Fundamental Concepts of Programming Languages

Implementation of PLs
Lecture 04

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1. The implementation of PLs
2. Interpretation
3. Translation
4. Comparisons
5. The compiling process
6. Compiler structure
7. Analysis and synthesis
8. Compiling the assignment instruction

Implementation of PLs

- All computers execute low level programs written in machine language
- In order to execute high level languages two methods are used:
  - interpretation
  - translation

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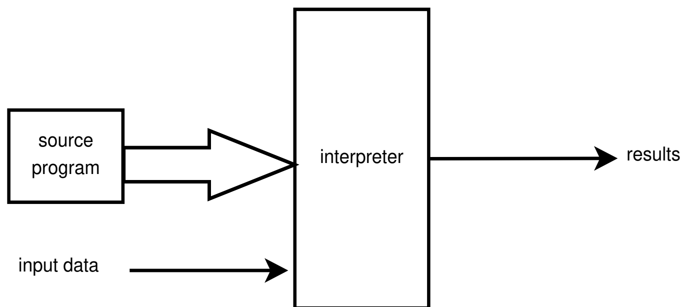
Interpretation

- Means executing directly the high level instructions
- Each high level instruction consists in a sequence of machine instructions
- Program execution is done by an interpreter
  - Reads the high level instructions
  - Decodes them
  - Executes the machine instructions sequence

Interpreter working cycle

- Read next instruction
- Decode instruction
- Execute corresponding machine instructions



Interpretation

- follows the von Neumann normal cycle
- is a simulation on a regular computer of a high level language computer

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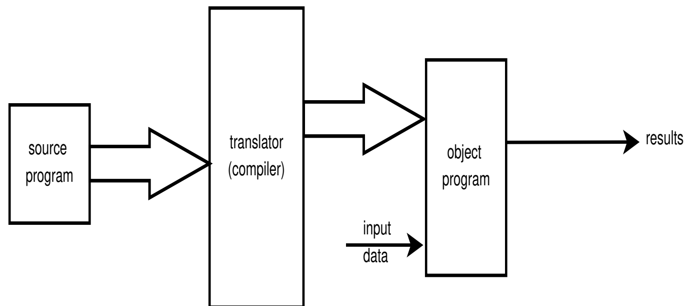
Translation

- Before execution the program is translated from high level language in machine code
- The process is highly complex
- Done in several steps
- Done by several specialized software
  - Preprocessors
  - Compilers
  - Assemblers
  - Link editors
- The result is the object program, machine code to be executed

Implementation by translation



- Compiler - compilation

Translation with interpretation

- Translation into object program
  - not machine code
  - but intermediary code (abstract machine)
- Interpretation of the intermediary code
- present in Java and C#

The Java approach

- Source program compiles into bytecode
- Bytecode instruction sequence for the Java virtual machine (JVM)
- Bytecode can be transferred to any machine having an interpreter
- Advantages
  - High Portability
  - Platform independence
- Drawback
  - Increased interpretation time
- Compromise solution
  - JIT compiler (just in time) - bytecode to machine code

The C# approach

- Compilation result is a pseudocode called MicroSoft intermediate language (MSIL)
- MSIL
  - is a portable assembly language
  - Needs the Common Language Runtime (CLR) to be converted in machine code
  - CLR activates a JIT compiler to convert MSIL code into machine code as needed
- fast
- portable

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Time comparison

- Compiled programs are faster then interpreted programs
- Instruction interpreting implies instruction translation
- Object program
    - Compiled once
    - Run several times without translation
- Interpretation time becomes critical when the application is run several times

Space comparison

- Interpreting takes less memory space
- Compilation involves replacing each high level instruction with the sequence of machine instructions

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The compiling process

- Basic compiler functionalities
  - Source program analysis
  - Destination program synthesis
- The compiler parts
  - Analysis part
    - breaks the program into basic components
    - Creates an intermediate representation
  - Synthesis part
    - Builds the destination program from the intermediate representation

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Compiler structure

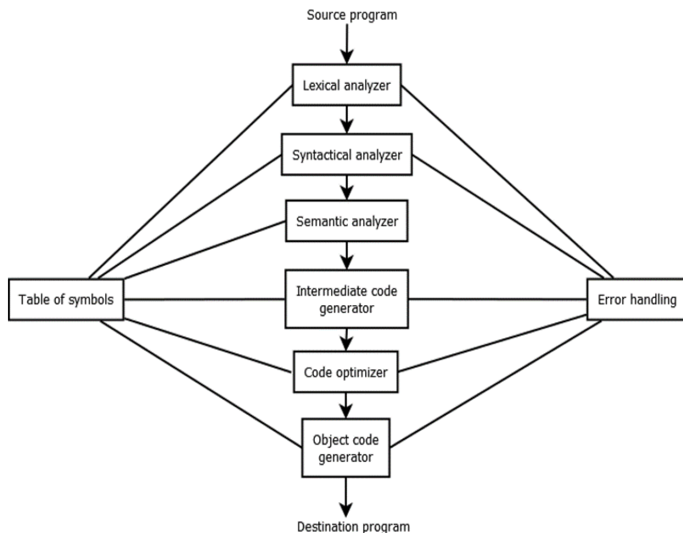

Table of symbols

- Basic compiler tasks
  - to manage identifiers
  - to gather information about their attributes
    - Constants
    - Variables (domain, type)
    - Functions (number, type, order, transmission type for parameters)
- Is a data structure with a record for each identifier
- Must allow fast search of identifiers
- Adding a record in lexical or syntactical analysis
- Auxiliary information are added during the analysis process
- Information is used
  - To check semantic actions
  - To generate the correct object code

Error handling

- Errors can be discovered in the first phase of the compilation
- Different reactions
  - To stop at first error, to correct it and to recompile from the start
  - To handle the errors such as to continue compilation, to detect also other errors and to correct them globally
    - Returning from error
- Most errors are detected in syntactical and semantic analysis phases

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Analysis phases

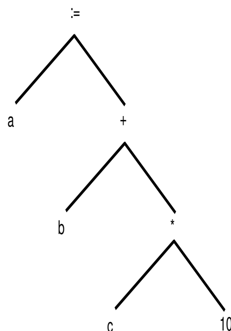
- Lexical or linear analysis
- Syntactical or hierarchy analysis
- Semantic or contextual analysis

Lexical or linear analysis

- The program source
  - is a string of characters
  - is read from left to right
  - is grouped in lexical symbols sequences of characters with specific semantic
- Example a:=b+c*10
  - Identifiers: a, b, c
  - Operators: :=, +, *
  - Integers: 10
- White spaces are ignored

Syntactical or hierarchy analysis

- Symbols are grouped in greater collections
  - Expressions, declarations, instructions
- Syntactic tree
  - Each node represents an operation
  - The sons represent the arguments



Syntactical or hierarchy analysis

- The hierarchical structure is expressed by recursive rules
  - Recursive rules for defining
    - expressions
    - instructions
- Splitting lexical and syntactical analysis is arbitrary
  - To simplify the overall task
  - Numbers, strings, identifiers, punctuation are lexical symbols
  - Expressions, instructions, declarations are syntactical constructions

Semantic or contextual analysis

- Verifications that relate to the meaning of the program
- Source program contextual restrictions
- Gathers type information for the code generation
- Identifies operators, operand and instructions using the hierarchical structure
- Type checking verifies whether each operator has the right operands
  - E.g. a real number can not be used to index a table
- Domain analysis verifies that each identifier is used in its own visibility domain

Synthesis phases

- Intermediate code generation
- Code optimization
- Object code generation

Intermediate code generation

- Intermediate representation of the source text is done after lexical and syntactic analysis
- Can be seen as a program for an abstract computer
- There are several forms of intermediate representations
- 3 address code
  - looks like an assembly language for a computer
  - Each memory location plays the role of a register

The 3 address code

- Sequence of instructions
- At most 3 operands
- Each instruction has at most one operator together with the assignment
- The compiler needs to decide on the order of the operators priority)
- In order to keep computed values in each instruction the compiler must generate temporary variables
  - With no relation with the source text
- There can be instructions with less than 3 operands

Code optimization

- The purpose is to optimize the intermediate code to make fast machine code
- To eliminate
  - Redundancies
  - Useless calculation, variables
- Compilers with optimizations
  - The amount of time consumed for optimization is large
- Simple optimizations
  - Good code efficiency
  - Do not slow down too much compilation

Object code generation

- Is the final phase of the compiler
- Generated object code can be
  - Locatable machine code
  - Virtual code
- To translate intermediate code into machine code
- To select and allocate memory cells for the program variables
- To choose and implement the best variable access techniques using the hardware addressing facilities: indexing, indirection etc
- To allocate registers for computation and for temporary storage of the intermediate results

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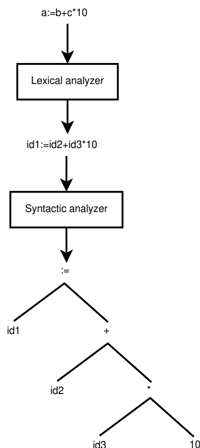
Compiling an assignment instruction

a:=b+c*10

a, b, c - real type variables



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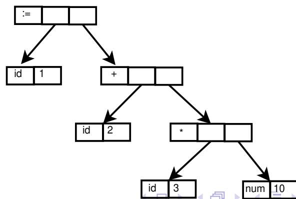
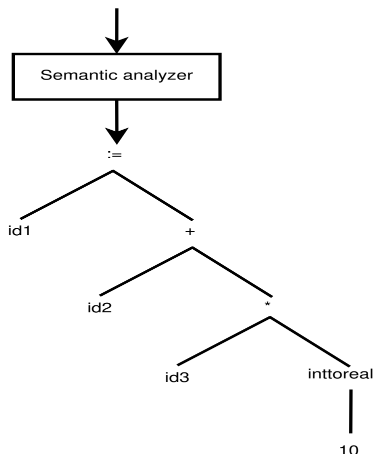
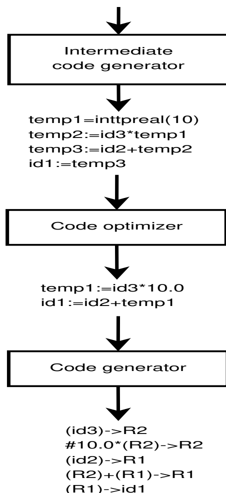
1	a	....
2	b	....
3	c	....
4		....



Compiling an assignment instruction



Compiling an assignment instruction



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