OBJECT ORIENTED PROGRAMMING USING C++

Overloading, Overriding

POLYMORPHISM

poly	morphos
many	forms

- Overloading – single method name having several alternative implementations.

- Overriding – child class provides alternative implementation for parent class method.

- Polymorphic variable – a variable that is declared as one type but holds a value of a different type.

Polymorphic Variable

Example :

```
Class Shape {
…
}

Class Triangle extends Shape {
…
}
Shape s = new Triangle;
```

- Java – all variables can be polymorphic.
- C++ – only pointers and references can be polymorphic.

Method Binding

- Determining the method to execute in response to a message.
- Binding can be accomplished either statically or dynamically.

Static Binding –

- Also known as "*Early Binding*".
- Resolved at compile time.
- Resolution based on static type of the object(s).

Dynamic Binding –

- Also known as "*Late Binding*".
- Resolved at run-time.
- Resolution based on the dynamic type of the object(s).
- Uses method dispatch table or Virtual function table.

Method Binding Example

```
Class Shape {
public:
virtual void Draw() { cout << “Shape Draw!” << endl; }
}

Class Triangle : public Shape {
public:
void Draw() { cout << “Triangle Draw!” << endl; }
}

Shape * sptr = new Triangle();
Sptr->Draw();                    // Triangle Draw!
```

Overloading

- **Overloading Based on Scopes**
- **Overloading based on Type Signatures**

Overloading

Overloading Based on Scopes

- same method name in different scopes.
- the scopes cannot overlap.
- No restriction on semantic similarity.
- No restriction on type signatures.
- Resolution of overloaded names based on class of receiver.

Example

```
Class SomeCards {
  Draw() {…}   // Paint the face of the card
}

Class SomeGame {
  Draw() {…}   // Remove a card from the deck of cards
}
```

Overloading

Overloading Based on Type Signatures

- same method name with different implementations having different type signatures.
- Resolution of overloaded names is based on type signatures.
- Occurs in object-oriented languages (C++, Java, C#, Delphi Pascal)
- Occurs in imperative languages (Ada), and many functional languages.

```
Class Example {
  Add(int a) { return a; }
  Add(int a, int b) { return a + b; }
  Add(int a, int b, int c) { return a + b + c; }
}
```

- C++ allows methods as well as operators to be overloaded.
- Java does not allow operators to be overloaded.

Overloading and Method Binding

Resolution of Overloaded Methods

- Method binding at compile time.
- Based on static types of argument values
- Methods cannot be overloaded based on differences in their return types alone.

```
Class SomeParent {…}
Class SomeChild : public SomeParent {…}

void Test (SomeParent *sp) { cout << “In Parent”; }
void Test (SomeChild *sc) { cout << “In Child”;}
SomeParent *value = new SomeChild();

Test(value);      // “In Parent”
}
```

Overloading Example

Overloading can be used to extend library functions and operators so they can work with user-defined data types.

```
Class Fraction
private:
  int t, b;

public:
  Fraction (int num, int denum) { t = num; b = denum; }
  int numerator() { return t; }
  int denominator() { return b; }
}

ostream & operator << (ostream & destination, Fraction & source)
{
  destination << source.numerator() << “/” << source.denominator;
  return destination;
}
```

Some Associated Mechanisms

- Coercion and Conversion
- Redefinition
- Polyadicity
- Multi-Methods

Coercion and Conversion

- Used when actual arguments of a method do not match the formal parameter specifications, but can be converted into a form that will match

- Coercion - implicitly implemented

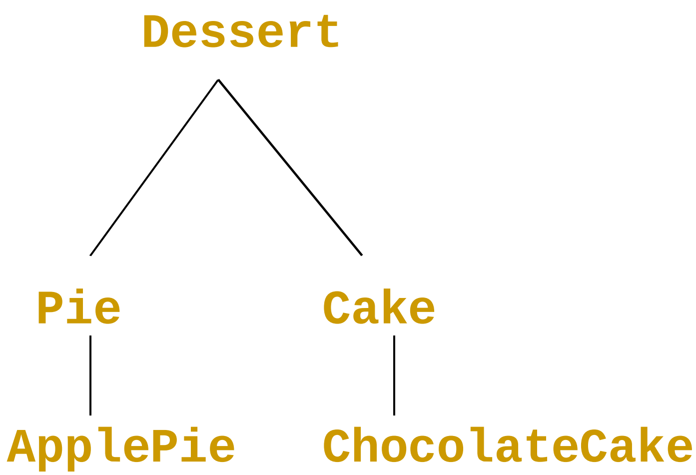
  Example floatvar = intvar;

- Conversion - explicitly requested by the programmer

  Example floatvar = (double) intvar;

Substitution as Conversion

• Used when there is parent-child relationship between formal and actual parameters of a method




```
void order ( Dessert d, Cake c );
void order ( Pie p, Dessert d );
void order ( ApplePie a, Cake c );
```

```
order (aDessert, aCake);
order (anApplePie, aDessert)
order (aDessert, aDessert);            // illegal
order (anApplePie, aChocolateCake)
order (aPie, aCake);
```

Substitution as Conversion

Resolution rules (when substitution is used as conversion in overloaded methods)

- If there is an exact match, execute that method.
- If there are more than one matching methods, execute the method that has the most specific formal parameters.
- If there are two or more methods that are equally applicable, the method invocation is ambiguous, so generate compiler error.
- If there is no matching method, generate compiler error.

Conversion

Conversion operators in C++

(these are the user supplied conversions)

• *One-argument constructor* : to convert from argument type to class type.

```
Fraction (int value)
{
  t = value; b = 1;   // Converts int into Fraction
}
```

• *Operator with type name as its name* : to convert class type to named type.

```
operator double ()
{ // Converts Fraction into double
  return numerator() / (double) denominator;
}
```

Conversion

Rules for Resolution of Overloaded methods

(taking into account all of the various conversion mechanisms)

• execute method whose formal parameters are an exact match for the actual parameters

• match using standard type promotions (e.g. integer to float)

• match using standard substitution (e.g. child types as parent types)

• match using user-supplied conversions (e.g. one-argument constructor, type name operator)

• if no match found, or more than one method matches, generate compiler error

Redefinition

When a child class defines a method with the same name as a method in the parent class but with a *different type signature*.

```
Class Parent {
  public void Test (int a) {…}
}

Class Child extends Parent {
  public void Test (int a, int b) {…}
}

Child aChild = new Child();
aChild.Test(5);
```

How is it different from overrriding?

Different type signature in Child class.

Redefinition

Two approaches to resolution

Merge model

• used by Java, C#

• method implementations found in all currently active scopes are merged into one list and the closest match from this list is executed.

• in the example, parent class method wil be executed.

Hierarchical model

• used by C++

• each currently active scope is examined in turn to find the closest matching method

• in the example, compilation error in Hierarchical model

Delphi Pascal - can choose which model is used

merge model - if overload modifier is used with child class method.

Hierarchical model - otherwise.

Polyadicity

Polyadic method - method that can take a variable number of arguments.

```
printf("%s", strvar);
printf("%s, %d", strvar, intvar);
```

- **Easy to use, difficult to implement**
- ***printf* in C and C++; *writeln* in Pascal; + *operator* in CLOS**

```
#include <stdarg.h>
int sum (int argcnt, …)        // C++ uses a data structure called
{                              // variable argument list
  va_list ap;
  int result = 0;
  va_start(ap, argcnt);
  while (argcnt > 0) {
    result += va_arg(ap, int);
    argcnt--;
  }
  va_end(ap);
  return result;
}
```

Optional Parameters

Another technique for writing Polyadic methods.

- Provide default values for some parameters.
- If values for these parameters are provided then use them, else use the default values.
- Found in C++ and Delphi Pascal

```
AmtDue(int fixedCharge);
AmtDue(int fixedCharge, int fines);
AmtDue(int fixedCharge, int fines, int missc);
```

same as

```
AmtDue(int fixedCharge, int fines = 0, int missc = 0);
```

Multi-Methods

Multi-Methods

- combines the concepts of overloading and overriding.
- Method resolution based on the types of all arguments and not just the type of the receiver.
- Resolved at runtime.

The classes integer and real are derived from the parent class number.

```
function add (Integer a, Integer b) : Integer { … }
function add (Integer a, Real b) : Real { … }
function add (Real a, Integer b) : Real { … }
function add (Real a, Real b) : Real { … }

Number x = … ;          // x and y are assigned some unknown values
Number y = … ;
Real r = 3.14;

Real r2 = add(r, x);   // which method to execute
Real r3 = add(x, y);   // this is not type safe
```

Multi-Methods

Double dispatch

- a message can be used to determine the type of a receiver.

- To determine the types of two values, the same message is sent twice, using each value as receiver in turn.

- Then execute the appropriate method.

Overloading Based on Values

Overloading based on values

- overload a method based on argument values and not just types.
- Occurs only in Lisp-based languages - CLOS, Dylan.
- High cost of method selection algorithm.

Example

```
function sum(a : integer, b : integer) {return a + b;}
function sum(a : integer = 0, b : integer) {return b;}
```

The second method will be executed if the first argument is the constant value zero, otherwise the first method will be executed.

Overriding

A method in child class overrides a method in parent class if they have the same name and type signature.

Overriding

- classes in which methods are defined must be in a parent-child relationship.
- Type signatures must match.
- Dynamic binding of messages.
- Runtime mechanism based on the dynamic type of the receiver.
- Contributes to code sharing (non-overriding classes share same method).

Overriding Notation

C++

```
class Parent {
  public:
    virtual int test (int a) { … }
}
class Child : public Parent {
  public:
    int test (int a) { … }
}
```

C#

```
class Parent {
  public virtual int test (int a) { … }
}
class Child : Parent {
  public override int test (int a) { … }
}
```

Overriding Notation

Java

```
class Parent {
  public int test (int a) { … }
}
class Child extends Parent {
  public int test (int a) { … }
}
```

Object Pascal

```
type
  Parent = object
    function test(int) : integer;
  end;
  Child = object (Parent)
    function test(int) : integer; override;
  end;
```

Overriding

Overriding as Replacement

- child class method totally overwrites parent class method.
- Parent class method not executed at all.
- Smalltalk, C++.

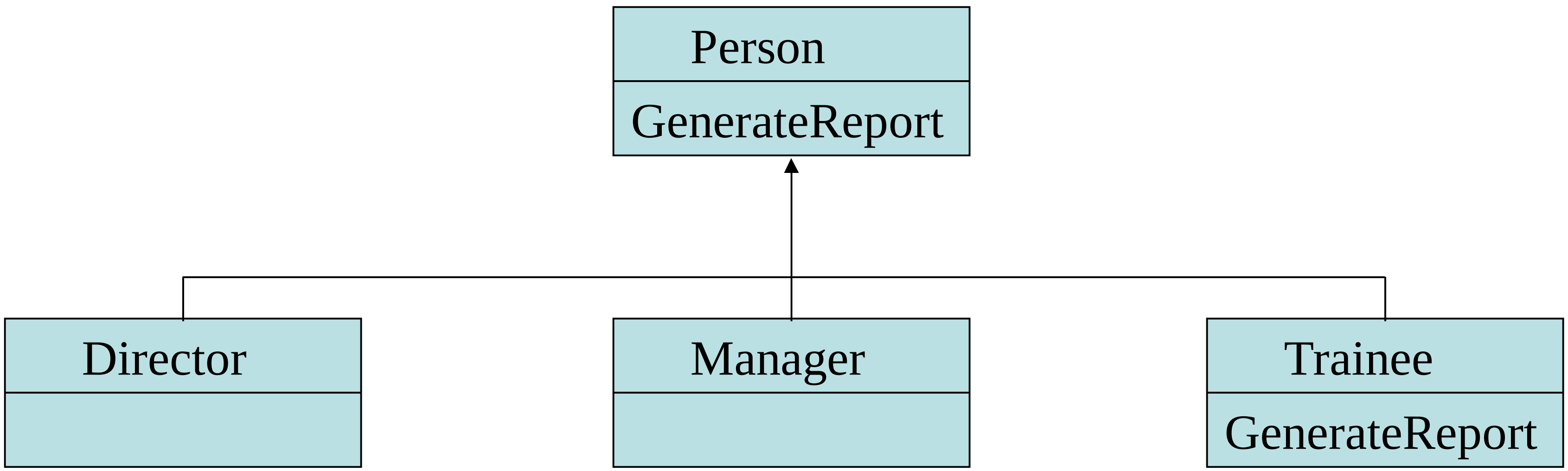
Overriding as Refinement

- Parent class method executed within child class method.
- Behavior of parent class method is preserved and augmented.
- Simula, Beta

Constructors always use the refinement semantics of overriding.

Replacement in SmallTalk

In support of code reuse



<----------------- Code Reuse ---------------------->

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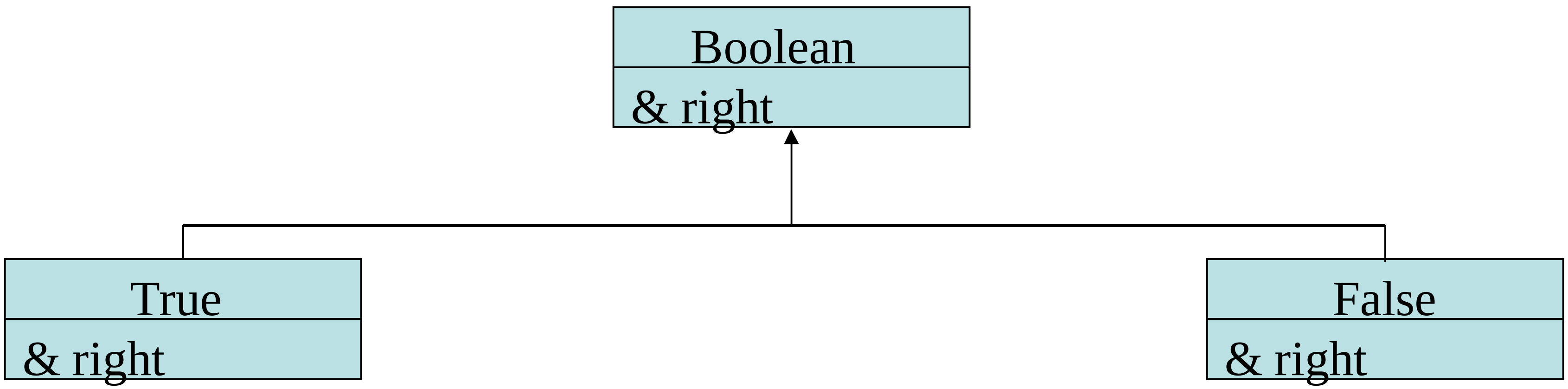
Overriden method

as replacement

Replacement in SmallTalk

In support of code optimization




```
“class boolean”
{&} right
  self ifTrue: [right ifTrue: [^true] ].
  ^ false
```

```
“class True”
{&} right
^ right

“class False”
{&} right
^ false
```

Refinement in Beta

- Always code from parent class is executed first.
- When '*inner*' statement is encountered, code from child class is executed.
- If parent class has no subclass, then '*inner*' statement does nothing.

Example

```
class Parent {
  public void printResult () {
    print('< Parent Result; ');
    inner;
    print('>');
  }
}
```

```
class Child extends Parent {
  public void printResult () {
    print('Child Result; ');
    inner;
  }
}
```

```
Parent p = new Child();
p.printResult();
```

```
< Parent Result; Child Result; >
```

Simulation of Refinement using Replacement

C++

```
void Parent::test () {
  cout << “in parent \n” ;
}
void Child::test () {
  Parent::test();
  cout << “in child \n”;
}
```

Object Pascal

```
procedure Parent.test ();
begin
  writeln(“in parent”);
end;
procedure Child.test ();
begin
  inherited test ();
  writeln(“in child”);
end;
```

Java

```
class Parent {
  void test () {System.out.println(“in parent”);}
}
class Child extends Parent {
  void test () {
    super.test();
    System.out.println(“in child”);  }
}
```

Refinement Vs Replacement

Refinement

- Conceptually very elegant mechanism
- Preserves the behavior of parent.
  (impossible to write a subclass that is not also a subtype)
- Cannot simulate replacement using refinement.

Replacement

- No guarantee that behavior of parent will be preserved.
  (it is possible to write a subclass that is not also a subtype).
- Can be used to support code reuse and code optimization
- Can simulate refinement using replacement.

Wrappers in CLOS

This mechanism can be used to simulate refinement.

A subclass overrides parent method and specifies a wrapping method.

Wrapping method can be

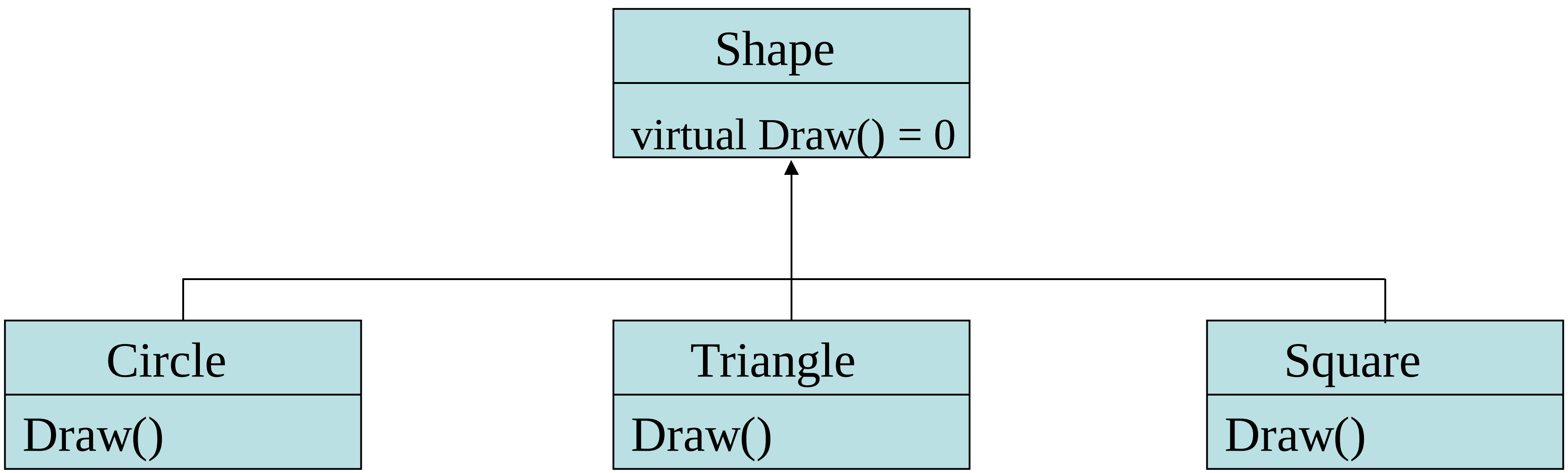
- **'before' method**
- **'after' method**
- **'around' method**

```
(defclass parent () () )
(defclass child (parent) )
(defmethod test ((x parent)) (print "test parent"))
(defmethod atest :after ((x child)) (print "atest child"))
(defmethod btest :before ((x child)) (print "btest child"))
(defmethod rtest :around ((x child))
  (list "rtest chld before" (call-next-method) "rtest chld after"))

(defvar aChild (make-instance 'child))
(atest aChild)                       "atest child" "test parent"
(atest aChild)                       "test parent" "btest child"
(atest aChild)  "rtest chld before" "test parent" "rtest chld after"
```

Deferred Methods

- Defined but not implemented in parent class.
- Also known as abstract method (Java) and pure virtual method (C++)
- Associates an activity with an abstraction at a higher level than it actually is.



- Used to avoid compilation error in statically typed languages.

Deferred Method Example

C++

```
class Shape {
  public:
    virtual void Draw () = 0;
}
```

Java

```
abstract class Shape {
  abstract public void Draw ();
```

Smalltalk

```
Draw
  " child class should override this"
  ^ self subclassResponsibility
```

(Smalltalk does implement the deferred method in parent class but when invoked will raise an error)

Shadowing

Child class implementation shadows the parent class implementation of a method.

- **As example in C++, when overridden methods are not declared with ‘virtual’ keyword.**
- **Resolution is at compile time based on static type of the receiver.**

```
class Parent {
public:
  void test () { cout << “in Parent” << endl; }
}
class Child : public Parent {
public:
  void test () { cout << “in Child” << endl; }
}

Parent *p = new Parent();
p->test();                    // in Parent
Child *c new Child();
c->test();                    // in Child
p = c;
p->test();                    // in Parent
```

Overriding, Shadowing and Redefinition

Overriding

- Same type signature and method name in both parent and child classes.
- Method declared with language dependent keywords indicating overriding.

Shadowing

- Same type signature and method name in both parent and child classes.
- Method not declared with language dependent keywords indicating overriding.

Redefinition

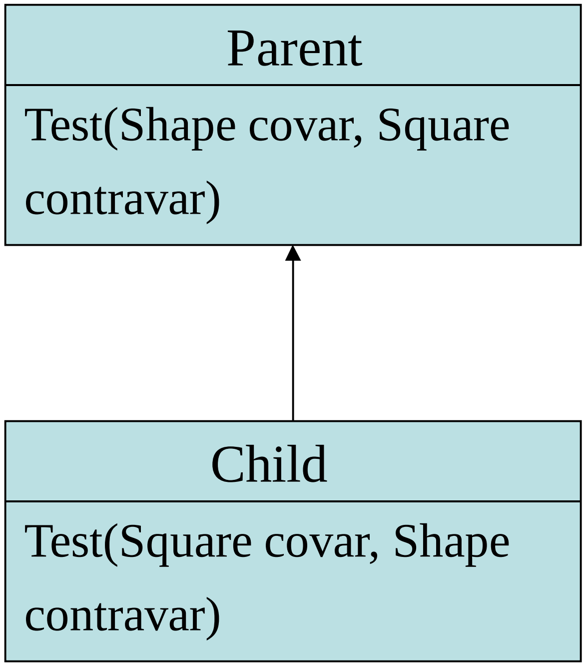
- Same method name in both parent and child classes.
- Type signature in child class different from that in parent class.

Covariance and Contravariance

- An overridden method in child class has a different type signature than that in the parent class.
- Difference in type signature is in moving up or down the type hierarchy.

```
class Parent {
  public void test (Shape s, Square sq)
  { ... }
}

class Child extends Parent {
  public void test (Square sq, Shape s)
  { ... }
}
```



Covariance and Contravariance

- Covariant change - when the type moves down the type hierarchy in the same direction as the child class.

```
Parent aValue = new Child();
aValue.func(aTriangle, aSquare);    // Run-time error
                                 // No compile-time error
```

- Contravariant change - when the type moves in the direction opposite to the direction of subclassing.

```
Parent aValue = new Child();
aValue.func(aSquare, aSquare);     // No errors
```

Covariance and Contravariance

- Covariant change in return type

```
Shape func () { return new Triangle(); } // In Parent Class
Square func () { return new Square(); }  // In Child Class

Parent aValue = new Child();
Shape aShape = aValue.func(); // No compile-time or Run-Time errors
```

- Contravariant change in return type

```
Square func () { return new Square(); }  // In Parent Class
Shape func () { return new Triangle(); } // In Child Class

Parent aValue = new Child();
Square aSquare = aValue.func();          // No compile-time errors
                                         // Run-Time error
```

- C++ allows covariant change in return type.
- Eiffel, Sather allows both covariant and contravariant overriding
- Most other languages employ novariance

And Finally...

Java

- 'final' keyword applied to functions prohibits overriding.
- 'final' keyword applied to classes prohibits subclassing.

C#

- 'sealed' keyword applied to classes prohibits subclassing.
- 'sealed' keyword cannot be applied to individual functions.