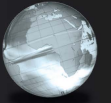


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Chapter 2

Evolution of the Major Programming Languages

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Concepts of Programming Languages

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ROBERT W. SEBESTA



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

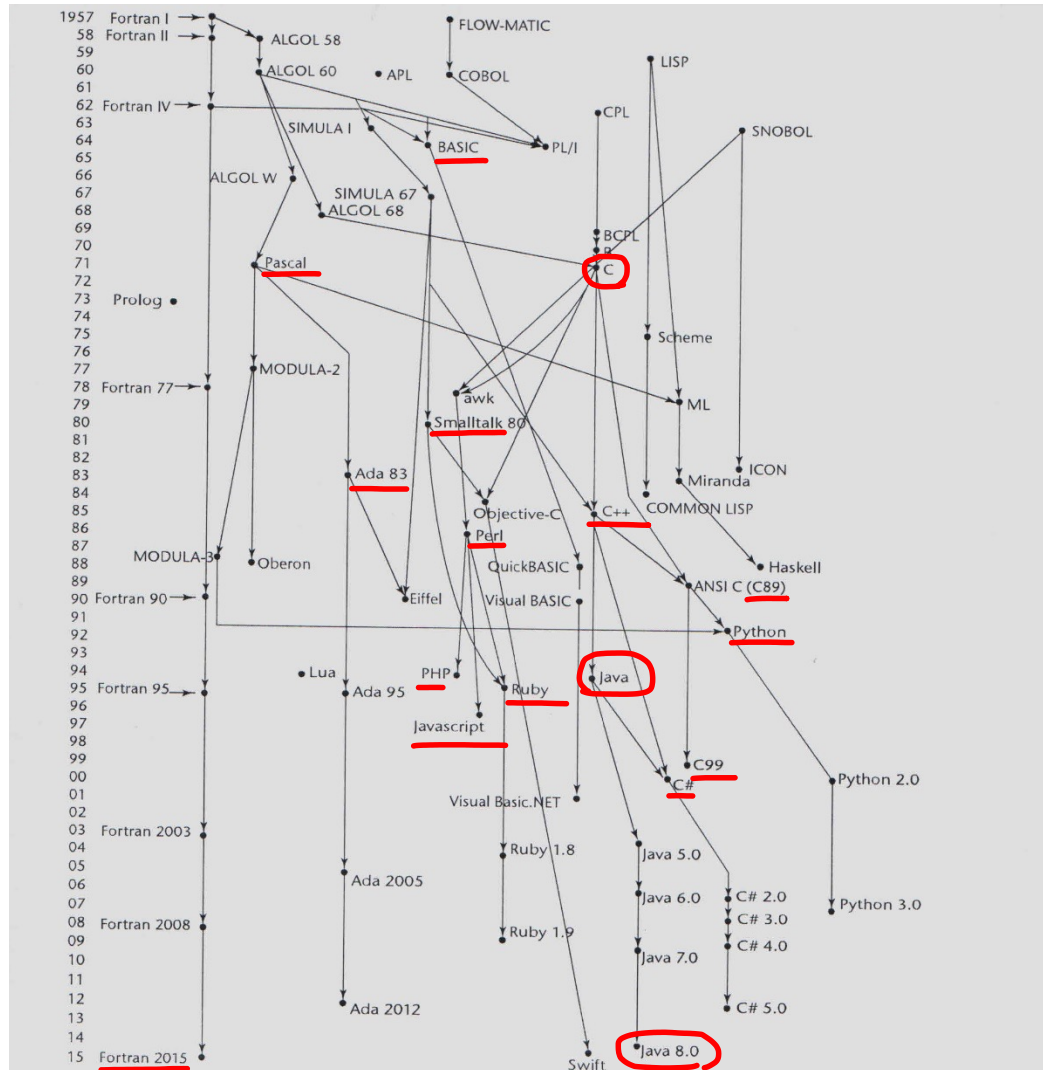
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- Everything for Everybody: PL/I
- Two Early Dynamic Languages: APL and SNOBOL
- The Beginnings of Data Abstraction: SIMULA 67
- Orthogonal Design: ALGOL 68
- Some Early Descendants of the ALGOLs
- Programming Based on Logic: Prolog
- History's Largest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

- **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 $A[5]$

		$A + 1$	\Rightarrow	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**
 - 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`

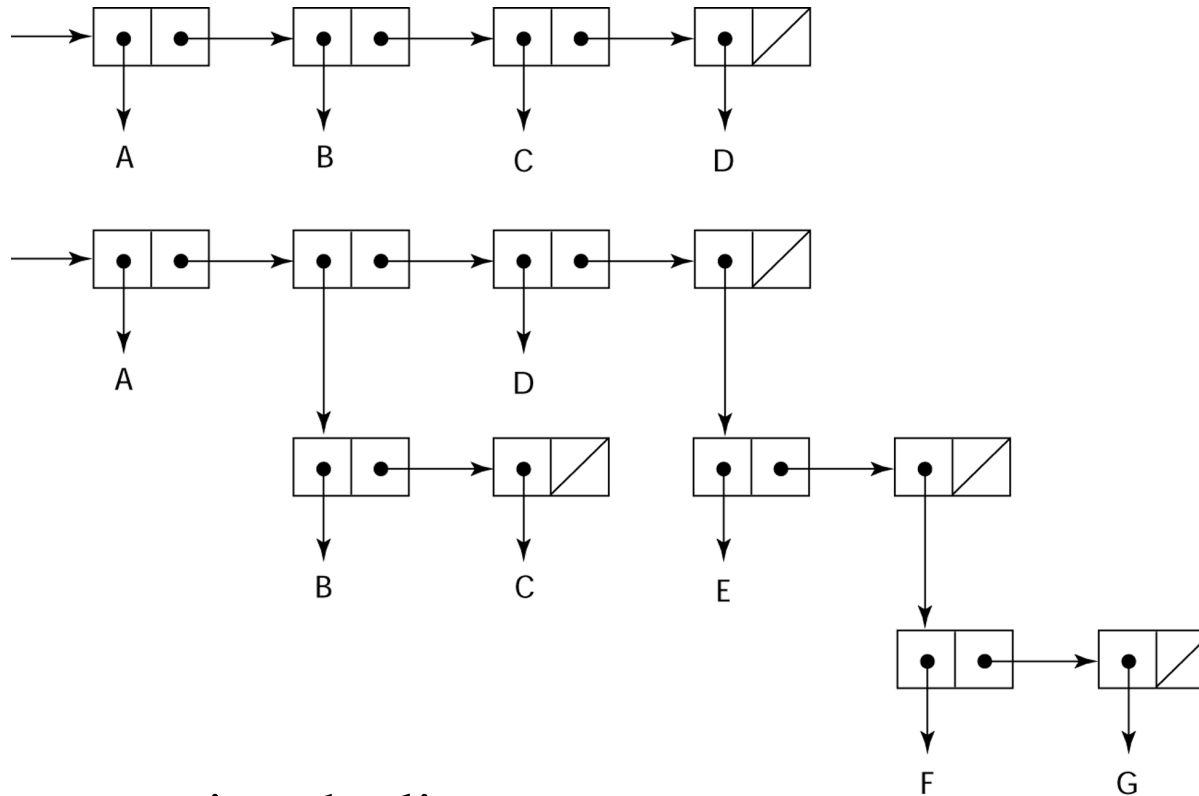
Fortran Evaluation

- 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

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, 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

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

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 (美國國防部)
 - 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

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

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

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

A Related OOP Language

- Swift – a replacement for Objective-C
 - Released in 2014
 - Two categories of types, classes and struct, like C#
 - Used by Apple for systems programs
- Delphi – another related language
 - A hybrid language, like C++
 - Began as an object-oriented version of Pascal
 - Designed by Anders Hejlsberg, who also designed Turbo Pascal and 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, 8, released in 2014

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 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

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 (XSLT) 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