

# A Compiler Designed for the VSOP Language

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**Abstract**—In this report, we focus on explaining our different implementation choices, as well as our personal choices for the interpretation of a VSOP source code file.

## I. INTRODUCTION

The VSOP language is a ULg designed programming language aiming at being Turing-complete and providing the most used functionalities of well-known programming languages while focusing on keeping a lightweight syntax and little syntactic sugar.

In this context, we are building a compiler for this language that should be able to reach the LLVM transition format, to apply any other backed compiler afterwards. The designed compiler should also report errors in a convenient fashion.

We now describe each part of the frontend of the compiler in the following sections.

## II. LEXER

The lexer uses a JFlex produced regular expression analyzer to cut the input file into a stream of tokens. It tries not to stop on the first error to report as many errors as possible. Literals are determined by a look-ahead of either a white space character or an operator, so that ending the file with a literal will output an error. However, as VSOP is class-defined, the last character of any file should be a closing bracket, and this should not be a problem. To ensure compatibility with tests, however, we use a stream reader that adds a white space to the end of the stream, allowing those matchings to occur.

Upon errors, the lexer tries to determine which kind of error happened to produce more useful feedback to the user. This way, if the problems happens while parsing the beginning of a non-decimal number, the lexer will be able to output a specific message, for instance.

A final EOF token is added to the end of the stream, token used by java\_cup but which is not rendered while displaying the found tokens.

## III. PARSER

The parser reads the stream of symbols generated by the lexer to give them as feed to the java\_cup implementation of the VSOP grammar. The value associated to a mathematical

expression is still not computed on the fly, even if can be known at compile time.

Each generated node of the tree is an ASTNode that still embeds the information of position in the source code if it is a terminal symbol, or the beginning of a syntactically determined block remembered (for instance, a class, but not a parenthesis). The terminals typically have a value, either a string or an integer one, while all nodes can have properties such as a position. A type is associated to the leaves of the created AST so that the type of all object identifiers is already known at this time.

The dumping is done recursively from the root node, exploring the children's state.

Error recovery is kept minimal, it only tries to correctly parse three next tokens. If this is possible, the generation of the tree is continued, but by default the generated tree is not output as it may refer to garbage only. The position of the error is reported to the last correctly parsed token if the symbol involved is not a terminal or at the position of the terminal itself if known. So far, the position of elements is not recorded upwards so that some errors might still not be accurate in position.

## IV. SEMANTICS ANALYZER

A first incomplete pass is performed in the AST in order to find all the classes and then to populate all classes with their methods. At this step no check is done to validate inheritance nor method overriding.

From a first complete pass in prefix order in the AST the analyzer creates the scope of each node, by adding elements for all children of a node that declares a new element in the scope. From the same pass the semantic analyzer creates a tree of classes that extend from each other and verifies that each atom used as a leaf (not in a declaration) is indeed present in the scope of this leaf. A second pass is then issued in postfix order to add a type information to each statement and block of code. The leaves' type is already known by the parser and the type of a super node is uniquely determined by the operation applied to children expressions of this operation. At the same time the analyzer verifies

that the involved operations exists, are correctly called, with arguments matching in type and number. Thanks to the "extends tree" the analyzer is able to substitute a child class to a parent one to retrieve a legible operation.

## V. LLVM IR GENERATION

Known limitation: when using some special characters in strings, the C behaves so that it merges characters and therefore the output renders not as expected in VSOP, this is what makes our latest tests fail.

The generation comes down to building a OOP-free representation of an OOP language: each method is turned into a global function whose name is prefixed with the name of its class and that takes as first argument a structure representing the class: a structure that contains only the fields of the class.

The new operator invokes the constructor of the class, that issues a "super();" -like call if it extends something else than Object. The fields in a class are ordered with highest in extends-tree first so that those calls are easily managed.

The code is then emitted recursively, and the entry point of the program is set to a new Main.main().

### A. Direct LLVM emission

The compiler was originally designed to emit native LLVM directly, but in order to ease the integration of new functionalities, we have rather focused on generating C code, that CLang can compile either to LLVM or native code, and adding functionalities on top. We actually first thought we would emit native LLVM code, but Java really has a poor support for LLVM, that is why we changed our mind. You can find a stub for LLVM that never could produce anything in the src directory.

### B. C generation

This C generation is done as depicted above, only the "let" keyword has to be transformed into larger closures, with randomly generated new values. This is actually very close to direct LLVM generation and we think directly generating LLVM would not be too hard to implement, being almost only a matter of learning its syntax.

## VI. VSOP EXTENDED

We added the following features to extend the initial language, we describe here how they can be used.

### A. Garbage collection

The language is garbage collected at run-time.

### B. IO

The language can dump out values to the standard output using a class that will extend the built-in IO. Facilities for inputting values also exist and comply with the language semantics.

### C. Default parameters to methods

Methods arguments can have default values, using a syntax such as *name : type : defaultvalue*. These default values are overridden when the method is called with other arguments, and if not enough parameters are given, the compiler tries to add the remaining from their default values (one should therefore have the last arguments predefined, or there will be an error).

### D. Defined dispatch

Using the syntax *object < type.method(params)*, one can cast *object* to *type* and use the method defined as in *type*. Obviously the extension must exist and the method be defined at the upper level as well.

### E. Missing operators

Added OR, GREATER, GREATER\_EQUAL, SHIFT\_LEFT and SHIFT\_RIGHT operators.

### F. Numeric types

The float type has been added, with facilities for all operations and printing. POW operations still requires an int32 as exponent. The format of floats is to be  $[0-9] + .[0-9] + f$ . One can also switch between int32 and float types by using the @ symbol.

The byte type has been added, and represents only one byte of information. This type should be usable almost anywhere where an int32 is expected and casted down or up depending upon the situation.

### G. Arrays

One can use arrays, in a much like-java fashion, except that no protection against out of index exists. You can allocate arrays of any type, or arrays of arrays, the compiler checks that you access arrays as their type, and that you do not dereference them too much. The arrays are given by address, and assigning an array to another only copies the address, not the real contents. These arrays also support easy matrix semantics, that is, it is allowed to allocate over several dimensions with one instruction, where all dimensions will have the same length.

#### *H. Public, protected and private*

All methods and fields must be declared public, protected or private, using the +, ~ and - modifiers. Assignments to fields obtained through a method are allowed, eg: `foo.getBar().baz <- 2`; is a legal instruction.

#### *I. Cast to children*

The compiler allows forced casts to child classes, although this may cause a run-time error. Those casts have to be explicitly requested.

#### *J. Include*

In order to reuse part of the code, one can include file for compilation using the # directive, followed by a file name. These directives must be given at the beginning of a file, any number of such may be given. This file may be given relative or absolute, and will be included only if no other previous file included a file whose hash is the same. Note that this is not compilation avoidance, as the so given files are plain source code that will be recompiled.

#### *K. Automatic generation of getters and setters*

The syntax + in front of a field name allows the compiler to automatically generate a getter and a setter for the field, named `getField` and `setField` respectively, where the setter returns the self pointer in order to chain calls.

#### *L. Wrapper types*

The compiler automatically includes a file that declares wrappers for basic types, the classes `Unit`, `Bool`, `String`, `Float` and `Integer`. When possible, the compiler will wrap basic types in a wrapper class when required (such as in an assignment towards such a class), and unwrap them if needed (such as in mathematical expression or array dereferencing or passing as argument to a method that expects basic types).

#### *M. Easier constructor use*

For default uses of the `NEW` operator, support of inline constructors has been added, that is, `new Class(args)` is allowed and will dispatch a call to the `init` method of the newly generated object right after its creation.

#### *N. For loop on arrays*

Arrays support for-loop constructs, where type is inferred, using the construct `"for item : array : array_length do"`. If the expression given as array is not an array or if the length is not an integer, an error is thrown. This construction is recommended as easy as does not involve a function.

#### *O. Several local variables at once*

The syntax of the `"let"` keyword has been extended to allow the declaration of several variables at once in a `"let"` construct, using commas between each declaration.

#### *P. Equals, hash code and enhanced methods*

The `Object` class defines an equals method that is nothing but address comparison. Children classes are free to redefine locally this mechanism, as is done by the `String` class that uses the `C strcmp` function on its value field. The `String` class is thus extended to allow for comparison, concatenation etc, that the native type does not support.

In the same fashion, the code method computes a hash of the object, usually of the address, unless overridden as for `String` for instance.

Other wrapper types also have their equals method overridden and some helper methods.

All these features have been added, because of we attempted the implementation of native hash tables with a dedicated syntax. That is why we determined which hashing methods would be the most efficient for diverse data types such as memory addresses, strings, and float values. The implementation of the hash table was written, but not the code generation. It would have been possible to add set hash table keys and values to any desired type.

#### *Q. Object erasing*

Unlike many OO languages, VSOP extended can allow for object explicit destruction, using the `"erase"` keyword. This should only be used for values that should not remain in memory at run time for undefined amounts of time, such as for cryptography libraries. The `"erase"` operation always returns a null object whose type is the type of the destructured object. Only objects can be destroyed. If a public or protected method named `"delete"` that does not take arguments and returns self exists in the extension tree of the destroyed class, it is called before destruction happens, to garble up memory that should not be recoverable.

#### *R. External interfaces*

In order to not re-invent the wheel over and over, VSOP extended can use any C defined function in the following way: you have to add the includes you will need using `-ci` parameter of `vsopc`, and the libraries using `-cl`. Now, you can interface by creating a class whose names begins with `External`. All methods of such a class are taken to be defined outside, with a C function of the same name, taking the same arguments except the self pointer omitted. The correspondence of types is `int32(int)`, `string(char*)`, `float(float)`, `byte(char)`, `bool(char)`. You should just return something from the method, but it won't ever get evaluated, so often 0. Check the `TestExtended.ve` file for example. You should only interface other structure to `Object`, having them

passed by reference.

### *S. Interval testing*

The syntax "expression <> a:b" returns true if the expression is within bounded range a:b, working for integer types only obviously.

## VII. CONCLUSION

We presented our still under work compiler for the VSOP language. As one can see, it boils down to assemble the right generators finely tuned for a given language, but generic options to generate compilers now exist.

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