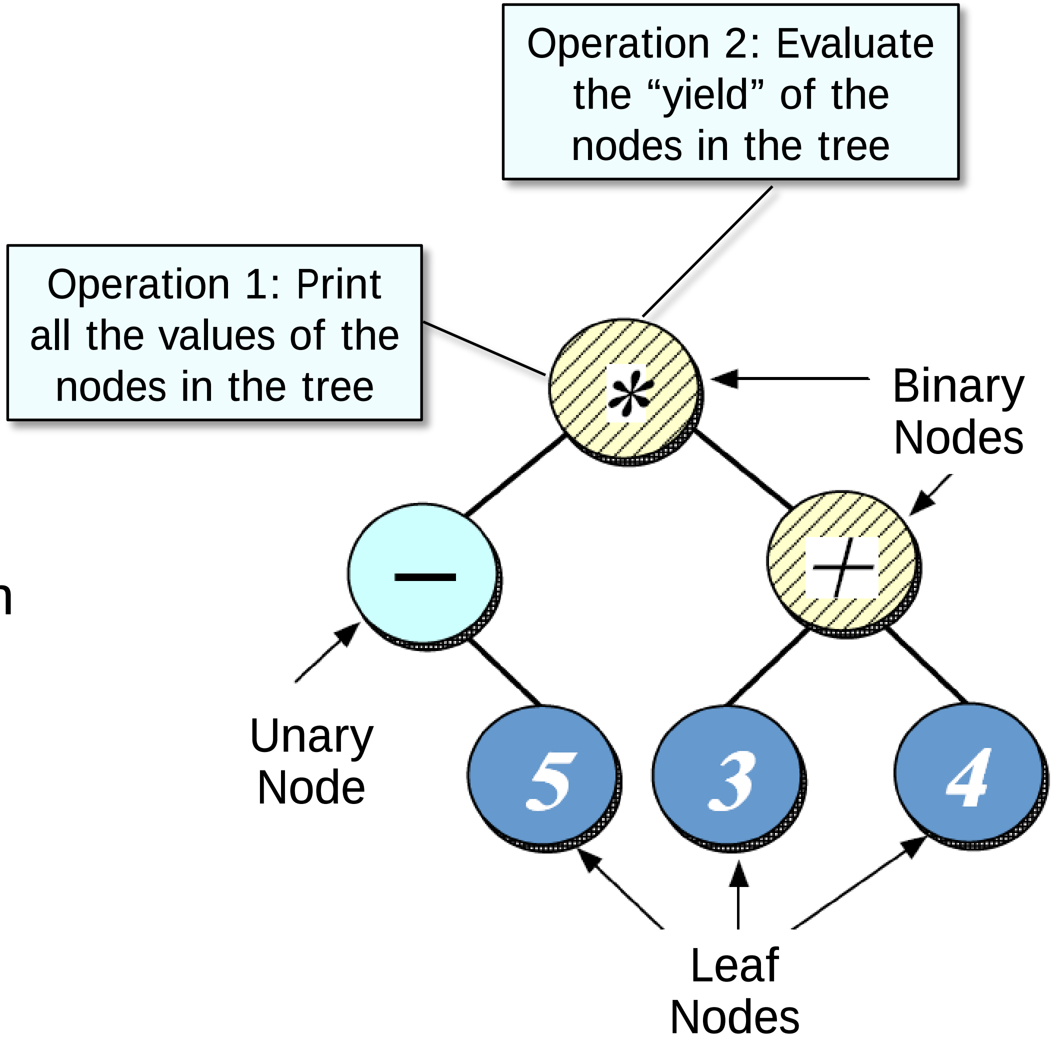
Problem: Extensible Expression Tree Operations

Goals

- Create a framework for performing operations that affect nodes in a tree

Constraints/forces

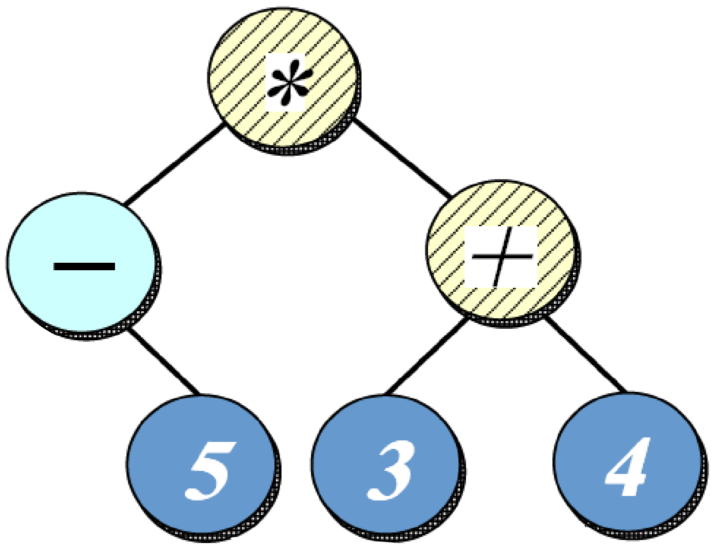
- Support multiple operations on the expression tree without tightly coupling operations with the tree structure
  - i.e., don't have **`print()`** & **`evaluate()`** methods in the node classes



Solution (Part A): Encapsulate Traversal

Iterator

- Encapsulates a traversal algorithm without exposing representation details to callers
- e.g.,
  - "in-order iterator" = **-5*(3+4)**
  - "pre-order iterator" = ***-5+34**
  - "post-order iterator" = **5-34+***
  - "level-order iterator" = ***-+534**

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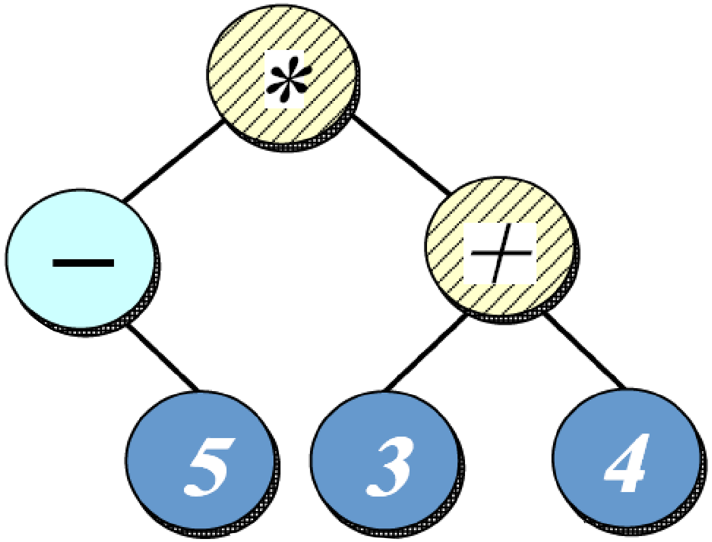
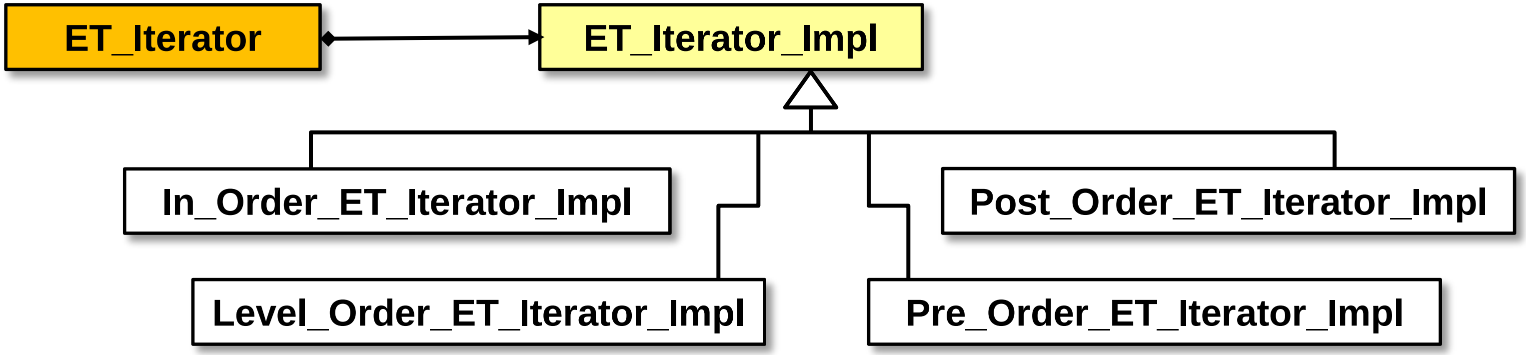


Iterator Structure



Bridge pattern encapsulates variability & simplifies memory management

ET_Iterator Class Interface

- Interface for iterator that traverses all nodes in an expression tree instance

Interface

This interface plays the role of the abstraction in the *Bridge* pattern

```
                           ET_Iterator(ET_Iterator_Impl *)
                           ET_Iterator(const ET_Iterator &)
      Expression_Tree operator *()
const Expression_Tree operator *() const
        ET_Iterator & operator++()
          ET_Iterator operator++(int)
                 bool operator==(const ET_Iterator &rhs)
                 bool operator!=(const ET_Iterator &rhs)
```

Overloaded C++ operators conform to what's expected from an STL iterator

...

- **Commonality**: Provides a common interface for expression tree iterators that conforms to the standard STL iterator interface
- **Variability**: Can be configured with specific expression tree iterator algorithms via the *Abstract Factory* pattern

ET_Iterator_Impl Class Interface

- Base class of the iterator implementor hierarchy that defines the various iterations algorithms that can be performed to traverse the expression tree

Interface

```
                           ET_Iterator_Impl
                                 (const Expression_Tree &)
                   virtual ~ET_Iterator_Impl()
    virtual Expression_Tree operator *()=0
               virtual void operator++()=0
               virtual bool operator==
                              (const ET_Iterator_Impl &)=0
               virtual bool operator!=
                              (const ET_Iterator_Impl &)=0
 virtual ET_Iterator_Impl * clone()=0
```

This class doesn't need to mimic the *Bridge* interface

clone() is used by *Prototype* pattern

- **Commonality**: Provides a common interface for implementing expression tree iterators that conforms to the standard STL iterator interface
- **Variability**: Can be subclassed to define various algorithms for accessing nodes in the expression trees in a particular traversal order

Iterator GoF Object Behavioral

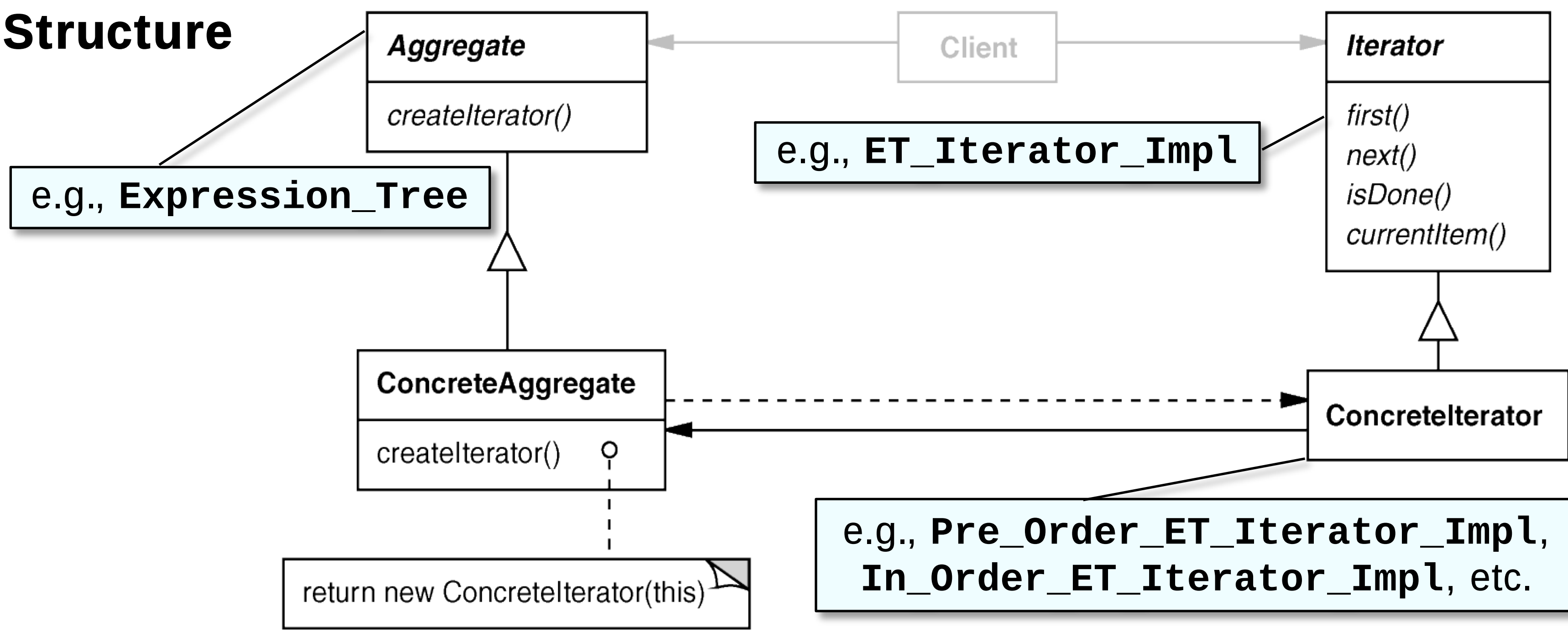
Intent

- Access elements of an aggregate without exposing its representation

Applicability

- Require multiple traversal algorithms over an aggregate
- Require a uniform traversal interface over different aggregates
- When aggregate classes & traversal algorithm must vary independently

Structure



Iterator GoF Object Behavioral

Comparing STL iterators with GoF iterators

- STL iterators have "value-semantics", e.g.:

```
for (auto iter = expr_tree.begin();
     iter != expr_tree.end();
     ++iter)
 (*iter).accept(print_visitor);
```

Easy to use, harder to implement

- In contrast, GoF iterators have "pointer semantics", e.g.:

Easy to implement, harder to use (correctly)

```
Iterator *iter;

for (iter = exprTree.createIterator();
     iter->done() == false;
     iter->advance())
 iter->currentElement()->accept(printVisitor);

delete iter;
```

The *Bridge* pattern enables STL iterator use in expression tree processing app

Iterator GoF Object Behavioral

Comparing Java iterators with GoF iterators

- Java iterators are closer to GoF iterators than STL iterators are, e.g.:

```
for (Iterator<ExpressionTree> iter = exprTree.iterator();
     iter.hasNext();
     )
   iter.next().accept(printVisitor);
}
```

- Here's the equivalent Java code for GoF-style iterators, e.g.:

```
for (ETIterator iter = tree.createIterator();
     !iter.done();
     iter.advance())
  (iter.currentElement()).accept(printVisitor);
```

Often, the simplest way to use an iterator in C++/Java is to use a for loop

Iterator GoF Object Behavioral

Comparing Java iterators with STL iterators

- Often, the simplest way to use an iterator in C++/Java is to use a for loop, e.g.:

C++11 range-based for loop

```
for (auto &iter : expr_tree)
  iter.accept(print_visitor);
```

Java for-each loop

```
for (ComponentNode node : exprTree)
  node.accept(printVisitor);
```

Iterator GoF Object Behavioral

Iterator example in C++

- An STL **std::stack** can be used to traverse an expression tree in pre-order

```
class Pre_Order_ET_Iterator_Impl : public ET_Iterator_Impl {
public:
  Pre_Order_ET_Iterator_Impl(const Expression_Tree &root)
  { if (!root.is_null()) stack_.push (root); }

  virtual Expression_Tree operator*() { return stack_.top (); }

  virtual void operator++() {
    if (!stack_.is_empty()) {
      Expression_Tree current = stack_.top(); stack_.pop();
      if (!current.right().is_null())
        stack_.push(current.right());
      if (!current.left().is_null())
        stack_.push(current.left());
    }
  }
  ...
```

Begin iteration

Return current item

Advance one item

The use of a stack simulates recursion, one item at a time

Iterator GoF Object Behavioral

Consequences

+ *Flexibility*: Aggregate & traversal are independent
+ *Multiplicity*: Multiple iterators & multiple traversal algorithms

– *Overhead*: Additional communication between iterator & aggregate
  – Particularly problematic for iterators in concurrent or distributed systems

Iterator GoF Object Behavioral

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Implementation

- Internal vs. external iterators
- Violating the object structure's encapsulation
- Robust iterators
- Synchronization overhead in multi-threaded programs
- Batching in distributed & concurrent programs

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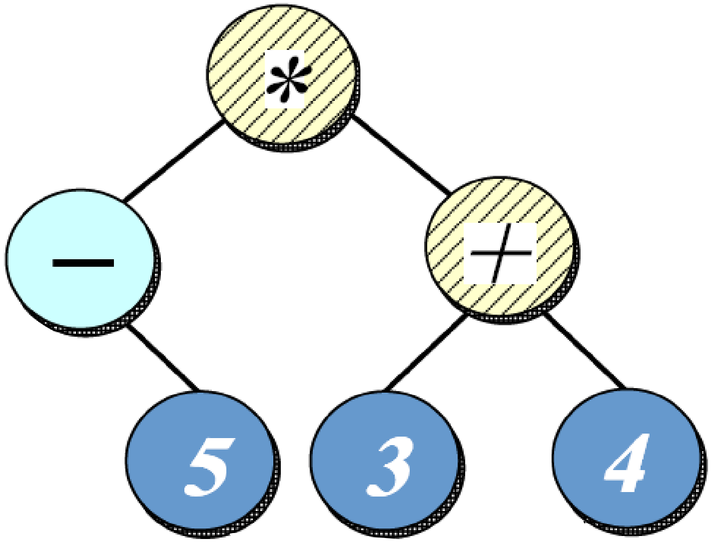
Known Uses

- C++ STL iterators
- JDK Enumeration, Iterator
- Unidraw Iterator
- C++11 range-based for loops & Java for-each loops
- C buffered I/O

Solution (Part B): Decouple Operations from Expression Tree Structure

Visitor

- Defines action(s) at each step of traversal & avoids hard-coding action(s) into nodes



Solution (Part B): Decouple Operations from Expression Tree Structure

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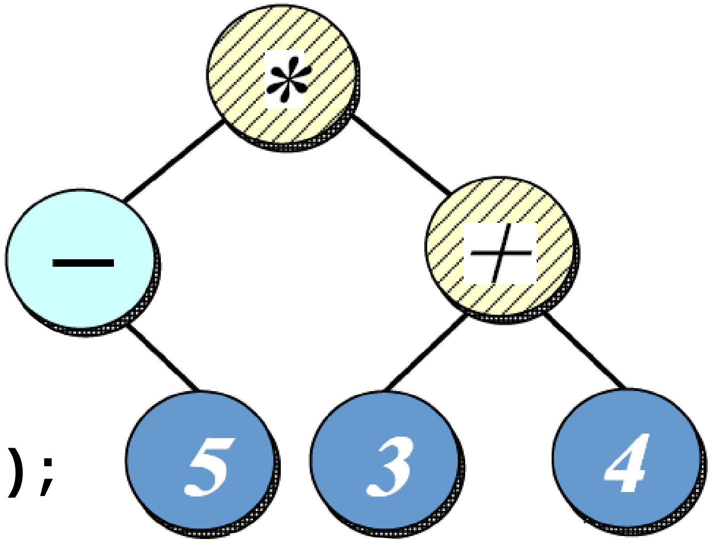
- Iterator calls **`accept(ET_Visitor&)`** method on each node in expression tree

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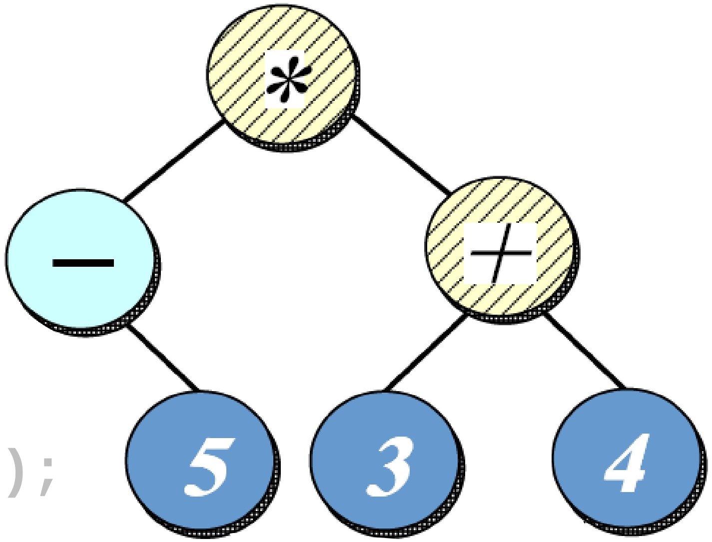

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for (auto iter = expr_tree.begin();
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```

- **`accept()`** calls back on visitor, e.g.:

```
void Leaf_Node::accept(ET_Visitor &v) {
  v.visit(*this);
}
```

Note “static polymorphism” based on method overloading by type