fastjet

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TUTORIAL

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The tutorial on this page describes how the user can use Awkward Arrays to perform clustering on the particle data.

CHAPTER

ONE

CLUSTERING SPECIFICATION

The fastjet library has some clases specifically made to provide the different parameters for clustering. This includes the following classes :

- JetDefinition
- AreaDefinition
- RangeDefinition

For example, the JetDefinition class can be instantiated in the following way:

```
import fastjet
jetdef = fastjet.JetDefinition(fastjet.antikt_algorithm, 0.6)
```

The JetDefinition class takes varied number of arguments, the first argument is always the type of algorithm, the number of rest of the arguments depends on how many parameters the given algorithm requires.

CHAPTER

TWO

THE JETALGORITHMS

The JetDefinition class takes JetAlgorithms as arguments. In the above example we have chosen the Anti-kt algorithm. The list of algorithms is as following:

- `kt_algorithm` : The longitudinally invariant k_t algorithm with distance measures

$$d_{ij} = \min(p_{Ti}^2, p_{Tj}^2)\frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = p_{Ti}^2.$$

- `cambridge_algorithm` : The longitudinally invariant variant of the cambridge algorithm (aka Aachen algoithm) with distance measures

$$d_{ij} = \frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = 1.$$

- `antikt_algorithm` : Like the k_t but with distance measures

$$d_{ij} = \min(p_{Ti}^{-2}, p_{Tj}^{-2})\frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = p_{Ti}^{-2}.$$

- `genkt_algorithm` : The generalized k_t algorithm but with distance measures

$$d_{ij} = \min(p_{Ti}^{2p}, p_{Tj}^{2p})\frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = p_{Ti}^{2p}$$

  where `p = extra_param()`. Special cases are for $p = 1$ (gives the k_t algorithm), $p = 0$ (gives the Cambridge/Aachen algorithm), and $p = -1$ (gives the anti-k_t algorithm),.

- `ee_kt_algorithm` : The e^+e^- k_t algorithm (also known as Durham algoithm) with distance measure

$$d_{ij} = 2\min(E_i^2, E_j^2)(1 - \cos\theta_{ij}).$$

- `ee_genkt_algorithm` : The e^+e^- `genkt` algorithm with distance measures

$$d_{ij} = \min(E_i^{2p}, E_j^{2p})\frac{1 - \cos\theta_{ij}}{1 - \cos R},$$
$$d_{iB} = E_i^{2p}$$

  For $\pi < R < 3\pi$ and $p = 1$ it gives the `ee_kt` algorithm.

- `cambridge_for_passive_algorithm` : A version of cambridge with a special distance measure for particles with `pt < extra_param()`. This is not usually intended for end users, but is instead automatically selected when requesting a passive Cambridge area.
- Other algorithms that are not mentioned are most likely not implemented yet.

For a more complete description of the algorithms, please refer to the fastjet manual.

CHAPTER

THREE

THE DATA

The input data for the Multi-event interface has to be an Awkward Array. One such example is as follows:

```
    >>> import awkward as ak
    >>> array1 = ak.Array(
...     [
...         {"px": 1.2, "py": 3.2, "pz": 5.4, "E": 23.5},
...         {"px": 32.2, "py": 64.21, "pz": 543.34, "E": 755.12},
...         {"px": 32.45, "py": 63.21, "pz": 543.14, "E": 835.56},
...     ],
... )
```

The Awkward Array here is a Record Array of Lorentz Vectors. `fastjet` is able to handle record arrays automatically when the fields are named `("px", "py", "pz", "E")`. In order to pass arrays with `("pt", "eta", "phi", "M")` fields, the user has to use `vector` and register the behavior. For example:

```
>>> import vector
>>> vector.register_awkward()
>>> array2 = ak.Array(
...     [
...         {"pt": 3.42, "eta": 1.24, "phi": 1.21, "M": 22.6},
...         {"pt": 71.8, "eta": 2.72, "phi": 1.11, "M": 519},
...         {"pt": 71.1, "eta": 2.73, "phi": 1.1, "M": 631},
...     ],
...     with_name="Momentum4D",
... )
```

The `with_name` argument is used to specify the name of the vector that will be used to override the default behavior. The `vector.register_awkward()` function registers the behavior of `Momentum4D` in `awkward`. The previous example with `("px", "py", "pz", "E")` fields still works:

```
>>> array3 = ak.Array(
...     [
...         {"px": 1.2, "py": 3.2, "pz": 5.4, "E": 23.5},
...         {"px": 32.2, "py": 64.21, "pz": 543.34, "E": 755.12},
...         {"px": 32.45, "py": 63.21, "pz": 543.14, "E": 835.56},
...     ],
...     with_name="Momentum4D",
... )
```

It is good practice to register the behavior of the vector before using it in `fastjet`.

CHAPTER

FOUR

CLUSTERSEQUENCE CLASS

After defining the JetDefinition class, the user can provide this instance to the ClusterSequence class as an argument, along with the input data to perform the clustering:

```
>>> cluster = fastjet.ClusterSequence(array1, jetdef)
#--------------------------------------------------------------------------
#                         FastJet release 3.4.1
#                 M. Cacciari, G.P. Salam and G. Soyez
#     A software package for jet finding and analysis at colliders
#                           http://fastjet.fr
#
# Please cite EPJC72(2012)1896 [arXiv:1111.6097] if you use this package
# for scientific work and optionally PLB641(2006)57 [hep-ph/0512210].
#
# FastJet is provided without warranty under the GNU GPL v2 or higher.
# It uses T. Chan's closest pair algorithm, S. Fortune's Voronoi code,
# CGAL and 3rd party plugin jet algorithms. See COPYING file for details.
#--------------------------------------------------------------------------
>>> cluster
<fastjet._pyjet.AwkwardClusterSequence object at 0x7f1413120a90>
```

CHAPTER

FIVE

EXTRACTING INFORMATION

Any output that has to be an Array will be an Awkward Array in the array oriented interface. For example:

```
>>> cluster.inclusive_jets()
<MomentumArray4D [{px: 1.2, py: 3.2, pz: 5.4, ...}, ...] type='2 * Momentum...'>
```

CHAPTER

SIX

LIMITATIONS

The Awkward Array interface is only available for the fastjet.ClusterSequence class. The Awkward Array functionality is likely to be expanded to other classes in the future.

CHAPTER

SEVEN

THE OBJECT ORIENTED INTERFACE

7.1 Clustering the data

The fastjet library provides many options for the user to perform clustering on HEP data. The library has been designed keeping in mind the different requirements of users. The basic clustering process is described below.

7.2 Clustering Specification

The fastjet library has some clases specifically made to provide the different parameters for clustering. This includes the following classes :

- JetDefinition
- AreaDefinition
- RangeDefinition

For example, the JetDefinition class can be instantiated in the following way:

```
import fastjet
jetdef = fastjet.JetDefinition(fastjet.antikt_algorithm, 0.6)
```

The JetDefinition class takes varied number of arguments, the first argument is always the type of algorithm, the number of rest of the arguments depends on how many parameters the given algorithm requires.

7.3 The JetAlgorithms

The JetDefinition class takes JetAlgorithms as arguments. In the above example we have chosen the Anti-kt algorithm. The list of algorithms is as following:

- `kt_algorithm` : The longitudinally invariant k_t algorithm with distance measures

$$d_{ij} = \min(p_{Ti}^2, p_{Tj}^2)\frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = p_{Ti}^2.$$

- `cambridge_algorithm` : The longitudinally invariant variant of the cambridge algorithm (aka Aachen algorithm) with distance measures

$$d_{ij} = \frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = 1.$$

- `antikt_algorithm` : Like the k_t but with distance measures

$$d_{ij} = \min(p_{Ti}^{-2}, p_{Tj}^{-2}) \frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = p_{Ti}^{-2}.$$

- `genkt_algorithm` : The generalized k_t algorithm but with distance measures

$$d_{ij} = \min(p_{Ti}^{2p}, p_{Tj}^{2p}) \frac{\Delta R_{ij}^2}{R^2},$$
$$d_{iB} = p_{Ti}^{2p}$$

  where `p = extra_param()`. Special cases are for $p = 1$ (gives the k_t algorithm), $p = 0$ (gives the Cambridge/Aachen algorithm), and $p = -1$ (gives the anti-k_t algorithm),.

- `ee_kt_algorithm` : The e^+e^- k_t algorithm (also known as Durham algoithm) with distance measure

$$d_{ij} = 2\min(E_i^2, E_j^2)(1 - \cos\theta_{ij}).$$

- `ee_genkt_algorithm` : The e^+e^- `genkt` algorithm with distance measures

$$d_{ij} = \min(E_i^{2p}, E_j^{2p}) \frac{1 - \cos\theta_{ij}}{1 - \cos R},$$
$$d_{iB} = E_i^{2p}$$

  For $\pi < R < 3\pi$ and $p = 1$ it gives the `ee_kt` algorithm.

- `cambridge_for_passive_algorithm` : A version of cambridge with a special distance measure for particles with `pt < extra_param()`. This is not usually intended for end users, but is instead automatically selected when requesting a passive Cambridge area.
- Other algorithms that are not mentioned are most likely not implemented yet.

For a more complete description of the algorithms, please refer to the fastjet manual.

7.4 The Data

The input for the classic interface is a list of PseudoJets. To use the classic interface here's what the data should look like (This is a single event interface, one function call can only process one event):

```
>>> array = [
...     fastjet.PseudoJet(1.1,1.2,1.3,11.4),
...     fastjet.PseudoJet(2.1,2.2,2.3,12.4),
...     fastjet.PseudoJet(3.1,3.2,3.3,13.4)
... ]
```

7.5 ClusterSequence Class

After defining the JetDefinition class, the user can provide this instance to the ClusterSequence class as an argument, along with the input data to perform the clustering:

```
>>> cluster = fastjet.ClusterSequence(array, jetdef)
#--------------------------------------------------------------------------
#                         FastJet release 3.4.1
#                 M. Cacciari, G.P. Salam and G. Soyez
#     A software package for jet finding and analysis at colliders
#                           http://fastjet.fr
#
# Please cite EPJC72(2012)1896 [arXiv:1111.6097] if you use this package
# for scientific work and optionally PLB641(2006)57 [hep-ph/0512210].
#
# FastJet is provided without warranty under the GNU GPL v2 or higher.
# It uses T. Chan's closest pair algorithm, S. Fortune's Voronoi code,
# CGAL and 3rd party plugin jet algorithms. See COPYING file for details.
#--------------------------------------------------------------------------
>>> cluster
<fastjet._swig.ClusterSequence; proxy of <Swig Object of type 'fastjet::ClusterSequence *
↪' at 0x11b15bc90> >
```

7.6 Extracting Information

Any output that has to be an Array will be a list of PseudoJets if it's particle data. For example:

```
>>> inc_jets = cluster.inclusive_jets()
>>> for elem in inc_jets:
...     print("px:", elem.px(),"py:", elem.py(),"pz:", elem.pz(),"E:", elem.E(),)
px: 6.300000000000001 py: 6.6000000000000005 pz: 6.8999999999999995 E: 37.2
```

CHAPTER

EIGHT

THE CLASSIC INTERFACE CLASSES

The documentation for the C++ Fastjet covers all the classes in fastjet. The python classes of the classic interface behave exactly like they do in C++, therefore we are providing a link to the respective doxygen pages:

- PseudoJet
- JetDefinition
- ClusterSequenceArea
- AreaDefinition
- Every Other C++ Class (Almost all available through the classic interface)

CHAPTER

NINE

FASTJET.CLUSTERSEQUENCE

class fastjet.**ClusterSequence**(*data*, *jetdef*)

The base class for all clustering.

Parameters

- **data** (*awkward.highlevel.Array*) – The data for clustering.
- **jetdef** (*fastjet._swig.JetDefinition*) – The JetDefinition for clustering specification.

Q() → Array | float

Returns the sum of all energies in the event (relevant mainly for e+e-)

Parameters
None –

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

Q2() → Array | float

Return Q()^2

Parameters
None –

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

childless_pseudojets() → Array

Return the list of pseudojets in the ClusterSequence that do not have children (and are not among the inclusive jets).

Parameters
None –

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`constituent_index`(*min_pt: float = 0*) → Array

Returns the index of the constituent of each Jet.

Parameters
`min_pt` (*float*) – The minimum value of the pt for the inclusive jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`constituents`(*min_p: float = 0*) → Array

Returns the particles that make up each Jet.

Parameters
`min_pt` (*float*) – The minimum value of the pt for the inclusive jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`exclusive_dmerge`(*njets: int = 10*) → Array | float

Returns the dmin corresponding to the recombination that went from n+1 to n jets.

Parameters
`n_jets` (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`exclusive_dmerge_max`(*njets: int = 10*) → Array | float

Returns the maximum of the dmin encountered during all recombinations up to the one that led to an n-jet final state.

Parameters
`n_jets` (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`exclusive_jets`(*n_jets: int = -1*, *dcut: float = -1*) → Array

Returns the exclusive jets after clustering in the same format as the input awkward array. Either takes njets or dcut as argument.

Parameters

- `n_jets` (*int*) – The number of jets it was clustered to.
- `dcut` (*float*) – The dcut for the result.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_jets_constituents(*njets: int = 10*) → Array

Returns the particles that make up each exclusive jet.

Parameters
njets (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_jets_constituents_index(*njets: int = 10*) → Array

Returns the index of the constituent of each exclusive jet.

Parameters
njets (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_jets_energy_correlator(*njets: int = 1*, *beta: int = 1*, *npoint: int = 0*, *angles: int = -1*, *alpha=0*, *func='generalized'*, *normalized=True*) → Array

Returns the energy correlator of each exclusive jet.

Parameters

- **njets** (*int*) – The number of jets it was clustered to.
- **n_point** (*int*) – The number of points in the correlator.
- **angle** – The number of angles to be used in the correlator (if angle != n_point, ECFG is used).
- **beta** – The beta value for the correlator.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_jets_lund_declusterings(*njets: int = 10*) → Array

Returns the Lund declustering Delta and k_T parameters from exclusive n_jets.

Parameters
njets (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_jets_softdrop_grooming(*njets: int = 1*, *beta: int = 0*, *symmetry_cut: float = 0.1*, *symmetry_measure='scalar_z'*, *R0: float = 0.8*, *recursion_choice='larger_pt'*, *mu_cut: float = inf*) → Array

Performs softdrop pruning on jets. :param n_jets: number of exclusive subjets. :param beta: softdrop beta parameter. :param symmetry_cut: softdrop symmetry cut value. :param symmetry_measure: Which symmetry measure to use, found in RecursiveSymmetryCutBase.hh :param R0: softdrop R0 parameter. :param recursion_choice: Which recursion choice to use, found in RecursiveSymmetryCutBase.hh :param subtractor: an optional pointer to a pileup subtractor (ignored if zero)

Returns
Returns an array of values from the jet after it has been groomed by softdrop.

`exclusive_jets_ycut`(*ycut: float = -1*) → Array

Returns the exclusive jets after clustering in the same format as the input awkward array.

Parameters
ycut (*float*) – The dcut for the result.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`exclusive_subdmerge`(*data: Array*, *nsub: int = 0*) → Array | float

Returns the dij that was present in the merging nsub+1 -> nsub subjets inside this jet.

Parameters

- **data** (*awkward.highlevel.Array*) – An Awkward Array containing the Jets.
- **n_sub** (*int*) – The number of subjets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`exclusive_subdmerge_max`(*data: Array*, *nsub: int = 0*) → Array | float

Returns the maximum dij that occurred in the whole event at the stage that the nsub+1 -> nsub merge of subjets occurred inside this jet.

Parameters

- **data** (*awkward.highlevel.Array*) – An Awkward Array containing the Jets.
- **n_sub** (*int*) – The number of subjets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`exclusive_subjets`(*data: Array*, *dcut: float = -1*, *nsub: int = -1*) → Array

Returns an Awkward Array of all subjets of the current jet (in the sense of the exclusive algorithm) that would be obtained when running the algorithm with the given dcut.

Parameters

- **data** (*awkward.highlevel.Array*) – An Array containing the Jets.
- **dcut** (*float*) – The dcut for the result.
- **n_sub** (*int*) – The number of subjets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_subjets_up_to(*data: Array*, *nsub: int = 0*) → Array

Returns the list of subjets obtained by unclustering the supplied jet down to nsub subjets (or all constituents if there are fewer than nsub).

Parameters

- **data** (*awkward.highlevel.Array*) – An Awkward Array containing the Jets.
- **n_sub** (*int*) – The number of subjets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_ymerge(*njets: int = 10*) → Array | float

Returns the ymin corresponding to the recombination that went from n+1 to n jets.

Parameters
n_jets (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

exclusive_ymerge_max(*njets: int = 10*) → Array | float

Same as exclusive_dmerge_max, but normalised to squared total energy.

Parameters
n_jets (*int*) – The number of jets it was clustered to.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

get_child(*data: Array*) → Array

If the jet has parents in the clustering, it returns them.

Parameters
data (*awkward.highlevel.Array*) – An Array containing the Jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

get_parents(*data: Array*) → Array

If the jet has parents in the clustering, it returns them.

Parameters
data (*awkward.highlevel.Array*) – An Array containing the Jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`has_child`(*data: Array*) → Array | bool

If the jet has children in the clustering, it returns true.

Parameters
data (*awkward.highlevel.Array*) – An Array containing the Jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`has_parents`(*data: Array*) → Array | bool

if the jet has parents in the clustering, it returns true.

Parameters
data (*awkward.highlevel.Array*) – An Array containing the Jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`inclusive_jets`(*min_pt: float = 0*) → Array

Returns the inclusive jets after clustering in the same format as the input awkward array

Parameters
min_pt (*float*) – The minimum value of the pt for the inclusive jets.

Returns
Returns an Awkward Array of the same type as the input containting inclusive jets.

Return type
awkward.highlevel.Array

`jet_def`() → JetDefinition

Returns the Jet Definition Object associated with the instance

Parameters
None –

Returns
Returns the jetdefinition stored as an attribute.

Return type
JetDefinition

`jet_scale_for_algorithm`(*data: Array*) → Array | float

Returns the scale associated with a jet as required for this clustering algorithm (kt^2 for the kt-algorithm, 1 for the Cambridge algorithm).

Parameters
data (*awkward.highlevel.Array*) – An Array containing the Jets.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`jets()` → Array

Allows the user to access the internally stored _jets() array, which contains both the initial particles and the various intermediate and final stages of recombination.

Parameters
none –

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`n_exclusive_jets`(*dcut: float = 0*) → Array | int

Returns the number of jets (in the sense of the exclusive algorithm) that would be obtained when running the algorithm with the given dcut.

Parameters
dcut (*float*) – The dcut for the result.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`n_exclusive_subjets`(*data: Array*, *dcut: float = 0*) → Array | int

Returns the size of exclusive_subjets(…); still n ln n with same coefficient, but marginally more efficient than manually taking len(exclusive_subjets)

Parameters

- **data** (*awkward.highlevel.Array*) – An Array containing the Jets.
- **dcut** (*float*) – The dcut for the result.

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`n_particles()` → Array | int

Returns the number of particles that were provided to the clustering algorithm.

Parameters
None –

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

`unclustered_particles()` → Array

Returns the unclustered particles after clustering in the same format as the input awkward array

Parameters
None –

Returns
Returns an Awkward Array of the same type as the input contating the unclustered particles.

Return type
awkward.highlevel.Array

`unique_history_order()` → Array

Routine that returns an order in which to read the history such that clusterings that lead to identical jet compositions but different histories (because of degeneracies in the clustering order) will have matching constituents for each matching entry in the unique_history_order.

Parameters
`None` –

Returns
Returns an Awkward Array of the same type as the input.

Return type
awkward.highlevel.Array

Fastjet is a library for performing Jet-Finding *within* the Scikit-HEP ecosystem. The library includes the classic interface, and a new interface built to perform clustering on multi-event Awkward Array objects.

Note: Any questions about the C++ library, the jet finding algorithms, etc. should be directed to fastjet.fr. This page is meant to document the Python interfaces.

CHAPTER

TEN

DOCUMENTATION

- Python interface - This site.
- GitHub

CHAPTER

ELEVEN

INSTALLATION

fastjet can be installed from pypi using pip:

```
pip install fastjet
```

Most users will get a precompiled binary (wheel) for your operating system and Python version. If not, the above attempts to compile from source.

CHAPTER

TWELVE

THE INTERFACES

The fastjet library provides many options for the user to perform clustering on HEP data. The library has been designed keeping in mind the different requirements of users.

The fastjet library contains two interfaces within:

- **The Awkward interface**
- **The Classic interface**

The Awkward interface is the new interface made to handle multi-event data, whereas the classic interface is the same as the C++ library, designed to handle the data in a particle-at-a-time fashion. The tutorials are divided into two to explain how each of the interfaces work. Please take a look at the tutorial section to get started.

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