The Design of A Pascal Compiler

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Introduction

- The Compiler is for the programming language PASCAL.
- The design decisions Concern the layout of program and data, syntax analyzer.
- The compiler is written in its own language.
- The compiler is intended for the CDC 6000 computer family.
  - CDC 6000 is a family of mainframe computer manufactured by Control Data Corporation in the 1960s.
  - It consisted of CDC 6400, CDC 6500, CDC 6600 and CDC 6700 computers, which all were extremely rapid and efficient for their time.
  - It had a distributed architecture and was a reduced instruction set (RISC) machine many years before such a
Pascal Language

- Imperative Computer Programming Language, developed in 1971 by Niklaus Wirth.
- The primary unit in Pascal is the procedure.
- Each procedure is represented by a data segment and the program/code segment. The two segments are disjoint.
Compiling Programs: Basic View

- Pascal program
- `filename.p`
- `gcc`
- `a.out`
- Machine language program

Flow:
- Input
- Compile
- Output
Representation of Data

- Compute all the addresses at compile time to optimize certain index calculation.
- Entire variables always are assigned at least one full PSU “Physical Storage Unit” i.e. CDC6000 has ‘wordlength’ of 60 bits.
- Scalar types
- Array types
  the first term is computed by the compiler
  \[ w = a + (i-l)s \]
- Record types: reside only within one PSU if it is represented as packed. If it is not packed its size will be the size of the largest possible variant.
Data types ... 

- Powerset types
  - The set operations of PASCAL are realized by the conventional bit-parallel logical instructions ‘and’ for intersection, ‘or’ for union.

- File types
  - The data transfer between the main store buffer and the secondary store is performed by a Peripheral Processor (PP).
  - The CPU actions caused by the standard procedures put and get by just change pointers.
    - s ” buffer size”
    - n ” n>2”
    - s’ ”File component size”
    - s=n*s’
  - The buffer should be able to hold at least one Physical Record Unit (PRU). “PRU : the unit that is used to represent file on secondary storage”

- Class types
  - Domain: the component of the class variable to which they are bound.
  - The allocated area of memory is calculated by the compiler.
Basic Structure Of Pascal Programs

Program name.p (Pascal source code)

Part I: Header
Program documentation
program name (input, output);

Part II: Declarations
const
:

Part III: Statements
begin
:
end.
Program documentation

- Comments for the reader of the program (and not the computer)
  - (*) Marks the Start of the documentation
  - *) Marks the End of the documentation

Program heading

- Keyword: program, Name of program, if input and/or output operations performed by the program.
Example Header

(*
* Tax-It v1.0: This program will
* electronically calculate your tax
* return.
*
* This program will only allow you to
* complete a Canadian tax return
*)

program taxIt (input, output);

Documentation

Heading
Declarations

- List of constants
- List of variables
Reserved Words

- Have a predefined meaning in Pascal that cannot be changed

- and
- array
- begin
- case
- const
- div
- do
- downto
- else
- end
- file
- for
- foward
- functio
- n
- goto
- if
- in
- label
- open
- procedure
- protected
- qoto
- record
- retn
- set
- start
- stop
- then
- to
- true
- try
- var
- while
- with
- xor
Reserved Words

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- and
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- else
- end
- file
- for
- foward
- function
- goto
- if
- in
- label
- mod
- nil
- not
- of
- or
- packed
- procedur
- e
- program
- record
- repeat
- set
- then
- to
- type
- until
- var
- while

For more information on reserved words go to the url: http://www.gnu-pascal.de/gpc/index.html
Standard Identifiers

- Have a predefined meaning in Pascal that **SHOULD NOT** be changed
- Predefined constants
  - false
  - true
  - maxint
- Predefined types
  - boolean
  - char
  - integer
  - real
  - text
- Predefined files
  - input
  - output

For more information on standard identifiers go to the url: http://www.gnu-pascal.de/gpc/index.html
## Predefined Functions

- abs
- arctan
- chr
- cos
- eof
- eoln
- exp
- ln
- odd

- ord
- pred
- round
- sin
- sqr
- sqrt
- succ
- trunc

*Know the ones in Table 3.1 of your book.*
Predefined Procedures

- dispose
- get
- new
- pack
- page
- put
- read

- readln
- reset
- rewrite
- unpack
- write
- writeln
Declaring Variables

Declare variables between the ‘begin’ and ‘end.’

Part I: Header
- Program documentation
- program name (input, output);

Part II: Declarations
- const
- :

Part III:
- begin
- :
- end.

Declare variables just after the ‘begin’
Procedure Parameters

- Parameters denoting a constant "no assignment is allowed"
- Parameters denoting a variable.
- Parameters denoting procedure:
  - To represent procedure uniquely:
    - The address of the entry point of the code.
    - The address of the data segment of that procedure declared local variables.
Code Optimization

- Taking array index into consideration. This done mutually by HW or by Compiler.
- The 2\textsuperscript{nd} important optimization is arithmetic optimization
  - $x \div c$ if $c$ is 2,4,8… Just shift right 1,2,3.. times.
  - $x \times c$ and $c$ is 2,4,8… Just shift left 1,2,3.. times.
Syntax Analysis

- Conway “Separable transition diagram”:
  - The syntax of the language is presented as a finite set of *pseudo-finite-state* recognizers. This is because the basic symbols to be recognized are replaced by sentences are replaced by the member of this set. Using TD Parsing.
  - The syntax of the language is formulated as a set \( S \) of finite graphs.
  - It is straightforward to translate to and from the diagrams to BNF and it is easy to verify unambiguity.
  - To strictly adhere to the constraint of a one-symbol lookahead.
Part II

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Performance and statistical data

● At a Glance
  ○ The Source Program
    ■ 4000
    ■ 130,000
    ■ 33
  ○ Contents
    ■ Distinct identifiers
    ■ Word-delimiters
      ■ End, begin, if, then, and else
The object program:

- Field length requires 19,000 words
  - Compiler Program proper – 67.8%
  - Object code Buffering – 4.7%
  - Object Table – 9.2%
  - Other Data – 4.5%
  - Input and Output Buffering – 8.3%
  - Interface and I/O routines - 5.5%
Program Instruction Set

- Program consists of 32,700 instructions as follows:
  - Long instructions (30-bit) = 48.7%
  - Short instructions (15-bit) = 28.7%
  - Padding Instructions (NOOP) = 22.8%

- Long/Short instruction breakdown
  - Fetch/store, load literal, arithmetic, logical/shift, base address register, and jumps/subroutine calls.
● On registers
  ● X-registers – used as a stack, holds results while evaluating expressions
    ○ X1, X2, X3, X4, and X5 percentages.

  ● B-registers – are used for the display D
    ○ B1, B2, B3, and B4 percentages.
Performance on recompilation

- Time to load and compile (the source program)
  40 sec(CP)+15 sec(PP)

- Yielding an average of
  - 100 lines of source code processed per (CP) second.
  - 820 instructions generated per second.
Compiler Design Technique

- 1968 – Earlier version of PASCAL
  - Compiler written in FORTRAN - the motive here is a result of wanting a compiler that could be available automatically for multiple computers.

- 1969 – Written in PASCAL
  - Here the compiler was translated 'by hand' and did not attempt to optimize. Several features were omitted.
● Task division
  ○ Type definitions, variable declarations and procedure headings including formal parameter list.
  ○ Expressions and Statements.
  ○ Interface with the operating system.
Part III

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Relationship Between The Complexity of Compilation and Computer Architecture
Desirable Computer Architecture Properties

- Pascal is a language designed without any specific computer in mind
- At Least Two Registers
- Simplicity of Instruction Set
- Make optimizations unnecessary
CDC 6000 Architecture

- Regularity and brevity of instruction set
- 64 Total Instructions
- 42 used in compiler (66 percent)
Graph of Instructions By %Source Code
Conclusions
• Compared Algol, Fortran & Pascal on 4 programs:
  o Matrix multiplication B: A*A, no output
  o Sorting an array of 2,000 numbers
  o Finding all possible additive partitions of integers 1-30
  o Counting the characters in a file
• The performance differences between languages was negligible
• The reliability of the code generated by Pascal was higher
Successes

● High Reliability
● Scheme of syntax analysis allows separate features to be tested separately
● Recursive Descent for syntax analysis - requires implementation language supporting recursion
● Syntax designed in flow diagrams instead of BNF (giving readability)
<Simple Expression> ::= <Term> | <Simple Expression>
<adding operator><Term> | <adding operator><Term>
<Term> ::= <Factor> | <Term> <multiplying operator><Factor>
<Factor> ::= <variable> | <unsigned constant> | <function designator> | <set> | (<expression>) | !<factor>