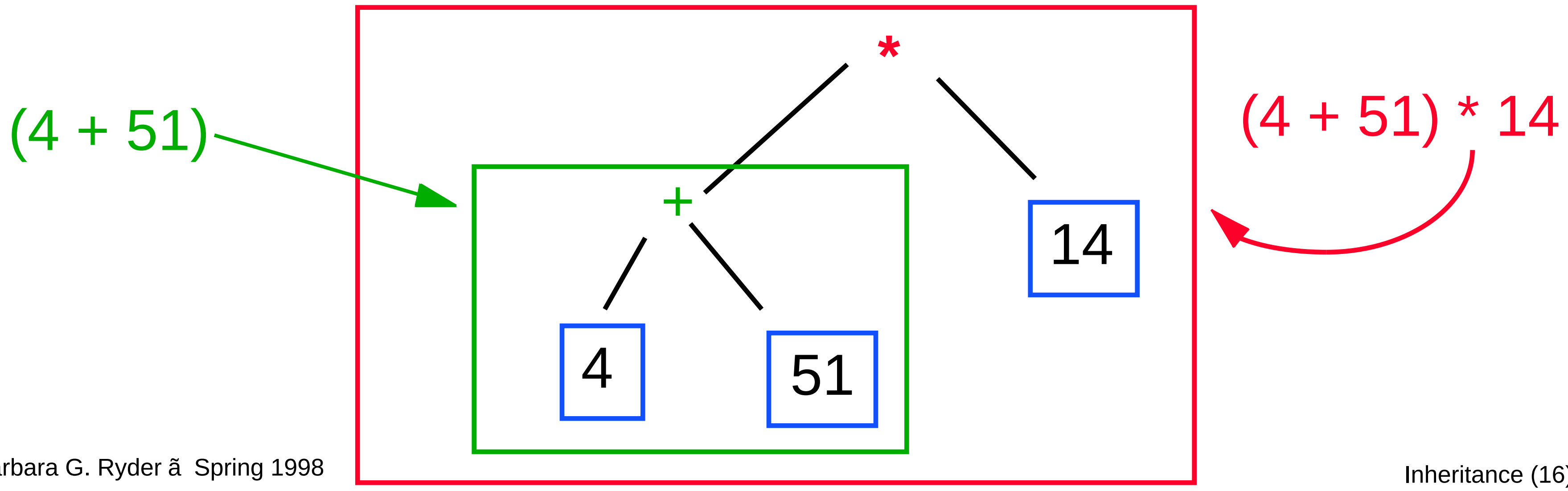
Inheritance - Assignment5

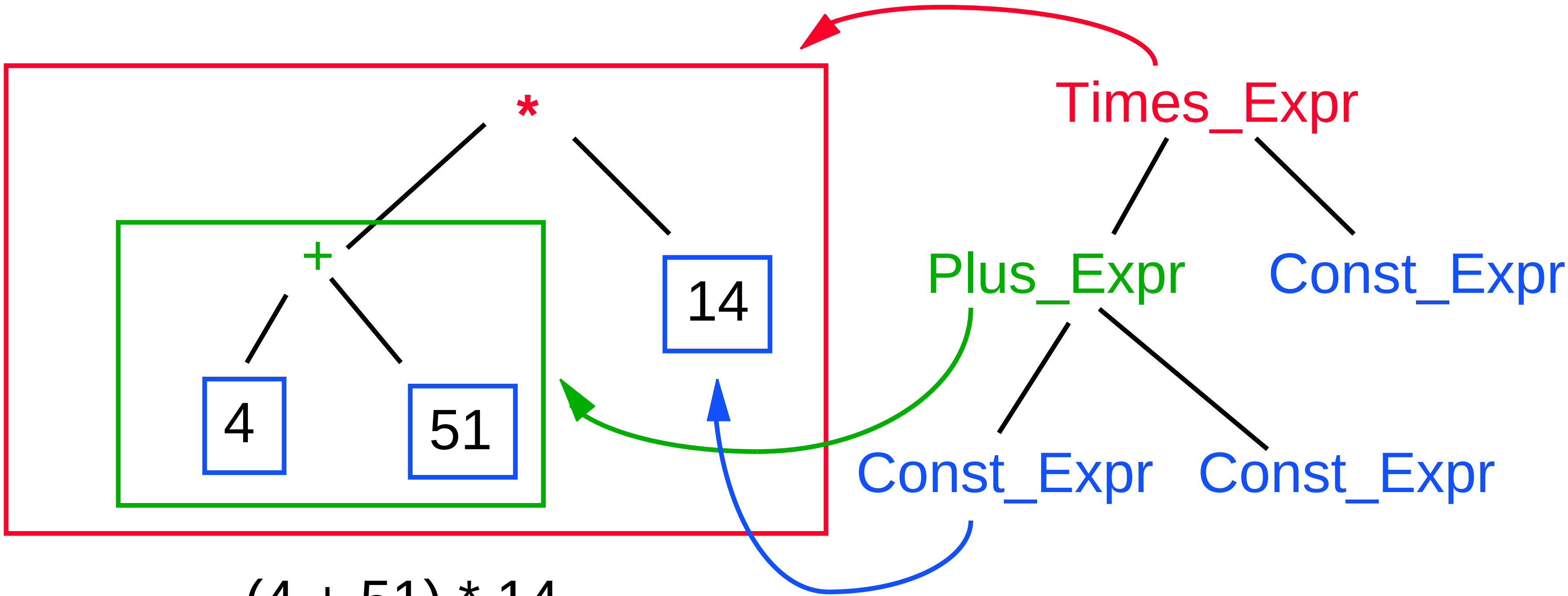
- **Expr objects**
  - **What they look like?**
- **Inheritance hierarchy**
  - **Inheriting instance variables and methods**
    - **How to do method lookup?**
    - **Polymorphism**
  - **Abstract classes**
- **Complex objects**
  - **Recursive methods**
  - **Structural equality**

Expr Objects

- **Examples of expressions**
  - **1, 2 + 3, (4 + 51) * 14, 16 - 1, -3, -(6 - 4)**
- **Operators: +, -, *, /, % (unary minus)**
  - **Each operator takes one or two Expr operands**
  - **Can be simple constants (e.g., 1, 50, 3) or subexpressions themselves, as %3 or (4 + 51) the first operand in (4 + 51) * 14 (see below)**



Expr Objects - Structure



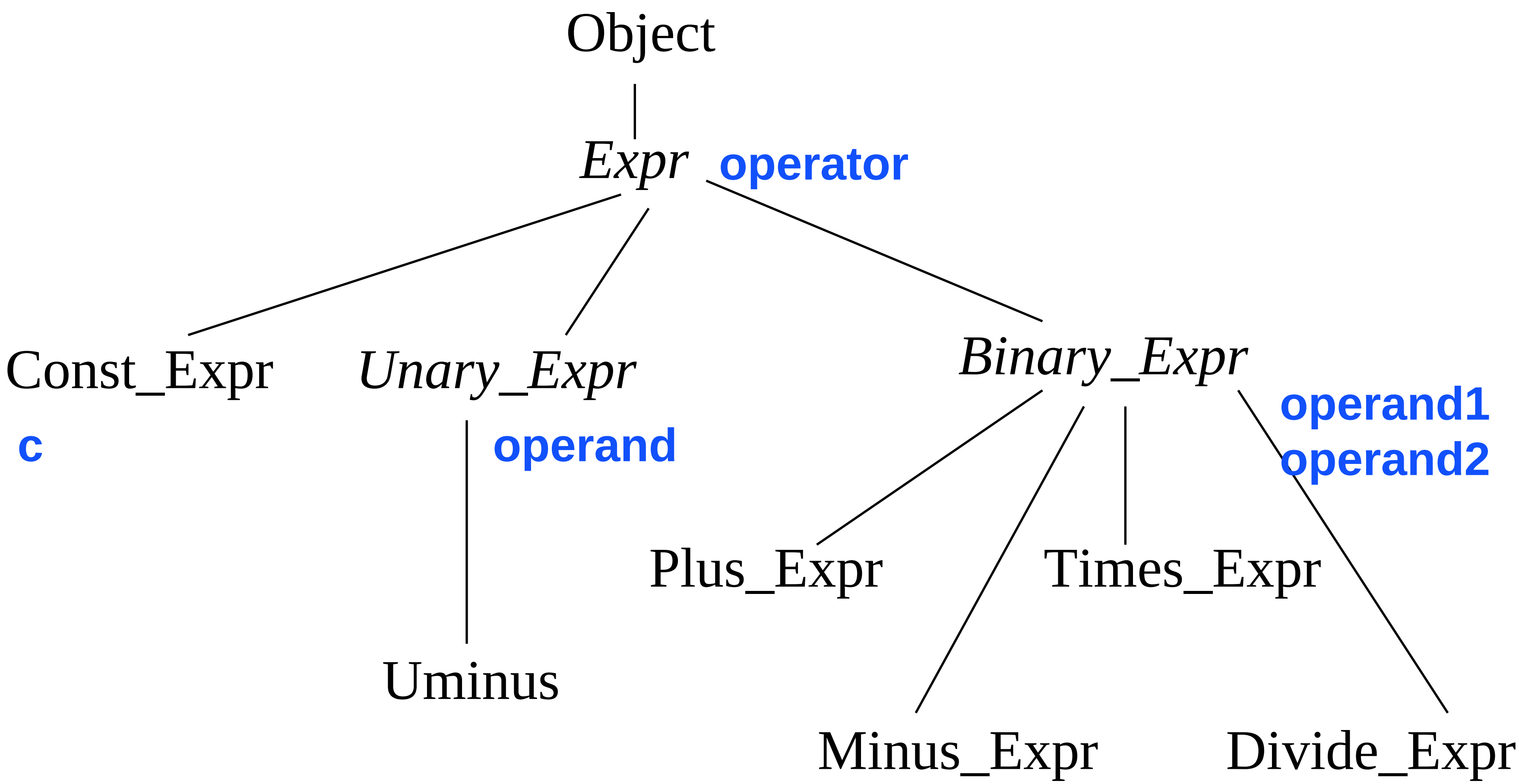
(4 + 51) * 14

Times_Expr (Plus_Expr (Const_Expr,Const_Expr),Const_Expr)

operand1

operand2

Inheritance Hierarchy - Instance Variables



Inheriting Instance Variables

- **A Times_Expr object consists of an operator (in Expr), and operand1, operand2 (in Binary_Expr)**

operator	**Must be initialized in Expr**
operand1 operand2	**Must be initialized in Binary_Expr**

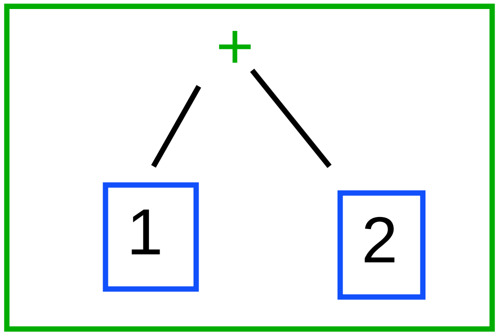
Every Times_Expr object is also a Binary_Expr object and an Expr object, since Times_Expr class extends Binary_Expr and Binary_Expr class extends Expr

Example I : 1 + 2

Plus_Expr object:

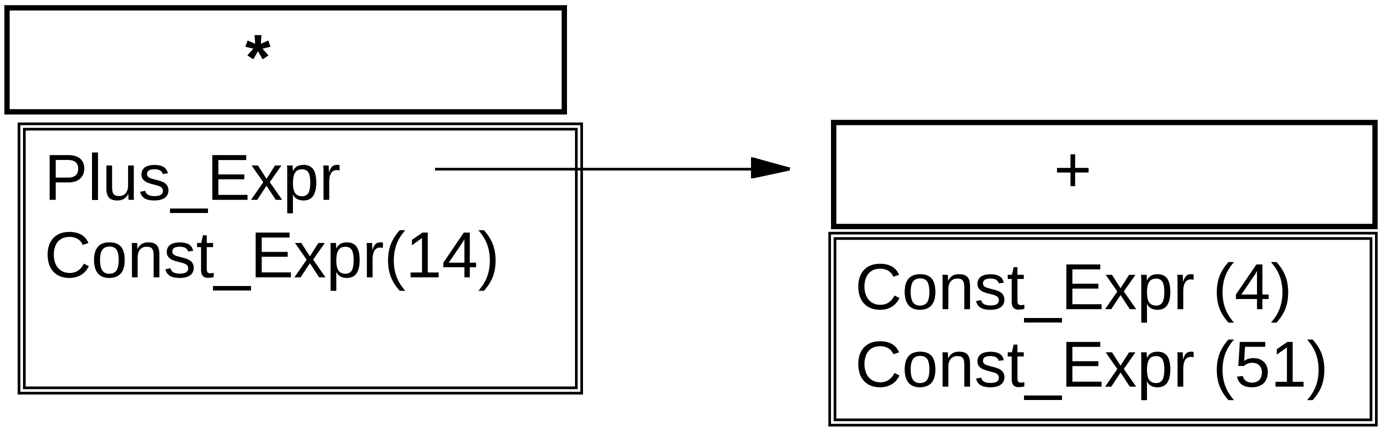
operator	+
operand1 operand2	Const_Expr(1) Const_Expr(2)

or pictorially:

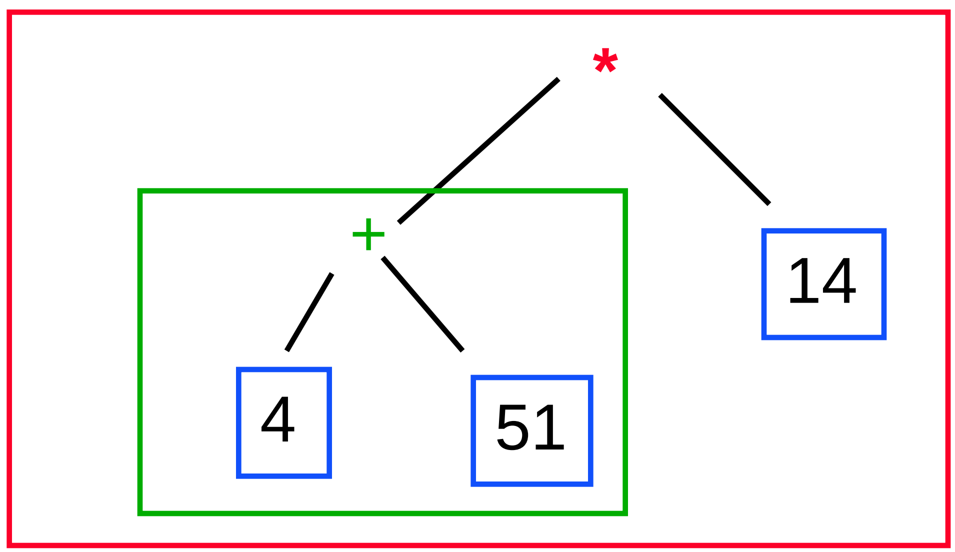


Example II : (4 + 51) * 14

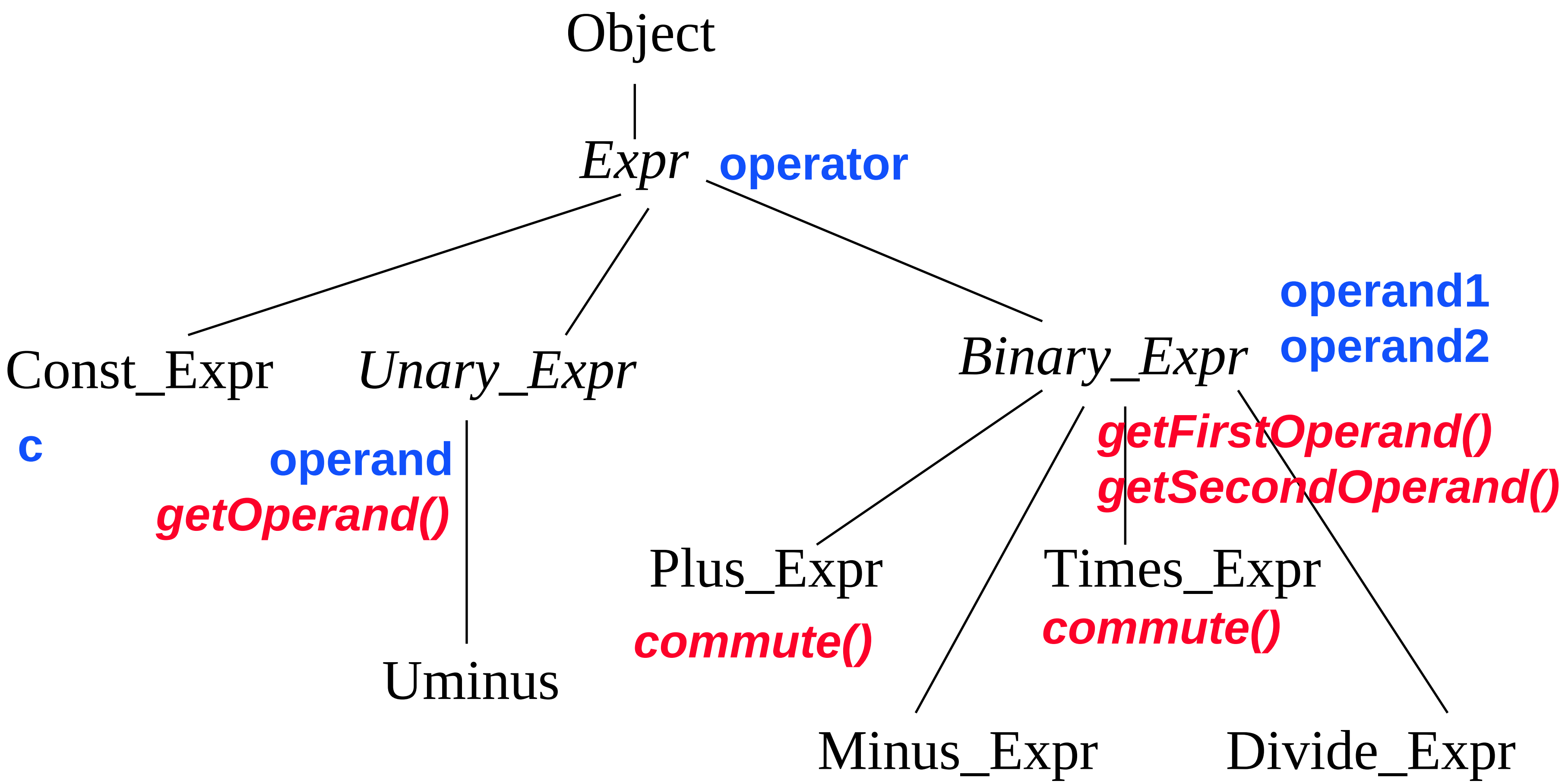
Time_Expr object:



or pictorially:



Inheritance Hierarchy-Inheriting Methods



Inheritance

- Class Times_Expr extends class Binary_Expr which extends class Expr
- If `times` is a Times_Expr object, where do we find methods which can be invoked on `times`?
  - `times.commute()`
  - `times.getFirstOperand(), times.getSecondOperand()`

Method Lookup

- **Without inheritance, method must be in class of receiver**
- **With inheritance, method used is in class of receiver or its “closest” ancestor class**
  - **Method lookup starts in class of receiver and proceeds up the tree until first method of same name is found**
    - `commute()` **is in Times_Expr**
    - `getFirstOperand(),getSecondOperand()` **are in Binary_Expr**

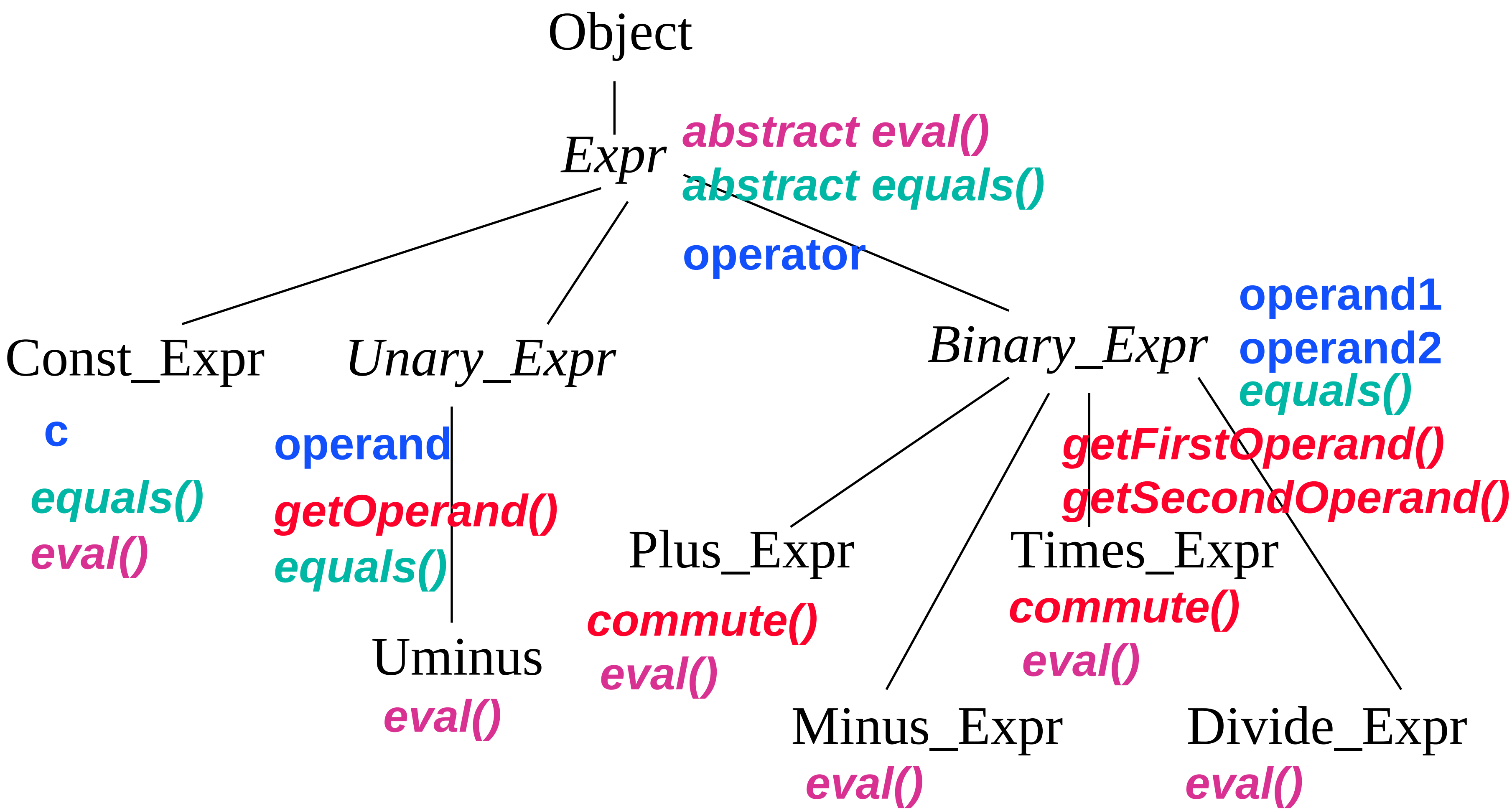
Abstract Classes

- **Can define methods (and implementations) in an abstract class which can be inherited by subclasses**
- **Can also contain instance variables to be inherited by subclasses**
- **Abstract classes in Assignment 5: *Expr, Unary_Expr, Binary_Expr***
  - **Non-abstract classes are at leaves of the Expr inheritance tree**

Abstract Classes

- **Useful when you want to define only part of an implementation**
- **Abstract classes**
  - **Abstract methods are signatures of promised methods to be provided in subclasses of the abstract class**
    - **Can provide these through definition or inheritance**
  - **No objects can be created as instances of an abstract class**
    - **Because abstract method implementations don't exist**

Assignment 5: Expressions



Eval( )

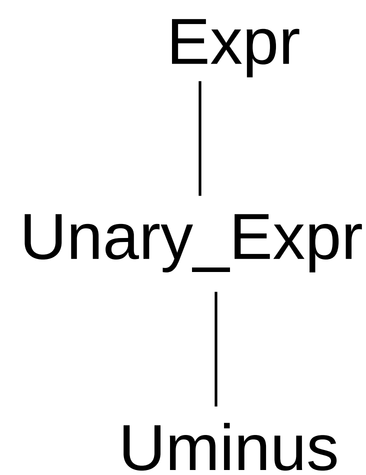
- Abstract in Expr, only signature provided
- Implementation provided in Const_Expr, Plus_Expr, Times_Expr, Minus_Expr, Divide_Expr
- Provides a way to evaluate an Expr object

Constructors with Inheritance

- **With inheritance, within a constructor for a subclass object, constructors for the superclass are implicitly called by system**
- **If instance variable data needs initialization in a superclass, can use `super` to explicitly call constructor of superclass with initialization values**

Constructors - Example

```
public abstract class Expr extends Object
{ Expr(String s)//constructor
  { operator = s; }
}
public abstract class Unary_Expr
{    Unary_Expr(Expr e, String s)
  {  super(s); operand = e;}
}
public class Uminus
{    Uminus (Expr e, String s)
  {  super(e,s); }
```



Uminus u = new Uminus (new Const_Expr(3),"%")

Super

- **Super acts as a reference to an object as an instance of its superclass**
- **The reference to super in the Unary_Expr class constructor, means call the Expr constructor with argument String s.**
  - **Implicitly, when a subclass object is created, the constructor of the superclass is called before anything else is done in the subclass constructor**
  - **If arguments are needed, super(<args>) is used to call the superclass constructor explicitly.**

Objects

- Simple objects have instance variables of primitive types
- Complex objects have instance variables which themselves are objects
  - e.g., Expr objects with instance variables that are other Expr objects
  - Why needed? allows for all possible kinds of subexpressions:

    1 + 2, 1 + (3 + 4), 1 + (2 * 5), 1 + %4, etc.
- Requires us to define operands as Expr's

Equals( )

- **Tests structural equality**
  - **Two Expr objects are *structurally equal* if their operand(s) are structurally equal and they have the same operator**
  - **i.e., Plus_Expr objects can only be equal to other Plus_Expr objects**
  - **e.g., 2 + 1 is equal to 2 + 1, but not to 1 + 2;**

  2*3 + 4 is equal to (2*3) + 4, but not to (2*2)+6
- **Provided by inheritance for all kinds of binary or unary expressions, defined in Const_Expr**

Equals( )

- **Equals( ) is example of a useful recursive function on Expr objects**
- **Const_Expr objects are equal to other Const_Expr objects representing the same integer value**
  - **2 equals 2, 2 not equal to 5**
- **Unary_Expr objects are equal only to other Unary_Expr objects, if their operands are equal and their operator is the same**
  - **%1 equal to %1 but not equal to %(1*1)**

Equals( )

- **Binary_Expr objects are equal if both are Binary_Expr objects, their first operands are equal, their second operands are equal and their operators are equal**
- **Remember this is *structural equality* NOT equal in value (such as 1 + 3 and 5 + %1)**
- **Can think of it as “sliding” one expression tree over another and “matching” shape and nodes**
- **Example of polymorphism, where a function can take parameters of different types**

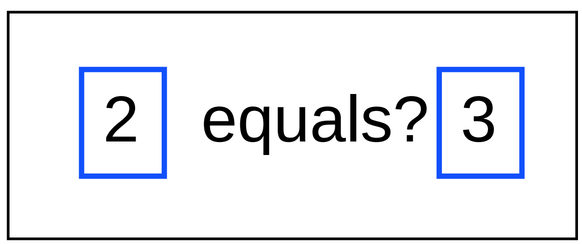
Equals( )

in Const_Expr:

```
public boolean equals(Expr other)
{ if (!(other instanceof Const_Expr)) return false;
  else return (this.c == (other.eval()));
}
```

instanceof is a way of checking the runtime class membership of an object. red expression returns true when other is a Const_Expr object and false otherwise;

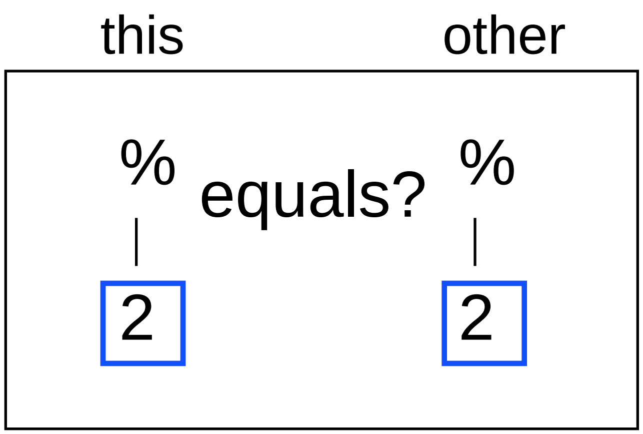
method checks that other is a Const_Expr object and if so, checks its value versus the value of the receiver object

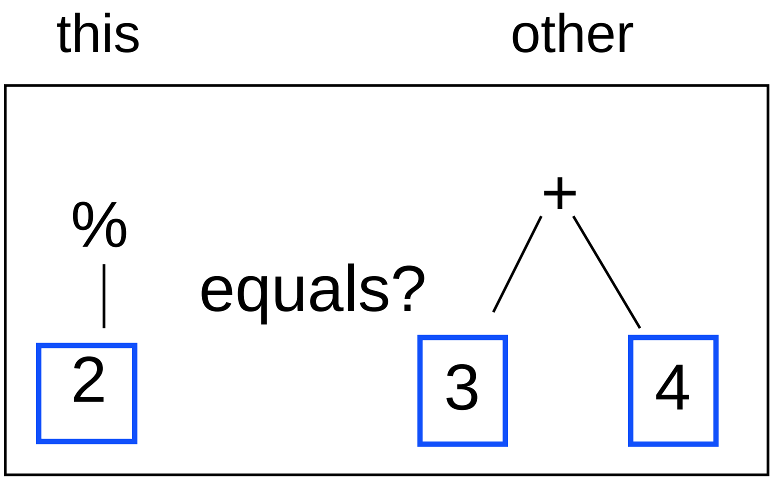


Equals( )

in Unary_Expr:

```
public boolean equals(Expr other)
{ if (!(other instanceof Unary_Expr)) return false;
  else if
   ((other.getOperator()).equals(this.getOperator()) &&
   (operand.equals(((Unary_Expr)other).getOperand()))
              return true;
  else return false;
}
```





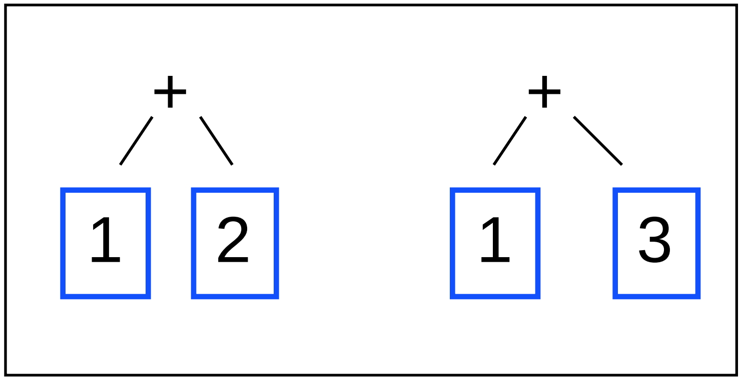
Equals( )

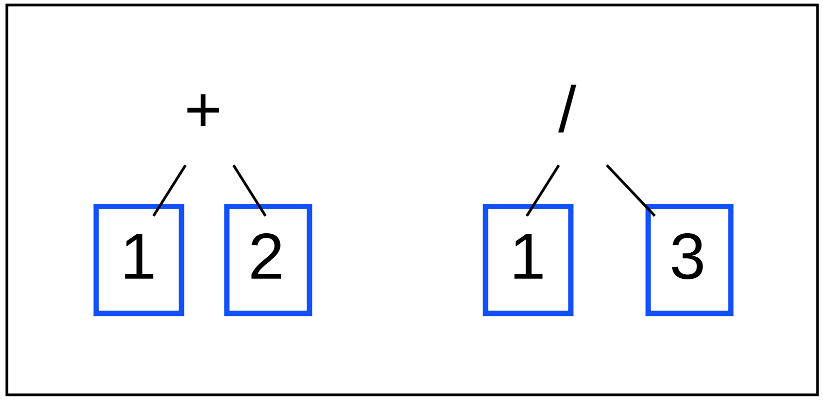
other can be a Const_Expr, Plus_Expr, Times_Expr, Divide_Expr, Minus_Expr, or Uminus

in Binary_Expr:

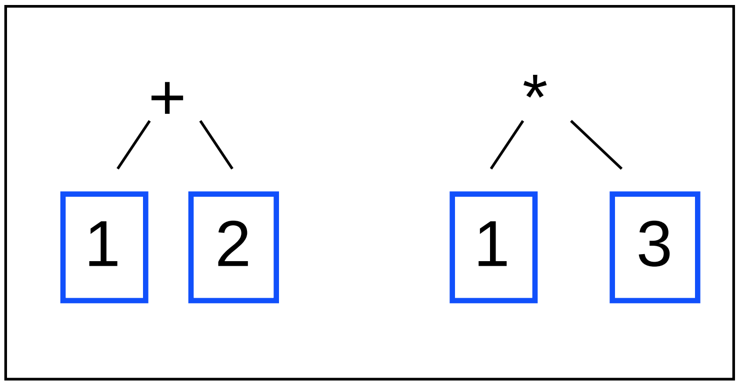
```
public boolean equals(Expr other)
{ if  (!(other instanceof Binary_Expr)) return false;
  else if
   (!(this.getOperator().equals(other.getOperator())))
      return false;
  else return
         ((this.getFirstOperand().equals(
            ((Binary_Expr)other).getFirstOperand()))
               &&
         (this.getSecondOperand().equals(
            (Binary_Expr)other).getSecondOperand()));
}
```

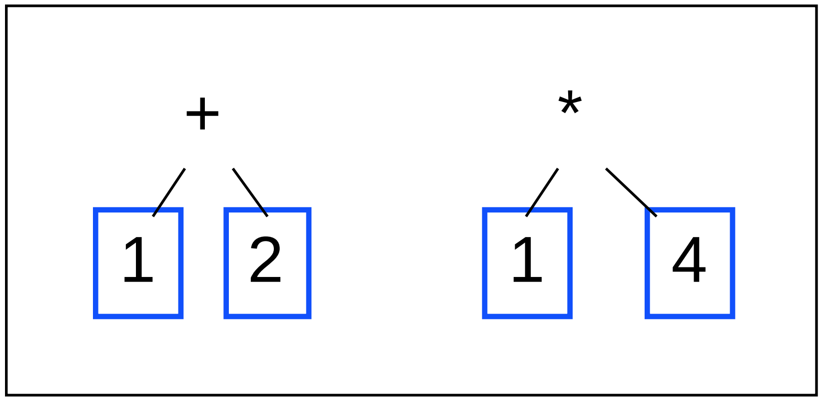
Equals( ) in Binary_Expr





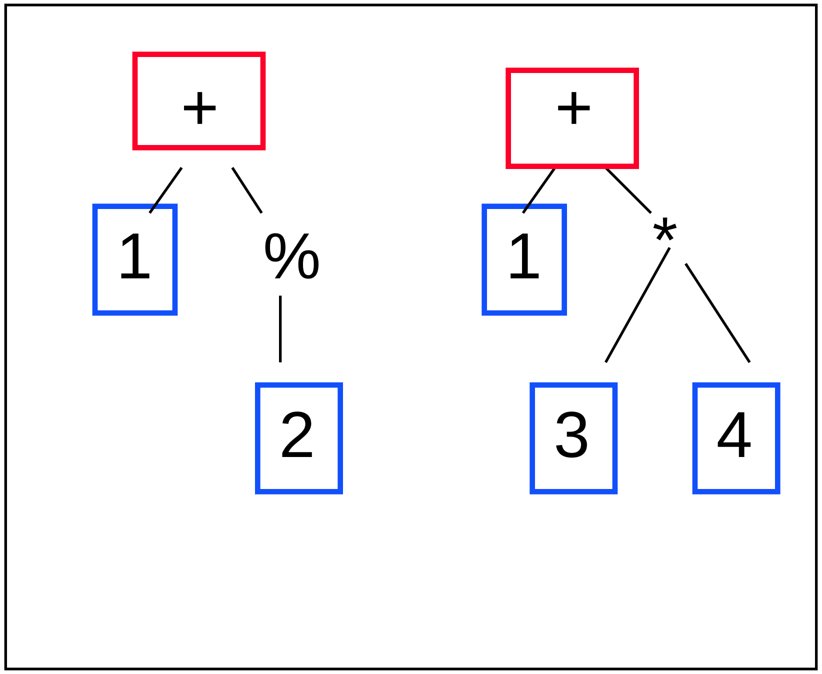
equals?

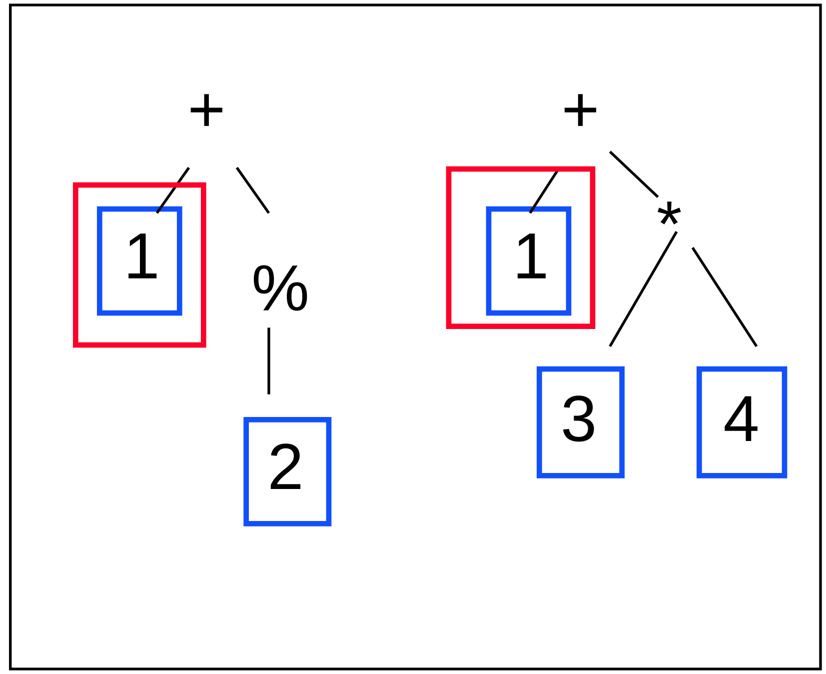




equals?

Equals( ) in Binary_Expr

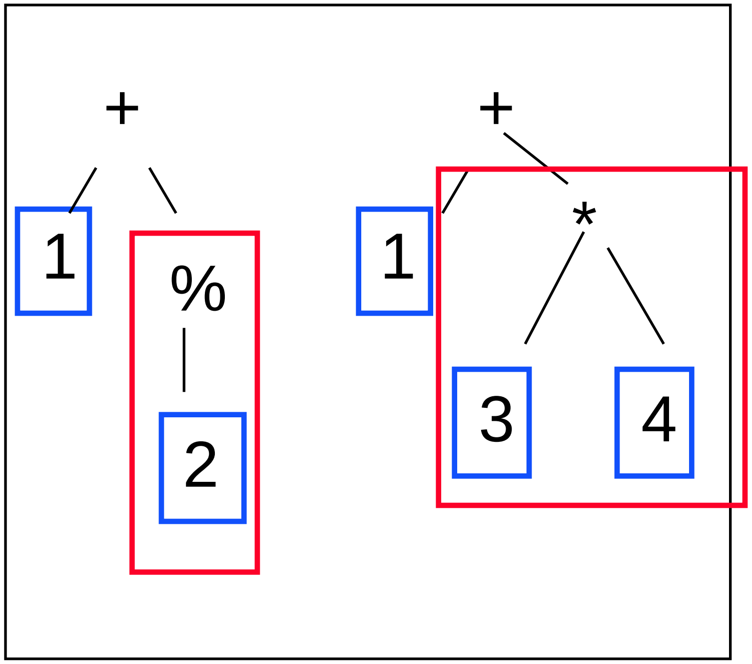




1. see both are Binary_Expr's then check operators same

2. check first operands same through call which in this case calls equals in Const_Expr

Equals( ) in Binary_Expr



Methods we called in example (in order):

equals() in Binary_Expr
getOperator()
getFirstOperand()
equals() in Const_Expr
getSecondOperand()
equals() in Binary_Expr

3. check second operands
through call to equals() in Unary_Expr.
returns false since 2nd Expr is not unary!