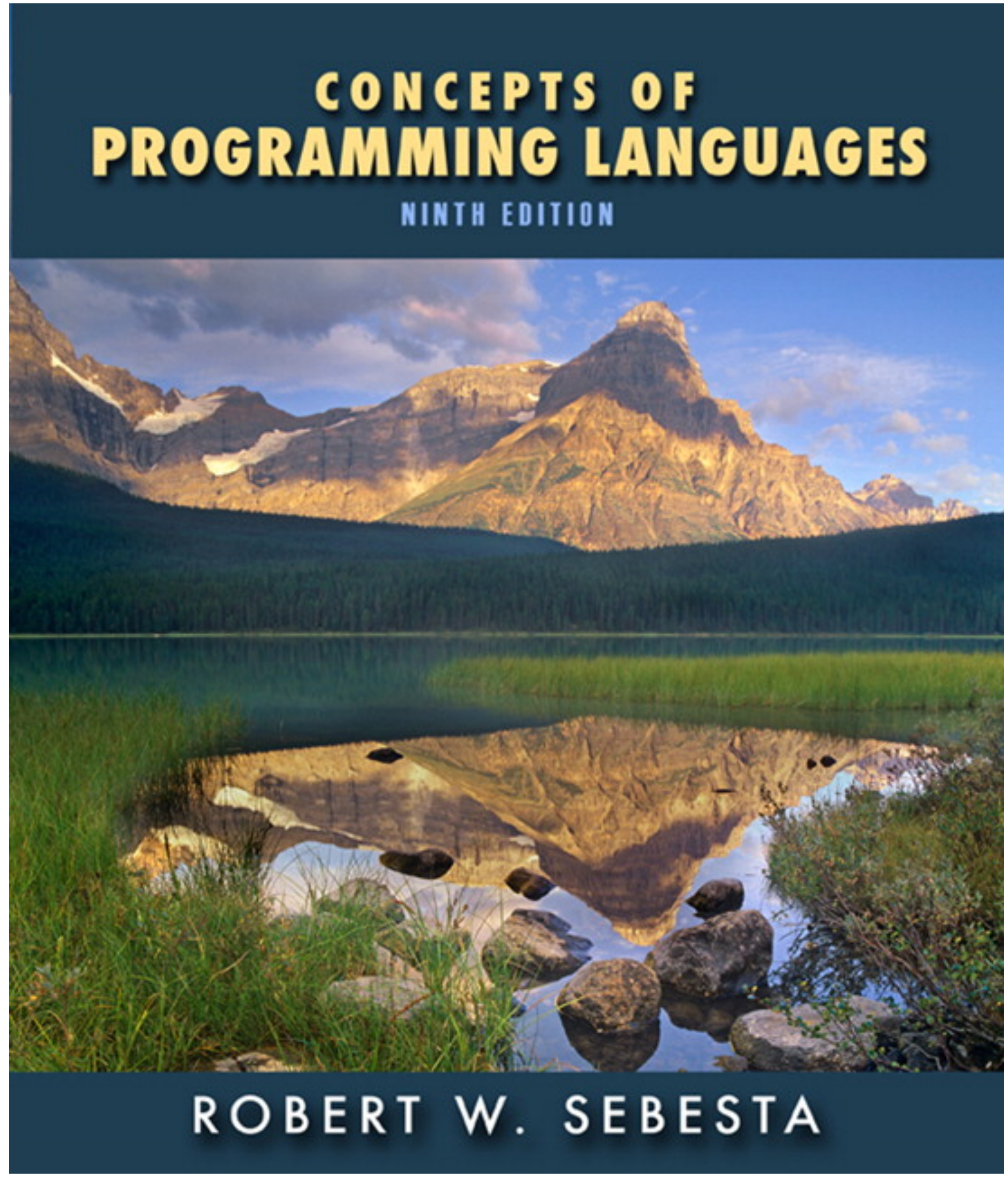
Chapter 2

Evolution of the Major Programming Languages



Chapter 2 Topics

- Zuse’s Plankalkül
- Minimal Hardware Programming: Pseudocodes
- The IBM 704 and Fortran
- Functional Programming: LISP
- The First Step Toward Sophistication: ALGOL 60
- Computerizing Business Records: COBOL
- The Beginnings of Timesharing: BASIC

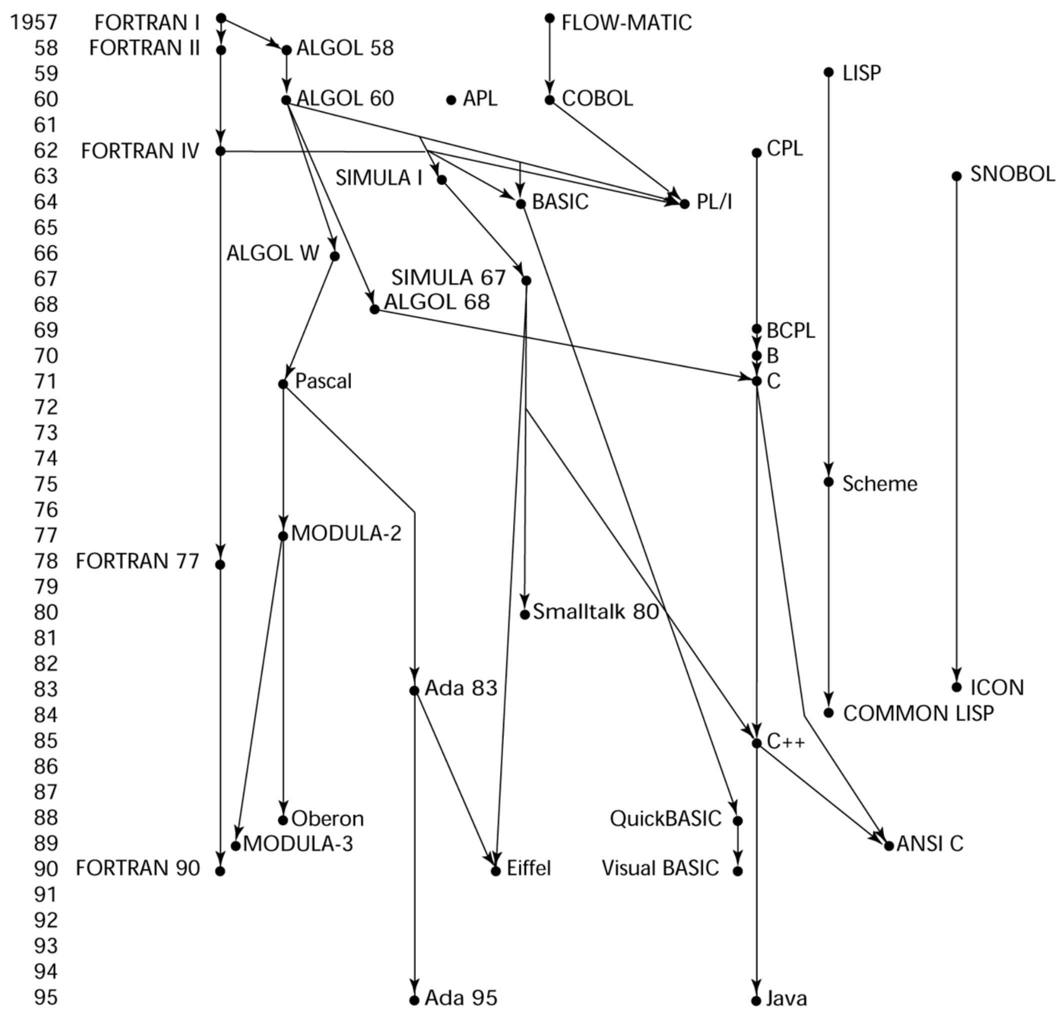
Chapter 2 Topics (continued)

- Everything for Everybody: PL/I
- Two Early Dynamic Languages: APL and SNOBOL
- The Beginnings of Data Abstraction: SIMULA 67
- Orthogonal Design: ALGOL 68
- Some Early Descendants of the ALGOLs
- Programming Based on Logic: Prolog
- History's Largest Design Effort: Ada

Chapter 2 Topics (continued)

- Object-Oriented Programming: Smalltalk
- Combining Imperative ad Object-Oriented Features: C++
- An Imperative-Based Object-Oriented Language: Java
- Scripting Languages
- A C-Based Language for the New Millennium: C#
- Markup/Programming Hybrid Languages

Genealogy of Common Languages



Zuse's Plankalkül

- Designed in 1945, but not published until 1972
- Never implemented
- Advanced data structures
  - floating point, arrays, records
- Invariants

Plankalkül Syntax

- An assignment statement to assign the expression A[4] + 1 to A[5]

	|	A + 1 => A		
V	|	4	5	(subscripts)
S	|	1.n	1.n	(data types)

Minimal Hardware Programming: Pseudocodes

- What was wrong with using machine code?
  - Poor readability
  - Poor modifiability
  - Expression coding was tedious
  - Machine deficiencies--no indexing or floating point

Pseudocodes: Short Code

- Short Code developed by Mauchly in 1949 for BINAC computers
  - Expressions were coded, left to right
  - Example of operations:

```
01 – 06 abs value 1n (n+2)nd power
02 ) 07 +         2n (n+2)nd root
03 = 08 pause     4n if <= n
04 / 09 (         58 print and tab
```

Pseudocodes: Speedcoding

- Speedcoding developed by Backus in 1954 for IBM 701
  - Pseudo ops for arithmetic and math functions
  - Conditional and unconditional branching
  - Auto-increment registers for array access
  - Slow!
  - Only 700 words left for user program

Pseudocodes: Related Systems

- The UNIVAC Compiling System
  - Developed by a team led by Grace Hopper
  - Pseudocode expanded into machine code
- David J. Wheeler (Cambridge University)
  - developed a method of using blocks of re-locatable addresses to solve the problem of absolute addressing

IBM 704 and Fortran

- Fortran 0: 1954 - not implemented
- Fortran I:1957
  - Designed for the new IBM 704, which had index registers and floating point hardware
    - This led to the idea of compiled programming languages, because there was no place to hide the cost of interpretation (no floating-point software)
  - Environment of development
    - Computers were small and unreliable
    - Applications were scientific
    - No programming methodology or tools
    - Machine efficiency was the most important concern

Design Process of Fortran

- Impact of environment on design of Fortran I
  - No need for dynamic storage
  - Need good array handling and counting loops
  - No string handling, decimal arithmetic, or powerful input/output (for business software)

Fortran I Overview

- First implemented version of Fortran
  - Names could have up to six characters
  - Post-test counting loop (`DO`)
  - Formatted I/O
  - User-defined subprograms
  - Three-way selection statement (arithmetic `IF`)
  - No data typing statements

Fortran I Overview (continued)

- First implemented version of FORTRAN
  - No separate compilation
  - Compiler released in April 1957, after 18 worker-years of effort
  - Programs larger than 400 lines rarely compiled correctly, mainly due to poor reliability of 704
  - Code was very fast
  - Quickly became widely used

Fortran II

- Distributed in 1958
  - Independent compilation
  - Fixed the bugs

Fortran II Example

```
C AREA OF A TRIANGLE - HERON'S FORMULA
C INPUT - CARD READER UNIT 5, INTEGER INPUT
C OUTPUT - LINE PRINTER UNIT 6, REAL OUTPUT
C INPUT ERROR DISPLAY ERROR OUTPUT CODE 1 IN JOB CONTROL LISTING
      INTEGER A,B,C
      READ(5,501) A,B,C
  501 FORMAT(3I5)
      IF(A.EQ.0 .OR. B.EQ.0 .OR. C.EQ.0) STOP 1
      S = (A + B + C) / 2.0
      AREA = SQRT( S * (S - A) * (S - B) * (S - C))
      WRITE(6,601) A,B,C,AREA
  601 FORMAT(4H A= ,I5,5H  B= ,I5,5H  C= ,I5,8H  AREA= ,F10.2,12HSQUARE
UNITS)
      STOP
      END
```

Fortran IV

- Evolved during 1960-62
  - Explicit type declarations
  - Logical selection statement
  - Subprogram names could be parameters
  - ANSI standard in 1966

Fortran 77

- Became the new standard in 1978
  - Character string handling
  - Logical loop control statement
  - **`IF-THEN-ELSE`** statement

Fortran 77

```
C AREA OF A TRIANGLE - HERON'S FORMULA
C INPUT - CARD READER UNIT 5, INTEGER INPUT, NO BLANK CARD FOR END OF DATA
C OUTPUT - LINE PRINTER UNIT 6, REAL OUTPUT
C INPUT ERROR DISPAYS ERROR MESSAGE ON OUTPUT
  501 FORMAT(3I5)
  601 FORMAT(" A= ",I5,"  B= ",I5,"  C= ",I5,"  AREA= ",F10.2,"SQUARE UNITS")
  602 FORMAT("NORMAL END")
  603 FORMAT("INPUT ERROR OR ZERO VALUE ERROR")
      INTEGER A,B,C
   10 READ(5,501,END=50,ERR=90) A,B,C
      IF(A=0 .OR. B=0 .OR. C=0) GO TO 90
      S = (A + B + C) / 2.0
      AREA = SQRT( S * (S - A) * (S - B) * (S - C))
      WRITE(6,601) A,B,C,AREA
      GO TO 10
   50 WRITE(6,602)
      STOP
   90 WRITE(6,603)
      STOP
      END
```

Fortran 90

- Most significant changes from Fortran 77
  - Modules
  - Dynamic arrays
  - Pointers
  - Recursion
  - `CASE` statement
  - Parameter type checking

Latest versions of Fortran

- Fortran 95 – relatively minor additions, plus some deletions
- Fortran 2003 – ditto

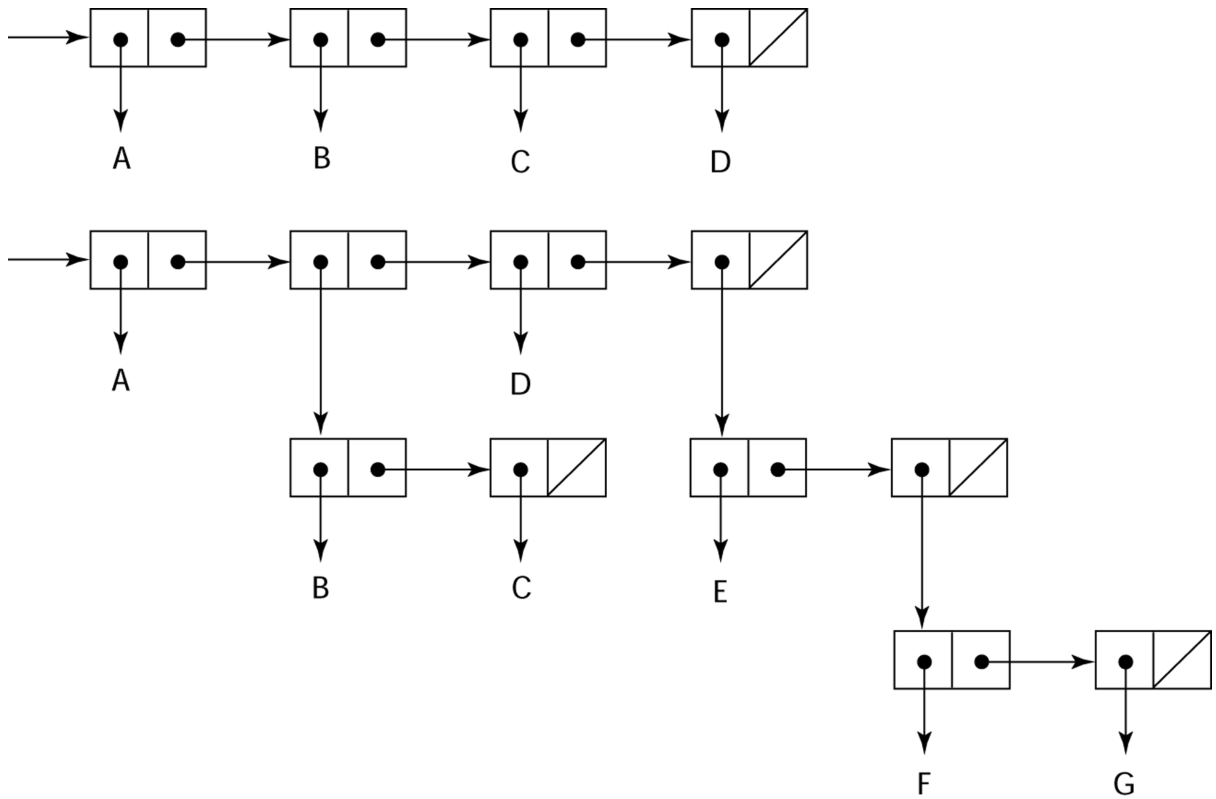
Fortran Evaluation

- Highly optimizing compilers (all versions before 90)
  - Types and storage of all variables are fixed before run time
- Dramatically changed forever the way computers are used
- Characterized as the *lingua franca* of the computing world

Functional Programming: LISP

- LISt Processing language
  - Designed at MIT by McCarthy
- AI research needed a language to
  - Process data in lists (rather than arrays)
  - Symbolic computation (rather than numeric)
- Only two data types: atoms and lists
- Syntax is based on *lambda calculus*

Representation of Two LISP Lists



Representing the lists `(A B C D)`
and `(A (B C) D (E (F G)))`

LISP Evaluation

- Pioneered functional programming
  - No need for variables or assignment
  - Control via recursion and conditional expressions
- Still the dominant language for AI
- COMMON LISP and Scheme are contemporary dialects of LISP
- ML, Miranda, and Haskell are related languages

Scheme

- Developed at MIT in mid 1970s
- Small
- Extensive use of static scoping
- Functions as first-class entities
- Simple syntax (and small size) make it ideal for educational applications

Scheme – sample code

```
(define fun  (lambda (n)
(if (= n 0)  0
     (if (= n 1) 1
          (+ (fun (- n 1)) (fun (- n 2)))))))
```

- What does this do?
- What's missing from this?
- Show Racket example.
- What's cool about this?

COMMON LISP

- An effort to combine features of several dialects of LISP into a single language
- Large, complex
- Do you know an editor that is based on LISP?

The First Step Toward Sophistication: ALGOL 60

- Environment of development
  - FORTRAN had (barely) arrived for IBM 70x
  - Many other languages were being developed, all for specific machines
  - No portable language; all were machine-dependent
  - No universal language for communicating algorithms
- ALGOL 60 was the result of efforts to design a universal language

Early Design Process

- ACM and GAMM met for four days for design (May 27 to June 1, 1958)

- Goals of the language
  - Close to mathematical notation
  - Good for describing algorithms
  - Must be translatable to machine code

ALGOL 58

- Concept of type was formalized
- Names could be any length
- Arrays could have any number of subscripts
- Parameters were separated by mode (in & out)
- Subscripts were placed in brackets
- Compound statements (`begin ... end`)
- Semicolon as a statement separator
- Assignment operator was :=
- `if` had an `else-if` clause
- No I/O – "would make it machine dependent"

ALGOL 58 Implementation

- Not meant to be implemented, but variations of it were (MAD, JOVIAL)
- Although IBM was initially enthusiastic, all support was dropped by mid 1959

ALGOL 60 Overview

- Modified ALGOL 58 at 6-day meeting in Paris
- New features
  - Block structure (local scope)
  - Two parameter passing methods
  - Subprogram recursion
  - Stack-dynamic arrays

  - Still no I/O and no string handling

ALGOL 60 Example

```
BEGIN
COMMENT define the sieve data structure ;
INTEGER ARRAY candidates[0:1000];
INTEGER i,j,k;
COMMENT 1000 to protect against strict evaluation of AND ;
FOR i := 0 STEP 1 UNTIL 1000 DO
BEGIN
COMMENT everything is potentially prime until proven otherwise ;
candidates[i] := 1;
END;
COMMENT Neither 1 nor 0 is prime, so flag them off ;
candidates[0] := 0;
candidates[1] := 0;
COMMENT start the sieve with the integer 0 ;
i := 0;
FOR i := i WHILE i<1000 DO
BEGIN
COMMENT advance to the next un-crossed out number. ;
COMMENT this number must be a prime ;
FOR i := i WHILE i<1000 AND candidates[i] = 0 DO
BEGIN
i := i+1;
END;
COMMENT insure against running off the end of the data structure ;
IF i<1000 THEN
BEGIN
COMMENT cross out all multiples of the prime, starting with 2*p.;
j := 2;
k := j*i;
FOR k := k WHILE k < 1000 DO
BEGIN
candidates[k] := 0;
j := j + 1;
k := j*i;
END;
COMMENT advance to the next candidate ;
i := i+1;
END
END;
COMMENT all uncrossed-out numbers are prime (and only those numbers) ;
COMMENT print all primes ;
FOR i := 0 STEP 1 UNTIL 999 DO
BEGIN
IF candidates[i] # 0 THEN
BEGIN
write(1,i);
text(1," is prime*N")
END
END;
END
FINISH
```

ALGOL 60 Evaluation

- Successes
  - It was the standard way to publish algorithms for over 20 years
  - All subsequent imperative languages are based on it
  - First machine-independent language
  - First language whose syntax was formally defined (BNF)

ALGOL 60 Evaluation (continued)

- Failure
  - Never widely used, especially in U.S.
  - Reasons
    - Lack of I/O and the character set made programs non-portable
    - Too flexible--hard to implement
    - Entrenchment of Fortran
    - Formal syntax description
    - Lack of support from IBM

Computerizing Business Records: COBOL

- Environment of development
  - UNIVAC was beginning to use FLOW-MATIC
  - USAF was beginning to use AIMACO
  - IBM was developing COMTRAN

COBOL Historical Background

- Based on FLOW-MATIC
- FLOW-MATIC features
  - Names up to 12 characters, with embedded hyphens
  - English names for arithmetic operators (no arithmetic expressions)
  - Data and code were completely separate
  - The first word in every statement was a verb

COBOL Design Process

- First Design Meeting (Pentagon) – May 1959
- Design goals
  - Must look like simple English
  - Must be easy to use, even if that means it will be less powerful
  - Must broaden the base of computer users
  - Must not be biased by current compiler problems
- Design committee members were all from computer manufacturers and DoD branches
- Design Problems: arithmetic expressions? subscripts? Fights among manufacturers

COBOL Evaluation

- Contributions
  - First macro facility in a high-level language
  - Hierarchical data structures (records)
  - Nested selection statements
  - Long names (up to 30 characters), with hyphens
  - Separate data division

COBOL: DoD Influence

- First language required by DoD
  - would have failed without DoD
- Still the most widely used business applications language

COBOL: Example

```
$ SET SOURCEFORMAT"FREE"
IDENTIFICATION DIVISION.
PROGRAM-ID.  Iteration-If.

DATA DIVISION.
WORKING-STORAGE SECTION.
01  Num1          PIC 9  VALUE ZEROS.
01  Num2          PIC 9  VALUE ZEROS.
01  Result        PIC 99 VALUE ZEROS.
01  Operator      PIC X  VALUE SPACE.

PROCEDURE DIVISION.
Calculator.
   PERFORM 3 TIMES
      DISPLAY "Enter First Number      : " WITH NO ADVANCING
      ACCEPT Num1
      DISPLAY "Enter Second Number     : " WITH NO
ADVANCING
      ACCEPT Num2
      DISPLAY "Enter operator (+ or *) : " WITH NO
ADVANCING
      ACCEPT Operator
      IF Operator = "+" THEN
         ADD Num1, Num2 GIVING Result
      END-IF
      IF Operator = "*" THEN
         MULTIPLY Num1 BY Num2 GIVING Result
      END-IF
      DISPLAY "Result is = ", Result
   END-PERFORM.
   STOP RUN.
```

The Beginning of Timesharing: BASIC

- Designed by Kemeny & Kurtz at Dartmouth
- Design Goals:
  - Easy to learn and use for non-science students
  - Must be “pleasant and friendly”
  - Fast turnaround for homework
  - Free and private access
  - User time is more important than computer time
- Current popular dialect: Visual BASIC
- First widely used language with time sharing

2.8 Everything for Everybody: PL/I

- Designed by IBM and SHARE
- Computing situation in 1964 (IBM's point of view)
  - Scientific computing
    - IBM 1620 and 7090 computers
    - FORTRAN
    - SHARE user group
  - Business computing
    - IBM 1401, 7080 computers
    - COBOL
    - GUIDE user group

PL/I: Background

- By 1963
  - Scientific users began to need more elaborate I/O, like COBOL had; business users began to need floating point and arrays for MIS
  - It looked like many shops would begin to need two kinds of computers, languages, and support staff--too costly
- The obvious solution
  - Build a new computer to do both kinds of applications
  - Design a new language to do both kinds of applications

PL/I: Design Process

- Designed in five months by the 3 X 3 Committee
  - Three members from IBM, three members from SHARE
- Initial concept
  - An extension of Fortran IV
- Initially called NPL (New Programming Language)
- Name changed to PL/I in 1965

PL/I: Evaluation

- PL/I contributions
  - First unit-level concurrency
  - First exception handling
  - Switch-selectable recursion
  - First pointer data type
  - First array cross sections
- Concerns
  - Many new features were poorly designed
  - Too large and too complex

PL/I: Example

PROGRAM SAMPLE:

```
$ create MSG.PLI
msg3: proc;
        dcl MSG3_NOTDEC  globalref fixed bin(31);
        dcl lib$signal entry(fixed bin(31));
        call lib$signal (MSG3_NOTDEC);
end msg3;
$ say := write sys$output
$ say "compiling MSG.PLI"
$ pli MSG.PLI
$ create msg3.msg
.TITLE MSG3_NOTDEC
.FACILITY MSG3,1
.SEVERITY INFO
NOTDEC < Terminal is not DEC compatible>/FAO=0
.end
$ say "compiling MSG3.MSG"
$ message msg3.msg
$ say "linking MSG, MSG3"
$ link msg,msg3
$ say "beginning execution"
$ run msg
```

Two Early Dynamic Languages: APL and SNOBOL

- Characterized by dynamic typing and dynamic storage allocation
- Variables are untyped
  - A variable acquires a type when it is assigned a value
- Storage is allocated to a variable when it is assigned a value

APL: A Programming Language

- Designed as a hardware description language at IBM by Ken Iverson around 1960
  - Highly expressive (many operators, for both scalars and arrays of various dimensions)
  - Programs are very difficult to read
- Still in use; minimal changes

APL: A Programming Language

- What does the following do?
- $(\sim R \in R \circ . \times R)/R \leftarrow 1 \downarrow \iota R$
- The same as this in C:

```
#include <stdio.h>
#define R 100
int main()
{ int i, j, v[R + 1];
for (i = 2; i <= R; v[i++] = 1); for (i = 2; i * i <= R; i++)
for (j = 2; v[i] && i * j <= R; v[i * j++]= 0);
for (i = 2; i <= R; i++)
if (v[i]) printf("%d ", i);
return 0; }
```

SNOBOL

- Designed as a string manipulation language at Bell Labs by Farber, Griswold, and Polensky in 1964
- Powerful operators for string pattern matching
- Slower than alternative languages (and thus no longer used for writing editors)
- Still used for certain text processing tasks

The Beginning of Data Abstraction: SIMULA 67

- Designed primarily for system simulation in Norway by Nygaard and Dahl
- Based on ALGOL 60 and SIMULA I
- Primary Contributions
  - Coroutines - a kind of subprogram
  - Classes, objects, and inheritance

Orthogonal Design: ALGOL 68

- From the continued development of ALGOL 60 but not a superset of that language
- Source of several new ideas (even though the language itself never achieved widespread use)
- Design is based on the concept of orthogonality
  - A few basic concepts, plus a few combining mechanisms

ALGOL 68 Evaluation

- Contributions
  - User-defined data structures
  - Reference types
  - Dynamic arrays (called flex arrays)

- Comments
  - Less usage than ALGOL 60
  - Had strong influence on subsequent languages, especially Pascal, C, and Ada

Pascal - 1971

- Developed by Wirth (a former member of the ALGOL 68 committee)
- Designed for teaching structured programming
- Small, simple, nothing really new
- Largest impact was on teaching programming
  - From mid-1970s until the late 1990s, it was the most widely used language for teaching programming

Pascal – Example

```
Program Pascal;
Var
   Num1, Num2, Sum : Integer;

Begin {no semicolon}
 Write('Input number 1:');
 Readln(Num1);
 Writeln('Input number 2:');
 Readln(Num2);
 Sum := Num1 + Num2; {addition}
 Writeln(Sum);
 Readln;
End.
```

C – 1972

- Designed for systems programming (at Bell Labs by Dennis Richie)
- Evolved primarily from BCLP, B, but also ALGOL 68
- Powerful set of operators, but poor type checking
- Initially spread through UNIX
- Many areas of application

Programming Based on Logic: Prolog

- Developed, by Comerauer and Roussel (University of Aix-Marseille), with help from Kowalski (University of Edinburgh)
- Based on formal logic
- Non-procedural
- Can be summarized as being an intelligent database system that uses an inferencing process to infer the truth of given queries
- Highly inefficient, small application areas

Programming Based on Logic: Prolog

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.

?-  woman(mia). Yes
?-  playsAirGuitar(yolanda). No
```

History’s Largest Design Effort: Ada

- Huge design effort, involving hundreds of people, much money, and about eight years
  - Strawman requirements (April 1975)
  - Woodman requirements (August 1975)
  - Tinman requirements (1976)
  - Ironman equipments (1977)
  - Steelman requirements (1978)
- Named Ada after Augusta Ada Byron, the first programmer

Ada Evaluation

- Contributions
  - Packages – support for data abstraction
  - Exception handling – elaborate
  - Generic program units
  - Concurrency – through the tasking model
- Comments
  - Competitive design
  - Included all that was then known about software engineering and language design
  - First compilers were very difficult; the first really usable compiler came nearly five years after the language design was completed

Ada 95

- Ada 95 (began in 1988)
  - Support for OOP through type derivation
  - Better control mechanisms for shared data
  - New concurrency features
  - More flexible libraries
- Popularity suffered because the DoD no longer requires its use but also because of popularity of C++

Object-Oriented Programming: Smalltalk

- Developed at Xerox PARC, initially by Alan Kay, later by Adele Goldberg
- First full implementation of an object-oriented language (data abstraction, inheritance, and dynamic binding)
- Pioneered the graphical user interface design
- Promoted OOP

Combining Imperative and Object-Oriented Programming: C++

- Developed at Bell Labs by Stroustrup in 1980
- Evolved from C and SIMULA 67
- Facilities for object-oriented programming, taken partially from SIMULA 67
- Provides exception handling
- A large and complex language, in part because it supports both procedural and OO programming
- Rapidly grew in popularity, along with OOP
- ANSI standard approved in November 1997
- Microsoft's version (released with .NET in 2002): Managed C++
  - delegates, interfaces, no multiple inheritance

Related OOP Languages

- Eiffel (designed by Bertrand Meyer - 1992)
  - Not directly derived from any other language
  - Smaller and simpler than C++, but still has most of the power
  - Lacked popularity of C++ because many C++ enthusiasts were already C programmers
- Delphi (Borland)
  - Pascal plus features to support OOP
  - More elegant and safer than C++

An Imperative-Based Object-Oriented Language: Java

- Developed at Sun in the early 1990s
  - C and C++ were not satisfactory for embedded electronic devices
- Based on C++
  - Significantly simplified (does not include **`struct`**, **`union`**, **`enum`**, pointer arithmetic, and half of the assignment coercions of C++)
  - Supports *only* OOP
  - Has references, but not pointers
  - Includes support for applets and a form of concurrency

Java Evaluation

- Eliminated many unsafe features of C++
- Supports concurrency
- Libraries for applets, GUIs, database access
- Portable: Java Virtual Machine concept, JIT compilers
- Widely used for Web programming
- Use increased faster than any previous language
- Most recent version, 5.0, released in 2004

Scripting Languages for the Web

- Perl
  - Designed by Larry Wall—first released in 1987
  - Variables are statically typed but implicitly declared
  - Three distinctive namespaces, denoted by the first character of a variable's name
  - Powerful, but somewhat dangerous
  - Gained widespread use for CGI programming on the Web
  - Also used for a replacement for UNIX system administration language
- JavaScript
  - Began at Netscape, but later became a joint venture of Netscape and Sun Microsystems
  - A client-side HTML-embedded scripting language, often used to create dynamic HTML documents
  - Purely interpreted
  - Related to Java only through similar syntax
- PHP
  - PHP: Hypertext Preprocessor, designed by Rasmus Lerdorf
  - A server-side HTML-embedded scripting language, often used for form processing and database access through the Web
  - Purely interpreted

Scripting Languages for the Web

- Python
  - An OO interpreted scripting language
  - Type checked but dynamically typed
  - Used for CGI programming and form processing
  - Dynamically typed, but type checked
  - Supports lists, tuples, and hashes
- Lua
  - An OO interpreted scripting language
  - Type checked but dynamically typed
  - Used for CGI programming and form processing
  - Dynamically typed, but type checked
  - Supports lists, tuples, and hashes, all with its single data structure, the table
  - Easily extendable

Scripting Languages for the Web

- Ruby
  - Designed in Japan by Yukihiro Matsumoto (a.k.a, "Matz")
  - Began as a replacement for Perl and Python
  - A pure object-oriented scripting language
    - All data are objects
  - Most operators are implemented as methods, which can be redefined by user code
  - Purely interpreted

A C-Based Language for the New Millennium: C#

- Part of the .NET development platform (2000)
- Based on C++ , Java, and Delphi
- Provides a language for component-based software development
- All .NET languages use Common Type System (CTS), which provides a common class library

Markup/Programming Hybrid Languages

- XSLT
  - eXtensible Markup Language (XML): a metamarkup language
  - eXtensible Stylesheet Language Transformation (XSTL) transforms XML documents for display
  - Programming constructs (e.g., looping)

- JSP
  - Java Server Pages: a collection of technologies to support dynamic Web documents
  - servlet: a Java program that resides on a Web server and is enacted when called by a requested HTML document; a servlet's output is displayed by the browser
  - JSTL includes programming constructs in the form of HTML elements

Summary

- Development, development environment, and evaluation of a number of important programming languages
- Perspective into current issues in language design