



Human-centric algebraic machine learning

AML-DL Interpreter - Final

Deliverable D3.7

WP3 - AML Description Language



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Executive summary

Algebraic Machine Learning (AML) is a relatively new machine learning technique based on algebraic representations of data. Unlike statistical learning, AML algorithms are robust regarding the statistical properties of the data and are parameter-free. The aim of the EU-funded ALMA project is to leverage AML properties to develop a new generation of interactive, human-centric machine learning systems. These systems are expected to reduce bias and prevent discrimination, remember what they know when they are taught something new, facilitate trust and reliability and integrate complex ethical constraints into human-artificial intelligence systems. Furthermore, they are expected to promote distributed, collaborative learning.

This report corresponds to *Deliverable D3.7 - AML-DL Interpreter - Final* of the ALMA project. This deliverable describes the architecture and usage of the AML-DL Interpreter (AML-DL Interpreter) that can transform human-readable semantic embeddings, written in AML Description Language (AML-DL), into AML input data for the AML Engine. Use instructions for the interpreter are described, and examples of use are provided for each individual one. Together with this document, the Python module that implements the interpreter is provided, as well as example embeddings.

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Acronyms

AML	Algebraic Machine Learning.
AML-DL	AML Description Language.
AML-DL Interpreter	AML-DL Interpreter.

1 Introduction

The primary goals of Algebraic Machine Learning Description Language (AML-DL) are to give the user the capability to concisely describe elaborate algebraic semantic embeddings and to establish a methodology to build embeddings for real-life problems. The specification of AML-DL is described in *Deliverable D3.4 - AML-DL Specification - Final*.

The AML-DL Interpreter implements the AML-DL Specification into an interpreter that can transform human-readable semantic embeddings into AML input data for the AML Engine.

2 AML-DL Interpreter

The AML-DL Interpreter is provided in the form of a Python module and strictly follows the AML-DL Specification as described in *Deliverable D3.4 - AML-DL Specification - Final*. Using a base language such as Python has obvious advantages as the entire base language is available as a platform to add control flow, variable handling, etc. Relying on a base language also makes the implementation simpler as it makes unnecessary to use a parser or a lexer. Python has the additional advantage of being well-maintained, easy to use, and widely used in data science and machine learning.

The implementation of AML-DL, as described in the specification, is highly customizable, but also instructions perform relatively simple operations. This can lead to the repetition of certain instructions and the appearance of common patterns. The use of a base language can help with code reusability as these repeated instructions and patterns can be grouped into functions and classes. In the future, if certain patterns are common to a wide range of problems in the AML community, they can be added to the AML-DL Python module.

2.1 AML-DL Interpreter architecture overview

The output of the AML-DL Interpreter is comprised of a set of descriptors representing constants, and a set of duples, which are formed by a pair of sets of descriptors. Descriptors can contain constants or other nested descriptors, giving rise to a tree structure. As the leaves of this tree structure are always formed by constants, duples can in essence be assimilated to a pair of sets of constants.

Commands are either final or bound. Commands are *final* if their return descriptors are directly appended to the embedding's output. These commands are `C`, `CV`, `ADD`. Commands are *bound* if their return descriptors are not appended to the embedding's output. These descriptors are meant to be used as inputs for other commands and bound to the output at a later step.

At any point, the program state corresponds to a set of final descriptors collected so far, and an internal dictionary that maps names to descriptor objects. Names are regular character strings that can be used to invoke descriptor objects by name.

2.2 Command Set

The functions and classes of the AML-DL Interpreter are defined in the module `amldl`. They can be individually imported with

```
1 from amldl import (
2     load_embedding,
3     Descriptor,
4     ADD, APP, C, CMP, CV, E, EXC, F, HEADER,
5     INC, M, N, R, S, SOME, T, V
6 )
```

In this document, it is assumed that they are all imported into the main namespace with

```
1 from amldl import *
```

2.2.1 Embedding creation

Most functions in the `amldl` module need to be called from within a Python Context that represents an embedding. An embedding is an instance of the class `Descriptor`.

```
1 with Descriptor() as theEmbedding:
2     ...
```

All examples below are assumed to be executed within such a Python Context.

All duples are assigned the region of their embedding at the time they are created. The `REGION` property of the embedding can be modified at any point.

```
1 with Descriptor() as theEmbedding:
2     theEmbedding.REGION = 5
```

2.2.2 Constant creation

`C(name)`

Defines a constant with the given name.

```
1 C("Q")
```

`CV(name, n)`

Defines a vector of constants with names: `name[0]`, `name[1]`, ..., `name[n-1]`.

```
1 CV("Q", 10)
```

`V([name])`

Defines an empty vector.

```
1 V("Qx")
2 APP(F("Qx"), V())
```

2.2.3 Duple creation

`INC(left term, right term)`

Defines a positive duple $l \leq h$.

l and h cannot be duples.

```
1 ADD(INC("U", B))
```

`EXC(left term, right term)`

Defines a negative duple $l \not\leq h$.

l and h cannot be duples.

```
1 ADD(EXC("Qx", "Qy"))
```

2.2.4 Term creation and manipulation

APP(*p*, *a*)

Appends *a* to *p*, where *p* is of type vector.

The vector *p* is modified in place.

```

1  # Create a vector that contains two empty vectors
2  V("Qx")
3  APP(F("Qx"), V())
4  APP(F("Qx"), V())

```

M(*p*₁ , ..., *p*_n)

Returns a set containing the *p*₁ to *p*_n elements.

If any argument is of type *tvector*, returns a descriptor of type *tvector* whose components are sets.

```

1  M(Qx, Qy, B, U)

```

R(*p*, *r*)

Removes *r* from the vector *p*.

If *r* is an integer, removes the *r*-th element of *p*.

Returns a new vector, and *p* is not modified.

```

1  b = CV("black", 2)
2  w = CV("white", 2)
3  wb[0] = M(w, R(b, 0)) # w[0], w[1], b[1]
4  wb[1] = M(w, R(b, 1)) # w[0], w[1], b[0]

```

CMP(*p*₁, *p*₂)

Declares *p*₁ and *p*₂ as the logical negations of each other.

Operates component-wise if *p*₁ and *p*₂ are vectors of the same length.

No return value.

```

1  CV("Q", 5)
2  CV("E", 5)
3  CMP("Q", "E")

```

CMP(*p*)

Finds or calculates the complementary of *p*.

Returns a copy of *p* where every element is substituted by its complementary.

```

1  CV("Q", 5)
2  CV("E", 5)
3  CMP("Q", "E")
4  F("E") == CMP("Q")

```

T(*p* [, *i*])

Associates an iterator to *p*, where *p* cannot be a duple.

The optional parameter *i* is an integer that identifies the iterator.

Returns a *tvector*.

```

1  b = CV("black", 2)
2  w = CV("white", 2)
3  wb = M(w , R(b, T(b)))
4  # wb.t[0] = M(w , R(b, 0)) = w[0], w[1], b[1]
5  # wb.t[1] = M(w , R(b, 1)) = w[0], w[1], b[0]

```

2.2.5 Auxiliary commands

F(name [,i])

Returns the descriptor associated with name.

If i is given and p is a vector, return the i-th element of p.

```

1  CV("black", 5)
2  b3 = F("black", 3)

```

SOME(p, prob [,atLeastOne, notAll])

Randomly chooses items from p with a probability **prob** per element.

When set to True, the flags ensure that there is at least one element, and not all have been chosen, respectively. By default, they are set to False.

```

1  CV("black", 5)
2  SOME("black", 0.5)

```

HEADER(name)

Guards a section of the embedding that should be read just once.

Returns True the first time, False otherwise.

```

1  if HEADER("black constants"):
2      CV("black", 5)

```

2.2.6 Loading an embedding

The embedding can be wrapped in a function **embedding** that takes any number of input arguments, that can be used as parameters, and returns the embedding's output.

```

1  def embedding():
2      with Descriptor() as theEmbedding:
3          C("A")
4          C("B")
5          ADD(INC("A", "B"))
6
7          constantNames = [el.key for el in F(theEmbedding.PEND_TRANSF).r]
8          p = F(theEmbedding.INCLUSIONS).r
9          n = F(theEmbedding.EXCLUSIONS).r
10
11     return (constantNames, p, n)

```

From a different script the embedding can be loaded using the **load_embedding** function.

```

1  (constantNames, p, n) = amldl.load_embedding("path/to/embedding.py")

```

3 Demonstrator

3.1 Instructions

Instructions for installation and usage are included in `README.md` in the project folder.

In this final version of the AML-DL Interpreter the Python module is provided as a Python file and can be directly executed in most Python versions. To avoid compatibility issues, it is possible to use a Docker container.

3.2 Options

The `interpreter` app has been recently enhanced with the following features:

- Saving to file
- Output to `stdout`
- Output with CSV friendly format
- Output internal constant ID or embedding name

3.3 Examples

The interpreter is distributed with two full semantic embeddings written in AML-DL, and an example script, `interpreter.py` that simplifies the task of reading embeddings.

These examples provide an overview of how to use the library to build a semantic embedding and how to load the resulting AML input data.

The script `interpreter.py` can be used from the command line. Full documentation can be found invoking the `--help` flag. The two examples provided can be run with the following commands, respectively:

```
1 $ python interpreter.py -i embeddings/cyclicGroupEmbedding.py
2
3 $ python interpreter.py -i embeddings/queensEmbedding.py N
```

Notice that `queensEmbedding.py` takes a parameter `N` that is provided as an input after the rest of parameters.

4 Future work

The implementation of AML-DL presented in this work is highly customizable. It provides the user with a powerful tool to describe embeddings. As common patterns appear, they can be identified and added to the tool, speeding up the process and reducing the amount of boilerplate code in the semantic embeddings. Regarding the current Python implementation, where the interpreter is under the form of a module, common patterns can be directly added to it as submodules, or distributed as independent modules.