Chapter 9
Technicalities: Classes, etc.

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Overview

- Classes
  - Implementation and interface
  - Constructors
  - Member functions
- Enumerations
- Operator overloading

Classes

- The idea:
  - A class directly represents a concept in a program
    - If you can think of "it" as a separate entity, it is plausible that it could be a class or an object of a class
    - Examples: vector, matrix, input stream, string, FFT, valve controller, robot arm, device driver, picture on screen, dialog box, graph, window, temperature reading, clock
  - A class is a (user-defined) type that specifies how objects of its type can be created and used
  - In C++ (as in most modern languages), a class is the key building block for large programs
    - And very useful for small ones also
  - The concept was originally introduced in Simula67

Members and member access

- One way of looking at a class;

```
class X {           // this class' name is X
   // data members (they store information)
   // function members (they do things, using the information)
};
```

- Example

```
class X {
public:
   int m;  // data member
   int mf(int v) { int old = m; m=v; return old; }   // function member
};

X var;   // var is a variable of type X
var.m = 7;          // access var's data member m
int x = var.mf(9);          // call var's member function mf()
```

Classes

- A class is a user-defined type

```
class X {        // this class' name is X
public:          // public members -- that's the interface to users
                 //          (accessible by all)
    // functions
    // types
    // data (often best kept private)
private:         // private members -- that's the implementation details
                 //          (accessible by members of this class only)
    // functions
    // types
    // data
};
```

Struct and class

- Class members are private by default:

```
class X {
        int mf();
        // …
};
```

- Means

```
class X {
private:
        int mf();
        // …
};
```

- So

```
X x;                // variable x of type X
int y = x.mf();     // error: mf is private (i.e., inaccessible)
```

Struct and class

- A struct is a class where members are public by default:

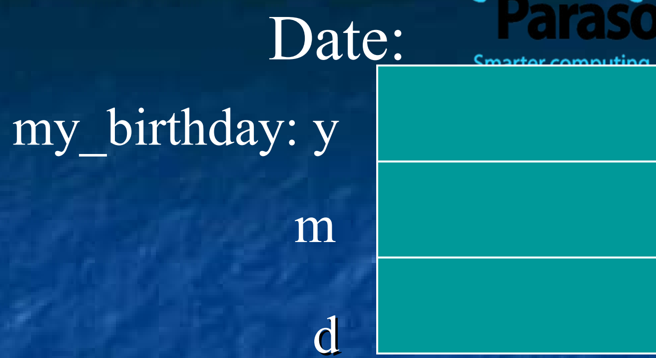
```
struct X {
        int m;
        // ...
};
```

- Means

```
class X {
public:
        int m;
        // ...
};
```

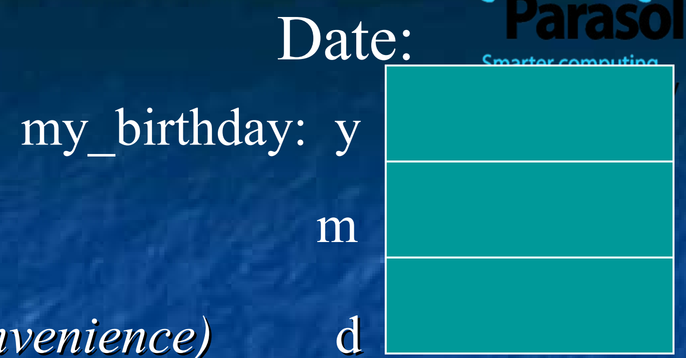
- **struct**s are primarily used for data structures where the members can take any value

Structs



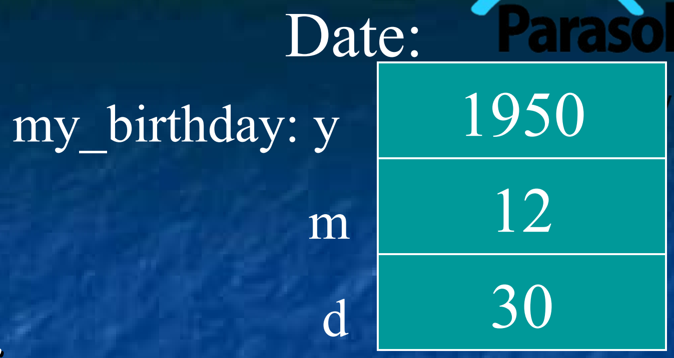

```
// simplest Date (just data)
struct Date {
    int y,m,d;      // year, month, day
};

Date my_birthday;         // a Date variable (object)

my_birthday.y = 12;
my_birthday.m = 30;
my_birthday.d = 1950;     // oops! (no day 1950 in month 30)
                          // later in the program, we'll have a problem
```

Structs



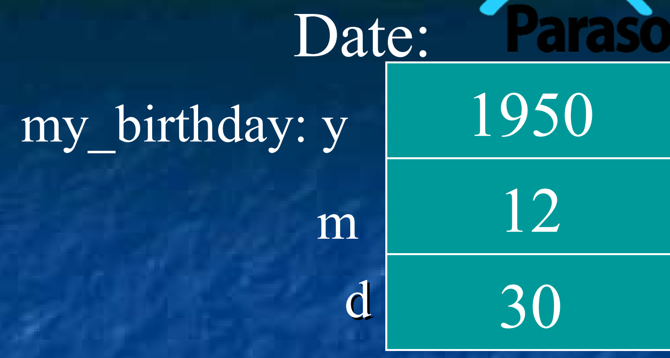

```
// simple Date (with a few helper functions for convenience)
struct Date {
    int y,m,d;      // year, month, day
};

Date my_birthday;       // a Date variable (object)

// helper functions:

void init_day(Date& dd, int y, int m, int d); // check for valid date and initialize
                                              // Note: this y, m, and d are local

void add_day(Date& dd, int n);   // increase the Date by n days
// …

init_day(my_birthday, 12, 30, 1950); // run time error: no day 1950 in month 30
```

Structs




```
// simple Date
//          guarantee initialization with constructor
//          provide some notational convenience
struct Date {
    int y,m,d;                  // year, month, day
    Date(int y, int m, int d);  // constructor: check for valid date and initialize
    void add_day(int n);        // increase the Date by n days
};

// …
Date my_birthday;                   // error: my_birthday not initialized
Date my_birthday(12, 30, 1950);     // oops! Runtime error
Date my_day(1950, 12, 30);          // ok
my_day.add_day(2);                  // January 1, 1951
my_day.m = 14;                      // ouch! (now my_day is a bad date)
```

Classes




```
// simple Date (control access)
class Date {
    int y,m,d;      // year, month, day
public:
    Date(int y, int m, int d);  // constructor: check for valid date and initialize

    // access functions:
    void add_day(int n);      // increase the Date by n days
    int month() { return m; }
    int day() { return d; }
    int year() { return y; }
};

// …
Date my_birthday(1950, 12, 30);           // ok
cout << my_birthday.month() << endl;      // we can read
my_birthday.m = 14;                       // error: Date::m is private
```

Classes

- The notion of a "valid Date" is an important special case of the idea of a valid value
- We try to design our types so that values are guaranteed to be valid
  - Or we have to check for validity all the time
- A rule for what constitutes a valid value is called an "invariant"
  - The invariant for Date ("Date must represent a date in the past, present, or future") is unusually hard to state precisely
    - Remember February 28, leap years, etc.
- If we can't think of a good invariant, we are probably dealing with plain data
  - If so, use a struct
  - Try hard to think of good invariants for your classes
    - that saves you from poor buggy code

Classes

Date:

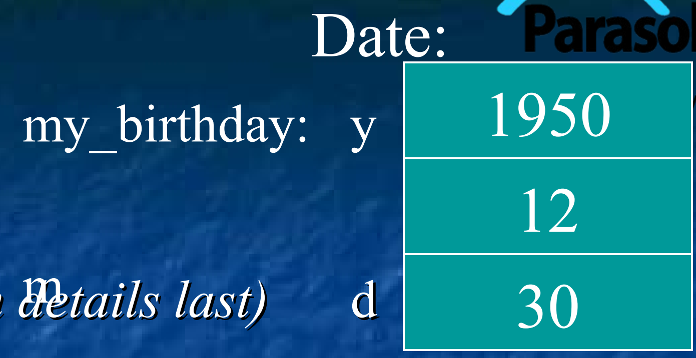
my_birthday: y 1950

m 12

d 30

```
// simple Date (some people prefer implementation details last)
class Date {
public:
    Date(int yy, int mm, int dd);    // constructor: check for valid date and
                                     // initialize
    void add_day(int n);             // increase the Date by n days
    int month();
    // …
private:
    int y,m,d;      // year, month, day
};

Date::Date(int yy, int mm, int dd)                     // definition; note :: "member of"
    :y(yy), m(mm), d(dd) { /* … */ };          // note: member initializers

void Date::add_day(int n) { /* … */ };         // definition
```

Classes




```
// simple Date (some people prefer implementation details last)
class Date {
public:
    Date(int yy, int mm, int dd);  // constructor: check for valid date and
                                   // initialize
    void add_day(int n);           // increase the Date by n days
    int month();
    // …
private:
    int y,m,d;     // year, month, day
};

int month() { return m; }    // error: forgot Date::
                             // this month() will be seen as a global function
                             // not the member function, so can't access members

int Date::season() { /* … */ }      // error: no member called season
```

Classes

```
// simple Date (what can we do in case of an invalid date?)
class Date {
public:
    class Invalid { };                          // to be used as exception
    Date(int y, int m, int d);                  // check for valid date and initialize
    // …
private:
    int y,m,d;                                  // year, month, day
    bool check(int y, int m, int d);  // is (y,m,d) a valid date?
};

Date:: Date(int yy, int mm, int dd)
    : y(yy), m(mm), d(dd)                       // initialize data members
{
    if (!check(y,m,d)) throw Invalid();         // check for validity
}
```

Classes

- Why bother with the public/private distinction?
- Why not make everything public?
  - To provide a clean interface
    - Data and messy functions can be made private
  - To maintain an invariant
    - Only a fixed set of functions can access the data
  - To ease debugging
    - Only a fixed set of functions can access the data
    - (known as the “round up the usual suspects” technique)
  - To allow a change of representation
    - You need only to change a fixed set of functions
    - You don’t really know who is using a public member

Enumerations

- An **enum** (enumeration) is a very simple user-defined type, specifying its set of values (its enumerators)
- For example:

```
enum Month {
    jan=1, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec
};

Month m = feb;
m = 7;                      // error: can't assign int to Month
int n = m;                  // ok: we can get the numeric value of a Month
Month mm = Month(7);        // convert int to Month (unchecked)
```

Enumerations

- Simple list of constants:

```
enum { red, green };  // the enum { } doesn't define a scope
int a = red;   // red is available here
enum { red, blue, purple };     // error: red defined twice
```

- Type with list of constants

```
enum Color { red, green, blue, /* … */  };
enum Month { jan, feb, mar, /* … */ };

Month m1 = jan;
Month m2 = red;       // error: red isn't a Month
Month m3 = 7;         // error: 7 isn't a Month
int i = m1;    // ok: an enumerator is converted to its value, i==0
```

Enumerations – Values

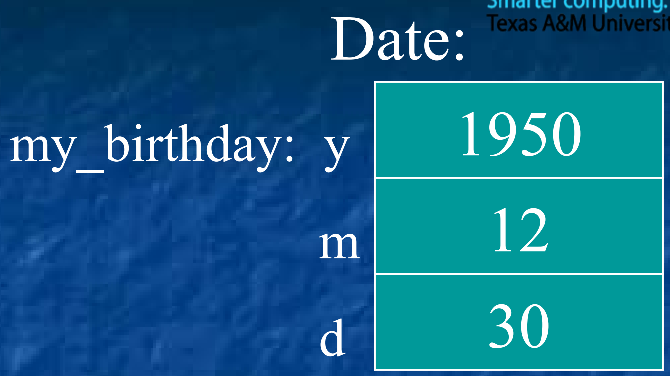
- By default

```
// the first enumerator  has the value  0,
// the next enumerator has the value "one plus the value of the
// enumerator before it"
enum { horse, pig, chicken };  // horse==0, pig==1, chicken==2
```

- You can control numbering

```
enum { jan=1, feb, march /* … */ };     // feb==2, march==3
enum stream_state { good=1, fail=2, bad=4, eof=8 };
int flags = fail+eof;     // flags==10
stream_state s = flags;             // error: can't assign an int to a stream_state
stream_state s2 = stream_state(flags); // explicit conversion (be careful!)
```

Classes




```
// simple Date (use Month type)
class Date {
public:
    enum Month {
        jan=1, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec
    };
    Date(int y, Month m, int d);  // check for valid date and initialize
    // …
private:
    int y;          // year
    Month m;
    int d;          // day
};

Date my_birthday(1950, 30, Date::dec);   // error: 2nd argument not a Month
Date my_birthday(1950, Date::dec, 30);   // ok
```

Const

```
class Date {
public:
    // …
    int day() const { return d; }      // const member: can't modify
    void add_day(int n);               // non-const member: can modify
    // …
};

Date d(2000, Date::jan, 20);
const Date cd(2001, Date::feb, 21);

cout << d.day() << " – " << cd.day() << endl;      // ok
d.add_day(1);      // ok
cd.add_day(1);     // error: cd is a const
```

Const

```
//
Date d(2004, Date::jan, 7);                 // a variable
const Date d2(2004, Date::feb, 28);         // a constant
d2 = d;            // error: d2 is const
d2.add(1);         // error d2 is const
d = d2;            // fine
d.add(1);          // fine

d2.f();    // should work if and only if f() doesn't modify d2
           // how do we achieve that? (say that's what we want, of course)
```

Const member functions

```
// Distinguish between functions that can modify (mutate) objects
// and those that cannot ("const member functions")
class Date {
public:
    // …
    int day() const;          // get (a copy of) the day
    // …
    void add_day(int n);   // move the date n days forward
    // …
};

const Date dx(2008, Month::nov, 4);
int d = dx.day(); // fine
dx.add_day(4);   // error: can't modify constant (immutable) date
```

Classes

- What makes a good interface?
  - Minimal
    - As small as possible
  - Complete
    - And no smaller
  - Type safe
    - Beware of confusing argument orders
  - Const correct

Classes

- Essential operations
  - Default constructor (defaults to: nothing)
    - No default if any other constructor is declared
  - Copy constructor (defaults to: copy the member)
  - Copy assignment (defaults to: copy the members)
  - Destructor (defaults to: nothing)
- For example

```
Date d;          // error: no default constructor
Date d2 = d;     // ok: copy initialized (copy the elements)
d = d2;          // ok copy assignment (copy the elements)
```

Interfaces and "helper functions"

- Keep a class interface (the set of public functions) minimal
  - Simplifies understanding
  - Simplifies debugging
  - Simplifies maintenance
- When we keep the class interface simple and minimal, we need extra "helper functions" outside the class (non-member functions)
  - E.g. == (equality) , != (inequality)
  - **next_weekday(), next_Sunday()**

Helper functions

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```
Date next_Sunday(const Date& d)
{
    // access d using d.day(), d.month(), and d.year()
    // make new Date to return
}

Date next_weekday(const Date& d) { /* ... */ }

bool operator==(const Date& a, const Date& b)
{
    return a.year()==b.year()
        && a.month()==b.month()
        && a.day()==b.day();
}

bool operator!=(const Date& a, const Date& b) { return !(a==b); }
```

Operator overloading

- You can define almost all C++ operators for a class or enumeration operands
  - that's often called "operator overloading"

```
enum Month {
    jan=1, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec
};

Month operator++(Month& m)    // prefix increment operator
{
    m = (m==dec) ? jan : Month(m+1);        // "wrap around"
    return m;
}

Month m = nov;
++m;    // m becomes dec
++m;    // m becomes jan
```

Operator overloading

- You can define only existing operators
  - *E.g.*, + - * / % [] () ^ ! & < <= > >=
- You can define operators only with their conventional number of operands
  - *E.g.*, no unary <= (less than or equal) and no binary ! (not)
- An overloaded operator must have at least one user-defined type as operand
  - **int operator+(int,int);** // error: you can't overload built-in +
  - **Vector operator+(const Vector&, const Vector &);** // ok
- Advice (not language rule):
  - Overload operators only with their conventional meaning
  - + should be addition, * be multiplication, [] be access, () be call, etc.
- Advice (not language rule):
  - Don't overload unless you really have to

Strong **enums**

- Regular **enums** provide convenient aliases for values which are a subrange of **int**:

  enum Color {red, green, blue}; //red==0, **green**==1, blue==2

  with the type name (**Color**) exported to the enclosing scope.

- Now C++11 allows other underlying classes to be specified:

  enum class Month : unsigned char {jan=1,…};

  which also defines a [class] scope. These are called "strong" **enums**.

Range-based **for**

- "For each **int e** in vector **v**, print the element":

```
vector<int> v(5);
for(int e : v) cout << e << endl;
```

- We can use **auto** too, which is useful:

```
for(auto e : v) cout << e << endl;
```

- We can also say things like

```
for(int& e : v) e = -1;
```

to set each element to -1, since making **e** a reference (with the **&**) makes it an lvalue (see pages 94-95).