Lambda Functions

Now, we'll study a special type of function: the lambda.

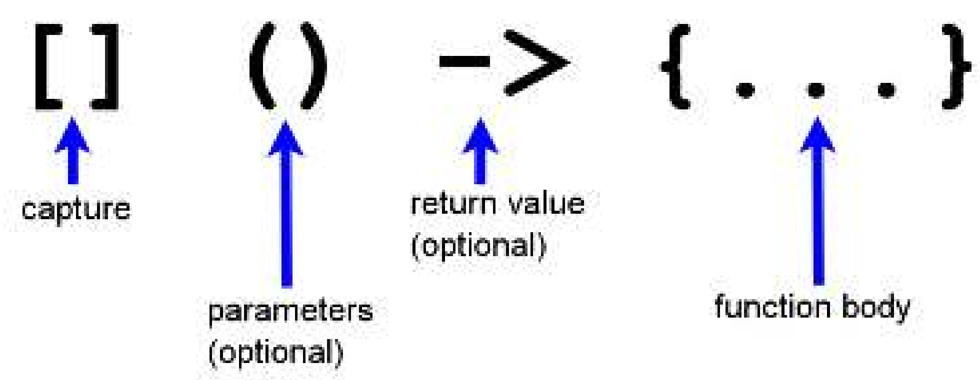
WE'LL COVER THE FOLLOWING

> A lambda function, or **lambda**, is a function without a name.

A lambda can be written in-place and doesn't require complete implementation outside the scope of the main program.

A cool feature of lambdas is that they can be treated as data. Hence, they can be stored or copied in variables.

Syntax



- `[]`: Captures the used variables.
- `()`: Necessary for parameters.

- `()`: Necessary for parameters.
- `->`: Necessary for complex lambda functions.
- `{}`: Function body, per default `const`.
    - `[]() mutable -> {...}` has a non-constant function body.

What exactly do we mean by *capture*?

Function vs. function object

The first thing we need to know is that lambdas are just function objects automatically created by the compiler.

A function object is an instance of a class for which the call operator, `operator()`, is overloaded. This means that a function object is an object that behaves like a function. The main difference between a function and a function object is that **a function object is an object and can, therefore, have a state**.

Here is a simple example.

```
int addFunc(int a, int b){ return a + b; }

int main(){

    struct AddObj{
        int operator()(int a, int b) const { return a + b; }
    };

    AddObj addObj;
    addObj(3, 4) == addFunc(3, 4);

}
```

Instances of the struct, `AddObj`, and the function, `addFunc`, are both callable. I just defined the struct `AddObj` in place. That is what the C++ compiler does implicitly if I use a lambda expression.

Have a look.

```
int addFunc(int a, int b){ return a + b; }

int main(){

    auto addObj = [](int a, int b){ return a + b; };
```

```
    addObj(3, 4) == addFunc(3, 4);


}
```

That's all! If the lambda expression captures its environment and therefore has a state, the corresponding struct, `AddObj`, gets a constructor for initializing its members. If the lambda expression captures its argument by reference, so does the constructor. The same holds for capturing by value.

Closure

Lambda functions can bind their invocation context. This is perhaps the best feature of C++ lambdas.

Binding allows any variables passed in the surrounding scope(invocation context) to be passed to the lambda. This is what the `[]` in the beginning is for. Within these square brackets, we can specify which variables we want the lambda to *capture*.

The empty brackets we've used so far indicate that no variables should be bound.

There are several types of bindings provided by C++ for lambda functions. Have a look:

Binding	Description
`[]`	no binding
`[a]`	`a` per copy
`[&a]`	`a` per reference
`[=]`	all used variables per copy
`[&]`	all used variables per reference
`[=,&a]`	per default per copy; `a` per reference
`[&,a]`	per default per reference; a per copy
`[this]`	data and member of the enclosing class per copy
`[l= std::move(lock)]`	moves `lock` (C++14)

Generic lambda functions

With C++14, we have generic lambdas, which means that lambdas can deduce their argument types. Therefore, we can define a lambda expression such as `[](auto a, auto b){ return a + b; };`. What does that mean for the call operator of `AddObj`?

The call operator becomes a template. I want to emphasize it explicitly: **a generic lambda is a function template**.

Here's an example:

```
#include <iostream>
#include <vector>
#include <numeric>
using namespace std::string_literals;

int main() {
  auto add11=[ ](int i, int i2){ return i + i2; };
  auto add14= [ ](auto i, auto i2){ return i + i2; };
  std::vector<int> myVec{1, 2, 3, 4, 5};
  auto res11= std::accumulate(myVec.begin(), myVec.end(), 0, add11);
  auto res14= std::accumulate(myVec.begin(), myVec.end(), 0, add14);

  std::cout << res11 << std::endl;
  std::cout << res14 << std::endl;

  std::vector<std::string> myVecStr{"Hello"s, " World"s};
  auto st= std::accumulate(myVecStr.begin(), myVecStr.end(), ""s, add14);
  std::cout << st << std::endl; // Hello World
}
```

Capturing local variables

The difference between the usage of functions and lambda functions boils down to two points:

1. We cannot overload lambdas.

2. A lambda function can capture local variables.

Here is a contrived example of the second point.

```
#include <functional>
```

```
std::function<int(int)> makeLambda(int a){
    return [a](int b){ return a + b; };
}

int main(){

    auto add5 = makeLambda(5);

    auto add10 = makeLambda(10);

    add5(10) == add10(5);

}
```

The function, `makeLambda`, returns a lambda expression. The lambda expression takes an `int` and returns an `int`. This is the type of the polymorph function wrapper, `std::function: std::function<int(int)>`, in line 3.

Invoking `makeLambda(5)` in line 9 creates a lambda expression that captures `a` which is, in this case, is `5`. The same argument holds for `makeLambda(10)` in line 11; therefore, `add5(10)` and `add10(5)` are both `15` in line 13.

Last, here are a couple of tips for how we should design lambdas:

- A lambda should be short and concise.
- A lambda should be self-explanatory, especially since it does not have a name.

We will see more examples of lambdas in the next lesson.