301AA - Advanced Programming

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AP-09*: Polymorphism*

Outline

- Polymorphism: a classification
- Overloading
- Coercion
- Inclusion polymorphism
- Overriding

Polymorphism

- From Greek: **πολυμορφος**, composed of **πολυ** (many) and **μορφή** (form), thus "having several forms"
- "Forms" are **types**
- "Polymorphic" are **function names** (also *operators*, *methods*, ...)
- "Polymorphic" can also be **types** (parametric data types, type constructors, generics, ...)
  – Usually as encapsulation of several related function names

Flavors of polymorphism

- Ad hoc
- Bounded
- Contravariant
- Covariant
- Inclusion
- Invariant
- Parametric
- Universal
- …

Related concepts:

- Coercion
- Generics
- Inheritance
- Macros
- Overloading
- Overriding
- Subtyping
- Templates
- …

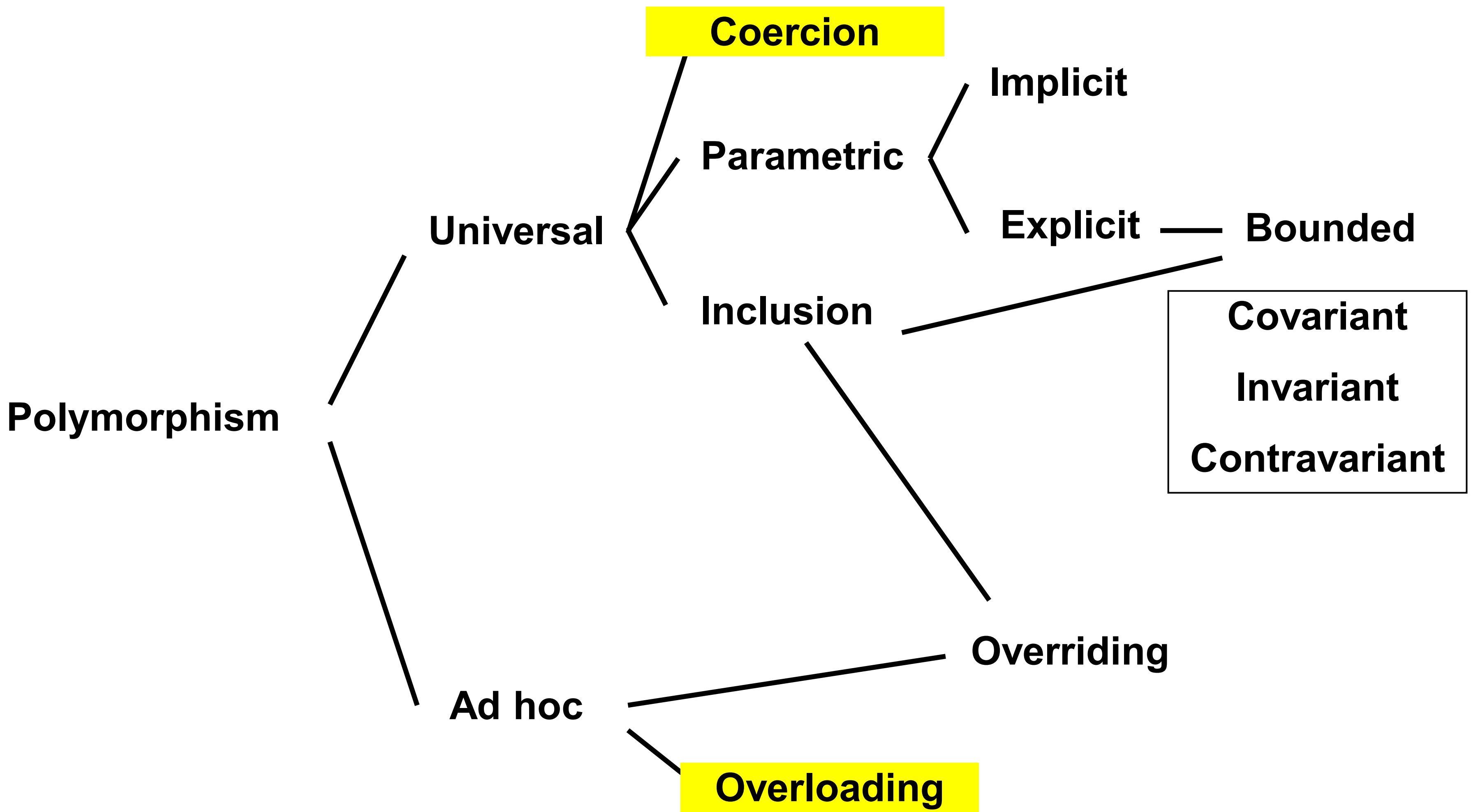
Universal vs. **ad hoc** polymorphism

- With **ad hoc** polymorphism the same function name denotes different algorithms, determined by the actual types
- With **universal** polymorphism there is only one algorithm: a single (universal) solution applies to objects of different types
- Ad hoc and universal polymorphism can coexist

Binding time

- The **binding** of the function name with the actual code to execute can be
  - at **compile time – early, static binding**
  - at **linking time**
  - at **execution time – late, dynamic binding**
- If it spans over different phases, the **binding time** is the last one.
- The earlier the better, for debugging reasons.

Classification of Polymorphism



Ad hoc polymorphism: **overloading**

- Present in all languages, at least for built-in arithmetic operators: +, *, -, …
- Sometimes supported for user defined functions (Java, C++, …)
- C++, Haskell, Python,… allow overloading of primitive operators by user defined functions
- The code to execute is determined by the type of the arguments, thus
  - **early binding** in statically typed languages
  - **late binding** in dynamically typed languages

Overloading: an example

- Function for squaring a number:

```
sqr(x) { return x * x; }
```

- Typed version (like in C) :

```
int sqr(int x) { return x * x; }
```

- Multiple versions for different types (C):

```
int sqrInt(int x) { return x * x; }
double sqrDouble(double x) { return x * x; }
```

- Overloading (Java, C++):

```
int sqr(int x) { return x * x; }
double sqr(double x) { return x * x; }
```

Overloading in Haskell

- Haskell introduces **type classes** for handling overloading in presence of type inference
- Very nice and clean solution, unlike most programming languages
- Adopted by Rust: **traits**
- We shall present this later in the course

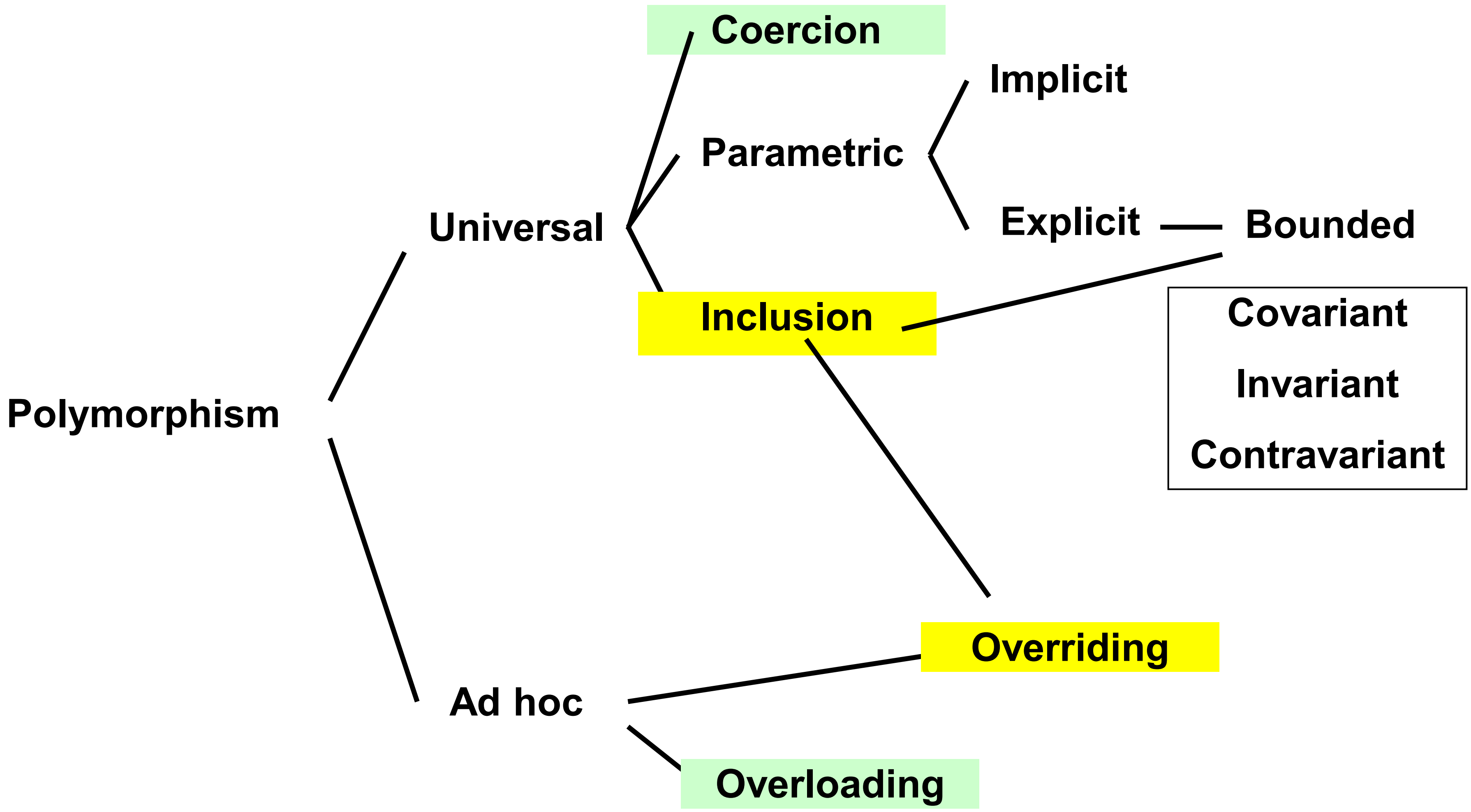
Universal polymorphism: **Coercion**

- **Coercion**: automatic conversion of an object to a different type
- Opposed to **casting**, which is explicit

```
double sqrt(double x){…}
double d = sqrt(5) // applied to int
```

- Thus the same code is applied to arguments of different types
- In well-designed languages, coercion only possible if there is no loss of information (Java vs C++)
- Degenerate, uninteresting case of polymorphism

Classification of Polymorphism



Inclusion polymorphism

- Also known as **subtyping polymorphism**, or just **inheritance**
- Polymorphism ensured by (Barbara Liskov') **Substitution principle**: an object of a subtype (subclass) can be used in any context where an object of the supertype (superclass) is expected
- [Java, C++,…] methods/functions with a formal parameter of type **T** accept an actual parameter of type **S <: T** (**S** subtype of **T**).
- Methods/virtual functions declared in a class can be invoked on objects of subclasses, if not redefined…

Overriding

```
class A{
    public void m(){
        // prints "A"
}}
class B extends A{
    public void m(){
        // prints "B"
}}
```

- [Java] A method **m** of a class **A** can be redefined in a subclass **B** of **A**.
- **Dynamic binding**:

```
A a = new B();   // legal
a.m();   // overridden method in B is invoked
```

- Overriding introduces ad hoc polymorphism in the universal polymorphism of inheritance
- Resolved at runtime by the lookup done by the **`invokevirtual`** operation of the JVM

Overloading + Overriding: C++ vs Java

```
class A {
public:
   virtual void onFoo() {}
   virtual void onFoo(int i) {}
};

class B : public A {
public:
    virtual void onFoo(int i) {}
};

class C : public B {
};


int main() {

    C* c = new C();
    c->onFoo();
                //Compile error -
                 // doesn't exist
}
```

```
class A {

    public void onFoo() {}
    public void onFoo(int i) {}
}

class B extends A {

    public void onFoo(int i) {}
}

class C extends B {
}

class D {
public static void main(String[] s)
{
        C c = new C();
        c.onFoo();
                    //Compiles !!
    }
}
```

Overriding + Overloading

- **[Java]** Overloading is type-checked by the compiler
- Overriding resolved at runtime by the lookup done by `invokevirtual`
- **[C++]** Dynamic method dispatch: C++ adds a v-table to each object from a class having virtual methods
- The compiler does not see any declaration of `onFoo` in `C`, so it continues upwards in the hierarchy. When it checks `B`, it finds a declaration of `void onFoo(int i)`, so it stops lookup and tries overload resolution, but it fails due to the inconsistency in the arguments.
- `void onFoo(int i)` **hides** the definitions of onFoo in the superclass.
- Solution: add `using A::onFoo;` to class B