Method Resolution Approaches

- Static - procedural languages (w/o fcn ptrs)
- Dynamically determined by data values
  - C with function pointers
  - Compile-time analysis can estimate possible callees
- Dynamically determined by receiver type
  - Some polymorphic OOPLs use run-time type of first parameter to specialize behaviors
  - Some OOPLs also use run-time types of other arguments
  - Challenge: how to have an efficient implementation of this kind of dynamic dispatch?

Dynamic Dispatch

- Choices PLs have to make:
  - When resolve function targets?
  - What to look at to do the method resolution? (e.g., receiver run-time type? Argument run-time types?)
  - How to divide the work between runtime and compile time, so as to minimize overhead for virtual calls?
  - Emphasize flexibility or performance?

Method Redefinition

- *Overriding* - replacing a superclass's implementation of a method, by one with identical signature (except receiver type)
  - Method must be accessible, non-static
- *Overloading* - providing more than one method with same name, but different signatures to distinguish them
- Simple cases of both are intuitive

Inheritance

- Overriding can widen method visibility
  - void f() {super f();} – where f protected in superclass
- Can override instance variables, but can still get to superclass variable using *super*
- Preferred inheritance uses all *private* data and provides *observer* and *mutator* methods
  - Using geta(), seta() methods means that changing superclass structure will not affect subclasses
- Access to
  - Methods is by run-time type of object referenced
  - Instance variables is by compile-time type of reference

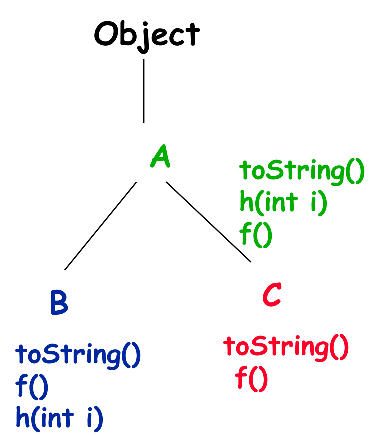
Possible Cases

- Inheritance, but all method names are unique
- Inheritance with *overriding*
  - Lookup happens at runtime based only on receiver's class
  - Next slide, eg1: A,B,C with respect to f(); A,B wrt h()
- Inheritance with *overloading* (different method signatures)
  - Java: Lookup establishes best match type signature at compile-time based on arguments' and receiver's declared classes; actual binding done by run-time lookup to match selection
  - Next slide, eg2, A,B wrt s()

Overriding Example

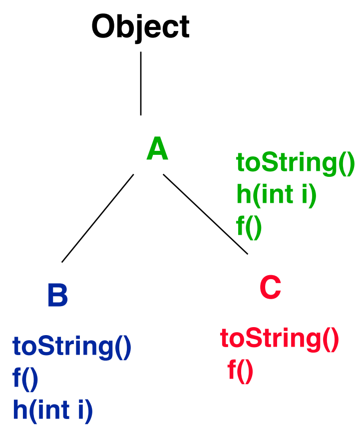
A a = new B();

How to resolve a.toString()?
1. At runtime, determine class of the object (e.g., a refers to an B object).
2. Start lookup for method with same signature in class B.
3. Proceed up inheritance hierarchy until find closest superclass with same signature method (i.e., method toString()); this may be class B itself



Java Overriding Example 1

```
//overriding - fcns have
//same signature
A a1 = new B();
A a2 = new C();
B b = new B();
A a = new A();
a.f();//A's f()
a1.f();//B's f()
a2.f();//C's f()
b.h(0);//B's h()
a1.h(2);//B's h()
a2.h(1);//A's h()
a.h(3);//A's h()
```



C++ Approach to Overriding

- If return type and signature of 2 functions match exactly, the 2nd is a re-declaration of the first and is an override
- If signatures of 2 functions match exactly, but return types differ, then 2nd declaration is in *error*
- If signatures differ in number or type of arguments, the 2 function instances are OVERLOADED. (return type not considered as part of signature here)

S. Lippman, C++ Primer

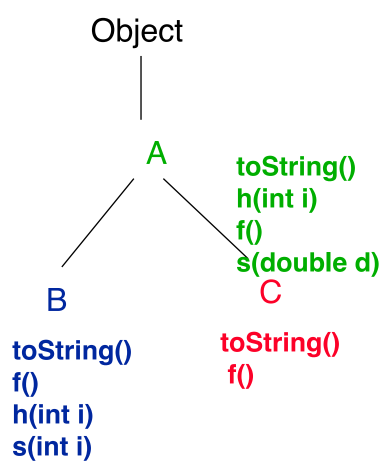
Overloading

- Java chooses to optimize dynamic dispatch by partially resolving references through preprocessing at compile-time
  - Need to use declared type and number of arguments + receiver type to help select an unique method
- Results in a not-just-dynamic lookup procedure because pre-selection is done
- Different from multi-methods (e.g., in Cecil) where dynamic lookup is based totally on *run-time* types of receiver and the arguments!

Example – unexpected results

```
A a1 = new B();
A a2 = new C();
B b = new B();
A a = new A();
```

```
//overloading -when signatures
//not same, must look at type
//matching between arg and
//param
a.s(3.);//A's s()
a1.s(3.);//A's s() because
  //arg is a double and B's
  //s() expects an int
b.s(0);//B's s()
b.s(1.0);//A's s()
  //casting is not type
  //conversionin Java
((A) a1).h(4);//uses B's h()
  //matching rules are not
  //always straight-forward
a1.s(0);//A's s()
```



Overloading Resolution in Java

- **At compile-time,** assemble a set of methods whose parameters are type compatible with the arguments and receiver
- For each invocation
  - Look at compile-time class of receiver and arguments
  - Move up class hierarchy from declared receiver type class trying for a match (possibly widening argument or receiver types)
  - Collect all possible matching methods into a set and then find the *most specific match* (defined on next slide)

Most Specific Match

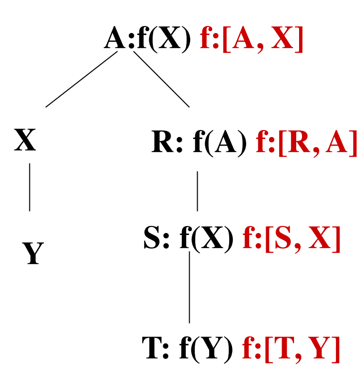
- If find unique method with exact match in type and number of arguments and compatible receiver type, choose it.
- Otherwise,
  - If any method f has arguments + receiver that can be assigned to any other method g in the set, discard g; Repeat as much as possible.
  - If only 1 method remains, use it as *template*.
  - If more than 1 method remains, the invocation is ambiguous, so the invoking code is invalid. *Compile-time error!!*

Overloading Resolution in Java Run-time Overriding

- At run-time, use run-time type of receiver to start search up class hierarchy for function exactly matching previously defined *template*. (Note: ignore run-time types of arguments)
- Stop going up the hierarchy when find first match to *template* type. Overloading guarantees there will be at least one match.

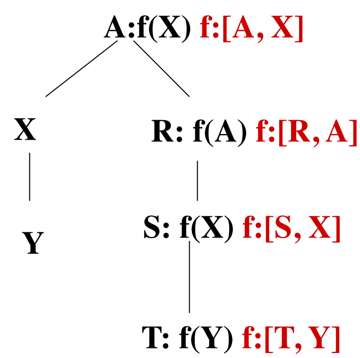
Java Example (cf Don Smith, Rutgers)

- Class hierarchy as shown contains 4 variants of method f()
- Signatures[...] include compile-time types of receiver and argument.
- Objects named for their compile-time type



Java Example

- a.f(x)
  - signature *f:[A, X]*
  - check classes *A*
  - matches f:[A, X]
- s.f(a)
  - signature *f:[S, A]*
  - check classes S, R, A
  - matches f:[R, A]

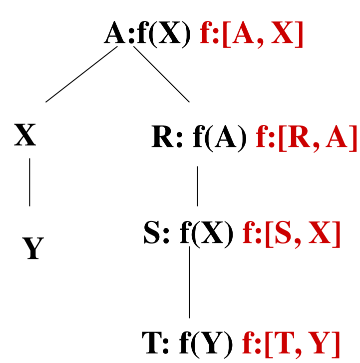


Java Example

- s.f(y)
  - signature *f:[S, Y]*
  - checks S, R, A
  - matches [S, X], [R, A], [A, X].
- check pairwise for most specific

[S, X] with [R, A]
[S, X] with [A, X]
[R, A] with [A, X]

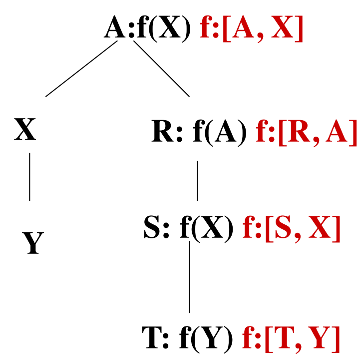
[S, X] is choice-most specific



If any method f has arguments + receiver that can be assigned to any other method g in the set, discard g;

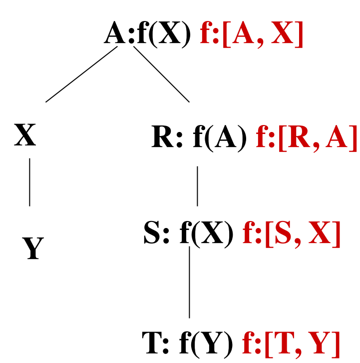
Java Example

- r.f(x)
  - signature *f:[R, X]*
  - checks R, *A*
  - matches [R, *A*], [*A*, X]
- check pair
  - R << *A* but *A* >> X
  - incomparable
  - no match
  - compile-time ERROR!



Java Example

- t.f(y)
  - signature *f:[T, Y]*
  - checks T, S, R, *A*
  - matches [T, Y], [S, X], [R, *A*], [*A*, X]
- pairwise check and get [T, Y]



Java Example

```
T t = new T();
X x = new Y( );
…
t.f(x);
```

signature is [T, X]

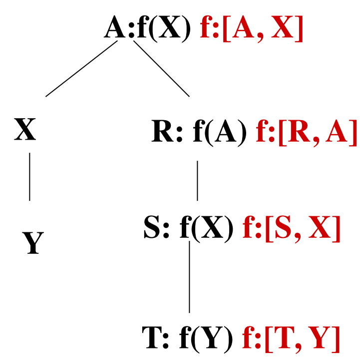
checks T, S, R, A

matches [S,X], [R,A], [A,X]

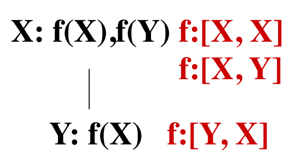
specificity eliminates all but [S, X]

at run-time receiver is class T and argument is class Y.

However, call will be resolved to f(X) in class S and not to f(Y) in class T, even though t.f(Y) is a perfect match to these types at runtime!



Java Example - 2




```
X x = new X( );
Y y = new Y( );
X xy = (X) y;
```

x.f(x) -- invokes X:f(X)

x.f(y) -- invokes X:f(Y) since more specific than X:f(X)

x.f(xy) -- invokes X:f(X)

y.f(x) -- invokes Y:f(X), since more specific than X:f(X)

xy.f(x) -- invokes Y:f(X) which overrides X:f(X) for Y receivers.

Key point is only receiver's run-time type is looked at for method resolution to the pre-computed template.