CPSC 323
Compilers and Languages

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What we will learn

- Understanding basic concepts of languages
  - High-level programming languages, Assembly languages, Machine Languages

- Understanding compilers as the means to implement programming languages
  - Compilation vs. Interpretation
  - Phases of a compiler
  - Fundamental theories and algorithms in each phase
  - Lexical Analyzer
  - Syntactic Analyzer
  - Intermediate Code Generation (Semantic Analysis)
  - Simple code optimization
  - Code generation
  - Practice implementing some phases (tentative)
    - Scanners and parsers

Languages

❑ Natural languages

- Tools for expressing information
  - ideas, knowledge, commands, questions, …
  - Facilitate communication between people
- Different natural languages
  - English, Spanish, Chinese, French, German, …

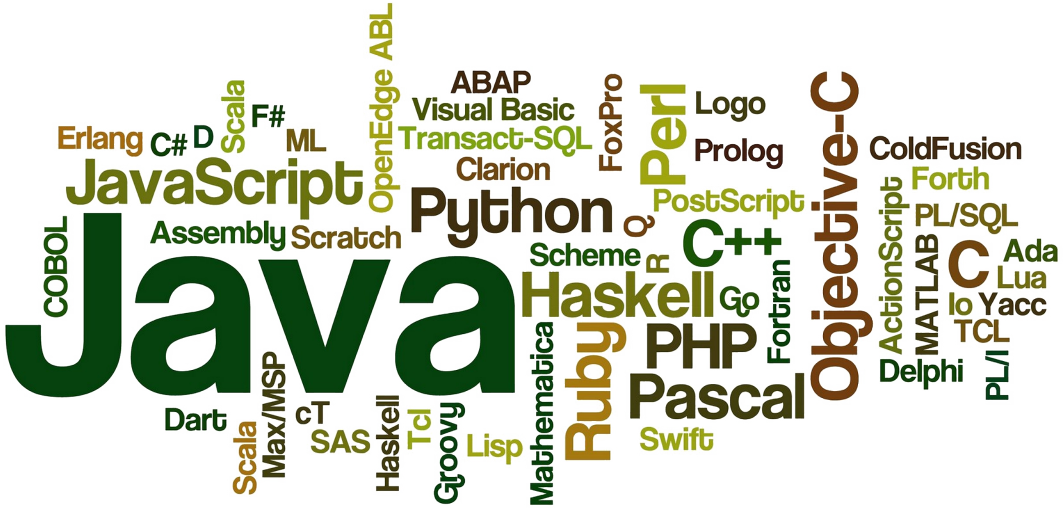
❑ Formal languages

- Tools for use in specific situations, such as math or computer programming
- They often use symbols, numbers, and characters that natural languages do not.
- in computer science, formal languages are used among others as the basis for defining the grammar of programming languages

❑ Programming languages

- Tools for expressing data and algorithms
  - Instructing machines what to do
  - Facilitate communication between programmers and computers
- Different levels of programming languages
  - High-level, low-level

Levels of Programming Languages



High-level (HL) language:

Low-level (LL) language :

High Level Languages

- A user-friendly programming context and is generally independent of the computer's hardware architecture.
- Does not require addressing hardware constraints.
- Every single program written in a high-level language must be interpreted into machine language before being executed by the computer.
- BASIC, C/C++ and Java are popular examples of high-level languages.

Low level Languages

Assembly language (ASM)

- A type of low-level programming language that is intended to communicate directly with a computer’s hardware
- A single line of assembly-language code normally corresponds to a single machine-language instruction (1:1)
- It is useful when you need to control your grogram closely, down to the byte and even the bit level.

Machine language

- the native language of the computer consisting of binary or hexadecimal instructions which a computer can respond to directly.
- This is literally the only language the computer can properly be said to “understand”
- Ex: A typical machine-language instruction in the IBM 370 family of computers looks like: 0001100000110101 or 1835 (written in hexadecimal), it causes the computer to copy the contents of general register 5 into general register 3

Advantages and Disadvantages of HLL

Advantages

- Expressions
- Control structures/abstractions
- Data types
- Encapsulation
- Strongly-typed language: everything must be declared by the programmer before use

Disadvantages

- Execution is slow
- Occupies more memory
- Hardware control is less
- Not Time-efficient

Advantages and Disadvantages of LLL

Advantages

- Fast and memory efficient
- Utilize processor and memory in better way
- Time efficient
- Direct manipulation of computer registers and storage
- Directly communicate with hardware devices

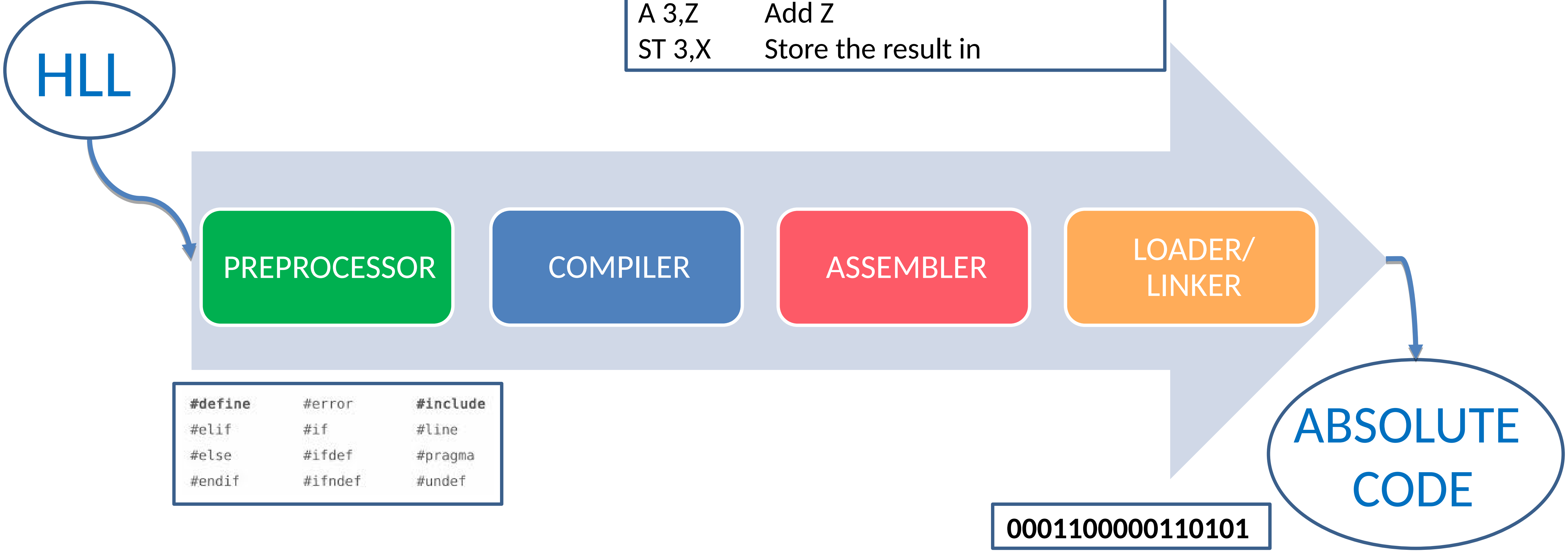
Disadvantages

- Difficult to develop, debug and maintain
- Machine dependent and are not portable.
- Error prone.
- Poor programming productivity
- Must have additional knowledge of the computer architecture of particular machine.

Levels of Programming languages

```
x := a + b * c ;
```

```
L 3,Y       Load the working register with Y
A 3,Z       Add Z
ST 3,X      Store the result in
```



```
#define     #error      #include
#elif       #if         #line
#else       #ifdef      #pragma
#endif      #ifndef     #undef
```

```
0001100000110101
```

Economy of Programming Languages

Three obvious questions:

- Why are there so many programming languages?
- Why are there new programming languages?
- What is a good programming languages?

Economy of Programming Languages

Three obvious questions:

- Why are there so many programming languages?
  - Application domains have distinctive/conflicting needs.
  - It is hard to design one system for all.
    - Ex., scientific computing (good float points, good arrays, parallelism, etc.) – Fortran
    - Ex., business computing (persistence, good report facilities, data analysis, etc.) – SQL
    - Ex., system programming (control of resources, real time constraints, etc.) – C/C++

Economy of Programming Languages

Three obvious questions:

- Why are there new programming languages?
  - Old languages are not easy to change, it is much easier to design new languages for new opportunities
- What is a good programming languages?
  - There is no universally accepted metric for language design

Basic Terminology

- *Compiler*: is a software (program) that translates a program written in a source language (source code) into the code in the object language of a target machine (object code).
- *Source Language*: Programming language that the compiler accepts as an input (e.g., Pascal, C, C++, Fortran)
- *Object Language*: A particular machine (or assembly) language that is used to generate as the output of a compiler (Object Code).
- *Object file*: an external file storing object code (E.g., Myprog.obj)
- Target Machine: the computer on which the object code is to be run

Why should we study compiler?

Compilers are everywhere!

Many applications of compiler technology

- Parsers for HTML in web browser
- Interpreters for JavaScript/Flash
- Machine code generation for high-level programming languages
- Design of new computer architectures
- Hardware synthesis: VHDL to RTL translation
- Software productivity tools

History of compiler

- A-0 System
  - First implemented compiler was written by Grace Hopper (1951)
  - Which functioned as Linker/Loader

- Fortran I (Formula Translator)
  - Was the 1st successful HL programming language
  - The first commercially available compiler (by John Backus at IBM, 1950s)
  - Huge impact on computer science

- Modern compilers preserve the outline of Fortran I

Structure of Compiler

1. Lexical Analysis
2. Syntax Analysis (Parsing)
3. Semantic Analysis (Intermediate Code Generation)
4. Code Optimization
5. Target Code Generation