Dynamic binding

Noticing differences between types when it matters

A simple view of the problem

- Suppose we have a class `Circle` derived from a base class `Shape`.
- If we have a pointer or reference to `Shape`, it might actually be pointing referring to a `Circle`.
- Why should we care?
- How can we tell?

Why do we care?

- The usual reason is that we want to take one action if the `Shape` is a `Circle` and some other action if it i
- Example: rotating a `Circle` require no action at all

An obvious solution

- Put a type code in each object
- Make sure that the type code is at th
  same offset in all objects
- Use the type code to decide what to

The obvious solution can be made to work

- C (and C++) guarantees that if two structures begin with the same sequence of component types, they have compatible layouts

mplementation (in C)

```
struct Shape {
    int type;
    Point center;
};
struct Circle {
    int type;          // Same as in
    Point center;      // the Shape struct
    int radius;
};
```

Using the type code

```
struct Shape *sp;
/* … */
switch (sp->type) {
case CIRCLE:
    /* … */
    break;
    /* and so on... */
};
```

What's wrong with the simple approach?

- Nothing is wrong with it
  - It can be made to work
- But it does have disadvantages
  - Adding a new type entails changing all `switch` statements
  - Layout compatibility comes about only through convention
  - The code to deal with `Circles` is scattered all over the place

The C++ approach: virtual functions

```
class Shape {
public:
    virtual void draw();
    // …
};
class Circle: public Shape {
public:
    virtual void draw();
    // …
};
```

The function definitions look normal

```
void Shape::draw() {
    // …
}
void Circle::draw() {
    // …
}
```

Calling a virtual function

- When a pointer (or reference) to a b class actually points (or refers) to a derived class object, *and*
- You use that pointer (or reference) t call a function that is declared virtua the base class, then
- The derived-class function is the one that is actually called.

Examples

```
Shape s;  Circle c;
Shape* sp;  Circle* cp;
Shape& sr = /* something */;
Circle& cr = /* something */;
s.draw();        // Shape::draw
c.draw();        // Circle::draw
sp->draw();      // depends on the object
cp->draw();      // depends on the object
sr.draw();       // depends on the object
cr.draw();       // depends on the object
```

A virtual call happens when

- A function is virtual in the base class
- A pointer or reference to a base class actually points or refers to a derived class object

Typical implementation

- Every object of a type with one or m
virtual functions includes a pointer to
virtual function table
- Every virtual call fetches the address
the function from a known offset (fix
at compile time) in the table
- Typical cost: a few memory referenc
per call

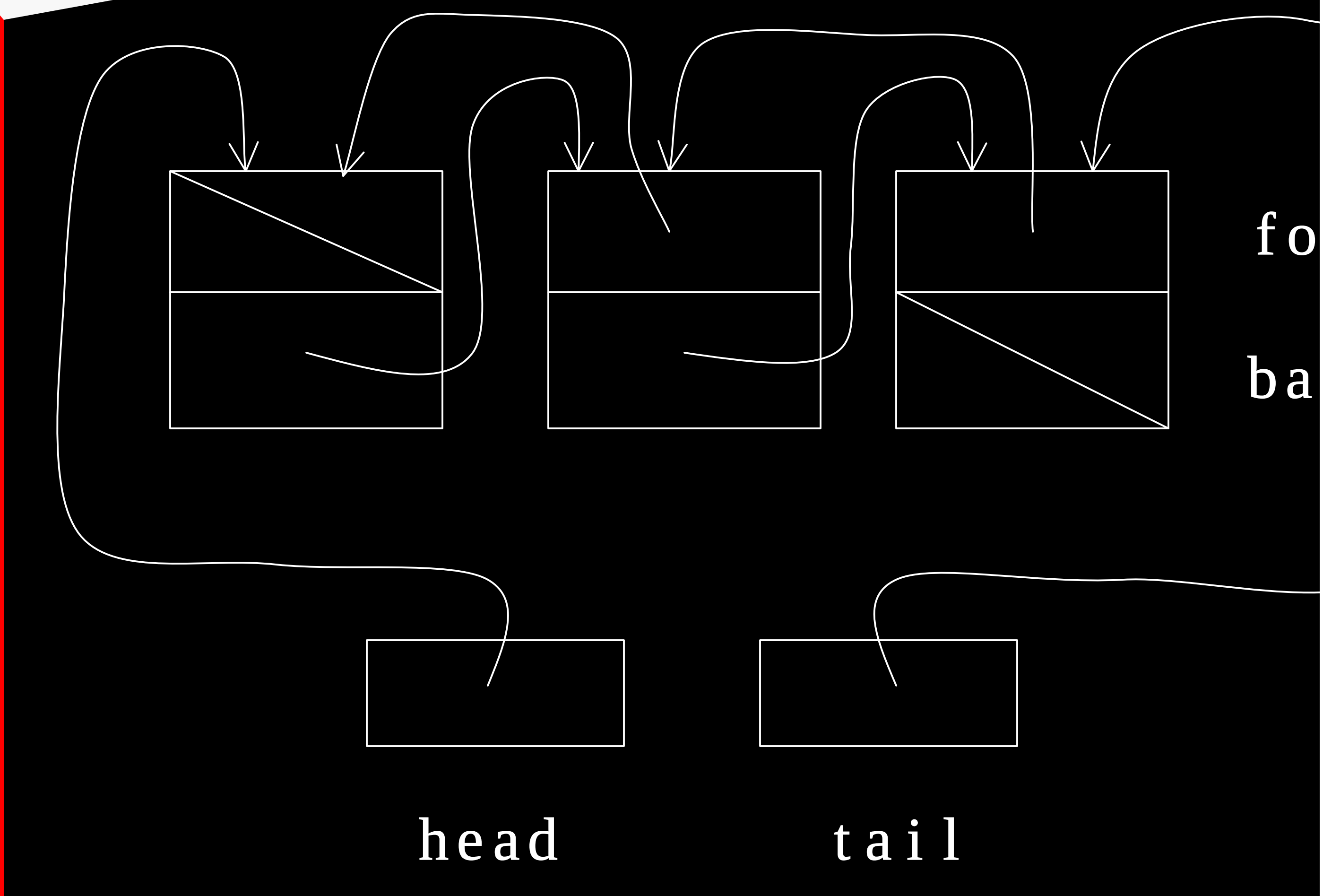
Types of virtual functions

- The argument types must be identic
  in base and derived classes
- The result types too, unless
  - The base class function returns a point
    (or reference) to some type T, and
  - The derived class function returns a po
    (or reference) to a type derived from T

An example

- We might have every `Shape` in the universe put itself on a doubly-linked list
- Then we could easily draw all the `Shapes`, even if some of them were really objects of classes derived from `Shape`

The data structure



Example code, part 1

```
Class Shape {
public:
     Shape();
     virtual ~Shape();
     virtual void draw();

private:
     Shape* forw;
     Shape* back;
     // …
};
```

Code, part 2

```
Shape* head = 0;
Shape* tail = 0;
Shape::Shape()
{
    forw = tail;
    back = 0;
    (tail? tail->back: head) = this;
    tail = this;
}
```

Code, part 3

```
Shape::~Shape()
{
   (this==head?head:forw->back) = bac
   (this==tail?tail:back->forw) = for
}
```

Adding new shapes

- Just do it...

```
class Circle: public Shape {
public:
    virtual void draw();
// …
};
void Circle::draw()
{ /* … */ }
```

Draw all the shapes

```
void drawall()
{
    Shape* p = head;
    while (p) {
        p->draw();   // virtual call
        p = p->back;
    }
}
```

Why the virtual destructor?

- Whenever
  - You say `delete p`, *and*
  - The type of `p` is "pointer to base," *and*
  - `p` actually points at a derived object
- Then the base class must have a virtual destructor, even if it does nothing

What does a virtual destructo do?

- It is a signal to the compiler that usi `delete` (which always destroys the object) should go through the virtua call mechanism
- It has no effect otherwise

Multiple abstractions

- A `Shape` is something that can go o the list defined by `head` and `tail`
- A `Shape` is something that supports `draw` operation
- A `Circle` is a kind of `Shape` whose `draw` operation is implemented in a particular way

Virtual functions and type fields

- You can use virtual functions to implement type fields:

```
enum Kind { SHAPE, CIRCLE /* … */
class Shape {
public:
    virtual Kind my_type() {
        return SHAPE;
    }
    // …
};
```

- But it's often unnecessary in practice

Virtual functions and constructors

- While an object is under construction destruction, its type is what it was declared to be:

```
class Shape {
public:
    // …
    virtual void draw();
    Shape() {
        draw();    // Shape::draw
    }
};
```

Why aren t all member functions virtual?

- Not every class needs inheritance
- The overhead, although small, exists
- Sometimes functions shouldn t be virtual (for example, `operator[]` in the `Vector` example from last lectu

Summary

- Inheritance makes it easier to descri
  a family of types by describing their
  similarities and differences
  - The similar parts go in base classes
  - Each set of relevant differences gets its
    own derived class
- Virtual functions are an efficient way
  recovering the differences in C++