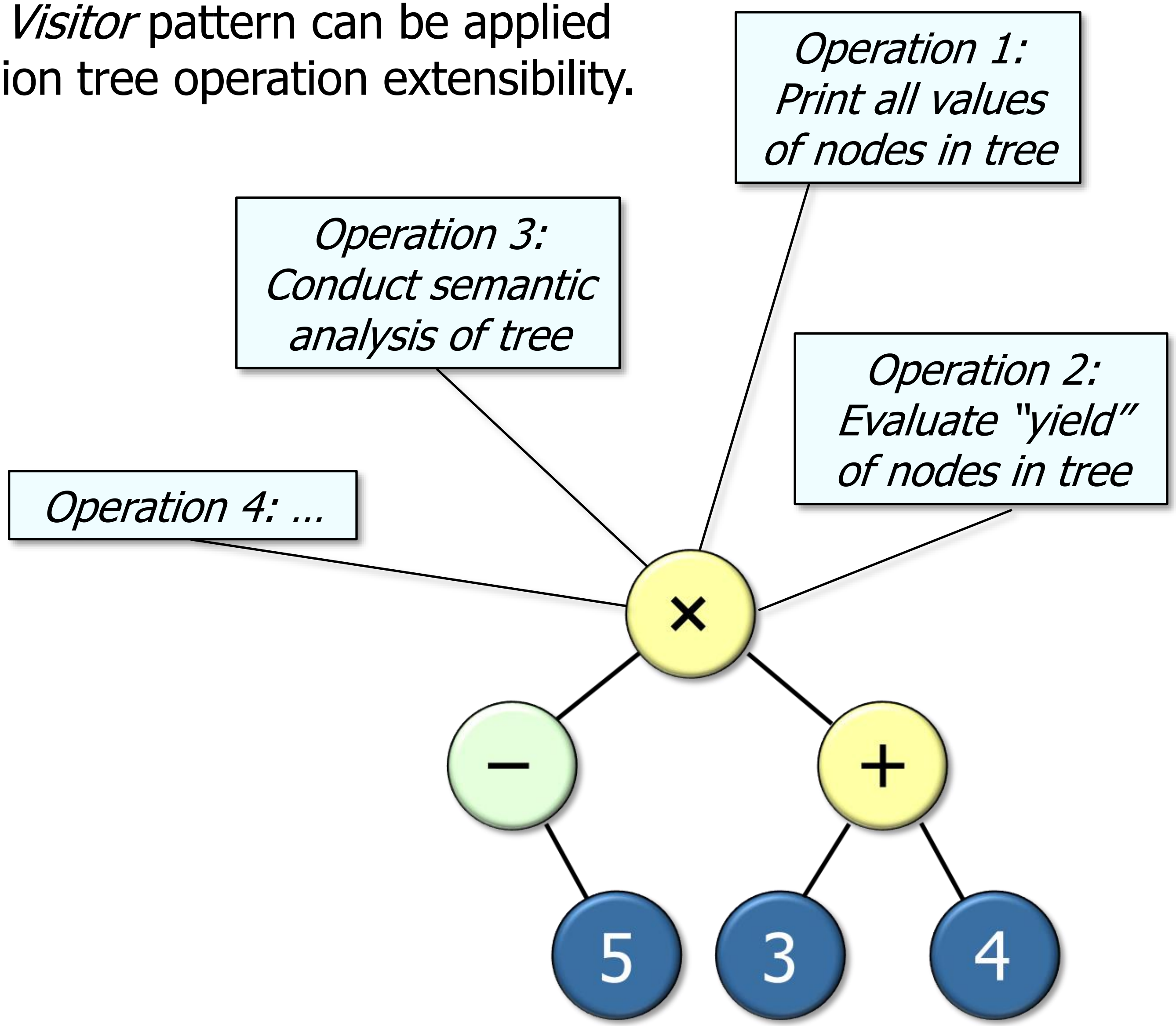
The Visitor Pattern

Motivating Example

Douglas C. Schmidt

Learning Objectives in This Lesson

- Recognize how the *Visitor* pattern can be applied to enhance expression tree operation extensibility.



Operation 1: Print all values of nodes in tree

Operation 2: Evaluate "yield" of nodes in tree

Operation 3: Conduct semantic analysis of tree

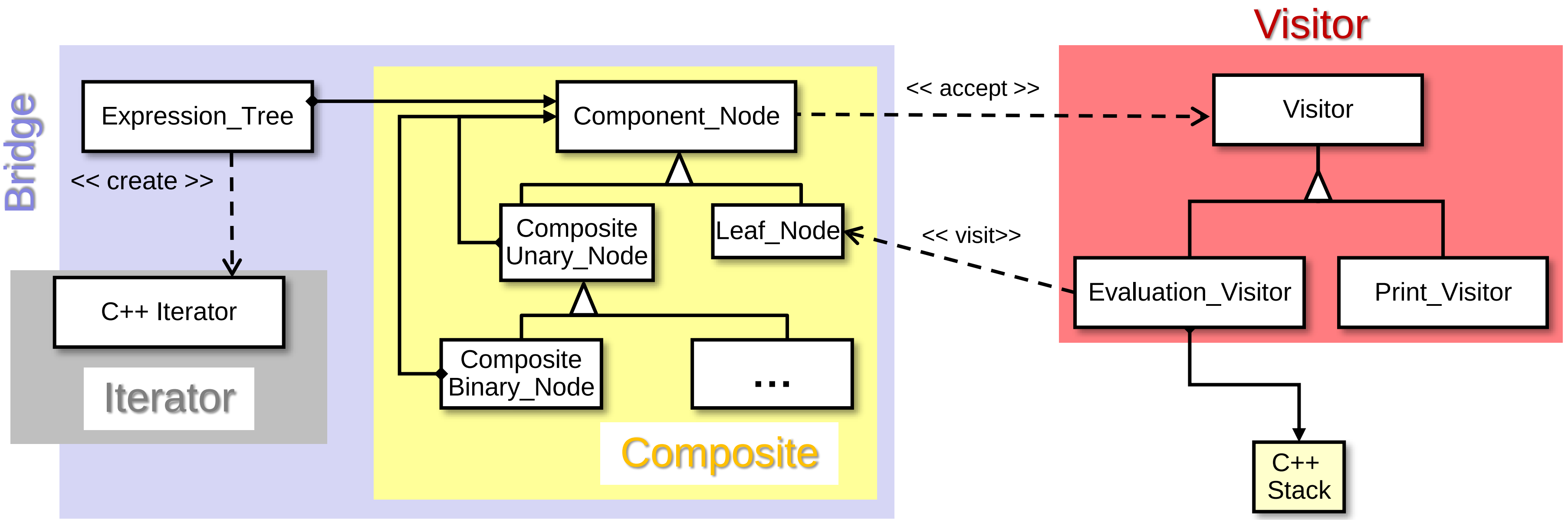
Operation 4: …

Douglas C. Schmidt

Motivating the Need for the Visitor Pattern in the Expression Tree App

A Pattern for Applying Operations on a Composite

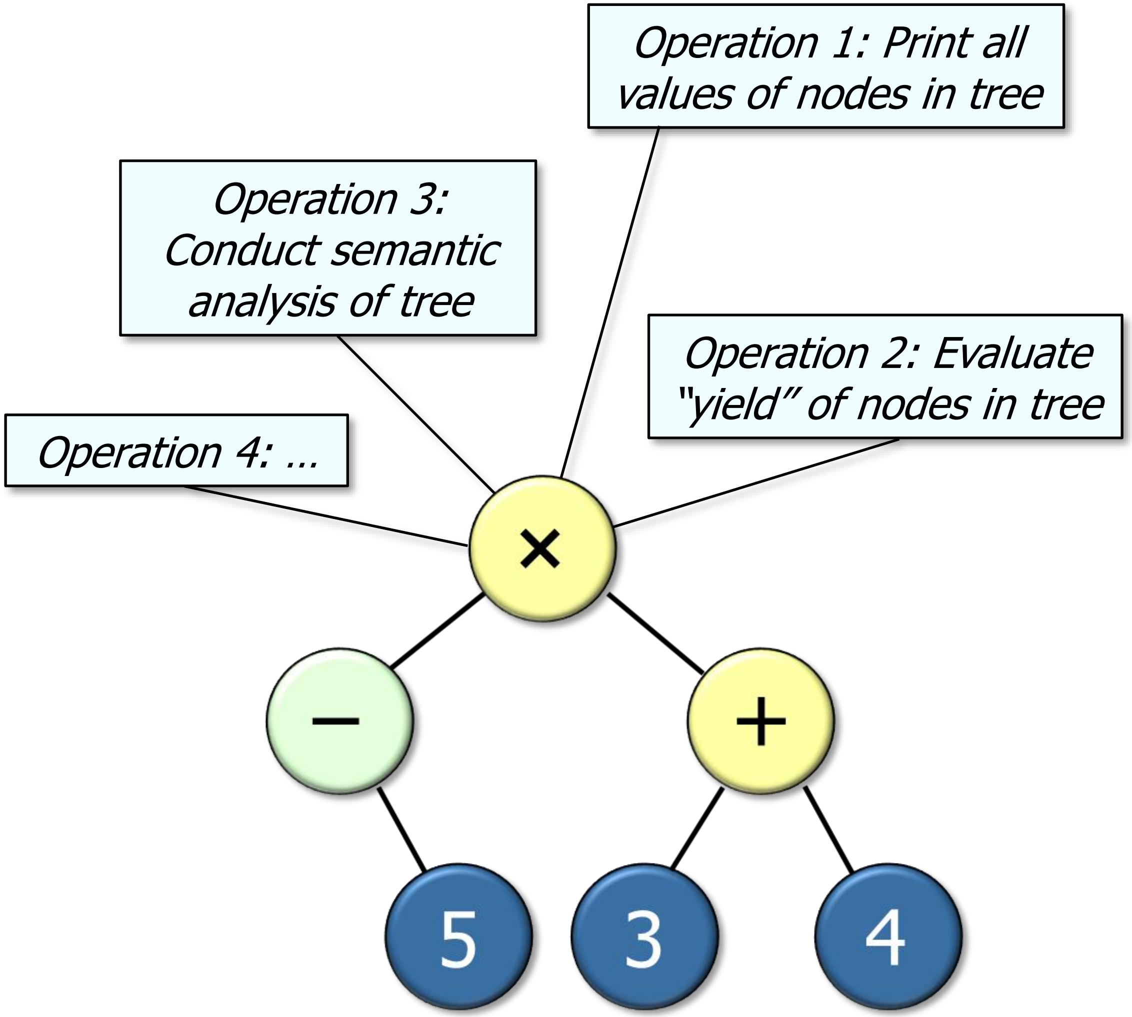
***Purpose**: Perform an extensible set of operations on an expression tree without requiring any changes to the tree itself.*



Visitor decouples expression tree structure from operations performed on it.

Context: OO Expression Tree Processing App

- Adding new operations to an expression tree should require no changes to the tree's structure & implementation.



Operation 1: Print all values of nodes in tree

Operation 3: Conduct semantic analysis of tree

Operation 2: Evaluate "yield" of nodes in tree

Operation 4: …

Problem: Non-Extensible Tree Operations

- Hard-coding operations in **`Expression_Tree`** or in **`Component_Node`** subclasses limits extensibility.
  - e.g., adding new operations would violate the *Open/Closed Principle* since the **`Expression_Tree`** class API would change.

```
class Expression_Tree {
…
  Expression_Tree
        (Component_Node *root):
                  : root_(root) {
   }
   …

  void print();
  int evaluate();
   …
}
```

See en.wikipedia.org/wiki/Open/closed_principle

Problem: Non-Extensible Tree Operations

- Hard-coding dynamic_cast to access Expression_Tree nodes limits extensibility.

```
Expression_Tree expr_tree = ...;

cout << "Tree contents:" << endl;

for (auto iter = tree.begin(order);
     iter != tree.end(order);
     ++iter) {
   Expression_Tree node = *iter;
   if (dynamic_cast<Leaf_Node *> (node.get_root())
     cout << (int) node.item() + " ";
   else
     cout << (char) node.item() + " ";
}
```

See earlier lesson on “*The Iterator Pattern: Implementation in C++*”

Problem: Non-Extensible Tree Operations

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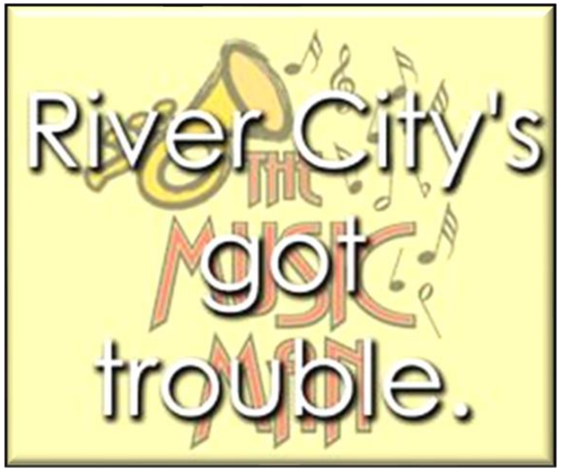
}
```

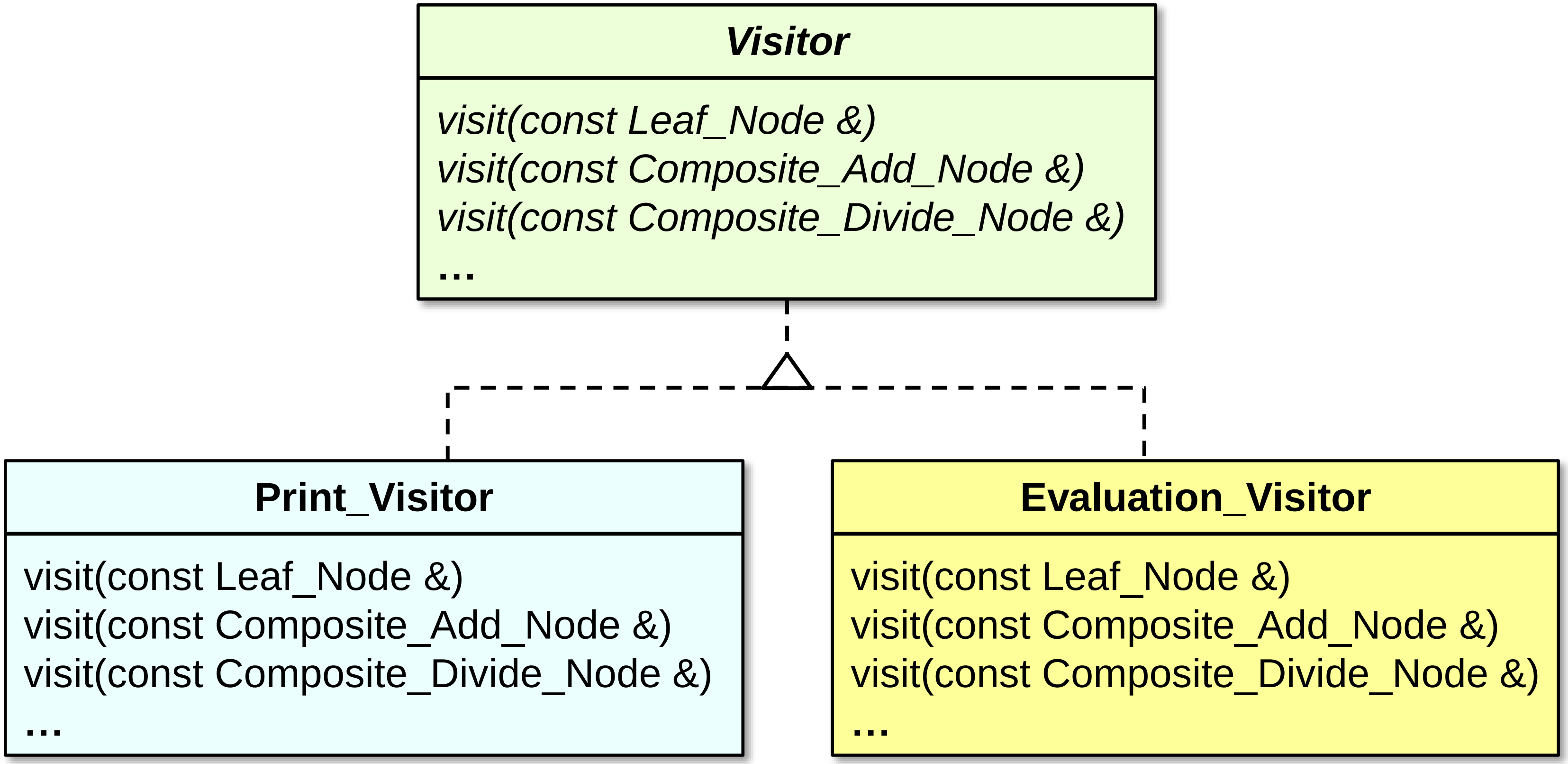
Code like this will cause trouble at some point since dynamic downcasting leads to maintainability & readability concerns.



See www.aristeia.com/EC3E/3E_item27.pdf

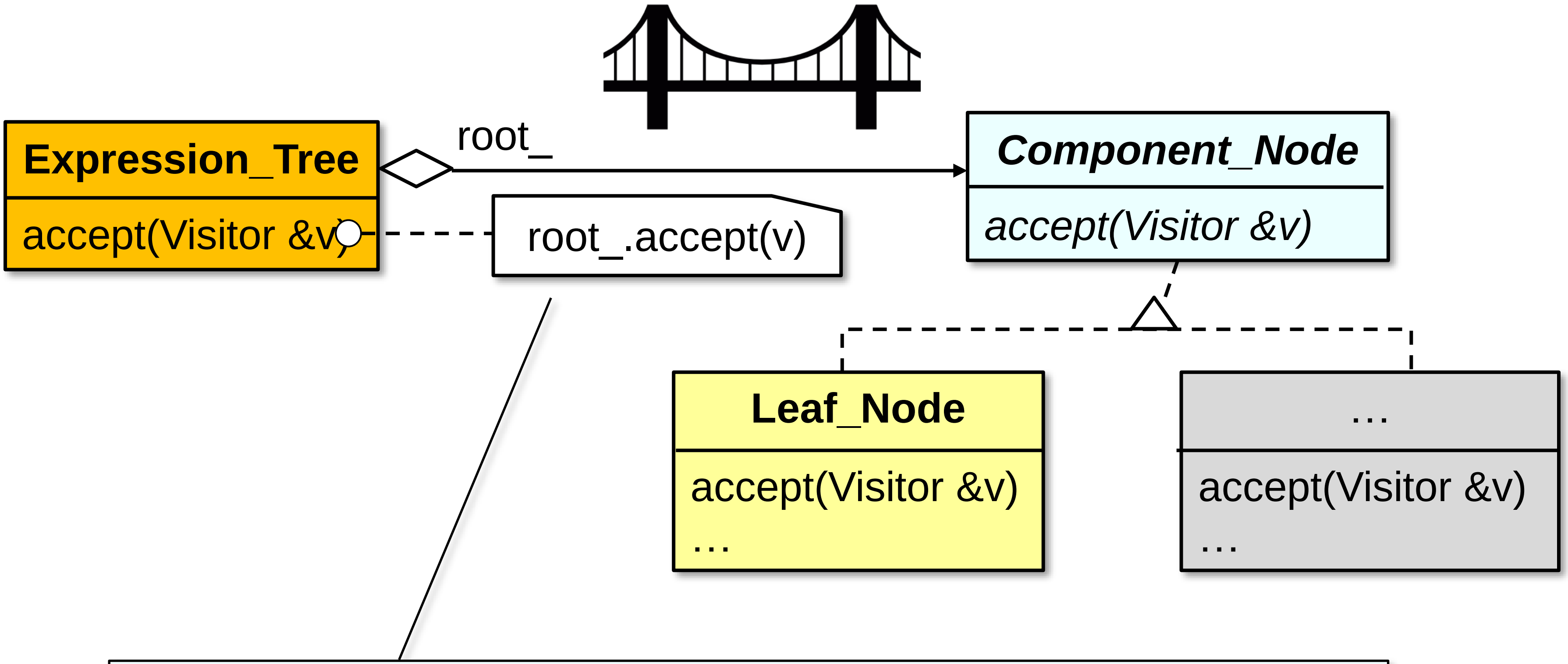
Solution: Decouple Operations From Structure

- Create a hierarchy of visitors that define overloaded **`visit()`** methods to perform operations on each expression tree node implementation.


Visitor
visit(const Leaf_Node &)
visit(const Composite_Add_Node &)
visit(const Composite_Divide_Node &)
…
Print_Visitor
visit(const Leaf_Node &)
visit(const Composite_Add_Node &)
visit(const Composite_Divide_Node &)
…
Evaluation_Visitor
visit(const Leaf_Node &)
visit(const Composite_Add_Node &)
visit(const Composite_Divide_Node &)
…

Solution: Decouple Operations From Structure

- Define an **`accept()`** method in the **`Expression_Tree`** class API that is passed an instance of a visitor implementation.



Expression_Tree

accept(Visitor &v)

root_

root_.accept(v)

Component_Node

accept(Visitor &v)

Leaf_Node

accept(Visitor &v)

…

…

accept(Visitor &v)

…

The ***`accept()`*** *method on* ***`Expression_Tree`*** *forwards to the* ***`accept()`*** *method in the* ***`Component_Node`*** *implementation.*

See earlier lesson on “*The Bridge Pattern: Motivating Example*”

Solution: Decouple Operations From Structure

- During an iteration over the expression tree call **`accept()`** on each node & pass in the visitor instance, e.g.,

```
Visitor &print_visitor = visitor_factory.make_visitor("print");
```

Use a factory method to create a print visitor

```
Expression_Tree tree = make_expression_tree("-5 * (3 + 4)");



for(auto it = tree.begin("post-order");
    it != tree.end("post-order");
    ++it)
  it->accept(print_visitor);
```

See earlier lesson on "*The Factory Method Pattern*"

Solution: Decouple Operations From Structure

- During an iteration over the expression tree call `accept()` on each node & pass in the visitor instance, e.g.,

```
Visitor &print_visitor = visitor_factory.make_visitor("print");
```

```
Expression_Tree tree = make_expression_tree("-5 * (3 + 4)");
```

Apply a Creational pattern to make an expression tree

```
for(auto it = tree.begin("post-order");
    it != tree.end("post-order");
    ++it)
  it->accept(print_visitor);
```

See earlier lessons on "*The Interpreter Pattern*" & "*The Builder Pattern*"

Solution: Decouple Operations From Structure

- During an iteration over the expression tree call **`accept()`** on each node & pass in the visitor instance, e.g.,

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Visitor &print_visitor = visitor_factory.make_visitor("print");



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for(auto it = tree.begin("post-order");
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  it->accept(print_visitor);
```

Apply a Creational pattern to make iterator for an expression tree

See earlier lesson on "*The Factory Method Pattern*"

Solution: Decouple Operations From Structure

- During an iteration over the expression tree call **accept()** on each node & pass in the visitor instance, e.g.,

```
Visitor &print_visitor = visitor_factory.make_visitor("print");



Expression_Tree tree = make_expression_tree("-5 * (3 + 4)");



for(auto it = tree.begin("post-order");
    it != tree.end("post-order");
    ++it)
  it->accept(print_visitor);
```

The ***accept()*** *method on* ***Expression_Tree*** *forwards to the* ***accept()*** *method in the* ***Component_Node*** *implementation.*

Solution: Decouple Operations From Structure

- Have **accept()** call back to the **visitor.visit()** method, passing in the corresponding node in the expression tree to perform the operation, e.g.,

```
class Leaf_Node : public Component_Node {
  void accept(Visitor &visitor)
    visitor.visit(*this);
  }
...
```

This indirection & "double dispatching" avoids hard-coding operations into expression tree nodes & also eliminates the need for downcasts.

en.wikipedia.org/wiki/Double_dispatch has more info on double dispatching.

Solution: Decouple Operations From Structure

- Have **`accept()`** call back to the **`visitor.visit()`** method, passing in the corresponding node in the expression tree to perform the operation, e.g.,

```
class Leaf_Node : public Component_Node {
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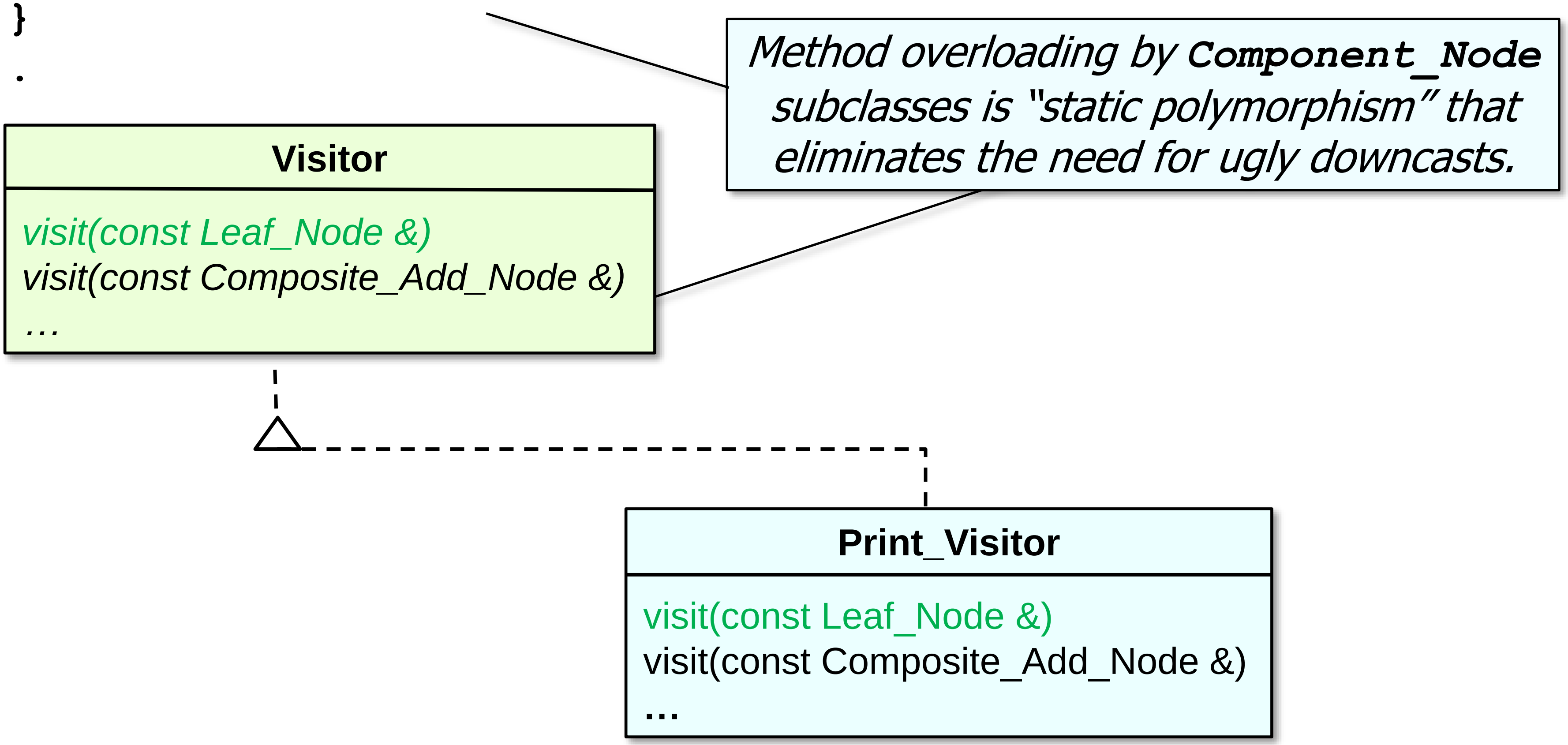

*Method overloading by **`Component_Node`** subclasses is "static polymorphism" that eliminates the need for ugly downcasts.*

Visitor

visit(const Leaf_Node &)
visit(const Composite_Add_Node &)
…

Print_Visitor

visit(const Leaf_Node &)
visit(const Composite_Add_Node &)
…

See mrbool.com/static-polymorphism-in-java/29706

Visitor Abstract Base Class Overview

- Specifies an extensible set of operations that can be performed on each subclass of `Component_Node` in an expression tree

Class methods

```
virtual void  visit(const Leaf_Node &) = 0
virtual void  visit(const Composite_Negate_Node &) = 0
virtual void  visit(const Composite_Add_Node &) = 0
virtual void  visit(const Composite_Subtract_Node &) = 0
virtual void  visit(const Composite_Divide_Node &) = 0
virtual void  visit(const Composite_Multiply_Node &) = 0
```

Visitor Abstract Base Class Overview

- Specifies an extensible set of operations that can be performed on each subclass of `Component_Node` in an expression tree

Class methods

An overloaded visit() method is defined by each subclass of `Component_Node`.

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```
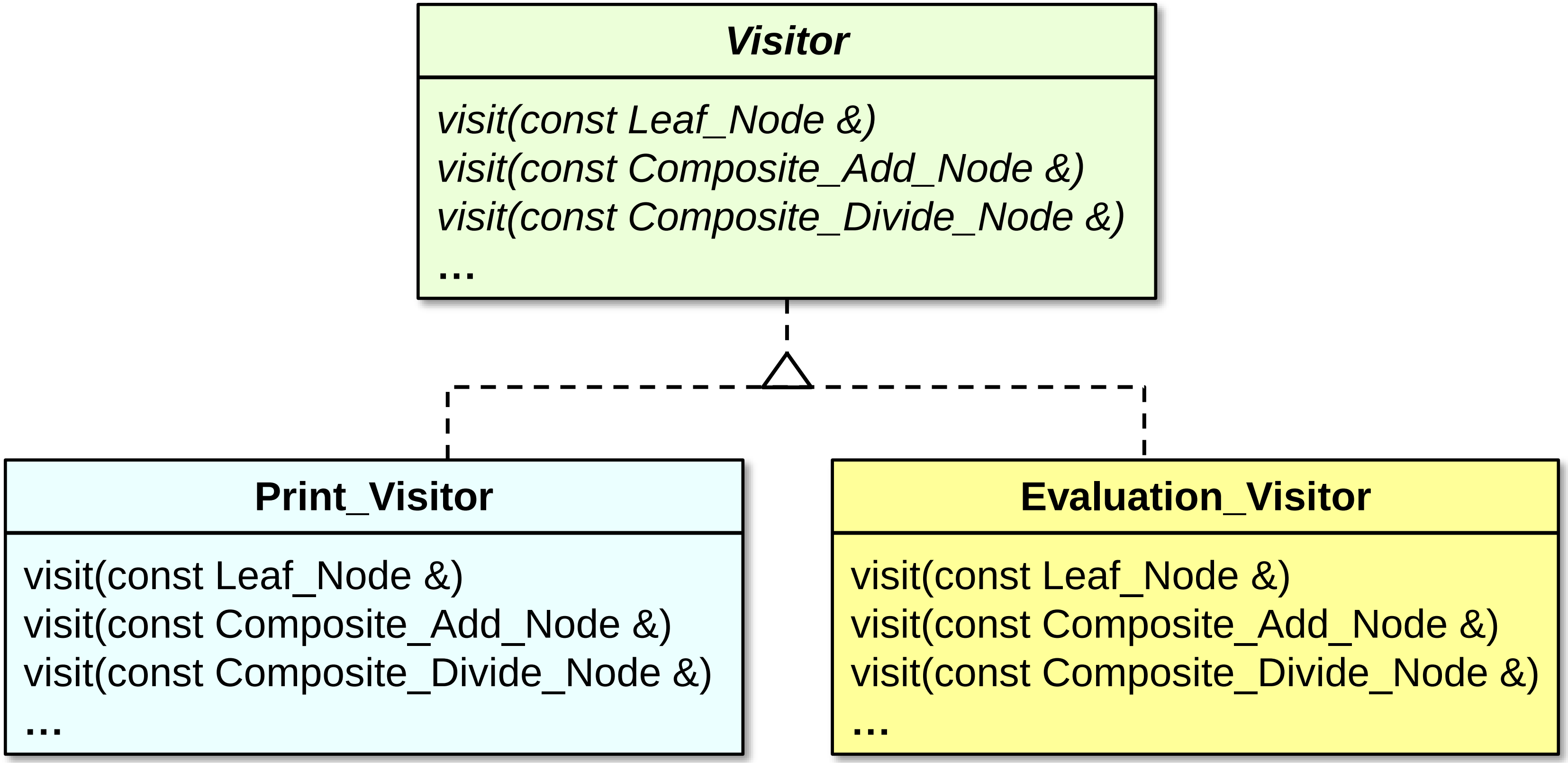

- **Commonality**: provides a common set of `visit()` methods, one for each subclass of `Component_Node`
- **Variability**: Subclasses of this interface define specific behaviors for different types of visitors

Visitor Implementation Hierarchy Overview

- A class hierarchy that defines operations performed on implementations of **`Component_Node`** in an expression tree



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visit(const Composite_Divide_Node &)
…
Evaluation_Visitor
visit(const Leaf_Node &)
visit(const Composite_Add_Node &)
visit(const Composite_Divide_Node &)
…

`Visitor` *subclsses* define operations rather than the **`Expression_Tree`** API.