

COMPILERS

HAL

Héctor Ramón Jiménez

Alvaro España Buxo

June 4, 2014
Facultat d'Informàtica de Barcelona

Contents

1	Introduction	3
2	Features	4
2.1	Clean syntax	4
2.2	Everything is an object	4
2.3	Every method can be overridden	5
2.4	Lambda blocks	6
2.5	First-class methods	7
2.6	Parameter groups	7
2.7	Keyword parameters	8
2.8	Module imports	8
2.9	Four levels of scopes	9
2.10	Inheritance	10
2.11	Execution of shell commands	11
2.12	Native types	11
3	Syntax	13
3.1	Indentation	13
3.2	Lexical rules	15
3.3	Grammatical rules	18
4	Interpreter	24
4.1	Methods	24
4.2	Builtin methods	24
4.3	Types	25
5	HalTeX	27
5.1	--method_missing--	27
5.2	Use example	27

1 Introduction

Our main objective was to create a programming language we would find **useful** in the future. With that in mind we have developed **HAL**, an scripting language with these characteristics.

- A **clean** syntax, perfect for creating **Domain-Specific Languages**
- A **consistent** object-oriented architecture with **inheritance**
- **Dynamic typing** and **duck typing**
- Builtin methods that can be **rewritten** in **HAL** itself
- **Module** imports
- **First-class functions** methods
- An **extensible, intuitive** and **interactive** interpreter

We use **Python** and **Ruby** a lot, and find them very interesting. In fact, most of the features of **HAL** are directly influenced by these two languages. However, we implemented everything in our own way, thinking in our needs as programmers and what made sense to include in **HAL**.

Thourough this document ther will be a lot of examples of **HAL**. The code will be highlighted and in monospace font. The output from the snippet will appear with a gray background. As example:

```
5.times: print "Hello world!"
```

```
Hello world!  
Hello world!  
Hello world!  
Hello world!  
Hello world!
```

Figure 1: HAL says: “Hello world!”

2 Features¹

2.1 Clean syntax

HAL can be easily used to create **Domain-Specific Languages**! Parentheses in calls are optional, **self** is implicitly set accordingly to the **scope** and **blocks** can be defined easily with indentation!

```
class Array:
  def sort!:
    return self if size < 2
    p = first
    q = pop!
    lesser = q.filter with x: x < p
    greater = q.filter with x: x >= p
    lesser.sort! ++ [p] ++ greater.sort!

a = [1, 2, 3, -1, -2, -3, 20, 40, 1, 2, 200, -5]
print a.sort!
```

```
[-5, -3, -2, -1, 1, 1, 2, 2, 3, 20, 40, 200]
```

Figure 2: HAL can quicksort!

2.2 Everything is an object

That's why we said that HAL has a consistent object-oriented architecture. Even **none** is an object!

```
print \
  1.add(2), Array.new, "Chunky bacon!".size,
  range(10).sum, &range.arity, Class.repr, none.none?
```

```
3
[]
13
45
1
Class
true
```

Figure 3: Objects everywhere

¹Discover them by yourself! Open the interactive interpreter (**bin/hal**) and play!

All the instructions return objects in HAL. The value returned by the last instruction of a method is the returned value of the method.

2.3 Every method can be overridden

Like in Python there is no method visibility concept, which means that all methods can be called from everywhere. Also, like in Ruby any class can be reopened at any moment to define or override methods. It is even possible to override builtin methods²!

```
def concat: range(10) ++ range(20, start => 10)

print concat

class Array:
  def __concat__ x:
    x.each with index, element:
      self[index] = self[index] + element
    self

print concat
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]
[10, 12, 14, 16, 18, 20, 22, 24, 26, 28]
```

Figure 4: Overriding Array concatenation!

²Native methods written in Java.

2.4 Lambda blocks

Like in Ruby, it is possible to pass lambda blocks to methods. However, in HAL you can define the block using the “:” keyword and indenting accordingly. In a method, the names `block_given?` and `yield` are set depending to whether some block was given or not.

```
def list title => none, numbered? => false:
  print "<h1>" + title + "</h1>" if not title.none?
  print "<ol>" if numbered? else print "<ul>"
  yield
  print "</ol>" if numbered? else print "</ul>"

def item x:
  if block_given?:
    print "<li>" + x
    yield
    print "</li>"
  else:
    print "<li>" + x + "</li>"

list "Shopping list":
  item "Meat":
    list:
      item "Bacon"
  item "Vegetables":
    list numbered? => true:
      item "Cabbage"
      item "Cucumber"
```

```
<h1>Shopping list</h1>
<ul>
<li>Meat
<ul>
<li>Bacon</li>
</ul>
</li>
<li>Vegetables
<ol>
<li>Cabbage</li>
<li>Cucumber</li>
</ol>
</li>
</ul>
```

Figure 5: Generating HTML lists with HAL!

2.5 First-class methods

Methods are objects too! The `&` accessor can be used to avoid calling and obtain the value stored under a name.

```
def lambda: &yield

add = lambda with x, y: x + y

print add 5, add 3, add 1, 2
print &add.arity
```

```
11
2
```

Figure 6: Creating lambdas in one line of code!

2.6 Parameter groups

HAL method definitions support parameter grouping! The parameter marked with `*` will store the arguments that are not captured by other parameters in an `Array`. Arrays can be flattened using `*` to pass its elements as arguments!

```
def reverse head, *rest:
  [head] if rest == [] else reverse(*rest) << head

print range 20
print reverse *range 20
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]
[19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0]
```

Figure 7: Dealing with arrays with parameter grouping

2.7 Keyword parameters

HAL methods support keywords too! A *keyword* is a parameter that has a default value, thus it is optional to provide an argument for it. In HAL keywords are defined using the `=>` symbol.

```
def greet name => "John", age => 21:  
    print "My name is " + name.capitalize +  
    " and I'm " + age.str
```

```
greet  
greet "manel", 30  
greet "manel", age => 30  
greet age => 30, name => "manel"
```

```
My name is John and I'm 21  
My name is Manel and I'm 30  
My name is Manel and I'm 30  
My name is Manel and I'm 30
```

Figure 8: A simple example using keywords

2.8 Module imports

Like in Python every file that contains code is a **module**. Modules can be imported inside other modules using the `import` statement.

```
import hal
```

```
hal.disconnect!
```

```
I'm afraid I can't do that.
```

Figure 9: Importing some examples

2.9 Four levels of scopes

HAL has four different variable scopes. Variables can be defined in those scopes using different access operators:

Local Without any accessor

Instance Using the “@” accessor

Static Using the “@@” accessor

Module Instance variables defined in the current module

When a name is referenced without any accessor, HAL searches it following that order.

```
@m = "Module variable"

class Foo:
    @a = "Class variable"

    def init:
        @a = "Instance variable"
        @m = m

    def __str__:
        @@a

print Foo.a, Foo.new.a, Foo.new.m, Foo.new

@m = "Another module variable"

print Foo.new.m
```

```
Class variable
Instance variable
Module variable
Class variable
Another module variable
```

Figure 10: Playing with the different scope levels

2.10 Inheritance

Objects can inherit methods from other objects! The name `super` contains a reference to the method with the same name implemented by the parent class, if there is any. The `init` method is called after instantiating an object.

```
class Animal:
  def init type:
    @type = type

  def __str__:
    "A " + @type

class Fox << Animal:
  def init name:
    super "fox"
    @name = name

  def __str__:
    super + " named " + @name

print Animal.new "horse"
print Fox.new "Tod"
```

```
A horse
A fox named Tod
```

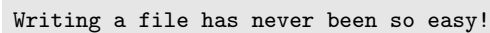
Figure 11: The tale of Tod and the horse with no name

2.11 Execution of shell commands

Command shells can be executed using **backticks** (```). The value returned is the output of the execution. Additionally, it is possible to use the class `Process` to have information about the **exit status** and the **error output**.

```
File.open "test.txt" with f:
  f.write "Writing a file has never been so easy!"

print `cat test.txt`
```



```
Writing a file has never been so easy!
```

Figure 12: Writing a file and showing its contents

2.12 Native types

HAL defines a set of useful classes natively:

- Boolean
- Class
- Enumerable
 - Array
 - Dictionary
 - String
- File
- Kernel
 - Module
- None
- Number
 - Float
 - Integer
 - Long
 - Rational
- Object

- Package
- Process

3 Syntax

3.1 Indentation

We wanted HAL to be **readable**, **clean** and **easy to write**. We think that one of the things Python does well is the way it defines blocks by indentation because it avoids the verbosity of a *closing* token. We wanted HAL to be as non-verbose as possible. The relevant part of the grammar that allows blocks by indentation is the following:

```
@lexer::members
{
    public static final int MAX_INDENTS = 100;
    private int indentLevel = 0;
    private boolean end = false;
    int[] indentStack = new int[MAX_INDENTS];
    java.util.Queue<Token> tokens =
        new java.util.LinkedList<Token>();

    {
        // Compute first line indentation manually
        int i = 1;
        while(input.LA(i) == ' ') i++;

        int next = input.LA(i);

        // Ignore empty lines
        if(i > 1 && next != '\n' && next != '\r' && next != -1) {
            jump(Indent);
            indentStack[indentLevel] = i-1;
        }
    }

    @Override
    public void emit(Token t) {
        state.token = t;
        tokens.offer(t);
        //System.err.println("=> " + t);
    }

    @Override
    public Token nextToken() {
        super.nextToken();

        if(tokens.isEmpty()) {
            // End file with new line
            if(!end) {
                emit(new CommonToken(NEWLINE, "\\n"));
                end = true;
            }

            // Undo all indentation
            if(indentLevel > 0) {
                jump(Dedent);
                return nextToken();
            }

            emit(Token.EOF_TOKEN);
        }
        Token t = tokens.poll();
    }
}
```

```

        //System.err.println("<= " + t);
        return t;
    }

    private void jump(int ttype) {
        String name;
        if(ttype == Indent) {
            name = "Indentation";
            indentLevel++;
        }
        else {
            name = "Dedentation";
            indentLevel--;
        }
        emit(new CommonToken(ttype, name));
    }
}

```

It is also important, when the NEWLINE tokens are emitted:

```

;
WS      : SP {skip();};
LINEBREAK : '\\\r' NL {skip();};
COMMENT  : '#' ~('\\n'|'\\r')* {skip();};

NEWLINE
@init
{
    int n = 0;
}
: NL ( ' ' {n++;} | '\\t' {n += 8; n -= (n % 8); })*
{
    emit(new CommonToken(NEWLINE, "\\n"));

    int next = input.LA(1);
    int currentIndent = indentStack[indentLevel];

    // Skip if same indentation or empty line or comment
    if(n == currentIndent || next == '\\n'
        || next == '\\r' || next == -1 || next=='#')
    {
        skip();
    }
    else if(n > currentIndent)
    {
        jump(Indent);
        indentStack[indentLevel] = n;
    }
    else
    {
        while(indentLevel > 0 && indentStack[indentLevel] > n)
        {
            jump(Dedent);
        }

        if(indentStack[indentLevel] != n)
            throw new RuntimeException("Unexpected indentation.");
    }
}

```

3.2 Lexical rules

The lexical rules are really simple. We tried to have a small set of keywords:

```
// LEXICAL RULES

// OPERATORS
ASSIGN : '=' ;
EQUAL  : '==';
NOT_EQUAL : '!=' ;
LT     : '<';
LE     : '<=';
GT     : '>';
GE     : '>=';
PLUS   : '+' ;
DOUBLE_PLUS : '++';
MINUS  : '-' ;
MUL    : '*' ;
POW    : '**';
DIV    : '/';
DDIV   : '//';
MOD    : '%';
LSHIFT : '<<';
RSHIFT : '>>';

// KEYWORDS
NOT      : 'not';
AND      : 'and';
OR       : 'or';
TRUE     : 'true';
FALSE    : 'false';
NONE     : 'none';
IF       : 'if';
ELIF     : 'elif';
ELSE     : 'else';
FOR      : 'for';
WHILE    : 'while';
IN       : 'in';
DEF      : 'def';
LKW      : 'with';
RETURN   : 'return';
CLASS    : 'class';
IMPORT   : 'import';
FROM     : 'from';

// SPECIAL SYMBOLS
COLON    : ':' ;
SEMICOLON : ';';
LPAREN   : '(';
RPAREN   : ')';
LBRACK   : '[' NL?;
RBRACK   : NL? SP? ']' ;
LBRACE   : '{' NL?;
RBRACE   : NL? SP? '}' ;
LARROW   : '=>';
AT       : '@';
DOUBLE_AT : '@@';
DOLLAR   : '$';
AMPERSAND : '&';
```

```
// Useful fragments
fragment DIGIT : ('0'..'9');
```



```

fragment LOWER : ('a'..'z');
fragment UPPER : ('A'..'Z');
fragment LETTER: (LOWER|UPPER);
fragment NL     : (('r')? '\n')+;
fragment SP     : (' ' | '\t')+;

// Identifiers
ID : (LETTER|'_') (LETTER|'_'|DIGIT)* (('!'|'?')('_')*)?;

// Numbers
NUMBER : {$type=INT;}(DIGIT+ (('.' DIGIT)=> '.' DIGIT+ {$type=FLOAT;})
↪ ?);
fragment INT    ;;
fragment FLOAT  ;;

// Strings
STRING
@init { final StringBuilder buf = new StringBuilder(); }
: ''' ( ESC_SEQ[buf]
    | i = ~('\\"'|'') { buf.appendCodePoint(i); }
    )* '''
    { setText(buf.toString()); }
| '\\'' ( ESC_SEQ[buf]
    | i = ~('\\"'|'\''|'') { buf.appendCodePoint(i); }
    )* '\\''
    { setText(buf.toString()); }
;

BACKTICKS
@init { final StringBuilder buf = new StringBuilder(); }
: '`' (
    '\\`' { buf.append('`'); }
    | i = ~('`') { buf.appendCodePoint(i); }
    )* '`'
    { setText(buf.toString()); }
;

fragment ESC_SEQ[StringBuilder buf]
: '\\\
    ('b' { buf.append('\b'); }
    | 't' { buf.append('\t'); }
    | 'n' { buf.append('\n'); }
    | 'f' { buf.append('\f'); }
    | 'r' { buf.append('\r'); }
    | '"' { buf.append('"'); }
    | '\'' { buf.append('\''); }
    | '\\\ { buf.append('\\'); } )
;

WS      : SP {skip();};
LINEBREAK : '\\\ NL {skip();};
COMMENT  : '#' ~('\n'|\r)* {skip();};

NEWLINE
@init
{
    int n = 0;
}
: NL (' ' {n++;} | '\t' {n += 8; n -= (n \% 8); })*
{
    emit(new CommonToken(NEWLINE, "\\n"));
}

```

```

int next = input.LA(1);
int currentIndent = indentStack[indentLevel];

// Skip if same indentation or empty line or comment
if(n == currentIndent || next == '\n'
   || next == '\r' || next == -1 || next=='#')
{
    skip();
}
else if(n > currentIndent)
{
    jump(Indent);
    indentStack[indentLevel] = n;
}
else
{
    while(indentLevel > 0 && indentStack[indentLevel] > n)
    {
        jump(Dedent);
    }

    if(indentStack[indentLevel] != n)
        throw new RuntimeException("Unexpected indentation.");
}
}
;

fragment Indent : ;

```

Thus giving the programmer more freedom to define its own *keywords*.

```

def unless expr:
    if not expr:
        yield

unless 1 == 0:
    print "Everything works as expected"

```

```
Everything works as expected
```

Figure 13: It's easy to create new *expressions* in HAL. Notice how similar to if looks.

3.3 Grammatical rules

The grammar is a bit complex. We engineered it thinking in HAL (the result) instead of thinking in the grammar itself. Because of that, we used some helpful Java functions, using multiple features of `antlr` to disambiguate some cases:

```
@parser::members {
    public boolean before(int before, int type) {
        int i = 1;
        Token t;

        do {
            t = input.LT(i);
            i++;

            if(t.getType() == type)
                return true;
        } while(t.getType() != EOF && t.getType() != before);

        return false;
    }

    public boolean space(TokenStream input) {
        return !directlyFollows(input.LT(-1), input.LT(1));
    }

    private boolean directlyFollows(Token first, Token second) {
        CommonToken firstT = (CommonToken) first;
        CommonToken secondT = (CommonToken) second;

        if (firstT.getStopIndex() + 1 != secondT.getStartIndex())
            return false;

        return true;
    }

    public boolean directlyNext(int type) {
        if(input.LT(1).getType() != type)
            return false;

        return directlyFollows(input.LT(-1), input.LT(1));
    }

    public boolean nextIs(int... types) {
        int type = input.LT(1).getType();

        for(int i = 0; i < types.length; ++i) {
            if(types[i] == type)
                return true;
        }

        return false;
    }

    public boolean keywordIsNext() {
        return input.LT(1).getType() == ID
            && input.LT(2).getType() == LARROW;
    }
}
```

Some important features of the grammar are:

- Statements with if at the end (a if cond else b).
- List expressions ([i for i in range 3] == [0,1,2]).
- Statements such if, for, while or import.
- *Intelligent* spaces in arguments lists:

```
def a: 5
a - 1 # 4
a-1   # 4
a -1  # Call a with argument -1
```

- Function calls with optional parentheses
- Multiline indented lambda blocks

```
prog
:   (stmt)* EOF -> ^(BLOCK stmt*)
;

stmt
:   simple_stmt
|   compound_stmt
|   NEWLINE!
;

simple_stmt
@init{boolean conditional = false;}
:   s1=small_stmt (
        (options {greedy=true;}:SEMICOLON small_stmt)*
        ↪ SEMICOLON?
        |   IF {conditional=true;} expr (ELSE s2=small_stmt)?
    )
    NEWLINE
    -> {conditional}? ^(IF_STMT expr ^(BLOCK $s1) ^(BLOCK $s2)?)
    -> small_stmt+
;

small_stmt
:   assign_or_expr
|   r=RETURN expr -> ^(RETURN[$r, "RETURN"] expr)
;

assign_or_expr
:   expr (a=ASSIGN assign_or_expr)? // Right-associative
    -> {a==null}? ^(EXPR expr)
    -> ^(ASSIGN expr assign_or_expr)
;

compound_stmt
:   if_stmt
|   for_stmt
|   while_stmt
```

```

|   import_stmt
|   classdef
|   fundef
|   do_lambda
|   assign_lambda
;

if_stmt
:   IF if_body -> ^(IF_STMT if_body)
;

if_body
:   expr COLON! block if_extension?
;

if_extension
:   ELIF if_body -> ^(BLOCK ^(IF_STMT if_body))
|   ELSE! COLON! block
;

for_stmt
:   FOR paramlist IN expr COLON block
  -> ^(FOR_STMT expr ^(LAMBDA ^(PARAMS paramlist) block))
;

while_stmt
:   WHILE expr COLON block -> ^(WHILE_STMT expr block)
;

import_stmt
:   IMPORT module -> ^(IMPORT_STMT module)
|   FROM module IMPORT ID (COMMA ID)* -> ^(IMPORT_STMT module ID+)
;

module
:   ID ('.' ID)*
;

block
:   simple_stmt -> ^(BLOCK simple_stmt)
|   multiline_block
;

multiline_block
:   NEWLINE Indent (stmt)+ Dedent -> ^(BLOCK (stmt)+)
;

classdef
:   CLASS ID ('<<' expr)? COLON block -> ^(CLASSDEF ID ^(PARENT
  ↪ expr?) block)
;

fundef
:   DEF ID params COLON block -> ^(FUNDEF ID params block)
;

params
:   paramlist? -> ^(PARAMS paramlist?)
;

paramlist

```

```

: (ID | param_group) (COMMA! (ID | param_group))* (COMMA!
  ↳ keyword)*
| keyword (COMMA! keyword)*
;

param_group
: '*' ID -> ^(PARAM_GROUP ID)
;

keyword
: {keywordIsNext()}?
  ID LARROW expr -> ^(KEYWORD ID expr)
;

funcall
: (options {greedy=true;}: ID args) -> ^(FUNCALL ID args)
;

args
: {directlyNext(LPAREN)}?=> LPAREN arglist? RPAREN -> ^(ARGS
  ↳ arglist?)
| space_arglist? -> ^(ARGS space_arglist?)
;

space_arglist
: {space(input) && (!input.LT(1).getText().equals("-") ||
  directlyFollows(input.LT(1), input.LT(2)))}?
  arglist
;

arglist
@init{boolean keywords=false;}
: (flatten_arg | expr | keyword {keywords=true;}) (options {
  ↳ greedy=true;}: COMMA! (
  {keywords==false}?=> (flatten_arg | expr | keyword {
    ↳ keywords=true;})
  | keyword {keywords=true;}
  ))*
;

flatten_arg
: {input.LT(1).getText().equals("*") && directlyFollows(input.LT
  ↳ (1), input.LT(2))}?
  '*' expr -> ^(FLATTEN_ARG expr)
;

do_lambda
: {!nextIs(FOR, WHILE, IF, ELSE, ELIF, DEF, CLASS)
  && before(NEWLINE, COLON) && !before(COLON, ASSIGN)}?
  methcalls lambda -> ^(LAMBDACALL methcalls lambda)
;

methcalls
: (atom -> atom) ('.' f=funcall -> ^(METHCALL $methcalls $f))*
;

assign_lambda
: {before(NEWLINE, COLON) && before(COLON, ASSIGN)}?
  expr ASSIGN^ do_lambda
;

lambda

```

```

:
:   (LKW paramlist)? COLON block -> ^(LAMBDA ^(PARAMS paramlist?)
:       ↪ block)
:
expr
:   boolterm (options {greedy=true;}: OR^ boolterm)*
:
boolterm
:   boolfact (options {greedy=true;}: AND^ boolfact)*
:
boolfact
:   shift_expr (options {greedy=true;}:
:       (EQUAL^ | NOT_EQUAL^ | LT^ | LE^ | GT^ | GE^ ) shift_expr)?
:
shift_expr
:   num_expr (options {greedy=true;}: (LSHIFT^ | RSHIFT^ ) num_expr
:       ↪ )*
:
num_expr
:   term (options {greedy=true;}: (PLUS^ | MINUS^ | DOUBLE_PLUS^ )
:       ↪ term)*
:
term
:   power (options {greedy=true;}: (MUL^ | DIV^ | DDIV^ | MOD^ )
:       ↪ power)*
:
power
:   factor (options {greedy=true;}: POW^ factor)*
:
factor
:   NOT^ item
:   | MINUS item -> ^(MINUS["NEGATE"] item)
:   | item
:
item
:   (atom -> atom) (options {greedy=true;}:
:       a=access -> ^(GET_ITEM $item $a)
:       | ('.' f=funcall -> ^(METHCALL $item $f))
:       )*
:
atom
:   INT
:   | FLOAT
:   | STRING
:   | BACKTICKS
:   | (b=TRUE | b=FALSE) -> ^(BOOLEAN[$b,$b.text])
:   | NONE
:   | global_var
:   | instance_var
:   | klass_var
:   | reference_var
:   | list

```

```

| dict
| funcall // An ID can be considered a "funcall" with 0 args
| LPAREN! expr RPAREN!
;

global_var
: DOLLAR ID -> ^(GLOBAL_VAR ID)
;

instance_var
: AT ID -> ^(INSTANCE_VAR ID)
;

klass_var
: DOUBLE_AT ID -> ^(KLASS_VAR ID)
;

reference_var
: AMPERSAND ID -> ^(REFERENCE_VAR ID)
;

list
@init{boolean f = false;}
: LBRACK (e1=expr ((COMMA expr)* | FOR paramlist IN e2=expr {f=
  ↳ true;}))? RBRACK
  -> {f}? ^(LIST_EXPR $e2 ^(LAMBDA ^(PARAMS paramlist) ^(BLOCK
    ↳ ^(EXPR $e1))))
  -> ^(ARRAY expr*)
;

dict
: LBRACE (entry (COMMA entry)*)? RBRACE -> ^(DICT entry*)
;

entry
: expr LARROW expr -> ^(PAIR expr expr)
;

access
: {directlyNext(LBRACK)}?
  LBRACK! expr RBRACK!

```

The major problem we encountered with the syntax is that a call with a lambda block is not an expression, but a call without a lambda block is (this will be fixed soon!). Thus, we needed to help the parser to **differentiate** between these two rules that start in the same way. To do so, we used the **:** keyword present in a call with a lambda block **before the end of the line**: iff it is present, then is a lambda block call. There are other rules that use interesting tricks (checking token separation, spacing...).

4 Interpreter

In this section we try to explain how HAL is structured and works internally, focusing in the most relevant parts of the language.

4.1 Methods

How does HAL difference between a variable access and a method call? There's no difference, they are always calls. Every `HalObject` implements the `call` method. This method has three parameters: the instance to be set as `self`, a `HalMethod` (used to pass `HalLambda`, if any) and an instance of `Arguments` which contains the arguments of the call. The `call` method needs to return a `HalObject`. Then, using polymorphism on this method, every type can act differently when it's called. Actually, this method returns the object itself by default and it's only overridden in the `HalMethod` class. Also, this polymorphism is really useful because the interpreter does not need to take into account if a `HalMethod` is a `Builtin`³ or a method defined in HAL itself that needs to be interpreted, it delegates the responsibility to the type.

```
abstract public class HalMethod extends HalObject<MethodDefinition>
{
    public HalMethod(MethodDefinition def) {
        super(def);
    }

    public HalObject call(HalObject instance, HalMethod lambda,
        ↪ Arguments args) {
        return mcall(instance, lambda, value.params.fill(args));
    }

    public HalObject mcall(HalObject instance, HalMethod lambda,
        ↪ Arguments args) {
        throw new RuntimeException("mcall not implemented");
    }
}
```

All the classes that inherit from `HalMethod` need to define the method `mcall`. The method `mcall` is exactly the same as `call` but with the arguments processed, validated and ready to be used by the method.

4.2 Builtin methods

There are two name references for every builtin provided with the interpreter: one that is surrounded with “`__`” (double underscores) and another that is not (`__range__` and `range` for example). The name surrounded with underscores is the one that the interpreter can use internally in case it needs it. This means that overriding this methods you can get in the way of how the interpreter does things and use it at your favour. For example, you can

³Natively implemented in Java

filter arrays on creation overriding the `--append!--` method (see Figure 14). The reference without underscores is provided for readability purposes and as a backup.

```
def ugly_array: [1, 2, [], [], 3, [[]], 4, 5, 6]

print ugly_array

class Array:
  def --append!__ x:
    append! x if x != [] else self

print ugly_array
```

```
[1, 2, [], [], 3, [[]], 4, 5, 6]
[1, 2, 3, 4, 5, 6]
```

Figure 14: Filtering empty Arrays on construction

4.3 Types

It's relatively easy to add more native types to HAL. Normally it would only consist in writing one Java class that represents the type. Many types in HAL are a mere interface to existing types in Java. We thought datastructures such as Hashes, Rationals or Files could be useful, so we added them as builtins.

A type needs to:

1. Extend `HalObject`
2. Define its methods
3. Define the `getKlass` method that returns the `HalClass` of the type.

```

public class HalFile extends HalObject<PrintWriter> {
    public HalFile(PrintWriter writer) {
        super(writer);
    }

    public HalBoolean bool() {
        return new HalBoolean(true);
    }

    private static final Reference __open__ = new Reference(new
        ↪ Builtin("open", new Params.Param("path")) {
            @Override
            public HalObject mcall(HalObject instance, HalMethod lambda,
                ↪ Arguments args) {
                try {
                    HalFile file = new HalFile(new PrintWriter(args.get("
                        ↪ path").toString(), "UTF-8"));

                    if(lambda != null) {
                        lambda.call(instance, null, file);
                        file.value.close();
                    }

                    return file;
                } catch (FileNotFoundException e) {
                    throw new OSEException(e.getMessage());
                } catch (UnsupportedEncodingException e) {
                    throw new OSEException(e.getMessage());
                }
            }
        });

    private static final Reference __write__ = new Reference(new
        ↪ Builtin("write", new Params.Param("str")) {
            @Override
            public HalObject mcall(HalObject instance, HalMethod lambda,
                ↪ Arguments args) {
                ((HalFile)instance).value.print(args.get("str").toString()
                    ↪ );
                return HalNone.NONE;
            }
        });

    private static final Reference __close__ = new Reference(new
        ↪ Builtin("close") {
            @Override
            public HalObject mcall(HalObject instance, HalMethod lambda,
                ↪ Arguments args) {
                ((HalFile)instance).value.close();
                return HalNone.NONE;
            }
        });

    public static final HalClass klass = new HalClass("File",
        ↪ HalObject.klass, new Reference[]{
            __write__,
            __close__
        },
        __open__);

    public HalClass getKlass() { return HalFile.klass; }
}

```

Figure 15: File type implementation in Java

5 HalTeX

As a *real life* example and to be sure that HAL is powerful enough at this early stage, we created a *DSL* to write in L^AT_EX. The output from L^AT_EX is very beautiful, but the syntax sometimes can be a bit cumbersome. In this section we will detail the implementation of such *DSL*.

5.1 `__method_missing__`

The most powerful thing to create *DSLs* in HAL (apart from the syntax) is the special method `__method_missing__`. This method can be defined in any level of the scope (instance, class, module, kernel). When in a scope a variable/function is undefined, `__method_missing__` is called in that scope. The default behaviour is to check for the variable/function in the upper level (raising a `NameException` when it's not defined in the outermost level). This can be modified, and allows the programmer to control even more the scope. One typical use of this could be *barewords*.

```
class Kernel:
    def __method_missing__ name, str => '':
        name + ' ' + str

s = This creates a string
print s
```



Figure 16: Simple example using `method_missing` special method.

5.2 Use example

This document was written using this *DSL* (we call it HalTeX). HalTeX comes as a builtin module and the source code can be found in the `bin/lib/` directory. The source code of this document is also included in the `doc/` directory.

```
import haltex

section 'Use example'
enumerate:
  item; p '*First item*'
  item; p '|second|'
  item; p '**third**'
```

```
\section{Use example}
\begin{enumerate}
\item
\emph{First item}
\item
\texttt{second}
\item
\textbf{third}
\end{enumerate}
```

Figure 17: This should be applicable to many markup languages.