Object Oriented C++

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Object Orientation
You Should Known ...

Today's software is complex:

- code base becomes bigger and bigger

Object Oriented programming:

- has been proven to be effective [1] on handling big things

Common knowledge:

- cool features – e.g. polymorphism
- features have a cost – e.g. virtual calls

C++ statement:

- if you known what you are doing, you can have both features and performance

[1] essential

Object Orientation
A Running Example

For this/these classes we will use a small example:

- a processor simulator

It is very simple:

- just print instructions instead of executing them

Contents

Classes
Evolving C **struct**

Abstract Data Types force programmer focusing on:

- data
- operations on data

Classes are the preferred way to implement ADT in C++:

- just take C **struct**
- allow to declare member functions as **struct** fields
- add scoping rules to implement information hiding
- introduce the **class** keyword as syntactic sugar

C++ classes are ready!

Classes
Hardware is Good

Considering classes an extension of **struct** allows to focus on data, without loosing the hardware perspective:

Big

```
class Big {
  char a;
  int b;
  char c;
};
```

Compact

```
class Compact {
  char a;
  char c;
  int b;
};
```

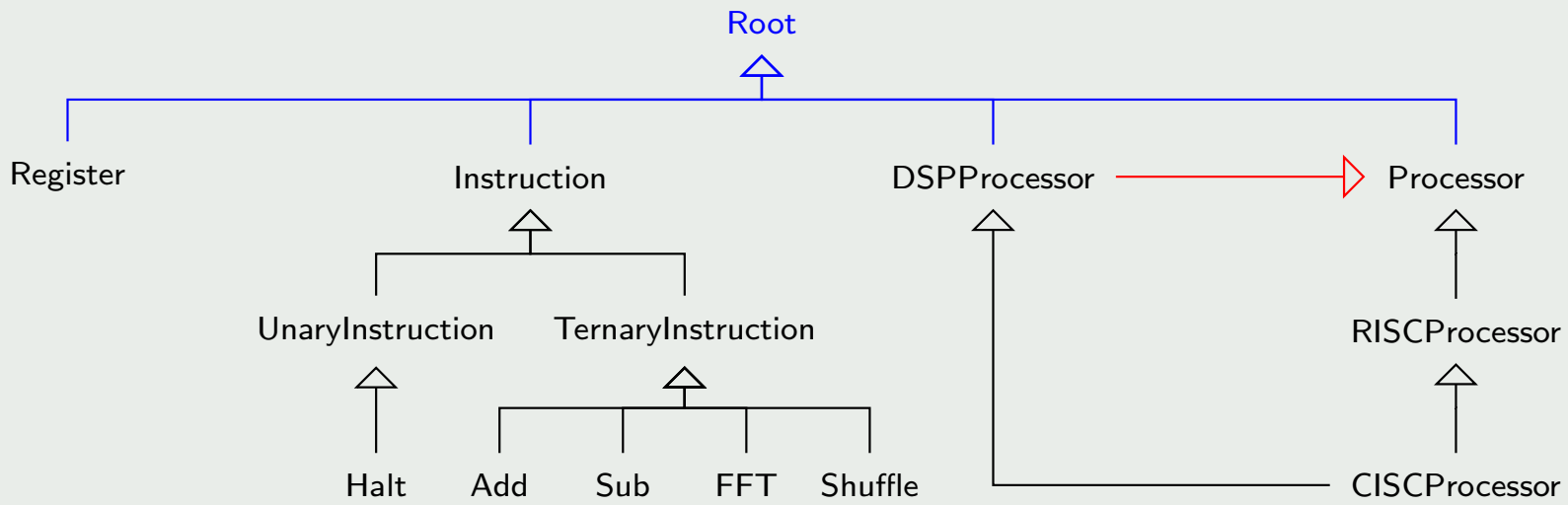
How much memory is consumed by Big and Compact?

- simple test in `simple-mem-layout.cpp`

The class hierarchy is used to:

- organizing classes
- establishing a contract with class users
- promoting code re-using

Processor Class Hierarchy



Class Hierarchy
Files

Showing code on slides is both boring and error-prone, so I will use as much as possible `vi` *and the shell. All sources are available on the course site. They are heavily commented. On slides there are only some tips.*

"Talk is cheap, show me the code" [5]

A Java-to-C++ translation table is available at slides end.

The reported class diagram refers to examples found in files `{java,cpp,dsp}-processor.cpp`

Class Hierarchy
Comment

C++ inheritance tree is not single rooted:

- it is not a tree, it is a DAG
- blue lines do not exist

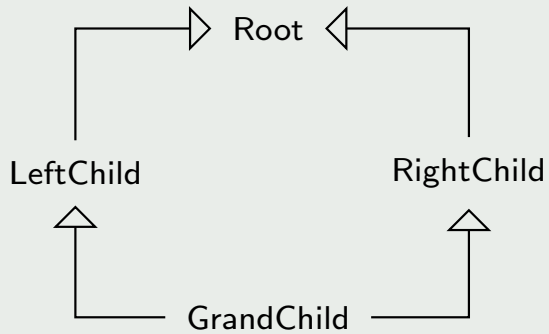
It is up to programmer avoiding dangerous inheritance shapes:

- diamond problem
- red extension should not be used

Let us analyze the diamond problem

It is an ambiguity in the class derivation process:

Basic Diamond



Both LeftChild and RightChild inherits members from Root. How are they inherited by GrandChild?

- a precise semantic is needed
- problem addressed in different ways
- we will see two basic solutions

Diamond Problem
Avoid by Construction

The problem arises only in presence of multiple inheritance:

- force using single inheritance – e.g. Java
- adopt a programming discipline – avoid using it

Problems:

- new constructs could be added to the language – e.g. Java interfaces
- limit code reuse

Diamond Problem
Construct Hierarchy Carefully

C++ does not prevent you using multiple inheritance:

- useful in many applications

It is up to the programmer avoiding dangerous derivations:

- it makes no sense deriving DSPProcessor from Processor
- it cannot be used alone
- its purpose is to implement code for DSP-specific instructions

Diamond Problem
Code

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In the file `diamond-mem-layout.cpp` is shown how C++ allows building diamond in the derivation process, but only under the assumption that ambiguities can be solved at compile-time.

Polymorphism
Same Interface, Different Implementations?

Polymorphism is a key concept on modern programming languages:

- it enable handling different data types using the same interface
- it allows defining the behavior of a family of data types, decoupling specification from implementation

C++ supports two kind of polymorphism:

- subtype polymorphism
- parametric polymorphism

Now, focus on the first kind

Subtype Polymorphism
Recalling Java . . .

You should known it:

- a class define some functionalities
- subclasses refine functionalities
- programmers uses root class interface
- call to the actual implementation resolved at runtime – dynamic binding

Dynamic binding performed using a virtual table

Subtype Polymorphism
Java Example

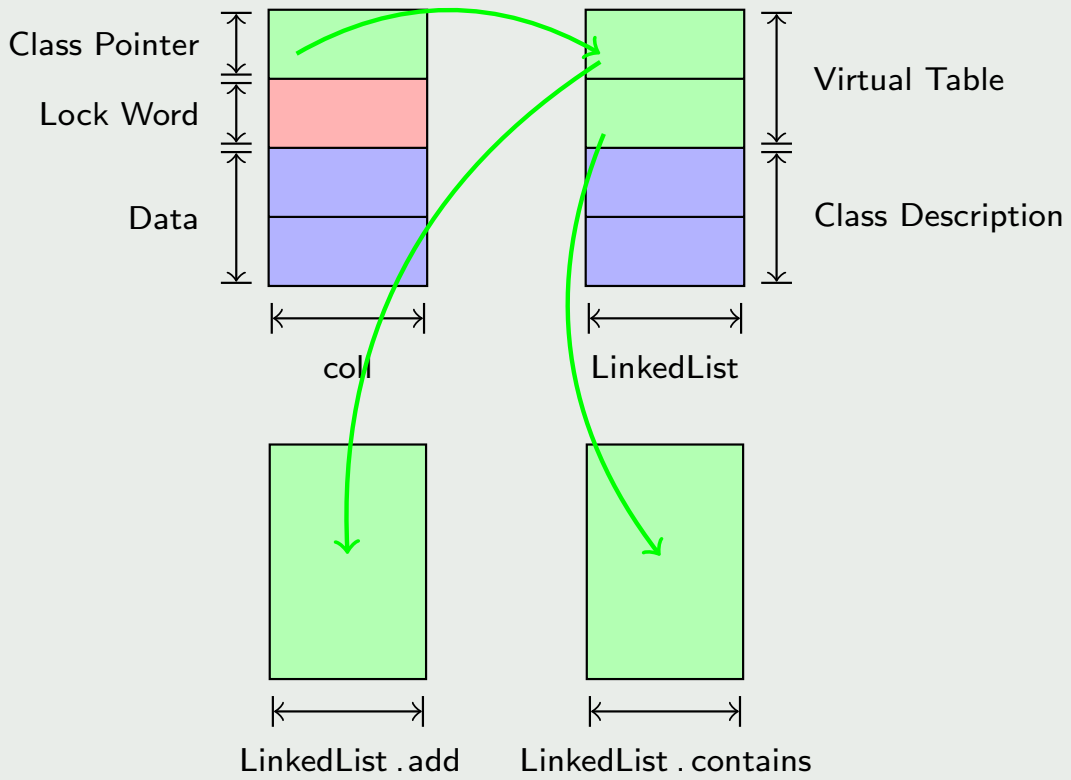
Dynamic Collections

```
interface Collection {
  public boolean add(Object o);
  public boolean contains();
}

class LinkedList implements Collection {
  public boolean add(Object o) { ... }
  public boolean contains() { ... }
}

Collection coll = new LinkedList();
coll.add(new Object());
```

LinkedList in HotSpot Memory



C++ class layout is similar [2]

[2] See `cpp-processor.cpp`

Subtype Polymorphism
Code

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Following slides will refer to `{java,cpp}-processor.cpp` files

Subtype Polymorphism
Comment

Try running `java-processor.cpp`:

- you do not get the expected result!

In Java all non-static methods are virtual:

- dynamic dispatching by default
- JVM tries to optimize calls

In C++ virtual tables is under programmer control:

- member functions calls resolved at compile-time by default
- dynamic dispatching enabled using the **virtual** keyword

Try running `cpp-processor.cpp`:

- size of *Processor increases due to VT emission!

Subtype Polymorphism
Overhead

Virtual Call

```
movl (%eax), %eax
movl (%eax), %edx
call *%edx

movl (%eax), %eax
addl $4, %eax
movl (%eax), %edx
call *%edx
```

Call overhead:

- VT fetching
- VT lookup
- indirect call

On average [1]:

- 5.2%/13.7% of execution time

Normal Call

```
call _ZN10LinkedList4sizeE
```

Call overhead:

- zero

Name Decoration

Some C++ features are not hardware-oriented:

- e.g. function overloading

These features allows an user to refer to different things using the same name:

- impossible for hardware distinguish between them
- C++ front-end decorates names in order to uniquely identify functions, classes, variables, ...

The `c++filt` tool allows to un-decorate names:

Decorated	Un-decorated
_ZN10LinkedList4sizeE	LinkedList :: size

Pure Virtual Functions
Code

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In `program.cpp` there is an example of pure virtual function

Multiple Inheritance
Code

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The `dsp-processor.cpp` file contains an example of multiple inheritance. Please keep attention at the inheritance graph:

- DSPProcessor is a processor, but it cannot be used alone
- it does not inherit from Processor, avoiding the diamond problem

Contents

Iterators
Augmenting Pointers

Recalling streams:

- an extension of files

Iterators built starting from pointers:

Pointers:

- abstract from memory holding data
- used to pass data by address

Iterators:

- mainly associated with containers
- abstract from the specific container holding pointed element

Iterators act like pointers:

- **operator**$*$, **operator**$->$, **operator**$++$, ...

Iterators
Code

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Following slides refer to
`program{,-pointers,-custom-iterator,-iterator}.cpp`

Iterators
Comment

Starting from `program.cpp`:

- explicit access to instruction through **operator**[]

With pointers – `program-pointers.cpp`:

- C-style interface

With iterators – `program-custom-iterator.cpp`:

- same interface used with pointers

After refactoring, you get `program-iterator.cpp`

Iterators
Interaction with C++ Library

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In `program-functors.cpp` iterators are used together with std :: for_each . Many algorithms of C++ library are iterator-based

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Java Concepts

Java shares many concepts with C++:

- both are object-oriented
- both are C-based
- ...

Here is an incomplete translation table from Java to C++:

- Java abstract methods are called pure virtual functions in C++
- A C++ class is said to be abstract if it has at least one pure virtual function. If the only members of a C++ class are pure virtual functions, the class is said to be pure abstract
- Java interfaces can be realized in C++ using pure abstract classes

Contents

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