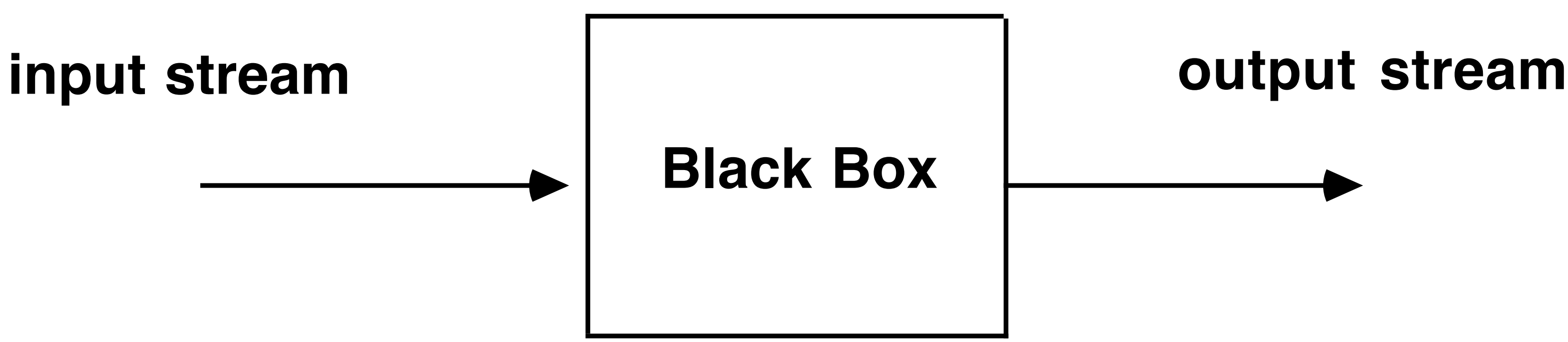
Terminology & Basic Concepts

Language Processors

- The basic model of a language processor is the black box translator (or transducer)
- Has one input stream, one output stream, and a black box (program) that translates between the two



Language Processors

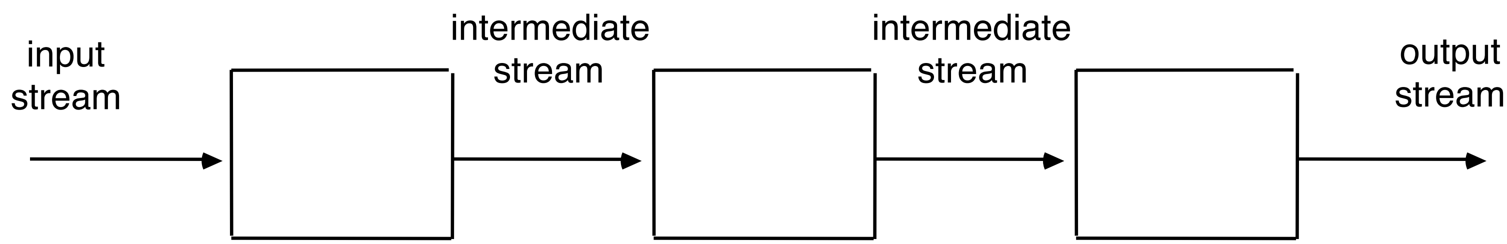
Kinds of Black Box Translators

- Although all are similar in many ways, we call language processors different things depending on their input and output streams
- A translator takes as input a program written in one programming language (the source language) and outputs another version of the program written in a different language (the object or target language)
- A compiler is a translator that takes as input a high level programming language (such as C, Java or Pascal) and outputs machine or assembly language for a target computer
- An assembler is a translator that takes as input assembly language and outputs machine language for a target computer
- A transliterator or preprocessor is a translator that translates one high level language to another high level language

Language Processors

Intermediate Languages

- Often compilers, assemblers and other language processors are implemented in multiple stages, using a separate translator for each stage

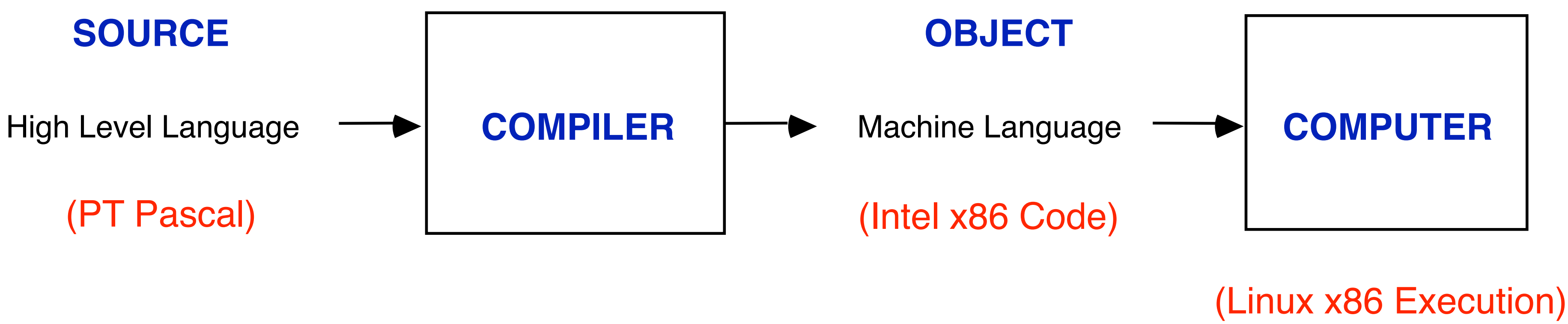


- In this case there may be an intermediate form of the program between stages
- An intermediate language is a language used internally in a compiler to represent the program between stages
- An intermediate code is an intermediate language that is the machine language of an imaginary ideal ("virtual") machine (e.g., Pascal P-code, Java JVM byte code)
- An interpreter is a program that directly executes intermediate code by simulating the hardware of the virtual machine

Compilers

What is a Compiler?

- We will concentrate in this course on compilers, since all stages except the last are very similar for all high level language processors (interpreters, transliterators, HTML processors, etc.)
- A compiler is a program that translates a high level language (Pascal, C++, Turing, Java, C# etc.) to the machine or assembly language of a target computer



History of Compilers

First Computers (early 1940's)

- Programmed by hand in machine language using binary codes input using switches

Assemblers (late 1940's)

- Replaced binary codes with mnemonic operation names (e.g., "ADD") and binary memory addresses with location (variable) names (e.g., "A", "B", etc.)

```
ADD  A,R2    →   011110
                 010010
```

History of Compilers

Early High Level Languages (1950's)

- First high level language compilers (TRANSCODE, FORTRAN) simply handled translation of simple algebraic statements to machine or assembly code

```
X=A*B+C    →    MOV   A,R2
                MUL   B,R2
                MOV   C,R3
                ADD   R2,R3
                MOV   R3,X
```

- Compilers were among the most complex programs of the time - large, challenging and difficult to build
- Since then, advances in both theory (formal languages and automata) and practice (modularity and table-driven methods) have combined to make compilers among the best understood and most elegantly engineered software systems

Goals for a Compiler

The Compiler Itself

- Compilers should be small (use reasonable amounts of memory) and fast (use reasonable amounts of CPU and real time)
  - Classical time / space tradeoff - can make compiler smaller in memory by storing data structures on disk, but that will make it much slower due to increased disk access
- Compilers must be reliable - should handle every input program, every time
- Compilers must be diagnostic - should give informative error messages about exactly what is wrong and where
- Compilers should have a good human interface - it should be easy and obvious to use and control, whether on the command line or in an IDE

Goals for a Compiler

Generated Code

- Generated code should also be small and fast
  - But again, we are faced with a tradeoff - for example unrolled loops are faster, but bigger
- There is also a tradeoff between the speed of the compiler and the speed of the generated code
  - If the compiler spends a lot more time on optimization, it can make much faster generated code
- Generated code should be reliable - it should always work
- Generated code should be secure - it should not allow accidental violation of language constraints (e.g., subscripts out of bounds)
- Generated code should be diagnostic - run time failures should be caught and reported in terms of the original source program
- Generated code should be faithful - the code should do what the user wrote, not something else

Goals for a Compiler

Implementation and Maintenance

- Like any software system, a compiler should be implemented in reasonable time and at reasonable cost
- It is particularly important that compilers be easy to maintain - compilers are critical components in computer use and must be fixed quickly
- Compilers be easy to modify - languages evolve and target machines change over time

Goals for a Compiler

Error Handling

- A compiler should reliably both detect and diagnose language violations in the programs it compiles - it must check every language rule, and should give good advice on what exactly the problem is in each case
- A compiler must recover from detection of errors - that is, it should continue processing the rest of the program to look for other errors if at all possible
- Compilers should correct (but not ignore) simple errors when possible - for example, but supplying missing semicolons when flagging the error

Summary

Language Processors

- Basic model input-translator-output
- Assemblers, compilers, transliterators
- Phased translation, intermediate languages, interpreters
- Goals for a compiler

References

- Text, chapter 1

Next

- Basic structure of modern compilers and interpreters, and the role of their phases