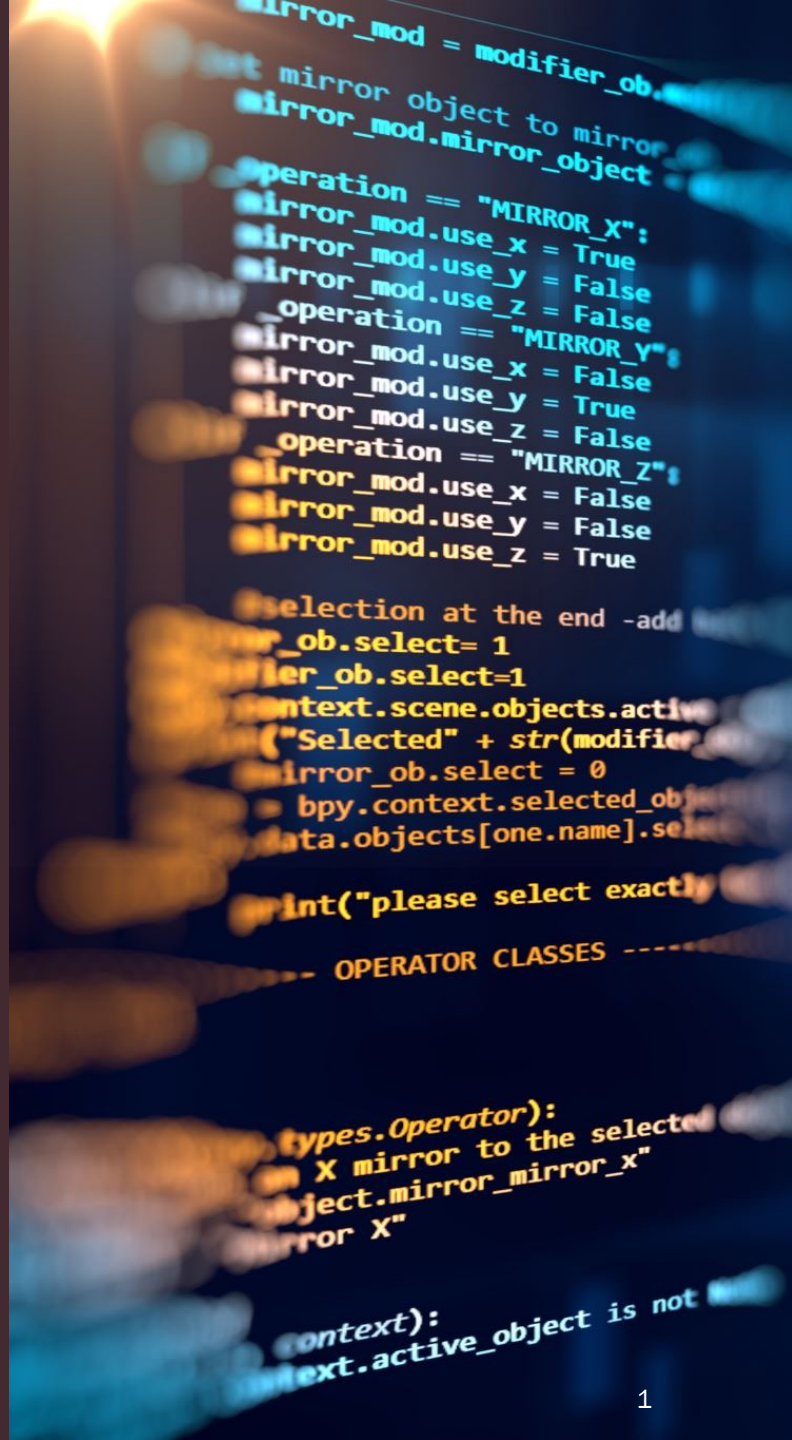
PROGRAMMING LANGUAGES



Outline

- What makes programming languages an interesting subject?
  - *The amazing variety*
  - *The odd controversies*
  - *The intriguing evolution*
  - *The connection to programming practice*
  - *The many other connections*

The Amazing Variety

- There are very many, very different languages
  - *A list that used to be posted occasionally on* `comp.lang.misc` *had over 2300 published languages in 1995*
- Often grouped into four families:
  - *Imperative*
  - *Functional*
  - *Logic*
  - *Object-oriented*

Imperative Languages

- Example: a factorial function in C

```
int fact(int n) {
  int sofar = 1;
  while (n>0) sofar *= n--;
  return sofar;
}
```

- Hallmarks of imperative languages:
  - *Assignment*
  - *Iteration*
  - *Order of execution is critical*

Functional Languages

- Example: a factorial function in ML

```
fun fact x =
  if x <= 0 then 1 else x * fact(x-1);
```

- Hallmarks of functional languages:
  - *Single-valued variables*
  - *Heavy use of recursion*

Another Functional Language

- Example: a factorial function in Lisp

```
(defun fact (x)
  (if (<= x 0) 1 (* x (fact (- x 1)))))
```

- Looks very different from ML
- But ML and Lisp are closely related
  - *Single-valued variables: no assignment*
  - *Heavy use of recursion: no iteration*

Logic Languages

- Example: a factorial function in Prolog

```
fact(X,1) :-
  X =:= 1.
fact(X,Fact) :-
  X > 1,
  NewX is X - 1,
  fact(NewX,NF),
  Fact is X * NF.
```

- Hallmark of logic languages
  - *Program expressed as rules in formal logic*

Object-Oriented Languages

- Example: a Java definition for a kind of object that can store an integer and compute its factorial

```
public class MyInt {
  private int value;
  public MyInt(int value) {
    this.value = value;
  }
  public int getValue() {
    return value;
  }
  public MyInt getFact() {
    return new MyInt(fact(value));
  }
  private int fact(int n) {
    int sofar = 1;
    while (n > 1) sofar *= n--;
    return sofar;
  }
}
```

Object-Oriented Languages

- Hallmarks of object-oriented languages:
  - *Usually imperative, plus…*
  - *Constructs to help programmers use "objects"—little bundles of data that know how to do things to themselves*

Strengths and Weaknesses

- The different language groups show to advantage on different kinds of problems
- Decide for yourself at the end of the semester, after experimenting with them
- For now, one comment: don't jump to conclusions based on factorial!
  - *Functional languages do well on such functions*
  - *Imperative languages, a bit less well*
  - *Logic languages, considerably less well*
  - *Object-oriented languages need larger examples*

About Those Families

- There are many other language family terms (not exhaustive and sometimes overlapping)
  - *Applicative, concurrent, constraint, declarative, definitional, procedural, scripting, single-assignment, …*
- Some *multi-paradigm* languages straddle families: JavaScript, OCaml, Python, Ruby
- Others are so unique that assigning them to a family is pointless

Example: Forth Factorial

```
: FACTORIAL
   1 SWAP BEGIN ?DUP WHILE TUCK * SWAP 1- REPEAT ;
```

- A stack-oriented language
- Postscript is similar
- Could be called *imperative*, but has little in common with most imperative languages

Example: APL Factorial

×/⍳X

- An APL expression that computes X's factorial
- Expands X it into a vector of the integers 1..X, then multiplies them all together
- (You would not really do it that way in APL, since there is a predefined factorial operator: !X)
- Could be called *functional*, but has little in common with most functional languages

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The Odd Controversies

- Programming languages are the subject of many heated debates:
  - *Partisan arguments*
  - *Language standards*
  - *Fundamental definitions*

Language Partisans

- There is a lot of argument about the relative merits of different languages
- Every language has partisans, who praise it in extreme terms and defend it against all detractors

Language Standards

- The documents that define language standards are often drafted by international committees
- Can be a slow, complicated and rancorous process
- Fortran 82 8X 88 90 standard released in 1991

Basic Definitions

- Some terms refer to fuzzy concepts: all those language family names, for example
- No problem; just remember they are fuzzy
  - *Bad: Is X really an object-oriented language?*
  - *Good: What aspects of X support an object-oriented style of programming?*
- Some crisp concepts have conflicting terminology: one person's *argument* is another person's *actual parameter*

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The Intriguing Evolution

- Programming languages are evolving rapidly
  - *New languages are being invented*
  - *Old ones are developing new dialects*

New Languages

- A clean slate: no need to maintain compatibility with an existing body of code
- But never entirely *new* any more: always using ideas from earlier designs
- Some become widely used, others do not
- Whether widely used or not, they can serve as a source of ideas for the next generation

Widely Used: Java

- Quick rise to popularity since 1995 release
- Java uses many ideas from C++, plus some from Mesa, Modula, and other languages
- C++ uses most of C and extends it with ideas from Simula 67, Ada, Clu, ML and Algol 68
- C was derived from B, which was derived from BCPL, which was derived from CPL, which was derived from Algol 60

Not Widely Used: Algol

- One of the earliest languages: Algol 58, Algol 60, Algol 68
- Never widely used
- Introduced many ideas that were used in later languages, including
  - *Block structure and scope*
  - *Recursive functions*
  - *Parameter passing by value*

Dialects

- Experience with languages reveals their design weaknesses and leads to new dialects
- New ideas pass into new dialects of old languages

Some Dialects Of Fortran

- Original Fortran, IBM
- Major standards:
  - *Fortran II*
  - *Fortran III*
  - *Fortran IV*
  - *Fortran 66*
  - *Fortran 77*
  - *Fortran 90*
  - *Fortran 95*
  - *Fortran 2003*
  - *Fortran 2008?*

Deviations in each implementation

Parallel processing

- HPF
- Fortran M
- Vienna Fortran

And many more…

Outline

- *The connection to programming practice*

The Connection To Programming Practice

- Languages influence programming practice
  - *A language favors a particular programming style—a particular approach to algorithmic problem-solving*
- Programming experience influences language design

Language Influences Programming Practice

- Languages often strongly favor a particular style of programming
  - *Object-oriented languages: a style making heavy use of objects*
  - *Functional languages: a style using many small side-effect-free functions*
  - *Logic languages: a style using searches in a logically-defined problem space*

Fighting the Language

- Languages favor a particular style, but do not force the programmer to follow it
- It is always possible to write in a style not favored by the language
- It is not usually a good idea…

Imperative ML

ML makes it hard to use assignment and side-effects. But it is still possible:

```
fun fact n =
  let
    val i = ref 1;
    val xn = ref n
  in
    while !xn>1 do (
      i := !i * !xn;
      xn := !xn - 1
    );
    !i
  end;
```

Non-object-oriented Java

Java, more than C++, tries to encourage you to adopt an object-oriented mode. But you can still put your whole program into static methods of a single class:

```
class Fubar {
  public static void main (String[] args) {
    // whole program here!
  }
}
```

Functional Pascal

Any imperative language that supports recursion can be used as a functional language:

```
function ForLoop(Low, High: Integer): Boolean;
  begin
    if Low <= High then
      begin
        {for-loop body here}
        ForLoop := ForLoop(Low+1, High)
      end
    else
      ForLoop := True
  end;
```

Programming Experience Influences Language Design

- Corrections to design problems make future dialects, as already noted
- Programming styles can emerge before there is a language that supports them
  - *Programming with objects predates object-oriented languages*
  - *Automated theorem proving predates logic languages*

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Other Connections: Computer Architecture

- Language evolution drives and is driven by hardware evolution:
  - *Call-stack support – languages with recursion*
  - *Parallel architectures – parallel languages*
  - *Internet – Java*

Other Connections: Theory of Formal Languages

- Theory of formal languages is a core mathematical area of computer science
  - *Regular grammars, finite-state automata – lexical structure of programming languages, scanner in a compiler*
  - *Context-free grammars, pushdown automata – phrase-level structure of programming languages, parser in a compiler*
  - *Turing machines – Turing-equivalence of programming languages*

Turing Equivalence

- Languages have different strengths, but fundamentally they all have the same power
  - *{problems solvable in Java}*
    = *{problems solvable in Fortran}*
    = …
- And all have the same power as various mathematical models of computation
  - = *{problems solvable by Turing machine}*
    = *{problems solvable by lambda calculus}*
    = …
- *Church-Turing thesis*: this is what "computability" means

Conclusion

- Why programming languages are worth studying (and this course worth taking):
  - *The amazing variety*
  - *The odd controversies*
  - *The intriguing evolution*
  - *The connection to programming practice*
  - *The many other connections*
- Plus…there is the fun of learning three new languages!