# Programming Languages

Overview of PLs, Paradigms

## Outline

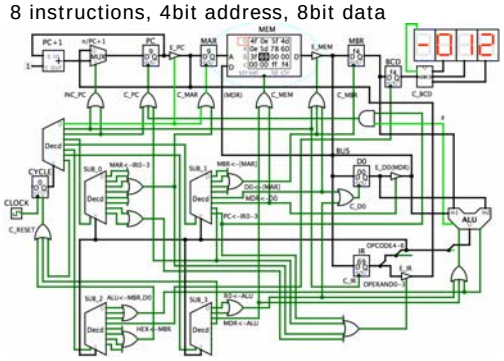
- What is Programming?
- Language Popularity
- Why Programming Languages?
- Programming Language Influence
- Major Programming Languages
- Programming Language Paradigms
- Programming Languages Evolutions

## Computer Foundation

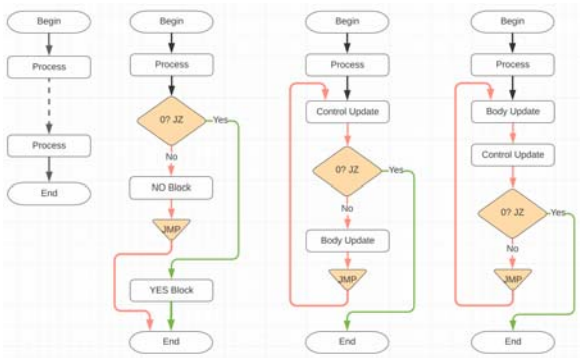
- Computer Foundations (221)
  - Turing machine (TM)
    - Tape read/write, Tape move, Operations
  - Universal Turing Machine (UTM)
  - UTM emulates solver TM
    - Hardware – UTM
    - Software – TMs
  - Instructions as vocabulary of TM
    - Read/write, jmp/jz, add…
    - LD/ST, BR/BRz, ADD/AND/NOT
  - 3 Programming Structures
    - Sequential, selective, iterative

## An Working UTM – CPU

- TinyCPU (321)
  - 8 instructions, 4bit address, 8bit data



## Programming at the Lowest Level




## Programming at the Low Level

- Recall LC3
- Just Observation/Conclusions
  - Program = Data(reg/mem) + Control (if/loop)
  - Programming = changing machine states
    - Machine state = reg+mem content
  - Very hard for human
  - Very low expressive power
  - Can get the job done
- Driven force of CS – Demand, L&G
- Over 3000 languages
  - How easy to create a new language?

# How Popular are Various PLs (1)?

| Position Jan 2006 | Position Jan 2005 | Delta | Programming Language | Ratings Jan 2006 | Delta Jan 2005 | Status |
|---|---|---|---|---|---|---|
| 1 | 2 | | Java | 22.254% | +4.77% | A |
| 2 | 1 | | C | 19.008% | -1.70% | A |
| 3 | 3 | | C++ | 11.464% | -0.46% | A |
| 4 | 4 | | PHP | 9.402% | -0.07% | A |
| 5 | 5 | | (Visual) Basic | 9.089% | +1.16% | A |
| 6 | 6 | | Perl | 7.045% | -0.41% | A |
| 7 | 9 | | C# | 3.554% | +1.35% | A |
| 8 | 7 | | Python | 2.604% | -0.23% | A |
| 9 | 8 | | Delphi/Kylix | 1.582% | -0.98% | A |
| 10 | 10 | | JavaScript | 1.538% | -0.16% | A |
| 11 | 12 | | SAS | 1.162% | -0.24% | A |
| 12 | 11 | | PL/SQL | 1.032% | -0.62% | A |
| 13 | 13 | | COBOL | 0.763% | -0.30% | A |
| 14 | 17 | | Lisp/Scheme | 0.604% | +0.00% | A-- |
| 15 | 16 | | Pascal | 0.525% | -0.11% | B |
| 16 | 25 | | ColdFusion | 0.520% | +0.25% | B |
| 17 | 18 | | VB.NET | 0.511% | -0.04% | A-- |
| 18 | 19 | | Fortran | 0.466% | -0.05% | B |
| 19 | 20 | | Ada | 0.465% | -0.02% | B |
| 20 | 48 | ! | Visual FoxPro | 0.448% | +0.37% | B |

# How Popular are Various PLs (2)?

| Position May 2009 | Position May 2008 | Delta | Programming Language | Ratings May 2009 | Delta May 2008 | Status |
|---|---|---|---|---|---|---|
| 1 | 1 | | Java | 19.537% | -1.35% | A |
| 2 | 2 | | C | 16.128% | +0.62% | A |
| 3 | 3 | | C++ | 11.068% | +0.26% | A |
| 4 | 4 | | PHP | 9.921% | -0.28% | A |
| 5 | 5 | | (Visual) Basic | 8.631% | -1.16% | A |
| 6 | 7 | | Python | 5.548% | +0.65% | A |
| 7 | 8 | | C# | 4.266% | +0.21% | A |
| 8 | 9 | | JavaScript | 3.548% | +0.62% | A |
| 9 | 6 | | Perl | 3.525% | -2.02% | A |
| 10 | 10 | | Ruby | 2.692% | +0.05% | A |
| 11 | 11 | | Delphi | 2.327% | +0.30% | A |
| 12 | 14 | | PL/SQL | 1.101% | +0.34% | A |
| 13 | 13 | | SAS | 0.801% | -0.12% | A |
| 14 | 15 | | Pascal | 0.776% | +0.18% | A |
| 15 | 26 | | RPG (OS/400) | 0.678% | +0.43% | B |
| 16 | 27 | | ABAP | 0.670% | +0.43% | B |
| 17 | 12 | | D | 0.628% | -0.82% | A- |
| 18 | 23 | | MATLAB | 0.517% | +0.25% | B |
| 19 | 21 | | Logo | 0.504% | +0.17% | A- |
| 20 | 19 | | Lua | 0.486% | +0.12% | B |

http://www.tiobe.com/tpci.htm

# How Popular are Various PLs (3)?

| Position Aug 2013 | Position Aug 2012 | Delta | Programming Language | Ratings | Delta | Status |
|---|---|---|---|---|---|---|
| 1 | 2 | | Java | 15.978% | -0.37% | A |
| 2 | 1 | | C | 15.974% | -2.96% | A |
| 3 | 4 | | C++ | 9.371% | +0.04% | A |
| 4 | 3 | | Objective-C | 8.082% | -1.46% | A |
| 5 | 6 | | PHP | 6.694% | +1.17% | A |
| 6 | 5 | | C# | 6.117% | -0.47% | A |
| 7 | 7 | | (Visual) Basic | 3.873% | -1.46% | A |
| 8 | 8 | | Python | 3.603% | -0.27% | A |
| 9 | 11 | | JavaScript | 2.093% | +0.73% | A |
| 10 | 10 | | Ruby | 2.067% | +0.38% | A |
| 11 | 9 | | Perl | 2.041% | -0.23% | A |
| 12 | 15 | | Transact-SQL | 1.393% | +0.54% | A |
| 13 | 14 | | Visual Basic .NET | 1.320% | +0.44% | A |
| 14 | 12 | | Delphi/Object Pascal | 0.918% | -0.09% | A-- |
| 15 | 20 | | MATLAB | 0.841% | +0.31% | A-- |
| 16 | 13 | | Lisp | 0.752% | -0.22% | A |
| 17 | 19 | | PL/SQL | 0.751% | +0.14% | A |
| 18 | 16 | | Pascal | 0.620% | -0.17% | A- |
| 19 | 23 | | Assembly | 0.616% | +0.11% | B |
| 20 | 22 | | SAS | 0.580% | +0.06% | B |

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# How Popular are Various PLs (4)?

| Position Dec 2015 | Position Dec 2016 | Change | Programming Language | Ratings | Delta | Status |
|---|---|---|---|---|---|---|
| 1 | 1 | change | Java | 17.856% | -3.12% | |
| 2 | 2 | change | C | 8.726% | -7.73% | |
| 3 | 3 | change | C++ | 5.335% | -0.61% | |
| 4 | 4 | change | Python | 4.239% | -0.19% | |
| 5 | 7 | change | Visual Basic .NET | 3.302% | +0.91% | |
| 6 | 5 | change | C# | 3.171% | -0.94% | |
| 7 | 6 | change | PHP | 2.919% | +0.13% | |
| 8 | 8 | change | JavaScript | 2.862% | +0.50% | |
| 9 | 11 | change | Assembly language | 2.539% | +0.61% | |
| 10 | 9 | change | Perl | 2.338% | +0.13% | |
| 11 | 15 | change | Objective-C | 2.325% | +0.97% | |
| 12 | 10 | change | Ruby | 2.147% | +0.09% | |
| 13 | 14 | change | Swift | 2.134% | +0.73% | |
| 14 | 12 | change | Visual Basic | 1.967% | +0.31% | |
| 15 | 13 | change | Delphi/Object Pascal | 1.950% | +0.31% | |
| 16 | 50 | change | Go | 1.939% | +1.74% | |
| 17 | 18 | change | R | 1.826% | +0.70% | |
| 18 | 16 | change | MATLAB | 1.818% | +0.65% | |
| 19 | 24 | change | Groovy | 1.786% | +1.01% | |
| 20 | 19 | change | PL/SQL | 1.495% | +0.39 | |

http://www.tiobe.com/tpci.htm

# How Popular are Various PLs (5)?

| Position Dec 2018 | Position Dec 2019 | Change | Programming Language | Ratings | Delta | Status |
|---|---|---|---|---|---|---|
| 1 | 1 | | Java | 13.268% | -4.59% | |
| 2 | 2 | | C | 10.158% | +1.43% | |
| 3 | 3 | | C++ | 4.717% | -0.62% | |
| 4 | 4 | | Python | 3.777% | -0.46% | |
| 5 | 6 | change | C# | 2.822% | -0.35% | |
| 6 | 8 | change | JavaScript | 2.474% | -0.39% | |
| 7 | 5 | change | Visual Basic .NET | 2.471% | -0.83% | |
| 8 | 17 | change | R | 1.906% | +0.08% | |
| 9 | 7 | change | PHP | 1.590% | -1.33% | |
| 10 | 18 | change | MATLAB | 1.569% | -0.25% | |
| 11 | 13 | change | Swift | 1.566% | -0.57% | |
| 12 | 11 | change | Objective-C | 1.497% | -0.83% | |
| 13 | 9 | change | Assembly language | 1.471% | -1.07% | |
| 14 | 10 | change | Perl | 1.437% | -0.90% | |
| 15 | 12 | change | Ruby | 1.424% | -0.72% | |
| 16 | 15 | change | Delphi/Object Pascal | 1.395% | -0.55% | |
| 17 | 16 | change | Go | 1.387% | -0.55% | |
| 18 | 25 | change | Scratch | 1.374% | +0.19% | |
| 19 | 20 | change | PL/SQL | 1.368% | -0.13% | |
| 20 | 14 | change | Visual Basic | 1.347% | -0.62% | |

http://www.tiobe.com/tpci.htm

# How Popular are Various PLs (6)?

| Position Dec 2019 | Position Dec 2020 | Change | Programming Language | Ratings | Delta | Status |
|---|---|---|---|---|---|---|
| 1 | 2 | change | C | 16.98% | +1.83% | 1 |
| 2 | 1 | change | Java | 14.43% | -1.60% | 2 |
| 3 | 3 | | Python | 9.69% | -0.33% | 3 |
| 4 | 4 | | C++ | 6.84% | +0.78% | 4 |
| 5 | 5 | | C# | 4.68% | +0.83% | 5 |
| 6 | 6 | | Visual Basic | 4.66% | +0.97% | 6 |
| 7 | 7 | | JavaScript | 2.87% | +0.62% | 7 |
| 8 | 20 | change | R | 2.79% | +1.97% | 8 |
| 9 | 8 | change | PHP | 2.24% | +0.17% | 9 |
| 10 | 10 | | SQL | 1.46% | -0.17% | 10 |
| 11 | 17 | change | Go | 1.43% | +0.45% | 11 |
| 12 | 18 | change | Swift | 1.42% | +0.53% | 12 |
| 13 | 19 | change | Perl | 1.11% | +0.25% | 13 |
| 14 | 15 | change | Assembly language | 1.04% | -0.07% | 14 |
| 15 | 11 | change | Ruby | 1.03% | -0.28% | 15 |
| 16 | 12 | change | MATLAB | 0.86% | -0.41% | 16 |
| 17 | 16 | change | Classic Visual Basic | 0.82% | -0.20% | 17 |
| 18 | 13 | change | Groovy | 0.77% | -0.46% | 18 |
| 19 | 9 | change | Objective-C | 0.76% | -0.93% | 19 |
| 20 | 28 | change | Rust | 0.74% | +0.29% | 20 |

http://www.tiobe.com/tpci.htm

## How Popular are Various PLs (7)?

| Position Aug 2022 | Position Aug 2021 | Change | Programming Language | Ratings | Delta | Status |
|---|---|---|---|---|---|---|
| 1 | 2 | change | Python | 15.42% | +3.56% | |
| 2 | 1 | change | C | 14.59% | +2.03% | |
| 3 | 3 | | Java | 12.40% | +1.96% | |
| 4 | 4 | | C++ | 10.17% | +2.81% | |
| 5 | 5 | | C# | 5.59% | +0.45% | |
| 6 | 6 | | Visual Basic | 4.99% | +0.33% | |
| 7 | 7 | | JavaScript | 2.33% | -0.61% | |
| 8 | 9 | change | Assembly language | 2.17% | +0.14% | |
| 9 | 10 | change | SQL | 1.70% | +0.23% | |
| 10 | 8 | change | PHP | 1.39% | -0.80% | |
| 11 | 16 | change | Swift | 1.27% | +0.30% | |
| 12 | 12 | change | Classic Visual Basic | 1.27% | +0.04% | |
| 13 | 22 | change | Delphi/Object Pascal | 1.22% | +0.60% | |
| 14 | 23 | change | Objective-C | 1.22% | +0.61% | |
| 15 | 18 | change | Go | 0.98% | +0.08% | |
| 16 | 14 | change | R | 0.92% | -0.13% | |
| 17 | 17 | change | MATLAB | 0.90% | -0.08% | |
| 18 | 15 | change | Ruby | 0.82% | -0.18% | |
| 19 | 13 | change | Fortran | 0.81% | -0.32% | |
| 20 | 20 | change | Perl | 0.72% | -0.06% | |

https://www.tiobe.com/tiobe-index/

## Motivation: Why Study PLs?

- Increased ability to express ideas
- Improved background for choosing appropriate languages
- Greater ability to learn new languages
- Understand significance of implementation
- Ability to design new languages
- Overall advancement of computing
- Bottom line – tool to drive computers
- Your thought?

## Similarity of PLs

- Programming languages are related
  - Programming language concepts tend to be constant, like design principles.
  - The language designers borrow ideas or concepts from each other, use them with a different implementation.
- Similarity 'Levels'
  - Syntax
  - Concept
  - Paradigm

## Syntax Level Similarity

- Dart Kotlin Swift TypeScript


## Dynamic Binding and Reflection

- Recall your Java 'Polymorphism'
- 100 Rect and Circ objects, 100 display
  - How many variables?
  - How many new()?
  - How many display()?
  - How many lines in total?
- Dynamic Binding, Reflection, Optional Args
- Demand driven
- Revisit in December

## Languages (1)

```
program mine(output);

  procedure print(var i: integer);

    function next(i: integer): integer;
    begin
      next := i + 1
    end;

  begin
    writeln('The total is: ', i);
    i := next(i)
  end;

begin
  i := 1;
  while i <= 10 do print(i)
end.
```

## Languages (2)

```
program HelloWorld(output);

begin
  writeln('Hello, World!')
end.
```

```
with Ada.Text_IO;

procedure Hello is
begin
   Ada.Text_IO.Put_Line("Hello, world!");
end Hello;
```

http://www.roesler-ac.de/wolfram/hello.htm

## Languages (3)

```
/* hello.c -- initialize the toolkit using an application context and a
** toplevel shell widget, then create a pushbutton that says Hello using
** the varargs interface.
*/
#include <Xm/PushB.h>

main (int argc, char *argv[]){
     Widget       toplevel, button;
     XtAppContext app;
     void         button_pushed(Widget, XtPointer, XtPointer);
     XmString     label;
     Arg          args[2];

     XtSetLanguageProc (NULL, NULL, NULL);

     toplevel = XtVaOpenApplication (&app, "Hello", NULL, 0, &argc, argv, NULL,
                                     sessionShellWidgetClass, NULL);

     label = XmStringCreateLocalized ("Push here to say hello");
     XtSetArg(args[0], XmNlabelString, label);
     button = XmCreatePushButton (toplevel, "pushme", args, 1);
     XmStringFree (label);

     XtAddCallback (button, XmNactivateCallback, button_pushed, NULL);
     XtManageChild (button);

     XtRealizeWidget (toplevel);
     XtAppMainLoop (app);
}

void button_pushed (Widget widget, XtPointer client_data, XtPointer call_data){
    printf ("Hello Yourself!\n");
}
```

## Languages (4)

```
qsort( a, lo, hi )
int a[], hi, lo; {
  int h, l, p, t;

  if (lo < hi) {
    l = lo;
    h = hi;
    p = a[hi];

    do {
      while ((l < h) && (a[l] <= p))
          l = l+1;
      while ((h > l) && (a[h] >= p))
          h = h-1;
      if (l < h) {
          t = a[l];
          a[l] = a[h];
          a[h] = t;
      }
    } while (l < h);

    t = a[l];
    a[l] = a[hi];
    a[hi] = t;

    qsort( a, lo, l-1 );
    qsort( a, l+1, hi );
  }
}
```

## Languages (5)

```
qsort []     = []
qsort (x:xs) = qsort (filter (< x) xs) ++ [x] ++
  qsort (filter (>= x) xs)
```

```
#
# Example 18-1
# "Hello, World!" Tk program.
#

#!/usr/local/bin/wish
button .hello -text Hello \
  -command {puts stdout "Hello, World!"}
pack .hello -padx 20 -pady 10
```

## Languages (6)

```
fun fac : (fn: int -> int) 0 = 1
 | fac n = n * fac (n-1);
```

```
fac :: Integer -> Integer
fac 0 = 1
fac n | n > 0 = n * fac (n-1)
```

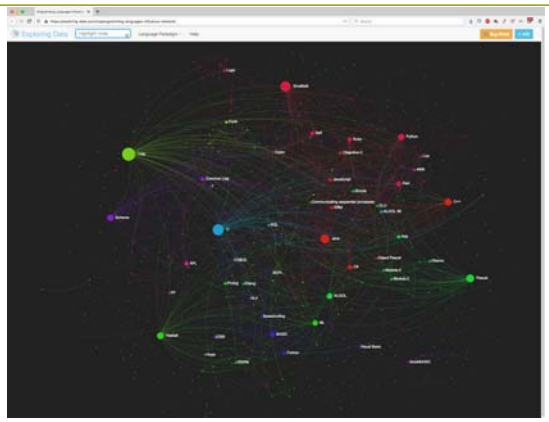
```
(defun fac (n)
  (if (= n 0) 1
     (* n (fac (- n 1)))))
```

## How to Learn All PLs?

- Which is the best PL?
  - Instead, the more important thing I want to share is: How to master the skills of learning a new programming language.
- Why are there so many PLs?
- Language Evolution, Influence
- Focus on language concepts, not syntax
- Goal of this class
  - This class will NOT focus on Syntax
  - This class will NOT focus on Concepts
  - This class will make you COMPLETE

https://coderscat.com/learn-programming-languages/

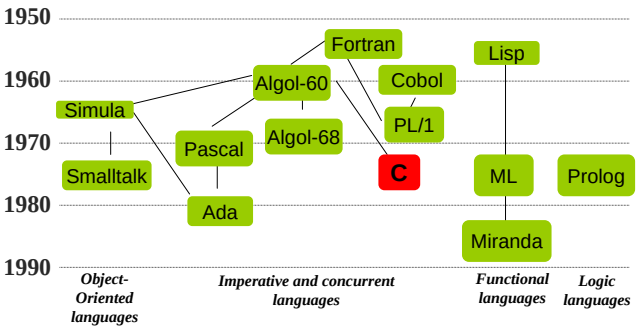
## Programming Language Influence



## Paradigms of PLs

- Classify thousands of languages in
- Paradigms
- 4 Major Paradigms
  - Imperative
  - Functional
  - Logical
  - OO

## High-Level Languages




Dates and ancestry of major programming languages, Watt [1990]