Welcome - CSC 301

CSC 301- Fundamentals of Programming Languages

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(for more details see BrightSpace)

Why Study Programming Languages?

- Amazing variety
  - ~2300 different programming languages discussed on online forums*.
- "Strange" controversies
  - Should a programming language have a 'goto' statement?
  - Should an OO language support inheritance?
  - Terminology: argument vs. actual parameter.
- Many connections
  - Programming languages touch upon virtually all areas of computer science: from the mathematical theory of **formal languages** and **automata** to the implementation of **operating systems**.
- Intriguing evolution
  - Programming languages change!
    - New ideas and experiences trigger new languages.
    - New languages trigger new ideas, etc.

*Source: Webber, Modern Programming Languages: A Practical Introduction.

Programming Language Classes

There are many different programming language classes, but three classes or paradigms stand out:

- Imperative Languages
- Functional Languages
- Logic/Rule Based Languages

What Happened to OOP?

- Object-orientation is really a property of the type system of a language.
- OO features have traditionally been added to imperative languages (C++, Java, Python)
- Object-oriented features have also been added to:
  - Functional programming languages like Lisp (CLOS)
  - Logic languages like Prolog (Logtalk)
- Here we look at object-based programming within the multi-paradigm language Asteroid

Meet Our Languages

- Asteroid – An object-based, imperative, and functional programming language being developed right here at URI
  - asteroid-lang.org
- Prolog – A logic programming language, most famously used in IBM Watson
  - The IBM Watson knowledge base was filled with 200 million pages of information, including the entire Wikipedia website. To parse the questions into a form that IBM Watson could understand, the IBM team used Prolog to parse natural-language questions into new facts that could be used in the IBM Watson pipeline. In 2011, the system competed in the game *Jeopardy!* and defeated former winners of the game.
  - www.swi-prolog.com

Source: developer.ibm.com/articles/cc-languages-artificial-intelligence/

Example Computation

- Recursive definition of the factorial operator

$$x! = \begin{cases} 1 \text{ if } x = 1, \\ x(x-1)! \text{ otherwise.} \end{cases}$$

for all $x > 0$.

Imperative Languages

- Hallmarks: assignment and iteration
- Examples: C, FORTRAN, Imperative sublanguage of Asteroid
- Example Program: factorial program in (imperative) Asteroid

```
function fact with n:%integer do
  let val = 1.
  while n > 1 do
    let val = val*n.
    let n = n-1.
  end
  return val.
end
```

Imperative Languages

Observations:

- The program text determines the order of execution of the statements.
- We have the notion of a '*current value*' of a variable – accessible state of variable.

This is not always true in other languages.

Imperative Asteroid

```
1  -- compute the factorial
2
3  load system "io".
4  load system "type".
5
6  function fact with n:%integer do
7    let val = 1.
8    while n > 1 do
9      let val = val*n.
10     let n = n-1.
11   end
12   return val.
13 end
14
15 let x = tointeger(input("Enter a positive integer: ")).
16 println ("The factorial of "+x+" is "+(fact x)).
```

Functional Languages

- Hallmarks: recursion, multi-dispatch, single valued variables.
- Examples: ML, Lisp, Haskell, Functional sublanguage of Asteroid
- Example Program: factorial program in (functional) Asteroid

multi-dispatch

```
function fact
  with 1 do
    return 1
  orwith n:%integer do
    return n*fact(n-1).
end
```

n is single valued variable.

recursion

Functional Languages

Observations:

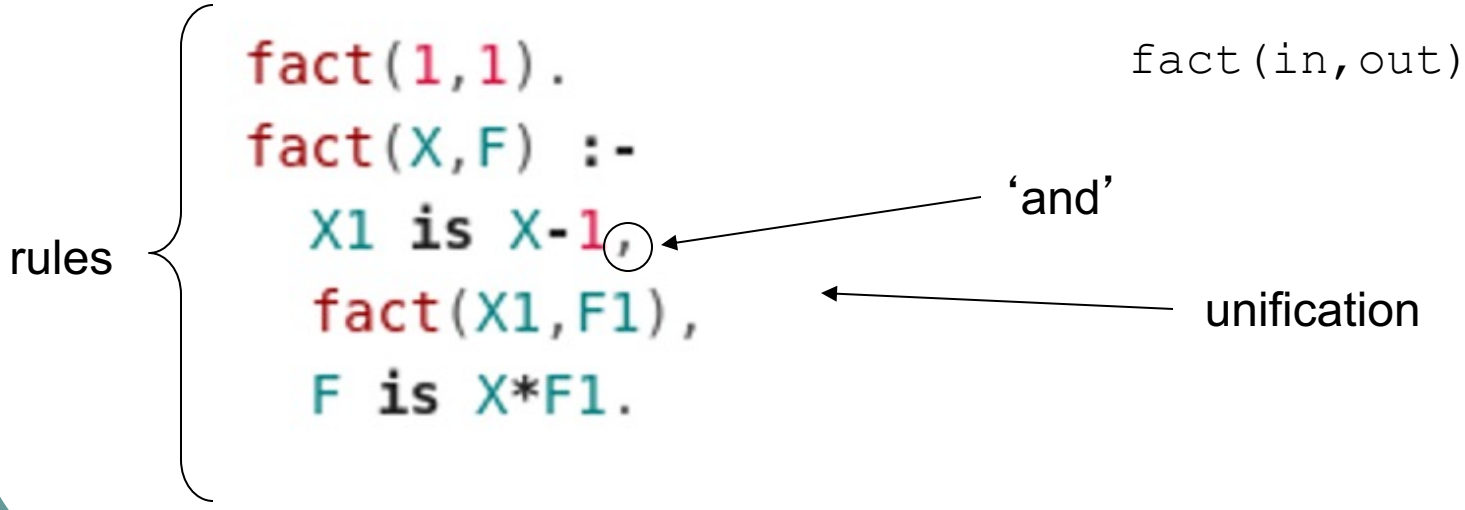
- There are **no** explicit assignments.
- The name stems from the fact that programs consist of *recursive* definitions of **functions**.

Functional Asteroid

```
1  -- compute the factorial
2
3  load system "io".
4  load system "type".
5
6  function fact
7    with 1 do
8      return 1
9    orwith n:%integer do
10     return n*fact(n-1).
11 end
12
13 let x = tointeger(input("Enter a positive integer: ")).
14 println ("The factorial of "+x+" is "+(fact x)).
```

Logic Programming Languages

- Hallmarks: programs consist of **rules** that specify the problem solution.
- Examples: Prolog, Maude, Isabelle
- Example Program: factorial program written in Prolog



Logic Programming Languages

Observations:

- Rules do *not* appear in the order of execution in the program text.
- No specific order of execution is given – rules ‘fire’ when necessary.

Prolog

```
% factorial program

fact(1,1).
fact(X,F) :-
  X1 is X-1,
  fact(X1,F1),
  F is X*F1.

compute :-
  X is 3,
  fact(X,F),
  writeln(F).
```

Object-Based Languages

- Hallmarks: bundle data with the allowed operations ☞ Objects
- Asteroid takes an interesting approach here – structures with functions.

```
1  -- simple object-based program
2
3  load system "io".
4
5  -- define our rectangular structure with member functions
6  structure Rect with
7  ··data xdim.
8  ··data ydim.
9
10 ··-- return the area of the rectangle
11 ··function area with none do
12 ····return this@xdim * this@ydim.
13 ··end
14 end
15
16 let r = Rect(4,2).
17 println ("The area of rectangle <"+r@xdim+","+r@ydim+"> is "+r@area()).
```

Programming Language Classes

General Observations:

- Programming languages guide programmers towards a particular programming style:
  - Imperative → iteration/assignment
  - Functional → mathematical functions
  - OO → objects
  - Logic → rules
- Programming itself guides the developer towards new language ideas:
  - Recursion was introduced by John McCarthy in the 1950's with the programming language Lisp to solve problems in AI.
  - Classes and objects were developed by Nygaard and Dahl in the 1960's and 70's for the language Simula in order to solve problem in simulations.

Take Away

- There exist many programming languages today (> 2000)
- In order to understand the similarities and differences $\Rightarrow$ sort into *classes*
  - Imperative
    - assignment and iteration
  - Functional
    - Recursion, single valued variables
  - Logic/rule based
    - programs consist of rules
- Object-based
  - bundle data with the allowed operations

Reading & Assignments

- Reading: Asteroid User Guide
  - github.com/lutzhamel/asteroid/blob/master/Asteroid%20User%20Guide.md
- Assignment #0: Download & Read Syllabus – upload a copy of it into BS