D C++ for Java Programmers

D.1 Introduction

- General differences to Java
- Objects and Classes in C++
- Constructors and Destructors
- Inheritance
- Exceptions
- Odds and Ends
- Operator overloading
- No: Templates
- No: Standard Template Library (STL)

1 A Short History of C++

- 1980: Dennis Ritchie extends C to *C with Classes*
- 1983: Bjarne Stroustrup introduces C++ V1.0
- 1986: Bjarne Stroustrup publishes *The C++ Programming Language* (1st Edition)
- 1989: ANSI approves Standard C with elements from C++
- 1989: ANSI committee X3J16 begins standardization of C++ (V2.0)
- 1991: *The Annotated C++ Reference Manual* defines C++ V3.0 including *Templates* and *Exceptions*
- 1993: C++ V3.1 includes *Namespaces* and *Run-Time Type Identification*
- 1997: ISO WG21 and ANSI X3J16 adopt *C++* and the *Standard Template Library (STL)* as standard ISO/IEC FDIS 14882

2 What is C++?

- Super-set of C
- A better C
  - Strong typing
  - Prototypes
  - Overloading
- Extends C to include object-oriented concepts
  - Objects
  - Classes
  - Inheritance
  - Polymorphism
- *BUT*: C++ does not enforce an object-oriented style of programming
  - ➨ Therefore you learn Java first!

3 Literature

- Bjarne Stroustrup: *The C++ Programming Language*. 3rd Edition, Addison-Wesley, Reading MA, 1997.
- *ANSI C++ Public Comment Draft*, December 1996.
  See tutorial web page
- Scott Meyers: *Effective C++*, 2nd Edition, Addison-Wesley, Reading MA, 1997.
- Scott Meyers: *More Effective C++*, Addison-Wesley, Reading MA, 1995.
- Harvey M. Deitel, Paul J. Deitel. *C++ - How to program*. 2nd Edition, Prentice-Hall, 1998.

D.2 General Differences to Java

- Input and output
- Inlining
- Scope operator
- Namespaces
- Memory management
- Function overloading
- Reference variables
- Default parameters
- Constants

1 Input and output

- Input and output to *Streams* via *Operators*
  - **`cin`** — Input stream (global)
  - **`cout`**, **`cerr`**, (**`clog`**) — Output streams (global)
  - **`>>`** — Input operator
  - **`<<`** — Output operator

- Example:

```
#include <iostream>

void main() {
    int test;  // i/o test variable
    cin >> test;
    cout << "test=" << test << "\n";
}
```

- C: **`scanf`** and **`printf`** are not type-safe (format string)

2 Inlining

- Reserved word **`inline`**:

```
inline return_type function_name( parameter_list ) {
    function_body
}
```

  - ◆ Compiler tries to optimize function calls
  - ◆ Instead of a function call the body of the whole function is inserted
    - ➨ Faster calls, but larger programs
  - ◆ Further optimizations possible (e.g. for calls with constant parameters)
  - ◆ Not possible for recursive functions
  - ◆ *Function body must be implemented in the header file (.H or .hh)*!!!

- Differences to pre-processor macros (**`#define`**):
  - ◆ Macros are expanded as normal text
    - ➨ No type checking, often mysterious syntax errors
  - ◆ No repeated expansion for **`inline`** functions

3 Scope operator

- New operator `::` for accessing scopes
- Mainly used with classes and namespaces
- *Here*: Accessing hidden variables with the same identifier in other scopes
- Example:

```
#include <iostream>

int test = 4711;       // global variable

void main() {
    int test = 1234;   // local variable

    cout << "The global variable is " << ::test << "\n";
    cout << "The local variable is " << test << "\n";
}
```

4 Namespaces

- New reserved word **`namespace`**:

```
namespace namespace_name {
     declarations/definitions
}
```

  - Opens a new namespace for identifiers
  - Can be nested
  - Access via scope operator `::`
  - Like **`package`** in Java, but no relation to file organisation

- Example:

```
namespace Date {
     struct Time {
          int year;
          …
     };
}

Date::Time today;
```

4 Namespaces (2)

- Import of identifiers from other name spaces via **`using`**:

```
using namespace_name::identifier;
```

  - Like **`import`** *package*`.`*identifer*`;` in Java

- Import of complete name spaces:

```
using namespace namespace_name;
```

  - Like **`import`** *package*`.*;` in Java

- Example:

```
namespace Date {
    struct Time { ...
    };
}

namespace MyApp {
    using Date::Time;

    Date::Time today;
}
```

5 Memory management

- Two operators in C++:
  - ◆ Memory allocation with **`new`**

```
type *pointer_to_type;
pointer_to_type = new type;
```

    - ➤ If allocation fails a **`std::bad_alloc`** exception is thrown (or a **`NULL`** pointer is returned)
    - ➤ C: No explicit type casting necessary
  - ◆ Memory deallocation with **`delete`**

```
delete pointer_to_type;
```

    - ➤ Programmer is responsible for deallocation
    - ➤ Pointer is still accessible after deallocation
    - ➤ Common source of programming errors
    - ➤ **`delete`** for a **`NULL`** pointer is allowed
- C: memory management with **`malloc`** and **`free`**

5 Memory management (2)

- Example:

```
int *x=0;        // okay
delete x;        // okay
x = new int;     // okay
delete x;        // okay
delete x;        // wrong
```

- Special syntax for arrays:

```
int *ap = new int[7];
delete[] ap;     // not delete ap !!!
```

- *Never ever* mix **malloc** / **free** with **new** / **delete**
  - ➨ Caution: E.g. **strdup** does an implicit **malloc**

- Unfortunately no *Garbage Collection* in C++

6 Function overloading

- Same function name for different implementations
  - Works for pure C functions and C++ methods
- Overloaded functions are distinguished by:
  - Number of parameters
  - Type of parameters
  - Sequence of parameter types
  - *Not*: Return type of function (Return value may be irgnored)
- Example:

```
void    Print();              // okay
void    Print(int, char*);    // okay
int     Print(float);         // okay
int     Print();              // error, not distinguishable
```

7 Reference variables

- Adress operator `&` in variable declaration

```
type &reference_variable = variable_of_type;
```

- Reference variable
  - No real variables
  - Proxy or alias for another variable
  - Must be initialized during declaration (with *lvalue* - a thing that can be on the left side of an assignment, i.e. it can take a value)

- Example:

```
int x = 5;      // variable
int &rx = x;    // reference to x
x = 6;          // x==6 and rx==6
rx++;           // x==7 and rx==7
```

- Operations on reference variables affect the referenced variables

- Similar to pointers with implicit dereferencing but less flexible

7 Reference variables (2)

- Reference parameters
  - Allow implicit *call-by-reference* semantics
  - No pointers necessary
  - Caller writes down call with normal syntax
  - Disadvantage: syntax of call does not show semantics

- Example:

```
#include <iostream>

void increment(int& x) {
    x++;
}

void main() {
    int x = 5;
    increment( x );
    cout << "x=" << x << "\n";    // x==6
}
```

7 Reference variables (3)

- Returning references is also possible
- Function returns a variable (*lvalue*) not a value

```
int global = 0;         // global variable

int& func() {
    return global;      // returns reference to global
}

int main() {
    int x;
    x = func() + 1;     // x = global + 1;
    func() = x;         // global = x;
}
```

- Returning references to local variables is forbidden

```
int& func() {
    int x = 0;
    int& rx = x;
    return rx;      // forbidden
}
```

8 Default parameters

- Function parameters may contain *default* values
- Will be used when the actual parameter in a call is missing
  - ➨ Only at the end of the parameter list, no gaps allowed
- Example:

```
void print(char* string, int nl = 1);

print( "Test", 0 );
print( "Test" );   // is equal to print( "Test", 1 )
print();           // wrong, char* parameter is missing
```

- Caution: overloading and default parameters may generate ambiguities

```
void print(char* string);
void print(char* string, int nl = 1);

print( "Test" );   // which function ??????????
```

9 Constants

- Reserved word **`const`** modifies declaration
  - **`const`** variables are read-only (**`final`** in Java)
  - Initialization during declaration

- Example:

```
const int k = 42;
char* const s1 = "Test1";
const char* s2 = "Test2";
const char* const s3 = "Test3";

k = 4;                // error: k is const
s1 = "New test";      // error: pointer is const
*s1 = 'P';            // okay, characters are not const
s2 = "New test";      // okay, pointer is not const
*s2 = 'P';            // error: characters are const
```

- Should be preferred to **`#define`**, because managed by the compiler
  - Definition of local constants
  - Pointer to constants possible (like pointers to variables)

D.3 Objects and Classes in C++

- Extension of `structs`
- Classes
- Visibility
- Object creation
- Object access
- Member functions (methods)

1 Extension of structs

- New concept for **`structs`**
  - ◆ Every **`struct`** defines a type
  - ◆ Local functions in **`structs`**

- Example:

```
struct Person
{
    char*   name;
    int     age;

    void    setName( char* );
    void    setAge( int );
};
```

- Disadvantage: unrestricted access to all parts from the outside

2 Classes

- Class declaration in C++ with reserved word **`class`**:

```
class class_name {
        Declaration of member variables and functions
};
```

  - Contains declaration of data and methods (in C++ called *members*)
  - Sending a message means in C++: accessing a member

- Example:

```
class Person
{
    char*   name;
    int     age;

    void    setName( char* );
    void    setAge( int );
};
```

3 Visibility

- Different visibility for parts of an object:
  - **`private:`** Member can be accessed only from within its class
  - **`public:`** Member can be accessed from anywhere
  - **`protected:`** like **`private`**, but subclasses have access
- Parts can be declared in any order and can be repeated
- **`public`** parts are the interface for other objects
- Default visibility is **`private`** !

3 Visibility (2)

- Example:

```
class Person {
private:
    char*   name;                // private member variables
    int     age;
public:
    void    setName( char* ); // public member functions
    void    setAge( int );
};
```

4 Object creation

- Syntax is the same like declaring a variable
- *Static* creation:

```
Person peter;
Person john;
```

  - Object deleted when identifier goes out of scope

- *Dynamic* creation:

```
Person* peter;
peter = new Person;    // object is created now
```

  - Object explicitly deleted

```
delete peter;          // object is deleted now
```

5 Object access

- Access from outside the object
  - Private member variables are not accessible
  - Private member functions are not accessible
  - Public member variables and functions are accessible

- Access operators
  - As in **`structs`** with the dot operator **.**
  - With pointers to objects use the arrow operator **->**

- Example:

```
Person peter;
Person* john = new Person;

peter.setName( "Peter Smith" );  // okay, public
cout << peter.name;              // error, private
john->setAge( 35 );              // okay, public
cout << john->age;               // error, private
delete john;
```

6 Member functions (methods)

- Definition *within* the class declaration:
  - Function body comes directly after the declaration (as in Java)
  - Function becomes automatically **`inline`**
  - Usually used in header files (**`.h`**, **`.H`** or **`.hh`**)

- Definition *outside* the class:
  - Within the class only declaration of the function prototype
  - During definition you first have to name the class
  - Afterwards comes the function name separated by the scope operator **`::`**
  - Usually used in implementation files (**`.C`**, **`.cc`**, or **`.cpp`**)

7 Member functions (methods) (2)

- Example:
  - Header (**Person.h**)

```
#ifndef PERSON_H
#define PERSON_H
class Person {
private:
    char*   name;
    int     age;
public:
    void    setName( char* n ) {      // inline
        name = n;
    }
    void    setAge( int );
};
#endif
```

  - Implementation (**Person.cpp**)

```
#include "Person.h"

void Person::setAge( int i ) {
    age = i;
}
```

8 Constant Objects

- Variable declared **`const`**
  - ◆ Initialized when declared
  - ◆ Cannot be changed afterwards
  - ◆ Very useful for method parameters
- Silly example:

```
const Person nobody;
```

- Only operations that do not alter the object may be executed
  - ◆ Easy for member variable access
  - ◆ Methods that do not alter members
- How does the compiler know?
  - ◆ It does not!
  - ◆ Needs a hint from the programmer

8 Constant objects (2)

- Methods may be declared **`const`**
- **`Const`** methods do not change the object they are called at
- Example:

```
class Person {

private:
    char*   name;
    int     age;

public:
    int getAge() const {
        return age;
    }
};
```

D.4 Constructors and Destructors

- Constructors
- Destructors
- Member objects
- Copy constructor
- Arrays of objects

1 Constructors

- Like in Java
- Class method
- Method name is the name of the class
- *No* return type (not even **`void`**)
- Different constructors through overloading
- Declaration usually in the **`public`** part of the class
- Purpose: New object is automatically initialized after creation
  - ➨ Constructor has to put object in a consistent state
- Compiler creates a minimal default constructor (no arguments) if not declared in class

1 Constructors (2)

- Called during:
  - Creation of an object via the operator **`new`**
  - Creation of a static object
- Minimal default constructor (created by the compiler):

```
Person::Person() {}
```

- Default constructor (replaces minimal constructor):

```
Person::Person() {
    name = NULL;
    age = 0;
}
```

1 Constructors (3)

- Other constructors:

```
Person::Person( char *n, int i = 0 ) {
    name = n;
    age = i;
}
```

  - Default values are possible

2 Destructors

- Similar to `finalize` in Java
- Class method
- Method name is the name of the class with `~` in front
- *No* return type (not even `void`)
- Only *one* destructor possible, no overloading
- Destructors have *no* parameters
- Declaration usually in the `public` part of the class
- Purpose: Cleaning up before deleting the object
- Compiler creates a default destructor (does nothing) if not declared in class

2 Destructors (2)

- Called during:
  - Destruction of an object via the operator **`delete`**
  - Leaving the scope of a static object
- Minimal default destructor (created by the compiler):

```
Person::~Person() {}
```

3 Member objects

- Objects of other classes as members within a class

```
class Workplace {
    Person worker;
    ...
};
```

- Access via operators . und -> as usual

- Problems during initialization:
  - ◆ Will the constructors of the member objects be called?
  - ◆ If yes, when will they be called?
  - ◆ Which constructors will be called?
  - ◆ Which parameter values will be used?

- Similar problem with object destruction:
  - ◆ When will the destructors of the member objects be called?
  - ◆ No problem: There is only one destructor which has no parameters

3 Member objects (2)

- Definition of an initialization list in the constructor:

```
class_name::class_name( parameter_list )
    : member1( parameters ), member2( parameters ), ...
{ ... }
```

- Example:

```
class Person {
public:
    Person( char* );
    ...
};

class Workplace {
    Person worker;
    ...
};

Workplace::Workplace( char* name )
    : worker( name )
{ ... }
```

4 Copy constructor

- When is a copy constructor used?
  - Object is a value parameter in a function call (*call-by-value*)
  - Object is a return value of a function
  - Initialization of an object with an existing object

```
Person peter( john );
```

- Example:

```
Person::Person( const Person& p ) {
    name = p.name;
    age = p.age;
}
```

- Important: use reference operator **&**
- Default copy constructor (created by the compiler) copies bit-by-bit

5 Arrays of objects

- Static arrays
  - Without initialization
    - ➨ For all elements the standard constructor is called

```
Person test[4];    // calls 4 times Person::Person()
```

  - With initialization
    - ➨ Initialization expressions are used for the first elements, for the rest the standard constructor is called

```
Person test[4] =
    { "Peter", Person("John") };
    // test[0] and test[1]: Person::Person( char* )
    // test[2] and test[3]: Person::Person()
```

5 Arrays of objects (2)

- Dynamically allocated arrays
  - ◆ The default constructor is always called

```
Person *table;
table = new Person[4];    // 4 times Person::Person()
```

- Access as usual via operator `[]`

```
Person table[4];

table[0].SetName( "Peter" );
```

- Destruction of arrays
  - ◆ For all elements the destructor is called
  - ◆ Dynamically allocated arrays have to be deleted via **delete[]**

D.5 Inheritance

- Single Inheritance
- Scope operator
- Modification of visibility
- Constructors und Destructors
- Type casting
- Virtual methods
- Polymorphism
- Virtual destructors
- Abstract base class
- Multiple inhertiance

1 Inheritance

- Like in Java
- Reuse of existing implementations (classes)
- New class *inherits* features from the existing class
- Denotation:
- Class that inherits: Subclass
- Class that is inherited from: Superclass or Base class
- In C++: *Derivation* of new classes from existing ones
- Derivation/Inheritance is a "is-a" relation
- One base class: Single inhertiance, otherwise Multiple inhertiance

1 Inheritance (2)

- Syntax:

```
class subclass :
[modifier] superclass1, [modifier] superclass2, ... {
        Declaration of new member variables and
        new or re-implemented member functions (methods)
};
```

- Not inherited
  - Constructors
  - Destructor
  - Assignment operator

1 Inheritance (3)

- Rule in C++: Everything that is not re-implemented, is inherited

```
class Person { ...
public:
    void print();
    void setName( char* );
};

class Employee : public Person { ...
public:
    void print();
    void setSalary( float );
};
```

behaves like

```
class Employee : public Person { ...
public:
    void print();               // from Employee
    void setName( char* );      // from Person
    void setSalary( float );    // from Employee
};
```

2 Scope operator

- Often access to re-implemented methods of a superclass is needed
- *Scope*-Operator `::`

  class_name`::`*method*`( ... )`

- No **`super`** as in Java
- Example:

```
class Employee : public Person { ...
public:
    void print() {
        // print();    // no, endless recursion
        Person::print();
        cout << "Salary:" << salary << "\n";
    }
};
...
Employee a;
a.print();
a.Person::print();
```

3 Modification of visibility

- Specification how members of a base class should be visible in the subclass

- **`public`** modifier for inheritance:
  - **`public`** stays **`public`**
  - **`protected`** stays **`protected`**
  - **`private`** not accessible in subclass

- **`protected`** / **`private`** modifiers for inheritance:
  - **`public`** becomes **`protected`** / **`private`**
  - **`protected`** becomes **`protected`** / **`private`**
  - **`private`** not accessible in subclass

3 Modification of visibility (2)

- Usually only **`public`** inheritance is used
- **`protected`** and **`private`** inheritance make the interface smaller
  - ➨ Subclass is no longer a subtype of the superclass
- Default modifier is **`private`** !

4 Constructors

- Initialization of superclass members via superclass constructors
- Subclass constructor calls superclass constructor via *initialisation list*

```
class_name::class_name( parameter_list )
    : superclass1( parameters ), superclass2( parameters ), ...
{ ... }
```

- Superclass constructors are called *before* subclass constructor
- Subclass members are initialized *after* superclass members
- Example:

```
Employee::Employee( char* n, int a, float s )
    : Person( n, a ), salary( s )
{
    ...
}
```

5 Destructors

- Destruction of superclass members has to happen in the destructor of the superclass
- Superclass destructor is *automatically* called *after* the subclass destructor (other way round as with constructors)
- Example:

```
Employee::~Employee()
{
        Destroy only new members in employee
}
```

6 Pointers to objects

- Pointer to a subclass object can be assigned to a a pointer to a superclass object:
  - ◆ Subclass is extension of superclass, therefore also subtype
- Doesn’t work the other way round:
  - ◆ Explicit type *casting* necessary
  - ◆ Not very nice but sometimes unavoidable
- General rule:

  Specialized type can be assigned to a more general type.
- Pointers have a *static* and a *dynamic* type:
  - ◆ static: Class from pointer declaration
  - ◆ dynamic: Class of the object that the pointer points to (can be the class from the pointer declaration or any subclass of it)
- Static type defines accessible interface (members and methods)

7 Type casting

- C-style casts:

```
class Person { … };
class Employee : public Person { … };
…
Employee* e = new Employee;       // okay
Person* p = new Person;           // okay
Person* pe = e;                   // okay
Employee* e1 = p;                 // compiler error
Employee* e2 = pe;                // compiler error
Employee* e3 = (Employee*) pe;    // okay
Employee* e4 = (Employee*) p;     // unrecognisable error
```

  - ◆ Compiler doesn’t look at dynamic type
  - ◆ Before ANSI-C++ there was no Run-Time Type Information (RTTI)
  - ◆ Avoid them !!!

- In ANSI-C++ use **`static_cast`** or **`reinterpret_cast`** for low-level type casting

```
type variable = static_cast<type>( parameter );
ype variable = reinterpret_cast<type>( parameter );
```

7 Type casting (2)

- Dynamic casts:

```
type variable = dynamic_cast<type>( parameter );
```

  - Uses Run-Time Type Information to determine if valid
  - Like all Java casts
  - Returns NULL if cast fails, no exceptions thrown !!!

- Example:

```
class Person { … };
class Employee : public Person { … };
…
Employee* e = new Employee;
Person* p = new Person;
Person* pe = e;
Employee* e3 = dynamic_cast<Employee*>( pe ); // okay
Employee* e4 = dynamic_cast<Employee*>( p );  // returns NULL
```

- Additionally **const_cast** for casting away constness

8 Virtual methods

- Up to now:
  - Type of pointer (static type) not type of object pointed to (dynamic type) defines interface semantics of a call
  - Access to subclass members only after type casting of the pointer

- Aim is *polymorphism*: Execution of the suitable subclass method without explicitly knowing the subclass (*This is what you always have in Java!*)

- Solution: *Virtual* methods
  - ➨ Object defines semantics, not the pointer

- Syntax with reserved word **`virtual`**:

```
class class_name {
    virtual return_type method_name( parameter_list )
    { … }
};
```

- **`virtual`** has to be specified in the base class and is inherited

9 Polymorphism

- Example:

```
class Person { ...
public:    virtual void print();
};
class Employee : public Person { ...
public:    void print();
};
...
Person* p = new Person;
Person* pe = new Employee;
p->print();                 // Person::print()
pe->print();                // Employee::print()
```

- Called method is determined at run-time
- Called object has a defined type, therefore method to be called is unambigouos
- Compiler generates *vtables* (jump tables for virtual methods)
  - ◆ Every object contains pointer to vtable of its class, therefore larger objects

10 Virtual destructors

- Dynamically allocated objects may be assigned to superclass pointers
- Problem: If object is deleted, only the superclass destructor is called because of the static type of the superclass pointer
  - ➨ Objects are not destroyed properly
- Solution: *Virtual* destructor:

```
class class_name {
    virtual class_name::~class_name()
    { … }
};
```

- **`virtual`** has to be specified in the base class
- Is inhertied by all subclasses although destructor names are different in subclasses

11 Abstract classes

- Abstract classes:
  - No all methods that were declared are also implemented
  - There can be no instances/objects of this class
  - Subclasses can only have instances if all declared methods are also implemented

- Abstract classes can be used
  - As superclasses without instances (**`class`** with **`abstract`** methods in Java)
  - To define a type/interface (**`interface`** in Java)

- Syntax for methods that are not implemented (*pure virtual*):

```
class class_name {
    virtual return_type method_name( parameter_list ) = 0;
};
```

- Pointers to abstract classes are possible but have to be initialized with object of a subclass that is not abstact

12 Multiple inheritance

- Subclass has *multiple* superclasses (forbidden in Java)
- Subclass contains *every* superclass as an implicit part
- The subclass constructor can call constructors of every superclass in the initialization list

```
class Base1 { ...
public:    Base1( int, char* );
};
class Base2 { ...
public:    Base2( int, float );
};
class Derived : public Base1, public Base2 { ...
public:    Derived( char *s, int i ) :
               : Base1( i, s ), Base2( i, 4.2 ) { }
};
```

- When an object of the subclass is destroyed the destructors of all superclasses are called

12 Multiple inheritance (2)

- Problem: *Ambiguities* through name clashes

- Two or more superclasses have the same member:
  - ◆ Member variables with the same name
  - ◆ Methods with the same name and the same parameters

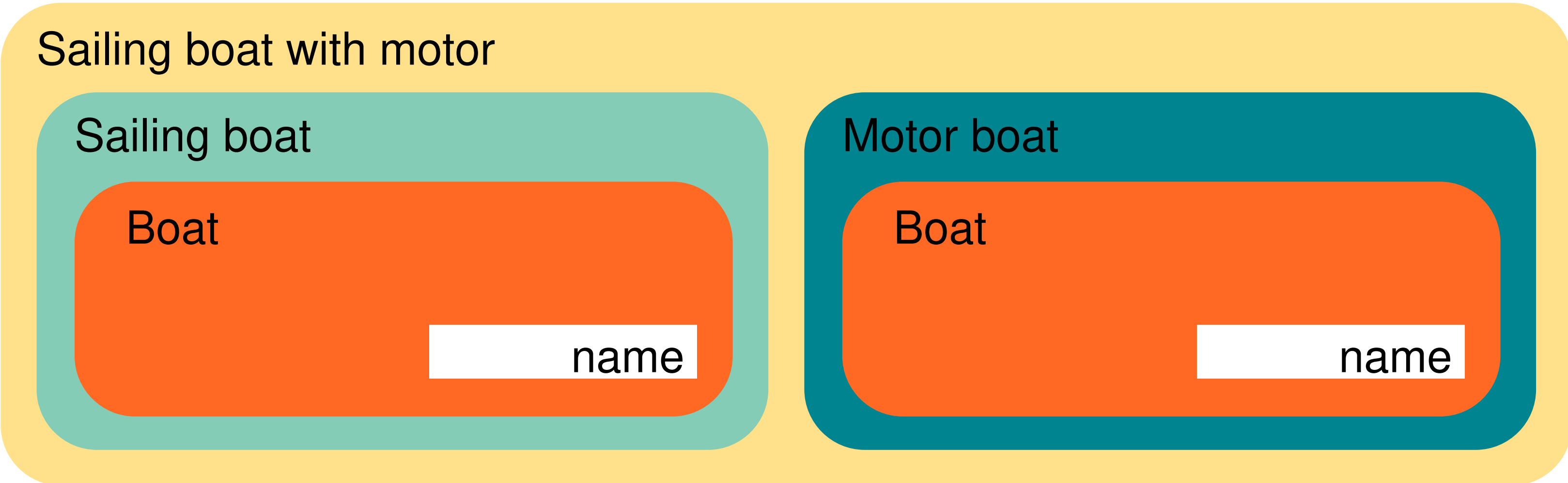
- First automatic resolution of ambiguities, then access control (visibility)
  - ➨ Making one member private doesn't help

- Explicit resolution of name clashes for variables:
  - ◆ Specify the superclass before the variable name using the scope operator `::`

- Possible solution for methods:
  - ◆ Reimplement method and use the desired superclass method(s) via the scope operator `::`

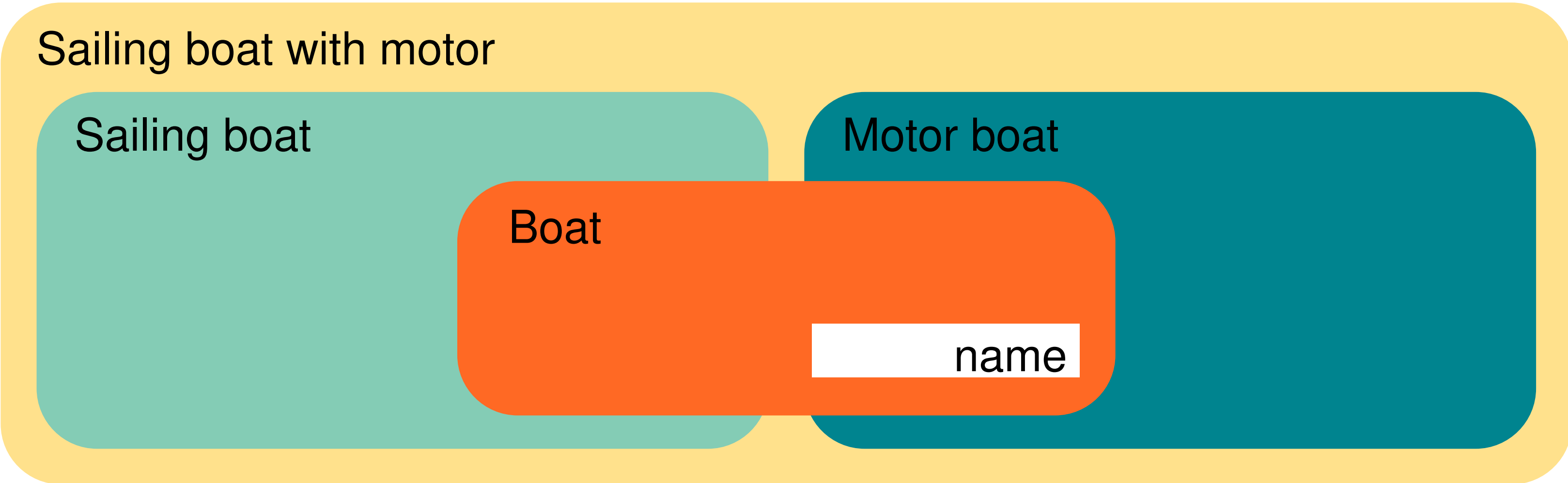
12 Multiple inheritance (3)

- Superclass contains common features (intersection set) of all subclasses (generalization)
- Problem with multiple inheritance: Common base class is contained multiple times
- Example:



12 Multiple Inheritance (4)

- Implementation with a *virtual* base class
- Example:



- Syntax for *virtual inheritance*:

```
class subclass : virtual public superclass {
    Declaration of member variables and functions
};
```

12 Multiple inheritance (5)

- Example:

```
class Boat {
protected: char* name;
public:    Boat( char* n ) : name( n ) { }
};

class SailingBoat : virtual public Boat {
protected: Sail mySail;
public:    SailingBoat( char* n ) : Boat( n ) { }
};

class MotorBoat : virtual public Boat {
protected: Motor myMotor;
public:    MotorBoat( char* n ) : Boat( n ) { }
};

class SailingBoatWithMotor
    : public SailingBoat, public MotorBoat {
public:    SailingBoatWithMotor( char* n )
              : Boat( n ), SailingBoat( n ), MotorBoat( n )
           { }
};
```

D.6 Exceptions

- Exception syntax
- How exceptions work
- Example: Ressource allocation
- Differences to Java
- Exceptions in ANSI C++
- Solution for the **`new`** problem

1 Exception Syntax

- 3 reserved words:
  - **`try`** tries to execute the following block
  - **`throw`** creates an exception and starts exception handling
  - **`catch`** catches an exception from the **`try`** block and processes it in the following block
- Example:

```
try {
      computation
      if error: throw exception_class( ... );
}
catch( exception_class variable ) {
      exception processing
}
```

2 How Exceptions Work

- Linear processing of the **`catch`** list
- Grouping of error types through inheritance
  - ◆ **`catch`**ing a base class also catches all subclasses
- Exceptions are propagated upwards until a **`catch`** clause is found who's type matches the type of the exception
- All destructors are called when leaving a block because of an exception
- There is no suitable **`catch`** clause ➨ Program is aborted
- **`catch(...)`** catches all exceptions

3 Differences to Java

- No **`finally`** block
- Similar functionality can be achieved through:

```
catch( ... ) {
    // clean up
    throw;      // re-throw caught exception
}
```

  - Attention: Not executed if there are other catch clauses that match or when no exception was thrown

- Exceptions do *not* belong to a method's type
  - ➨ Can be thrown anywhere
  - ➨ Compiler cannot check if all thrown exceptions are caught at some point

4 Exceptions in ANSI C++

- Functions and methods *may* specifiy an exception list
- Reserved word **`throw`** in function prototype:

```
return_type method_name ( parameter_list ) throw ( exception_list ) {
        Body of method
}
```

- Similar to **`throws`** in Java
- Exception list is a guarantee to the the caller
- **`std::unexpected()`** is called if an exception that is not in the list leaves the function
- Functions without an exception list may still throw any exception

D.7 Odds and Ends

- This pointer
- Static members

1 This pointer

- **`this`** points to the called object itself
- Implicit parameter in every method call
- Looks like: *class_name* **`* const this`**
- If method is **`const`**: **`const`** *class_name* **`* const this`**
- Example:

```
class Person { ...
    char* name;
public:
    void print() { cout << this->name; } // = name
    void insertInto( List* l ) { l->insert(this) }
    void prettyPrint() {
        cout << "Data: ";
        this->print();          // = print()
    }
};
```

2 Static members

- Normally every object contains it's own set of variables
- Except for: member variables declared as **`static`**
- **`static`** members exist once for each class, no matter how many object of that class were created
- Makes it possible to use it as a shared variable for all instances of a class
  - ➨ Class variable
- Access rights can be specified as with instance variables

2 Static members (2)

- Global initialization outside the class (access rights don’t matter for initialization)
- Example:

```
class BankAccount {
    static float interestRate;
    ...
};
...
float BankAccount::interestRate = 0.5;
```

2 Static members (3)

- Methods that only access other **`static`** members may be declared **`static`** themselves
- **`static`** methods can be called without an object
- *No* access to dynamic (per instance) members of the class
- *No* **`this`** pointer

D.8 Operators

- Operator overloading
- Global operators
- Operators as members
- Binary operators
- Unary operators
- Allocation operators

1 Operator overloading

- In C++ (in contrast to Java) operators can be overloaded to work with new types
- Looks like function or method overloading
- New reserved word **operator**

return_type **operator** *operator* **(** *parameter_list* **)**
{ ... **};**

- Operators that can be overloaded

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

- Operators that cannot be overloaded

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

- Operator precedence and associativity cannot be changed

2 Global operators

- Work like (global) functions
- Can be friends of classes
- Always have the object itself as a parameter
- Example:

```
class Person { ...
    char* name;
    friend ostream& operator << ( ostream&, Person );
};

ostream& operator << ( ostream& os, Person& p ) {
    os << p.name;
    return os;
}
...
Person p( "Peter" );
cout << p;                   // call as operator
operator << ( cout, p );  // call as function
```

3 Operators as members

- Operator is treated like a method of the class
- Access to all members, there is a **`this`** pointer
- One parameter less than the same global operator (object via **`this`**)
- Example:

```
class Complex {    double real, imag;
public: Complex( double r=0, double i=0 )
            : real( r ), imag( i ) { }
        Complex operator + ( const Complex& ) const;
};

Complex Complex::operator + ( const Complex& c ) const {
    Complex result( real+c.real, imag+c.image );
    return result;
}
...
Complex c1, c2, c3;
c1 = c2 + c3;                  // normal call
c1 = c2.operator + ( c3 );     // generated by the compiler
```

4 Binary operators

- As a global operator: Two parameters
- As a member: One parameter
- Examples (only member operators):
  - Assignment operator

    class`& ` *class*`::operator = (` *class*`& )`

  - Index operator

    element_type`& ` *class*`::operator [] (` *index_type* `)`

    - ➤ Index type usually `int`
  - Arithmetic operators and their combination with the assignment operator

5 Unary operators

- As a global operator: One parameter
- As a member: No parameters
- Except for: Postfix operators
- Examples (only member operators):
  - ◆ Prefix increment operator

```
class& class::operator ++ ( )
```

  - ◆ Postfix increment operator

```
class& class::operator ++ ( int )
```

    - ➤ `int` is just a dummy parameter to distinguish it from the prefix version
  - ◆ Cast operator

```
class::operator target_type ( )
```

    - ➤ Target type of the cast is operator name and return type at once

6 Allocation operators

- Custom memory allocation strategies
- Global operators for all classes
- Operators for allocation on a per-class basis
  - Override global operators
  - E.g. memory pool for short-lived objects
- Operator syntax
  - Allocation operator

```
void* operator new ( size_t )
```

  - Deallocation operator

```
void operator delete ( void * )
```

  - For arrays operators **new[]** and **delete[]**