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Department of Electrical & Computer Engineering

ECE 150 *Fundamentals of Programming*

Reference variables, pass-by-reference and return-by-reference

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Reference variables, pass-by-reference and return-by-reference

Outline

- In this lesson, we will:
 - Learn about reference variables
 - Aliases to other assignable items (*lvalues*)
 - See how to use this for *pass-by-reference*
 - Changing arguments—not parameters—inside of functions
 - Useful for updating arguments that hold values
 - We will also see *return-by-reference*






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Reference variables, pass-by-reference and return-by-reference

Definition

- An *alias* is another name for a person or something
 - Sometimes written *a.k.a.* for also-known-as
 - Mark Twain is an alias for Samuel Langhorne Clemens
 - Charles Lutwidge Dodgson, a.k.a. Lewis Carroll, was a mathematician
- An alias in a programming language is one identifier that is another name for a different identifier

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Reference variables, pass-by-reference and return-by-reference

Reference local variables

- Aliases in C++ are through *references variables*

```
typename &new_identifier{ existing_identifier };
```

 - Reference variables must be initialized
 - Whatever they are initialized to must be *assignable*
 - It must be able to be the left-hand side of an assignment operator
 - Anything that can be assigned to is also called an *lvalue*
- Whenever the reference variable is read, what *lvalue* it was initialized with is read
- Whenever the reference variable is assigned to, whatever *lvalue* it was initialized with is assigned to
- An alias does not create a new local variable, parameter, etc.
 - It simply gives another name for an existing identifier

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Reference local variables

- For example:

```
#include <iostream>
int main();

int main() {
    int m{42};
    int &n{m};
    // Now, 'n' is an alias for 'm'
    std::cout << "m = " << m << ", \tn = " << n << std::endl;
    m = 91;
    std::cout << "m = " << m << ", \tn = " << n << std::endl;
    n = 360;
    std::cout << "m = " << m << ", \tn = " << n << std::endl;

    return 0;
}
```

Output:

m = 42,	n = 42
m = 91,	n = 91
m = 360,	n = 360



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Reference local variables

- You could use this to simplify the appearance of your code

```
#include <iostream>
#include <cmath>

int main();

int main() {
    double const &pi{ M_PI };
    // From here on in, you can just use 'pi' instead of 'M_PI'

    return 0;
}
```

This does not introduce a new local variable



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Pass-by-value

- Notice that whenever we called a function, the value of the argument was assigned to the parameter
- This leaves the argument unchanged

```
// Function definitions
void f( int k ) {
    k++;
    std::cout << k << std::endl;
}

int main() {
    int n{42};
    f( 42 );
    f( n );
    f( n + 107 );
    std::cout << "n = " << n << std::endl;

    return 0;
}
```

Output:

```
43
43
150
n = 42
```



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Pass-by-reference

- If a parameter is prefixed by an &, the parameter is now an alias for the argument
- Now arguments are restricted to what can be assigned to
 - That is, lvalues
- Any change to the parameter changes the value of the argument



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Pass-by-reference

- Example:


```
void reset( int &n );

void reset( int &n ) {
    n = 0;
}
```
- Any argument is passed by reference
 - A change to the parameter n also changes the argument

```
int main() {
    int k{42};
    reset( k );
    std::cout << k << std::endl;
    return 0;
}
```

Output:
0



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Pass-by-reference

- Only those items that can appear on the left-hand side of assignment statements can be passed by reference:

```
int main() {
    int k{42};
    reset( k + 1 );
    std::cout << k << std::endl;
    return 0;
}
```

example.cpp: In function 'int main()':
example.cpp:12:11: error: invalid initialization of non-const reference of type 'int&' from an rvalue of type 'int'
reset(k + 1);
 ^

example.cpp:6:6: error: in passing argument 1 of 'void reset(int&)'
void reset(int &n) {
 ^



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Pass-by-reference

- When you perform a `std::cin` statement, the second operand is passed by reference


```
int main() {
    int k;
    std::cout << "Enter an integer: " << std::endl;
    std::cin >> k;
    std::cout << k << "*" << k << " = " << (k*k)
              << std::endl;
    return 0;
}
```



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Application: multiple return values

- Suppose you need both the minimum and maximum of three values:

```
void min_max( int a, int b, int c, int &min, int &max ) {
    if ( a < b ) {
        min = a;
        max = b;
    } else {
        min = b;
        max = a;
    }

    if ( c < min ) {
        min = c;
    } else if ( c > max ) {
        max = c;
    }
}
```



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Counting time

- Suppose we want to track and print time:
 - You'd need three local variables storing
 - Hours
 - Minutes
 - Seconds
 - Each time a second reaches 60, it must reset to 0 and increment the minutes
 - Each time the minutes reaches 60, it must reset to 0 and increment the hours
 - Each time the hours reaches 13, it must reset to 1, but we increment the periods when we reach 12
 - Two periods makes one day

```

10:57:43
10:57:44
10:57:45
10:57:46
10:57:47
10:57:48
10:57:49
10:57:50
10:57:51
10:57:52
10:57:53
10:57:54
10:57:55
10:57:56
10:57:57
10:57:58
10:57:59
10:58:00
:
1:44:18
1:44:19
1:44:20
1:44:21
1:44:22

```

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Counting time

```

int main() {
    int hour{10};
    int minute{57};
    int second{42};

    for ( int k{0}; hour < 10000; ++k ) {
        ++second;

        if ( second == 60 ) {
            second = 0;
            ++minute;

            if ( minute == 60 ) {
                minute = 0;
                ++hour;

                if ( hour == 13 ) {
                    hour = 1;
                }
            }
        }
    }
}

```

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Counting time

```

if ( hour < 10 ) {
    std::cout << " ";
}

std::cout << hour << ":";

if ( minute < 10 ) {
    std::cout << "0";
}

std::cout << minute << ":";

if ( second < 10 ) {
    std::cout << "0";
}

std::cout << second << std::endl;

}

return 0;
}

```

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Counting time

- Suppose you want to increment a variable that stores minutes or seconds:


```

bool increment_minute_second( int &min_sec ) {
    if ( min_sec == 59 ) {
        min_sec = 0;
        return true;
    } else {
        ++min_sec;
        return false;
    }
}

```

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Counting time

- Suppose you want to increment a variable that stores hours:

```
bool increment_hour( int &hour ) {
    if ( hour == 12 ) {
        hour = 1;
        return false;
    } else {
        ++hour;
        // Return 'true' if we reach 12 o'clock
        return (hour == 12);
    }
}
```



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Counting time

- While we're at it, let's print time nicely

```
– Hours may be prefixed by a space or "
– Minutes and seconds may be prefixed by a "0"
std::string to_string( std::string prefix, int time ) {
    if ( time < 10 ) {
        return prefix + std::to_string( time );
    } else {
        return std::to_string( time );
    }
}
```

These convert an int into a std::string.
Adding two std::string concatenates them.

3:30:00
4:01:57
12:00:00



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Counting time

- We can now use this to count time:

```
int main() {
    // Count hours, minutes and seconds starting at 10:57:42
    // breaking at 1:00

    int hour{10};
    int minute{57};
    int second{42};
```



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Counting time

```
for ( int k{0}; k < 10000; ++k ) {
    bool minute_passed( increment_minute_second( second ) );

    if ( minute_passed ) {
        bool hour_passed( increment_minute_second( minute ) );

        if ( hour_passed ) {
            increment_hour( hour );
        }
    }

    std::cout << to_string( " ", hour ) << ":"
              << to_string( "0", minute ) << ":"
              << to_string( "0", second ) << std::endl;
}

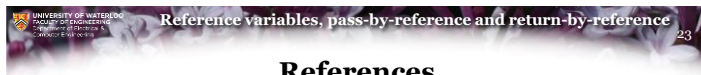
return 0;
}
```





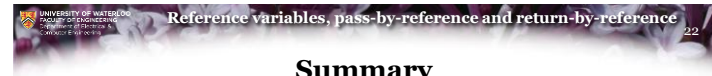
In this course...

- In this course, we will only use pass-by-reference
 - We generally will not use reference variables
 - It is possible to return-by-reference, but that is for another course



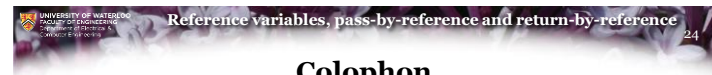
References

- [1] No references?



Summary

- Following this lesson, you now
 - Know how to create an *alias* or *reference* to another assignable variable
 - Understand that a parameter can be an alias to the argument
 - This is known as *pass-by-reference*
 - Are aware of numerous applications of pass-by-reference
 - Returning more information than one return value allows
 - Know that there is also a *return-by-reference*



Colophon

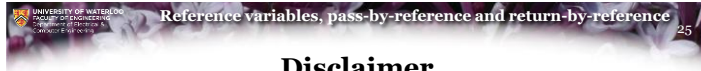
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