6. Objects and Classes

6.1. Classes

6.2. Constructors and Destructors

6.3. `this` and initializing `const` attributes

6.4. `static` members

6.5. The `string` Class

6.6. The `ifstream` and `ofstream` Classes

6.7. The `tuple` Class

6.1. Classes and Objects

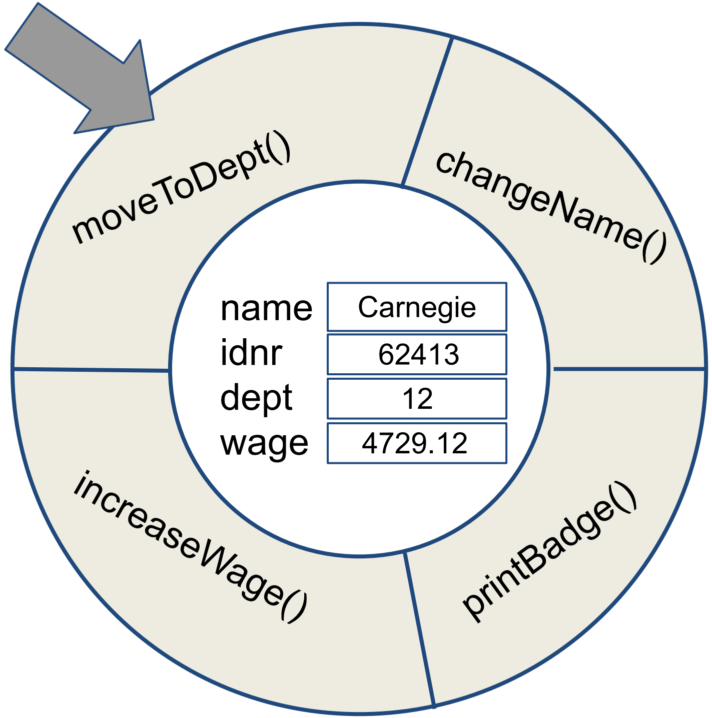
- A **class** essentially defines a new type, containing:
  - a collection of variables (data members, attributes)
  - a set of related operations (member functions, methods)
- An **object** is an instance (an entity) of a class
  - it is called object, since it usually models a real-world object
  - a class then can be viewed as a model or a blueprint for a certain class of objects

6.1. Classes and Objects

Encapsulation: The bundling together of all information, capabilities, and responsibilities (data and functions) into one single object:

```
// create a new employee:
Employee user("Carnegie", 62413,
              12, 4729.12);

// move the user to department 17:
user.movetoDept(17);
// change the user's name:
user.changeName("Carnegie-Mellon");
```

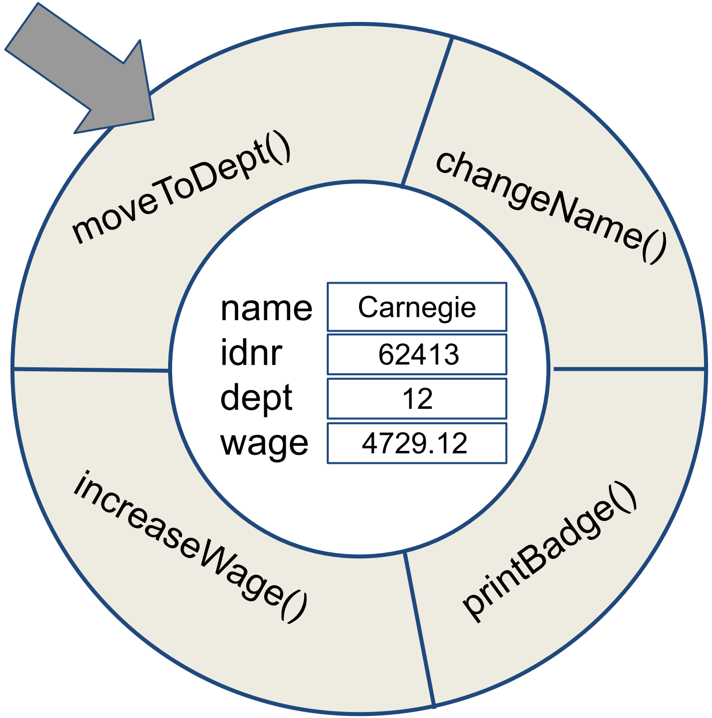


6.1. Classes and Objects

Encapsulation has two properties:

1) Data protection: Attributes are **private**, access to attributes goes through the available methods

2) Information hiding: Internal implementation is hidden from external code, only the **public** interface of the class is accessible



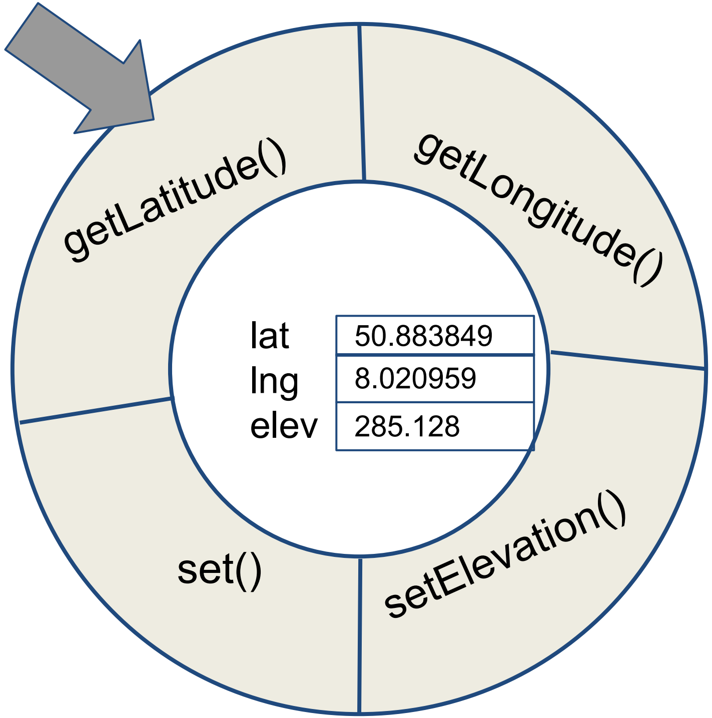
6.1. Classes and Objects

Access to object's attributes goes through the available methods. Example:

```
GPSCoord here; // GPS coordinate object

// we can modify latitude and
// longitude only together:
here.set(50.883849, 8.020959);

// we can modify the elevation:
here.setElevation(285.128);
// we can retrieve these attributes:
double lat = here.getLatitude();
double lng = here.getLongitude();
// .. but not elevation
```

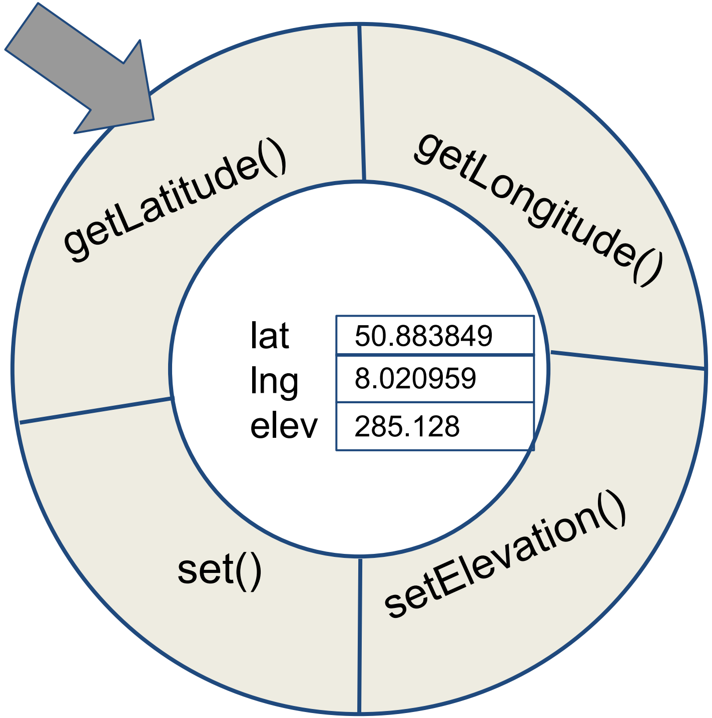


6. Objects and Classes

6.1. Classes and Objects

Declaring a class GPSCoord:

```
// GPS coordinate class:
class GPSCoord {
 private:
  // latitude, longitude, elevation:
  double lat, lng, elev;
 public:
  // set latitude and longitude:
  void   set(double la, double lo);
  void   setElevation(double val);
  double getLatitude();
  double getLongitude();
};
```



6.1. Classes and Objects

Implementing the methods for the class GPSCoord:

```
void GPSCoord::set(double la, double lo){
  lat = la; lng = lo;
}
void GPSCoord::setElevation(double val){
  elev = val;
}
double GPSCoord::getLatitude(){
  return lat;
}
double GPSCoord::getLongitude(){
  return lng;
}
```

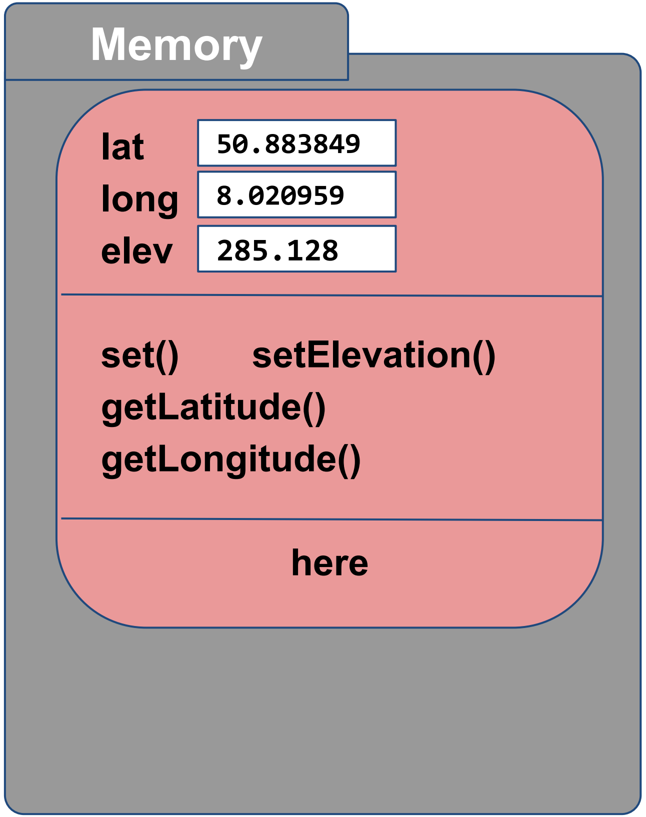
6.1. Classes and Objects

Creating an object of the class GPSCoord:

```
GPSCoord here; // GPS coordinate object

// we can modify latitude and
// longitude only together:
here.set(50.883849, 8.020959);

// we can modify the elevation:
here.setElevation(285.128);
// we can retrieve these attributes:
double lat = here.getLatitude();
double lng = here.getLongitude();
// .. but not elevation
```

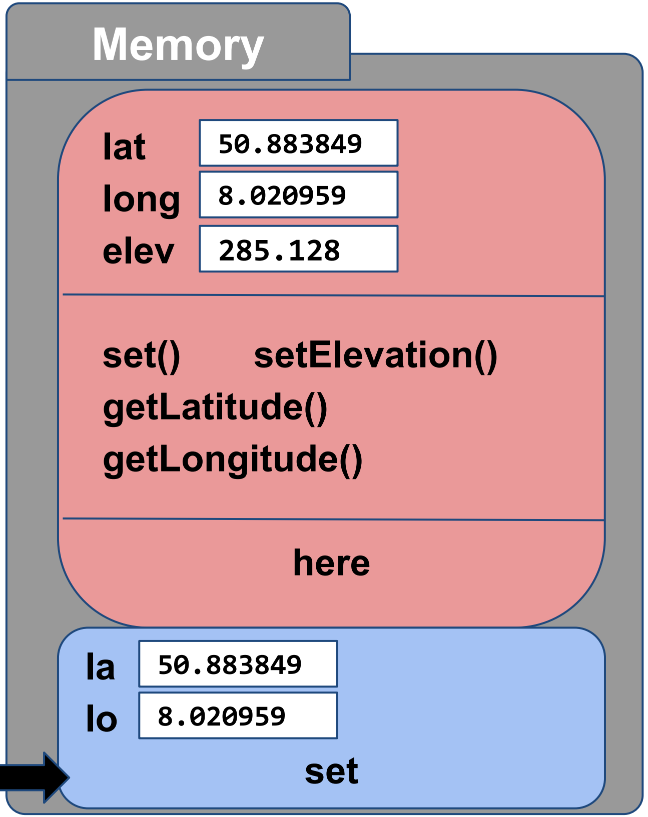


6.1. Classes and Objects

An object's method (member function) has access to *all* its attributes (variables) and methods

```
void GPSCoord::set(double la, double lo){
  lat = la; long = lo;  // defaults
  // call GPSCoord methods to update:
  lat = getLatitude();
  lng = getLongitude();
  setElevation(285.128);
}
```

```
GPSCoord here; // GPS coordinate object
// set latitude and longitude:
here.set(50.883849, 8.020959);
```



6.1. Classes and Objects

❗ Note new suggested indentation & syntax for classes. One space should come before private or public, and a colon (':') after these keywords. Example:

```
// GPS coordinate class:
class GPSCoord {
◇private:
◇◇// latitude, longitude, elevation:
◇◇double lat, lng, elev;
◇public:
◇◇// set latitude and longitude:
◇◇void set(double la, double lo);
◇◇void etElevation(double val);
◇◇double getLatitude();
◇◇double getLongitude();
};  // mind the semicolon after the declaration
```

6.1. Classes and Objects: Minor notes

Attributes could also be public (but usually aren't)
Methods can also be implemented in the class declaration

```
class Test {
 private:
  int attribute1;  // a private attribute
 public:
  bool attribute2;  // a public attribute
  void method1(int parameter) { attribute1 = parameter; };   // methods implemented
  void method2() { std::cout << attribute1 << std::endl; };  // in class declaration
};

int main(){
  Test myTest;  // create an object of class Test
  myTest.attribute2 = false;  // we can access public attributes
  myTest.method1(21); // we can call public methods
}
```

6.1. Classes and Objects: Minor notes

The class declaration is usually in the file **`className.h`**, the class' method implementations in the file **`className.cpp`**

Test.h

```
class Test {
 private:
  int attribute1;
 public:
  bool attribute2;
  void method1(int parameter);
  void method2();
};
```

Test.cpp

```
#include "Test.h"
void Test::method1(int parameter) {
  attribute1 = parameter;
};
void Test::method2() {
  std::cout << attribute1 << std::endl;
};
```

mainTest.cpp

```
#include "Test.h"
int main(){
  Test myTest;
  myTest.attribute2 = false;
  myTest.method1(21);
}
```

6.1. Classes and Objects: Minor notes: `struct`

`struct` allows to group multiple variable in C++ into one variable. All of its attributes (or members) and methods (or member functions) are public.
Since C++20, structs can use Designated Initializers.

```
struct Key {
 char label;
 bool pressed;
};

int main() {
  Key item1;
  item1.label = 'q';
  item2.pressed = false;
  // initialize members to values:
  Key item2 = {'w', true};
}
```

```
struct Date {
 int day, month, year;
};

int main() {
  // Designated Initializers allow to
  // make initialization more flexible
  // (from C++20)
  Date today = { .day = 9, .month = 5,
                 .year = 2025
  };
}
```

6.1. Classes and Objects: Minor notes: Scope Resolution

The scope resolution operator `::` lets you access variables from other scopes:

```cpp
#include <iostream>  // std scope

auto a = 'a';  // global scope

namespace myscope {  // myscope scope
  auto a = "a string!";
}

int main() {
  auto a = 7;
  std::cout <<  // std scope
    "a = " << a << '\n' <<    // local scope
    "::a = " << ::a << '\n' <<    // global scope
    "myscope::a = " << myscope::a << '\n';  // "myscope" scope
}
```

6.2. Constructors and Destructors

Reminder: Variables can be declared and later initialized, or they can be immediately initialized within the declaration:

```
char mySymbol = '?';
```

This declaration and initialization can be done for classes' objects as well:

```
GPSCoord myLocation(50.88385, 8.02096, 285.128);  // coordinates of Siegen
Employee user("Carnegie", 62413, 12, 4729.12);  // employee Carnegie
SizedSymbol bigQuestion('?', 14);  // a SizedSymbol '?' with size 14
```

This requires a special method with the class' name: The constructor

6.2. Constructors and Destructors

A constructor has no return value (not even void) and is automatically called

```
class Test {
 private:
  int attribute1;
 public:
  Test(int parameter) {  // this is a constructor for class Test
    attribute1 = parameter;
  };
  void method2() {
    std::cout << attribute1 << std::endl;
  };
};

int main(){
  Test myTest(21);    // object's constructor initializes is automatically called
  myTest.method2();   // this will print out '21' to the terminal
}
```

6.2. Constructors and Destructors

Constructors can be overloaded (distinguished by their parameters):

```
class Test {
 private:
  int attribute1, attribute2;
 public:
  // multiple constructors for class Test:
  Test() { attribute1 = 0; }; // this is a default constructor
  Test(int parameter) { attribute1 = parameter; };
  Test(int parameter1, int parameter2) { attribute1 = parameter2; };
  void method2() { std::cout << attribute1 << std::endl; };
};

int main(){
  Test myTest(4, 12);  // object of class Test has attribute1 initialized to 12
  myTest.method2();  // this will print out '12' to the terminal
}
```

6.2. Constructors and Destructors

- A class' default constructor is a constructor without parameters
- A class without declared constructors results in the compiler automatically generating a default constructor
- A default constructor is invoked when an object is created, but not initialized

```
class Test {
 private:
  int attribute1;
 public:
  // Test() {}  --> an automatically generated constructor would look like this
  void method2() { std::cout << attribute1 << std::endl; };
};

int main(){
  Test myTest;  // this object is initialized with empty default constructor
}
```

6.2. Constructors and Destructors

A destructor is automatically called whenever an object is destroyed:

```
bool myFunction(){
  Test myTest(17);  // this object is created and initialized here
  return false;     // myTest's destructor is called when function returns
}
```

This destructor is another special method with the same name as the class, starting with a ~:

```
Test::~Test() {  // this is the destructor for class Test
  // here come statements for application-specific clean up
}
```

6.2. Constructors and Destructors

Example 00 (difficulty level: 🌶️)

```
/**
  Write a program that declares, implements, and uses a class with no attributes.
  The class should print 'hello' to the terminal when its object is created and
  'bye' when its object is removed from memory.
*/
#include <iostream>     // terminal input and output classes and objects

// write the class here

int main() {
  // create a class object here

}
```

6.2. Constructors and Destructors

Example 01 (difficulty level: 🌶️🌶️)

```
/**
  Write a program that declares, implements, and uses a class with two attributes,
  a boolean called 'flag' and an integer called 'number', which can only be changed
  or read through a constructor. The class should also have a method 'get' with no
  parameters, which returns the integer 'number' only if 'flag' is true, and
  otherwise 0.
*/
// write the class here
int main() {
  int returnValue;
  // create a class object here
  // and use its get method
  return returnValue;
}
```

6.2. Constructors and Destructors: Maze Game v.4.00

Change the module into a class Maze, with **`mazeGame.cpp`** looking this way:

mazeGame.cpp

```
/* Fourth draft of Maze Game: drawing is in class "Maze" */
#include "Maze.h"  // everything related to the maze
int main() {
  auto c = ' ';        // used for user key input
  Maze maze(10, 5);    // initialize the maze and put player at (10, 5)
  while ( c != 'q' ) {  // as long as the user doesn't press q ..
    maze.draw('@', 3);    // draw player as a '@' with color pair 3
    c = getch();          // capture the user's pressed key
    switch (c) {
      case 'w': maze.up(); break;  // go up
      case 's': maze.down(); break;  // go down
      case 'a': maze.left(); break;  // go left
      case 'd': maze.right(); break;  // go right
    }
  }
}
```

6.3. **`this`** and initializing **`const`** attributes

Class methods often reuse attribute names, leading to a problem:

```
class Maze {
 public:
  Maze(int16_t x, int16_t y);
  ...
 private:
  int16_t x, y;
  ...
};
```

```
Maze::Maze(int16_t x, int16_t y) {
 // how to assign the values of
 // constructor parameters x and y
 // to class attributes x and y?
  ...
}
Maze::Maze() {
 int16_t x, int16_t y;
 // how to assign the values of
 // constructor parameters x and y
 // to local variables x and y?
  ...
}
```

6.3. **this** and initializing **const** attributes

One solution that works in all the class' methods is to use **this**

```
Maze::Maze(int16_t x, int16_t y) {
   this->x = x;   // attribute x = value of constructor parameter x
   this->y = y;   // attribute y = value of constructor parameter y
   ...
}
```

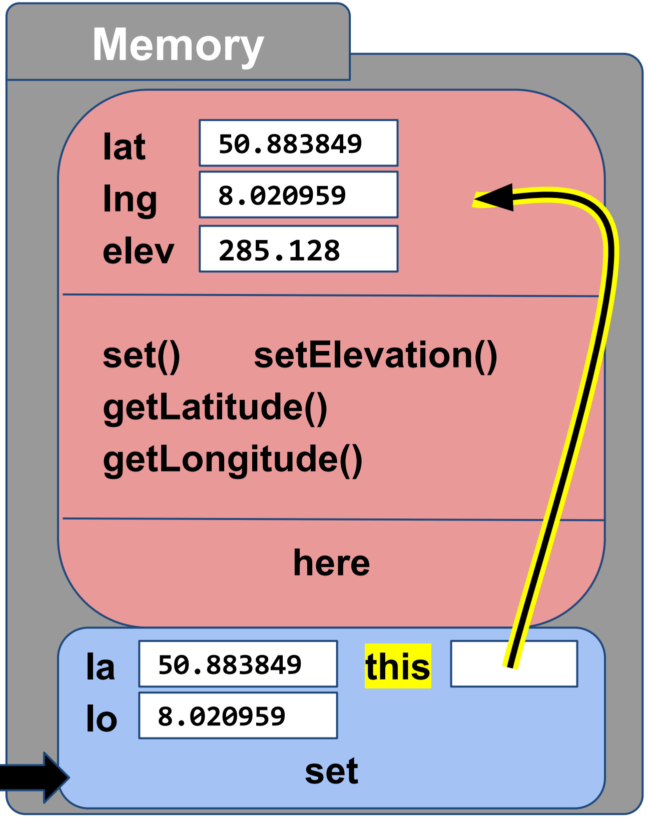
- Note: Each object gets its own copy of data members, all objects share a single copy of the class' methods
- **this** is an implicit pointer (see later) that is passed as a hidden parameter for all the class' methods, and is there available as another local variable

6.3. **this** and initializing **const** attributes

this is passed as a hidden parameter for all the class' methods, as an extra (pointer) variable

```
void GPSCoord::set(double lat, double lng){
   this->lat = lat;
   this->lng = lng;
   this->lat = getLatitude();
   this->lng = getLongitude();
   setElevation(285.128);
}
```

```
GPSCoord here; // GPS coordinate object
// set latitude and longitude:
here.set(50.883849, 8.020959);
```



6.3. **`this`** and initializing **`const`** attributes

Another (shorter) solution for constructors is to use this initialization syntax:

```
Maze::Maze(int16_t x, int16_t y) : x(x), y(y) {
  // attributes x and y have now the same value as constructor
  // parameters x and y
}
```

This *member initializer list* syntax in constructors is not an assignment but a real initialization of the attribute. Curly braces can also be used:

```
Maze::Maze(int16_t x, int16_t y) : x{x}, y{y} {
  // attributes x and y have now the same value as constructor
  // parameters x and y
}
```

6.3. **this** and initializing **const** attributes

This syntax addresses the problem of initializing a class' **const** attribute:

```
class Maze {
  ...
 private:
  const int16_t mazeXlen;
  const int16_t mazeYlen;
  ...
};
```

```
Maze::Maze(int16_t x, int16_t y) {
  // we cannot assign to const:
  mazeXlen = 15; // compiler error
  mazeYlen = 10; // compiler error
  ...
}
```

This syntax is not an assignment but an initialization, and thus works:

```
Maze::Maze(int16_t x, int16_t y) : mazeXlen(15), mazeYlen(10) {
  // mazeXlen is now 15, mazeYlen 10
  ...
}
```

6.3. **this** and initializing **const** attributes

This syntax similarly addresses other initialization problem, e.g. for C strings:

```
class Label {
  ...
 private:
  // name is initialized:
  char name[25] = "default";
  ...
};
```

```
Label::label() {
  name = "none";  // --> compiler error
}
Label::label(int8_t i) {
  name = "int8_t"; // --> compiler error
}
  ...
```

This syntax is not an assignment but an initialization, and thus works:

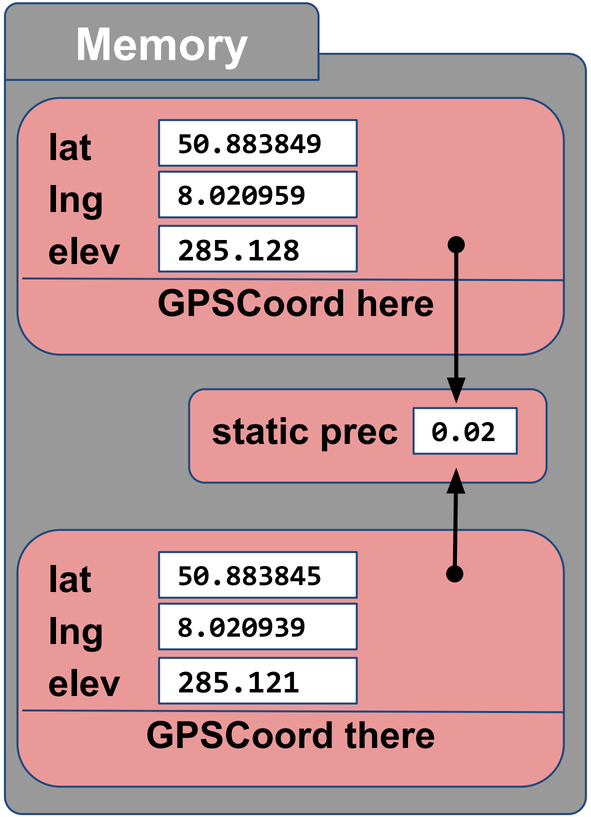
```
Label::Label() : name("none") { /* name is now "none" */ }
Label::Label(int8_t i) : name("int8_t") { /* name is now "int8_t" */ }
  ...
```

6.4. `static` members

- Each object has its own class attributes
- All objects share one copy of the class' methods
- **`static`** attributes, or [static members](), are stored once across all objects. *Changing it through one object will change it for all objects.*

```
double GPSCoord::prec;  // define static member once
GPSCoord here;
GPSCoord there;

there.prec = 0.02;
// the following will print out 0.02:
std::cout << here.prec;
```



6.4. **`static`** members

- They exist even if no objects of the class have been defined
- Static class members are declared in the class declaration, and are defined (and/or initialized) in the implementation / source file:

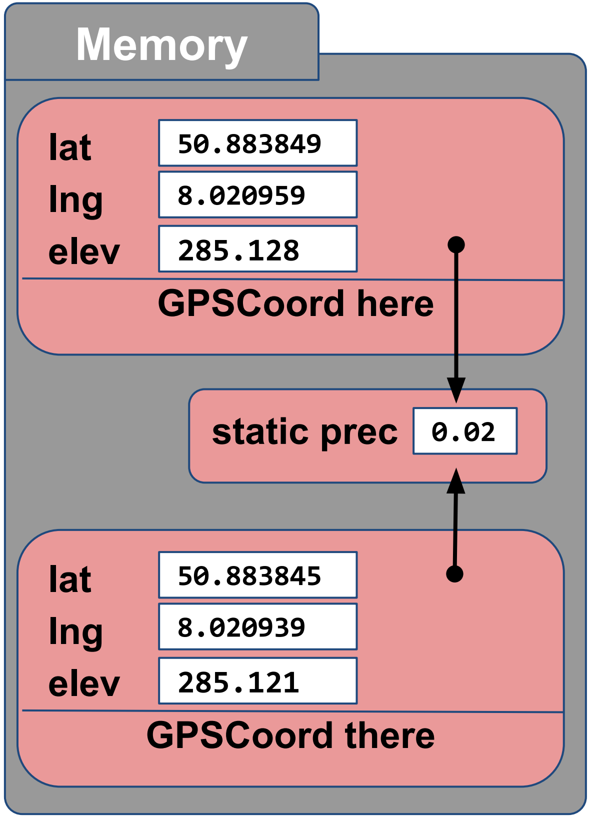
GPSCoord.h

```cpp
class GPSCoord {
 public:
  // declaring a precision
  // attribute for all
  // GPSCoord objects:
  static double prec;
 ...
};
```

GPSCoord.cpp

```cpp
// precision definition
// note that only here
// the variable is
// in fact created:
double GPSCoord::prec;

 ...
```

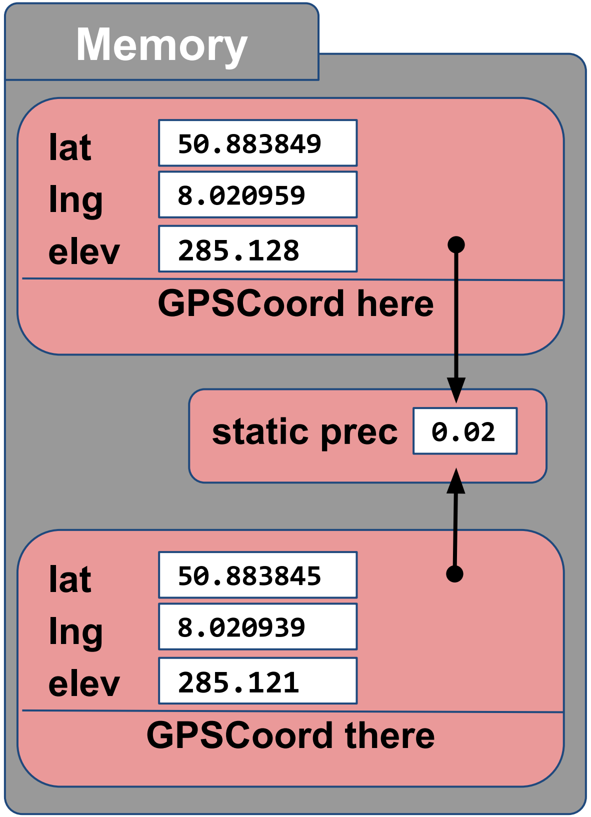


6.4. **`static`** members

These are not the same as **`static`** variables:

- Local variables that are declared as **`static`** are stored as global variables in the static data segment in memory
- Their size has to be known at compile time (e.g., for arrays)

```
void GPSCoord::set(){
  // this variable will stay in memory and keep
  // its value after the method finishes:
  static double elevationPrec = 0.01;
  setElevation(285.128, elevationPrec);
}
```



6.4. **static** members

Example 02 (difficulty level: 🌶️)

```
/**
  Create a class with just a static member, and illustrate that it exists, even
  without any objects.
*/
#include <iostream>      // terminal output
// write the class below:

int main() {
  // do not create an object here, but assign a value to static member here
  std::cout << " The value of the static member is ";
  // print its value here:

  std::cout << '\n';
}
```

6.4. **static** members

Example 03 (difficulty level: 🌶️🌶️)

```
/**
  Create a class Counter below with a static member "count" that holds the number of
  objects of that class. Also, the public attribute "type" of the class should
  contain the type of the supplied parameter to the constructor, as a C string.
*/
#include <iostream>     // terminal output
// write the class, and then define the static member below:

int main() {
  Counter c1, c2(2), c3(3.4);
  // The next line should return "void,int,double,3":
  std::cout << c1.type << ',' << c2.type << ',' << c3.type << '\n';
  // Finally, print out the count of Counter objects below:

}
```

6.5. The **`string`** Class

`iostream` has a class called [`std::string`](), helping in dealing with strings:

```
#include <iostream>     // terminal input and output classes and objects
int main() {
  std::string myFirstName("John");  // initialize with constructor
  std::string myLastName = "Doe";  // initialize with assignment
  std::string myString = myFirstName + myLastName;  // concatenation

  std::cout << myString << ", length = " ;
  std::cout << myString.length() << '\n';  // returns myString length

  std::cout << " Do found at = ";
  std::cout << myString.find("Do") << '\n';  // return position of "Do"

  std::cout << myString.compare(4, 3, "Do");  // is substring at position 4
  std::cout << '\n';                         // and length 3 the same as "Do"?
}
```

6.5. The **string** Class

iostream has a class called [**std::string**](), helping in dealing with strings.
Several **std::string** alternatives use instead of **char**:

[**std::wstring**]()	uses **wchar_t** for [wide strings]()
std::u8string (since C++20)	uses **char8_t**
std::u16string (since C++11)	uses **char16_t**
std::u32string (since C++11)	uses **char32_t**

```
#include <iostream>     // terminal input and output classes and objects
int main() {
  std::wcout.imbue(std::locale("en_US.UTF-8"));
  std::string  myString  = "¡Hola! 日本 שלום 你好 مرحبا";   // UTF-8
  std::wstring mywString = L"¡Hola! 日本 שלום 你好 مرحبا";  // wide chars
  std::cout  << myString << sizeof(myString[0]) << '\n';
  std::wcout << mywString << sizeof(mywString[0]) << '\n';  // ! note wcout
}
```

6.6. The **ifstream** and **ofstream** Classes

The module **fstream** contains a class [**std::ifstream**]() for reading from a file:

fileTest.cpp

```
#include <iostream>     // terminal input/output classes & objects
#include <fstream>      // input file stream class std::ifstream

int main() {
  std::ifstream myFile("fileTest.cpp");  // initialize with constructor

  char c;
  while (myFile.get(c)) {   // get a character from the file, move to next
    std::cout << c;         // and output it to the terminal
  }

}
```

6.6. The **ifstream** and **ofstream** Classes

The module **fstream** also contains a class [**std::ofstream**] for writing to a file:

copyTest.cpp

```
#include <fstream> // in/output file stream classes

int main() {
  std::ifstream myFile("copyTest.cpp");    // initialize input and output file
  std::ofstream myFileCopy("copyTest_copy.cpp");  // streams with constructors

  char c;
  while (myFile.get(c)) {   // get a character from the input file stream
    myFileCopy << c;        // and output it to the output file stream
  }

}
```

6.7. The **`tuple`** Class

A **`std::tuple`** is a fixed-sized collection of values of various data types (preview of what is still to come, as it uses templates under the hood):

```
#include <iostream> // for std::cout and tuples functionality
int main() {
  auto myUser = std::make_tuple("James", "Smith", 187.2);  // auto → std::tuple
  // get with index-based access:
  std::cout << std::get<0>(myUser) << " " << std::get<1>(myUser);
  // get with type-based access:
  std::cout << ":" << std::get<double>(myUser) << '\n';
  // output: "James Smith: 187.2" and goes to next line
}
```

- `get<0>(myUser)` accesses first element (hence index-based access, since C++11)
- `get<double>(myUser)` accesses the double (hence type-based access, since C++14) (works only if 1 tuple element has this type, otherwise the compiler reports an error)

6.7. The **tuple** Class

With decomposition declarations or structured bindings (since C++17), you can unpack the contents of the tuple into individual variables:

```
#include <iostream> // for std::cout and tuples functionality
int main() {
  auto myUser = std::make_tuple("James", "Smith", 187.2);  // auto = std::tuple
  auto [fname, lname, height] = myUser;  // decomposition declaration, C++17
  std::cout << fname << " " << lname << ":" << height << '\n';
}
```

the first `auto` above can deduce myUser as an **std::tuple** object, as that is the return type from **std::make_tuple()**

6.7. The **tuple** Class

One use of **std::tuple** is to return such on object from a function, bundling several values (even of different types) together:

```
#include <iostream> // for std::cout and tuples functionality

auto arithmetic(int a, int b) {  // auto here is possible since C++14
  return std::make_tuple( a + b, a - b, a * b, a / b );
}

int main() {
  auto arith = arithmetic(5, 7);
  std::cout << " add: " << std::get<0>(arith) << '\n';
  std::cout << " sub: " << std::get<1>(arith) << '\n';
  std::cout << " mul: " << std::get<2>(arith) << '\n';
  std::cout << " div: " << std::get<3>(arith) << '\n';
}
```

6.7. The **tuple** Class

One use of **std::tuple** is to return such on object from a function, bundling several values (even of different types) together:

```
#include <iostream> // for std::cout and tuples functionality

auto arithmetic(int a, int b) {  // auto here is possible since C++14
  return std::make_tuple( a + b, a - b, a * b, a / b );
}

int main() {  // now using structured bindings, since C++17
  auto [add, sub, mul, div] = arithmetic(5, 7);
  std::cout << " add: " << add << '\n';
  std::cout << " sub: " << sub << '\n';
  std::cout << " mul: " << mul << '\n';
  std::cout << " div: " << div << '\n';
}
```