Programming Languages

Lecture 3

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1. Programming Languages
2. Building an Executable Program
3. Example
4. Program Organization
5. Examples

Outline

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High-Level Languages

C++ Code

```
cin >> cost;
if (cost > 100.0)
{
    discount = 0.10 * cost;
    price = cost - discount;
}
else
    price = cost;
cout << price;
```

- Instructions use some English words (if, else, while, etc.)
- Expressions are written in something resembling standard algebraic notation.

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Program Translation

- A computer is capable of interpreting and executing only machine language (numerical) instructions.
- Humans (almost always) write programs in high-level languages such as C++.
- Therefore, a C++ program must be *translated* into machine language in order to be run.
- The translation process is referred to as compiling.

Compilers

- A compiler is a program that translates (compiles) a high-level language such as C++ into machine language.
- The compiler must first check the syntax of the source code.
- A syntax error is a violation of the grammar rules of the language.
- If there are syntax errors, then error messages are displayed and the process stops.

Assemblers

- Most compilers produce assembly code as an intermediate step.
- Assembly code is an intermediate-level language that is still somewhat readable, but also very close to machine language.
- An assembler translates the assembly code into machine language.
- If there are no syntax errors, then the assembler produces the object code (machine language, mostly).

Linkers

- A linker combines the object code produced by the compiler with library functions (e.g., the square root function) needed by the program.
- If the linker is unable to locate a function, it reports a link error and the process stops.
- If there are no link errors, the linker produces a fully functioning program.

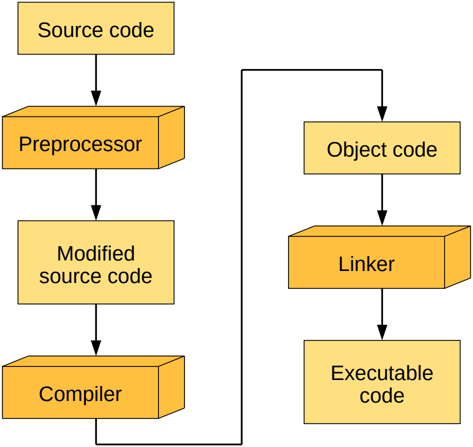
Loaders

- The loader copies the program into a suitable location in main memory and begins execution.
- A run-time (or logical) error is an error that occurs during execution.
- Typically, run-time errors cannot be detected by the compiler or the linker before execution.
- Division by zero would be a run-time error.

Division by Zero

```
a = 0;
b = 2/a;
```

Program Translation



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High-Level Languages

C++ Code

```
int c = 3*(10 + 20);
```

- C++ code to add 10 and 20 and multiply by 3.

Assembly Language

Assembly Code

```
li   $4,10
addi $5,$4,20
li   $4,3
mult $5,$4
mflo $5
```

- Each instruction represents a single basic operation at the machine level (add, multiply, assign, etc.)
- Mnemonics are used instead of words.

Machine Language

Machine Code

Hex	Binary	Assembly
2404000A	00100100000001000000000000001010	li $4,10
20850014	00100000100001010000000000010100	addi $5,$4,20
24040003	00100100000001000000000000000011	li $4,3
00A40018	00000000101001000000000000011000	mult $5,$4
00002812	00000000000000000010100000010010	mflo $5

- Each instruction represents a single basic operation.
- Each instruction is written entirely numerically.

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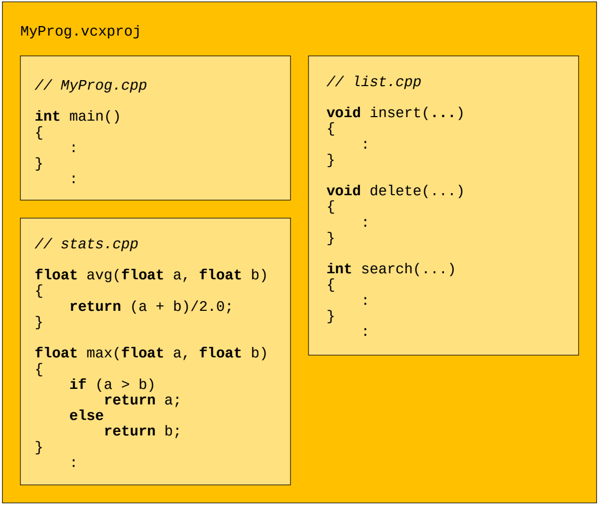
The C++ Program Hierarchy

- A token is the smallest meaningful unit.
  - Number (`123`), variable (`cost`), operator (`+`), etc.
- A statement is a group of tokens that express a simple task.
  - `price = cost - discount;`
- A function is a group of statements that accomplish a task requiring several steps.
  - For example, insert a new name into a list of names.
- A file contains a collection of related functions.
  - For example, all functions that manage lists of names.
- A program consists of a collection of related files.

The C++ Program Hierarchy



MyProg.vcxproj

```
// MyProg.cpp

int main()
{
    :
}
    :
```

```
// stats.cpp

float avg(float a, float b)
{
    return (a + b)/2.0;
}

float max(float a, float b)
{
    if (a > b)
        return a;
    else
        return b;
}
    :
```

```
// list.cpp

void insert(...)
{
    :
}

void delete(...)
{
    :
}

int search(...)
{
    :
}
    :
```

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Examples of C++ Programs

- Example
  - `GradeReport.cpp`
  - `GradeStats.cpp`