# Lambda Cases (lcases)

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## Contents

## 1 Introduction

Haskell is a delightful language. Yet, for some reason, it doesn't seem to have it's rightful place in terms of popularity in industry. Why is it so? Is it inherently hard to learn and therefore only the brave enough students and corporations dare to use it, or could it be that the syntax is perplexing to the amateur eye? It is my belief that with some syntax changes that give a greater familiarity to the new user, there would be no language more compelling than (the new) Haskell. In an attempt to achieve that familiarity, I present some new syntax, of which some is closer to the imperative/OOP style (to attract more already experienced programmers from these languages), some is closer to mathematics (in which most programmers should be experienced) and some is closer to natural language (in which we are all already experienced).

## 2 Language Description

An lcases program consists of a set of value, type and predicate definitions along with type theorems. The "main" value determines the program's behaviour. Constants and functions are all considered values and they have no real distinction other than the fact that functions have a function type and constants don't. Functions (just like "values") can be passed to other functions as arguments or can be returned as a result of other functions.

**Program example: extended euclidean alogirthm**

```
// type definitions

tuple_type PrevCoeffs
value (prev_prev, prev : Int, Int)

tuple_type GcdAndCoeffs
value (gcd, a, b : Int, Int, Int)

// algorithm

extended_euclidean: (Int, Int) -> GcdAndCoeffs
  = (init_a_coeffs, init_b_coeffs) ==> ee_recursion

init_a_coeffs, init_b_coeffs: all PrevCoeffs
  = (1, 0), (0, 1)

ee_recursion: (PrevCoeffs, PrevCoeffs, Int, Int) -> GcdAndCoeffs
  = (a_coeffs, b_coeffs, x, cases) ->
    0 -> (x, a_coeffs.prev_prev, b_coeffs.prev_prev)
    y ->
      ee_recursion(next <== a_coeffs, next <== b_coeffs, y, x ==> mod <== y)
      where
      next: PrevCoeffs -> PrevCoeffs
        = fields -> (prev, prev_prev - x ==> div <== y * prev)

// reading, printing and main

read_two_ints : (Int x Int)WithIO
  = print <== "Please give me 2 ints";
    get_line >>= split_words o> apply(from_string)to_all o> ints ->
    ints ==> length ==> cases ->
      2 -> ints ==> with_env
      ... -> io_error <== "You didn't give me 2 ints"

print_gcd_and_coeffs : GcdAndCoeffs -> (EmptyValue)WithIO
  = fields -> print("Gcd: " + gcd + "\nCoefficients: a = " + a + ", b = " + b)

main : (EmptyValue)WithIO
```

```
= read_two_ints >>= ints ->
  extended_euclidean(ints.1st, ints.2nd) ==> print_gcd_and_coeffs
```

## 2.1 Value Expressions

### 2.1.1 Literals

Literals are the same as haskell

| Examples | Type |
|---|---|
| 1, 2, 17, 42, -100 | Int |
| 1.61, 2.71, 3.14, -1234.567 | Real |
| 'a', 'b', 'c', 'x', 'y', 'z', '.', ',', '\n' | Char |
| "Hello World!", "What's up, doc?", "Alrighty then!" | String |

TODO add the grammar from the haskell report

### 2.1.2 Identifiers

**Examples**

`x`

`y`

`z`

`funny_identifier`

`unnecessarily_long_identifier`

**Description**

An identifier is a string of lower case letters or underscore. It is used to give names to values when they are defined, so that they can later be used with that name as functions or arguments in the definition of other values.

QUESTION maybe shouldn't let '_' be an identifier?
QUESTION should add numbers?

**Grammar**

⟨*identifier*⟩ ::= ( [a-z_] )*

### 2.1.3 Operators

**Function application operators**

The function application operators "==>" and "<==" are a different way to apply functions to arguments than the usual parenthesis function application. Each one applies the function from the corresponding direction. The operators are meant to look like arrows that point from the argument to the function. These operators are very useful for chaining many function applications without the clutter of having to open and close parentheses for each one of the functions.

For example assuming we have the following functions with the behaviour suggested by their names and types:

```
apply()to_all : (A -> B, ListOf(A)s) -> ListOf(B)s
string_length: String -> Int
filter : (A -> Bool, ListOf(A)s) -> ListOf(A)s
is_odd : Int -> Bool
sum_ints : List(Int)s -> Int
```

And a list of strings:

```
strings : List(String)s
```

Here is a simple way to get the number of characters in all the strings that have odd length:

```
chars_in_odd_length_strings : Int
  = strings ==> apply(string_length)to_all ==> filter(is_odd) ==> sum_ints
```

Ofcourse this can be done equivalently using the other operator:

```
chars_in_odd_length_strings : Int
  = sum_ints <== filter(is_odd) <== apply(string_length)to_all <== strings
```

These operators can also be used together to put a function between two arguments if that function is commonly used that way in math (or if it looks better for a certain function). For example the "mod" function can be used like so:

```
x ==> mod <== y
```

Instead of:

```
mod(x, y)
```

**Function composition operators**

The function composition operators "o>" and "<o" are used to compose funtions, each one in the corresponding direction. The use of the letter 'o' is meant to be similar to the mathematical function composition symbol: $\circ$. Since, the A neat example using function composition is the following:

```
reverse_words : String -> String
  = split_words o> apply(reverse)to_all o> merge_words
```

| Operator | Type | Description |
|---|---|---|
| `==>` | (A, A -> B) -> B | Right function application |
| `<==` | (A -> B, A) -> B | Left function application |
| `o>` | (A -> B, B -> C) -> (A -> C) | Right function composition |
| `<o` | (B -> C, A -> B) -> (A -> C) | Left function composition |
| `^` | (A)ToThe(B)Gives(C) => (A, B) -> C | General exponentiation |
| `*` | (A)And(B)MultiplyTo(C) => (A, B) -> C | General multiplication |
| `/` | (A)Divides(B)To(C) => (B, A) -> C | General division |
| + | (A)And(B)AddTo(C) => (A, B) -> C | General addition |
| `-` | (A)SubtractsFrom(B)To(C) => (B, A) -> C | General subtraction |
| = /= | (A)HasEquality => (A, A) -> Bool | Equality operators |
| `> < >= <=` | (A)HasOrder => (A, A) -> Bool | Order operators |
| `& \|` | (Bool, Bool) -> Bool | Boolean operators |
| `>>=` | (E)IsAnEnvironment => (E(A), A -> E(B)) -> E(B) | Monad bind |
| `;` | (E)IsAnEnvironment => (E(A), E(B)) -> E(B) | Monad then |

| Operator | Precedence | Associativity |
|---|---|---|
| `==>` | 10 | Left |
| `<==` | 9 | Right |
| `o> <o` | 8 | Left |
| `^` | 7 | Right |
| `* /` | 6 | Left |
| `+ -` | 5 | Left |
| `= /= > < >= <=` | 4 | None |
| `&` | 3 | Left |
| `\|` | 2 | Left |
| `>>= ;` | 1 | Left |

**Grammar**

⟨*operator-expression*⟩ ::= ⟨*operator-argument*⟩ ⟨*operator*⟩ ⟨*operator-argument*⟩

⟨*operator-argument*⟩ ::= ⟨*literal*⟩ | ⟨*identifier*⟩ | ⟨*parenthesis-function-application*⟩

⟨*operator*⟩ ::= '␣' ⟨*op*⟩ '␣'

⟨*op*⟩ ::= '`==>`' | '`<==`' | '`o>`' | '`<o`' | '`^`' | '`*`' | '`/`' | '`+`' | '`-`' | '`=`' | '`/=`' | '`>`' | '`<`' | '`>=`' | '`<=`' | '`&`' | '`|`' | '`>>=`' | '`;`'

### 2.1.4 Tuples

**Examples**

```
(1, 2)

(1, 2, 3.14)

(1, 'a', "hello")

(a, my_val, 1)

(x -> x + 1, my_function, x -> x * 2)
```

**Description**

Tuples are used to group many values into one. The type of the tuple is either the product of the types of the subvalues or a defined tuple_type which is equivalent to the afformentioned product type i.e. the product type is in the definition of the tuple_type (see "tuple_type" section 2.3.2).

**Grammar**

⟨*tuple*⟩ ::= '`(`' ⟨*value-expression*⟩ ( '`,␣`' ⟨*value-expression*⟩ )+ '`)`'

### 2.1.5 Lists

**Description**

Lists are used to group many values of the same type into one. The type of the list is ListOf(A)s where A is the type of every value inside.

**Grammar**

⟨*list*⟩ ::= '`[`' [⟨*value-expression*⟩ ( '`,␣`' ⟨*value-expression*⟩ )*] '`]`'

### 2.1.6 Function Expressions

**Examples**

```
a -> 17 * a + 42

(x, y, z) -> (x ^ 2 + y ^ 2 + z ^ 2) ^ (1 / 2)
```

**Description**

Function expressions are used to define functions or pass anonymous functions as arguments to other functions. They are comprised by their parameters and their body. The parameters are either only one in which case a single identifier is used, or they are many in which case many identifiers are used in parenthesis, seperated by a comma. The parameters and the body are seperated by an arrow. The body is an operator expression.

**Grammar**

⟨*function-expression*⟩ ::= ⟨*parameters*⟩ '`␣->␣`' ⟨*operator-expression*⟩

⟨*parameters*⟩ ::= ⟨*identifier*⟩ | '`(`' ⟨*identifier*⟩ ( '`,␣`' ⟨*identifier*⟩ )+ '`)`'

### 2.1.7 Special Function Arguments

```
x -> body
(x, y, z) -> body
cases -> body
(x, cases, z) -> body
```

### 2.1.8 Expressions

#### Examples

```
42

x

funny_identifier

[1, 2, 3]

"Hello world!"

x ==> mod <== y

1.61 * 2.71 + 3.14

a -> 17 * a + 42

(x, y, z) -> (x ^ 2 + y ^ 2 + z ^ 2) ^ (1 / 2)

n ==> +1 ==> ^2 ==> *3 ==> print

f(x, y, z) + g(1, 2, 3)
```

#### Description

The base of expressions, are literals and identifiers, those can be combined either with operators, or by normal function application with mathematical notation. Finally, on top of that there can be added one of more abstractions (parameters) in the beginning of the expressions with an arrow.

#### Grammar

## 2.2 Value Definitions

#### Examples

```
foo : Int
  = 42

val1, val2, val3 : Int, Bool, Char
  = 42, true, ’a’

int1, int2, int3 : all Int
  = 1, 2, 3
```

```
succ : Int -> Int
  = +1

f : (Int, Int, Int) -> Int
  = (a, b, c) -> a + b * c
```

**Description**

To define a new value you give it a name, a type and an expression. It is possible to group value definitions by seperating the names, the types and the expressions with commas. It is also possible to use the keyword "all" to give the same type to all the values.

**Grammar**

⟨*value-definitions*⟩ ::= ⟨*identifiers*⟩ '␣:␣' (⟨*types*⟩ | 'all' ⟨*type*⟩) '\n␣␣=' ⟨*value-expressions*⟩

⟨*identifiers*⟩ ::= ⟨*identifier*⟩ ( ',␣' ⟨*identifier*⟩ )*

⟨*types*⟩ ::= ⟨*type*⟩ ( ',␣' ⟨*type*⟩ )*

⟨*value-expressions*⟩ ::= ⟨*value-expression*⟩ ( ',␣' ⟨*value-expression*⟩ )*

## 2.3 Types

### 2.3.1 Type expressions

**Examples**

```
Int

String -> String

Int x Int

Int x Int -> Real

A -> A

(A -> B, B -> C) -> (A -> C)

((A, A) -> A, A, ListOf(A)s) -> A

((B, A) -> B, B, ListOf(A)s) -> B

(T)HasStringRepresantion => T -> String
```

**Description**

| Examples | Description |
|---|---|
| Int<br>Char<br>String | Base types |
| A -> A<br>(A -> B, B -> C) -> (A -> C) | Polymorphic types. A, B, C ... are type variables |

**Differences from Haskell**

| lcases | haskell | difference description |
|---|---|---|
| A -> A | a -> a | Type variables for polymorphic types are |

**Grammar**

⟨*type*⟩ ::= ⟨*type-application*⟩ | ⟨*product-type*⟩ | ⟨*function-type*⟩

⟨*type-application*⟩ ::= [ ⟨*types-in-paren*⟩ ] ⟨*type-identifier*⟩ (⟨*types-in-paren*⟩ ( [A-Za-z] )*)* [ ⟨*types-in-paren*⟩ ]

⟨*types-in-paren*⟩ ::= '(' ⟨*type*⟩ (', ' ⟨*type*⟩)* ')'

⟨*type-identifier*⟩ ::= [A-Z] ( [A-Za-z] )*

⟨*product-type*⟩ ::= ⟨*product-subtype*⟩ ( '␣x␣' ⟨*product-subtype*⟩ )+

⟨*product-subtype*⟩ ::= '(' ( ⟨*function-type*⟩ | ⟨*product-type*⟩ ) ')' | ⟨*type-application*⟩

⟨*function-type*⟩ ::= ⟨*input-types-expression*⟩ '␣->␣' ⟨*one-type*⟩

⟨*input-types-expression*⟩ ::= ⟨*one-type*⟩ | ⟨*two-or-more-types-in-paren*⟩

⟨*one-type*⟩ ::= ⟨*type-application*⟩ | ⟨*product-type*⟩ | '(' ⟨*function-type*⟩ ')'

⟨*two-or-more-types-in-paren*⟩ ::= '(' ⟨*type*⟩ (', ' ⟨*type*⟩)+ ')'

### 2.3.2 Tuple Types

**Definition Examples**

```
tuple_type Name
value (first_name, last_name) : String x String

tuple_type ClientInfo
value (name, age, nationality) : Name x Int x String

tuple_type Date
value (day, month, year) : Int x Int x Int

tuple_type (A)And(B)
```

```
value (a_value, b_value) : A x B

tuple_type (ExprT)WithPosition
value (expr, line, column) : ExprT x Int x Int
```

**Usage Examples**

```
giorgos_info : ClientInfo
  = (("Giorgos", "Papadopoulos"), 42, "Greek")

john_info : ClientInfo
  = (("John", "Doe"), 42, "American")

name_to_string : Name -> String
  = fields -> "First Name: " + first_name + "\nLast Name: " + last_name

print_name_and_nationality : ClientInfo -> (EmptyValue)WithIO
  = fields -> print(name ==> name_to_string + "\nNationality: " + nationality)

print_error_in_expr : (SomeDefinedExprT)WithPosition -> (EmptyValue)WithIO
  = ewp ->
    print(
      "Error in the expression:" + es +
      "\nAt the position: (" + ls + ", " + cs + ")"
    )
    where
    es, ls, cs : all String
      = ewp.expr==>to_string, ewp.line==>to_string, ewp.column==>to_string
```

**Description**

Tuple types group many values into a single value. They are specified by their name, the names of their subvalues and the types of their subvalues. They generate projection functions for all of their subvalues by using a '.' before the name of the subvalue. For example the ClientInfo type above generates the following functions:

```
.name : ClientInfo -> String
.age : ClientInfo -> Int
.nationality : ClientInfo -> String
```

These functions shall be named "postfix functions" as the can just be appended to their argument.

**Definition Grammar**

⟨*tuple-type-definition*⟩ ::=
  '`tuple_type␣`' ⟨*type-application*⟩ '`\nvalue␣`' '`(`' ⟨*identifier*⟩ ('`,␣`' ⟨*identifier*⟩)* '`)`' '`␣:␣`' ⟨*product-type*⟩

### 2.3.3 Or Types

**Examples**

```
or_type Bool
values true | false

or_type Possibly(A)
values the_value:A | no_value
```

```
or_type ListOf(A)s
values non_empty:HeadAndTailOf(A)s | empty

tuple_type HeadAndTailOf(A)s
value (head : A, tail : ListOf(A)s)

is_empty : ListOf(A)s -> Bool
  = cases ->
    empty -> true
    non_empty:anything -> false

get_head : ListOf(A)s -> Possibly(A)
  = cases ->
    empty -> no_value
    non_empty:list -> the_value:list.head
```

### Description

Values of an or_type are one of many cases that possibly have other values inside. The cases which have other values inside are followed by a semicolon and the type of the internal value. The same syntax can be used for matching that particular case in a fucntion using the "cases" syntax, with the difference that after the colon, we write the name given to the value inside. Or_types and basic types are the only types on which the "cases" syntax can be used. The cases of an or_type which have a value inside create functions. For example, the case "non_empty" of a list creates the function "non_empty:" for which we can say:

```
non_empty: : HeadAndTailOf(A)s -> ListOf(A)s
```

Similarly:

```
the_value: : A -> Possibly(A)
```

These functions shall be named "prefix functions" as they are prepended to their argument. For example:

```
head_and_tail : HeadAndTailOf(Int)s
  = (1, [2, 3, 4])

list : ListOf(Int)s
  = non_empty:head_and_tail
```

These functions can be used like any other function as arguments to other functions. For example:

```
heads_and_tails_to_lists : ListOf(HeadAndTailOf(A)s)s -> ListOf(ListOf(A)s)s
  = apply(non_empty:)to_each
```

### Definition Grammar

⟨*or-type-definition*⟩ ::=
    '`or_type␣`' ⟨*type-application*⟩ '`\nvalues␣`' ⟨*identifier*⟩ [ '`:`' ⟨*type*⟩ ] ( '`␣|␣`' ⟨*identifier*⟩ [ '`:`' ⟨*type*⟩ ])*

## 2.4 Type Logic

### 2.4.1 Type Predicate

### 2.4.2 Type Theorem

## 2.5 Grammar

### 2.5.1 Tokens

**Keywords**

`cases use_fields tuple_type or_type`

**Value names**

**Type names**

### 2.5.2 Core Grammar

**Program**

⟨*program*⟩ ::= (⟨*value-definitions*⟩ | ⟨*type-def*⟩)+

⟨*value-definitions*⟩ ::= ⟨*identifiers*⟩ ‘`␣:␣`’ (⟨*types*⟩ | ‘`all`’ ⟨*type*⟩) ‘`\n␣␣=`’ ⟨*value-expressions*⟩

⟨*identifiers*⟩ ::= ⟨*identifier*⟩ ( ‘`,␣`’ ⟨*identifier*⟩ )*

⟨*types*⟩ ::= ⟨*type*⟩ ( ‘`,␣`’ ⟨*type*⟩ )*

⟨*value-expressions*⟩ ::= ⟨*value-expression*⟩ ( ‘`,␣`’ ⟨*value-expression*⟩ )*

**Types**

**Value Expressions**

⟨*value-expression*⟩ ::= [ ⟨*input-expr*⟩ ] ⟨*cases-or-where*⟩ | ⟨*op-expr*⟩

⟨*cases-or-where*⟩ ::= ⟨*cases-expr*⟩ | ⟨*where-expr*⟩

⟨*where-expr*⟩ ::= ‘`let`’ ⟨*spicy-nl*⟩ (⟨*value-definitions*⟩ ⟨*spicy-nls*⟩)+ ‘`in`’ ⟨*value-expression*⟩ ⟨*spicy-nl*⟩

⟨*cases-expr*⟩ ::= ‘`cases`’ ( ⟨*case*⟩ )+ [ ⟨*default-case*⟩ ]

## 3 Parser implimentation

The parser was implemented using the parsec library.

### 3.1 AST Types

### 3.2 Parsers

## 4 Translation to Haskell

## 5 Running examples

## 6 Conclusion

## 7 To be removed or incorporated

Addition/Subtraction:

```
+ : (A)HasAddition => (A, A) -> A
- : (A)HasSubtraction => (A, A) -> A
```

Equality and ordering:

```
= : (A)HasEquality => (A, A) -> Bool
<= : (A)HasOrder => (A, A) -> Bool
>= : (A)HasOrder => (A, A) -> Bool
```

(fmap)`<inside>` — (W)IsAWrapper `=>` (A `->` B, W(A)) `->` W(B) — Apply inside operator
`(<*>)<wrapped_inside>` — (W)IsAWrapper `=>` (W(A `->` B), W(A)) `->` W(B) — Order operators

better as postfix functions

**Examples in Haskell**

```
data ClientInfo =
  ClientInfoC String Int String

data WithPosition a =
  WithPositionC a Int Int

data Pair a b =
  PairC a b
```

**Examples in Haskell**

```
{-# language LambdaCase #-}

data Bool =
  Ctrue | Cfalse

data Possibly a =
  Cwrapper a | Cnothing
```

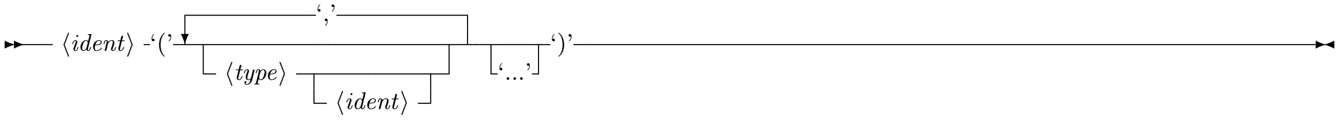
```
data ListOf_s a =
  Cnon_empty (NonEmptyValueListOf_s a) | Cempty

data NonEmptyValueListOf_s a =
  CNonEmptyValueListOf_s a (ListOf_s a)

is_empty :: ListOf_s a -> Bool
is_empty = \case
  Cempty -> Ctrue
  Cnon_empty (CNonEmptyValueListOf_s head tail) -> Cfalse

get_head :: ListOf_s a -> Possibly a
get_head = \case
  Cempty -> Cnothing
  Cnon_empty (CNonEmptyValueListOf_s head tail) -> Cwrapper head
```

### Examples in Haskell

```
foo :: Int
foo = 42

val1 :: Int
val1 = 42
val2 :: Bool
val2 = true
val3 :: Char
val3 = 'a'

int1 :: Int
int1 = 1
int2 :: Int
int2 = 2
int3 :: Int
int3 = 3

succ :: Int -> Int
succ = \x -> x + 1

f :: Int -> Int -> Int -> Int
f = \a b c -> a + b * c
```

Or Types the following have automatically generated functions:

```
is_case:
```


⟨ident⟩
'('
','
⟨type⟩
⟨ident⟩
'...'
')'