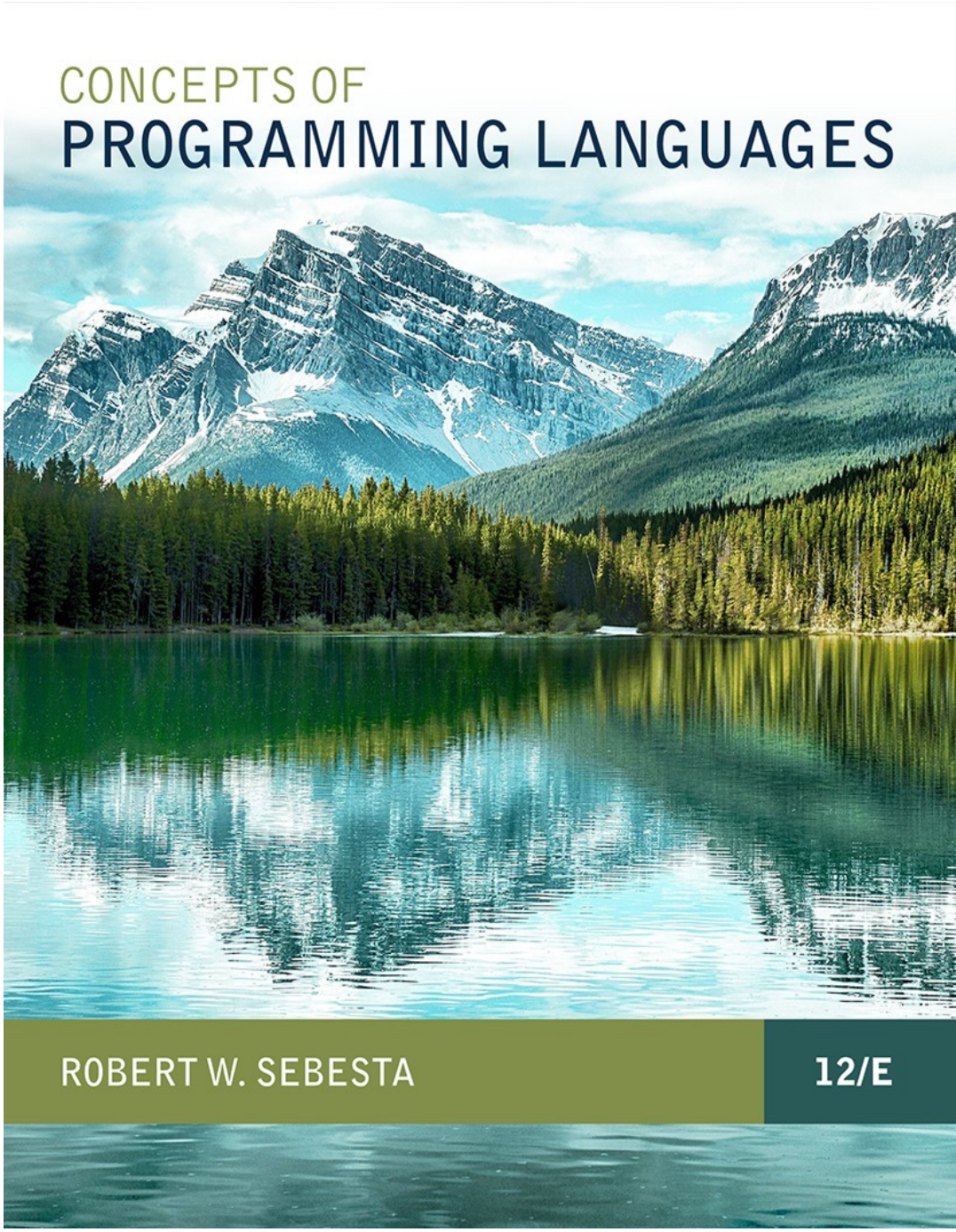
Chapter 2

Evolution of the Major Programming Languages



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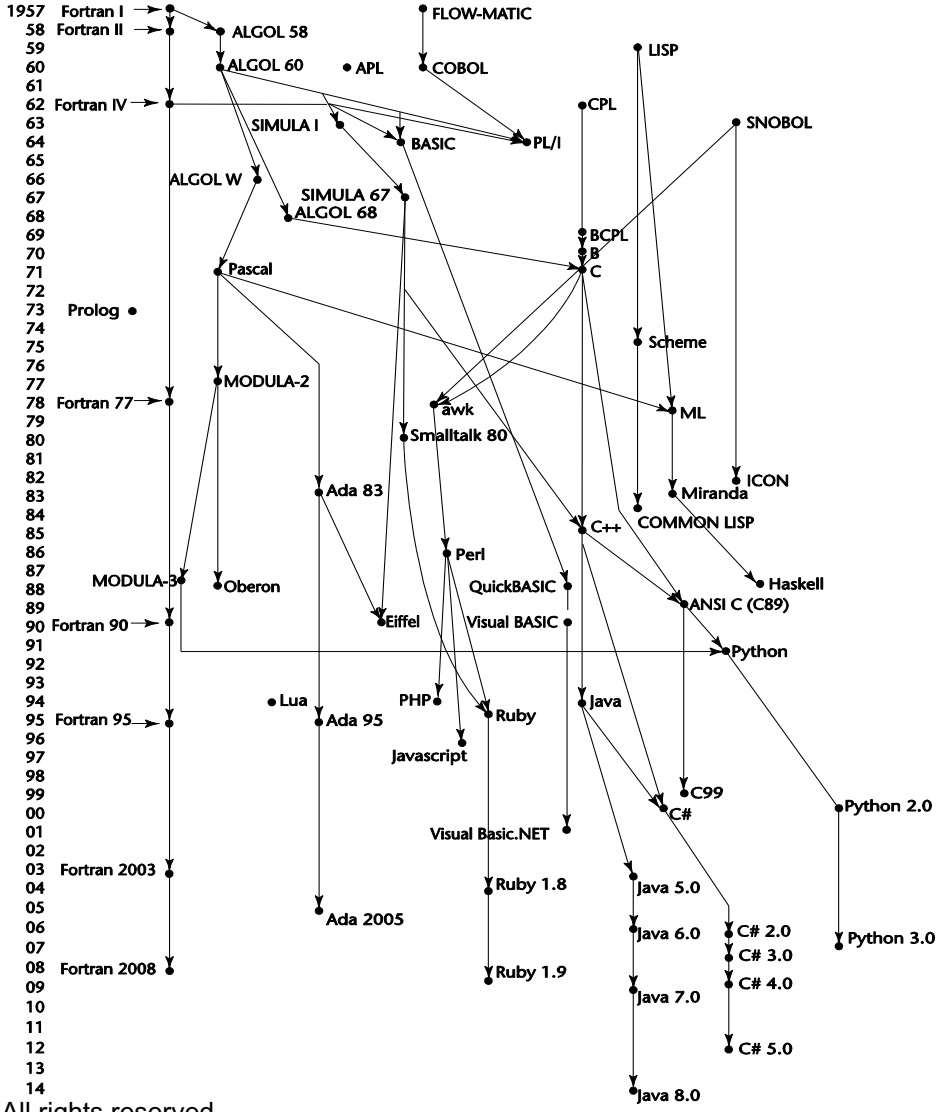
Genealogy of Common Languages



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]

e.g., A[5] = A[4] + 1

	|	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 (Binary Automatic) 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
```

  - Example of operations:

```
    X0 = SORT(ABS(Y0))
00 X0 03 20 06 Y0       // 00: padding to fill the word
```

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

- Ref: IBM 701 programming: http://basepath.com/new/701/Programming-the-IBM-701.pdf

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
  - 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`)
    - E.g., if (arithmetic_expression) S1, S2, S3
      - » S1 if arithmetic_expression < 0
      - » S2 if arithmetic_expression == 0
      - » S3 if arithmetic_expression > 0
  - No data typing statements

Fortran I Overview (continued)

- First implemented version of FORTRAN
  - No separate compilation
  - Compiler released in April 1957
  - 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
  - American National Standards Institute—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`

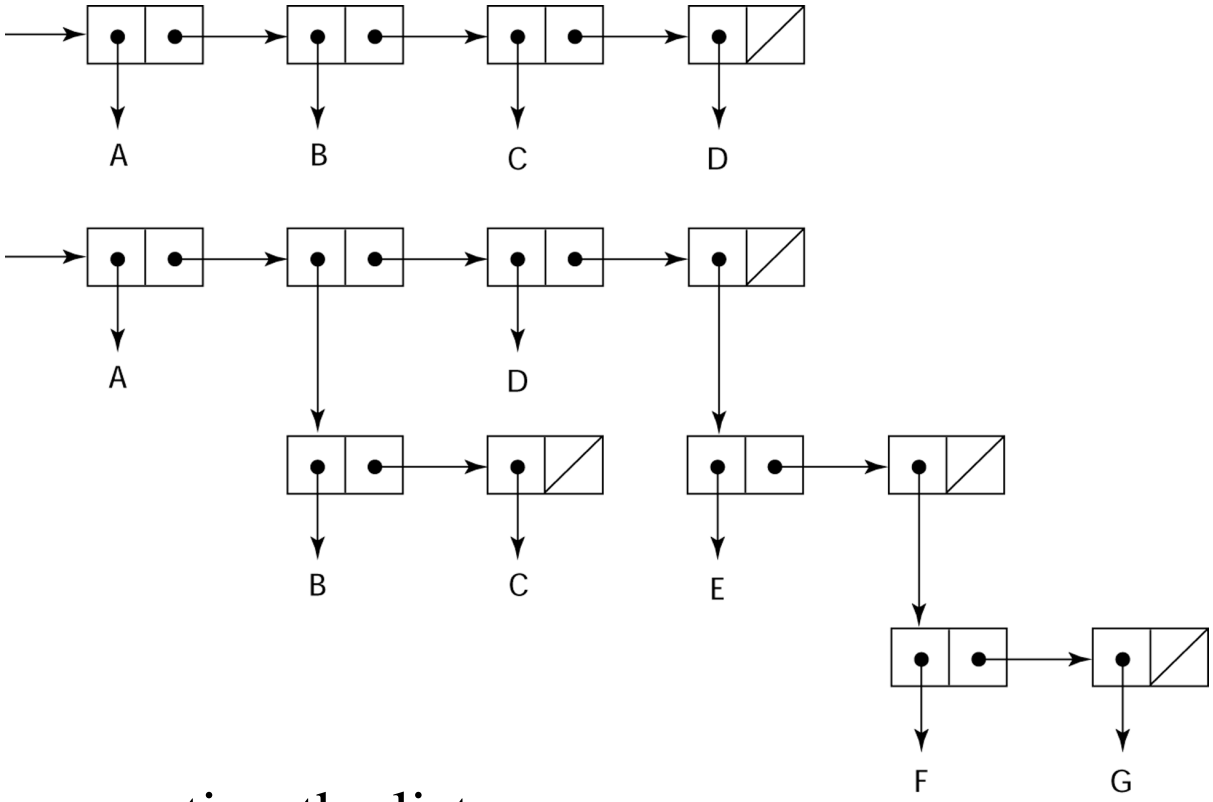
Fortran Evaluation

- Highly optimizing compilers (all versions before 90)
  - Types and storage of all variables are fixed before run time
- Dramatically changed 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 dialects of Lisp
- ML (MetaLanguage), 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

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

- Success
  - 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 in Backus-Naur Form (BNF).
    - E.g., <postal-address> ::= <name-part> <street-address> <zip-part>
  - Ref: https://en.wikipedia.org/wiki/Backus%E2%80%93Naur_Form

ALGOL 60 Evaluation (continued)

- Failure
  - Never widely used, especially in U.S.
  - Reasons
    - Lack of I/O
    - Too flexible--hard to implement
    - Formal syntax description
    - Lack of support from IBM

Ref: https://en.wikipedia.org/wiki/ALGOL_60

Computerizing Business Records: COBOL

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

  - Notes:
    - COBOL: COmmon Business-Oriented Language
    - FLOW-MATIC: first English-like data processing language
    - COMTRAN: COMmercial TRANslator programming language, IBM
    - AIMACO: AIr MAterial Complier
    - USAF: United States Air Force
    - UNIVAC: UNIVersal Automatic Computer, Eckert-Mauchly Computer Corporation

COBOL Historical Background

- 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
  - E.g.,

```
OPEN  INPUT STUDENT-FILE
MOVE  ZERO TO RECORDS-WRITTEN.
```

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

- Ref: https://en.wikipedia.org/wiki/COBOL

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—multiple users sharing/using a computer at the same time. (ref: https://en.wikipedia.org/wiki/Time-sharing)

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

Notes: **SHARE and GUIDE**: IBM mainframe user groups ; **PL/I**: Programming Language One

PL/I: Background

- By 1963
  - Scientific users need more elaborate I/O, like COBOL had;
  - Business users need floating point and arrays for management information systems (MIS)
  - Many shops would 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

Notes: APL: A Programming Language
SNOBOL: StriNg Oriented and symBOlic Language

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
  - "Changing A does not change B"

E.g., In Radio, changing the station does not change the volume.

Ref: http://stackoverflow.com/questions/1527393/what-is-orthogonality

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 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 BCPL 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

- Note: BCPL: Basic Combined Programming Language

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
- 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 8 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 5 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 and the 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

- Note: ANSI: American National Standards Institute

A Related OOP Language

- 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
  - 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`**, **`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, 9, released in 2017

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 Common Gateway Interface (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
  - Supports AI programming
  - Type checked, but dynamically
  - Used for CGI programming and form processing
  - 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
  - Supports procedural and functional programming with extensibility
  - Similar to JavaScript; can be extended to support OO programming
  - Supports lists, tuples, and hashes, all with its single data structure, the table
  - A relatively small and simple language, having only 21 reserved words

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

Other Programming Languages

- Google's GO (2007)
  - compiled, statically typed language in the tradition of Algol and C, with garbage collection
- Apple's Swift (2014)
  - Two categories of types, classes and struct
  - more resilient to erroneous code ("safer") than Objective-C
  - took language ideas from Objective-C, Haskell, Ruby, Python, C#, and far too many others.
  - Ref: https://en.wikipedia.org/wiki/Swift_(programming_language)
    https://en.wikipedia.org/wiki/Go_(programming_language)
    https://en.wikipedia.org/wiki/List_of_programming_languages