Basic C++ For Embedded

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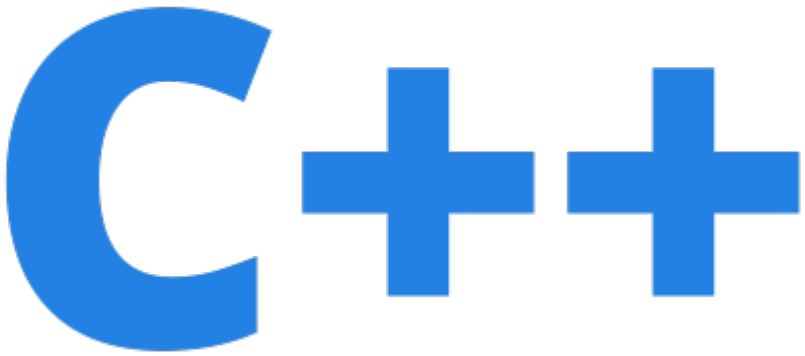
Last Time

- Talked about Basic C

Today

- Going to talk about C/C++



no need for typedefs for structs


```
struct Pt {
  int x;
  int y;
};

Pt p = { 1, 2 };
```

C in C++


```
extern "C" int foo(int x, char* s);
```

Variable definition in for loops


```
for (int i = 0; i < 10; i++) { ... }
```

Const


```
const int CAPACITY = 16;
```

Basic Concepts

- classes and objects – like C struct but with functions
- member functions – part of object
- private vs public members – access control

Classes

- like C structs
- C++ structs are like a class with only public members
- usually .h file has class defs and .cpp files has implementation
- inside member functions can refer to member fields by name

```
const int CAPACITY = 16;

class Queue {
public:
  void enq (int value);
  int deq ();
  int head;
  int tail;
  int data[CAPACITY];
};

void Queue::enq (int value) {
  data[tail] = value;
  tail = (tail + 1) % CAPACITY;
}
```

Dynamically Allocated Classes

- use `new` for object creation
- use `->` for calling member functions

```
queue = new Queue();
queue->enq(17);
```

Public / Private

- use `public` for API functions
- use `private` for hidden fields and functions

```
class Queue {
public:
  void enq (int value);
  int deq ();
private:
  int head, tail;
  int data[CAPACITY];
};
```

Constructors

- use same class name for constructor
- always define a constructor
- always initialize all fields

```
class Queue {
public:
  Queue (int cap);
  void enq (int value);
  int deq ();
private:
  int CAPACITY;
  int head, tail;
  int *data;
};

Queue::Queue(int cap) {
  head = tail = 0;
  CAPACITY = cap;
  data = new int[cap]; // Array construction
}
```

Destructors

- use ~ class name for destructor name
- define a destructor when have allocated data in fields
- also destructors can be used to close files etc
- if don't write destructor will create leaks

```
class Queue {
public:
  void enq (int value);
  int deq ();
  Queue(int cap);
  ~Queue();
private:
  int CAPACITY;
  int head, tail;
  int *data;
};

Queue::~Queue() {
  delete [] data;
}
```

Statically Allocated Classes

- declare object using class name
- put class arguments after variable name
- use dot for accessing functions
- destructor called when exiting scope

```
Queue q(10);
q.enq(17);
```

Inline Functions

- can write member function bodies in class definitions
- functions then are inlined

```
class Queue {
public:
  void enq (int value);
  int deq ();
  int capacity () {
    return CAPACITY;
  }
  Queue(int sz);
  ~Queue();
private:
  int CAPACITY;
  int head, tail;
  int *data;
};
```

Call by value

- copies value
- use dot notation

```
class Wrap {
  public:
   int value;
   Wrap (int a) { value = a; }
};

Wrap f (Wrap x, Wrap y) {
  return Wrap(x.value + y.value);
}
```

Inheritance

- inherit interface defined using virtual functions

```
class Queue {
public:
  virtual void enq (int value) = 0;
  virtual int size () = 0;
};
class CircularQueue : public Queue {
public:
  CircularQueue(int cap);
  virtual void enq(int value) {
    data[tail] = value; tail = (tail + 1) % CAPACITY;
  }
  virtual int size() {
    return ((tail - head) + capacity) % CAPACITY;
  }
private:
  int CAPACITY;
  int head, tail;
  int *data;
};
```

Shared Inheritance

- inheritance allows sharing implementation

```
class Queue {
public:
  virtual void enq (int value) = 0;
  virtual int size () = 0;
  bool is_empty () { return size() == 0; } // shared across implementations
};
class CircularQueue : public Queue {
public:
  CircularQueue(int sz);
  virtual void enq(int value) { ... }
  virtual int size() { ... }
private:
  int CAPACITY;
  int head, tail;
  int *data;
};
```

Templates with Type Parameter


```
template <typename T>
class Queue {
public:
  void enq (T value);
  T deq ();
  int capacity () {
    return CAPACITY;
  }
  Queue(int cap);
  ~Queue();
private:
  int CAPACITY;
  int head, tail;
  T *data;
};
```

```
template <typename T>
Queue<T>::Queue(int cap) {
  CAPACITY = cap;
  head = tail = 0;
  data = new T[cap];
}
```

Templates with Value Parameter


```
template <typename T, int CAPACITY>
class Queue {
public:
  void enq (T value);
  T deq ();
  int capacity () {
    return CAPACITY;
  }
  Queue(int cap);
  ~Queue();
private:
  int head, tail;
  T data[CAPACITY];
};
```

Namespaces

- defining
- using

```
namespace collections {
  class Queue { ...}
}
```

```
queue = new collections::Queue<int>(10);
```

```
using namespace collections;

queue = new Queue<int>(10);
```

Operator Overloading

- can redefine meaning of operators for particular classes

```
class Vec2f {
public:
  float x, y;
  Vec2f operator + (Vec2f o) {
    return Vec2f(x + o.x, y + o.y);
  }
  Vec2f (float ax, float ay) { x = ax; y = ay; }
};
```

```
Vec2f u(0.0, 1.0);
Vec2f w(0.0, 1.0);
Vec2f v = u + w;
```

Read/Write Operator Overloading

- overload normal reading and writing operations on variables
- can do for `[]` as well

```
class Wrap {
public:
  float x;
  operator int() { return x; }
  operator = (float n) { x = n; }
  Param (float ax) { x = ax; }
};
```

```
Wrap p(0.0);
p = 1.0;
float v = p;
```

Callback Functions

- callbacks

```
int f (int a, float b) { ... }
```

```
typedef int (*int_function_ptr)(int, float);
```

```
int main () {
  int (*fp)(int, float);
  fp = &f;
  int x = fp(1, 2.0);
}
```

```
int main () {
  int_function_ptr fp;
  fp = &f;
  int x = fp(1, 2.0);
}
```

C++ Standard Library

- `String`, `Set`, `Map`, `Vector`, `Stack`, `PriorityQueue`
- mostly discouraged in embedded applications because of memory
- dynamic memory allocation – fragmentation and pauses
- also blows up code size if that matters
- there are some emerging real time options – more later

```
#include <vector>
int main () {
  std::vector v<Int>();
  v.add(1);
  v.add(2);
  int sum = 0;
  for (int i = 0; i < v.size(); i++) {
    sum = sum + v[i];
  }
}
```

C++ compiler

- use same as C compiler

```
> g++ -o xs xs.cpp     # compiling and linking
```

separate compilation

```
> g++ -c xs.cpp        # compiling into xs.o
> g++ -o xs xs.o       # linking into xs
```

libraries

```
> g++ -o xs xs.cpp -lm # link in math library
```

Next Time

- mBED

References

- A Quick Introduction to C++ by Tom Anderson
- Effective C++ by Scott Meyers
- Effective Modern C++ by Scott Meyers
- STM32L432 Data Sheet
- Nucleo32 L432
  `https://developer.mbed.org/platforms/ST-Nucleo-L432KC/`