# Describe Data to get Science-Data-Ready Tooling: Awkward Target for KSY

Manasvi Goyal[1], Ianna Osborne[1], Jim Pivarski[1], Amy Roberts[2] Andrea Zonca[3]

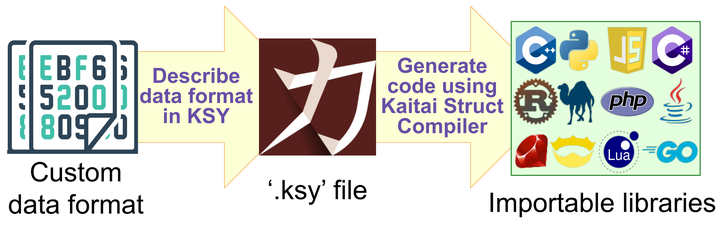
1. Princeton University, Princeton, NJ, USA; 2. University of Colorado Denver, Denver, CO, USA; 3. San Diego Supercomputer Center, La Jolla, CA, USA

## Need and Motivation

Scientific data formats can differ across experiments due to specialized hardware and data acquisition systems. The increase in custom data formats has posed a major challenge for collaborations like CDMS that spend hours writing their own tools to read and analyze their data. This project provides a simple solution. Collaborations only need to describe their custom data formats in KSY just once and then directly convert their data into Awkward Arrays using `kaitai_struct_awkward_runtime` API.

## What is Kaitai Struct YAML (KSY)?

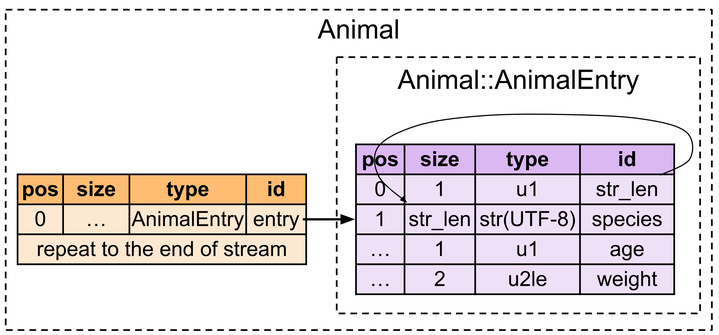
KSY is a declarative language that takes YAML-like descriptions of a data format structure and generates code in any of the supported languages to read a raw data file.




- Compile KSY with `kaitai_struct_compiler` into source files to read the structure in the languages of your choice.
- Utilize `kaitai_struct_[language]_runtime` API to write your own `main()` function to use these libraries for analysis.

## Example: `animal.ksy`

Here is a simple data structure that describes the animal data. However, the actual formats of scientific data are more complex.




| Bits | 0-7 | 8-15 | 16-23 | 24-31 | 32-39 | 40-55 |
|---|---|---|---|---|---|---|
| Value | 0x03 | 0x63 | 0x6f | 0x77 | 0x06 | 0xDC05 |

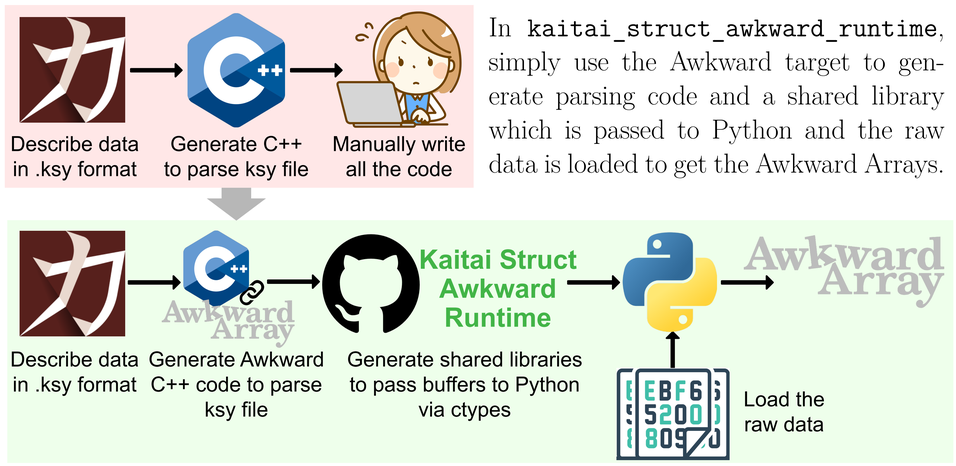
If you don't have a hex chart handy, this entry describes a 6 year old cow that weighs 1500 pounds.

## Why Awkward Arrays?

When dealing with large files and complicated data structures, even the most efficient Python code can be quite time and resource-heavy. Awkward Arrays offer a dynamic and efficient approach to represent complex data structures in NumPy-like arrays. Awkward arrays store data in jagged nested arrays of arbitrary types and variable lengths.

## Awkward Target for KSY: User Interface

Describe your custom data format into KSY just once. With just Kaitai, you have to write all the analysis code including `main()`. This takes a lot of time and efforts for complex nested data structures of scientic data.




In `kaitai_struct_awkward_runtime`, simply use the Awkward target to generate parsing code and a shared library which is passed to Python and the raw data is loaded to get the Awkward Arrays.

## KSY → LayoutBuilder in `animal.ksy`

```
using AnimalBuilderType =
  RecordBuilder<
    RecordField<Field_animal::
      animalA__Zentry,
      ListOffsetBuilder<int64_t,
        RecordBuilder<
          RecordField<Field_animal_entry::
            animal_entryA__Zstr_len,
            NumpyBuilder<uint8_t>>,
          RecordField<Field_animal_entry::
            animal_entryA__Zspecies,
            ListOffsetBuilder<int64_t,
              NumpyBuilder<uint8_t>>>,
          RecordField<Field_animal_entry::
            animal_entryA__Zage,
            NumpyBuilder<uint8_t>>,
          RecordField<Field_animal_entry::
            animal_entryA__Zweight,
            NumpyBuilder<uint16_t>>
        >>>
  >;
```

```
meta:
  id: animal
  endian: le
seq:
  - id: entry
    type: animal_entry
    repeat: eos
types:
  animal_entry:
    seq:
      - id: str_len
        type: u1
      - id: species
        type: str
        size: str_len
        encoding: UTF-8
      - id: age
        type: u1
      - id: weight
        type: u2
```

## `kaitai_struct_awkward_runtime` Steps

Clone, install `awkward-kaitai`, generate the C++ files for Awkward target and build `awkward_kaitai` for the main source file.

```
TERMINAL
> git clone --recursive https://github
.com/ManasviGoyal/kaitai_struct_awkward
_runtime.git
> ./kaitai-struct-compiler -t awkward
--outdir src-animal example_data/
schemas/animal.ksy
> pip install .
> awkward-kaitai-build src-animal/
animal.cpp -b build
```

Open python and print the returned ak.Array:

```
import awkward_kaitai
animal = awkward_kaitai.Reader(
    "./src-animal/libanimal.so"
) # pass the shared library
awkward_array = animal.load(
    "example_data/data/animal.raw"
) # pass the raw data file
awkward_array.to_list()[:2]
```

Finally, `animal.ksy` is represented in Awkward Arrays as:

```
[{'animalA__Zentry': [
    {'animal_entryA__Zstr_len': 3,
     'animal_entryA__Zspecies': 'cat',
     'animal_entryA__Zage': 5,
     'animal_entryA__Zweight': 12},
    {'animal_entryA__Zstr_len': 3,
     'animal_entryA__Zspecies': 'dog',
     'animal_entryA__Zage': 3,
     'animal_entryA__Zweight': 43}
]}]
```

## Acknowledgement

This work is supported by NSF cooperative agreements OAC-1836650 and PHY-2323298 (IRIS-HEP) and grants OAC-2104003 (PONDD) and OAC-2103945 (Awkward Array).