

C++ Function Pointers, Functors and Lambda Functions

CSCI 1061U — Programming Workshop 2

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Function Pointer

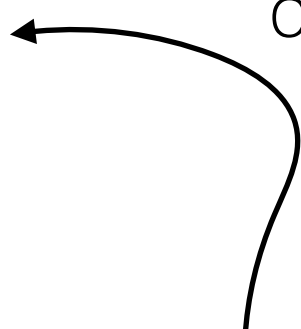
```
#include <iostream>
using std::cout;
using std::endl;
```

```
int square(int x)
{
    return x*x;
}
```

Function

arguments: int
return type: int

Can store any function
of this type

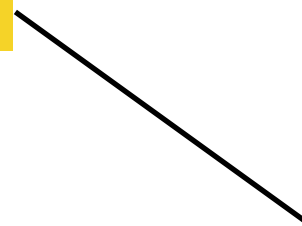



```
int main()
{
```

```
    int (*fnptr)(int); function pointer variable
```

```
    fnptr = square;
    cout << fnptr(2) << endl;
    return 0;
}
```

storing function address to a
function pointer variable, using &
is optional



Output 4

calling the function

Example

```
void swap(float* a, float* b)
{
    float tmp;
    tmp = *a;
    *a = *b;
    *b = tmp;
}
```

```
void (*m)(float* a, float* b);
m = swap;
```

Example

```
int neg(int x)
{
    return -1;
}
```

```
int (*k)(int x);
k = neg;
```

Example

```
bool gt(int a, int b)
{
    return a > b;
}
```

```
bool (*l)(int a, int b);
l = gt;
```

Example

```
double sum(double a[], int i, int j, int s)
{
    double sum=0.0;
    for int(k=i; k<=j; k+=s) {
        sum += a[k];
    }

    return sum;
}
```

```
double (*n)(double a[], int i, int j, int s);
n = sum;
```

Example

```
class Pt
{
    public:
    int x,y;
};
```

```
Pt* create_pt(int x, int y)
{
    Pt* p = new Pt;
    p->x = x;
    p->y = y;
    return p;
}
```

```
Pt* (*o)(int x, int y);
o = create_pt;
```

Passing Function Pointer as Argument

```
#include <iostream>
using std::cout;
using std::endl;
```

```
int square(int x)
{
    return x*x;
}
```

```
int neg(int x)
{
    return -x;
}
```

```
int do_some_process(int x, int (*process)(int))
{
    return process(x);
}
```

argument 1: int 'x'

argument 2: function pointer 'process'

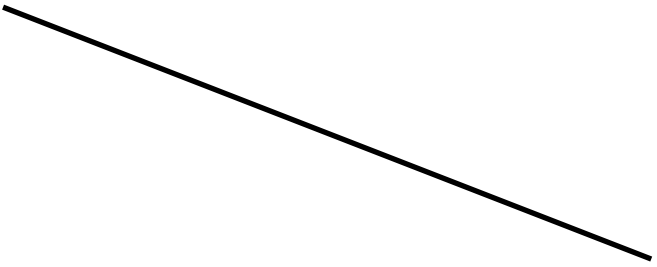
Using the passed function pointer to call the function

```
int main()
{
    cout << do_some_process(2, square) << endl;
    cout << do_some_process(2, neg) << endl;
    return 0;
}
```


Function Pointers Uses

- Callback functions
 - Set up listener or callback function that is called when an event occurs (e.g., GUI)

```
void glutMouseFunc(void (*func)(int button, int state, int x, int y));
```



Enables programmers to provide their own function that will be called whenever there is a mouse event.

Function Pointers

- It is also possible to avoid explicit function pointers by using virtual functions and polymorphism
- Virtual function, however, are implemented behind the scene using function pointers
- Function pointers are often used to pass around *processing instructions*

C++ Functors

- C++ provide function pointers or *functors*
- Functors are objects that can be used as if these are functions
- Functors are more powerful than good old function pointers, since functors can carry around state
- Functors are only available in C++

C++ Functors

```
#include <iostream>
using std::cout;
using std::endl;
```

```
class Square
```

```
{
```

```
    public:
```

```
    int operator()(int x) { return x*x; }
```

```
};
```

Overload **operator()**
to make a functor

```
int main()
```

```
{
```

```
    Square a;
```

```
    cout << a(3) << endl;
```

```
    return 0;
```

```
}
```

'a' behaves as if a
function

Using Functors for Callback

Use template to pass a functor

(remember it is just a class)

```
class Square functor
{
    public:
    int operator()(int x) { return x*x; }
};
```

```
class Neg functor
{
    public:
    int operator()(int x) { return -x; }
};
```

```
function
int mult_by_5(int x) { return x*5; }
```

```
template <typename T>
int do_some_process(int x, T process)
{
    return process(x);
}
```

```
int main()
{
    Square sq;
    Neg neg;

    cout << do_some_process(2, sq) << endl;
    cout << do_some_process(2, neg) << endl;

    cout << do_some_process(2, mult_by_5) << endl;

    return 0;
}
```

Using Functors for Callback

```
class Sum
{
public:
    int operator()(int x, int y)
    {
        return x + y;
    }
};
```

```
template <typename T>
int do_some_process(int x, T process)
{
    return process(x);
}

int main()
{
    Sum sum;

    cout << do_some_process(2, sum) << endl;

    return 0;
}
```

Do not match

Will this work? **No**

Function Pointers vs. Functors

```
class Pt
{
public:
    Pt(int x, int y) : _x(x), _y(y) {}

    int _x, _y;
};
```

But what if we want to add
'v' to 'pt._y'?

```
void do_some_process(Pt& pt, int v, Pt& (*process)(Pt&, int))
{
    process(pt, v);
}
```

Example

```
Pt& add(Pt& pt, int v)
{
    pt._x += v;
    return pt;
}
```

Create another function

```
Pt& add2(Pt& pt, int v)
{
    pt._y += v;
    return pt;
}
```

Function Pointers vs. Functors

```
class Pt
{
    public:
        Pt(int x, int y) : _x(x), _y(y) {}

        int _x, _y;
};

template <typename T>
void do_some_process2(Pt& pt, int v, T process)
{
    process(pt, v);
}
```

```
class AddFunctor
{
    public:
        AddFunctor(char c) : _c(c) {}
        Pt& operator()(Pt& pt, int v) {
            if (_c == 'x') pt._x += v;
            else pt._y += v; return pt;
        }
    private:
        char _c;
};
```

Uses state stored in the functor to perform them the desired processing.

Unlike function pointers where we needed to create a new function.

```
AddFunctor addx('x');
do_some_process2(pt, 10, addx);
```

```
AddFunctor addy('y');
do_some_process2(pt, 10, addy);
```


Lambda Functions (C++11)

```
#include <iostream>
```

```
using std::cout;
```

```
using std::endl;
```

```
int main()
```

```
{
```

```
    auto func = [ ] ( ) { cout << "Hello world." << endl; };  
    func( );
```

```
    return 0;
```

```
}
```

argument list

function body

capture specification indicating
the compiler that we are creating
a lambda function

Use the following command to compile

```
g++ -std=c++11 lambda.cpp
```

Lambda Functions Syntax

argument list function body invocation

```
[ ] ( ) { cout << "Hello world" << endl; } ( );
```

```
[ ] { cout << "Hello world" << endl; } ( );
```

argument list missing
ok if no arguments

```
cout << [ ] ( ) { return 42; } ( ) << endl;
```

return type is missing
ok if compiler can discern it

```
cout << [ ] ( ) -> int { return 42; } ( ) << endl;
```

return type

Lambda Function and Function Pointers

```
#include <iostream>
using std::cout;
using std::endl;

int do_some_process(int x, int (*process)(int))
{
    return process(x);
}

int main()
{
    cout << do_some_process(2, [](int x)->int{ return x*x; } ) << endl;

    return 0;
}
```

Variable Capture with Lambda Functions

```
#include <iostream>
#include <string>
using std::cout;
using std::endl;
using std::string;
```

```
int main()
{
    string name( "Jane" );

    [&]() { cout << name << endl; }();

    return 0;
}
```

How did this get here?
It was never passed as an argument.

[&] tells the compiler to perform variable capture

Variable Capture with Lambda Function

[] Capture nothing

[&] Capture any variable reference in the lambda function *by reference*

[=] Capture any variable reference in the lambda function *by value* (i.e., making a copy)

[=,&foo] Capture any variable reference in the lambda function *by value* (i.e., making a copy); capture variable foo by reference

[this] Capture the 'this' pointer of the enclosing class. This means that all members of the enclosing class are available within the lambda function

[foo] Capture variable foo by making a copy; do not capture anything else

Lambda Function Capture By Reference

- Lambda function can modify the values of the captured variable
- Beware of returning the lambda function from a function, since the captured variable might become invalid

Lambda Functions and STL

```
#include <iostream>
#include <vector>
using std::cout;
using std::endl;

int main()
{
    std::vector<int> v;

    for (int i=0; i<10; ++i) v.push_back(i*2);

    std::for_each(v.begin(), v.end(), [](int val){ cout << val << endl; });

    return 0;
}
```

Exercise

Implementing a general purpose find_smallest() method


```
bool smaller(int i, int j)
{
    return i < j;
}
```

Use this to specify different criteria!?

```
int find_smallest(int a[], int n)
{
    int smallest = a[0];
    for (int i=1; i<n; ++i) {
        if (smaller(a[i], smallest)) smallest = a[i];
    }
    return smallest;
}
```

Need to change the function signature

The logic is correct. No need to change that.

```
int main()
{
    srand(0);
    int a[6];
    for (int i=0; i<6; ++i) a[i] = rand();

    for (int i=0; i<6; ++i) cout << a[i] << endl;

    int smallest = find_smallest(a, 6);
    cout << "smallest = " << smallest << endl;

    return 0;
}
```

Exercise

Implementing a general purpose find_smallest() method

Available on the course web

Due in class

Submit via Blackboard