Miscellaneous Points

Object-Oriented Programming with C++

Named casts

- The C-style cast is:
  - dangerous because it can do (logically different) conversion.
  - not search-friendly
- If you must cast things, use a named cast:
  - static_cast (less likely to make mistakes)
  - dynamic_cast
  - reinterpret_cast
  - const_cast
  - …

Named casts

```
double d = 7.1;
int a;

a = d;                        // implicit

a = (int) d;                  // explicit

a = static_cast<int>(d); // exact meaning
```

Named casts

```
int a = 7;
double* p;

p = (double*) &a; // ok (but a is not a double)

p = static_cast<double*>(&a); // error

p = reinterpret_cast<double*>(&a); // ok: I
really mean it
```

Named casts

```
const int c = 7;
int* q;

q = &c; // error

q = (int*)&c; // ok (but is *q=2 really allowed?

q = static_cast<int*>(&c); // error

q = const_cast<int*>(&c); // I really mean it
```

Named casts

```
struct A {
  virtual void f() {}
};
struct B : public A {};
struct C : public A {};

int main()
{
  A *pa = new B;
  C *pc = static_cast<C*>(pa);  // OK: but *pa
is B!
}
```

Named casts

```
struct A {
  virtual void f() {}
};
struct B : public A {};
struct C : public A {};

int main()
{
  A *pa = new B;
  C *pc = static_cast<C*>(pa);  // OK: but *pa
is B!
  C *pc = dynamic_cast<C*>(pa); // return
nullptr
}
```

Named casts

```
struct A {
  // virtual void f() {}
};
struct B : public A {};
struct C : public A {};

int main()
{
  A *pa = new B;
  C *pc = static_cast<C*>(pa);  // OK: but *pa 
is B!
  C *pc = dynamic_cast<C*>(pa); // Error!
}
```

Named casts

```
struct A {
  // virtual void f() {}
};
struct B : public A {};
struct C : public A {};
struct D {};

int main()
{
  A *pa = new B;
  D *pd = static_cast<D*>(pa);  // Error!

  return 0;
}
```

Multiple inheritance

$$\begin{tikzcd}
\text{Temporary} & & & \text{Employee} & & \\
& & \text{Secretary} \arrow[ur] & \text{MTS} \arrow[u] & & \text{Administrator} \arrow[ull] \\
& \text{TempSec} \arrow[uul] \arrow[ur] & & & \text{Supervisor} \arrow[ul] \arrow[ur] & \\
& & & & & \text{President} \arrow[uu] \\
\text{Consultant} \arrow[uuuu] \arrow[uuurrr] & & & & &
\end{tikzcd}$$

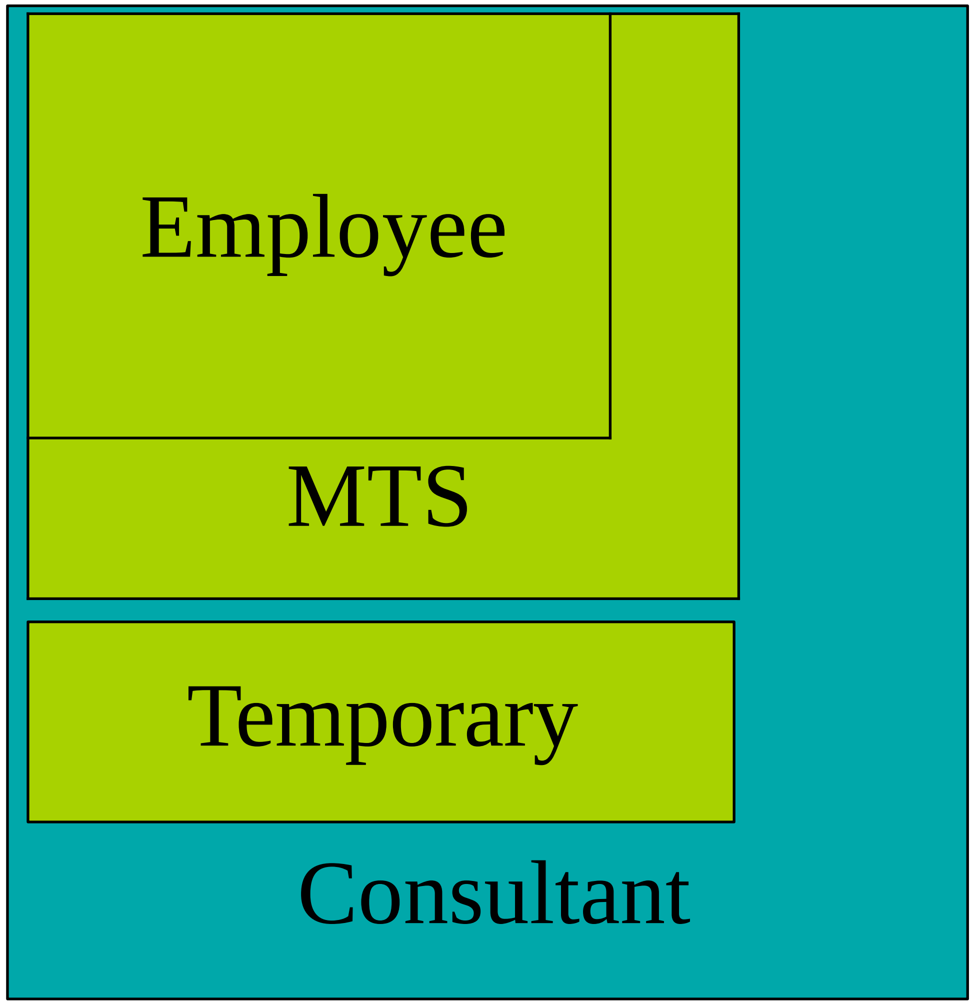
Mix and match

```
class Employee {
protected:
    String name;
    EmpID id;
};

class MTS : public Employee {
protected:
    Degrees degree_info;
};

class Temporary {
protected:
    Company employer;
};
```

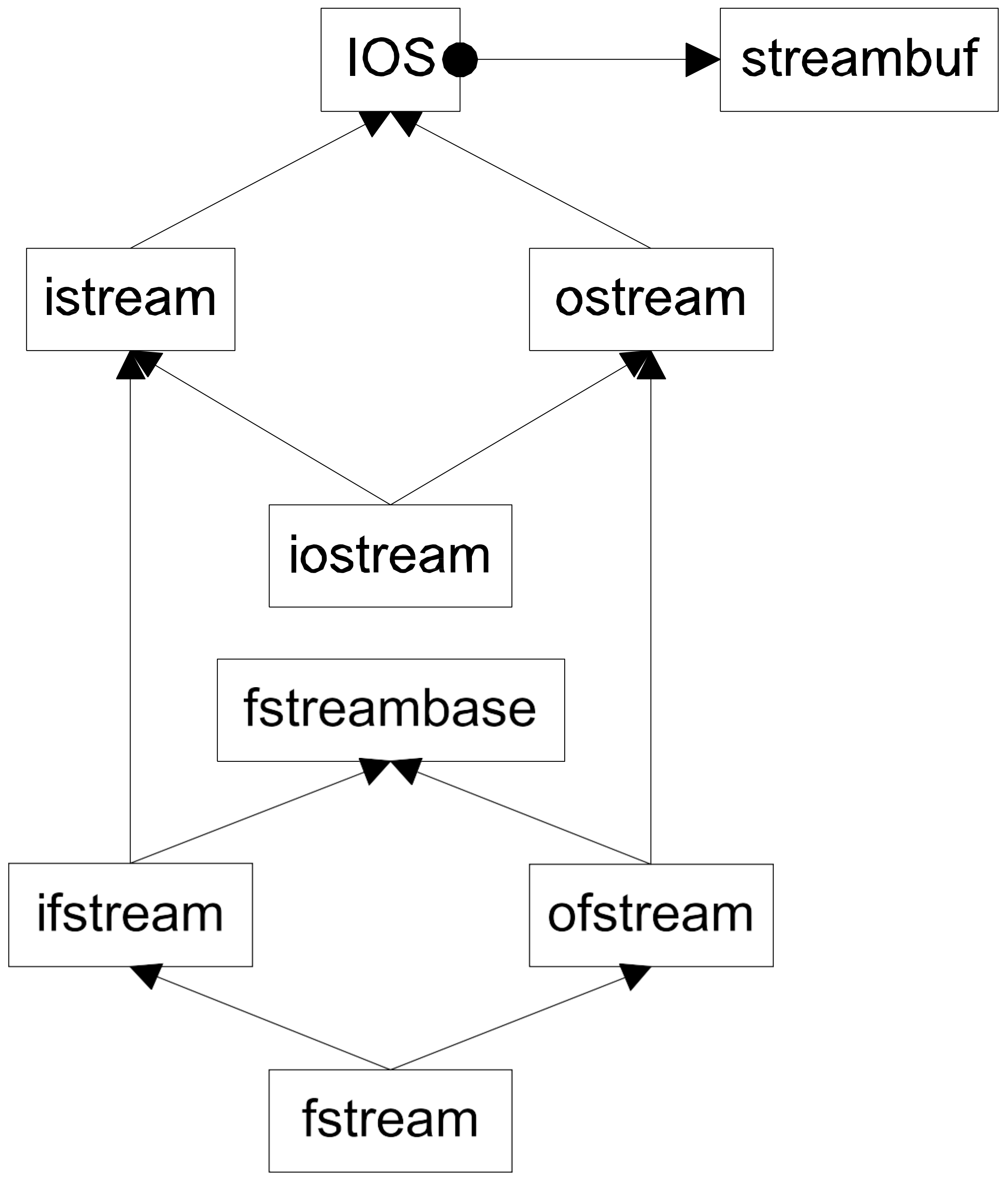
```
class Consultant:
  public MTS,
  public Temporary {
…
};
```

- Consultant picks up the attributes of both `MTS` and `Temporary`.
  - name
  - id
  - degree_info
  - employer

MI complicates data layouts

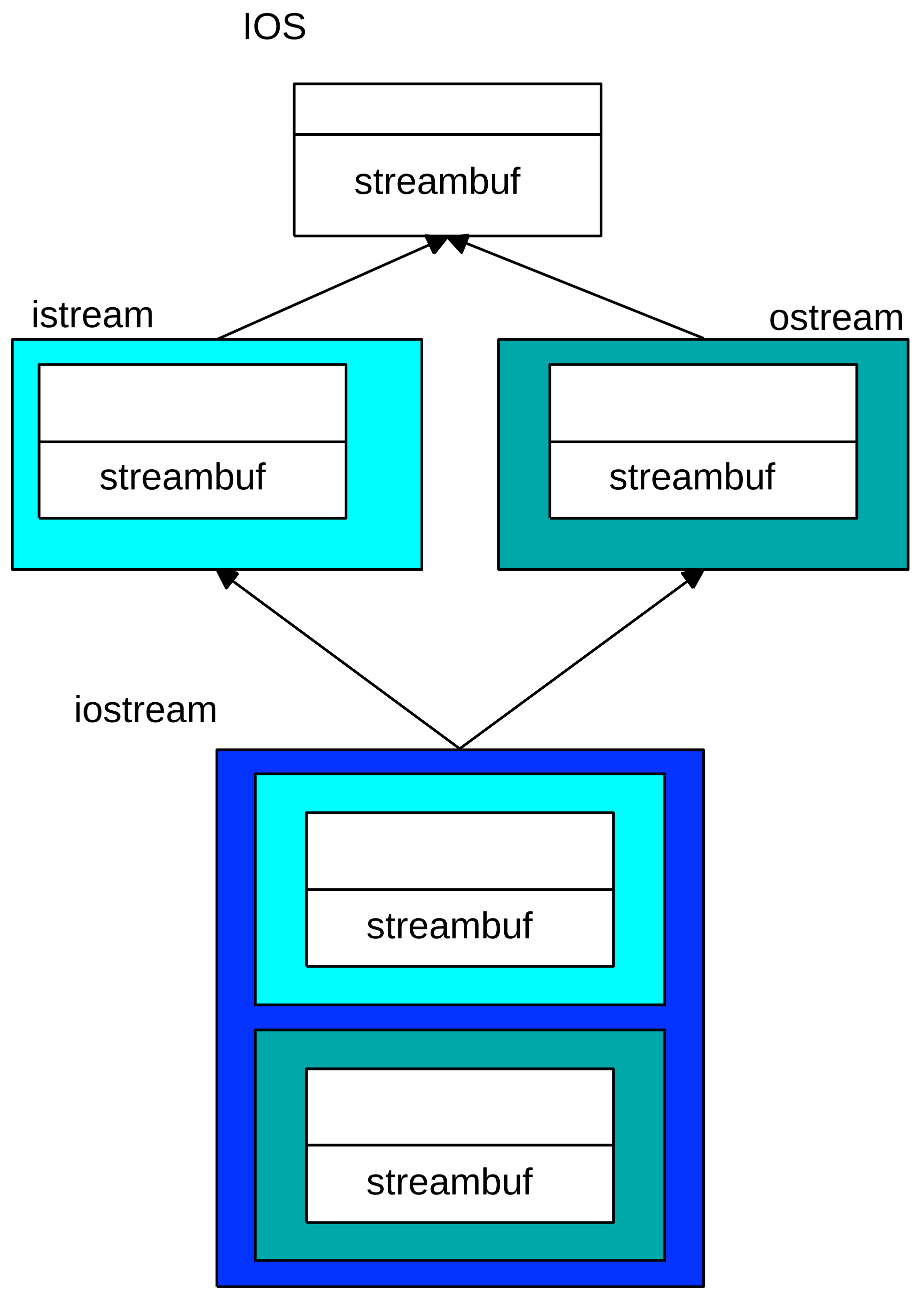


iostream package



Vanilla MI

- Members are duplicated
- Derived class has access to full copies of each base class
- This *can* be useful!
  - –Multiple links for lists
  - –Multiple streambufs for input and output



More on MI …

```
struct B1 { int m_i; };
struct D1 : public B1 {};
struct D2 : public B1 {};
struct M : public D1, public D2 {};

int main() {
  M m; // OK
  B1* p = &m; // ERROR: which B1???
  B1* p1 = static_cast<D1*>(&m); // OK
  B1* p2 = static_cast<D2*>(&m); // OK
}
```

`B1` is a *replicated* sub-object of `M`.

Replicated bases

- Normally replicated bases aren’t a problem (usage of B1 by D1 and D2 is an implementation detail).
- Replication becomes a problem if replicated data makes for confusing logic:

```
M m;
m.m_i++; // ERROR: D1::B1.m_i or D2::B1.m_i?
```

Safe uses

- Protocol classes

Protocol / Interface classes

- Abstract base class with
  - All non-static member functions are *pure* virtual except destructor
  - Virtual destructor with empty body
  - No non-static member variables, inherited or otherwise
    - May contain static members

Example interface

- Unix character device

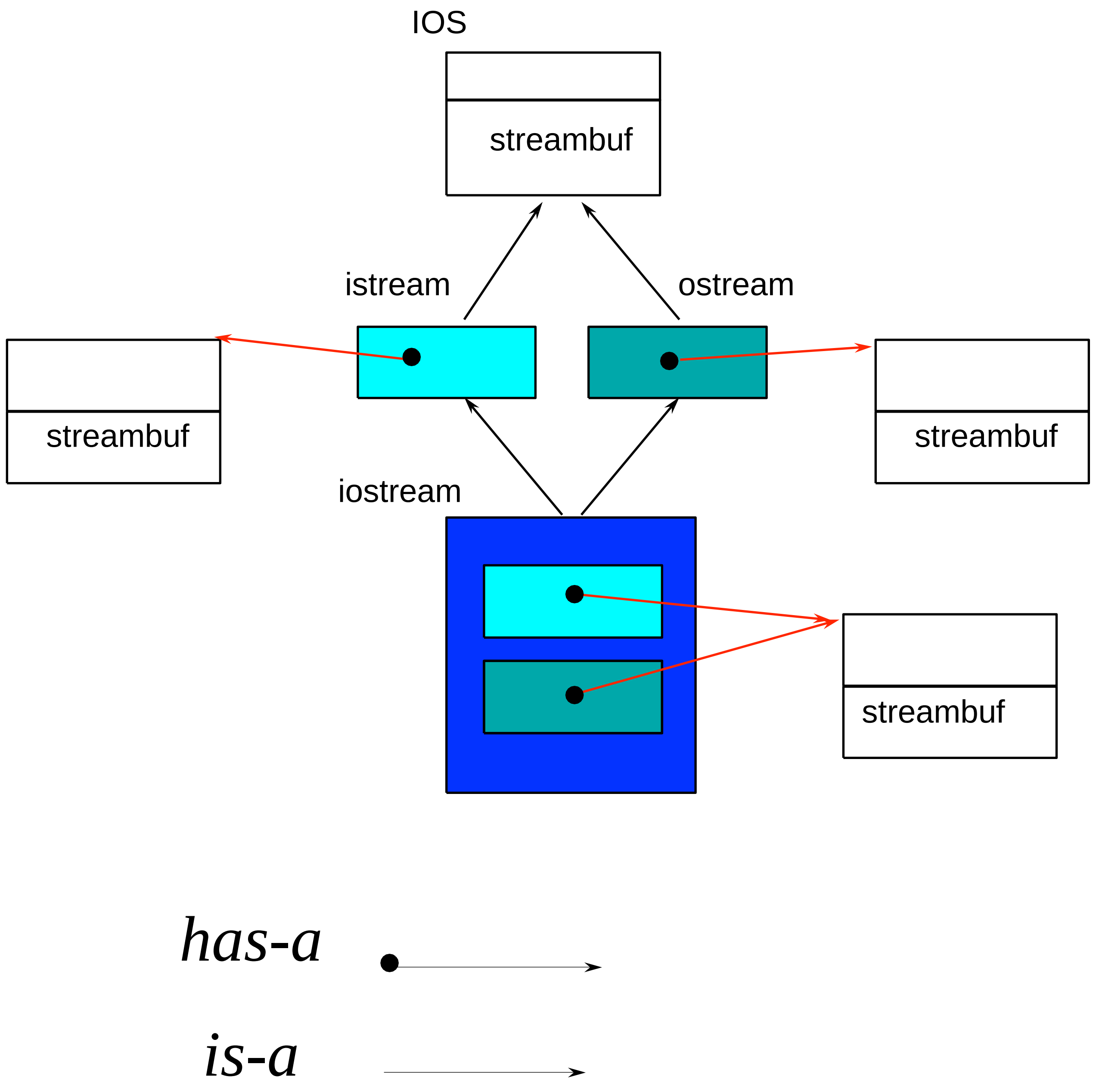
```
class CDevice {
public:
    virtual ~CDevice() {}

    virtual int read(...) = 0;
    virtual int write(...) = 0;
    virtual int open(...) = 0;
    virtual int close(...) = 0;
    virtual int ioctl(...) = 0;
};
```

What about sharing?

- How do you avoid having two streambufs?
- Base classes can be ***virtual***
  - To C++ people, “virtual” means “indirect”
- Virtual member functions have dynamic binding
  - They use pointer indirection
- Virtual base classes are represented indirectly
  - They use pointer indirection

Using virtual base classes

- Virtual base classes are ***shared***
- Derived classes have a single copy of the virtual base
- Full control over sharing
  – Up to you to choose
- Cost is in complications



Virtual bases

```
struct B1 { int m_i; };
struct D1 : virtual public B1 {};
struct D2 : virtual public B1 {};
struct M : public D1, public D2 {};
int main() {
   M m;  // OK
   m.m_i++; // OK, there is only one B1 in m
   B1* p = new M; // OK
}
```

Complications of MI

- Name conflicts
  - –Dominance rule
- Order of construction
  - –Who constructs virtual base?
- Virtual bases not declared when you need them

$$\begin{tikzcd}
 & A & \\
B \arrow[ur] & & C \arrow[ul] \\
 & D \arrow[ul] \arrow[ur] &
\end{tikzcd}$$

- Code in virtual bases called more than once
- Compilers are still iffy
- Moral:
  - Use sparingly
  - Avoid diamond patterns
    - expensive
    - hard

Virtual bases

- Use of virtual base imposes some runtime and space overhead.
- If replication isn’t a problem then you don’t need to make bases virtual.
- Abstract base classes (that hold no data except for a vptr) can be replicated with no problem – virtual base can be eliminated.

TIPS for MI

- In general, SAY

NO

Controlling names

- Controlling names through scoping
- We’ve done this kind of name control:

```
class Marbles {
    enum Colors { Blue, Red, Green };
    ...
};

class Candy {
    enum Colors { Blue, Red, Green };
    ...
};
```

Avoiding name clashes

- Including duplicate names at global scope is a problem:

```
// old1.h
   void f();
   void g();

// old2.h
   void f();
   void g();
```

Avoiding name clashes (cont)

- Wrap declarations in namespaces.

```
// old1.h
namespace old1 {
    void f();
    void g();
}

// old2.h
namespace old2 {
    void f();
    void g();
}
```

Namespace

- Expresses a logical grouping of classes, functions, variables, etc.
- A namespace is a scope just like a class
- Preferred when name encapsulation is needed

```
namespace Math {
  double abs(double);
  double sqrt(double);
  int trunc(double);
  ...
} // Note: No terminating end colon!
```

Defining namespaces

- Place namespaces in include files:

```
// Mylib.h
namespace MyLib {
    void foo();
    class Cat {
    public:
        void Meow();
    };
}
```

Defining namespace functions

- Use normal scoping to implement functions in namespaces.

```
// MyLib.cpp
#include "MyLib.h"

void MyLib::foo() { cout << "foo\n"; }
void MyLib::Cat::Meow() {
    cout << "meow\n";
}
```

Using names from a namespace

- Use scope resolution to qualify names from a namespace.
- Can be tedious and distracting.

```
#include "MyLib.h"
int main()
{
   MyLib::foo();
   MyLib::Cat c;
   c.Meow();
}
```

`using`-declarations

- Introduces a local synonym for name
- States in one place where a name comes from.
- Eliminates redundant scope qualification:

```
int main() {
    using MyLib::foo;
    using MyLib::Cat;
    foo();
    Cat c;
    c.Meow();
}
```

`using`-directives

- Makes *all* names from a namespace available.
- Can be used as a notational convenience.

```
int main() {
   using namespace std;
   using namespace MyLib;
   foo();
   Cat c;
   c.Meow();
   cout << "hello" << endl;
}
```

Ambiguities

- Using-directives may create *potential* ambiguities.
- Consider:

```
 // Mylib.h
namespace XLib {
    void x();
    void y();
}

namespace YLib {
    void y();
    void z();
}
```

Ambiguities (cont)

- Using-directives only make the names available.
- Ambiguities arise only when you make calls.
- Use scope resolution to resolve.

```
int main() {
  using namespace XLib;
  using namespace YLib;
  x();        // OK
  y();        // Error: ambiguous
  XLib::y(); // OK, resolves to XLib
  z();        // OK
}
```

Namespace aliases

- Namespace names that are too short may clash
- Names that are too long are hard to work with
- Use aliasing to create workable names
- Aliasing can be used to version libraries.

```
namespace supercalifragilistic {
    void f();
}
namespace short_ns = supercalifragilistic;
short_ns::f();
```

Namespace composition

- Compose new namespaces using names from other ones.
- Using-declarations can resolve potential clashes.
- Explicitly defined functions take precedence.

```
namespace first {
  void x();
  void y();
}
namespace second {
  void y();
  void z();
}
```

Namespace composition (cont)

```
namespace mine {
    using namespace first;
    using namespace second;
    using first::y; // resolve clashes
    void mystuff();
    ...
}
int main() {
    mine::x();
    mine::y(); // call first::y()
    mine::mystuff();
}
```

Namespace selection

- Compose namespaces by selecting a few features from other namespaces.
- Choose only the names you want rather than all.
- Changes to “orig” declaration become reflected in “mine”.

```
namespace mine {
  using orig::Cat; // use Cat class from orig
  void x();
  void y();
}
```

Namespaces are open

- Multiple namespace declarations add to the same namespace.
  - Namespace can be distributed across multiple files.

```
//header1.h
namespace X {
    void f();
}

// header2.h
namespace X {
    void g(); // X how has f() and g();
}
```

Visibility vs Accessibility

- Visibility refers to whether the members of classes and namespaces are recognized by the compiler within a given scope.
  - If a member is declared within a scope, it is visible anywhere in that scope. There is no way to hide or reduce the visibility of a member once it has been declared within a scope.

- Accessibility pertains to whether the visible members can actually be accessed or used.
  - Accessibility is determined by access specifiers (like public, protected, private in classes).
  - It is a separate concept from visibility and does not affect whether the member can be seen by the compiler, only whether it can be used.

- A member might be visible (i.e., the compiler knows it exists) but not accessible (i.e., the compiler will prevent you from using it if it is not allowed by the access specifiers).

Access protection

- Members

  - Public: ~~visible~~ accessible to all clients

  - Protected: ~~visible~~ accessible to classes derived from self (and to friends)

  - Private: ~~visible~~ accessible only to self and to friends!

- Inheritance
  - Public: `class Derived : `**`public`**` Base ...`
  - Protected: `class Derived : `**`protected`**` Base ...`
  - Private: `class Derived : `**`private`**` Base ...`

Static vs Dynamic Polymorphism

- Static polymorphism, also known as compile-time polymorphism, is achieved in C++ primarily through function overloading and template functions/classes.
  - It is called “static” because the decision about which function to execute is made at compile time.

- Dynamic polymorphism, also known as runtime polymorphism, is implemented in C++ through inheritance and virtual functions.
  - It is called "dynamic" because the decision about which function to call is deferred until runtime.

Overloaded operators

There are several ways used for implementing operator overloading in C++:

- Member Function
- Friend Function
- Non-member Function

Overloaded operators

Unary and binary operators can be overloaded:

```
+   -  *  /  %   ^   &   |   ~
=  <  >  +=   -=  *=  /=  %=
^=  &=  |= <<  >>   >>=  <<=  ==
!= <=  >=  !  &&  ||     ++  --
,  ->* -> ()  []
```

operator new   operator delete

operator new[]   operator delete[]

Operators you can't overload

```
.          .*          ::        ?:
```

sizeof   typeid

static_cast   dynamic_cast   const_cast

reinterpret_cast

Operators you can't overload using friend function

Among the in-built operators which operators cannot be overloaded using the friend function but can be overloaded by member functions are as follows:

- Assignment Operator =
- Function call Operator ()
- Subscript Operator []
- Arrow Operator ->
- Pointer-to-member access Operator via pointer ->*

Typedefs

- Annoying to type long names
  - `map<Name,list<PhoneNum>> phonebook;`
  - `map<Name,list<PhoneNum>>::iterator finger;`
- Simplify with typedef
  - `typedef map<Name,list<PhoneNum>> PB;`
  - `PB phonebook;`
  - `PB::iterator finger;`
- Easy to change implementation.
- C++ 11: *auto, using*

Using your own classes

- Might need:
  - Assignment Operator, `operator=()`
  - Default Constructor
- For sorted types, like `set,map,`…
  - Need less-than operator: `operator<()`
    - Some types have this by default:
      - int, char, string
    - Some do not:
      - char *

Example of user-defined type

- Sorted container needs sort function.

```
struct full_name {
    char * first;
    char * last;
    bool operator<(full_name & a) {
      return strcmp(first, a.first) < 0;
    }
}
map<full_name,int> phonebook;
```

cv-qualifier-list

It refers to the list of type qualifiers that can be applied to a type.

"cv" stands for "const" and "volatile", which are the two type qualifiers.

cv-qualifier-list

```
volatile int flag = 0; // flag might be modified by hardware
or other threads

    void func() {
        while (flag == 0) {
            // Without the volatile qualifier, the compiler
might optimize this loop into an infinite loop; volatile tells
the compiler to read the value of flag from memory each time
        }
    }
```

cv-qualifier-list

A cv-qualifier-list applied to a class method modifies ***this*** pointer, which points to the object the method is being called on.

- For instance, if a method is declared with const at the end (e.g., void myMethod() const), it means that this is a pointer to a const object, and the method promises not to modify the object's state.
- [cv-qualifier-list] classType *const *this*