Chapter 2
Evolution of the Major Programming Languages

Instructor
Chi–Jen Wu
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 and Object-Oriented Features: C++
- An Imperative-Based Object-Oriented Language: Java
- Scripting Languages
- The Flagship .NET Language: C#
- Markup/Programming Hybrid Languages

Genealogy of Common Languages

Zuse’s Plankalkül
Trend

TIOBE Programming Community Index

Normalized fraction of total hits (%)

Time

Java - Objective-C - C# - Python - Perl
C - C++ - PHP - (Visual) Basic - Ruby

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What Makes a Language Successful?

- **Easy to learn**
  - Basic, Pascal

- **Easy to express things**
  - “Powerful”
  - Easy to use once known
  - C, Lisp

- **Easy to implement**
  - Small machines, limited resources

- **Efficient compilers**
  - Generate small / fast code
  - Fortran

- **Backing of a powerful sponsor**
  - Ada, Visual Basic

- **Wide dissemination at a minimal cost**
  - Pascal, Java

- **Inertia**
  - Fortran, Cobol
Zuse’s Plankalkül

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

Plankalkül Syntax


$| \quad A + 1 \Rightarrow A$

$V \mid 4 \quad 5$ (subscripts)

$S \mid 1.n \quad 1.n$ (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
BINAC: The world’s first electronic general-purpose digital computer

- The first stored–program computer in the US
- It used approximately 700 vacuum tubes

Source: americaninvestors.blogspot.tw
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 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 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 – support for OOP, procedure pointers, interoperability with C
- Fortran 2008 – blocks for local scopes, co-arrays, Do Concurrent
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
Charles Babbage: Father of the Computer

- 26 December 1791 – 18 October 1871
- designed the first computer
  - the Analytical Engine
    - A memory holding 1000 numbers
    - Loops
    - Conditionals

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 \textit{lambda calculus}
  - Fibonacci Sequence
  - 1 1 2 3 5 8 13 21 34 55

Representation of Two LISP Lists

Representing the lists \((\text{A B C D})\) and \((\text{A (B C) D (E (F G))})\)
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, Haskell, and F# are also functional programming languages, but use very different syntax
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
COMMON LISP

- An effort to combine features of several dialects of LISP into a single language
- Large, complex, used in industry for some large applications
  - Easy debugging (reproduce and locate bugs)
  - For concurrency
  - No sharing memory
  - No critical section
  - Hot code deployment
Ada Lovelace: First Programmer

- 10 December 1815 – 27 November 1852
- Worked with Babbage
- Created first program for the
  - Analytical Engine
  - calculating Bernoulli numbers

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 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
Grace Hoper: The First Compiler

- December 9, 1906 – January 1, 1992
- Wrote first compiler, the “A” compiler for programming
  - Harvard Mark I computer
- Machine-independent PL
- Co-designer of COBOL
- “debugging”
• 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
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
Visual BASIC

- GUI applications
- drag-and-drop techniques
- Component Object Model (COM)
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
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
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

• The first object-oriented programming language (SIMULA I)

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
C – 1972

- Designed for systems programming (at Bell Labs by Dennis Richie)
- Evolved primarily from BCLP and B, but also ALGOL 68
- Powerful set of operators, but poor type checking
- Initially spread through UNIX
- Though designed as a systems language, it has been used in many application areas

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
• Comparatively inefficient
• Few application areas
History’s Largest Design Effort: Ada

- Huge design effort, involving hundreds of people, much money, and about eight years
- Sequence of requirements (1975–1978)
  - (Strawman, Woodman, Tinman, Ironman, Steelman)
- 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

- Ada 2005
  - Interfaces and synchronizing interfaces

- 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

“The best way to predict the future is to invent it.” 1971

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
- 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: MC++
  - Properties, delegates, interfaces, no multiple inheritance

Related OOP Languages

• Objective-C (designed by Brad Cox – early 1980s)
  – C plus support for OOP based on Smalltalk
  – Uses Smalltalk’s method calling syntax
  – Used by Apple for systems programs

• Delphi (Borland)
  – Pascal plus features to support OOP
  – More elegant and safer than C++

• Go (designed at Google – 2009)
  – Loosely based on C, but also quite different
  – Does not support traditional OOP
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, 7, released in 2011
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
Node.js

- Node.js is a platform built on Chrome's JavaScript runtime for easily building fast, scalable network applications
- Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient, perfect for data-intensive real-time applications that run across distributed devices
HipHop for PHP is an open source project developed by Facebook

HipHop programmatically transforms PHP source code into C++ and then uses g++ to compile it to machine code.
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

- **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
Scripting Languages for the Web

- 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
The Flagship .NET Language: C#

- Part of the .NET development platform (2000)
- Based on C++, Java, and Delphi
- Includes pointers, delegates, properties, enumeration types, a limited kind of dynamic typing, and anonymous types
- Is evolving rapidly
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
  - JSTL, a JSP library, 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