CS32 Summer 2013

Object-Oriented Programming in C++

RTTI, Advanced Inheritance, Intro to Templates

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Plan for Today

- Alternatives to Virtual Functions
  - type fields
  - dynamic_cast and RTTI
- Pure Virtual Functions and Abstract Classes
- Multiple Inheritance
- Intro to Templates
  - mainly, the topic of the last week

Alternatives to Virtual Functions

- In C++ we cannot tell the actual type of an object a pointer / reference points to (*unless* we do something special)

```
Base *pobj = get_object_addr();
// pobj may point to Base or any its derivative
```

- What to do with it:
  - The Good: live in ignorance and use *virtual functions* (do not need to know the actual type of an object; the proper implementations of virtual functions are called based on the info from the virtual table)
  - The Bad: introduce "*type field*"
  - The OK: use dynamic_cast<T> and typeid (RTTI)

Type Field

- “Type field” is a field dedicated to keeping information about the type of every object

```
// http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/type-field.cpp
class shape {
protected:
  string _type_name;
public:
  void draw() {
    if(_type_name == "triangle") {
      cout << "..drawing triangle..";
    } else if(_type_name == "circle") {
      cout << "..drawing circle..";
    } …
    } else { cout << “ERROR: unexpected type”; } // - new types may appear
  }
};

class triangle : public shape {
public:
  triangle() : _type_name(“triangle”) { }
};
```

- Does not always work (what if class *shape* does not know how to draw a *triangle*?)
- Problems with extending (what if we need to add class *rhombus*, but we cannot change code of class *shape* as it is compiled in .so/.dll?)

Preliminaries on C++-Style Casts

- C-Style casts – same syntax for semantically different casts

```
T var = (T)other;
T *pvar = (T*)pother;
```

- C++-Style casts:

`static_cast<T>` – used when the type is *known*

```
void doit(base *pobj) {
    // we know that pobj points to derived
    derived *pd = static_cast<derived*>(pobj);
}
```

`dynamic_cast<T>` – used when exact type is *unknown*

```
void doit(base *pobj) {
    if(derived *pd = dynamic_cast<derived*>(pobj))
        pd->some_advanced_method();
}
```

`const_cast<T>` – used to remove `const`'ness (bad idea)

`reinterpret_cast<T>` – allows treating `car` as a `cow`

RTTI: dynamic_cast<T> and typeid

- ***Run-Time Type Info:*** Compiler *can* include type information – something like *type field* – in each object. (g++ enables RTTI *by default*.) Consequently, we have the following two constructions:
  - `dynamic_cast<T>` – *try* to cast to T; if cannot cast, return NULL

```
void doit(base *pobj) {
    if(derived *pd = dynamic_cast<derived*>(pobj))
        pd->some_advanced_method();
}
```

  - `typeid` – like a type field

```
// http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/rtti.cpp
class shape {
public:
  virtual void dummy(){} // typeid works only for polymorphic classes
  void draw() {
    // name() returns const char* "{name_length}{name}"
    string type = typeid(*this).name();
    if(type == "8triangle") { cout << "..drawing triangle.."; }
    else if(type == "6circle") { cout << "..drawing circle.."; }
    // …
    else { cout << "Error: type not recognized"; }
  }
};
```

RTTI: dynamic_cast<T> and typeid

- Use case: polymorphic partial assign

```
// http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/polyasgn.cpp
class derived : public immediate_base {
public:
  void assign(const deepest_base *pother) /* override */ {
    // try to copy base state
    immediate_base::assign(pother);

    // try to copy current-level state
    const derived *pother_derived =
        dynamic_cast<const derived*>(pother);

    // if pother is of type derived
    if(pother_derived) {
        // copy pother's state's part declared in derived
        _c = pother_derived->_c;
        _d = pother_derived->_d;
    }
  }
};
```

Abstract Classes and Pure Virtual Functions

- We may not know how to implement a virtual method in a base class

```
class shape {
public:
    virtual void draw() const {
        /* do not know how to draw an abstract shape */
    }
};

class triangle : public shape {
public:
    void draw() const { /* know how to draw a triangle */ }
};
```

  - An empty virtual method does not enforce its implementation by the derived classes (can enforce in runtime, by throwing exceptions, but we strive for compile-time error checking)

- Sometimes we want to inherit only *interface*, not *implementation* (C++ does not have interfaces in Java/C# sense)

```
"interface" IDrawable {
    void draw() const;
    void resize(const rectangle &frame_to_fill);
}
```

Abstract Classes and Pure Virtual Functions

- Pure virtual function – a virtual function without implementation

```
class shape {
public:
    virtual void draw() const = 0;
    virtual ~shape() { }
    void some_implemented_method() { … }
};

class pretty_shape : public shape {
    /* still have no idea how to draw() */
}

class triangle : public pretty_shape {
public:
    void draw() const { /* drawing triangle */ }
};
```

- Class having *at least one* pure virtual function is abstract
- Abstract classes cannot be instantiated
- Class having no pure virtual functions is concrete

Abstract Classes and Pure Virtual Functions

- C++ Interfaces = abstract classes consisting of pure virtual functions (and, usually, an empty virtual destructor)

```
class IPlugin { // an interface for a browser plugin
public:
    virtual string plugin_name() = 0;
    virtual bool activate(context *pcontext) = 0;
    virtual void run() = 0;
    virtual ~IPlugin() { } // the only "impurity"
};

class YoutubeDownloaderPlugin : public IPlugin {
    /* implements methods of IPlugin */
};

IPlugin *pplugin = new YoutubeDownloaderPlugin(...);
firefox_connector.add_plugin(pplugin);
```

- If a class is derived from an interface class ("interface"), we usually say that the class *implements* that interface
- Class may implement many interfaces (see multiple inheritance)

Intermezzo: Composition vs. Inheritance

- Inheritance ("is-a") – extending classes of *similar nature*

```
class vehicle { … };
class car : public vehicle { … };
class delorean : public car { … };
```

- Composition ("has-a") – extending classes with *members* of possibly different nature

```
class car {
private:
    engine &_engine;
    list<passenger*> _passengers;
}
```

- Composition is better in that classes do not share their *internals* with derived classes (unless you decide to never use *protected* members)
- Composition is used more often than inheritance
- Prefer (relatively) small classes with clear responsibilities to "fat" classes that do *everything*; combine small classes using composition
- "Flat" classes may be preferred when for remote calls

Multiple Inheritance

- Multiple Inheritance – class derivation from more than one base class

```
// http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/multinher.cpp

class Vehicle { … };

class Mechanism { … };

class IDrivable { … };

class Car :
    public Vehicle,
    protected Mechanism,
    public IDrivable { … }
```

- Interface and implementation are inherited from each base

Problems of Multiple Inheritance

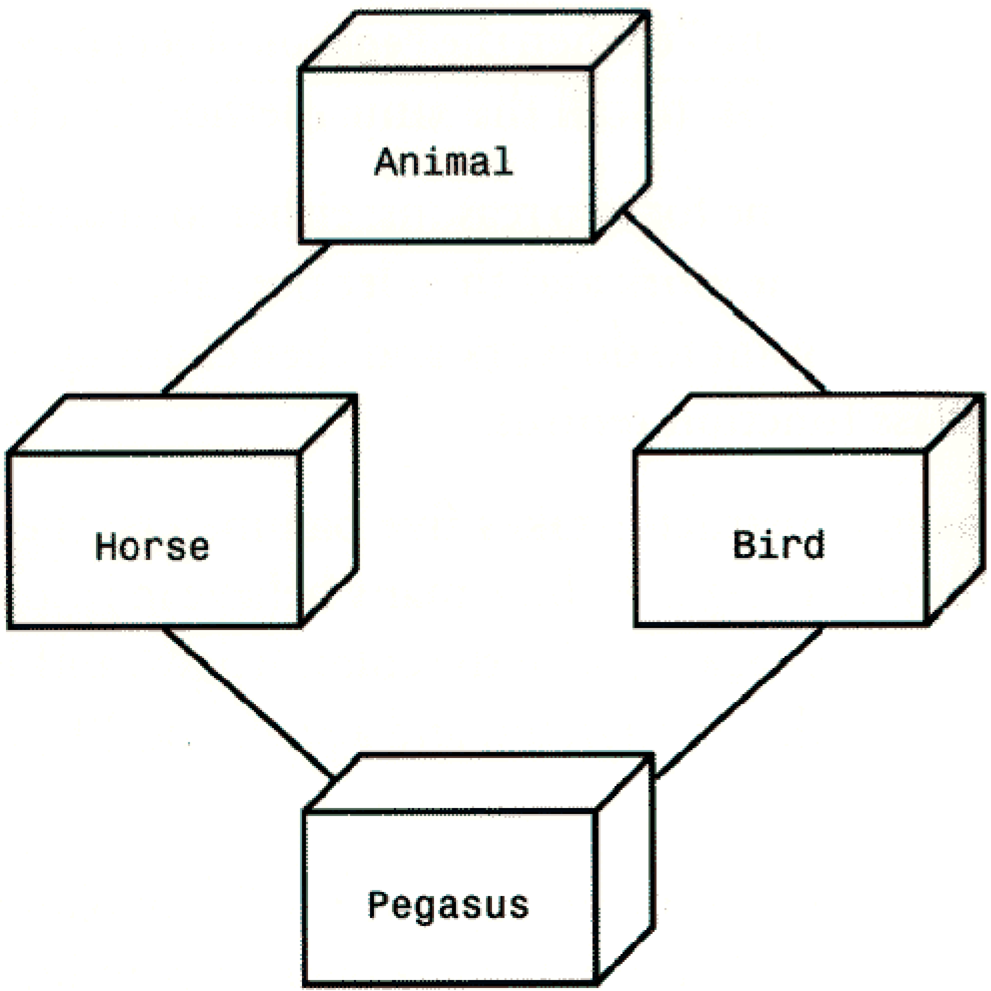
- Member collision and ambiguity resolution

```
// http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/miar.cpp

class base1 {
public:
   virtual void print() const { … }
};

class base2 {
public:
   virtual void print() const { … }
};

class derived : public base1, public base2 { };

derived obj;
obj.print(); // error: request for ‘print’ is ambiguous
obj.base2::print(); // ok (calling base2's print impl)
```

Problems of Multiple Inheritance

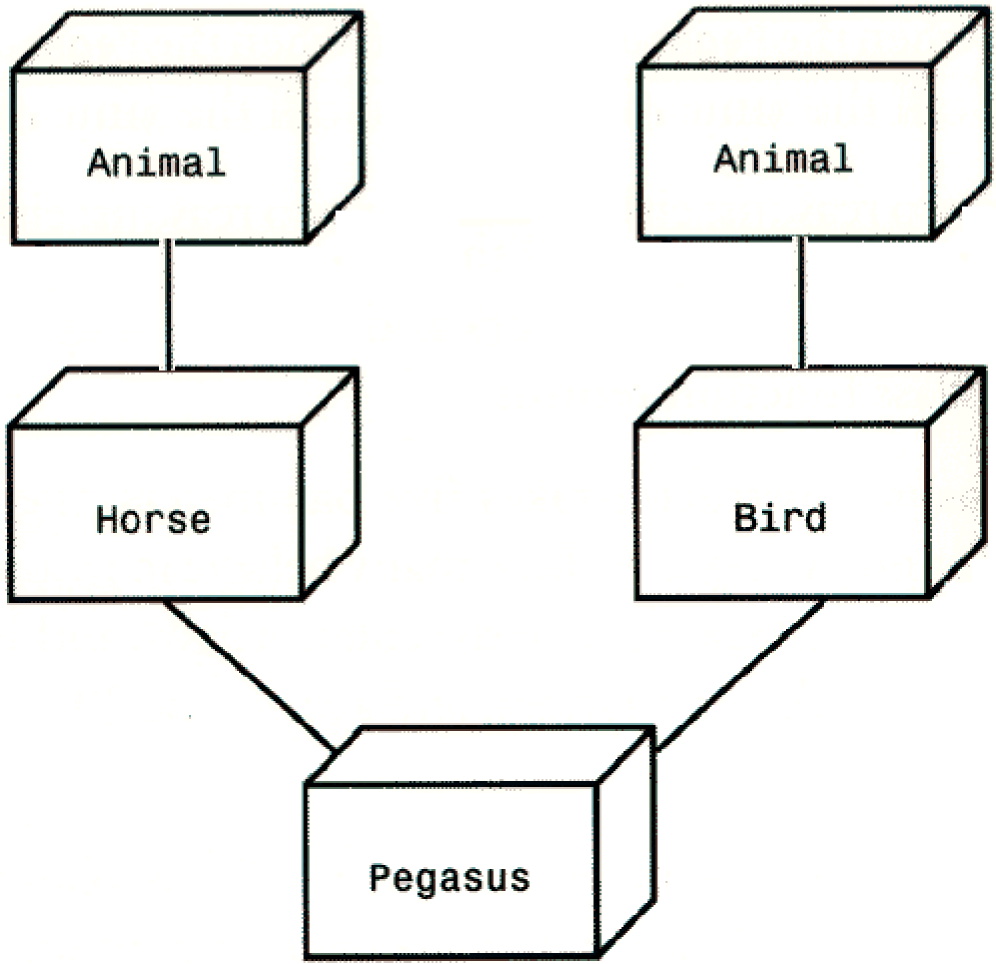
- Cyclic inheritance graph (simplest cycle – diamond):

// http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/diamond.cpp



Problems of Multiple Inheritance

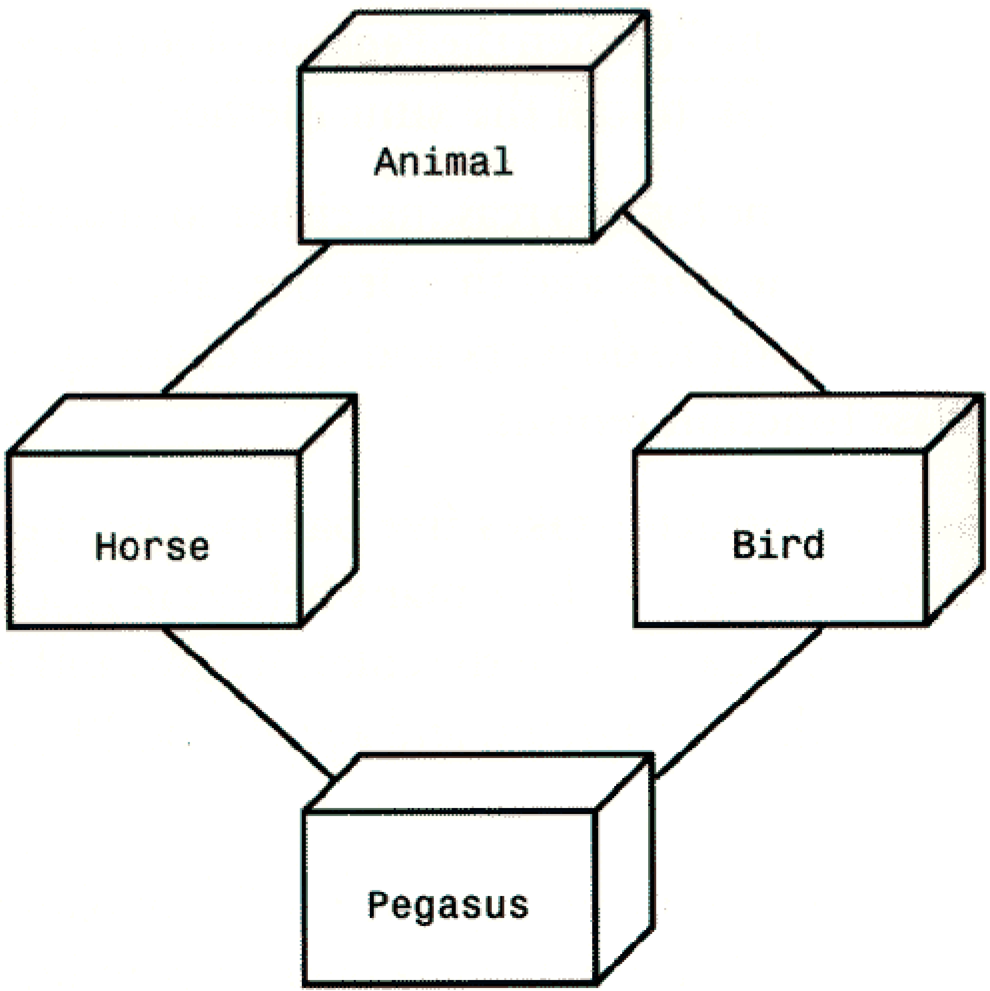
- By default, repeated base class is replicated



Problems of Multiple Inheritance

- To prevent replication, virtual base classes are used

  // http://cs.ucsb.edu/~victor/ta/cs32/disc5/code/virtbase.cpp



Multiple Inheritance

- There are many other problems with multiple inheritance
- That is why multiple inheritance is deliberately *not* included in Java and C# (exception – inheriting multiple interfaces)
- Safe uses of multiple inheritance in C++:
  - Implementing interfaces
  - Mix-in classes (– do not live on their own)

```
class uncopyable { // ← mix-in class
protected:
   uncopyable() { }
private:
   uncopyable(const uncopyable &other);
   uncopyable& operator=(const uncopyable &other);
};

class myclass : …, public uncopyable { … }

myclass obj1;
myclass obj2(obj1); // compile-time error
```

Templates

- C++ templates allow to write generic code using types and values as parameters

```
template<typename TChar>
class String {
private:
   TChar *pchars;
   int len;
public:
   String();
   explicit String(const TChar *src);
   String(const String &other);
   TChar& operator[](int i) { return pchars[i]; }
   ...
};

using PlainString = String<char>;

PlainString plain_str;
String<wchar_t> unicode_str;
String<bool> boolean_str;
```

Templates

- Each time a template is used with a unique set of template arguments, a new class is generated by the compiler

```
// 3 different versions of class String are generated
String<char> plain_str;
String<wchar_t> unicode_str;
String<bool> boolean_str;
```

- This generating process is called *template instantiation*

- Each such class generated for a particular template argument list is called *template specialization*

```
vector<car> myvec; // instantiating vector<T>
```

Templates and STL – next week

Before you leave...

- PA4 – due Thursday night

- PA5 will be released Thursday late afternoon
  - due: in ~7-8 days (TBA)

- **TA Evaluations**

~ Thanks ~