Refactoring AwkwardForth Generation in Uproot

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Intro to Uproot
Uproot is an I/O library for reading and writing ROOT files for use in Python [1]. To keep it lightweight and portable, it is kept strictly as an I/O library, and does not depend on ROOT.

**Figure 1:** Abstraction layers of various methods to use ROOT files in Python.
When reading in non-columnar data types, iteration is required, and Python loops are slow compared to compiled languages.

- A compiled language cannot be used since, at compile time, the byte-for-byte layout in ROOT files with complex data types is unknown.
- Just-in-time compilation could be used, but this affects portability.
AwkwardForth
Uproot instead implements the use of AwkwardForth, an internal domain specific language [2].

By generating AwkwardForth code to read in the incoming complex data types, Uproot is significantly optimized. In the case of std::vector<std::vector<float>>, AwkwardForth is faster than Python by a factor of about 400.
Unfortunately, the current implementation of AwkwardForth generation in Uproot has some problems.

**Issues**

- Excessively mutable: Objects that change their attributes in arbitrary ways as information needed to generate AwkwardForth accumulates.
- Readability: Dead code, nondescript attribute names.
Refactor
To fix these issues, the refator is focusing on rewriting the generation to avoid as much mutability as possible, while utilizing test-driven development.

There are \(~140\) tests relating to AwkwardForth in the current implementation.
I started by removing all the code that relied on AwkwardForth. My next step was to understand in depth how AwkwardForth currently generates for the case `std::vector<std::vector<float>>`. Then, I refactored AwkwardForth for just that case, using the already-written tests to ensure I had done it correctly.
Refactor

Note: What AwkwardForth code gets generated is not changing. The outer "generation-machinery" is.

As the program reads through the data, it decides what AwkwardForth code to generate, if any.

The program stores collected AwkwardForth code-snippets in nodes. These nodes are then worked into a tree.

At the end, it recurses through the tree to generate the complete AwkwardForth code that will read in the data.
The code-snippet tree is highly mutable. The main focus of the refactor has been making it append only.

Each case

- Get result in current implementation.
- Understand which parts are logic to generate AwkwardForth.
- Deconstruct, reorganize, and rework to get same result, but with append only.
Figure 2: Python code that generates Python code that generates Forth code in current implementation.
Bibliography
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