CS 4120
Introduction to Compilers

Andrew Myers

Cornell University

Lecture 31: Object layout and method dispatch

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Classes

- Components
  - fields/instance variables
    - values may differ from object to object
    - usually mutable
  - methods
    - values shared by all objects of a class
    - inherited from superclasses
    - usually immutable
    - usually function values with implicit argument: object itself (this/self)
  - all components have visibility: public/private/protected (subclass visible)

Implementing classes

- Environment binds type names to type objects, *i.e. class objects*
  - Java: class object visible in programming language (`java.lang.Class`)
- Class objects are environments:
  - identifier bound to type
    - + expression (e.g. method body)
    - + field/method
    - + static/non-static
    - + visibility

Code generation for objects

- Methods
  - Generating method code
  - Generating method calls (dispatching)
- Fields
  - Memory layout
  - Generating accessor code
  - Packing and alignment

Compiling methods

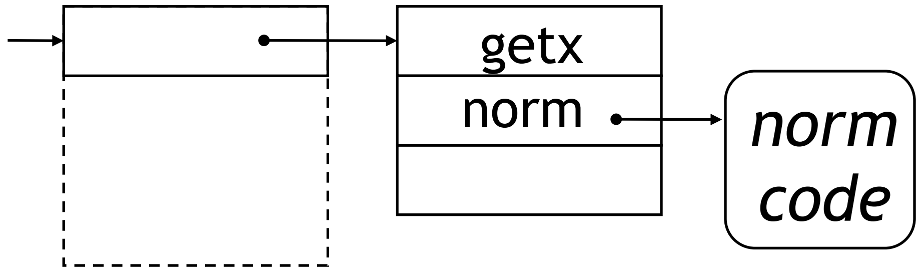
- Methods look like functions, are type-checked like functions…what is different?
- Argument list: implicit receiver argument
- Calling sequence: use *dispatch vector*

The need for dispatching

- Problem: compiler can't tell what code to run when method is called

```
interface Point { int getx(); float norm(); }
class ColoredPoint implements Point {...
   float norm() { return sqrt(x*x+y*y); }
class 3DPoint implements Point { ...
   float norm() return sqrt(x*x+y*y+z*z); }
```

- Solution: dispatch table (dispatch vector, selector table...)



Method dispatch

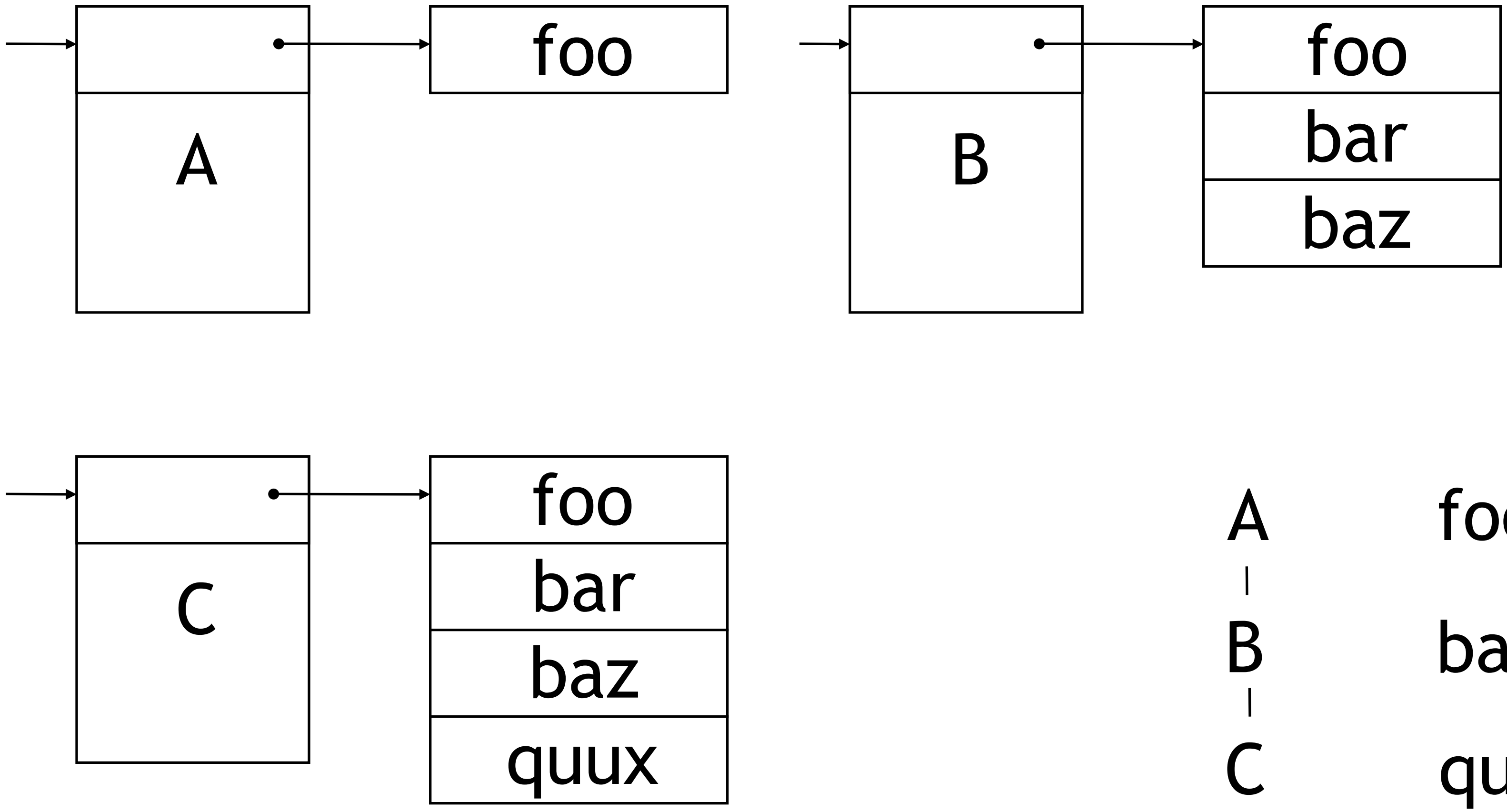
- Idea: every method has its own small integer index
- Index is used to look up method in dispatch vector

```
interface A {
   void foo();          0
}
interface B extends A {
   void bar();          1
   void baz();          2
}
```

```
class C implements B {
        void foo() {...}
        void bar() {...}
        void baz() {...}
        void quux() {...} 3
}
```

$$\begin{tikzcd}
A \arrow[d, dash] \\
B \arrow[d, dash] \\
C
\end{tikzcd}$$

Dispatch vector layouts



A	foo
B	bar,baz
C	quux

Method arguments

- Methods have a special variable (in Java, "this") called the *receiver object*
- Historically (Smalltalk): method calls thought of as *messages* sent to *receivers*
- Receiver object is (implicit) argument to method

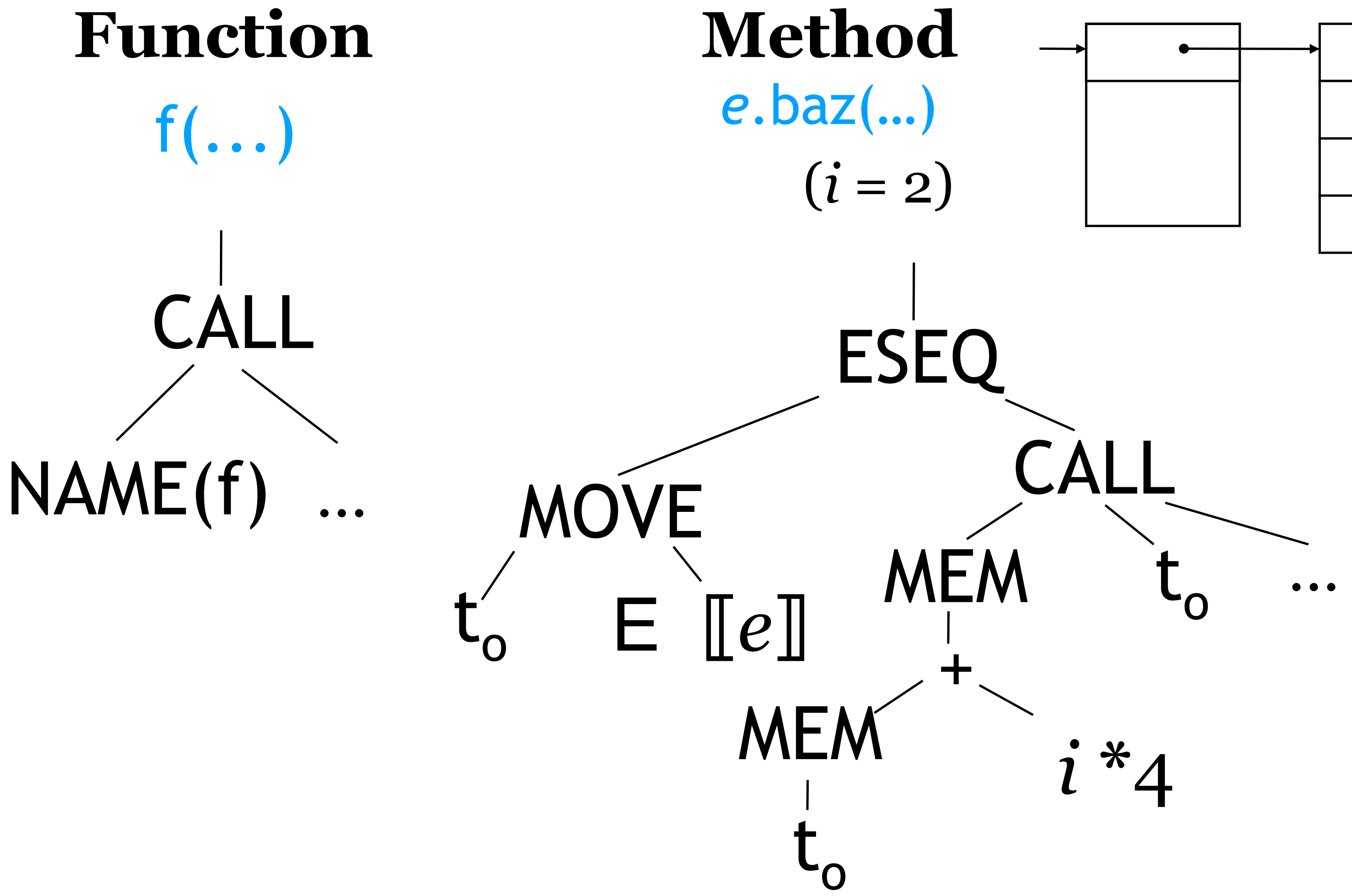
```
class Shape {
    int setCorner(int which, Point p) { … }
}
```

compiled like

```
int setCorner(Shape this, int which, Point p) { … }
```

How do we know the type of "this"?

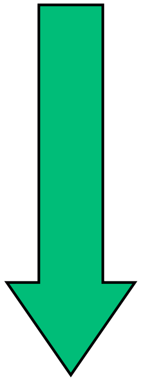
Calling sequence

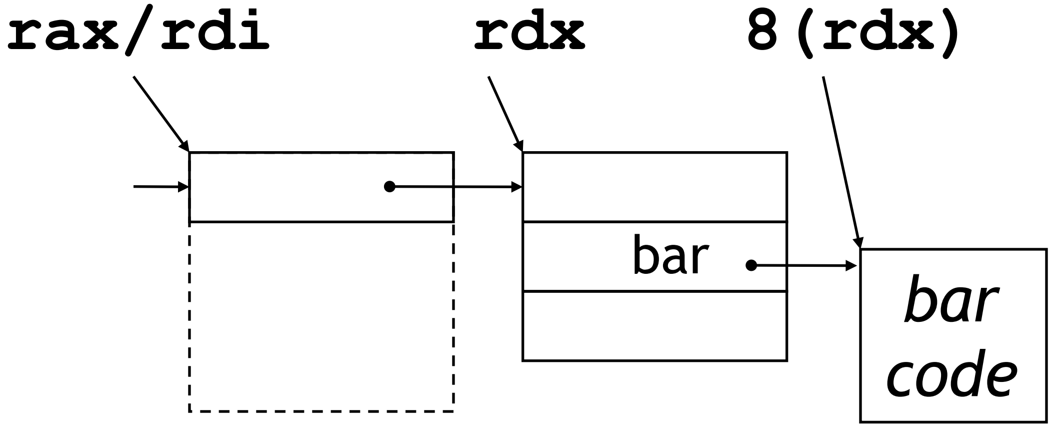


Example

A	foo
B	bar,baz
C	quux

b.bar(3);





```
mov t1, [tb]   (get DV)
mov rdi, tb    (arg 1)
mov rsi, 3     (arg 2)
call [rdx+8]   (bar=1)
```

Inheritance

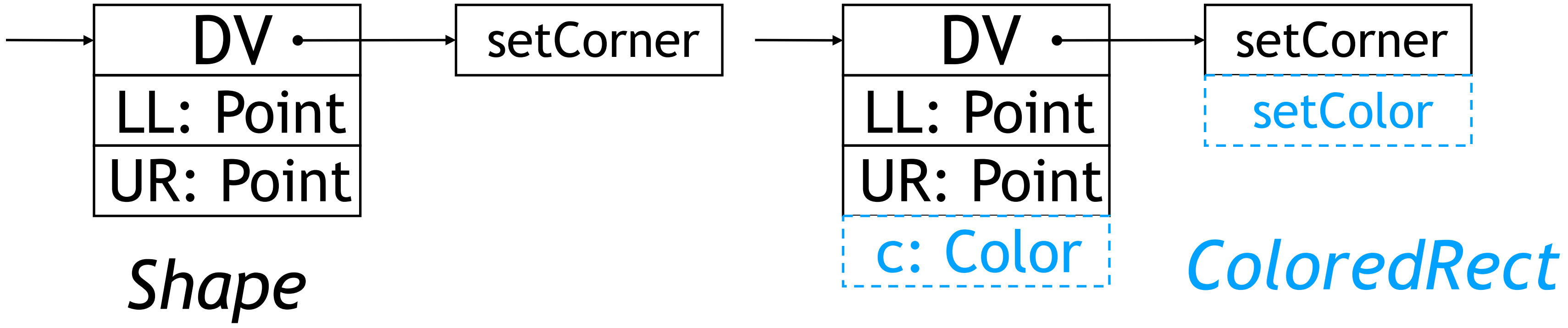
- Three traditional components of object-oriented languages
  - abstraction/encapsulation/information hiding
  - subtyping/interface inheritance -- interfaces inherit method signatures from supertypes
  - inheritance/implementation inheritance -- a class inherits signatures *and* code from a superclass (possibly “abstract”)

Inheritance

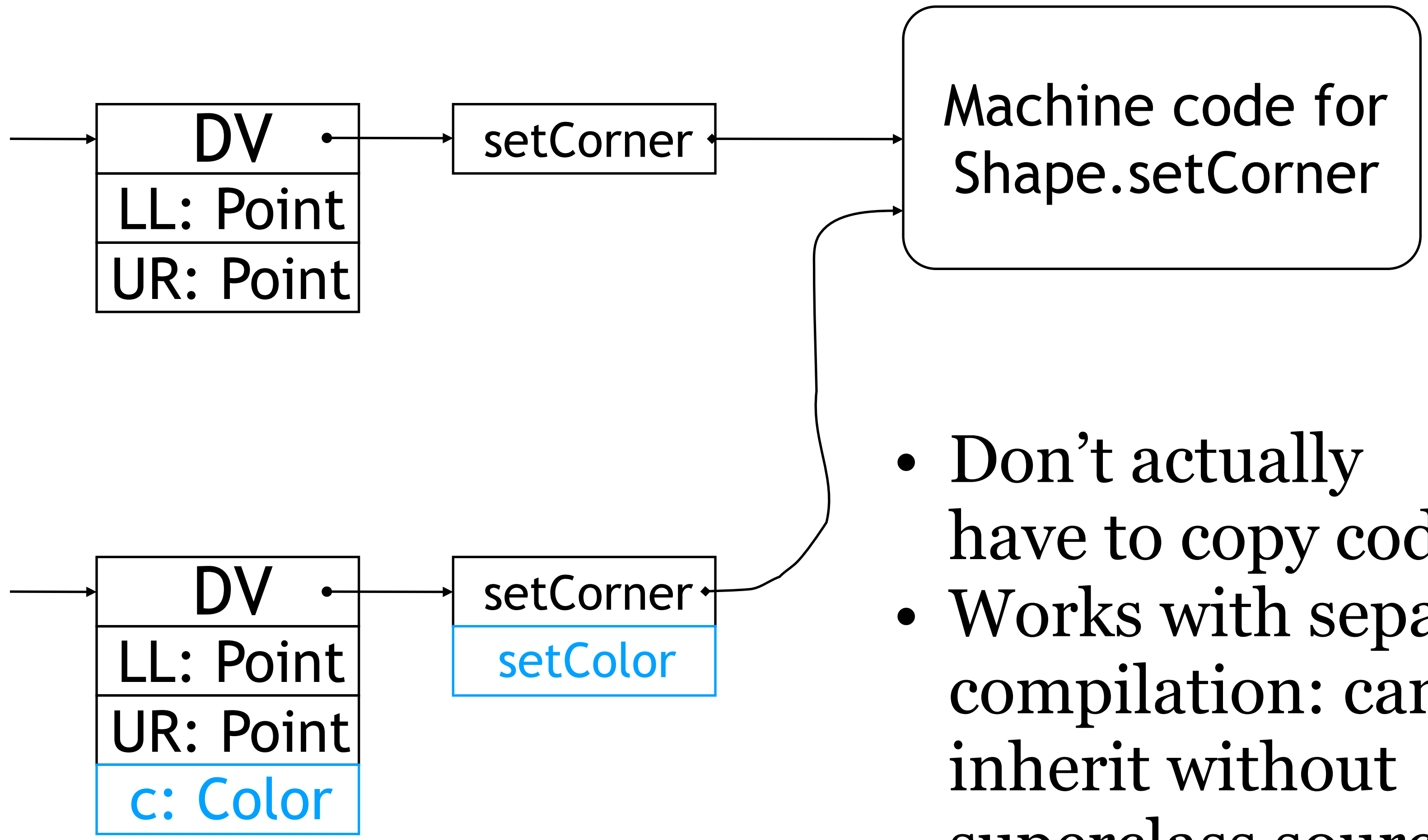
- Method code copied down from superclass if not *overridden* by subclass
- Fields also inherited (needed by inherited code in general)
- Fields checked just as for records: mutable fields must be invariant, immutable fields may be covariant

Object Layout

```
class Shape {
  Point LL, UR;
  void setCorner(int which, Point p);
}
class ColoredRect extends Shape {
  Color c;
  void setColor(Color c_);
}
```



Code Sharing



- Don’t actually have to copy code!
- Works with separate compilation: can inherit without superclass source

Interfaces, abstract classes

- Classes define a type *and* some values (methods)
- Interfaces are pure object types : no implementation
  - no dispatch vector: only a DV layout
- Abstract classes are halfway:
  - define some methods
  - leave others unimplemented
  - no objects (instances) of abstract class
- DV needed only for real classes

Static methods

- In Java, can declare methods *static* -- they have no receiver object
- Called exactly like normal functions
  - don't need to enter into dispatch vector
  - don't need implicit extra argument for receiver
- Treated as methods as way of getting functions inside the class scope (access to module internals for semantic analysis)

Constructors

- Java, C++: classes can declare *object constructors* that create new objects:
  `new C(x, y, z)`
- Other languages (Modula-3, Iota+): objects constructed by “new C”; no initialization code

```
class LenList {
    int len, head; List next;
    LenList() { len = 0; }
}
```

Compiling constructors

- Compiled just like static methods except:
  - pseudo-variable "this" is in scope as in methods
- this is initialized with newly allocated memory
  - first word in memory initialized to point to DV
  - value of this is return value of code

```
LenList() { len = 0; }
```

```
LenList$constr:
mov [rdi+8], 0
ret
...
mov rdi, 32; 3 fields + DV
call GC_malloc
mov [rax], LenList_DV
mov rdi, rax
call LenList$constructor
```

```
_DATA SEGMENT
LenList_DV DWORD LenList$first
           DWORD LenList$rest
           DWORD LenList$length
_DATA ENDS
```