Asteroid Functions

```
function inc with x do
    return x+1.
end

assert (inc 1 == 2).
```

In006/inc1.ast

Function call via juxtaposition

Asteroid Functions

- In the functional programming tradition, Asteroid's function calls are constructed by juxtaposing a function with a value, e.g.

  fact 3.

- The implication is that all **functions have only a single argument**. If you want to pass more than one value to a function you have to construct a **tuple of values**, e.g.

  foo (1,2).

- Syntactically this looks the same as a function call to foo in Python but semantically it is very different – call foo with the **value** (1,2) in Asteroid as apposed to call foo with the **list of values** (1,2) in Python.
- As we will see, this slight change of perspective enables effective pattern matching within function definitions in Asteroid.

Lambda Calculus

Alonzo Church (1903–1995), mathematician, logician.

- The mathematical idea of function application to values was used by the logician Alonzo Church to create the lambda calculus as a computational foundation of mathematics in the 1930’s.
- It can be considered as an alternative to the Turing machine
- It is Turing-complete
  - Anything a TM can compute can also be computed with the lambda calculus
- It is considered the semantic foundation of our modern functional languages such as Haskell, Ocaml, Clojure, etc
- We have more to say about the lambda calculus when we look at the functional paradigm.

https://en.wikipedia.org/wiki/Lambda_calculus

Lambda Calculus

- Here is an example of an increment function as a lambda expression applied to a value,

$$(\lambda x. x + 1)\ 1 \Longrightarrow x + 1[x \leftarrow 1] \Longrightarrow 1+1 \Longrightarrow 2$$

Asteroid Functions

```
function inc with x do
   return x+1.
end

assert (inc 1 == 2).
```

In006/inc1.ast

inc **applied** to the value 1

Lambda Calculus

- Another example that scales a point in 2D space (a pair of values),

$$(\lambda(x, y).\,(2x, 3y))\ (1,2) \Longrightarrow (2x, 3y)[x \leftarrow 1, y \leftarrow 2] \Longrightarrow (2,6)$$

Single parameter!

Asteroid Functions

- Due to its foundation in Lambda calculus, Asteroid functions have only a single formal parameter,

Single, formal parameter

```
function scale with x do
   if x is (a,b) do  -- using pattern matching on the value
      return (2*a,3*b).
   else do
      throw Error("expected a pair of values").
   end
end

assert (scale (1,2) == (2,6)).
```

ln006/scale1.ast

Asteroid Functions

- We can pattern match on the single formal parameter,

Single, formal parameter pattern matched

```
function scale with (a,b) do -- using pattern matching on the input arg
   return (2*a,3*b).
end

assert (scale (1,2) == (2,6)).
```

ln006/scale2.ast

Function Calls in Python

- The interpretation of function arguments as a list of values has unexpected implications in Python
  - foo (1,2) ≠ foo ((1,2)), but
  - (1,2) = ((1,2))
- Inconsistent handling of parenthesized tuples!

```
Python 3.8.11 (default, Jun 28 2021, 10:57:31)
[GCC 10.3.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> def foo(a,b):
...     pass
...
>>> foo (1,2)
>>> foo ((1,2))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: foo() missing 1 required positional argument: 'b'
>>>
```

but…

```
>>> (1,2) == ((1,2))
True
>>>
```

Function Calls

- But it works fine in Asteroid,

```
Asteroid Version 1.1.4
(c) University of Rhode Island
Type "asteroid -h" for help
Press CTRL-D to exit
ast> function foo with (a,b) do . end
ast> foo (1,2).
ast> foo ((1,2)).
ast>
ast> (1,2) == ((1,2)).
true
ast>
```

Pattern Matching in Functions

- As we have seen, we can pattern match on the function argument
- That means we can use all the patterns we have learned so far

In006/scale3.ast

```
load system math.

function scale with (a:%real,b:%real) do -- only allow pairs of real values
    return (2*a,3*b).
end

let (x,y) = scale (1.1,2.2).
assert (math @isclose (x,2.2) and math @isclose (y,6.6)).
```

In006/string1.ast

```
load system io.

function uppercase with (x:%string) if x is "[A-Z]*" do -- upper case words
    io @println ("\""+x+"\" is an uppercase string").
end

uppercase "HELLO".
```

Functions are Multi-Dispatch

- In Asteroid functions are multi-dispatch:
  - a single function can have multiple bodies each attached to a different pattern matching the actual argument.
- This is along the line of declarative programming
  - Highlight programmer’s intention instead of computational logic

Functions are Multi-Dispatch

$$sign(x) = \begin{cases} 1\ if\ x = 0 \\ 1\ if\ x\ > 0 \\ -1\ if\ x < 0 \end{cases}\ \text{only defined for } x \in Int$$

Multi-Dispatch

```
function sign with x do
   if x is 0 do
      return 1.
   elif x is (n:%integer) if n > 0 do
      return 1.
   elif x is (n:%integer) if n < 0 do
      return -1.
   else do
      throw Error("invalid input").
   end
end

assert (sign 1 == 1).
```

ln006/sign1a.ast

```
function sign
   with 0 do
      return 1.
   with (n:%integer) if n > 0 do
      return 1.
   with (n:%integer) if n < 0 do
      return -1.
end

assert (sign 1 == 1).
```

ln006/sign1b.ast

Multi-Dispatch and Recursion

- Multi-dispatch works exceptionally well with recursive functions
  - Separate ‘with’ clauses for base- and recursive cases

Recursion is a technique in programming where a function calls itself in order to solve a problem. The function defines a base case, which is the point at which the recursion stops, and a set of rules for reducing the problem to a simpler version of itself. Each time the function calls itself, it applies these rules to the problem in order to make progress towards the base case. Eventually, the problem is simplified enough that the base case is reached and the function stops calling itself, returning a final result.

Multi-Dispatch and Recursion

- Example: Recursive function that sums the elements of an integer list.
  - Observation: multi-dispatch preserves the declarative nature of pattern matching

```
function sumlist with x do
    if x is [] do
        return 0.
    else do
        let [(h:%integer) | t] = x.
        return h + sumlist t.
    end
end

assert (sumlist [1,2,3] == 6).
```

ln006/sumlist1a.ast

Multi-dispatch

```
function sumlist
    with [] do
        return 0.
    with [(h:%integer) | t] do
        return h + sumlist t.
end

assert (sumlist [1,2,3] == 6).
```

ln006/sumlist1b.ast

Multi-Dispatch and Recursion

$$x! = \begin{cases} 1 \text{ if } x = 0 \\ x(x-1)! \text{ otherwise} \end{cases}$$

for $x \in Int$ and $x \geq 0$

```
function factorial
    with 0 do
        return 1
    with (n:%integer) if n > 0 do
        return n * factorial (n-1).
end

assert (factorial 3 == 6).
```

In006/fact1.ast

Multi-Dispatch and Recursion

```
function qsort
    with [] do -- base case 1
        [].
    with [a] do -- base case 2
        [a].
    with [pivot|rest] do -- recursive step
        let less=[].
        let more=[].
        for e in rest do
            if e < pivot do
                less @append e.
            else
                more @append e.
            end
        end
        qsort less + [pivot] + qsort more.
end

assert (qsort [3,2,1,0] == [0,1,2,3]).
```

- The QuickSort
- Recursion with multiple base cases

Reading

- asteroid-lang.readthedocs.io/en/latest/User%20Guide.html#functions
- asteroid-lang.readthedocs.io/en/latest/User%20Guide.html#pattern-matching