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Programming language type systemsType systemsGeneral conceptsType safetyStrong vs. weak typingMajor categoriesStatic vs. dynamicManifest vs. inferredNominal vs. structuralDuck typingMinor categoriesAbstractDependentFlow-sensitiveGradualIntersectionLatentRefinementSubstructuralUniqueSessionvteIn computer programming, one of the many ways that programming languages are colloquially classified is whether the language's type system makes it strongly typed or weakly typed (loosely typed). However, there is no precise technical definition of what the terms mean and different authors disagree about the implied meaning of the terms and the relative rankings of the "strength" of the type systems of mainstream programming languages.[1] For this reason, writers who wish to write unambiguously about type systems often eschew the terms "strong typing" and "weak typing" in favor of specific expressions such as "type safety".Generally, a strongly typed language has stricter typing rules at compile time, which implies that errors are more likely to happen during compilation. Most of these rules affect variable assignment, function return values, procedure arguments and function calling. Dynamically typed languages (where type checking happens at run time) can also be strongly typed. In dynamically typed languages, values, rather than variables, have types.A weakly typed language has looser typing rules and may produce unpredictable or even erroneous results or may perform implicit type conversion at runtime.[2] A different but related concept is latent typing.In 1974, Barbara Liskov and Stephen Zilles defined a strongly typed language as one in which "whenever an object is passed from a calling function to a called function, its type must be compatible with the type declared in the called function."[3]In 1977, K. Jackson wrote, "In a strongly typed language each data area will have a distinct type and each process will state its communication requirements in terms of these types."[4]A number of different language design decisions have been referred to as evidence of "strong" or "weak" typing. Many of these are more accurately understood as the presence or absence of type safety, memory safety, static type-checking, or dynamic type-checking."Strong typing" generally refers to use of programming language types in order to both capture invariants of the code, and ensure its correctness, and definitely exclude certain classes of programming errors. Thus there are many "strong typing" disciplines used to achieve these goals.Some programming languages make it easy to use a value of one type as if it were a value of another type. This is sometimes described as "weak typing".For example, Aahz Maruch observes that "Coercion occurs when you have a statically typed language and you use the syntactic features of the language to force the usage of one type as if it were a different type (consider the common use of void* in C). Coercion is usually a symptom of weak typing. Conversion, on the other hand, creates a brand-new object of the appropriate type."[5]As another example, GCC describes this as type-punning and warns that it will break strict aliasing. Thiago Macieira discusses several problems that can arise when type-punning causes the compiler to make inappropriate optimizations.[6]There are many examples of languages that allow implicit type conversions, but in a type-safe manner. For example, both C++ and C# allow programs to define operators to convert a value from one type to another with well-defined semantics. When a C++ compiler encounters such a conversion, it treats the operation just like a function call. In contrast, converting a value to the C type void* is an unsafe operation that is invisible to the compiler.Some programming languages expose pointers as if they were numeric values, and allow users to perform arithmetic on them. These languages are sometimes referred to as "weakly typed", since pointer arithmetic can be used to bypass the language's type system.Some programming languages support untagged unions, which allow a value of one type to be viewed as if it were a value of another type.In Luca Cardelli's article Typeful Programming,[7] a "strong type system" is described as one in which there is no possibility of an unchecked runtime type error. In other writing, the absence of unchecked run-time errors is referred to as safety or type safety; Tony Hoare's early papers call this property security.[8]This section possibly contains original research. Please improve it by verifying the claims made and adding inline citations. Statements consisting only of original research should be removed. (May 2018) (Learn how and when to remove this message)This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed. (May 2020) (Learn how and when to remove this message)Some of these definitions are contradictory, others are merely conceptually independent, and still others are special cases (with additional constraints) of other, more "liberal" (less strong) definitions. Because of the wide divergence among these definitions, it is possible to defend claims about most programming languages that they are either strongly or weakly typed. For instance:Java, Pascal, Ada, and C require variables to have a declared type, and support the use of explicit casts of arithmetic values to other arithmetic types. Java, C#, Ada, and Pascal are sometimes said to be more strongly typed than C, because C supports more kinds of implicit conversions, and allows pointer values to be explicitly cast while Java and Pascal do not. Java may be considered more strongly typed than Pascal as methods of evading the static type system in Java are controlled by the Java virtual machine's type system. C# and VB.NET are similar to Java in that respect, though they allow disabling of dynamic type checking by explicitly putting code segments in an "unsafe context". Pascal's type system has been described as "too strong", because the size of an array or string is part of its type, making some programming tasks very difficult. However, Delphi fixes this issue.[9][10]Smalltalk, Ruby, Python, and Self are all "strongly typed" in the sense that typing errors are prevented at runtime and they do little implicit type conversion, but these languages make no use of static type checking: the compiler does not check or enforce type constraint rules. The term duck typing is now used to describe the dynamic typing paradigm used by the languages in this group.The Lisp family of languages are all "strongly typed" in the sense that typing errors are prevented at runtime. Some Lisp dialects like Common Lisp or Clojure do support various forms of type declarations[11] and some compilers (CMU Common Lisp (CMUCL)[12] and related) use these declarations together with type inference to enable various optimizations and limited forms of compile time type checks.Standard ML, F#, OCaml, Haskell, Go and Rust are statically type-checked, but the compiler automatically infers a precise type for most values.Assembly language and Forth can be characterized as untyped. There is no type checking; it is up to the programmer to ensure that data given to functions is of the appropriate type.Comparison of programming languagesData type includes a more thorough discussion of typing issuesDesign by contract (strong typing as implicit contract form)Latent typingMemory safetyType safetyType systemStrongly typed identifier^ "What to know before debating type systems | Ovid [blogs.perl.org]". blogs.perl.org. Retrieved 2023-06-27.^ "CS1130. Transition to OO programming. Spring 2012 --self-paced version". Cornell University, Department of Computer Science. 2005. Archived from the original on 2015-11-23. Retrieved 2015-11-23.{{cite web}}: CS1 maint: bot: original URL status unknown (link)^ Liskov, B; Zilles, S (1974). "Programming with abstract data types". ACM SIGPLAN Notices. 9 (4): 5059. CiteSeerX10.1.1.136.3043. doi:10.1145/942572.807045.^ Jackson, K. (1977). "Parallel processing and modular software construction". 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Statements consisting only of original research should be removed. (August 2009) (Learn how and when to remove this message)Programming languages can be grouped by the number and types of paradigms supported.A concise reference for the programming paradigms listed in this article.Concurrent programming have language constructs for concurrency, these may involve multi-threading, support for distributed computing, message passing, shared resources (including shared memory), or futuresActor programming concurrent computation with actors that make local decisions in response to the environment (capable of selfish or competitive behaviour)Constraint programming relations between variables are expressed as constraints (or constraint networks), directing allowable solutions (uses constraint satisfaction or simplex algorithm)Dataflow programming forced recalculation of formulas when data values change (e.g. spreadsheets)Declarative programming describes what computation should perform, without specifying detailed state changes cf. imperative programming (functional and logic programming are major subgroups of declarative programming)Distributed programming have support for multiple autonomous computers that communicate via computer networksFunctional programming uses evaluation of mathematical functions and avoids state and mutable dataGeneric programming uses algorithms written in terms of to-be-specified-later types that are then instantiated as needed for specific types provided as parametersImperative programming explicit statements that change a program stateLogic programming uses explicit mathematical logic for programmingMetaprogramming writing programs that write or manipulate other programs (or themselves) as their data, or that do part of the work at compile time that would otherwise be done at runtimeTemplate metaprogramming metaprogramming methods in which a compiler uses templates to generate temporary source code, which is merged by the compiler with the rest of the source code and then compiledReflective programming metaprogramming methods in which a program modifies or extends itselfObject-oriented programming uses data structures consisting of data fields and methods together with their interactions (objects) to design programsClass-based object-oriented programming in which inheritance is achieved by defining classes of objects, versus the objects themselvesPrototype-based object-oriented programming that avoids classes and implements inheritance via cloning of instancesPipeline programming a simple syntax change to add syntax to nest function calls to language originally designed with noneRule-based programming a network of rules of thumb that comprise a knowledge base and can be used for expert systems and problem deduction & resolutionVisual programming manipulating program elements graphically rather than by specifying them textually (e.g. Simulink); also termed diagrammatic programming[1]List of multi-paradigm programming languagesLanguageParadigm countConcurrentConstraintsDataflowDeclarativeDistributedFunctionalMetaprogrammingGenericImperativeLogicReflectionObject-orientedPipelinesVisualRule-basedOtherAda[2][3][4][5][6]5Yes[a 1]YesYesYesYes[a 2]ALF2YesYesAmigaE[citation needed]2YesYes[a 2]APL3YesYesArray (multi-dimensional)BETA[citation needed]3YesYesYes[a 2]C++7 (15)Yes[7][8][9]Library[10]Library[11][12]Library[13][14]Library[15][16]YesYes[17]Yes[a 3]YesLibrary[18][19]Library[20]Yes[a 2]Library[21]Library[22]Array (multi-dimensional; using STL)C#6 (7)YesLibrary[a 4]Yes[a 5]YesYesYesYes[a 2]Reactive[a 6]ChucK[citation needed]3YesYesYes[a 2]Claire2YesYes[a 2]Clojure5Yes[23] [24]YesYes[25]Yes[26]Library[27]Yes[28]Multiple dispatch,[29] Agents[30]Common Lisp7 (14)Library[31]Library[32]Library[33]Yes[34]Library[35]YesYesYes[36]YesLibrary[37]YesYes[a 7][a 2][38]Library[39]Library[40]Library[41]Multiple dispatch, meta-OOP system,[42] Language is extensible via metaprogramming.Curl5YesYes[a 3]YesYesYes[a 2]Curry4YesYesYesYesD (version 2.0)[43][44]7Yes[a 8]YesYes[45][a 3]Yes[a 3]YesYesYes[a 2]Delphi3Yes[a 3]YesYes[a 2]Dylan[citation needed]3YesYesYes[a 2]E3YesYesYes[a 2]ECMAScript[46][47] (ActionScript, E4X, JavaScript, JScript)4 (5)Partial[a 9][a 10]Library[48][49]YesYesYesYes[a 11]Library[50][51]Reactive,[a 12][52] event driven[a 13][a 14]Erlang3YesYesYesYesYesElixir4YesYesYesYesYesElm6YesYesYesYes (pure)[a 15]YesYesReactiveF#7 (8)Yes[a 8]Library[a 4]YesYesYesYesYes[a 2]Reactive[a 6]Fortran4 (5)Yes[a 15]Yes[a 16]Yes[a 2]Array (multi-dimensional)Go4YesYesYesYesHaskell8 (15)YesLibrary[53]Library[54]YesLibrary[55]Yes (lazy) (pure)[a 15]Yes[56]YesYesLibrary[57]Partial[a 17]YesYesLibrary[58]Literate, reactive, dependent types (partial)Io4Yes[a 8]YesYesYes[a 11][citation needed]3YesYesYes[a 2]Java6YesLibrary[59]Library[60]YesYesYesYes[a 2]Julia9 (17)YesLibrary[61]Library[62][63]Library[64]YesYes (eager)YesYesYesLibrary[65]YesPartial[a 18]YesLibrary[66][67]Multiple dispatch,Array (multi-dimensional); optionally lazy[68] and reactive (with libraries)Kotlin8YesYesYesYesYesYesYesYesYesLabVIEW4YesYesYesYesLava2Yes[a 2]YesLispWorks (version 6.0 with support for symmetric multi-processing, rules, logic (Prolog), CORBA)9YesYesYesYesYesYesYes[a 2]YesLua[citation needed]3YesYesYes[a 11]MATLAB6 (10)Toolbox[69]Toolbox[70]Yes[71]Toolbox[72]Yes[73]Yes[74]Yes[75]Yes[76]Yes[77]Array (multi-dimensional)Nemerle7YesYesYesYesYesYes[a 2]Object Pascal4YesYesYes[a 2]OCaml4YesYesYes[a 2]Oz11YesYesYesYesYesYesYes[a 2]YesYesPerl[citation needed]8 (9)Yes[78]Yes[79]YesYesYes[a 2]Yes[a 2]YesPHP[80][81] [82]4YesYesYes[a 2]Poplog3YesYesYesPrograph3YesYes[a 2]YesPython5 (10)Library[83][84]Library[85]Library[86]YesYes[87][88]Yes[89][90]YesLibrary[91]YesYes[a 2]StructuredR4 (6)Library[92]Library[93]YesYesYesYes[94]Array (multi-dimensional)Racket10Yes[95]Yes[96]Yes[97]Yes[98]YesYesYesYesYesYesLazy[99]Raku10Yes[100]Library[101]Yes[102]Library[103]YesYes[104]Yes[105]YesYes[106]Yes[107]YesMultiple dispatch, lazy lists, reactive.ROOP3YesYesYesRuby5YesYesYesYes[a 2]Rust (version 1.0.0-alpha)6Yes[a 8]YesYes[108][109]Yes[110]YesYesLinear, affline, and ownership typesSather[citation needed]2YesYes[a 2]Scala[111][112]9Yes[a 8]Yes[a 19]YesYesYesYesYesYes[a 2]Simula[citation needed]2YesYes[a 2]SISAL3YesYesYesSpreadsheets2YesYesSwift7YesYesYesYesYesYes[a 2]Block-structuredTcl with Snit extension[citation needed]3Yes[113]YesYes[a 11][114]Visual Basic .NET6 (7)YesLibrary[a 4]YesYesYesYesYes[a 2]Reactive[a 6]Windows PowerShell6YesYesYesYesYes[a 2]YesWolfram Language & Mathematica13[115] (14)YesYesYesYesYesYesYesYes[116]YesKnowledge BasedProgramming paradigmList of programming languages by typeDomain-specific languageDomain-specific multimodeling^ rendezvous and monitor-like based^ a b c d e f g h i j k l m n o p q r s t u v w x y z aa ab ac ad ae af ag ah ai class-based^ a b c d e template metaprogramming^ a b c using TPL Dataflow^ only lambda support (lazy functional programming)^ a b c using Reactive Extensions (Rx)^ multiple dispatch, method combinations^ a b c d e actor programming^ promises, native extensions^ using Node.js' cluster module or child_process.fork method, web workers in the browser, etc.^ a b c d Prototype-based^ using Reactive Extensions (RxJS)^ in Node.js via their events module^ in browsers via their native EventTarget API^ a b c purely functional^ parameterized classes^ immutable^ Uses structs with function polymorphism and multiple dispatch^ Akka Archived 2013-01-19 at the Wayback Machine^ Bragg, S.D.; Driskill, C.G. (2022 September 1994). "Diagrammatic-graphical programming languages and DoD-STD-2167A". Proceedings of AUTOTESTCON '94 (IEEEXplore). Institute of Electrical and Electronics Engineers (IEEE). pp.211220. doi:10.1109/AUTEST.1994.381508. ISBN978-0-7803-1910-3. S2CID62509261.^ Ada Reference Manual, ISO/IEC 8652:2005(E) Ed. 3, Section 9: Tasks and Synchronization^ Ada Reference Manual, ISO/IEC 8652:2005(E) Ed. 3 Annex E: Distributed Systems^ Ada Reference Manual, ISO/IEC 8652:2005(E) Ed. 3, Section 12: Generic Units^ Ada Reference Manual, ISO/IEC 8652:2005(E) Ed. 3, Section 6: Subprograms^ Ada Reference Manual, ISO/IEC 8652:2005(E) Ed. 3, 3.9 Tagged Types and Type Extensions^ Thread support^ Atomics support^ Memory model^ Gecode^ SystemC^ Boost.Iostreams^ Boolinq^ "AraRat" (PDF). Archived from the original (PDF) on 2019-08-19. Retrieved 2019-09-15.^ OpenMPI^ Boost.MPI^ Boost.MPL^ LC++^ Castor Archived 2013-01-25 at the Wayback Machine^ Reflect Library^ N3534^ Boost.Spirit^ Clojure - Concurrent Programming^ Clojure - core.async^ Clojure - Functional Programming^ Clojure - Macros^ Clojure - core.logic^ Clojure - Threading Macros Guide^ Multimethods and Hierarchies^ Agents and Asynchronous Actions^ "concurrency". CLiki.^ [1] constraint programming inside CL through extensions^ [2] dataflow extension^ [3] by creating DSLs using the built-in metaprogramming; also see note on functional, constraint and logic paradigms, which are part of declarative^ [4] MPI, etc via language extensions^ template metaprogramming using macros (see C++)^ [5] [6] [7] Prolog implemented as a language extension^ Common Lisp Object System see Wikipedia article on CLOS, the Common Lisp Object System.^ implemented by the user via a short macro, example of implementation^ - Visual programming tool based on Common Lisp^ [8] rule-based programming extension^ [9] Archived 2018-04-26 at the Wayback Machine through the Meta Object Protocol^ D Language Feature Table^ Phobos std.algorithm^ D language String Mixins^ The Little JavaScripter demonstrates fundamental commonality with Scheme, a functional language.^ Object-Oriented Programming in JavaScript Archived 2019-02-10 at the Wayback Machine gives an overview of object-oriented programming techniques in JavaScript.^ "React A JavaScript library for building user interfaces". 2019-04-08.^ "TNG-Hooks". 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Retrieved 22 October 2016.^ Notes for Programming Language Experts, Wolfram Language Documentation.^ External Programs, Wolfram Language Documentation.Jim Coplien, Multiparadigm Design for C++, Addison-Wesley Professional, 1998.Retrieved from " Title: Dart by Example Authors John Ryan License(s): The MIT License (MIT) Publisher: jpryan.me Paperback: N/A eBook: HTML Language: English ISBN-10/ASIN: N/A ISBN-13: N/A Share This: Book Description Dart is an open-source,scalable programming language, with robust libraries and runtimes for building web, server, and mobile apps. This book is a hands-on introduction to Dart using annotated example programs, inspired by Go By Example and Haskell By Example. With example code projects such as a live data monitoring and viewing system, a blogging system, a slides presentation application, and more, then this book will walk you through step by step through building data-driven web applications with ease and speed. 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