

# Java

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Informatica III - 2013/14

M4 java su syllabus

# Outline

- Language Overview
  - History and design goals
- Classes and Inheritance
  - Object features
  - Encapsulation
  - Inheritance
- Types and Subtyping
  - Primitive and ref types
  - Interfaces; arrays
  - Exception hierarchy
  - Subtype polymorphism and generic programming
- Saltiamo il resto

# Origins of the language

- James Gosling and others at Sun, 1990 - 95
- Oak language for “set-top box”
  - small networked device with television display
    - graphics
    - execution of simple programs
    - communication between local program and remote site
    - no “expert programmer” to deal with crash, etc.
- Internet application
  - simple language for writing programs that can be transmitted over network

# Design Goals

- Portability
  - Internet-wide distribution: PC, Unix, Mac
- Reliability
  - Avoid program crashes and error messages
- Safety
  - Programmer may be malicious
- Simplicity and familiarity
  - Appeal to average programmer; less complex than C++
- Efficiency
  - Important but secondary

# General design decisions

- **Simplicity**
  - Almost everything is an object
  - All objects on heap, accessed through pointers
  - No functions, no multiple inheritance, no go to, no operator overloading, few automatic coercions
- **Portability and network transfer**
  - Bytecode interpreter on many platforms
- **Reliability and Safety**
  - Typed source and typed bytecode language
  - Run-time type and bounds checks
  - Garbage collection

# Java System

- The Java programming language
- Compiler and run-time system
  - Programmer compiles code
  - Compiled code transmitted on network
  - Receiver executes on interpreter (JVM)
  - Safety checks made before/during execution
- Library, including graphics, security, etc.
  - Large library made it easier for projects to adopt Java
  - Interoperability
    - Provision for “native” methods

# Java Release History

- 1995 (1.0) – First public release
- 1997 (1.1) – Nested classes
  - Support for function objects
- 2001 (1.4) – Assertions
  - Verify programmers understanding of code
- 2004 (1.5) – Tiger
  - Generics, foreach, Autoboxing/Unboxing,
  - Typesafe Enums, Varargs, Static Import,
  - Annotations, concurrency utility library
- 2006 (1.6) – Mustang
- 2011 (1.7) – Dolphin

# Outline



## Objects in Java

- Classes, encapsulation, inheritance

## ◆ Type system

- Primitive types, interfaces, arrays, exceptions

## ◆ Generics (added in Java 1.5)

- Basics, wildcards, ...



# Language Terminology

- Class, object -
- Field -
- Method -
- Static members -
- this -
- Package - set of classes in shared namespace
- Native method -

# Java Classes and Objects (2)

- Syntax similar to C++
- Object
  - has fields and methods
  - is allocated on heap, not run-time stack
  - accessible through reference (only ptr assignment)
  - garbage collected
- Dynamic lookup
  - Similar in behavior to other languages
  - Static typing => more efficient than Smalltalk
  - Dynamic linking, interfaces => slower than C++

# Point Class

```
class Point {  
    static public Point O = new Point(0);  
    private int x;  
    protected void setX (int y) {x = y;}  
    public int  getX()    {return x;}  
    Point(int xval) {x = xval;}    // constructor  
}
```

- Visibility similar to C++, but not exactly (later slide)

# Object initialization

- Java guarantees constructor call for each object
  - Memory allocated
  - Constructor called to initialize memory
  - Some interesting issues related to inheritance
    - We'll discuss later ...
- Cannot do this (would be bad C++ style anyway):
  - `Obj* obj = (Obj*)malloc(sizeof(Obj));`
- Static fields of class initialized at class load time
  - Talk about class loading later

# Garbage Collection and Finalize

- Objects are garbage collected
  - No explicit *free*
  - Avoids dangling pointers and resulting type errors
- Problem
  - What if object has opened file or holds lock?
- Solution
  - *finalize* method, called by the garbage collector
    - Before space is reclaimed, or when virtual machine exits
    - Space overflow is not really the right condition to trigger finalization when an object holds a lock...)
  - Important convention: call `super.finalize`

# Estensione delle classi (3)

# Inheritance

- Similar to Smalltalk, C++
- Subclass inherits from superclass
  - Single inheritance only (but Java has interfaces)
- Some additional features
  - Conventions regarding *super* in constructor and *finalize* methods
  - Final classes and methods

# Example subclass

```
class ColorPoint extends Point {  
    // Additional fields and methods  
    private Color c;  
    protected void setC (Color d) {c = d;}  
    public Color  getC()    {return c;}  
    // Define constructor  
    ColorPoint(int xval, Color cval) {  
        super(xval);    // call Point constructor  
        c = cval; }    // initialize ColorPoint field  
}
```



# Class *Object*

- Every class extends another class
  - Superclass is *Object* if no other class named
- Methods of class *Object*
  - `getClass` - return the Class object representing class of the object
  - `toString` - returns string representation of object
  - `equals` - default object equality (not ptr equality)
  - `hashCode`
  - `clone` - makes a duplicate of an object
  - `wait`, `notify`, `notifyAll` - used with concurrency
  - `finalize`

# Constructors and Super

- Java guarantees constructor call for each object
- This must be preserved by inheritance
  - Subclass constructor must call super constructor
    - If first statement is not call to super, then call super() inserted automatically by compiler
    - If superclass does not have a constructor with no args, then this causes compiler error (yuck)
    - Exception to rule: if one constructor invokes another, then it is responsibility of second constructor to call super, e.g.,

```
ColorPoint() { ColorPoint(0,blue);}
```

is compiled without inserting call to super
- Different conventions for finalize and super
  - Compiler does not force call to super finalize

# Final classes and methods

- Restrict inheritance
  - Final classes and methods cannot be redefined
- Example
  - `java.lang.String`
- Reasons for this feature
  - Important for security
    - Programmer controls behavior of all subclasses
    - Critical because subclasses produce subtypes
  - Compare to C++ virtual/non-virtual
    - Method is “virtual” until it becomes final



# Altri argomenti

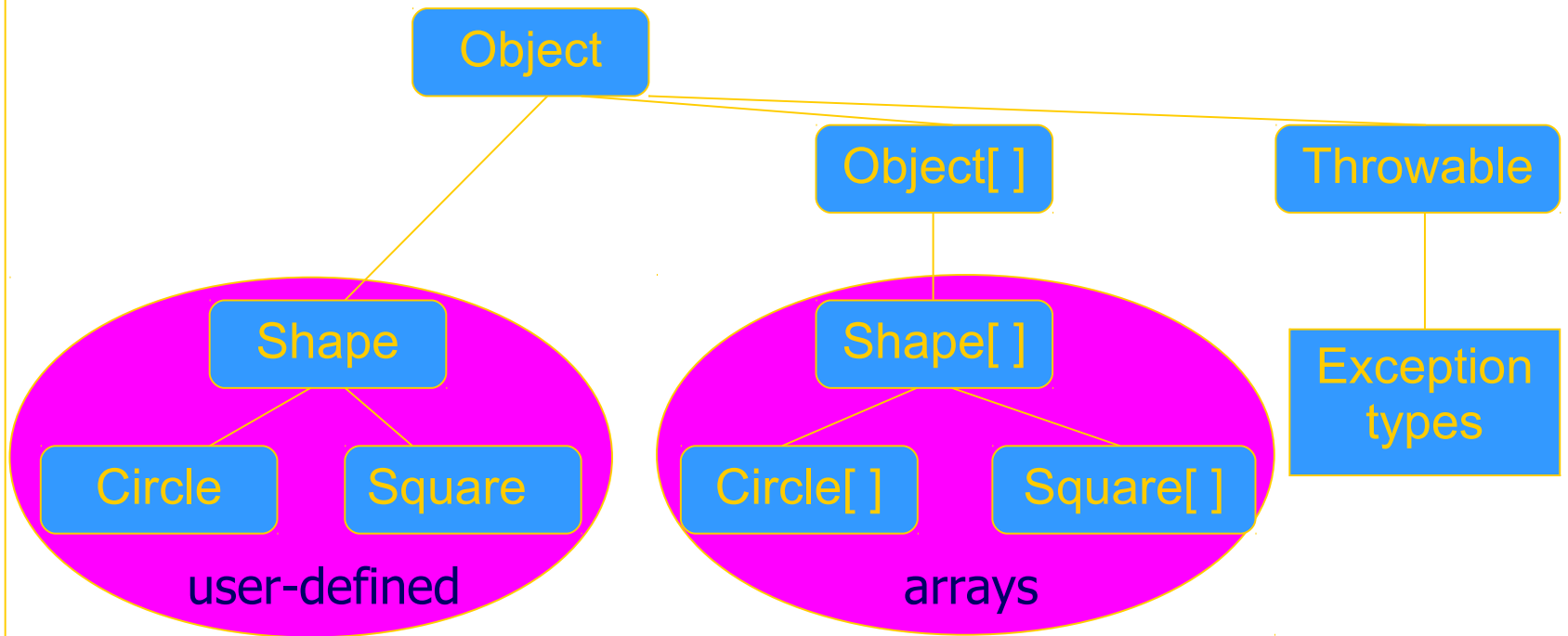
- Compatibilità di tipi e conversione
  - Sottoclassi e sottotipi
- Classi astratte
- Ereditarietà e ridefinizione dei membri
- Binding dinamico

# Java Types

- Two general kinds of types
  - Primitive types – *not* objects
    - Integers, Booleans, etc
  - Reference types
    - Classes, interfaces, arrays
    - No syntax distinguishing `Object *` from `Object`
- Static type checking
  - Every expression has type, determined from its parts
  - Some auto conversions, many casts are checked at run time
  - Example, assuming `A <: B` (A sottotipo di B)
    - Can use `A x` and type
    - If `B x`, then can try to cast `x` to `A`
    - Downcast checked at run-time, may raise exception

# Classification of Java types

## Reference Types



## Primitive Types



# Subtyping

- Primitive types
  - Conversions: int -> long, double -> long, ...
- Class subtyping similar to C++
  - Subclass produces subtype
  - Single inheritance => subclasses form tree
- Interfaces
  - Completely abstract classes
    - no implementation
  - Multiple subtyping
    - Interface can have multiple subtypes (extends, implements)
- Arrays
  - Covariant subtyping – not consistent with semantic principles

# Java class subtyping

- Signature Conformance
  - Subclass method signatures must conform to those of superclass
- Three ways signature could vary
  - Argument types
  - Return type
  - Exceptions

How much conformance is needed in principle?
- Java rule
  - Java 1.1: Arguments and returns must have identical types, may remove exceptions
  - Java 1.5: covariant return type specialization



# Covariance

- **Covariance** Definizione
- T si dice covariante (rispetto alla sottotipazione di Java) se ogni volta che A è sottotipo di B allora anche T di A è sottotipo di T B
  - T potrebbe essere il valore ritornato
  - ...
  -

# Covariance

- **Covariance** in Java 5
- I valori ritornati da un metodo ridefinito possono essere covarianti
- parameter types have to be exactly the same (invariant) for method overriding, otherwise the method is overloaded with a parallel definition instead.

```
class A {  
    public A whoAreYou() {...}  
}  
  
class B extends A {  
    // override A.whoAreYou *and* narrow the return  
    // type.  
    public B whoAreYou() {...}  
}
```

# Array types

- Automatically defined
  - Array type `T[]` exists for each class, interface type `T`
  - Cannot extended array types (array types are final)
  - Multi-dimensional arrays as arrays of arrays: `T[][]`
- Treated as reference type
  - An array variable is a pointer to an array, can be null
  - Example: `Circle[] x = new Circle[array_size]`
  - Anonymous array expression: `new int[] {1,2,3, ... 10}`
- Every array type is a subtype of `Object[]`, `Object`
  - Length of array is not part of its static type

# Array subtyping - covariance

- Covariance

- if  $S \leq T$  then  $S[] \leq T[]$

- $S \leq T$  means “S is subtype of T”

- Standard type error

```
class A {...}
```

```
class B extends A {...}
```

```
B[] bArray = new B[10]
```

```
A[] aArray = bArray // considered OK since  $B[] \leq A[]$ 
```

```
aArray[0] = new A() // compiles, but run-time error
```

```
// raises ArrayStoreException
```

```
// b/c aArray actually refers to an array of B objects
```

```
// so that assignment, aArray[0] = new A(); would violate  
the type of bArray
```

# Interfacce (4)

# Interface subtyping: example

```
interface Shape {  
    public float center();  
    public void rotate(float degrees);  
}  
interface Drawable {  
    public void setColor(Color c);  
    public void draw();  
}  
class Circle implements Shape, Drawable {  
    // does not inherit any implementation  
    // but must define Shape, Drawable methods  
}
```

# Properties of interfaces

- Flexibility
  - Allows subtype graph instead of tree
  - Avoids problems with multiple inheritance of implementations (remember C++ “diamond”)
- Cost
  - Offset in method lookup table not known at compile
  - Different bytecodes for method lookup
    - one when class is known
    - one when only interface is known
      - search for location of method
      - cache for use next time this call is made (from this line)

# Tipi enumerativi (6)



# Enumeration

- In prior releases, the standard way to represent an enumerated type was the int Enum pattern

```
// int Enum Pattern - has severe problems!  
public static final int SEASON_WINTER = 0;  
public static final int SEASON_SPRING = 1;  
public static final int SEASON_SUMMER = 2;  
public static final int SEASON_FALL   = 3;
```

- Not typesafe
- No namespace - You must prefix constants of an int enum with a string (in this case SEASON\_)
- Printed values are uninformative

# In Java5

```
public enum Season {  
    WINTER, SPRING, SUMMER, FALL }
```

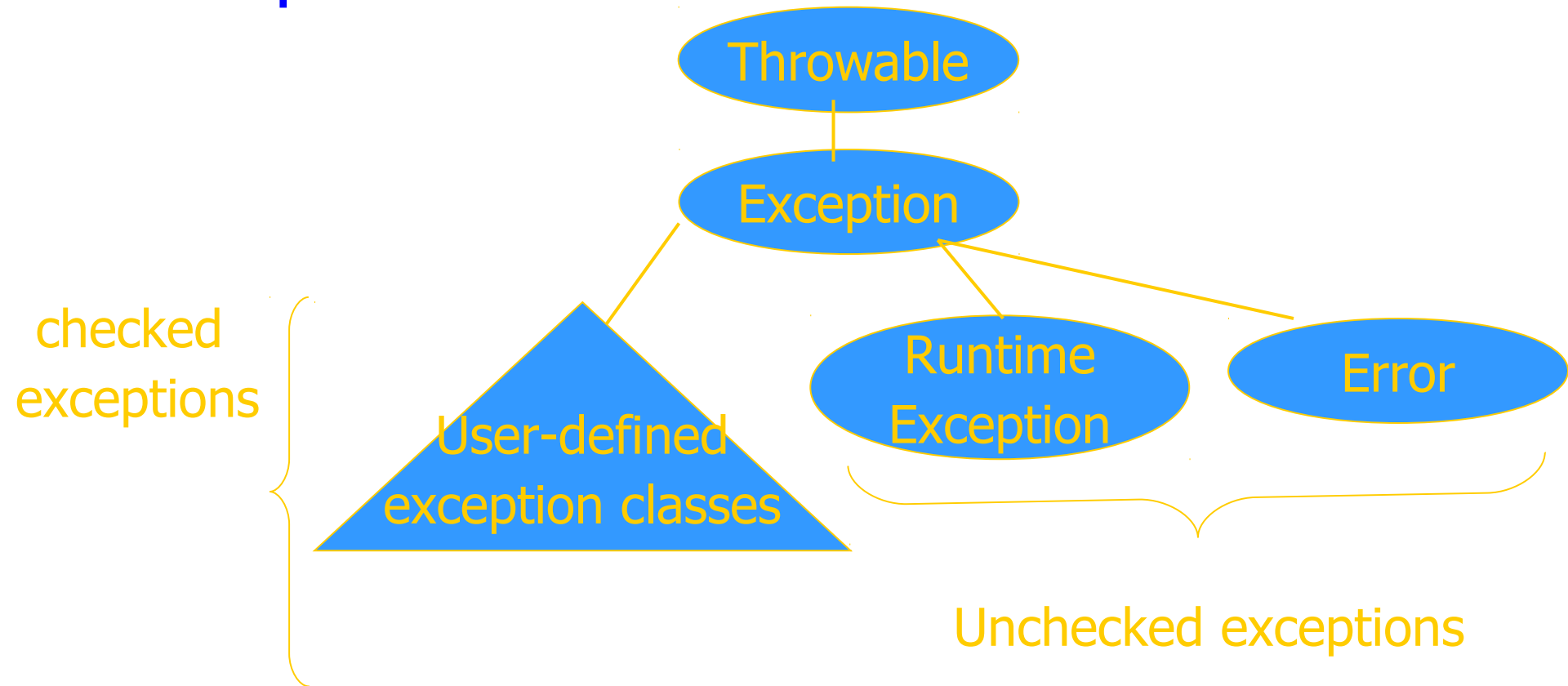
- Comparable
- toString which prints the name of the symbol
- static values method that returns an array containing all of the values of the enum type in the order they are declared
  - for (Season s : Season.values()) ...

# Eccezioni e asserzioni (12)

# Java Exceptions

- Similar basic functionality to ML, C++
  - Constructs to *throw* and *catch* exceptions
  - Dynamic scoping of handler
- Some differences
  - An exception is an object from an exception class
  - Subtyping between exception classes
    - Use subtyping to match type of exception or pass it on ...
    - Similar functionality to ML pattern matching in handler
  - Type of method includes exceptions it can throw
    - Actually, only subclasses of Exception (see next slide)

# Exception Classes



- If a method may throw a checked exception, then this must be in the type of the method

# Try/finally blocks

- Exceptions are caught in try blocks

```
try {  
    statements  
} catch (ex-type1 identifier1) {  
    statements  
} catch (ex-type2 identifier2) {  
    statements  
} finally {  
    statements  
}
```

- Implementation: finally compiled to jsr

# Why define new exception types?

- Exception may contain data
  - Class Throwable includes a string field so that cause of exception can be described
  - Pass other data by declaring additional fields or methods
- Subtype hierarchy used to catch exceptions

```
catch <exception-type> <identifier> { ... }
```

will catch any exception from any subtype of exception-type and bind object to identifier

# Binding Dinamico in Java



# Overload vs Override

- Overload = più metodi o costruttori con lo stesso nome ma diversa segnatura
  - Segnatura: nome del metodo e lista dei tipi dei suoi argomenti
- L'overloading viene risolto in fase di compilazione
- Esempio

```
public static double valoreAssoluto(double x) {  
    if (x > 0) return x;  
    else return -x;  
}  
  
public static int valoreAssoluto(int x) {  
    return (int) valoreAssoluto((double) x);  
}
```

# Compilazione: scelta segnatura

- In compilazione viene **scelta la segnatura del metodo da eseguire** in base:
  - (1) al **tipo del riferimento** utilizzato per invocare il metodo
  - (2) al **tipo degli argomenti** indicati nella chiamata

## Esempio

- A r;...
- r.m(2)
- Il compilatore cerca fra tutte le segnature di metodi di nome **m** disponibili per il tipo **A** quella **"più adatta"** per gli argomenti specificati

# Esempio

A r;

...

r.m(2)

- Se le signature disponibili per il tipo **A** sono:

int m(byte b)

int m(long l)

int m(double d)

- il compilatore sceglie la seconda

# Overriding

- Quando si riscrive in una sottoclasse un metodo della superclasse con la **stessa segnatura**.
- L'overriding viene risolto **in fase di esecuzione**
- **Compilazione:**
- scelta della segnatura: il compilatore stabilisce **la segnatura** del metodo da eseguire (early binding)
- **Esecuzione:**
- scelta del metodo: Il metodo da eseguire, tra quelli con la segnatura selezionata, viene scelto al momento dell'esecuzione, sulla base del **tipo dell'oggetto** (late binding)

# Fase di compilazione

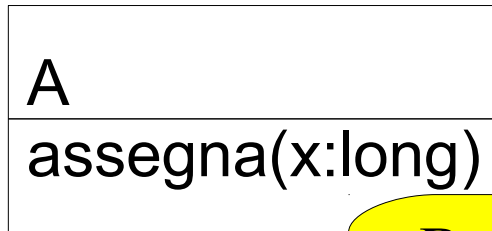
## (1) Scelta delle signature "candidate"

- Il compilatore individua le signature che possono **soddisfare la chiamata**
  - (a) **compatibile con gli argomenti utilizzati nella chiamata**  
il numero dei parametri nella signature `e uguale al numero degli argomenti utilizzati ogni argomento `e di un tipo assegnabile al corrispondente parametro
  - (b) **accessibile al codice chiamante**
- Se non esistono signature candidate, il compilatore segnala un errore.

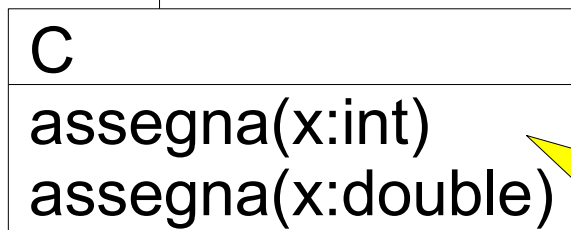
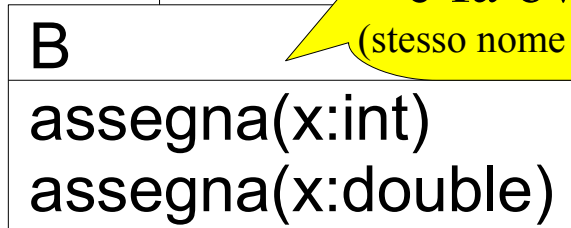
## (2) Scelta della signature "più specifica"

- Tra le signature candidate, il compilatore seleziona quella che richiede il minor numero di promozioni

# Esempio 1



B eredita da A  
e fa overloading  
(stesso nome segnatura diversa)



C eredita da B  
e fa overriding  
(stesso nome e segnatura)

A alfa;

- alfa.assegna(2)

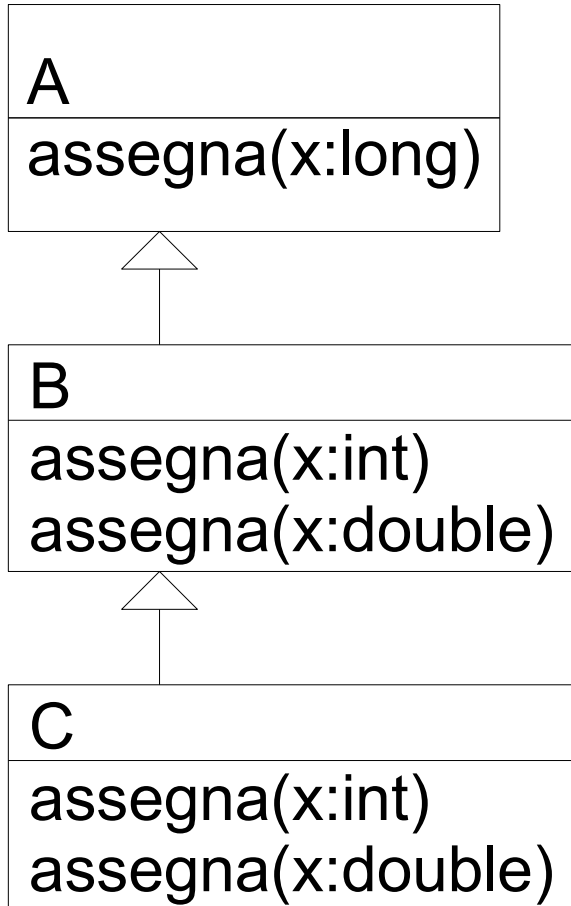
Una segnatura candidata:

assegna(long x)

- alfa.assegna(2.0)

Nessuna segnatura  
candidata (**errore**)

# Esempio 2



B beta;

`beta.assegna(2)`

Tre segnature candidate:

- `assegna(int x)`
- `assegna(double x)`
- `assegna(long x)`
- La più specifica è `assegna(int x)`

# Ambiguità

- Se per l'invocazione:
- `z(1, 2)`
- le signature candidate sono:
- `z(double x, int y)`
- `z(int x, double y)`
- Il compilatore non `e in grado di individuare la segnatura pi`u specifica e segnala un messaggio di errore



# Esecuzione: scelta del metodo

- La JVM sceglie il metodo da eseguire **sulla base della classe dell'oggetto** usato nell'invocazione
  - cerca un metodo con la segnatura selezionata in fase di compilazione
  - risalendo la gerarchia delle classi a partire dalla classe dell'oggetto che deve eseguire il metodo

# Esempio 1

A alpha = new B();

alpha.assegna(2l)

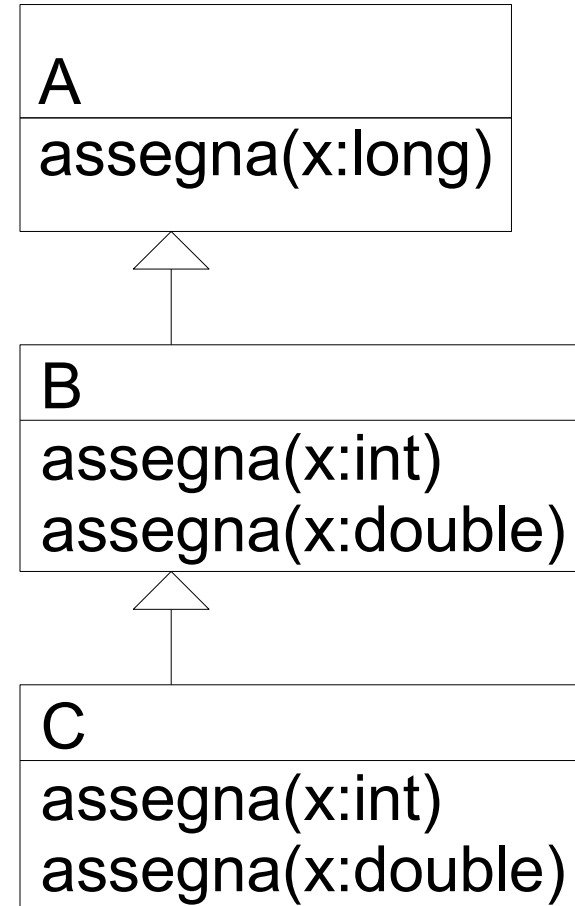
EB: segnatura selezionata in

A: **assegna(long x)**

LB: Ricerca a partire da B un  
metodo **assegna(long)**

Esegue il metodo di A

In questo caso metodo  
selezionato in EB ed  
eseguito coincidono



# Esempio 2

B beta = new C()

beta.assegna(2)

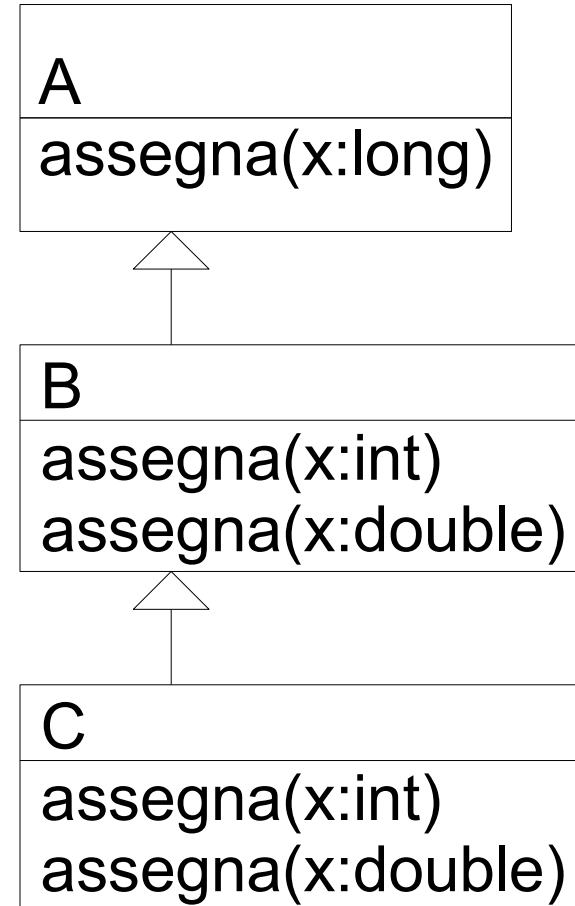
EB: segnatura selezionata di

B: **assegna(int x)**

LB: Ricerca a partire da C un  
metodo assegna(int)

Esegue il metodo di C

Come volevo,  
poichè ho ridefinito il metodo



# Esempio 3

A alfa = new C()

alfa.assegna(2)

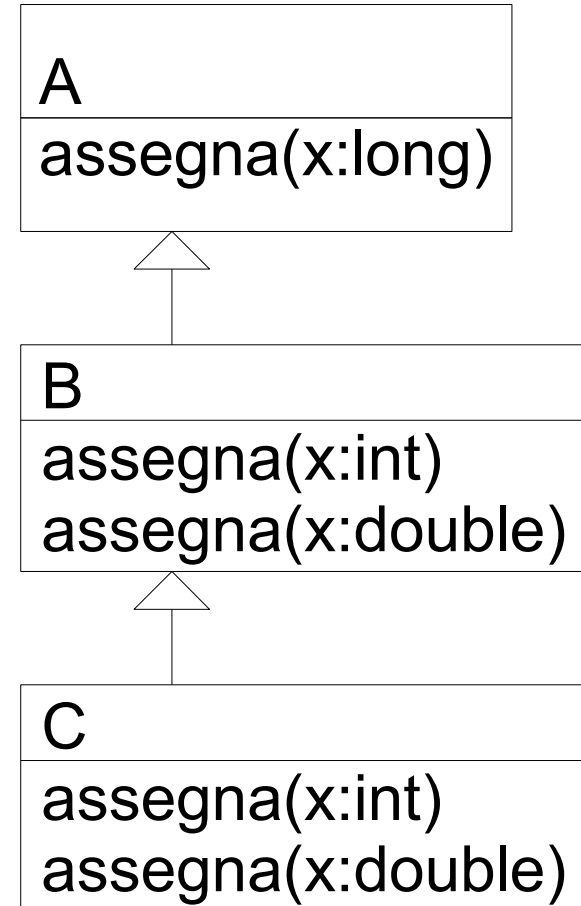
EB Una segnatura candidata:

assegna(long x)

LB: Ricerca a partire da C un  
metodo assegna(long)

Esegue il metodo di A anche  
se 2 è int !!!

E' dovuto al fatto che non ho  
ridefinito il metodo di A



# Attenzione

- Quando si ridefiniscono i metodi in java bisogna usare la stessa segnatura !!
- Vedi il problema con equals

```
class A {  
    int x;  
    A(int y){x = y;}  
    public equals(A a){ return (x == a.x);}  
}
```

```
Object a1 = new A(3);
```

```
A a2 = new A(3);
```

```
a1.equals(a2);
```

# Outline

- Objects in Java
  - Classes, encapsulation, inheritance
- Type system
  - Primitive types, interfaces, arrays, exceptions
- Generics (added in Java 1.5)
  - Basics, wildcards, ...
- ◆ Virtual machine
  - ◆
    - Loader, verifier, linker, interpreter
    - Bytecodes for method lookup
- ◆ Security issues

# Enhancements in JDK 5 (= Java 1.5)

- Enhanced for Loop
  - for iterating over collections and arrays
- Autoboxing/Unboxing
  - automatic conversion between primitive, wrapper types
- Typesafe Enums
  - enumerated types with arbitrary methods and fields
- Varargs
  - puts argument lists into an array; variable-length argument lists
- Static Import
  - avoid qualifying static members with class names
- Annotations (Metadata)
  - enables tools to generate code from annotations (JSR 175)
- Generics
  - polymorphism and compile-time type safety

# varargs

- Varargs sono usati per dichiarare un metodo che possa prendere in ingresso un oggetto, n- oggetti o un array di oggetti.
- Esempio
- `print(String ... s)`
- Permette le seguenti chiamate:
- `print("pippo")`
- `print("pippo", "pluto")`
- `print(new String[]{"a", "b", "c"})`
- Il tipo del parametro formale di un varargs è un array



# Java Generic Programming

- Java has class Object
  - Supertype of all object types
  - This allows “subtype polymorphism”
    - Can apply operation on class T to any subclass  $S \leq T$
- Java 1.0 – 1.4 do not have templates
  - No parametric polymorphism
  - Many consider this the biggest deficiency of Java
- Java type system does not let you cheat
  - Can cast from supertype to subtype
  - Cast is checked at run time

# Why no generics in early Java ?

- Many proposals
- Basic language goals seem clear
- Details take some effort to work out
  - Exact typing constraints
  - Implementation
    - Existing virtual machine?
    - Additional bytecodes?
    - Duplicate code for each instance?
    - Use same code (with casts) for all instances

Java Community proposal (JSR 14) incorporated into Java 1.5

# Motivazione per l'introduzione dei generici

- **Programmazione generica**
- Se voglio realizzare programmi generici, cioè che vanno bene per diversi tipi, come posso fare?
- Posso usare scrivere egli algoritmi usando Object che a runtime potrà essere una qualsiasi sottoclasse
- Così era prima di 1.5
- Ad esempio una collezione generica

# Esempio Lista di Object

(prima dei generici)

Ad esempio una lista

```
// creazione
List myList = new LinkedList();
// aggiungo
myList.add(new Integer(0));
// prendo il primo elemento
Integer x = (Integer)
myIntList.iterator().next();
```

- 1. Il cast è necessario
- 2. posso inserire qualsiasi oggetto

Stack:

```
class Stack {
    void push(Object o) {...}
    Object pop() { ... }
    ...}

```

```
String s = "Hello";
Stack st = new Stack();
...
st.push(s);
...
s = (String) st.pop();
```

# Come specializzare

- Posso specializzare mediante ereditarietà:

```
IntegerList extends ArrayList{  
    @Override  
    add(Object o){  
        // check o is Integer ...  
    }  
}
```

# Generics

Invece mediante i generici:

```
class Stack<A> {  
    void push(A a) { ... }  
    A pop() { ... }  
    ...  
}
```

Annoto con  $\langle \rangle$  il TIPO  
Generico. A non è una classe

```
String s = "Hello";  
Stack<String> st = new Stack<String>();  
st.push(s);  
...  
s = st.pop();
```

# Declaring Generic classes

- For example a Coppia of two objects one of type E and the other of type F

```
class Coppia<E,F>{  
    E sinistro;  
    F destro;  
  
    Coppia(E a, F b) { ... }  
  
    E getSinistro() { return sinistro; }  
  
}
```

# Generics and Subtyping

- Questo è corretto?
- 1. `List<String> ls = new ArrayList<String>();`
- 2. `List<Object> lo = ls;`
  - 1 sì (arrayList è un sottotipo di List).
  - Ma 2? Una Lista di String è un sottotipo di una stringa di Object
  - Attenzione, se fosse vero avrei ancora problemi simili a quelli degli array

`lo.add(new Object()); // 3`

`String s = ls.get(0); // 4: attempts to assign an Object to a String!`

- **NON C'è covarianza dei generici**
- **A <: B non implica I<A> sottotipo di I<B> !!**



# Generics e wildcard

- Vogliamo scrivere un metodo che prende una collezione e stampa tutti gli elementi:

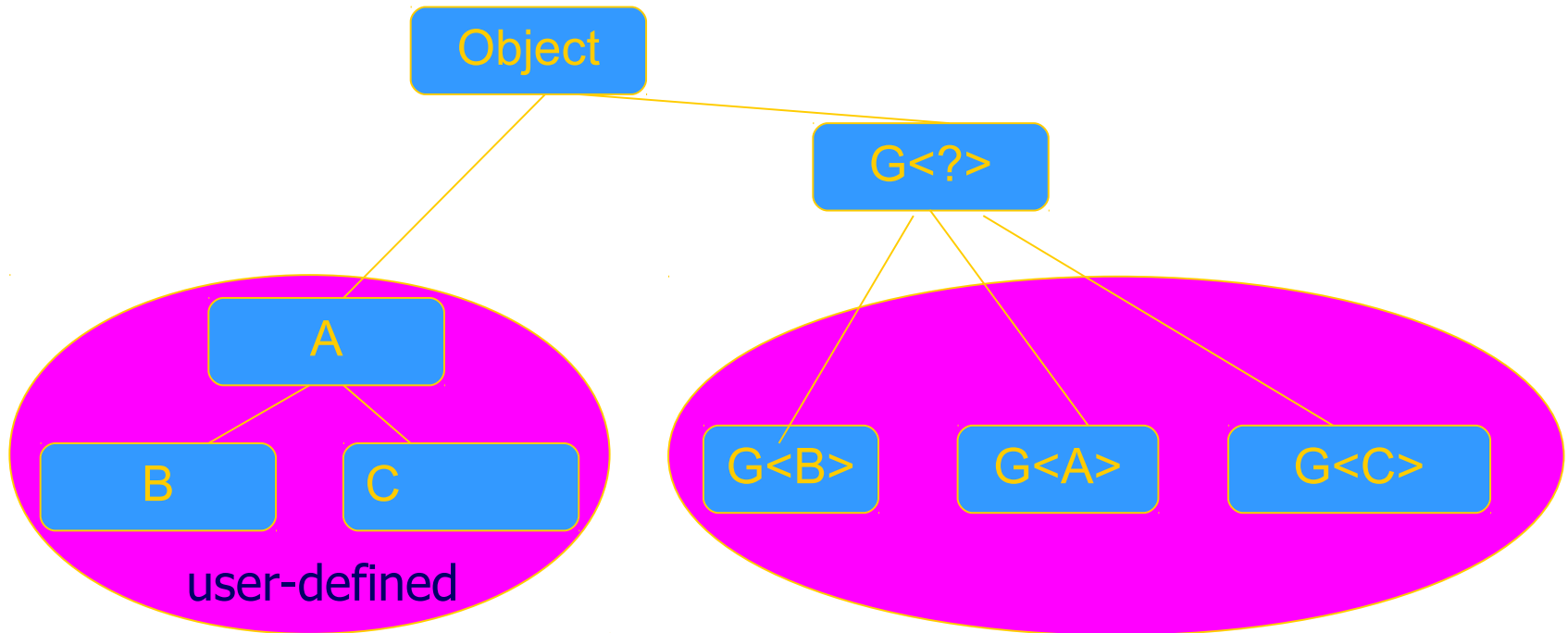
```
void printCollection(Collection c) {...}
```

- Con i generici???

```
void printCollection(Collection<Object> c) {  
    Iterator i = c.iterator();  
    for (k = 0; k < c.size(); k++) {  
        System.out.println(i.next().toString());  
    }  
}
```

- E se ho `Collection<Student>` non funziona !!!
- C'è un supertipo di `Collection<Student>`,  
`Collection<...>` ...??

# Supertipo di generics



```
void printCollection(Collection<?> c) {  
    for (Object e : c) {  
        System.out.println(e);  
    }  
}
```

# No covarianza dei generics → conseguenze

- Nota che se  $S <: T$  una classe  $P < S >$  non è sottotipo di  $P < T >$ 
  - In questo modo non ho i problemi degli array
  - Esempio: `Studente <: Persona`, non ho che `List < Studente > <: List < Persona >`
- Se un metodo chiede  $P < T >$  non posso passare  $P < T >$ 
  - Esempio:
    - `stampaAnagrafica(List < Persona > p)`
    - `List < Studente > ls;`
    - `stampaAnagrafica(ls)` non compila
  - Posso usare i wildcards per rendere il metodo più tollerante
    - `stampaAnagrafica(List < ? extends Persona > p)`

# Constraints on generic types

- One can introduce constraints over a type used as parameter in a generic class

< E extends T > : E must be a subtype of T

< E super T > : E must be a supertype of T

# Java generics are type checked

- A generic class may use operations on objects of a parameter type
  - Example: `PriorityQueue<T> ... if x.less(y) then ...`
- Two possible solutions
  - C++: Link and see if all operations can be resolved
  - Java: Type check and compile generics w/o linking
    - This requires programmer to give information about type parameter
    - Example: `PriorityQueue<T extends ...>`

# Example: Hash Table

```
interface Hashable {
    int hashCode ();
};
class HashTable < Key extends Hashable, Value >
{
    void insert (Key k, Value v) {
        int bucket = k.hashCode();
        insertAt (bucket, k, v);
    }
    ...
};
```

This expression must typecheck  
Use "Key extends Hashable"

# Interface Comparable<T>

- imposes a total ordering on the objects of each class that implements it (natural ordering)
- **int compareTo(T o):** comparison method
  - compares **this** object with o and returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.
- Lists (and arrays) of objects that implement this interface can be sorted automatically by Collections.sort (and Arrays.sort).
- Objects that implement this interface can be used as keys in a sorted map or elements in a sorted set, without the need to specify a comparator.

# compareTo

- The natural ordering for a class C is said to be **consistent** with equals if and only if  $(e1.compareTo((Object)e2) == 0)$  has the same boolean value as  $e1.equals((Object)e2)$  for every e1 and e2 of class C.
- Altri vincoli:
  - $\text{sgn}(x.compareTo(y)) == -\text{sgn}(y.compareTo(x))$
  - the relation must be transitive:
    - $(x.compareTo(y) > 0 \ \&\& \ y.compareTo(z) > 0)$  implies  $x.compareTo(z) > 0$ .
  - Finally, the implementer must ensure that  $x.compareTo(y) == 0$  implies that  $\text{sgn}(x.compareTo(z)) == \text{sgn}(y.compareTo(z))$ , for all z.



# Example

Class MyClass implements

```
Comparable<MyClass>{
```

```
private int a;
```

```
...
```

```
public int compareTo(MyClass other){
```


```
    return (this.a - other.a);
```

```
}
```

# Priority Queue Example

Generic types often requests the implementation of Comparable:

```
class PriorityQueue<T> extends Comparable<T>> {  
    List<T> queue;    ...  
    void insert(T t) {  
        ... if (t.compareTo(queue.get(i))  
            ...  
    }  
    T remove() { ... }  
    ...  
}
```



# Another example ...

```
interface LessAndEqual<I> {
    boolean lessThan(I);
    boolean equal(I);
}
class Relations<C extends LessAndEqual<C>> extends C {
    boolean greaterThan(Relations<C> a) {
        return a.lessThan(this);
    }
    boolean greaterEqual(Relations<C> a) {
        return greaterThan(a) || equal(a);
    }
    boolean notEqual(Relations<C> a) { ... }
    boolean lessEqual(Relations<C> a) { ... }
    ...
}
```

# Wildcard e generics

- Alcune volte non si vuole specificare esattamente il tipo ma si vuole essere più permissivi
- `Persona extends Comparable<Persona>`
- `Studiante extends Persona`
- `Studiante` non può essere sostituito a `T` in un generico che chiede `<T extends Comparable<T>>`
  - Non potrei fare liste ordinate di studente
  - Però potrei utilizzare il `compareTo` di `Persona`, senza necessità di introdurre un altro `compareTo` nella sottoclasse
- Introduco: `<T extends Comparable<? super T>`

# Metodi generici

- Analogamente a classi e interfacce generiche, in Java 5.0 è possibile definire metodi generici, ovvero parametrici rispetto ad uno o più tipi.

```
public class MaxGenerico {  
    public static <T extends Comparable<T>>  
        T max (Vector<T> elenco) {  
        ...  
    }  
}
```

- Nell'esempio:
  - la classe non ha parametri di tipo;
  - la dichiarazione di tipo è `<T extends Comparable<T>>`, immediatamente successiva ai modificatori;
  - il tipo del metodo è `T`;
  - la segnatura del metodo è `max(Vector<T>)`.

# Implementing Generics

- Type erasure
  - Compile-time type checking uses generics
  - Compiler eliminates generics by erasing them
    - Compile List<T> to List, T to Object, insert casts
- “Generics are not templates”
  - Generic declarations are typechecked
  - Generics are compiled once and for all
    - No instantiation
    - No “code bloat”

More later when we talk about virtual machine ...

# Esercizio

- Dichiarare una classe A che ha come membro un intero
  - Dichiarare una classe B extends A che ha un metodo equals(B a)
  - Dichiarare una classe C extends A che ha un metodo equals(Object)
  - Implementare i metodi toString in modo che stampino "A", "B" e "C" e il valore dell'intero
  - Dichiarare una Lista di A usando i generici
  - Inserisci qualche B e qualche C
  - Stampa il contenuto della lista con un ciclo for each
  - Domanda un intero x
    - Scanner sc = new Scanner(System.in);
    - int x = sc.nextInt();
  - e cerca nella lista un elemento che sia equals a new A(x)
    - usa for each e equals
    - usa contains
- QUALI PROBLEMI HAI???

# Auto boxing /unboxing

- Adds auto boxing/unboxing

User conversion

```
Stack<Integer> st =  
    new Stack<Integer>();  
st.push(new Integer(12));  
...  
int i = (st.pop()).intValue();
```

Automatic conversion

```
Stack<Integer> st =  
    new Stack<Integer>();  
st.push(12);  
...  
int i = st.pop();
```

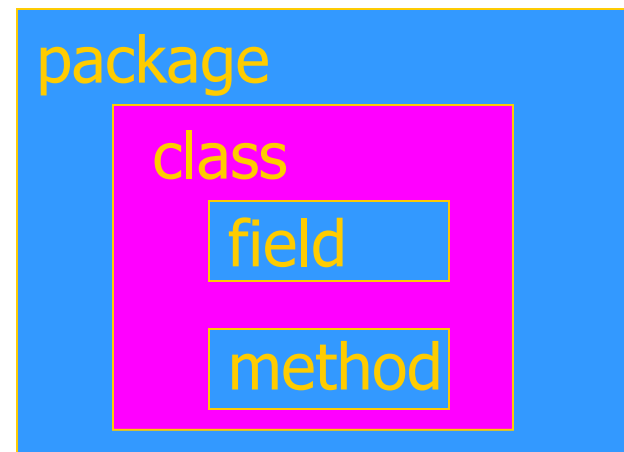
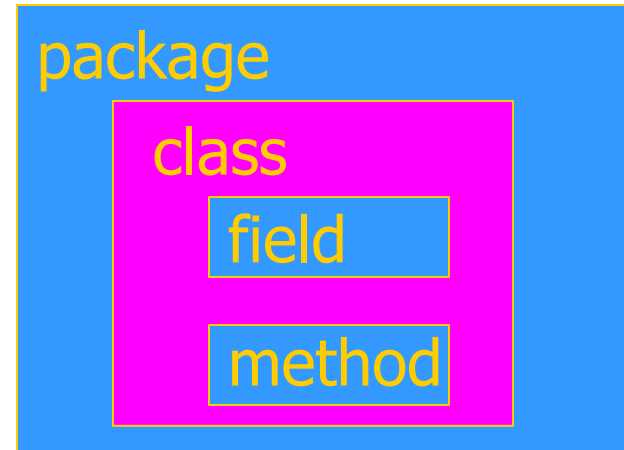


# Package e visibilità (18)

# Packages and visibility

## Encapsulation and packages

- Every field, method belongs to a class
- Every class is part of some package
  - Can be unnamed default package
  - File declares which package code belongs to



# Visibility and access

- Four visibility distinctions
  - public, private, protected, package
- Method can refer to
  - private members of class it belongs to
  - non-private members of all classes in same package
  - protected members of superclasses (in diff package)
  - public members of classes in visible packages

Visibility determined by files system, etc. (outside language)
- Qualified names (or use import)
  - `java.lang.String.substring()`

  
The diagram illustrates the components of the qualified name `java.lang.String.substring()`. Three yellow brackets are positioned above the text, each pointing to a specific part: the first bracket is under `java.lang`, the second is under `String`, and the third is under `substring()`. Below these brackets are the labels `package`, `class`, and `method` respectively. The word `Java` is written in a smaller font above the `method` label.

# Visibilità e overriding

- Quando si ridefinisce un metodo, questo non deve essere privato, altrimenti si fa overloading.

## Esempio

```
class A {  
    private void m(String s)  
        { /* ... */ }  
    void m(Object o) { /* ... */ }  
}  
class B extends A {  
    void m(String s) { /* ... */ }  
}
```

La classe B non ridefinisce m di A ma fa overloading:

Main in altra classe

```
A a = new A();  
a.m("def"); --- m(object)  
A b = new B();  
b.m("def"); - idem
```

# Overriding e visibilità

- Quando si ridefinisce, la visibilità può solo aumentare.
- Esempio:

```
public class A {  
    protected void m() { ... }  
    public static void main(String args[]) {  
        A a = new B();  
        a.m();  
    }  
}  
  
public class B extends A {  
    public void m() { ... }  
}
```

# Overriding ed eccezioni

- Quando si esegue overriding di un metodo che dichiara di sollevare eccezioni C, il metodo ridefinito non può mai sollevare "più" tipi di eccezione (controllate) di quelli sollevati dall'originale. Può:
  - dichiarare a sua volta di sollevare eccezioni di classe C;
  - dichiarare di sollevare eccezioni di una sottoclasse di C;
  - dichiarare di non sollevare eccezioni.
- Non potrebbe, invece:
  - dichiarare di sollevare eccezioni di una superclasse di C o di una classe non legata a C da legami di ereditarietà.

# Java Summary

- Objects
  - have fields and methods
  - alloc on heap, access by pointer, garbage collected
- Classes
  - Public, Private, Protected, Package (not exactly C++)
  - Can have static (class) members
  - Constructors and finalize methods
- Inheritance
  - Single inheritance
  - Final classes and methods

# Java Summary (II)

- Subtyping
  - Determined from inheritance hierarchy
  - Class may implement multiple interfaces
- Virtual machine
  - Load bytecode for classes at run time
  - Verifier checks bytecode
  - Interpreter also makes run-time checks
    - type casts
    - array bounds
    - ...
  - Portability and security are main considerations



# Some Highlights

- Dynamic lookup
  - Different bytecodes for by-class, by-interface
  - Search vtable + Bytecode rewriting or caching
- Subtyping
  - Interfaces instead of multiple inheritance
  - Awkward treatment of array subtyping (my opinion)
- Generics
  - Type checked, not instantiated, some limitations (<T>... new T)
- Bytecode-based JVM
  - Bytecode verifier
  - Security: security manager, stack inspection

# Comparison with C++

- Almost everything is object + Simplicity - Efficiency
  - except for values from primitive types
- Type safe + Safety +/- Code complexity - Efficiency
  - Arrays are bounds checked
  - No pointer arithmetic, no unchecked type casts
  - Garbage collected
- Interpreted + Portability + Safety - Efficiency
  - Compiled to byte code: a generalized form of assembly language designed to interpret quickly.
  - Byte codes contain type information

# Comparison

(cont'd)

- Objects accessed by ptr + Simplicity - Efficiency
  - No problems with direct manipulation of objects
- Garbage collection: + Safety + Simplicity - Efficiency
  - Needed to support type safety
- Built-in concurrency support + Portability
  - Used for concurrent garbage collection (avoid waiting?)
  - Concurrency control via synchronous methods
  - Part of network support: download data while executing
- Exceptions
  - As in C++, integral part of language design

# Links

- **Enhancements in JDK 5**

- <http://java.sun.com/j2se/1.5.0/docs/guide/language/index.html>

- J2SE 5.0 in a Nutshell

- <http://java.sun.com/developer/technicalArticles/releases/j2se15/>

- Generics

- <http://www.langer.camelot.de/Resources/Links/JavaGenerics.htm>