Basic Applied Topology Subprograms

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Python bindings for the BATS library. This includes:

- Simplicial, Cubical, and Cell Complexes
- Simplicial, Cubical, and Cellular Maps
- Homology and induced maps
- Persistent homology
- Zigzag homology
- A variety of topolgical constructions

Note that the C++ repository is the main library, and contains more features. This repository provides bindings for a subset of the functionality of BATS, and is under active development.

For background on what this repository does, refer to the paper Persistent and Zigzag Homology: A Matrix Factorization Viewpoint by Gunnar Carlsson, Anjan Dwaraknath, and Bradley J. Nelson.

CHAPTER

ONE

GET STARTED

First, install BATS.py.

Now, you can load BATS in python via

```
import bats
```

Next, check out the quickstart guide.

1.1 Installation

The easiest way to install `bats` is using `pip`

```
pip install bats-tda # gcc
```

To use clang (e.g. on a Mac) try

```
CC=clang pip install bats-tda # clang
```

Because `bats` uses OpenMP, it has to be compiled from source with a C++17 compliant complier. This means installation can take a few minutes. You can pass `--verbose` to `pip` to see what is going on with installation.

If you don't have OpenMP, you can install with a package manager.

GCC (e.g. on Linux)

```
dnf install libgomp-devel # Fedora
```

```
apt-get install libgomp1-dev # Ubuntu
```

Clang (e.g. on Mac)

```
brew install libomp
```

1.1.1 Compiling from Source

You can also complile `bats` from the source code. This can be useful for debugging installation or contributing to `bats`.

```
conda create -n bats python=3
conda install numpy matplotlib
```

if you want to use ipython notebooks, you may want to install

```
conda install ipython notebook
```

clone repository *use recursive option for submodules*

```
git clone --recurse-submodules git@github.com:CompTop/BATS.py.git
```

or if you want to use `https` protocol:

```
git clone --recurse-submodules https://github.com/CompTop/BATS.py.git
```

Assuming you cloned the repository successfully, just move to the root directory of the repository and install

```
cd BATS.py
python setup.py install
```

If you want to use `clang` (for example, on a mac), try

```
CC=clang python setup.py install
```

1.1.2 Development

Some useful commands for development:

build in directory

```
python setup.py build_ext --inplace
```

update submodules

```
git submodule update --remote
```

pull and update submodules

```
git pull --recurse-submodules
```

force a new build (`-f`), use parallelism (`-j`)

```
python setup.py build_ext -f -j4
python setup.py install
```

1.1.3 Testing

BATS.py uses the `unittest` framework. See documentation here.

Running all tests

First, you need to have the `bats` module built in-place.

```
python setup.py build_ext --inplace
```

From the root of the repository, run

```
python -m unittest discover
```

Running individual test files

From `BATS.py/test`, you can run individual test files

```
python -m unittest simplicial.py
```

1.1.4 Upgrading

If you want to update BATS.py to the latest development version, you need to pull and re-build. From the repository root directory:

```
git pull --recurse-submodules
python setup.py build --force # rebuilds all pybind executables
python setup.py install
```

1.2 Quickstart Guide

Once you have successfully installed `bats`, you can follow this guide to help you get started. You can download this guide as a Jupyter notebook here.

You can find additional information and examples in the tutorials and examples, and ultimately the API reference.

First, import `bats`:

[1]:
```
import bats
```

1.2.1 Simplicial Complexes and Homology

BATS offers two implementations of simplicial complexes: `SimplicialComplex` and `LightSimplicialComplex`. While the internal representations differ, they both have the same interface which can be used.

> Simplices in bats should generally be assumed to be *ordered*, meaning that `[0,1,2]` is not the same as `[1,2,0]`. If you want to use *unordered* simplices, you can either add vertices in sorted order, or use a sorting algorithm before adding simplices to complexes.

The add method will add simplices, assuming that all faces have previously been added. The `add_recursive` method will recursively add faces as needed.

[7]:
```
X = bats.SimplicialComplex()
X.add_recursive([0,1,2])
X.add_recursive([2,3])
X.add([1,3])

X.get_simplices()
```

[7]:
```
[[0], [1], [2], [3], [0, 1], [0, 2], [1, 2], [2, 3], [1, 3], [0, 1, 2]]
```

Now let's compute homology

[15]:
```
R = bats.reduce(X, bats.F2()) # F2 is coefficient field

for k in range(R.maxdim()):
    print("dim H_{}: {}".format(k, R.hdim(k)))
```

```
dim H_0: 1
dim H_1: 1
```

The output of `bats.reduce` is a `ReducedChainComplex` which holds information used to compute homology.

For `LightSimplicialComplex`, you need to provide an upper bound on the number of vertices and maximum simplex dimension.

[13]:
```
n = 4 # number of vertices
d = 2 # max simplex dimension
X = bats.LightSimplicialComplex(n, d)
X.add_recursive([0,1,2])
X.add_recursive([2,3])
X.add([1,3])

X.get_simplices()
```

[13]:
```
[[0], [1], [2], [3], [0, 1], [0, 2], [1, 2], [2, 3], [1, 3], [0, 1, 2]]
```

[14]:
```
R = bats.reduce(X, bats.F2())

for k in range(R.maxdim()):
    print("dim H_{}: {}".format(k, R.hdim(k)))
```

```
dim H_0: 1
dim H_1: 1
```

1.2.2 Persistent Homology

You can add simplices to a filtration by providing a parameter at which they first appear.

[17]:
```
F = bats.FilteredSimplicialComplex()
F.add_recursive(0.0, [0,1,2])
F.add_recursive(1.0, [2, 3])
F.add(2.0, [1,3])
```

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```
F.complex().get_simplices()
```

[17]:
```
[[0], [1], [2], [3], [0, 1], [0, 2], [1, 2], [2, 3], [1, 3], [0, 1, 2]]
```

again, we can use the `reduce` function, but now we get a `ReducedFilteredChainComplex`

[20]:
```
R = bats.reduce(F, bats.F2())

for k in range(R.maxdim()):
    for p in R.persistence_pairs(k):
        print(p)
```

```
0 : (0,inf) <0,-1>
0 : (0,0) <1,0>
0 : (0,0) <2,1>
0 : (1,1) <3,3>
1 : (0,0) <2,0>
1 : (2,inf) <4,-1>
```

The output of `R.persistence_pairs(k)` is a vector of `PersistencePairs` for k-dimensional persistent homology.

A `PersistencePair` includes 5 pieces of information: * The dimension of the homology class. * The birth and death parameters of the homology class. * The simplex indices responsible for birth and death.

[28]:
```
p = R.persistence_pairs(1)[-1]
print(p)
print(p.dim(), p.birth(), p.death(), p.birth_ind(), p.death_ind(), sep=', ')
```

```
1 : (2,inf) <4,-1>
1, 2.0, inf, 4, 18446744073709551615
```

infinite bars have a death index set to `2**64 - 1`

1.2.3 Maps

BATS makes dealing with maps between topological spaces and associated chain maps and induced maps on homology easy. The relevant class is a `CellularMap` which keeps track of what cells in one complex map to what cells in another.

We'll just look at a wrapper for `CellularMap`, called `SimplcialMap` which can be used to extend a map on the vertex set of a `SimplicialComplex` to a map of simplices.

First, we'll build identical simplicial complexes `X` and `Y` which are both cycle graphs on four vertices.

[30]:
```
X = bats.SimplicialComplex()
X.add_recursive([0,1])
X.add_recursive([1,2])
X.add_recursive([2,3])
X.add_recursive([0,3])

Y = X
```

We then build a simplicial map from X to Y which is extended from a reflection of the vertices.

[31]:
```
f0 = [2, 1, 0, 3]
F = bats.SimplicialMap(X, Y, f0)
```

The map is extended by sending vertex `i` in `X` to vertex `f0[i]` in `Y`. Next, we can apply the chain functor. We'll use F3 coefficients.

[32]:
```
CX = bats.Chain(X, bats.F3())
CY = bats.Chain(Y, bats.F3())
CF = bats.Chain(F, bats.F3())
```

Finally, we can compute homology of the chain complexes and the induced maps.

[41]:
```
RX = bats.reduce(CX)
RY = bats.reduce(CY)

for k in range(RX.maxdim()+1):
    HFk = bats.InducedMap(CF, RX, RY, k)
    print("induced map in dimension {}:".format(k))
    print(HFk.tolist())
```

```
induced map in dimension 0:
[[1]]
induced map in dimension 1:
[[2]]
```

The induced map in dimension 0 is the identity. The induced map in dimension 1 is multiplication by `2 = -1 mod 3`

1.2.4 Zigzag Homology

We'll now compute a simple zigzag barcode, using the above example. We'll consider a diagram with two (identical) spaces, connected by a single edge which applies the reflection map in the above example.

[43]:
```
D = bats.SimplicialComplexDiagram(2,1) # diagram with 2 nodes, 1 edge
D.set_node(0, X)
D.set_node(1, Y)
D.set_edge(0, 0, 1, F) # edge 0: F maps from node 0 to node 1
```

We can now apply the `Chain` and `Hom` functors to obtain a diagram of homology vector spaces and maps between them

[47]:
```
CD = bats.ChainFunctor(D, bats.F3())
```

[51]:
```
HD = bats.Hom(CD, 1) # computes homology in dimension 1
ps = bats.barcode(HD, 1) # extracts barcode
for p in ps:
    print(p)
```

```
1 : (0,1) <0,0>
```

This indicates there is a 1-dimensional homology bar, which is born in the space with index 0 and survives until the space with index 1. The `<0,0>` indicates which generators are associated with the homology class in the diagram.

1.3 Tutorials

1.3.1 Complexes and Filtrations

SimplicialComplex

Documentation

```
from bats import SimplicialComplex
C = SimplicialComplex()
```

```
X = bats.SimplicialComplex()
X.add([0])
X.add([1])
X.add([0,1])
X.print_summary()
X.boundary(1).print()
```

Add Simplices

Simplices are added as python lists

```
C.add([0])
C.add([1])
C.add([0,1])
```

Get Simplices

You can get a list of all simplices in a given dimension

```
C.get_simplices(0) # [[0], [1]]
G.get_simplices(1) # [[0, 1]]
```

Cell Complex

Documentation

1.3.2 Filtrations

BATS also exposes functionality for filtered verisons of `SimplicialComplex`, `ChainComplex`, and `ReducedChainComplex`

```
import bats

# create FilteredSimplicialComplex
F = bats.FilteredSimplicialComplex()
F.add(0.0, [0])
```

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```
F.add(0.0, [1])
F.add(0.0, [2])
F.add(1.0, [0,1])
F.add(1.0, [0,2])
F.add(1.0, [1,2])

FC2 = bats.FilteredF2ChainComplex(F)

RFC2 = bats.ReducedFilteredF2ChainComplex(FC2)

# H1, first generator
p = RFC2.persistence_pairs(1)[0]

# extract a homology representative for the generator
v = RFC2.representative(p)
```

1.3.3 Data Sets

1.3.4 Diagrams

Diagrams

Several Types of diagrams are available for use

```
import bats

c1 = [{0,1}, {1,2}]
c2 = [{0,2}, {0,1}]
c3, f1, f2 = bats.bivariate_cover(c1, c2)

D = bats.CoverDiagram(3,2)
D.set_node(0, c1)
D.set_node(1, c3)
D.set_node(2, c2)
D.set_edge(0, 1, 0, f1)
D.set_edge(1, 1, 2, f2)

# Nerve Functor applied to cover diagram
ND = bats.NerveDiagram(D, 1)

# F2 Chain functor applied to diagram of spaces
CD = bats.F2Chain(ND)

# Hom functor applied to diagram of Chain complexes
HD = bats.Hom(CD, 0)

# extract barcode
PD = bats.barcode(HD, 0)

for p in PD:
    print(p)
```

```
0 : (0,2) <0,0>
0 : (1,1) <1,1>
```

1.3.5 Geometric Constructions

Rips, Dowker, Witness, Nerve, Cover Complexes

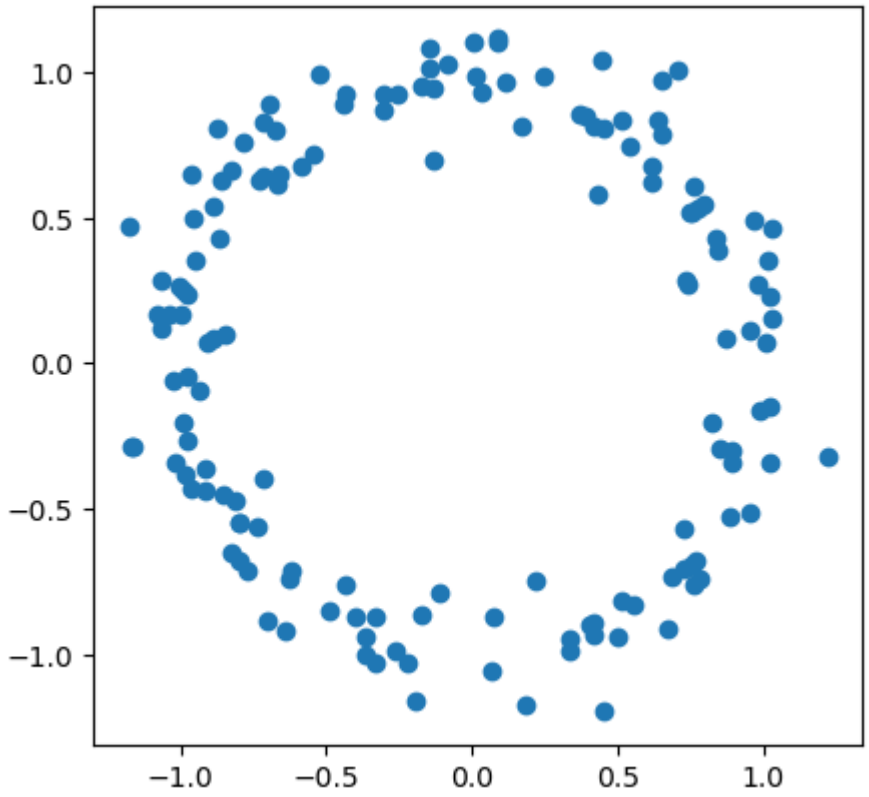
1.3.6 Rips Complex Tutorial

This is a quick Rips Filtration tutorial used to illustrate options provided in BATS.py.

[1]:
```
import bats
import numpy as np
import matplotlib.pyplot as plt
import scipy.spatial.distance as distance
import bats
import time
```

[2]:
```
# first, generate a circle
np.random.seed(0)

n = 150
X = np.random.normal(size=(n,2))
X = X / np.linalg.norm(X, axis=1).reshape(-1,1)
X = X + np.random.normal(size=(n,2), scale = 0.1 )
fig = plt.scatter(X[:,0], X[:,1])
fig.axes.set_aspect('equal')
plt.savefig('figures/RipsEx_data.png')
plt.show()
```



Rips filtrations are commonly used in conjunction with persistent homology to create features for finite dimensional metric spaces (point clouds). Given a metric space (X, d), a Rips complex consists of simplices with a maximum pairwise distance between vertices is less than some threshold r:

$$X_r = \{(x_0, \ldots, x_k) \mid x_i \in X, d(x_i, x_j) \leq r\}.$$

A Rips filtration is a filtration of Rips complexes $X_r \subseteq X_s$ if $r \leq s$.

[3]:
```
# compute pairwise distances
D = distance.squareform(distance.pdist(X))

# Rips complex for full metric space
# ie., threshold r = infinity now
F = bats.LightRipsFiltration(bats.Matrix(D), np.inf, 2)

# compute with F2 coefficents
t0 = time.monotonic()
R = bats.reduce(F, bats.F2())
t1 = time.monotonic()
print("time of compute persistent homology: {} sec.".format(t1-t0))
```

```
time of compute persistent homology: 2.9647895510006492 sec.
```

Now you are able to see persistent diagrams.

[4]:
```
# find persistence pairs at each dimension
ps = []
```

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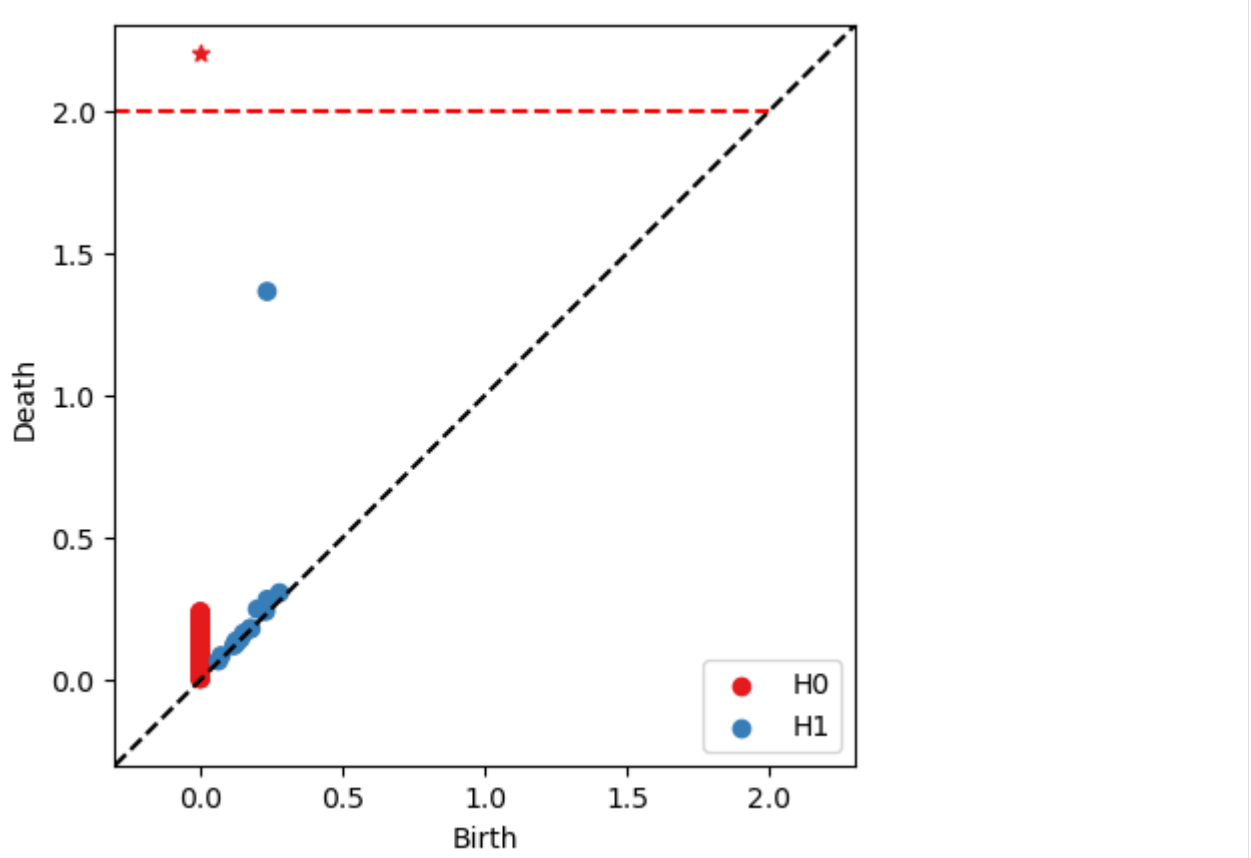
```
for d in range(R.maxdim()):
    ps.extend(R.persistence_pairs(d))

# Draw persistent diagram
# 'tmax' is the axis maixmum value
fig, ax = bats.persistence_diagram(ps, tmax = 2.0)
plt.show()
```



Efficient Computation

The number of simplices in Rips filtrations quickly grows with the size of the data set, and much effort has gone into developing efficient algorithms for computing persistent homology of Rips filtrations.

Construction optimization

The first method that has been applied in several high-performance packages for Rips computations is to stop a filtration at the enclosing ***radius*** of the metric space, at which point the complex becomes contractible, which can reduce the total number of simplices in the filtration considerably without changing persistent homology.

[5]:
```
# Two ways to find Enclosing Radius
r_enc = np.min(np.max(D, axis=0))
print("enclosing radius = {}".format(r_enc))
```

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```
r_enc = bats.enclosing_radius(bats.Matrix(D))
print("enclosing radius = {}".format(r_enc))
```

```
enclosing radius = 1.8481549465930773
enclosing radius = 1.8481549465930773
```

[6]:
```
# Rips complex up to enclosing radius
t0 = time.monotonic()
F_enc = bats.LightRipsFiltration(bats.Matrix(D), r_enc, 2)
t1 = time.monotonic()
print("construction time: {} sec.".format(t1-t0))

# compute with F2 coefficents
t0 = time.monotonic()
R_enc = bats.reduce(F_enc, bats.F2())
t1 = time.monotonic()
print("reduction time: {} sec.".format(t1-t0))
```

```
construction time: 0.07883952199881605 sec.
reduction time: 1.04050104900125 sec.
```

You can see the obvious improvement with about 2x speedup.

Algorithm optimization

There are also many efficent algorithms provided in BATS.py:

- Clearing/Compression: two options without basis returned.
- Cohomology: faster on some filtrations.
- Update Persistence: suitable when there are several similar datasets needed to be computed PH (e.g., optimization on persistence penalty).
- Extra Reduction: perform extra reduction to eliminate nonzeros even after pivot has been found. Performs
- Combinations of the above options

[7]:
```
def time_BATS_flags(X, flags=(bats.standard_reduction_flag(), bats.compute_basis_
↪flag())):

    t0 = time.monotonic()
    D = distance.squareform(distance.pdist(X))
    r_enc = bats.enclosing_radius(bats.Matrix(D))
    F_enc = bats.LightRipsFiltration(bats.Matrix(D), r_enc, 2)
    t0a = time.monotonic()
    R = bats.reduce(F_enc, bats.F2(), *flags)
    t1 = time.monotonic()
    print("{:.3f} sec.\t{:.3f} sec".format(t1 - t0a, t1 - t0))
```

[8]:
```
flags = [
    (bats.standard_reduction_flag(), bats.compute_basis_flag()),
    (bats.standard_reduction_flag(),),
```

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```
    (bats.standard_reduction_flag(), bats.clearing_flag()),
    (bats.standard_reduction_flag(), bats.compression_flag()),
    (bats.extra_reduction_flag(), bats.compute_basis_flag()),
    (bats.extra_reduction_flag(),),
    (bats.extra_reduction_flag(), bats.clearing_flag()),
    (bats.extra_reduction_flag(), bats.compression_flag()),
]
labels = [
    "standard w/ basis\t",
    "standard w/ no basis\t",
    "standard w/ clearing\t",
    "standard w/ compression\t",
    "extra w/ basis\t\t",
    "extra w/ no basis\t",
    "extra w/ clearing\t",
    "extra w/ compression\t"
]

print("flags\t\t\tReduction time\tTotal Time")
for flag, label in zip(flags, labels):
    print("{}".format(label),end=' ')
    time_BATS_flags(X, flag)
```

```
flags                   Reduction time  Total Time
standard w/ basis        1.019 sec.     1.117 sec
standard w/ no basis     0.521 sec.     0.602 sec
standard w/ clearing     0.519 sec.     0.607 sec
standard w/ compression  0.492 sec.     0.577 sec
extra w/ basis           0.905 sec.     0.985 sec
extra w/ no basis        0.301 sec.     0.386 sec
extra w/ clearing        0.304 sec.     0.388 sec
extra w/ compression     0.184 sec.     0.268 sec
```

[9]:
```
# add some noise to the original datasets
# to create a similar datasets to show the performance of update persistence
X2 = X + np.random.normal(size=(n,2), scale = 0.001)
```

[10]:
```
# PH computation on X1
D = distance.squareform(distance.pdist(X))
r_enc = bats.enclosing_radius(bats.Matrix(D))
F_X = bats.LightRipsFiltration(bats.Matrix(D), r_enc, 2)
R = bats.reduce(F_X, bats.F2())

# PH computation on X2 by update persistence on X1
t0 = time.monotonic()
D2 = distance.squareform(distance.pdist(X2))
r_enc2 = bats.enclosing_radius(bats.Matrix(D2))
F_Y = bats.LightRipsFiltration(bats.Matrix(D2), r_enc2, 2) # generate a RipsFiltration
UI = bats.UpdateInfoLightFiltration(F_X, F_Y) # find updating information
R.update_filtration_general(UI)
t1 = time.monotonic()
print("compute PH by updating persistence needs: {:.3f} sec.".format(t1 - t0))
```

```
compute PH by updating persistence needs: 0.492 sec.
```

Advantanges of updating persistence over the other options:

1. still keep the basis information;
2. with a comparable speedup with other optimization algorithms.

1.3.7 Linear Algebra

Fields

The fields `F2 = ModP<int, 2>`, `F3 = ModP<int, 3>`, and `F5 = ModP<int, 5>` are supported. Additional fields can be added to `libbats.cpp` if desired.

```
from bats import F2
print(F2(1) + F2(1)) # should be 0
```

Vectors

Sparse vectors for each supported field class are available: `F2Vector`, `F3Vector`, etc. as well as an `IntVector`.

The easiest way to construct these vectors is from a list of tuples, where each tuple contains a index-value pair (where the value is an integer - it will be cast to the relevant field).

```
from bats import F2Vector
v = F2Vector([(0,1), (2,1)])
```

Matrices

CSCMatrix

```
A = bats.CSCMatrix(2,2,[0,1,2],[0,1],[-1,-1])
A.print() # prints matrix
A(0,0) # returns -1
```

To construct a `CSCMatrix` using `scipy.sparse`:

```
import scipy.sparse as sparse

# create 2x2 identity matrix
data = [1, 1]
row = [0,1,2]
col = [0, 1]
A = sparse.csc_matrix((data, col, row), shape=[2,2])

# create BATS CSCMatrix
Ab = bats.CSCMatrix(*A.shape, A.indptr, A.indices, A.data)
```

You could also construct the `scipy.sparse` `csc_matrix` in a variety of different ways before passing to BATS.

Column Matrices

Column matrices can be created from `CSCMatrix`

```
A = bats.CSCMatrix(2,2,[0,1,2],[0,1],[1,1]) # 2x2 identity
C = bats.IntMat(A)
C2 = bats.F2Mat(A)
C3 = bats.F3mat(A)
CQ = bats.RationalMat(A)
```

You can also use `bats.Mat` and pass in the field.

```
C = bats.Mat(A) # IntMat
C = bats.Mat(A, bats.F2()) # F2Mat
```

In order to get the contents of a ColumnMatrix in Python, use the `tolist()` method

```
C.tolist()
```

You can add columns of the appropriate type to a column matrix

```
A = bats.F2Mat(3,0)
A.append_column(bats.F2Vector([(0,1), (1,1)]))
A.append_column(bats.F2Vector([(0,1), (2,1)]))
A.append_column(bats.F2Vector([(1,1), (2,1)]))
np.array(A.tolist()) # this will display the matrix in a nice way
```

To generate an identity matrix, just pass the desired size and relevant field type to `bats.Identity`

```
I = bats.Identity(3, bats.F2())
```

Dense Matrices

BATS dense matrices are by default stored in row major order to be compatible with numpy.

```
import bats
import numpy as np
Bnp = np.array([[0,1,2],[3,4,5]], dtype=np.float)
B = bats.Matrix(Bnp)
Bnp2 = np.array(B)
```

1.3.8 Maps

Topological Maps

All topological constructions use `bats.CellularMap` to represent topological maps.

To specify a `CellularMap`, you need to provide a map for cells in each dimension. These should be stored as `bats.IntMat`, which provide oriented boundaries. First let's define a `CellComplex` representing the circle with 2 vertices and 2 edges.

```
import numpy as np
import bats

X = bats.CellComplex()
X.add_vertices(2)
X.add([0,1],[-1,1],1)
X.add([0,1],[1,-1],1)
```

We can verify that `X` has the expected betti numbers mod-2

```
X2 = bats.Chain(X, bats.F2())
R2 = bats.ReducedF2ChainComplex(X2)
print(R2.hdim(0), R2.hdim(1)) # 1, 1
```

Now, we'll define a map from the cell complex to itself, via a doubling. Each vertex maps to (0), and each edge maps to the sum of edges

```
import scipy.sparse as sparse
M = bats.CellularMap(1)
M0_dense = np.array([[1,1],[0,0]])
A = sparse.csc_matrix(M0_dense)
M[0] = bats.Mat(bats.CSCMatrix(*A.shape, A.indptr, A.indices, A.data))
M1_dense = np.array([[1,1],[1,1]])
A = sparse.csc_matrix(M1_dense)
M[1] = bats.Mat(bats.CSCMatrix(*A.shape, A.indptr, A.indices, A.data))
```

`M` now contains the map that we want to represent. We can now apply the chain functor

```
M2 = bats.Chain(M, bats.F2())
```

And to compute induced maps, we need to supply a `ReducedChainComplex` for both the domain and range of the map. We computed these above. The output is a `bats` column matrix.

```
for dim in range(2):
    Mtilde = bats.InducedMap(M2, R2, R2, dim)
    print(Mtilde.tolist()) # [[1]], [[0]]
```

Note the doubling map on the circle creates the zero map on H1.

Algorithmic Constructions

There are a variety of common situations in which a `CellularMap` can be constructed algorithmically. `bats` provides a `SimplicialMap` and `CubicalMap` for `SimplicialComplex` and `CubicalComplex` types.

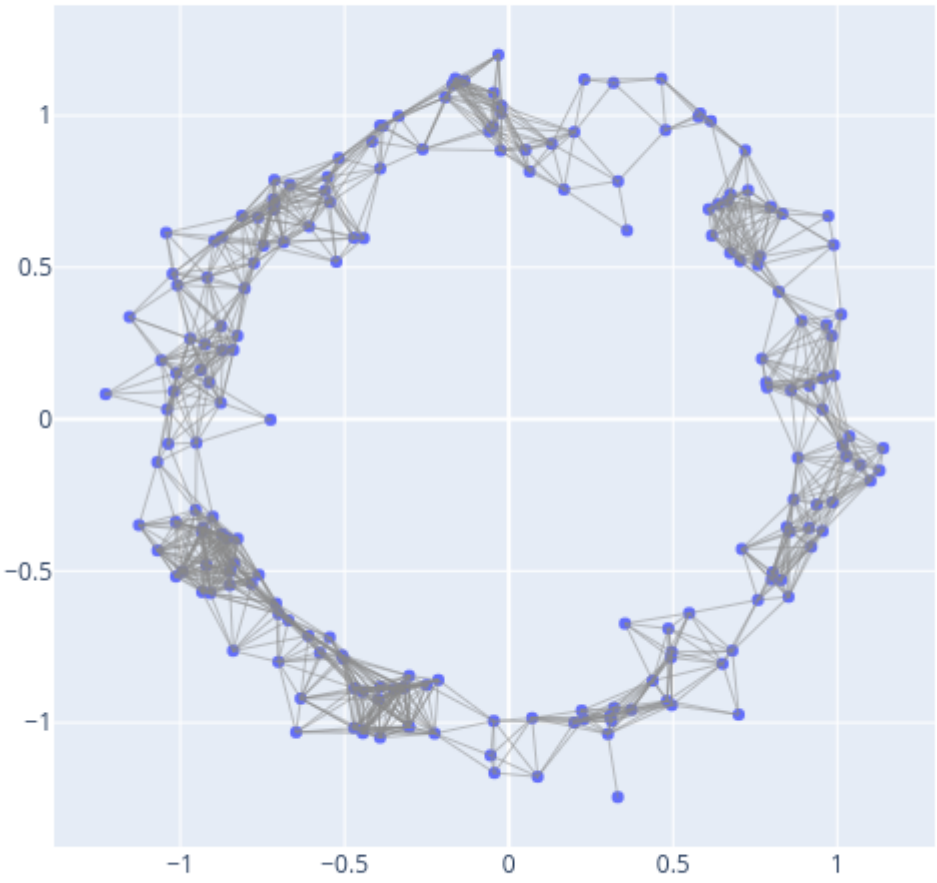
SimplicialMap

A simplicial map f is extended from a map on zero-cells of simplicial complexes. Let's create a noisy circle data set for example.

```
import numpy as np

def gen_circle(n, r=1.0, sigma=0.1):
    X = np.random.randn(n,2)
    X = r * X / np.linalg.norm(X, axis=1).reshape(-1,1)
    X += sigma*np.random.randn(n, 2)
    return X

np.random.seed(0)

X = gen_circle(200)
```

Now we'll create a `SimplicialComplex` using the Rips construction

```
from bats.visualization.plotly import ScatterVisualization
import scipy.spatial.distance as distance

pdist = distance.squareform(distance.pdist(X, 'euclidean'))

R = bats.RipsComplex(bats.Matrix(pdist), 0.25, 2)
fig = ScatterVisualization(R, pos=X)
fig.update_layout(width=600, height=600, showlegend=False)
fig.show()
```



We now can create an inclusion map (identity map) via

```
f = bats.SimplicialMap(R, R)
```

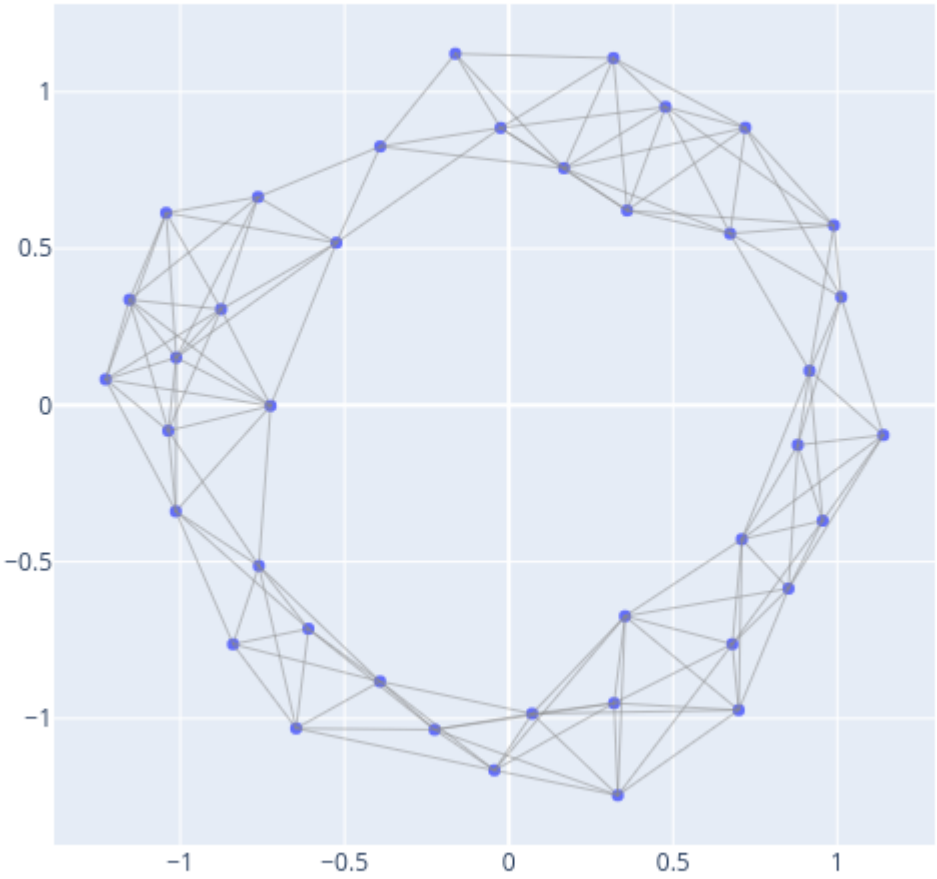
Now, we can compute the induced map on homology to see we get the identity on H1:

```
R2 = bats.ReducedChainComplex(R, bats.F2())
F2 = bats.Chain(f, bats.F2())
Ftil = bats.InducedMap(F2, R2, R2, 1)
Ftil.tolist() #  [[1, 0], [0, 1]]
```

Let's now do a non-inclusion `SimplicialMap`. We'll get a greedy cover of the data, and threshold to `k` points.

We'll construct a new Rips complex, where the parameter is increased by twice the Hausdorff distance to the full set.

```
k = 40
inds, dists = bats.greedy_landmarks_hausdorff(bats.Matrix(pdist), 0)
inds = inds[:k]
eps = dists[k-1]
eps # hausdorff distance from subset to total data set

Xk = X[inds]
pdist_k = np.array(pdist[inds][:,inds], copy=True)
Rk = bats.RipsComplex(bats.Matrix(pdist_k), 0.25 + 2*eps, 2)
fig = ScatterVisualization(Rk, pos=Xk)
fig.update_layout(width=600, height=600, showlegend=False)
fig.show()
```



We'll now define a map from the full data set to the sub-sampled data by sending points to their nearest neighbor

```
from scipy.spatial import cKDTree
tree = cKDTree(Xk)
ds, f0 = tree.query(X, k=1)
```

`f0` is now the map for vertices of `R` to vertices of `Rk`. We can extend the map

```
f = bats.SimplicialMap(R, Rk, f0)
```

Now, we can go through the process of computing the induced map on homology

```
Rk2 = bats.ReducedChainComplex(Rk, bats.F2())
F2 = bats.Chain(f, bats.F2())
Ftil = bats.InducedMap(F2, R2, Rk2, 1)
Ftil.tolist() # [[0, 1]]
```

We see the small H1 generator is killed.

We can visualize this (See visualization for details).

```
from bats.visualization.plotly import MapVisualization
fig = MapVisualization(pos=(X, Xk), cpx=(R, Rk), maps=(f,))
fig.show_generator(0, color='green', group_suffix=0)
fig.show_generator(1, color='red', group_suffix=1)
fig.show()
```

Generator

CubicalMap

Right now, `bats.CubicalMap` only supports inclusions - syntax is the same as that for `bats.SimplicialMap`, but inputs are `bats.CubicalComplex` objects.

1.3.9 Chain Complexes and Reduction

Chain Complexes

A chain complex can be obtained from a simplicial or cell complex via the chain functor

```
X = bats.SimplicialComplex()
X.add([0])
X.add([1])
X.add([0,1])

C2 = bats.F2ChainComplex(X)
C3 = bats.F3ChainComplex(X)
```

You can also use `bats.Chain`:

```
C2 = bats.Chain(X, bats.F2())
C3 = bats.Chain(X, bats.F3())
```

Reduced Chain Complex

```
R2 = bats.ReducedF2ChainComplex(C2)

R2.hdim(1) # = 1

v = bats.F2Vector([1], [bats.F2(1)])
print(v[0], v[1], v[2]) # 0 1 0

R2.find_preferred_representative(v, 0)
print(v[0], v[1], v[2]) # 1 0 0

# get preferred rep for first basis element in dim 0
v = R2.get_preferred_representative(0,0)
print(v[0], v[1], v[2]) # 1 0 0
```

bats.reduce

You can use `bats.reduce` to create a reduced chain complex from either a `SimplicialComplex`, or `ChainComplex`

For a chain complex:

```
C = bats.Chain(X, bats.F2())
R = bats.reduce(C)
```

You can also skip the explicit chain complex construction for `SimplicialComplex`

```
R = bats.reduce(X, bats.F2())
```

Reduction Flags

You can provide a variety of flags to `bats.reduce` which govern behavior of the reduction algorithm.

Algorithm Flags

- `bats.standard_reduction_flag()` - standard reduction algorithm
- `bats.extra_reduction_flag()` - eliminates all entries to the right of a pivot, even when not necessary for reduction

Optimization Flags

- `bats.clearing_flag()` - performs clearing optimization
- `bats.compression_flag()` - performs compression optimization

Basis Flags By default, when you pass in flags, the basis is not computed, which is fine when you just want the betti numbers or a persistence diagram. If you want to compute the basis, you can use `bats.compute_basis_flag()`, with either no optimizations, or the compression optimization. You can not compute the basis with the clearing optimization.

Valid Combinations When using flags, you must always first provide an algorithm flag. This is followed by an optional algorithm flag, and then an optional basis flag.

```
flags = (
    bats.standard_reduction_flag(), bats.compression_flag(), bats.compute_basis_flag()
)

R = bats.reduce(X, bats.F2(), *flags)
```

- You can only get homology generators if you compute a basis
- You must compute a basis and not use optimizations to compute induced maps.

Performance Computing a basis will always be slower than not computing a basis.

Clearing or compression optimizations will almost always be faster than not using them. Which optimization is better can be problem dependent.

The choice of reduction algorithm can also affect performance. The `bats.extra_reduction_flag()` is sometimes faster than the standard reduction - this may be because it encourages sparsity.

As a suggestion, try using

```
bats.standard_reduction_flag(), bats.compression_flag()
```

and see how this compares to just using

```
bats.standard_reduction_flag()
```

Reducing Matrices Manually

At a lower level, you can use the reduction algorithm on a matrix

```
A = bats.F2Mat(3,0)
A.append_column(bats.F2Vector([(0,1), (1,1)]))
A.append_column(bats.F2Vector([(0,1), (2,1)]))
A.append_column(bats.F2Vector([(1,1), (2,1)]))
U = bats.Identity(3, bats.F2())

R =
p2c = bats.reduce_matrix(A, U)
```

This will modify the matrices A and U in-place so A is reduced, and U is the applied change of basis to columns. I.e. it maintains the invariant `A * inv(U)`. `p2c` will be the pivot-to-column map for the reduced matrix.

1.3.10 Visualization

Visualization of Simplicial Complexes and Generators

In this section, we'll visualize simplicial complexes using plotly.

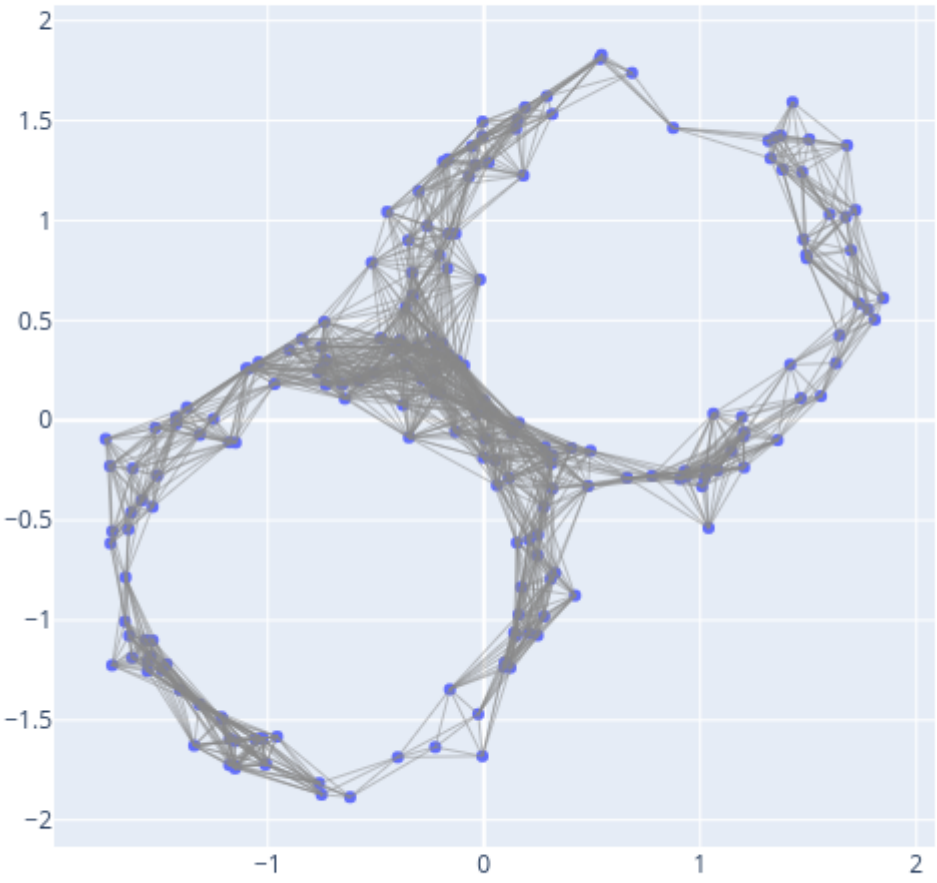
```
import numpy as np
import bats
from bats.visualization.plotly import ScatterVisualization
import scipy.spatial.distance as distance

np.random.seed(0)
```

Let's generate a figure-8 as a data set.

```
def gen_fig_8(n, r=1.0, sigma=0.1):
    X = np.random.randn(n,2)
    X = r * X / np.linalg.norm(X, axis=1).reshape(-1,1)
    X += sigma*np.random.randn(n, 2) + np.random.choice([-1/np.sqrt(2),1/np.sqrt(2)],␣
↪size=(n,1))
    return X

n = 200
X = gen_fig_8(n)
```

First, we'll construct a Rips complex on the data.

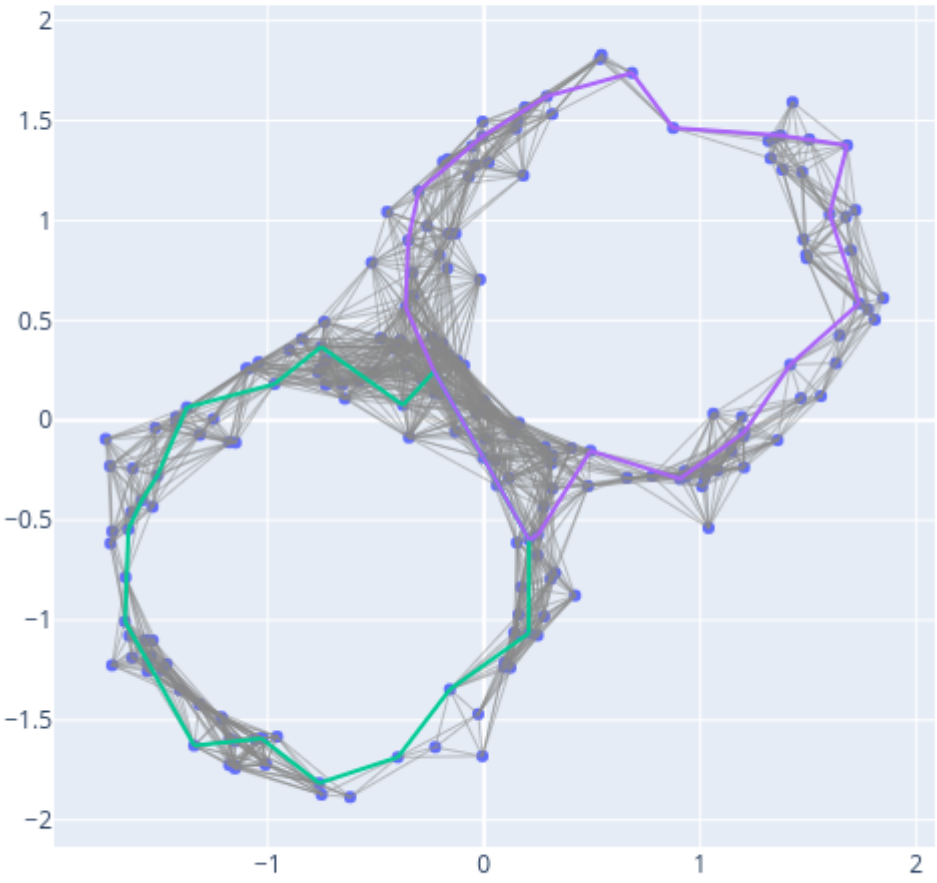
```
pdist = distance.squareform(distance.pdist(X, 'euclidean'))

R = bats.RipsComplex(bats.Matrix(pdist), 0.5, 2)
fig = ScatterVisualization(R, pos=X)
fig.update_layout(width=600, height=600, showlegend=False)
fig.show()
```



A `ScatterVisualization` object inherits from a plotly `Figure`, so you can add additional traces, update layout, or call any methods you'd like.

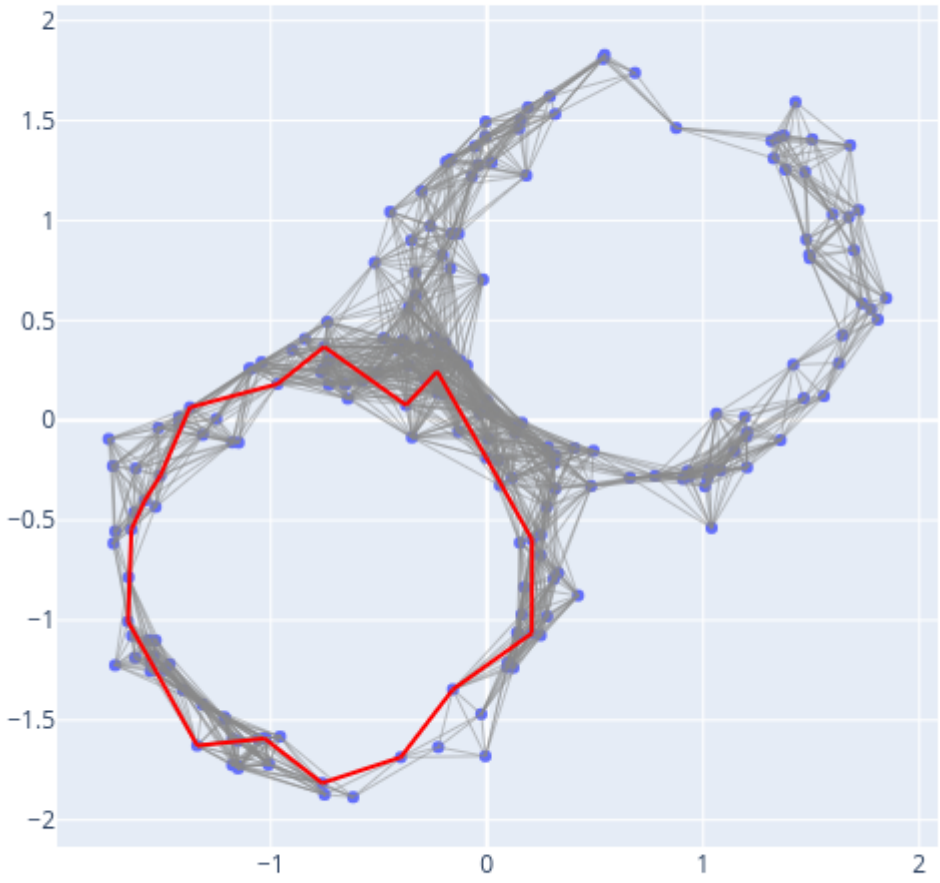
Now, let's visualize generators

```
fig.show_generators(1)
fig.show()
```



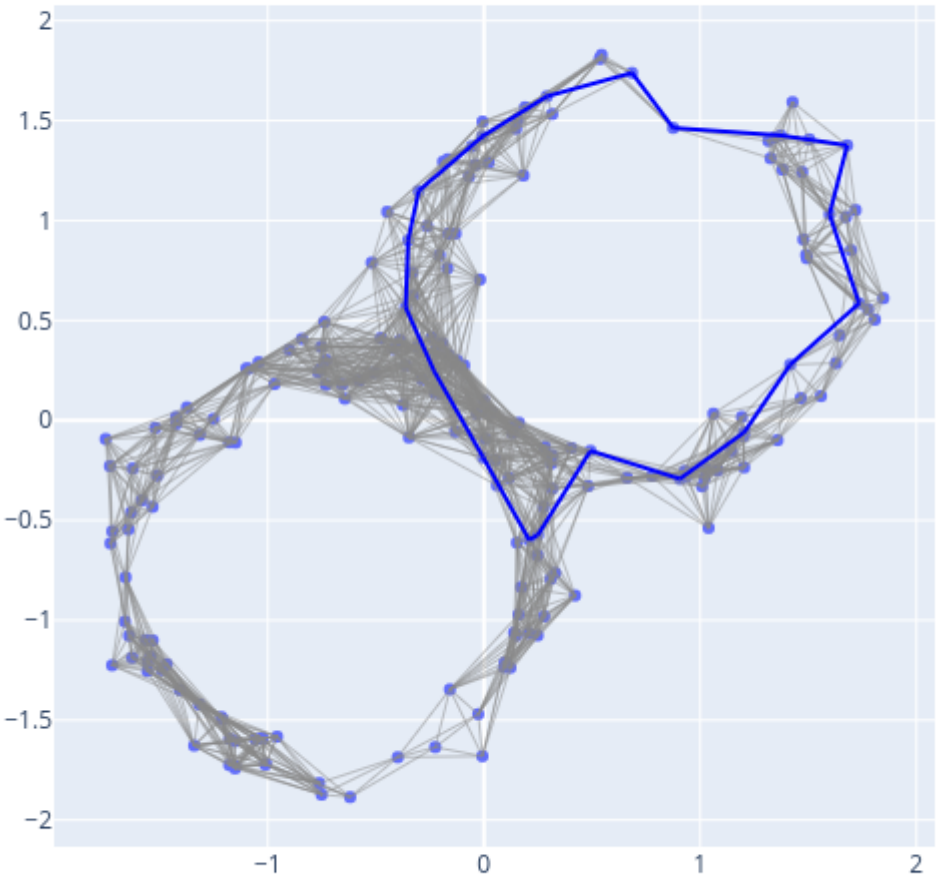
Let's now look at a single generator:

```
fig.reset() # resets figure to have no generators
fig.show_generator(0, hdim=1, color='red')
fig.show()
```



Let's visualize the second generator by passing in the representative 1-chain:

```
RC = bats.ReducedChainComplex(R, bats.F2())
r = RC.get_preferred_representative(1, 1)
fig.reset()
fig.show_chain(r, color='blue')
fig.show()
```



Visualization of Maps

You can visualize a `SimplicialMap` with a `MapVisualization`.

```
import numpy as np
import bats
from bats.visualization.plotly import MapVisualization
import scipy.spatial.distance as distance

np.random.seed(0)
```

Let's generate a cylinder in three dimensions:

```
def gen_cylinder(n, r=1.0, sigma=0.1):
    X = np.random.randn(n,2)
    X = r * X / np.linalg.norm(X, axis=1).reshape(-1,1)
    X = np.hstack((X, r*np.random.rand(n,1) - r/2))
    return X

X = gen_cylinder(500)
```

We'll generate a Rips Complex with parameter `0.25`

```
pdist = distance.squareform(distance.pdist(X, 'euclidean'))
R = bats.RipsComplex(bats.Matrix(pdist), 0.25, 2)
```

Let's investigate the inclusion of the lower half of the cylinder

```
inds = np.where(X[:,2] < 0)[0]
Xi = X[inds]
pdisti = distance.squareform(distance.pdist(Xi, 'euclidean'))
Ri = bats.RipsComplex(bats.Matrix(pdisti), 0.25, 2)
```

The inclusion map is

```
M = bats.SimplicialMap(Ri, R, inds)
```

Now, we can construct a visualization

```
fig = MapVisualization(pos=(Xi,X), cpx=(Ri,R), maps=(M,))
fig.update_layout(scene_aspectmode='manual',
                  scene_aspectratio=dict(x=1, y=1, z=0.5))
fig.show()
```

The `show_generator` method will visualize homology generators in the domain by visualizing the preferred representative used in calculations. By default, the image of the chain is visualized in the range, as well as the preferred representative for the homology class.

```
fig.reset()
fig.show_generator(1)
fig.show()
```

The `reset` method clears the visualization of chains/generators. You can also change the color of chains and homology. `group_suffix` can be used to group visualizations in the legend - try using the legend to toggle visualizations below:

```
fig.reset()
fig.show_generator(5, group_suffix=0)
fig.show_generator(3, color='orange', hcolor='black', group_suffix=1)
fig.show()
```

Let's now create a second map from the full data set to a projection onto two coordinates.

```
Xp = X[:,:2]
pdistp = distance.squareform(distance.pdist(Xp, 'euclidean'))
Rp = bats.RipsComplex(bats.Matrix(pdistp), 0.25, 2)
M2 = bats.SimplicialMap(R, Rp) # inclusion map
```

We can visualize the three spaces, with the maps between them, and mix 2-dimensional and 3-dimensional visualizations. Note that the homology class visualized in `show_generator(1)` is killed by the second map.

```
fig = MapVisualization(pos=(Xi,X, Xp), cpx=(Ri,R,Rp), maps=(M,M2))
fig.update_layout(scene_aspectmode='manual',
                  scene_aspectratio=dict(x=1, y=1, z=0.5))
fig.show_generator(1, color='green', hcolor='black', group_suffix=1)
fig.show_generator(5, color='red', hcolor='blue', group_suffix=5)
fig.show()
```

1.3.11 Zigzag Homology

There are two ways to compute zigzag homology in BATS.

1. Zigzag homology of a diagram of spaces over a line graph
2. Zigzag homology of a zigzag-filtered space

(2) is a special case of (1) which uses different data structures and functions for (potential) memory efficiency and performance gains.

Zigzag homology of a diagram of spaces

There are three categories you can use to create a diagram of spaces

1. Simplicial complexes/cellular maps: `SimplicialComplexDiagram`
2. Cubical complexes/cellular maps: `CubicalComplexDiagram`
3. Cell complexes/cellular maps: `CellComplexDiagram`

For zigzag homology, you want to create a diagram of spaces on a directed line graph

```
* --> * <-- * --> * --> ...
```

Where the arrows can go in any direction. This means you will have `n` nodes (spaces) and `n-1` edges (maps).

?> It is important to arrange your nodes in order i.e. there should be an edge between node 0 and 1, an edge between 1 and 2, etc. BATS will assume this, but won't check.

Let's use the following example of complexes:

```
0 <- 0 -> 0
|         |
1 <- 1 -> 1
```

The spaces on the left and right are identical (two vertices, numbered "0" and "1" connected by a single edge), and the space in the middle has the edge removed. The maps are identical inclusion maps. We expect a 0-dimensional zigzag barcode that looks like

```
*----*----*
     *
```

Simplicial Complexes

```
import bats

n = 3 # number of spaces

D = bats.SimplicialComplexDiagram(n, n-1)

# first, we add SimplicialComplexes to the diagram
X = bats.SimplicialComplex()
X.add_recursive([0,1])
D.set_node(0, X) # left node
D.set_node(2, X) # right node

Y = bats.SimplicialComplex()
Y.add([0])
Y.add([1])
D.set_node(1, Y)

# now, we add SimplicialMaps
f = bats.SimplicialMap(Y, X, [0, 1])
D.set_edge(0, 1, 0, f) # edge 0 maps space at node 1 to space at node 0.  The map is f
D.set_edge(1, 1, 2, f) # edge 1 maps space at node 1 to space at node 2.  The map is f
```

note that the type of `f` is a `CellularMap`. `SimplicialMap` is just a convenient way to construct cellular maps which are also simplicial maps.

```
type(f)
```

```
bats.libbats.CellularMap
```

Now, we apply the Chain functor. This creates a new diagram of `ChainComplexes` and `ChainMaps`. We simply have to provide the diagram of spaces and the field we wish to use. Let's do `F3` coefficients.

```
CD = bats.Chain(D, bats.F3())
```

Now, we apply the Homology functor. This creates a new diagram of `ReducedChainComplexes` and induced maps on Homology, stored as matrices.

```
HD = bats.Hom(CD, 0) # 0 is homology dimension
HD.edge_data(0).tolist() # [[1, 1]]
```

```
[[1, 1]]
```

To extract the barcode, we use the `barcode` function. We pass in the homology dimension for book-keeping. The output is a list of `PersistencePairs` which tell us about birth and death indices of homology classes.

```
ps = bats.barcode(HD, 0) # homology dimension is 0
for p in ps:
    print(p) # output is dimension : (birth, death) <birth basis index, death basis␣
↪index>
```

```
0 : (0,2) <0,0>
0 : (1,1) <1,1>
```

We see a class that is born at index 0 in the diagram and dies at index 2, and a second class that is only present at index 1, just as we expect.

Cubical Complexes

We'll now do the same example with a diagram of `CubicalComplexes`

```
n = 3 # number of spaces

D = bats.CubicalComplexDiagram(n, n-1)

# first, we add CubicalComplexes to the diagram
X = bats.CubicalComplex(1) # 1 is dimension of cubical complex
X.add_recursive([0,1])
D.set_node(0, X) # left node
D.set_node(2, X) # right node

Y = bats.CubicalComplex(1)
Y.add([0, 0])
Y.add([1, 1])
D.set_node(1, Y)

# now, we add maps
f = bats.CubicalMap(Y, X) # inclusion of Y into X
D.set_edge(0, 1, 0, f) # edge 0 maps space at node 1 to space at node 0.  The map is f
D.set_edge(1, 1, 2, f) # edge 1 maps space at node 1 to space at node 2.  The map is f
```

Again, the type of `f` is a `CellularMap` even though we constructed it as a `CubicalMap`.

Again, we then apply the Chain and Hom functors and then extract the barcode

```
CD = bats.Chain(D, bats.F3())
HD = bats.Hom(CD, 0) # 0 is homology dimension
print("Induced map: {}".format(HD.edge_data(0).tolist())) # [[1, 1]]

ps = bats.barcode(HD, 0)
for p in ps:
    print(p) # output is dimension : (birth, death) <birth basis index, death basis␣
↪index>
```

```
Induced map: [[1, 1]]
0 : (0,2) <0,0>
0 : (1,1) <1,1>
```

Cell Complexes

Now we'll use `CellComplexes`. These are more general, but also not combinatorially defined so they can be a bit more work to deal with if (it's not too bad in this simple example).

```
n = 3 # number of spaces

D = bats.CellComplexDiagram(n, n-1)

X = bats.CellComplex()
X.add_vertices(2)
# first list is boundary indices, second list is boundary coefficients, final argument␣
↪is dimension
X.add([0,1], [-1,1], 1)
D.set_node(0, X) # left node
D.set_node(2, X) # right node

Y = bats.CellComplex()
Y.add_vertices(2)
D.set_node(1, Y)

# now we create the map
f = bats.CellularMap(0) # 0-dimensional Cellular map.
f[0] = bats.IntMat(bats.CSCMatrix(2,2,[0,1,2],[0,1],[1,1])) # CSCMatrix to specify map
print("f[0] = {}".format(f[0].tolist())) # identity map on 0-cells
D.set_edge(0, 1, 0, f) # edge 0 maps space at node 1 to space at node 0.  The map is f
D.set_edge(1, 1, 2, f) # edge 1 maps space at node 1 to space at node 2.  The map is f
```

```
f[0] = [[1, 0], [0, 1]]
```

```
CD = bats.Chain(D, bats.F3())
HD = bats.Hom(CD, 0) # 0 is homology dimension
print("Induced map: {}".format(HD.edge_data(0).tolist())) # [[1, 1]]

ps = bats.barcode(HD, 0)
for p in ps:
    print(p) # output is dimension : (birth, death) <birth basis index, death basis␣
↪index>
```

```
Induced map: [[1, 1]]
0 : (0,2) <0,0>
0 : (1,1) <1,1>
```

Zigzag-Filtered Spaces

The above example also works for a zigzag filtered space. You can construct a zigzag filtration in a way that is similar to a regular filtration. You simply need to provide entry and exit times.

Our original example had discrete indices, but zigzag filtrations have continuous parameters. We'll say that the edge was removed for a small interval of radius `0.01` around parameter 1. Note that if a cell is added and removed at the same parameter, both copies of the cell will be considered present at that instant and the zigzag barcode will be different than if you were to remove one copy and then add the other.

```
eps = 0.01 # infentesimal
X = bats.ZigzagSimplicialComplex()
X.add(0, 2, [0]) # vertex is present for interval [0,2]
X.add(0, 2, [1]) # vertex is present for interval [0,2]
X.add(0, 1-eps, [0,1]) # edge is present at index 0 but not at index 1
X.add(1+eps, 2, [0,1]) # edge is added back and survives until parameter 2
```

You can see the tuples of entry/exit times of cells stored in a single list for each cell

```
X.vals()
```

```
[[[(0.0, 2.0)], [(0.0, 2.0)]], [[(0.0, 0.99), (1.01, 2.0)]]]
```

we can now print the Zigzag barcode

```
ps = bats.ZigzagBarcode(X, 0, bats.F2()) # second argument is maximum homology dimension
for p in ps[0]:
    print(p)
```

The behavior here is a bit different than the diagram. We see that there are some 0-length zigzag bars at parameters 0 and 2 which are due to the addition of the 0-cells before 1-cells. To filter these out, we can do the following:

```
for p in ps[0]:
    if p.length() > 0:
        print(p)
```

```
0 : (0,2) <0(1),0(0)>
0 : (0.99,1.01) <0(0),1(1)>
```

1.3.12 Counting Operations in BATS

Counting field arithmetic operations and column operations can be useful when investigating performance of different algorithms.

To compile BATS to count operations, you need to pass the compile flag `-DBATS_OPCOUNT` when installing BATS.

```
CFLAGS="-DBATS_OPCOUNT" python setup.py build_ext --force -j8
python setup.py install
```

Note that this currently will only work with the F2 field, and you must produce a `ReducedChainComplex` without going through the `reduce` interface. It will also slow down the code, so it is not turned on by default.

[1]:
```
import numpy as np
import matplotlib.pyplot as plt
import scipy.spatial.distance
import bats

np.random.seed(0)
```

[2]:
```
bats.reset_field_ops()
bats.reset_column_ops()
bats.get_field_ops(), bats.get_column_ops()
```

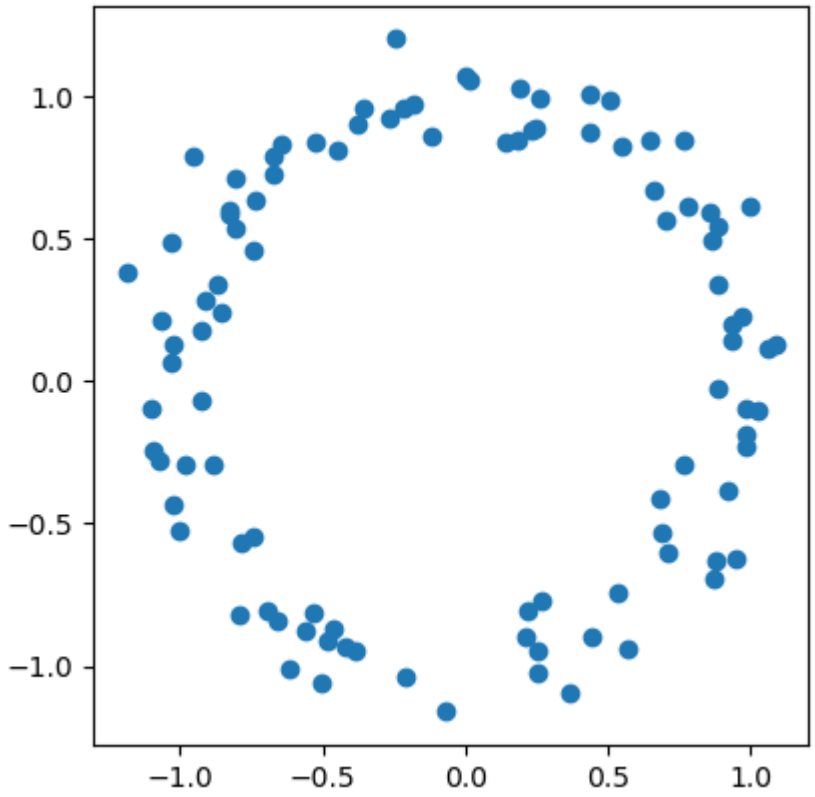
[2]:
```
(0, 0)
```

[3]:
```
a = bats.F2(1)
b = a + a
bats.get_field_ops()
```

[3]:
```
1
```

Example with Rips Reduction

[4]:
```
# first, generate a circle
n = 100
X = np.random.normal(size=(n,2))
X = X / np.linalg.norm(X, axis=1).reshape(-1,1)
X = X + np.random.normal(size=(n,2), scale = 0.1 )
fig = plt.scatter(X[:,0], X[:,1])
fig.axes.set_aspect('equal')
# plt.savefig('RipsEx_data.png')
plt.show(fig)
```



[5]:
```
data = bats.DataSet(bats.Matrix(X)) # put into a bats.DataSet
dist = bats.Euclidean()  # distance we would like to use
F = bats.RipsFiltration(data, dist, np.inf, 2) # generate a RipsFiltration
```

[6]:
```
bats.reset_field_ops(), bats.reset_column_ops()
C = bats.FilteredF2ChainComplex(F)
bats.get_field_ops(), bats.get_column_ops()
```

[6]:
```
(0, 0)
```

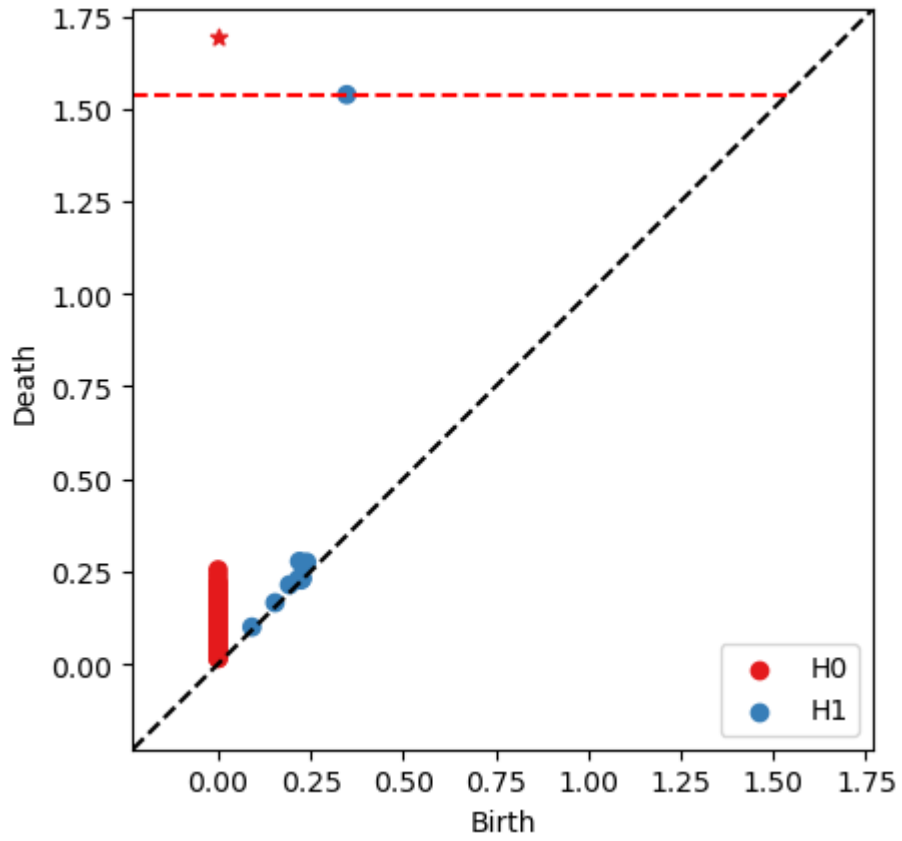
Options for the Reduction Algorithm

First, we'll try the standard reduction algorithm (with basis)

[7]:
```
bats.reset_field_ops(), bats.reset_column_ops()
RC = bats.ReducedFilteredF2ChainComplex(C)
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 19759887
column operations: 4984028
```

[8]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```

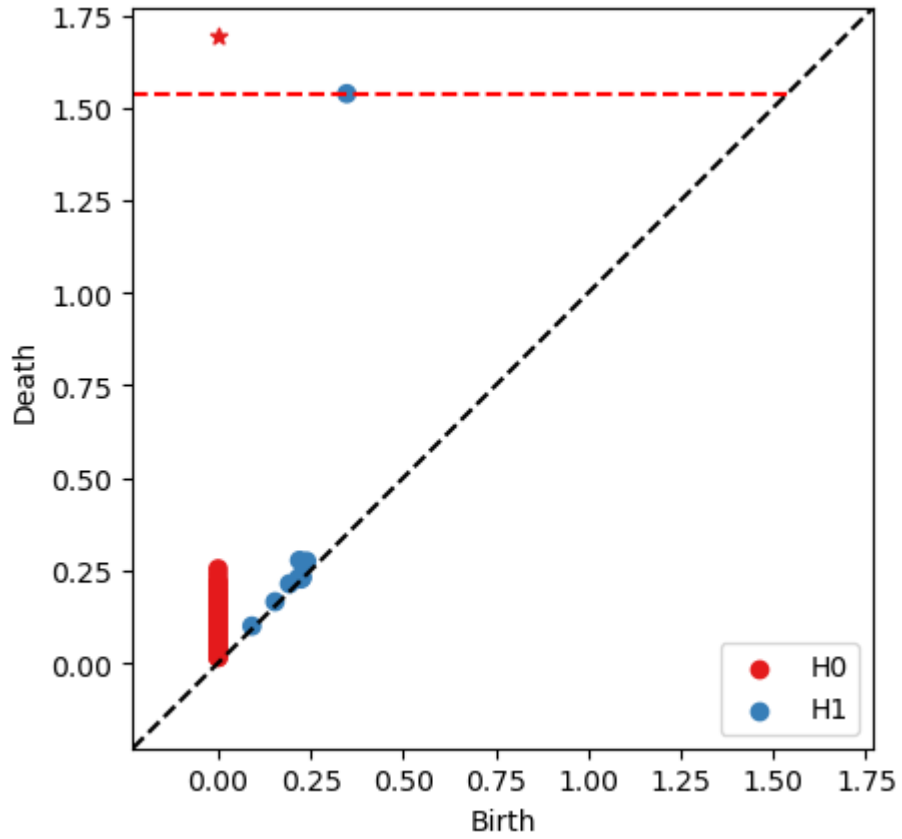


Next the standard reduction algorithm with no basis - the column operations are cut in half.

[9]:
```
bats.reset_field_ops(), bats.reset_column_ops()
RC = bats.ReducedFilteredF2ChainComplex(C, bats.standard_reduction_flag())
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 15465396
column operations: 2492014
```

[10]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```

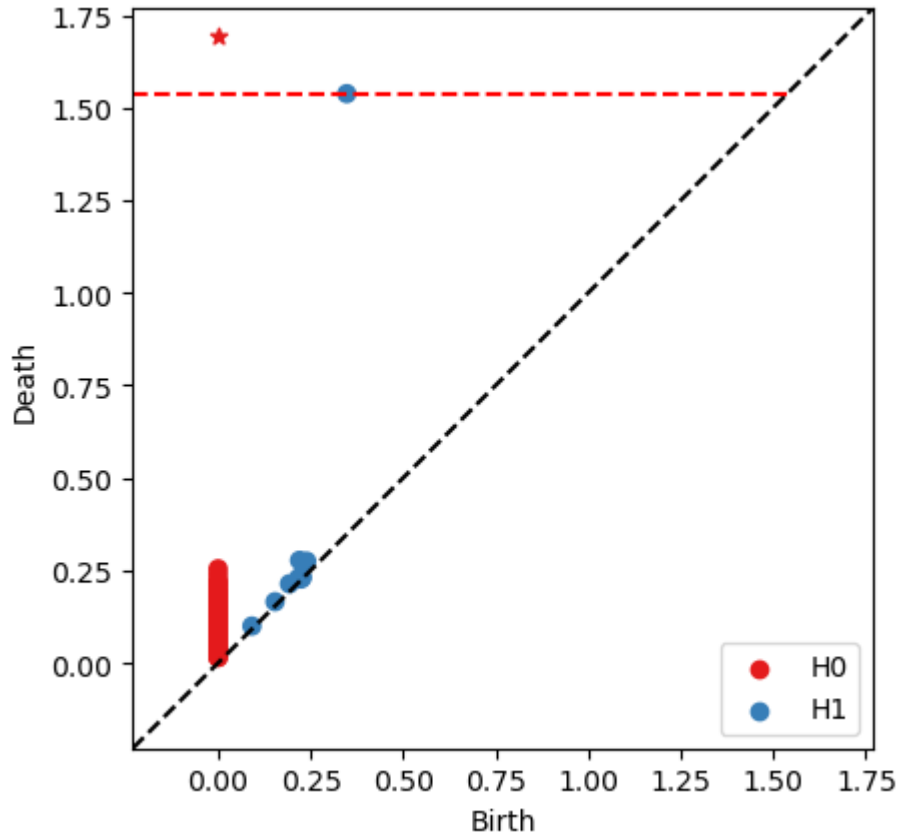


Now, let's try the clearing optimization

[11]:
```
bats.reset_field_ops(), bats.reset_column_ops()
RC = bats.ReducedFilteredF2ChainComplex(C, bats.standard_reduction_flag(), bats.clearing_
↪flag())
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 15341005
column operations: 2462129
```

[12]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```

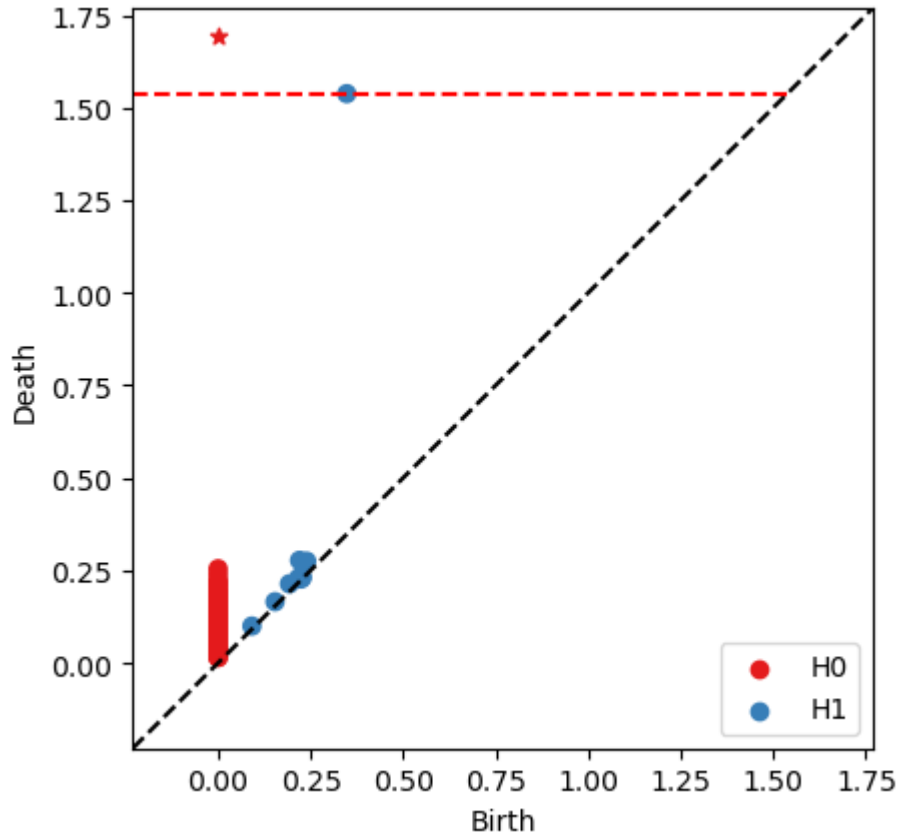


And finally, the extra reduction flag with clearing really decreases the number of column operations

[13]:
```
bats.reset_field_ops(), bats.reset_column_ops()
RC = bats.ReducedFilteredF2ChainComplex(C, bats.extra_reduction_flag(), bats.clearing_
↪flag())
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 19686497
column operations: 496491
```

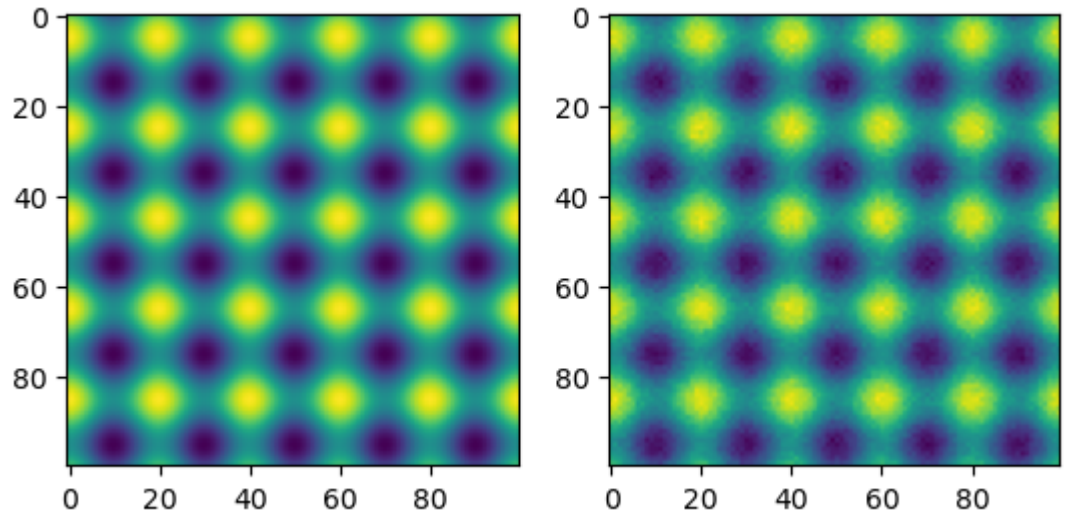
[14]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```



Example Updating Persistence

In this example, we update the level set persistence of an image

[15]:
```
n = 100

img = np.empty((n,n), dtype=np.float64)
for i in range(n):
    for j in range(n):
        img[i,j] = np.sin(10* np.pi * i / n) + np.cos(10* np.pi * j/n)

img2 = img + 0.1 * np.random.randn(n,n)
fig, ax = plt.subplots(1,2)
ax[0].imshow(img)
ax[1].imshow(img2)
plt.show()
```

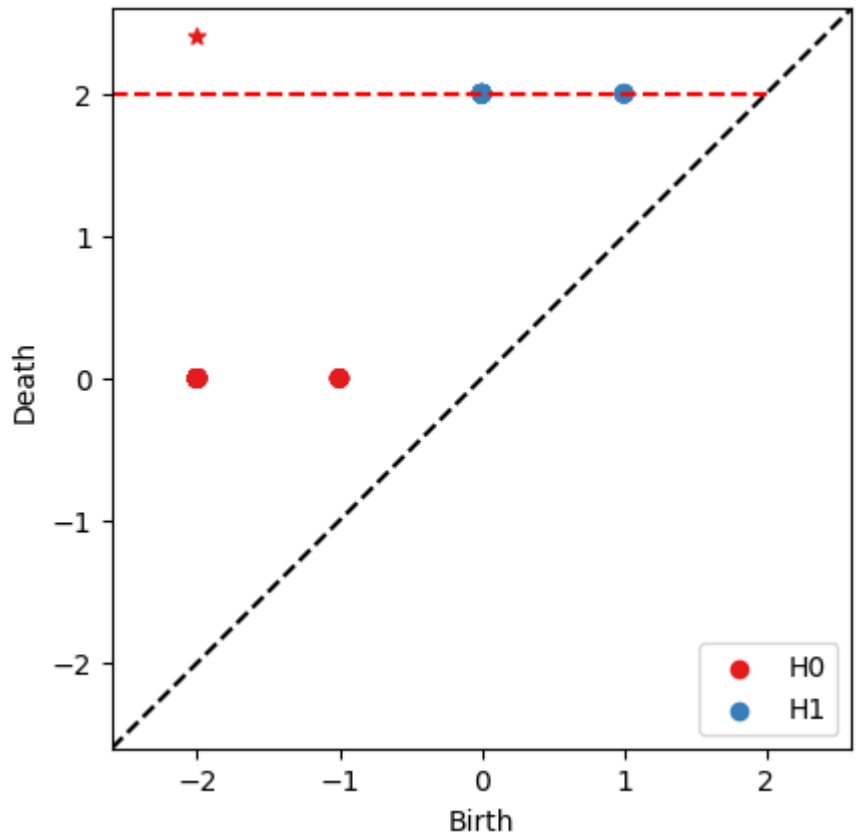


First, we compute the reduced chain complex for the original image

[16]:
```
X = bats.Freudenthal(n,n)

# extend image filtration to Freudenthal triangulation
vals, imap = bats.lower_star_filtration(X, img.flatten())
F = bats.FilteredSimplicialComplex(X, vals)

bats.reset_field_ops(), bats.reset_column_ops()
C = bats.FilteredF2ChainComplex(F)
RC = bats.ReducedFilteredF2ChainComplex(C)
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 1501302
column operations: 530266
```

[17]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```

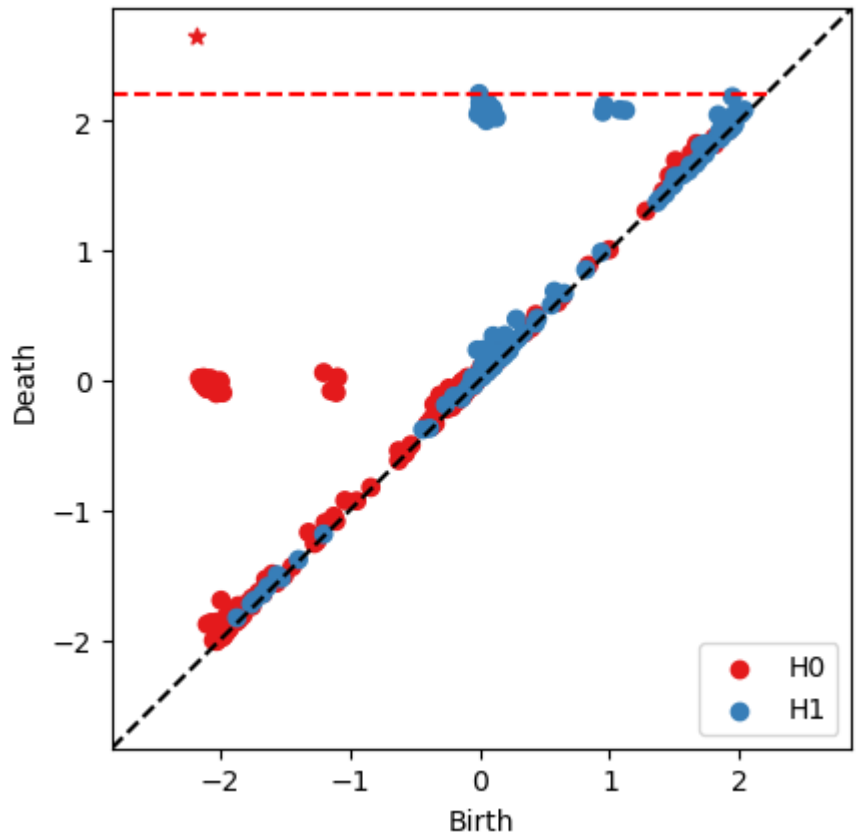


Now, let's update persistence

[18]:
```
vals, imap = bats.lower_star_filtration(X, img2.flatten())

bats.reset_field_ops(), bats.reset_column_ops()
RC.update_filtration(vals)
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 325913
column operations: 40158
```

[19]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```

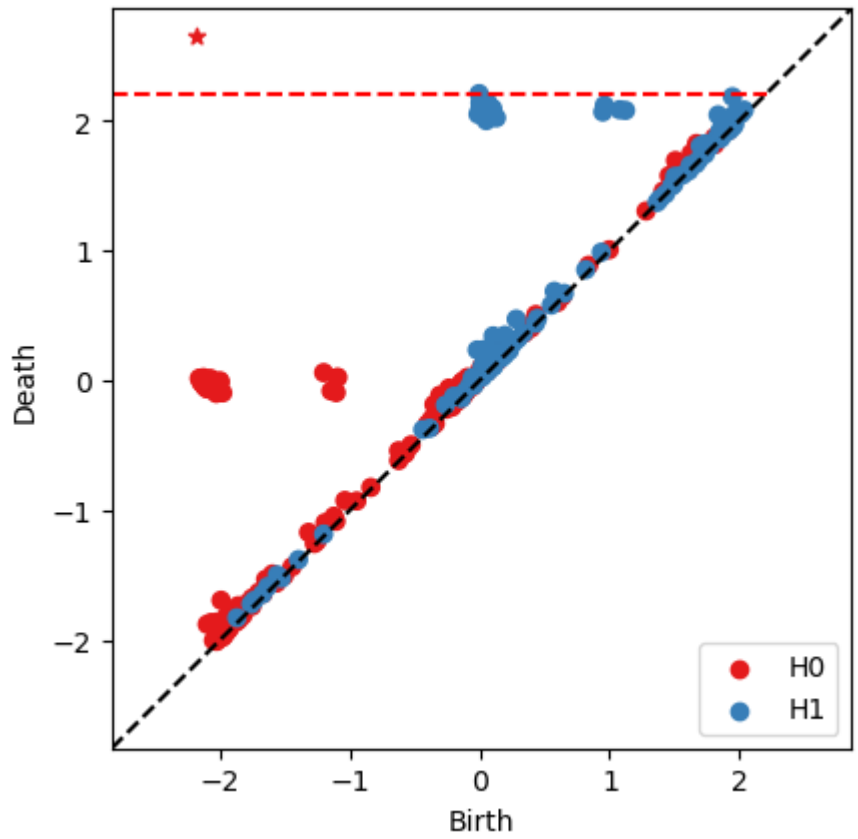


And compare to running the updated reduction from scratch

[20]:
```
bats.reset_field_ops(), bats.reset_column_ops()
vals, imap = bats.lower_star_filtration(X, img2.flatten())
F = bats.FilteredSimplicialComplex(X, vals)
C = bats.FilteredF2ChainComplex(F)
RC = bats.ReducedFilteredF2ChainComplex(C)
print("field operations: {}".format(bats.get_field_ops()))
print("column operations: {}".format(bats.get_column_ops()))
```

```
field operations: 1779741
column operations: 523044
```

[21]:
```
ps = RC.persistence_pairs(0) + RC.persistence_pairs(1)
bats.persistence_diagram(ps)
plt.show()
```



[ ]:

1.4 Examples

1.4.1 Cubical Complexes

In this example, we'll now see how to create cubical complexes using toplices, and how to compute a zigzag diagram through levelsets of an image.

```
import bats
import numpy as np
import matplotlib.pyplot as plt
```

Cubical Complexes

In BATS, cubical complexes are given a maximal dimension.

```
X = bats.CubicalComplex(3) # 3 = max dimension
```

maximum dimension cubes are defined by a list of length `2*d`, where `d` is the dimension

```
[0,1,1,2,0,1] # cube (0,1) x (1,2) x (0,1)
```

lower dimensional cubes have degeneracies, but are still a list of length `2*d`

```
[0,0,1,2,1,1] # cube (0) x (1,2) x (1)
```

Toplex

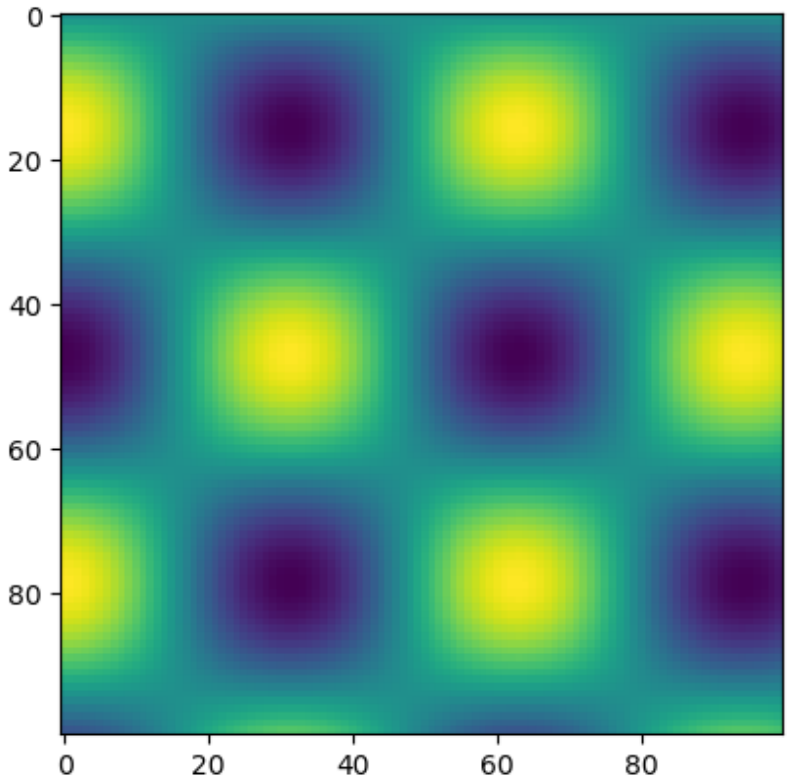
A toplex is a complex described by maximum dimension cells. All faces that must exist exist. Cubical complexes can be created by adding these top-level cells.

```
X.add_recursive([0,1,0,1,0,1]) # adds cube (0,1) x (0,1) x (0,1)
print(X.ncells()) # 27
```

Image Levelset Zigzag

Images are a common way to obtain cubical complexes. Let's generate one.

```
# generate image
m = 100
n = 100
A = np.empty((m,n))
for i in range(m):
    for j in range(n):
        A[i,j] = np.sin(i/10) * np.cos(j/10)
plt.imshow(A)
```



We'll zigzag through cubical complexes defined by level sets and their unions:

```
lsets = [[x/10, (x+2)/10] for x in range(-10,9,1)]
```

We'll operate on boolean images which indicate the support of each level set. The first thing to do is to compute top-level cubes from these images

```
def to_toplexes(A):
    """
    Create list of toplexes from boolean array A

    assume 2-dimensional for now
    """
    dims = A.shape
    toplex_list = []
    for i in range(dims[0]-1):
        for j in range(dims[1]-1):
            if (A[i,j] and A[i+1,j] and A[i,j+1] and A[i+1,j+1]):
                toplex_list.append([i,i+1,j,j+1])

    return toplex_list
```

Then we turn this list of cubes into a complex

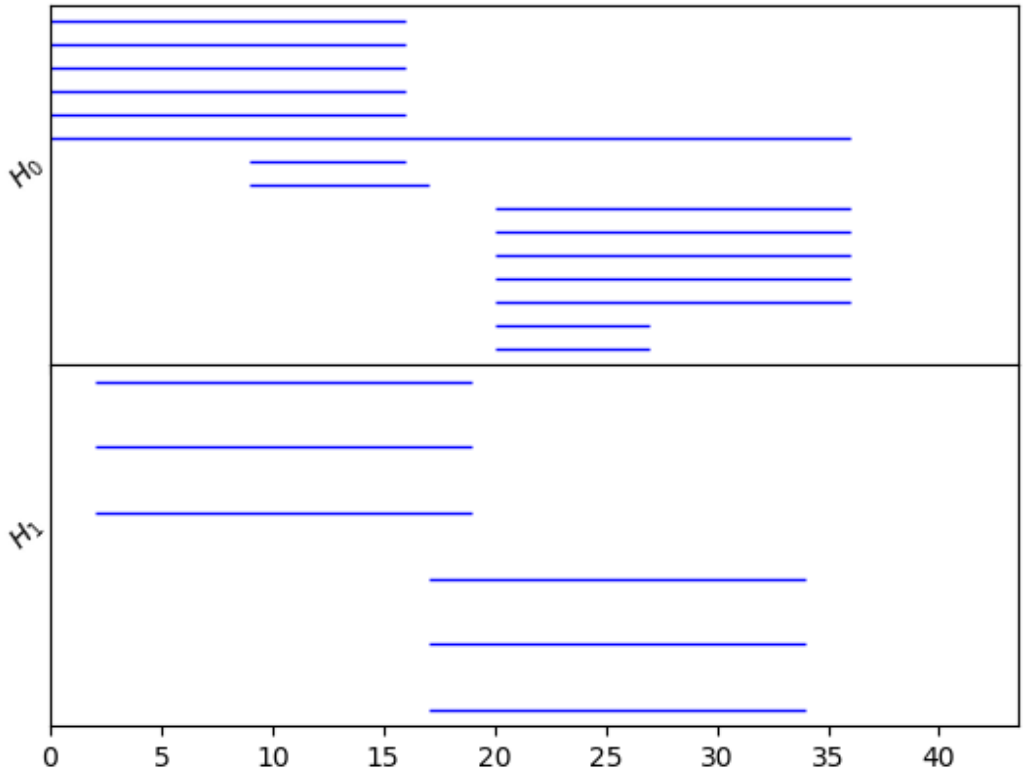
```
def image_to_complex(A):
    """
    Create cubical complex from boolean image A
    """
    toplex_list = to_toplexes(A)
    X = bats.CubicalComplex(2)
    for t in toplex_list:
        X.add_recursive(t)
    return X
```

Let's now create our diagram of complexes:

```
# create diagram of cubical complexes
D = bats.CubicalComplexDiagram()
for i in range(len(lsets)):
    lb = lsets[i][0]
    ub = lsets[i][1]
    AL = np.logical_and(lb < A, A < ub)
    ii = D.add_node(image_to_complex(AL))

    if i != 0:
        # add edge to previous union
        D.add_edge(ii, ii-1, bats.CubicalMap(D.node_data(ii), D.node_data(ii-1)))

    if i != len(lsets)-1:
        # add node for union
        ub = lsets[i+1][1]
        AL = np.logical_and(lb < A, A < ub)
        D.add_node(image_to_complex(AL))

        # add edge to union
        D.add_edge(ii, ii+1, bats.CubicalMap(D.node_data(ii), D.node_data(ii+1)))
```

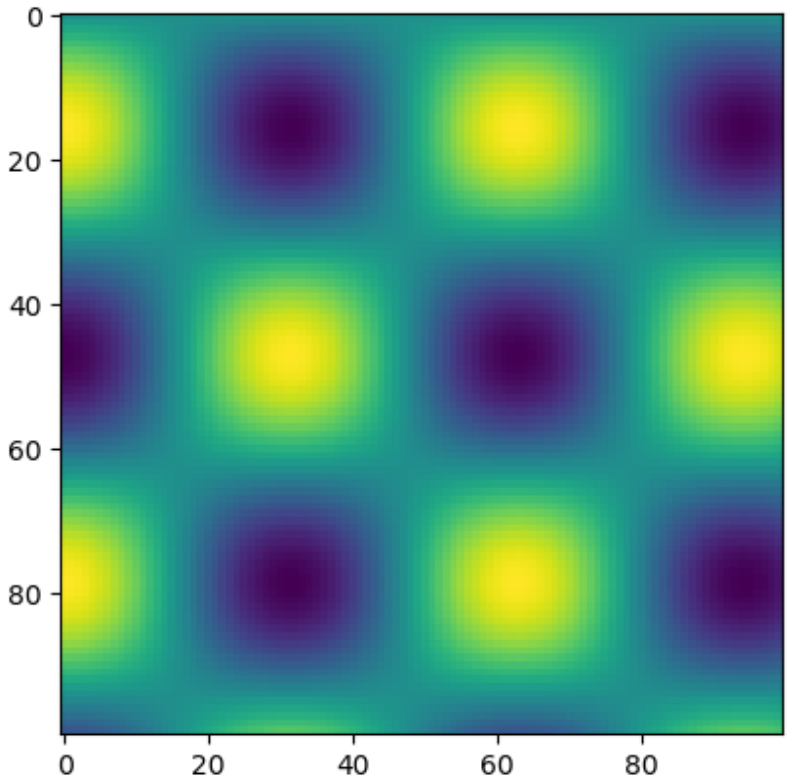
And we can compute the zigzag barcode:

```
FD = bats.Chain(D, bats.F2()) # F2 coefficients

ps = []
for hdim in range(2):
    RD = bats.Hom(FD, hdim)
    ps.extend(bats.barcode(RD, hdim))

fig, ax = bats.visualization.persistence_barcode(ps)
```



Filtered Cubical Complexes

We'll now look at computing persistent homology on the image from before



The idea is to filter toplexes by the largest pixel value

```
def to_filtered_toplexes(A):
    """
    Create list of toplexes from array A

    assume 2-dimensional for now
    """
    dims = A.shape
    toplex_list = []
    for i in range(dims[0]-1):
        for j in range(dims[1]-1):
            t = max(A[i,j], A[i+1,j],A[i,j+1],A[i+1,j+1])
            toplex_list.append((t,[i,i+1,j,j+1]))

    return toplex_list
```

We can then create a filtered cubical complex

```
def image_to_filtration(A):
    """
    Create cubical complex from boolean image A
    """
    toplex_list = to_filtered_toplexes(A)
```

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```
    toplex_list = sorted(toplex_list)
    X = bats.FilteredCubicalComplex(2)
    for t, s in toplex_list:
        X.add_recursive(t, s)
    return X
```

To put everything together:

```
X = image_to_filtration(A)
C = bats.FilteredF2ChainComplex(X)
R = bats.reduce(C)
ps = R.persistence_pairs(0) + R.persistence_pairs(1)

for p in ps:
    if p.length() > 0.1:
        print(p)
```

yields the following output

```
0 : (-0.996841,inf) <0,-1>
0 : (-0.995794,0.0029413) <4,9802>
0 : (-0.99572,0.00345711) <8,9812>
0 : (-0.994674,0.00268533) <12,9796>
0 : (-0.99272,0.0014712) <16,9770>
0 : (-0.991188,0.00242617) <20,9789>
0 : (-0.365212,0.00216782) <2463,9779>
0 : (-0.364648,0.00219438) <2470,9783>
1 : (0.00363827,0.999058) <9817,9790>
1 : (0.00382229,0.9988) <9821,9784>
1 : (0.0998193,0.999432) <11671,9794>
1 : (0.930355,0.999616) <19275,9800>
```

1.4.2 Covers and Nerves

Covers

In BATS, a set is a python set, and a cover is a list of sets.

```
cover0 = [ {1,2,3}, {3,4,5}, {5,6,1} ]
```

You can also generate covers from data using landmarks

Nerves

The nerve of a cover is a simplicial complex with a vertex for every set in a cover, and a k-simplex for every non-empty intersection of k+1 sets.

```
from bats import Nerve
N = Nerve(cover0, 2) # second argument is maximum dimension of simplices
```

We can then compute homology:

```
RN = bats.reduce(N, bats.F2()) # second argument is field to use for reduction
# print the betti numbers
for d in range(RN.maxdim() + 1):
    print("betti_{}: {}".format(d, RN.hdim(d)))
```

You should see

```
betti_0: 1
betti_1: 1
betti_2: 0
```

1.4.3 Rips Filtrations

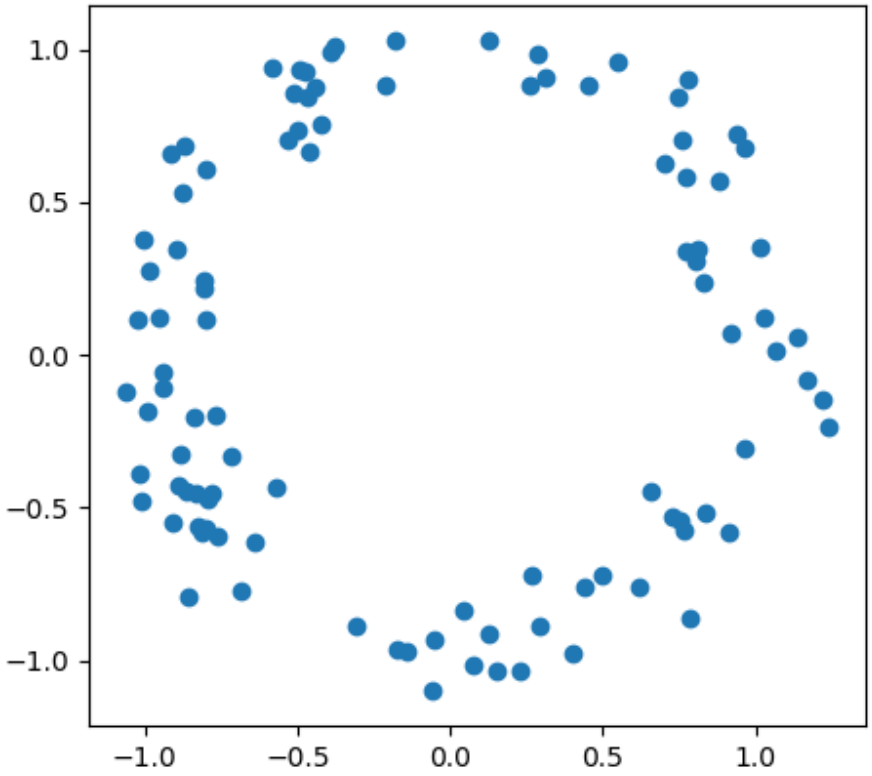
In this example, we'll cover a couple of ways to construct Rips filtrations, compute persistent homology, and subsample data.

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.spatial.distance
import bats
```

1.4.4 Generate data

We'll just generate a noisy circle for demonstration purposes.

```
# first, generate a circle
n = 100
X = np.random.normal(size=(n,2))
X = X / np.linalg.norm(X, axis=1).reshape(-1,1)
X = X + np.random.normal(size=(n,2), scale = 0.1 )
fig = plt.scatter(X[:,0], X[:,1])
fig.axes.set_aspect('equal')
plt.savefig('figures/RipsEx_data.png')
```



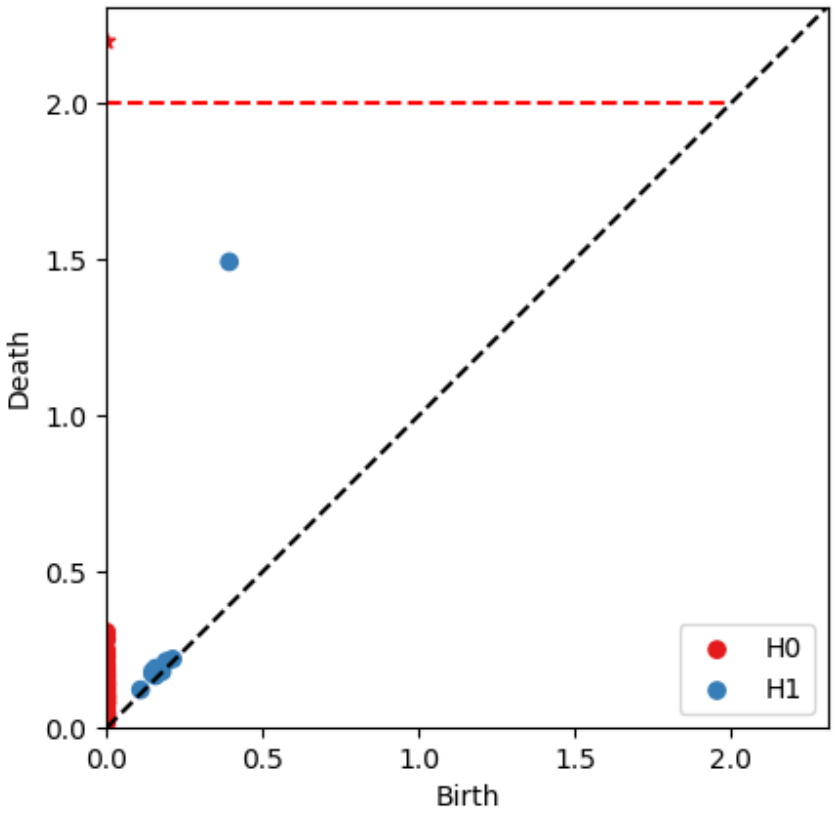
1.4.5 Use a BATS metric

You can use a distance in BATS to form a Rips filtration

```
# use bats to compute distances internally
data = bats.DataSet(bats.Matrix(X)) # put into a bats.DataSet
dist = bats.Euclidean()  # distance we would like to use
F = bats.RipsFiltration(data, dist, np.inf, 2) # generate a RipsFiltration

R = bats.reduce(F, bats.F2()) # reduce with F2 coefficients
ps = []
for d in range(R.maxdim()):
    ps.extend(R.persistence_pairs(d))

fig, ax = bats.persistence_diagram(ps, tmax = 2.0)
plt.savefig('figures/RipsEx_pd_euc.png')
```



We see a robust H1 class because we sampled near a circle.

1.4.6 Pairwise distances

You can also construct Rips filtrations from pairwise distances.

you can generate a matrix of pairwise distances from a BATS metric

```
# method 1: use bats to get pairwise distances
data = bats.DataSet(bats.Matrix(X)) # put into a bats.DataSet
dist = bats.Euclidean()  # distance we would like to use
pdist = dist(data, data) # returns a bats.Matrix of pairwise distances
```

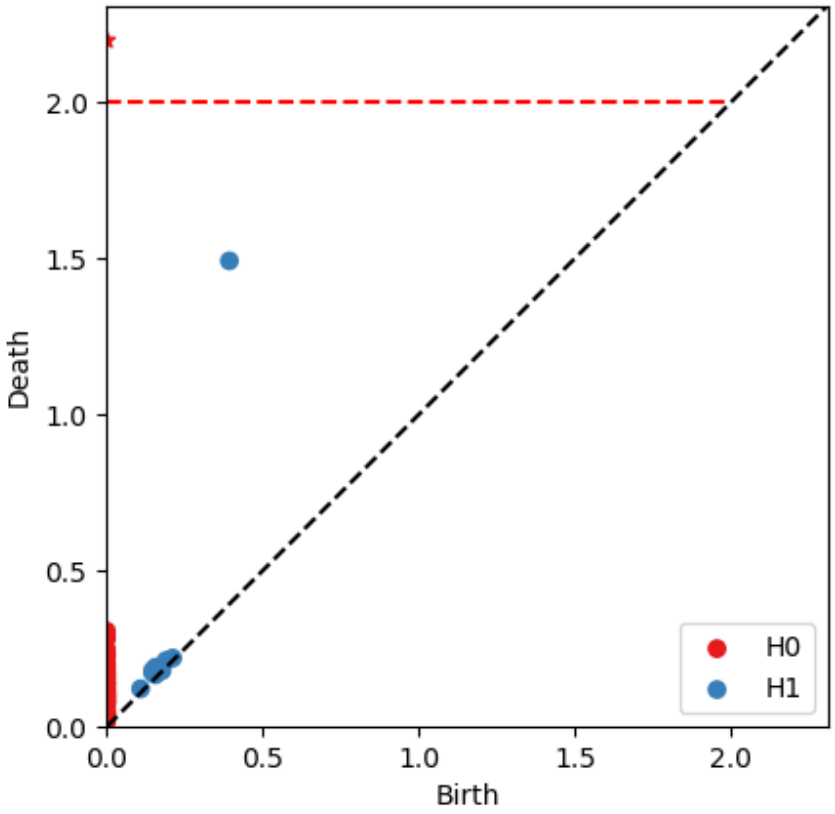
or, you can generate the pairwise distances some other way

```
# method 2: use scipy to get pairwise distances
pdist_sp = scipy.spatial.distance.squareform(scipy.spatial.distance.pdist(X, 'euclidean
↪'))
pdist = bats.Matrix(pdist_sp)
```

either way, you can construct a Rips filtration in a very similar way

```
F = bats.RipsFiltration(pdist, np.inf, 2) # generate a filtraiton on pariwise distances
R = bats.reduce(F, bats.F2()) # reduce with F2 coefficients
ps = []
for d in range(R.maxdim()):
    ps.extend(R.persistence_pairs(d))

fig, ax = bats.persistence_diagram(ps, tmax = 2.0)
plt.savefig('figures/RipsEx_pd.png')
```



1.4.7 Greedy Subsampling

BATS has a function provided to greedily subsample data. This can be used to reduce the number of points used to construct a Rips filtration, and speed up computations.

```
# inds is sequence of indices selected by greedy landmarking
# dists[k] is hausdorff distance from X[inds[:k]] to X
inds, dists = bats.greedy_landmarks_hausdorff(pdist, 0) # 0 is first index
```

We can look at the first k greedy samples, and obtain the hausdorff distance to the full data set.

```
k = 40 # we'll landmark 40 points
# print('hausdorff distance is {}'.format(dists[k]))
```

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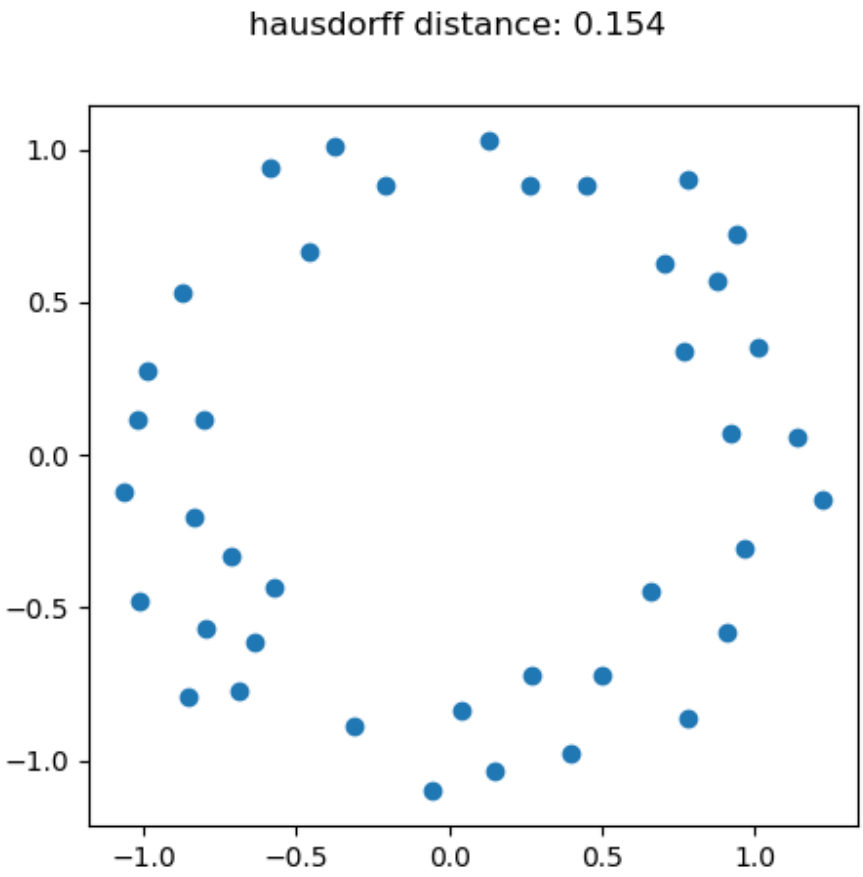
```
fig = plt.figure()
ret = plt.scatter(X[inds[:k],0], X[inds[:k],1])
fig.suptitle('hausdorff distance: {:.3f}'.format(dists[k]))
ret.axes.set_aspect('equal')
plt.savefig('figures/RipsEx_data_landmark.png')
```

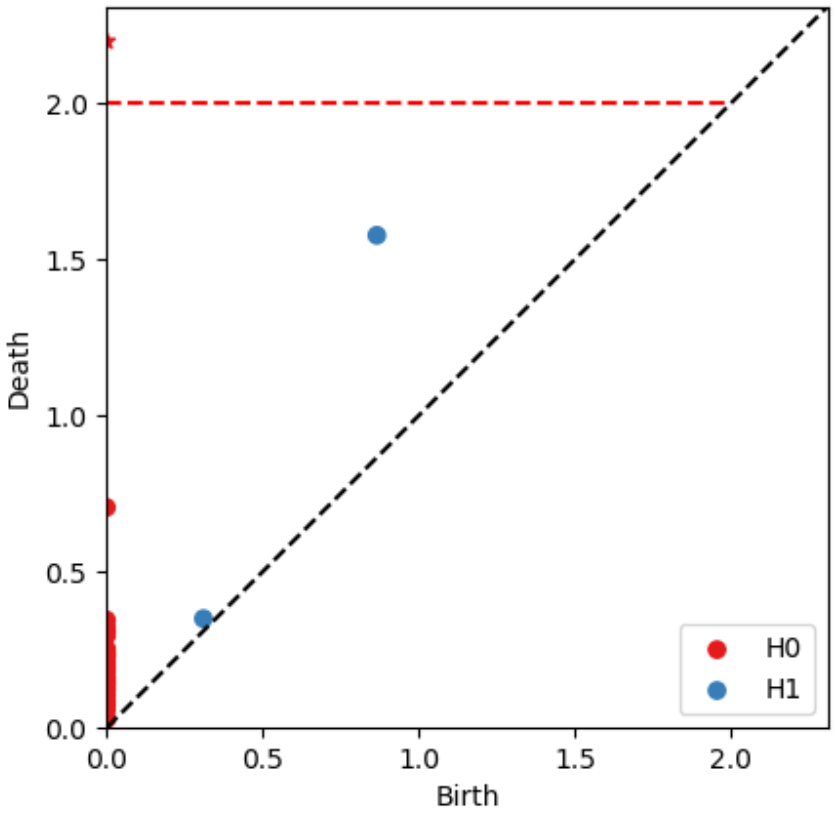


Now, we can compute persistent homology of a Rips filtration in the standard way.

```
# use scipy to get pairwise distances
pdist_sp = scipy.spatial.distance.squareform(scipy.spatial.distance.pdist(X[:k],
↪'euclidean'))
pdist = bats.Matrix(pdist_sp)

F = bats.RipsFiltration(pdist, np.inf, 2) # generate a filtraiton on pariwise distances
R = bats.reduce(F, bats.F2()) # reduce with F2 coefficients
ps = []
for d in range(R.maxdim()):
    ps.extend(R.persistence_pairs(d))

fig, ax = bats.persistence_diagram(ps, tmax = 2.0)
plt.savefig('figures/RipsEx_pd_landmark.png')
```



We still see a robust H1 class, but the birth is a bit later now.

1.4.8 Visualization of H1 generator

Here's an example of how to visualize the longest-length H1 generator with plotly:

```
import plotly
import plotly.graph_objects as go

# use bats to get pairwise distances
data = bats.DataSet(bats.Matrix(X)) # put into a bats.DataSet
dist = bats.L1Dist()  # distance we would like to use
pdist = dist(data, data) # returns a bats.Matrix of pairwise distances

pdist_np = np.array(pdist) # numpy array of pairwise distances

F = bats.RipsFiltration(pdist, np.inf, 2) # generate a filtraiton on pariwise distances
R = bats.reduce(F, bats.F2()) # reduce with F2 coefficients

# get longest H1 pair
ps1 = R.persistence_pairs(1)
lens = [p.death() - p.birth() for p in ps1] # find longest length pair
```

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```
ind = np.argmax(lens)
pair = ps1[ind]

def plot_representative_2D(X, F, R, pair, D, thresh=None, **kwargs):
    """
    Plot H1 represnetative on 2D scatter plot

    plot representative
    X: 2-dimensional locations of points
    F: bats FilteredSimplicialComplex
    R: bats ReducedFilteredChainComplex
    pair: bats PersistencePair
    D: N x N distance matrix
    thresh: threshold parameter
    kwargs: passed onto figure layout
    """
    if thresh is None:
        thresh = pair.birth()

    fig = go.Figure()
    fig.add_trace(go.Scatter(
        x=X[:,0], y=X[:,1],
        mode='markers',
    ))
    edge_x = []
    edge_y = []
    N = X.shape[0]
    for i in range(N):
        for j in range(N):
            if D[i, j] <= thresh:
                edge_x.extend([X[i,0], X[j,0], None])
                edge_y.extend([X[i,1], X[j,1], None])

    fig.add_trace(go.Scatter(
        x=edge_x, y=edge_y,
        line=dict(width=0.5, color='#888'),
        hoverinfo='none',
        mode='lines')
     )

    edge_x = []
    edge_y = []
    r = R.representative(pair)
    nzind = r.nzinds()
    cpx = F.complex()
    for k in nzind:
        [i, j] = cpx.get_simplex(1, k)
        if D[i, j] <= thresh:
            edge_x.extend([X[i,0], X[j,0], None])
            edge_y.extend([X[i,1], X[j,1], None])
    fig.add_trace(go.Scatter(
        x=edge_x, y=edge_y,
```

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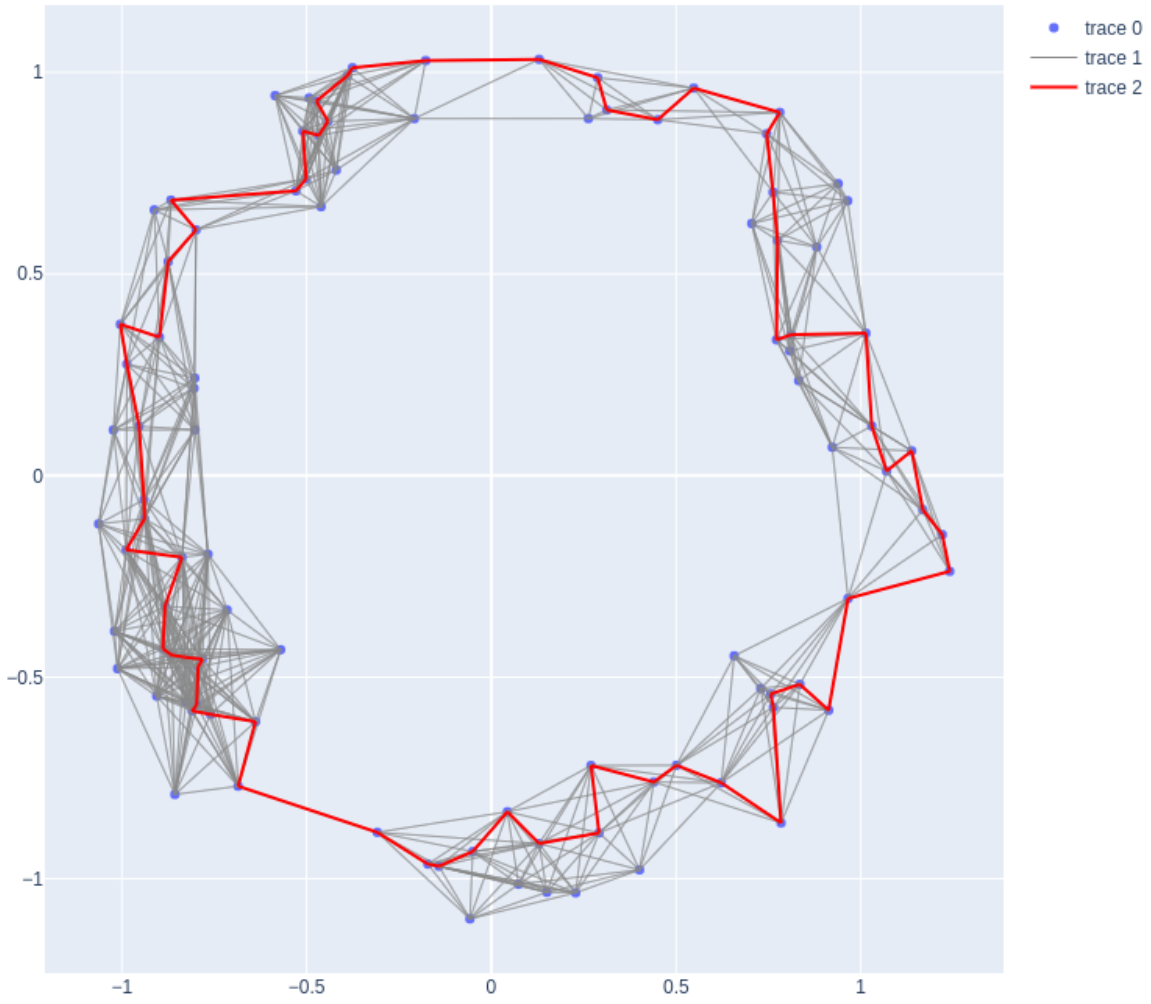
```
        line=dict(width=2, color='red'),
        hoverinfo='none',
        mode='lines')
     )
    fig.update_layout(**kwargs)
    return fig


fig = plot_representative_2D(X, F, R, pair, pdist_np, width=800, height=800)
fig.write_image('figures/H1_rep.png')
```



1.5 API Reference

class bats.**AngleDist**
Bases: pybind11_builtins.pybind11_object

class bats.**CSCMatrix**
Bases: pybind11_builtins.pybind11_object

ncol(*self:* bats.linalg.CSCMatrix) → int
number of columns.

nrow(*self:* bats.linalg.CSCMatrix) → int
number of rows.

print(*self:* bats.linalg.CSCMatrix) → None

class bats.**CellComplex**
Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.CellComplex, *arg0: List[int]*, *arg1: List[int]*, *arg2: int*) → int
add cell in dimension k by specifying boundary and coefficients.

add_vertex(*self:* bats.topology.CellComplex) → int
add vertex to cell complex

add_vertices(*self:* bats.topology.CellComplex, *arg0: int*) → int
add vertices to cell complex

boundary(*self:* bats.topology.CellComplex, *arg0: int*) → CSCMatrix<int, unsigned long>

maxdim(*self:* bats.topology.CellComplex) → int
maximum dimension cell

ncells(**args*, ***kwargs*)
Overloaded function.

1. ncells(self: bats.topology.CellComplex) -> int

number of cells

2. ncells(self: bats.topology.CellComplex, arg0: int) -> int

number of cells in given dimension

class bats.**CellComplexDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.topology.CellComplexDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.topology.CellularMap) → int

add_node(*self:* bats.topology.CellComplexDiagram, *arg0:* bats.topology.CellComplex) → int

edge_data(*self:* bats.topology.CellComplexDiagram, *arg0: int*) → *bats.topology.CellularMap*

edge_source(*self:* bats.topology.CellComplexDiagram, *arg0: int*) → int

edge_target(*self:* bats.topology.CellComplexDiagram, *arg0: int*) → int

nedge(*self:* bats.topology.CellComplexDiagram) → int

nnode(*self:* bats.topology.CellComplexDiagram) → int

node_data(*self:* bats.topology.CellComplexDiagram, *arg0: int*) → *bats.topology.CellComplex*

set_edge(*self:* bats.topology.CellComplexDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.topology.CellularMap) → None

set_node(*self:* bats.topology.CellComplexDiagram, *arg0: int*, *arg1:* bats.topology.CellComplex) → None

class bats.**CellularMap**

Bases: pybind11_builtins.pybind11_object

bats.**Chain**(**args*, ***kwargs*)

Overloaded function.

1. Chain(arg0: bats.topology.SimplicialComplexDiagram, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainDiagram
2. Chain(arg0: bats.topology.CubicalComplexDiagram, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainDiagram
3. Chain(arg0: bats.topology.CellComplexDiagram, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainDiagram
4. Chain(arg0: bats.topology.CellularMap, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainMap
5. Chain(arg0: bats.topology.CellularMap, arg1: bats.topology.SimplicialComplex, arg2: bats.topology.SimplicialComplex, arg3: bats.topology.SimplicialComplex, arg4: bats.topology.SimplicialComplex, arg5: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainMap
6. Chain(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainComplex
7. Chain(arg0: bats.topology.SimplicialComplex, arg1: bats.topology.SimplicialComplex, arg2: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainComplex
8. Chain(arg0: bats.topology.CubicalComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainComplex
9. Chain(arg0: bats.topology.CellComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainComplex
10. Chain(arg0: bats.topology.SimplicialComplexDiagram, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainDiagram
11. Chain(arg0: bats.topology.CubicalComplexDiagram, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainDiagram
12. Chain(arg0: bats.topology.CellComplexDiagram, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainDiagram
13. Chain(arg0: bats.topology.CellularMap, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainMap
14. Chain(arg0: bats.topology.CellularMap, arg1: bats.topology.SimplicialComplex, arg2: bats.topology.SimplicialComplex, arg3: bats.topology.SimplicialComplex, arg4: bats.topology.SimplicialComplex, arg5: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainMap
15. Chain(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainComplex
16. Chain(arg0: bats.topology.SimplicialComplex, arg1: bats.topology.SimplicialComplex, arg2: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainComplex
17. Chain(arg0: bats.topology.CubicalComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainComplex
18. Chain(arg0: bats.topology.CellComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainComplex

bats.**ChainFunctor**(**args*, ***kwargs*)

Overloaded function.

1. ChainFunctor(arg0: bats.topology.SimplicialComplexDiagram, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.F2ChainDiagram

2. ChainFunctor(arg0: bats.topology.SimplicialComplexDiagram, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.F3ChainDiagram

class bats.**CosineDist**
Bases: pybind11_builtins.pybind11_object

class bats.**CoverDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.topology.CoverDiagram, *arg0: int*, *arg1: int*, *arg2: List[int]*) → int

add_node(*self:* bats.topology.CoverDiagram, *arg0: List[Set[int]]*) → int

edge_data(*self:* bats.topology.CoverDiagram, *arg0: int*) → List[int]

edge_source(*self:* bats.topology.CoverDiagram, *arg0: int*) → int

edge_target(*self:* bats.topology.CoverDiagram, *arg0: int*) → int

nedge(*self:* bats.topology.CoverDiagram) → int

nnode(*self:* bats.topology.CoverDiagram) → int

node_data(*self:* bats.topology.CoverDiagram, *arg0: int*) → List[Set[int]]

set_edge(*self:* bats.topology.CoverDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3: List[int]*) → None

set_node(*self:* bats.topology.CoverDiagram, *arg0: int*, *arg1: List[Set[int]]*) → None

bats.**Cube**(**args*, ***kwargs*)
Overloaded function.

1. Cube(arg0: int, arg1: int) -> bats.topology.CubicalComplex
2. Cube(arg0: int, arg1: int, arg2: int) -> bats.topology.CubicalComplex
3. Cube(arg0: int, arg1: int, arg2: int, arg3: int, arg4: int, arg5: int, arg6: int, arg7: int, arg8: int) -> bats.topology.CubicalComplex

class bats.**CubicalComplex**
Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.CubicalComplex, *arg0: List[int]*) → *bats.topology.cell_ind*
add cube

add_recursive(*self:* bats.topology.CubicalComplex, *arg0: List[int]*) → List[*bats.topology.cell_ind*]
add cube as well as faces

boundary(*self:* bats.topology.CubicalComplex, *arg0: int*) → CSCMatrix<int, unsigned long>
integer boundary matrix

find_idx(*self:* bats.topology.CubicalComplex, *arg0: List[int]*) → int

get_cube(*self:* bats.topology.CubicalComplex, *arg0: int*, *arg1: int*) → List[int]
get cube in given dimension

get_cubes(**args*, ***kwargs*)
Overloaded function.

1. get_cubes(self: bats.topology.CubicalComplex, arg0: int) -> List[List[int]]

Returns a list of all cubes in given dimension.

2. get_cubes(self: bats.topology.CubicalComplex) -> List[List[int]]

Returns a list of all cubes.

load_cubes(*self:* bats.topology.CubicalComplex, *arg0: str*) → None
load cubes from a csv file.

maxdim(*self:* bats.topology.CubicalComplex) → int
maximum dimension cube

ncells(**args*, ***kwargs*)
Overloaded function.

1. ncells(self: bats.topology.CubicalComplex) -> int

number of cells

2. ncells(self: bats.topology.CubicalComplex, arg0: int) -> int

number of cells in given dimension

skeleton(*self:* bats.topology.CubicalComplex, *arg0: int*) → *bats.topology.CubicalComplex*
k-skeleton of complex

class bats.**CubicalComplexDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.topology.CellularMap) → int

add_node(*self:* bats.topology.CubicalComplexDiagram, *arg0:* bats.topology.CubicalComplex) → int

edge_data(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*) → *bats.topology.CellularMap*

edge_source(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*) → int

edge_target(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*) → int

nedge(*self:* bats.topology.CubicalComplexDiagram) → int

nnode(*self:* bats.topology.CubicalComplexDiagram) → int

node_data(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*) → *bats.topology.CubicalComplex*

set_edge(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.topology.CellularMap) → None

set_node(*self:* bats.topology.CubicalComplexDiagram, *arg0: int*, *arg1:* bats.topology.CubicalComplex) → None

bats.**CubicalMap**(*arg0:* bats.topology.CubicalComplex, *arg1:* bats.topology.CubicalComplex) → *bats.topology.CellularMap*

class bats.**DataSet**
Bases: pybind11_builtins.pybind11_object

data(*self:* bats.dense.DataSet) → *bats.dense.Matrix*

dim(*self:* bats.dense.DataSet) → int

size(*self:* bats.dense.DataSet) → int

bats.**DiscreteMorozovZigzag**(**args*, ***kwargs*)
Overloaded function.

1. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

2. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

3. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

4. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

5. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

6. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

7. DiscreteMorozovZigzag(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: int) -> Tuple[bats::Diagram<bats::SimplicialComplex, bats::CellularMap>, List[float]]

discrete Morozov Zigzag (dM-ZZ) construction.

bats.**DiscreteMorozovZigzagSets**(**args*, ***kwargs*)

Overloaded function.

1. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

2. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

3. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

4. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

5. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

6. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

7. DiscreteMorozovZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for discrete Morozov Zigzag (dM-ZZ) construction.

bats.**DowkerCoverFiltration**(**args*, ***kwargs*)

Overloaded function.

1. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.Euclidean, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

2. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.L1Dist, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

3. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.LInfDist, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

4. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.CosineDist, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

5. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPCosineDist, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

6. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.AngleDist, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

7. DowkerCoverFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPAngleDist, arg3: List[Set[int]], arg4: float, arg5: int) -> bats.topology.FilteredSimplicialComplex

8. DowkerCoverFiltration(arg0: A<Dense<double, RowMaj> >, arg1: List[Set[int]], arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex

bats.**DowkerFiltration**(**args*, ***kwargs*)

Overloaded function.

1. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.Euclidean, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex

2. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.L1Dist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex

3. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.LInfDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex

4. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.CosineDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex

5. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPCosineDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex

6. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.AngleDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
7. DowkerFiltration(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPAngleDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
8. DowkerFiltration(arg0: A<Dense<double, RowMaj> >, arg1: float, arg2: int) -> bats.topology.FilteredSimplicialComplex

bats.**EL_L_commute**(*arg0:* bats.linalg_f3.F3Mat, *arg1:* bats.linalg_f3.F3Mat) → *bats.linalg_f3.F3Mat*
E_L, L commutation

bats.**EU_U_commute**(*arg0:* bats.linalg_f3.F3Mat, *arg1:* bats.linalg_f3.F3Mat) → *bats.linalg_f3.F3Mat*
E_U, U commutation

class bats.**Euclidean**
Bases: pybind11_builtins.pybind11_object

class bats.**F2**
Bases: pybind11_builtins.pybind11_object

to_int(*self:* bats.linalg_f2.F2) → int
convert to integer.

bats.**F2Chain**(*arg0:* bats.topology.SimplicialComplexDiagram) → *bats.linalg_f2.F2ChainDiagram*

class bats.**F2ChainComplex**
Bases: pybind11_builtins.pybind11_object

clear_compress_apparent_pairs(*self:* bats.linalg_f2.F2ChainComplex) → None

dim(**args*, ***kwargs*)
Overloaded function.

1. dim(self: bats.linalg_f2.F2ChainComplex, arg0: int) -> int
2. dim(self: bats.linalg_f2.F2ChainComplex) -> int

maxdim(*self:* bats.linalg_f2.F2ChainComplex) → int

class bats.**F2ChainDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f2.F2ChainMap) → int

add_node(*self:* bats.linalg_f2.F2ChainDiagram, *arg0:* bats.linalg_f2.F2ChainComplex) → int

edge_data(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*) → *bats.linalg_f2.F2ChainMap*

edge_source(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2ChainDiagram) → int

nnode(*self:* bats.linalg_f2.F2ChainDiagram) → int

node_data(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*) → *bats.linalg_f2.F2ChainComplex*

set_edge(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f2.F2ChainMap) → None

set_node(*self:* bats.linalg_f2.F2ChainDiagram, *arg0: int*, *arg1:* bats.linalg_f2.F2ChainComplex) → None

class bats.**F2ChainMap**
Bases: pybind11_builtins.pybind11_object

class bats.**F2DGHomDiagram**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f2.F2Mat) → int

add_node(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0:* bats.linalg_f2.ReducedF2DGVectorSpace) → int

edge_data(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*) → *bats.linalg_f2.F2Mat*

edge_source(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2DGHomDiagram) → int

nnode(*self:* bats.linalg_f2.F2DGHomDiagram) → int

node_data(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*) → *bats.linalg_f2.ReducedF2DGVectorSpace*

set_edge(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f2.F2Mat) → None

set_node(*self:* bats.linalg_f2.F2DGHomDiagram, *arg0: int*, *arg1:* bats.linalg_f2.ReducedF2DGVectorSpace) → None

class bats.**F2DGHomDiagramAll**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*, *arg1: int*, *arg2: List[*bats.linalg_f2.F2Mat*]*) → int

add_node(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0:* bats.linalg_f2.ReducedF2DGVectorSpace) → int

edge_data(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*) → List[*bats.linalg_f2.F2Mat*]

edge_source(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2DGHomDiagramAll) → int

nnode(*self:* bats.linalg_f2.F2DGHomDiagramAll) → int

node_data(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*) → *bats.linalg_f2.ReducedF2DGVectorSpace*

set_edge(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*, *arg1: int*, *arg2: int*, *arg3: List[*bats.linalg_f2.F2Mat*]*) → None

set_node(*self:* bats.linalg_f2.F2DGHomDiagramAll, *arg0: int*, *arg1:* bats.linalg_f2.ReducedF2DGVectorSpace) → None

class bats.**F2DGLinearDiagram**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f2.F2DGLinearMap) → int

add_node(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0:* bats.linalg_f2.F2DGVectorSpace) → int

edge_data(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*) → *bats.linalg_f2.F2DGLinearMap*

edge_source(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2DGLinearDiagram) → int

nnode(*self:* bats.linalg_f2.F2DGLinearDiagram) → int

node_data(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*) → *bats.linalg_f2.F2DGVectorSpace*

set_edge(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f2.F2DGLinearMap) → None

set_node(*self:* bats.linalg_f2.F2DGLinearDiagram, *arg0: int*, *arg1:* bats.linalg_f2.F2DGVectorSpace) → None

bats.**F2DGLinearFunctor**(*arg0:* bats.topology.SimplicialComplexDiagram, *arg1: int*) → *bats.linalg_f2.F2DGLinearDiagram*

class bats.**F2DGLinearMap**

Bases: pybind11_builtins.pybind11_object

class bats.**F2DGVectorSpace**

Bases: pybind11_builtins.pybind11_object

maxdim(*self:* bats.linalg_f2.F2DGVectorSpace) → int

class bats.**F2Diagram**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2Diagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f2.F2Mat) → int

add_node(*self:* bats.linalg_f2.F2Diagram, *arg0: int*) → int

edge_data(*self:* bats.linalg_f2.F2Diagram, *arg0: int*) → *bats.linalg_f2.F2Mat*

edge_source(*self:* bats.linalg_f2.F2Diagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2Diagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2Diagram) → int

nnode(*self:* bats.linalg_f2.F2Diagram) → int

node_data(*self:* bats.linalg_f2.F2Diagram, *arg0: int*) → int

set_edge(*self:* bats.linalg_f2.F2Diagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f2.F2Mat) → None

set_node(*self:* bats.linalg_f2.F2Diagram, *arg0: int*, *arg1: int*) → None

class bats.**F2HomDiagram**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f2.F2Mat) → int

add_node(*self:* bats.linalg_f2.F2HomDiagram, *arg0:* bats.linalg_f2.ReducedF2ChainComplex) → int

edge_data(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*) → *bats.linalg_f2.F2Mat*

edge_source(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2HomDiagram) → int

nnode(*self:* bats.linalg_f2.F2HomDiagram) → int

node_data(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*) → *bats.linalg_f2.ReducedF2ChainComplex*

set_edge(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f2.F2Mat) → None

set_node(*self:* bats.linalg_f2.F2HomDiagram, *arg0: int*, *arg1:* bats.linalg_f2.ReducedF2ChainComplex) → None

class bats.**F2HomDiagramAll**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*, *arg1: int*, *arg2: List[*bats.linalg_f2.F2Mat*]*) → int

add_node(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0:* bats.linalg_f2.ReducedF2ChainComplex) → int

edge_data(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*) → List[*bats.linalg_f2.F2Mat*]

edge_source(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*) → int

edge_target(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*) → int

nedge(*self:* bats.linalg_f2.F2HomDiagramAll) → int

nnode(*self:* bats.linalg_f2.F2HomDiagramAll) → int

node_data(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*) → *bats.linalg_f2.ReducedF2ChainComplex*

set_edge(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*, *arg1: int*, *arg2: int*, *arg3: List[*bats.linalg_f2.F2Mat*]*) → None

set_node(*self:* bats.linalg_f2.F2HomDiagramAll, *arg0: int*, *arg1:* bats.linalg_f2.ReducedF2ChainComplex) → None

class bats.**F2Mat**

Bases: pybind11_builtins.pybind11_object

T(*self:* bats.linalg_f2.F2Mat) → *bats.linalg_f2.F2Mat*
transpose

append_column(*self:* bats.linalg_f2.F2Mat, *arg0:* bats.linalg_f2.F2Vector) → None
appends column

ncol(*self:* bats.linalg_f2.F2Mat) → int
number of columns.

nnz(*self:* bats.linalg_f2.F2Mat) → int
number of non-zeros

nrow(*self:* bats.linalg_f2.F2Mat) → int
number of rows.

permute_cols(*self:* bats.linalg_f2.F2Mat, *arg0: List[int]*) → None
permute columns

permute_rows(*self:* bats.linalg_f2.F2Mat, *arg0: List[int]*) → None
permute rows

tolist(*self:* bats.linalg_f2.F2Mat) → List[List[*bats.linalg_f2.F2*]]
return as C-style array

class bats.**F2Vector**

Bases: pybind11_builtins.pybind11_object

nnz(*self:* bats.linalg_f2.F2Vector) → int
number of non-zeros

nzinds(*self:* bats.linalg_f2.F2Vector) → List[int]

nzs(*self:* bats.linalg_f2.F2Vector) → Tuple[List[int], List[*bats.linalg_f2.F2*]]
tuple of lists: non-zero indices, and non-zero values

nzvals(*self:* bats.linalg_f2.F2Vector) → List[*bats.linalg_f2.F2*]

permute(*self:* bats.linalg_f2.F2Vector, *arg0: List[int]*) → None
permute the indices

sort(*self:* bats.linalg_f2.F2Vector) → None
put non-zeros in sorted order

class bats.**F3**
Bases: pybind11_builtins.pybind11_object

to_int(*self:* bats.linalg_f3.F3) → int
convert to integer.

bats.**F3Chain**(*arg0:* bats.topology.SimplicialComplexDiagram) → *bats.linalg_f3.F3ChainDiagram*

class bats.**F3ChainComplex**
Bases: pybind11_builtins.pybind11_object

clear_compress_apparent_pairs(*self:* bats.linalg_f3.F3ChainComplex) → None

dim(**args*, ***kwargs*)
Overloaded function.

1. dim(self: bats.linalg_f3.F3ChainComplex, arg0: int) -> int
2. dim(self: bats.linalg_f3.F3ChainComplex) -> int

maxdim(*self:* bats.linalg_f3.F3ChainComplex) → int

class bats.**F3ChainDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f3.F3ChainMap) → int

add_node(*self:* bats.linalg_f3.F3ChainDiagram, *arg0:* bats.linalg_f3.F3ChainComplex) → int

edge_data(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*) → *bats.linalg_f3.F3ChainMap*

edge_source(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3ChainDiagram) → int

nnode(*self:* bats.linalg_f3.F3ChainDiagram) → int

node_data(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*) → *bats.linalg_f3.F3ChainComplex*

set_edge(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f3.F3ChainMap) → None

set_node(*self:* bats.linalg_f3.F3ChainDiagram, *arg0: int*, *arg1:* bats.linalg_f3.F3ChainComplex) → None

class bats.**F3ChainMap**
Bases: pybind11_builtins.pybind11_object

class bats.**F3DGHomDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f3.F3Mat) → int

add_node(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0:* bats.linalg_f3.ReducedF3DGVectorSpace) → int

edge_data(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*) → *bats.linalg_f3.F3Mat*

edge_source(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3DGHomDiagram) → int

nnode(*self:* bats.linalg_f3.F3DGHomDiagram) → int

node_data(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*) → *bats.linalg_f3.ReducedF3DGVectorSpace*

set_edge(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f3.F3Mat) → None

set_node(*self:* bats.linalg_f3.F3DGHomDiagram, *arg0: int*, *arg1:* bats.linalg_f3.ReducedF3DGVectorSpace) → None

class bats.**F3DGHomDiagramAll**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*, *arg1: int*, *arg2: List[*bats.linalg_f3.F3Mat*]*) → int

add_node(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0:* bats.linalg_f3.ReducedF3DGVectorSpace) → int

edge_data(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*) → List[*bats.linalg_f3.F3Mat*]

edge_source(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3DGHomDiagramAll) → int

nnode(*self:* bats.linalg_f3.F3DGHomDiagramAll) → int

node_data(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*) → *bats.linalg_f3.ReducedF3DGVectorSpace*

set_edge(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*, *arg1: int*, *arg2: int*, *arg3: List[*bats.linalg_f3.F3Mat*]*) → None

set_node(*self:* bats.linalg_f3.F3DGHomDiagramAll, *arg0: int*, *arg1:* bats.linalg_f3.ReducedF3DGVectorSpace) → None

class bats.**F3DGLinearDiagram**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f3.F3DGLinearMap) → int

add_node(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0:* bats.linalg_f3.F3DGVectorSpace) → int

edge_data(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*) → *bats.linalg_f3.F3DGLinearMap*

edge_source(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3DGLinearDiagram) → int

nnode(*self:* bats.linalg_f3.F3DGLinearDiagram) → int

node_data(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*) → *bats.linalg_f3.F3DGVectorSpace*

set_edge(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f3.F3DGLinearMap) → None

set_node(*self:* bats.linalg_f3.F3DGLinearDiagram, *arg0: int*, *arg1:* bats.linalg_f3.F3DGVectorSpace) → None

bats.**F3DGLinearFunctor**(*arg0:* bats.topology.CubicalComplexDiagram, *arg1: int*) → *bats.linalg_f3.F3DGLinearDiagram*

class bats.**F3DGLinearMap**
Bases: pybind11_builtins.pybind11_object

class bats.**F3DGVectorSpace**
Bases: pybind11_builtins.pybind11_object

maxdim(*self:* bats.linalg_f3.F3DGVectorSpace) → int

class bats.**F3Diagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3Diagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f3.F3Mat) → int

add_node(*self:* bats.linalg_f3.F3Diagram, *arg0: int*) → int

edge_data(*self:* bats.linalg_f3.F3Diagram, *arg0: int*) → *bats.linalg_f3.F3Mat*

edge_source(*self:* bats.linalg_f3.F3Diagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3Diagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3Diagram) → int

nnode(*self:* bats.linalg_f3.F3Diagram) → int

node_data(*self:* bats.linalg_f3.F3Diagram, *arg0: int*) → int

set_edge(*self:* bats.linalg_f3.F3Diagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f3.F3Mat) → None

set_node(*self:* bats.linalg_f3.F3Diagram, *arg0: int*, *arg1: int*) → None

class bats.**F3HomDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.linalg_f3.F3Mat) → int

add_node(*self:* bats.linalg_f3.F3HomDiagram, *arg0:* bats.linalg_f3.ReducedF3ChainComplex) → int

edge_data(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*) → *bats.linalg_f3.F3Mat*

edge_source(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3HomDiagram) → int

nnode(*self:* bats.linalg_f3.F3HomDiagram) → int

node_data(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*) → *bats.linalg_f3.ReducedF3ChainComplex*

set_edge(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.linalg_f3.F3Mat) → None

set_node(*self:* bats.linalg_f3.F3HomDiagram, *arg0: int*, *arg1:* bats.linalg_f3.ReducedF3ChainComplex) → None

class bats.**F3HomDiagramAll**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*, *arg1: int*, *arg2: List[*bats.linalg_f3.F3Mat*]*) → int

add_node(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0:* bats.linalg_f3.ReducedF3ChainComplex) → int

edge_data(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*) → List[*bats.linalg_f3.F3Mat*]

edge_source(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*) → int

edge_target(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*) → int

nedge(*self:* bats.linalg_f3.F3HomDiagramAll) → int

nnode(*self:* bats.linalg_f3.F3HomDiagramAll) → int

node_data(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*) → *bats.linalg_f3.ReducedF3ChainComplex*

set_edge(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* *List[*bats.linalg_f3.F3Mat*]*) → None

set_node(*self:* bats.linalg_f3.F3HomDiagramAll, *arg0: int*, *arg1:* bats.linalg_f3.ReducedF3ChainComplex) → None

class bats.**F3Mat**

Bases: pybind11_builtins.pybind11_object

T(*self:* bats.linalg_f3.F3Mat) → *bats.linalg_f3.F3Mat*
transpose

append_column(*self:* bats.linalg_f3.F3Mat, *arg0:* bats.linalg_f3.F3Vector) → None
appends column

ncol(*self:* bats.linalg_f3.F3Mat) → int
number of columns.

nnz(*self:* bats.linalg_f3.F3Mat) → int
number of non-zeros

nrow(*self:* bats.linalg_f3.F3Mat) → int
number of rows.

permute_cols(*self:* bats.linalg_f3.F3Mat, *arg0: List[int]*) → None
permute columns

permute_rows(*self:* bats.linalg_f3.F3Mat, *arg0: List[int]*) → None
permute rows

tolist(*self:* bats.linalg_f3.F3Mat) → List[List[*bats.linalg_f3.F3*]]
return as C-style array

class bats.**F3Vector**

Bases: pybind11_builtins.pybind11_object

nnz(*self:* bats.linalg_f3.F3Vector) → int
number of non-zeros

nzinds(*self:* bats.linalg_f3.F3Vector) → List[int]

nzs(*self:* bats.linalg_f3.F3Vector) → Tuple[List[int], List[*bats.linalg_f3.F3*]]
tuple of lists: non-zero indices, and non-zero values

nzvals(*self:* bats.linalg_f3.F3Vector) → List[*bats.linalg_f3.F3*]

permute(*self:* bats.linalg_f3.F3Vector, *arg0: List[int]*) → None
permute the indices

sort(*self:* bats.linalg_f3.F3Vector) → None
put non-zeros in sorted order

class bats.**FilteredCubicalComplex**

Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.FilteredCubicalComplex, *arg0: float*, *arg1: List[int]*) → *bats.topology.cell_ind*

add_recursive(*self:* bats.topology.FilteredCubicalComplex, *arg0: float*, *arg1: List[int]*) → List[*bats.topology.cell_ind*]

all_vals(*self:* bats.topology.FilteredCubicalComplex) → List[List[float]]

complex(*self:* bats.topology.FilteredCubicalComplex) → *bats.topology.CubicalComplex*

maxdim(*self:* bats.topology.FilteredCubicalComplex) → int

ncells(*self:* bats.topology.FilteredCubicalComplex, *arg0: int*) → int

sublevelset(*self:* bats.topology.FilteredCubicalComplex, *arg0: float*) → *bats.topology.CubicalComplex*

update_filtration(*self:* bats.topology.FilteredCubicalComplex, *arg0: List[List[float]]*) → None

vals(*self:* bats.topology.FilteredCubicalComplex, *arg0: int*) → List[float]

class bats.**FilteredEdge**

Bases: pybind11_builtins.pybind11_object

class bats.**FilteredF2ChainComplex**

Bases: pybind11_builtins.pybind11_object

perm(*self:* bats.linalg_f2.FilteredF2ChainComplex) → List[List[int]]

permutation from original order

update_filtration(*self:* bats.linalg_f2.FilteredF2ChainComplex, *arg0: List[List[float]]*) → None

update filtration with new values

update_filtration_general(**args*, ***kwargs*)

Overloaded function.

1. update_filtration_general(self: bats.linalg_f2.FilteredF2ChainComplex, arg0: bats.topology.UpdateInfoFiltration) -> None

general update Filtered Chain Complex with updating information

2. update_filtration_general(self: bats.linalg_f2.FilteredF2ChainComplex, arg0: bats.topology.UpdateInfoLightFiltration) -> None

general update Filtered Chain Complex with updating information

val(*self:* bats.linalg_f2.FilteredF2ChainComplex) → List[List[float]]

filtration values.

class bats.**FilteredF3ChainComplex**

Bases: pybind11_builtins.pybind11_object

perm(*self:* bats.linalg_f3.FilteredF3ChainComplex) → List[List[int]]

permutation from original order

update_filtration(*self:* bats.linalg_f3.FilteredF3ChainComplex, *arg0: List[List[float]]*) → None

update filtration with new values

update_filtration_general(**args*, ***kwargs*)

Overloaded function.

1. update_filtration_general(self: bats.linalg_f3.FilteredF3ChainComplex, arg0: bats.topology.UpdateInfoFiltration) -> None

general update Filtered Chain Complex with updating information

2. update_filtration_general(self: bats.linalg_f3.FilteredF3ChainComplex, arg0: bats.topology.UpdateInfoLightFiltration) -> None

general update Filtered Chain Complex with updating information

val(*self:* bats.linalg_f3.FilteredF3ChainComplex) → List[List[float]]
filtration values.

class bats.**FilteredLightSimplicialComplex**
Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.FilteredLightSimplicialComplex, *arg0: float*, *arg1: List[int]*) → *bats.topology.cell_ind*

add_recursive(*self:* bats.topology.FilteredLightSimplicialComplex, *arg0: float*, *arg1: List[int]*) → List[*bats.topology.cell_ind*]

all_vals(*self:* bats.topology.FilteredLightSimplicialComplex) → List[List[float]]

complex(*self:* bats.topology.FilteredLightSimplicialComplex) → *bats.topology.LightSimplicialComplex*

maxdim(*self:* bats.topology.FilteredLightSimplicialComplex) → int

ncells(*self:* bats.topology.FilteredLightSimplicialComplex, *arg0: int*) → int

sublevelset(*self:* bats.topology.FilteredLightSimplicialComplex, *arg0: float*) → *bats.topology.LightSimplicialComplex*

update_filtration(*self:* bats.topology.FilteredLightSimplicialComplex, *arg0: List[List[float]]*) → None

vals(*self:* bats.topology.FilteredLightSimplicialComplex, *arg0: int*) → List[float]

class bats.**FilteredSimplicialComplex**
Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.FilteredSimplicialComplex, *arg0: float*, *arg1: List[int]*) → *bats.topology.cell_ind*

add_recursive(*self:* bats.topology.FilteredSimplicialComplex, *arg0: float*, *arg1: List[int]*) → List[*bats.topology.cell_ind*]

all_vals(*self:* bats.topology.FilteredSimplicialComplex) → List[List[float]]

complex(*self:* bats.topology.FilteredSimplicialComplex) → *bats.topology.SimplicialComplex*

maxdim(*self:* bats.topology.FilteredSimplicialComplex) → int

ncells(*self:* bats.topology.FilteredSimplicialComplex, *arg0: int*) → int

sublevelset(*self:* bats.topology.FilteredSimplicialComplex, *arg0: float*) → *bats.topology.SimplicialComplex*

update_filtration(*self:* bats.topology.FilteredSimplicialComplex, *arg0: List[List[float]]*) → None

vals(*self:* bats.topology.FilteredSimplicialComplex, *arg0: int*) → List[float]

bats.**Filtration**(**args*, ***kwargs*)
Overloaded function.

1. Filtration(arg0: bats.topology.SimplicialComplex, arg1: List[List[float]]) -> bats::Filtration<double, bats::SimplicialComplex>

2. Filtration(arg0: bats.topology.LightSimplicialComplex, arg1: List[List[float]]) -> bats::Filtration<double, bats::LightSimplicialComplex<unsigned long, std::unordered_map<unsigned long, unsigned long, std::hash<unsigned long>, std::equal_to<unsigned long>, std::allocator<std::pair<unsigned long const, unsigned long> > > > >

3. Filtration(arg0: bats.topology.CubicalComplex, arg1: List[List[float]]) -> bats::Filtration<double, bats::CubicalComplex>

bats.**FlagComplex**(*arg0: List[int]*, *arg1: int*, *arg2: int*) → *bats.topology.SimplicialComplex*
Flag complex constructed from a (flattened) list of edges.

bats.**Freudenthal**(**args*, ***kwargs*)
Overloaded function.

1. Freudenthal(arg0: int, arg1: int) -> bats.topology.SimplicialComplex
2. Freudenthal(arg0: int, arg1: int, arg2: int) -> bats.topology.SimplicialComplex
3. Freudenthal(arg0: int, arg1: int, arg2: int, arg3: int, arg4: int, arg5: int, arg6: int, arg7: int, arg8: int) -> bats.topology.SimplicialComplex
4. Freudenthal(arg0: bats.topology.CubicalComplex, arg1: int, arg2: int, arg3: int) -> bats.topology.SimplicialComplex

bats.**Hom**(**args*, ***kwargs*)
Overloaded function.

1. Hom(arg0: bats.linalg_f2.F2ChainDiagram, arg1: int) -> bats.linalg_f2.F2HomDiagram
2. Hom(arg0: bats.linalg_f2.F2ChainDiagram) -> bats.linalg_f2.F2HomDiagramAll
3. Hom(arg0: bats.linalg_f2.F2ChainDiagram, arg1: bool) -> bats.linalg_f2.F2HomDiagramAll
4. Hom(arg0: bats.linalg_f2.F2DGLinearDiagram, arg1: int) -> bats.linalg_f2.F2DGHomDiagram
5. Hom(arg0: bats.linalg_f2.F2DGLinearDiagram) -> bats.linalg_f2.F2DGHomDiagramAll
6. Hom(arg0: bats.linalg_f2.F2DGLinearDiagram, arg1: bool) -> bats.linalg_f2.F2DGHomDiagramAll
7. Hom(arg0: bats.linalg_f3.F3ChainDiagram, arg1: int) -> bats.linalg_f3.F3HomDiagram
8. Hom(arg0: bats.linalg_f3.F3ChainDiagram) -> bats.linalg_f3.F3HomDiagramAll
9. Hom(arg0: bats.linalg_f3.F3ChainDiagram, arg1: bool) -> bats.linalg_f3.F3HomDiagramAll
10. Hom(arg0: bats.linalg_f3.F3DGLinearDiagram, arg1: int) -> bats.linalg_f3.F3DGHomDiagram
11. Hom(arg0: bats.linalg_f3.F3DGLinearDiagram) -> bats.linalg_f3.F3DGHomDiagramAll
12. Hom(arg0: bats.linalg_f3.F3DGLinearDiagram, arg1: bool) -> bats.linalg_f3.F3DGHomDiagramAll

bats.**Identity**(*arg0: int*, *arg1:* bats.linalg_f3.F3) → *bats.linalg_f3.F3Mat*

bats.**IdentityMap**(*arg0:* bats.topology.SimplicialComplex) → *bats.topology.CellularMap*

bats.**InducedMap**(**args*, ***kwargs*)
Overloaded function.

1. InducedMap(arg0: bats.linalg_f3.F3ChainMap, arg1: bats.linalg_f3.ReducedF3ChainComplex, arg2: bats.linalg_f3.ReducedF3ChainComplex, arg3: int) -> bats.linalg_f3.F3Mat

Induced map on homology.

2. InducedMap(arg0: bats.linalg_f3.F3DGLinearMap, arg1: bats.linalg_f3.ReducedF3DGVectorSpace, arg2: bats.linalg_f3.ReducedF3DGVectorSpace, arg3: int) -> bats.linalg_f3.F3Mat

Induced map on homology.

class bats.**IntMat**
Bases: pybind11_builtins.pybind11_object

T(*self:* bats.linalg.IntMat) → *bats.linalg.IntMat*
transpose

append_column(*self:* bats.linalg.IntMat, *arg0:* bats.linalg.IntVector) → None
appends column

ncol(*self:* bats.linalg.IntMat) → int
number of columns.

nnz(*self:* bats.linalg.IntMat) → int
number of non-zeros

nrow(*self:* bats.linalg.IntMat) → int
number of rows.

permute_cols(*self:* bats.linalg.IntMat, *arg0: List[int]*) → None
permute columns

permute_rows(*self:* bats.linalg.IntMat, *arg0: List[int]*) → None
permute rows

tolist(*self:* bats.linalg.IntMat) → List[List[int]]
return as C-style array

class bats.**IntVector**
Bases: pybind11_builtins.pybind11_object

nnz(*self:* bats.linalg.IntVector) → int
number of non-zeros

nzinds(*self:* bats.linalg.IntVector) → List[int]

nzs(*self:* bats.linalg.IntVector) → Tuple[List[int], List[int]]
tuple of lists: non-zero indices, and non-zero values

nzvals(*self:* bats.linalg.IntVector) → List[int]

permute(*self:* bats.linalg.IntVector, *arg0: List[int]*) → None
permute the indices

sort(*self:* bats.linalg.IntVector) → None
put non-zeros in sorted order

class bats.**L1Dist**
Bases: pybind11_builtins.pybind11_object

bats.**LEUP**(*arg0:* bats.linalg_f3.F3Mat) → Tuple[*bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*]
LEUP factorization

class bats.**LInfDist**
Bases: pybind11_builtins.pybind11_object

bats.**LQU**(*arg0:* bats.linalg_f3.F3Mat) → Tuple[*bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*]
LQU factorization

bats.**L_EL_commute**(*arg0:* bats.linalg_f3.F3Mat, *arg1:* bats.linalg_f3.F3Mat) → *bats.linalg_f3.F3Mat*
L, E_L commutation

bats.**LightFlagComplex**(*arg0: List[int]*, *arg1: int*, *arg2: int*) → *bats.topology.LightSimplicialComplex*
Flag complex constructed from a (flattened) list of edges.

bats.**LightFreudenthal**(**args*, ***kwargs*)
Overloaded function.

1. LightFreudenthal(arg0: int, arg1: int) -> bats.topology.LightSimplicialComplex
2. LightFreudenthal(arg0: int, arg1: int, arg2: int) -> bats.topology.LightSimplicialComplex

3. LightFreudenthal(arg0: int, arg1: int, arg2: int, arg3: int, arg4: int, arg5: int, arg6: int, arg7: int, arg8: int) -> bats.topology.LightSimplicialComplex

4. LightFreudenthal(arg0: bats.topology.CubicalComplex, arg1: int, arg2: int, arg3: int) -> bats.topology.LightSimplicialComplex

bats.**LightRipsComplex**(*arg0: A<Dense<double, RowMaj> >*, *arg1: float*, *arg2: int*) → *bats.topology.LightSimplicialComplex*

Rips Complex constructed from pairwise distances.

bats.**LightRipsFiltration**(**args*, ***kwargs*)

Overloaded function.

1. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

2. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

3. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

4. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

5. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

6. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

7. LightRipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: int) -> bats.topology.FilteredLightSimplicialComplex

8. LightRipsFiltration(arg0: A<Dense<double, RowMaj> >, arg1: float, arg2: int) -> bats.topology.FilteredLightSimplicialComplex

Rips Filtration using built using pairwise distances.

bats.**LightRipsFiltration_extension**(**args*, ***kwargs*)

Overloaded function.

1. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

2. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

3. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

4. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

5. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

6. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

7. LightRipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

8. LightRipsFiltration_extension(arg0: A<Dense<double, RowMaj> >, arg1: float, arg2: int) -> Tuple[bats.topology.FilteredLightSimplicialComplex, List[List[int]]]

Rips Filtration built using pairwise distances with inverse map returned.

class bats.**LightSimplicialComplex**

Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.LightSimplicialComplex, *arg0: List[int]*) → *bats.topology.cell_ind*

add simplex

add_recursive(*self:* bats.topology.LightSimplicialComplex, *arg0: List[int]*) → List[*bats.topology.cell_ind*]

add simplex and missing faces

boundary(*self:* bats.topology.LightSimplicialComplex, *arg0: int*) → CSCMatrix<int, unsigned long>

find_idx(*self:* bats.topology.LightSimplicialComplex, *arg0: List[int]*) → int

get_simplex(*self:* bats.topology.LightSimplicialComplex, *arg0: int*, *arg1: int*) → List[int]

get_simplices(**args*, ***kwargs*)

Overloaded function.

1. get_simplices(self: bats.topology.LightSimplicialComplex, arg0: int) -> List[List[int]]

Returns a list of all simplices in given dimension.

2. get_simplices(self: bats.topology.LightSimplicialComplex) -> List[List[int]]

Returns a list of all simplices.

maxdim(*self:* bats.topology.LightSimplicialComplex) → int

maximum dimension simplex

ncells(**args*, ***kwargs*)

Overloaded function.

1. ncells(self: bats.topology.LightSimplicialComplex) -> int

number of cells

2. ncells(self: bats.topology.LightSimplicialComplex, arg0: int) -> int

number of cells in given dimension

bats.**Mat**(*arg0:* bats.linalg.CSCMatrix, *arg1:* bats.linalg_f3.F3) → *bats.linalg_f3.F3Mat*

class bats.**Matrix**

Bases: pybind11_builtins.pybind11_object

ncol(*self:* bats.dense.Matrix) → int

nrow(*self:* bats.dense.Matrix) → int

print(*self:* bats.dense.Matrix) → None

bats.**Nerve**(*arg0: List[Set[int]]*, *arg1: int*) → *bats.topology.SimplicialComplex*

bats.**NerveDiagram**(*arg0:* bats.topology.CoverDiagram, *arg1: int*) → *bats.topology.SimplicialComplexDiagram*

bats.**OscillatingRipsZigzagSets**(**args*, ***kwargs*)

Overloaded function.

1. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

2. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

3. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

4. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

5. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

6. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

7. OscillatingRipsZigzagSets(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: float) -> Tuple[bats::Diagram<std::set<unsigned long, std::less<unsigned long>, std::allocator<unsigned long> >, std::vector<unsigned long, std::allocator<unsigned long> > >, List[float]]

SetDiagram for Oscillating Rips Zigzag constrution.

bats.**PLEU**(*arg0:* bats.linalg_f3.F3Mat) → Tuple[*bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*]

PLEU factorization

bats.**PUEL**(*arg0:* bats.linalg_f3.F3Mat) → Tuple[*bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*]

PUEL factorization

class bats.**PersistencePair**

Bases: pybind11_builtins.pybind11_object

birth(*self:* bats.linalg.PersistencePair) → float

birth_ind(*self:* bats.linalg.PersistencePair) → int

death(*self:* bats.linalg.PersistencePair) → float

death_ind(*self:* bats.linalg.PersistencePair) → int

dim(*self:* bats.linalg.PersistencePair) → int

length(*self:* bats.linalg.PersistencePair) → float

mid(*self:* bats.linalg.PersistencePair) → float

class bats.**PersistencePair_int**

Bases: pybind11_builtins.pybind11_object

birth(*self:* bats.linalg.PersistencePair_int) → int

birth_ind(*self:* bats.linalg.PersistencePair_int) → int

death(*self:* bats.linalg.PersistencePair_int) → int

death_ind(*self:* bats.linalg.PersistencePair_int) → int

dim(*self:* bats.linalg.PersistencePair_int) → int

length(*self:* bats.linalg.PersistencePair_int) → int

mid(*self:* bats.linalg.PersistencePair_int) → int

class bats.**RPAngleDist**

Bases: pybind11_builtins.pybind11_object

class bats.**RPCosineDist**

Bases: pybind11_builtins.pybind11_object

bats.**ReducedChainComplex**(**args*, ***kwargs*)

Overloaded function.

1. ReducedChainComplex(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedF2ChainComplex
2. ReducedChainComplex(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedF2ChainComplex
3. ReducedChainComplex(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedF3ChainComplex
4. ReducedChainComplex(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedF3ChainComplex

class bats.**ReducedF2ChainComplex**

Bases: pybind11_builtins.pybind11_object

R(*self:* bats.linalg_f2.ReducedF2ChainComplex, *arg0: int*) → *bats.linalg_f2.F2Mat*

reduced matrix in specified dimension

U(*self:* bats.linalg_f2.ReducedF2ChainComplex, *arg0: int*) → *bats.linalg_f2.F2Mat*

basis matrix in specified dimension

chain_preferred_representative(*self:* bats.linalg_f2.ReducedF2ChainComplex, *arg0:* bats.linalg_f2.F2Vector, *arg1: int*) → *bats.linalg_f2.F2Vector*

return the preferred representative of a chain

find_preferred_representative(*self:* bats.linalg_f2.ReducedF2ChainComplex, *arg0:* bats.linalg_f2.F2Vector, *arg1: int*) → None

from_hom_basis(**args*, ***kwargs*)

Overloaded function.

1. from_hom_basis(self: bats.linalg_f2.ReducedF2ChainComplex, arg0: bats.linalg_f2.F2Mat, arg1: int) -> bats.linalg_f2.F2Mat

2. from_hom_basis(self: bats.linalg_f2.ReducedF2ChainComplex, arg0: bats.linalg_f2.F2Vector, arg1: int) -> bats.linalg_f2.F2Vector

get_preferred_representative(*self:* bats.linalg_f2.ReducedF2ChainComplex, *arg0: int*, *arg1: int*) → *bats.linalg_f2.F2Vector*

get the preferred representative for homology class

hdim(*self:* bats.linalg_f2.ReducedF2ChainComplex, *arg0: int*) → int

maxdim(*self:* bats.linalg_f2.ReducedF2ChainComplex) → int

to_hom_basis(**args*, ***kwargs*)

Overloaded function.

1. to_hom_basis(self: bats.linalg_f2.ReducedF2ChainComplex, arg0: bats.linalg_f2.F2Mat, arg1: int) -> bats.linalg_f2.F2Mat

2. to_hom_basis(self: bats.linalg_f2.ReducedF2ChainComplex, arg0: bats.linalg_f2.F2Vector, arg1: int) -> bats.linalg_f2.F2Vector

class bats.**ReducedF2DGVectorSpace**

Bases: pybind11_builtins.pybind11_object

hdim(*self:* bats.linalg_f2.ReducedF2DGVectorSpace, *arg0: int*) → int

maxdim(*self:* bats.linalg_f2.ReducedF2DGVectorSpace) → int

class bats.**ReducedF3ChainComplex**

Bases: pybind11_builtins.pybind11_object

R(*self:* bats.linalg_f3.ReducedF3ChainComplex, *arg0: int*) → *bats.linalg_f3.F3Mat*

reduced matrix in specified dimension

U(*self:* bats.linalg_f3.ReducedF3ChainComplex, *arg0: int*) → *bats.linalg_f3.F3Mat*

basis matrix in specified dimension

chain_preferred_representative(*self:* bats.linalg_f3.ReducedF3ChainComplex, *arg0:* bats.linalg_f3.F3Vector, *arg1: int*) → *bats.linalg_f3.F3Vector*

return the preferred representative of a chain

find_preferred_representative(*self:* bats.linalg_f3.ReducedF3ChainComplex, *arg0:* bats.linalg_f3.F3Vector, *arg1: int*) → None

from_hom_basis(**args*, ***kwargs*)

Overloaded function.

1. from_hom_basis(self: bats.linalg_f3.ReducedF3ChainComplex, arg0: bats.linalg_f3.F3Mat, arg1: int) -> bats.linalg_f3.F3Mat

2. from_hom_basis(self: bats.linalg_f3.ReducedF3ChainComplex, arg0: bats.linalg_f3.F3Vector, arg1: int) -> bats.linalg_f3.F3Vector

get_preferred_representative(*self:* bats.linalg_f3.ReducedF3ChainComplex, *arg0: int*, *arg1: int*) → *bats.linalg_f3.F3Vector*

get the preferred representative for homology class

hdim(*self:* bats.linalg_f3.ReducedF3ChainComplex, *arg0: int*) → int

maxdim(*self:* bats.linalg_f3.ReducedF3ChainComplex) → int

to_hom_basis(**args*, ***kwargs*)

Overloaded function.

1. to_hom_basis(self: bats.linalg_f3.ReducedF3ChainComplex, arg0: bats.linalg_f3.F3Mat, arg1: int) -> bats.linalg_f3.F3Mat

2. to_hom_basis(self: bats.linalg_f3.ReducedF3ChainComplex, arg0: bats.linalg_f3.F3Vector, arg1: int) -> bats.linalg_f3.F3Vector

class bats.**ReducedF3DGVectorSpace**

Bases: pybind11_builtins.pybind11_object

hdim(*self:* bats.linalg_f3.ReducedF3DGVectorSpace, *arg0: int*) → int

maxdim(*self:* bats.linalg_f3.ReducedF3DGVectorSpace) → int

bats.**ReducedFilteredChainComplex**(**args*, ***kwargs*)

Overloaded function.

1. ReducedFilteredChainComplex(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

2. ReducedFilteredChainComplex(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

3. ReducedFilteredChainComplex(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

4. ReducedFilteredChainComplex(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

5. ReducedFilteredChainComplex(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

6. ReducedFilteredChainComplex(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

class bats.**ReducedFilteredF2ChainComplex**

Bases: pybind11_builtins.pybind11_object

dim(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex, *arg0: int*) → int

maxdim(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex) → int

nnz_R(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex) → List[int]

get the number of non-zeros in R

nnz_U(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex) → List[int]

get the number of non-zeros in U

perm(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex) → List[List[int]]

permutation from original order

persistence_pairs(**args*, ***kwargs*)

Overloaded function.

1. persistence_pairs(self: bats.linalg_f2.ReducedFilteredF2ChainComplex, arg0: int) -> List[bats.linalg.PersistencePair]

2. persistence_pairs(self: bats.linalg_f2.ReducedFilteredF2ChainComplex, arg0: int, arg1: bool) -> List[bats.linalg.PersistencePair]

persistence_pairs_vec(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex, *arg0: int*) → Tuple[List[float], List[int]]

reduced_complex(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex) → *bats.linalg_f2.ReducedF2ChainComplex*

underlying reduced complex

representative(**args*, ***kwargs*)
Overloaded function.

1. representative(self: bats.linalg_f2.ReducedFilteredF2ChainComplex, arg0: bats.linalg.PersistencePair) -> bats.linalg_f2.F2Vector

2. representative(self: bats.linalg_f2.ReducedFilteredF2ChainComplex, arg0: bats.linalg.PersistencePair, arg1: bool) -> bats.linalg_f2.F2Vector

update_filtration(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex, *arg0: List[List[float]]*) → None
update filtration with new values

update_filtration_general(**args*, ***kwargs*)
Overloaded function.

1. update_filtration_general(self: bats.linalg_f2.ReducedFilteredF2ChainComplex, arg0: bats.topology.UpdateInfoFiltration) -> None

generally update filtration with updating information

2. update_filtration_general(self: bats.linalg_f2.ReducedFilteredF2ChainComplex, arg0: bats.topology.UpdateInfoLightFiltration) -> None

generally update filtration with updating information

val(*self:* bats.linalg_f2.ReducedFilteredF2ChainComplex) → List[List[float]]
filtration values

class bats.**ReducedFilteredF3ChainComplex**
Bases: pybind11_builtins.pybind11_object

dim(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex, *arg0: int*) → int

maxdim(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex) → int

nnz_R(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex) → List[int]
get the number of non-zeros in R

nnz_U(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex) → List[int]
get the number of non-zeros in U

perm(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex) → List[List[int]]
permutation from original order

persistence_pairs(**args*, ***kwargs*)
Overloaded function.

1. persistence_pairs(self: bats.linalg_f3.ReducedFilteredF3ChainComplex, arg0: int) -> List[bats.linalg.PersistencePair]

2. persistence_pairs(self: bats.linalg_f3.ReducedFilteredF3ChainComplex, arg0: int, arg1: bool) -> List[bats.linalg.PersistencePair]

reduced_complex(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex) → *bats.linalg_f3.ReducedF3ChainComplex*
underlying reduced complex

representative(**args*, ***kwargs*)
Overloaded function.

1. representative(self: bats.linalg_f3.ReducedFilteredF3ChainComplex, arg0: bats.linalg.PersistencePair) -> bats.linalg_f3.F3Vector

2. representative(self: bats.linalg_f3.ReducedFilteredF3ChainComplex, arg0: bats.linalg.PersistencePair, arg1: bool) -> bats.linalg_f3.F3Vector

update_filtration(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex, *arg0: List[List[float]]*) → None
update filtration with new values

update_filtration_general(**args*, ***kwargs*)
Overloaded function.

1. update_filtration_general(self: bats.linalg_f3.ReducedFilteredF3ChainComplex, arg0: bats.topology.UpdateInfoFiltration) -> None

generally update filtration with updating information

2. update_filtration_general(self: bats.linalg_f3.ReducedFilteredF3ChainComplex, arg0: bats.topology.UpdateInfoLightFiltration) -> None

generally update filtration with updating information

val(*self:* bats.linalg_f3.ReducedFilteredF3ChainComplex) → List[List[float]]
filtration values

bats.**Rips**(**args*, ***kwargs*)
Overloaded function.

1. Rips(arg0: bats.topology.SetDiagram, arg1: bats::DataSet<double>, arg2: bats.topology.Euclidean, arg3: float, arg4: int) -> bats.topology.SimplicialComplexDiagram

Construct a diagram of Rips complexes from a SetDiagram.

2. Rips(arg0: bats.topology.SetDiagram, arg1: bats::DataSet<double>, arg2: bats.topology.Euclidean, arg3: List[float], arg4: int) -> bats.topology.SimplicialComplexDiagram

Construct a diagram of Rips complexes from a SetDiagram.

bats.**RipsComplex**(**args*, ***kwargs*)
Overloaded function.

1. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

2. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

3. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

4. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

5. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

6. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

7. RipsComplex(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from data set and metric.

8. RipsComplex(arg0: A<Dense<double, RowMaj> >, arg1: float, arg2: int) -> bats.topology.SimplicialComplex

Rips Complex constructed from pairwise distances.

bats.**RipsCoverFiltration**(**args*, ***kwargs*)

Overloaded function.

1. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.Euclidean, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
2. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.L1Dist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
3. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.LInfDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
4. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.CosineDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
5. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.RPCosineDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
6. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.AngleDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex
7. RipsCoverFiltration(arg0: bats::DataSet<double>, arg1: List[Set[int]], arg2: bats.topology.RPAngleDist, arg3: float, arg4: int) -> bats.topology.FilteredSimplicialComplex

bats.**RipsFiltration**(**args*, ***kwargs*)

Overloaded function.

1. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
2. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
3. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
4. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
5. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
6. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
7. RipsFiltration(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: int) -> bats.topology.FilteredSimplicialComplex
8. RipsFiltration(arg0: A<Dense<double, RowMaj> >, arg1: float, arg2: int) -> bats.topology.FilteredSimplicialComplex

Rips Filtration using built using pairwise distances.

bats.**RipsFiltration_extension**(**args*, ***kwargs*)

Overloaded function.

1. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

2. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

3. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

4. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

5. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

6. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

7. RipsFiltration_extension(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: float, arg3: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration with inverse map returned

8. RipsFiltration_extension(arg0: A<Dense<double, RowMaj> >, arg1: float, arg2: int) -> Tuple[bats.topology.FilteredSimplicialComplex, List[List[int]]]

Rips Filtration built using pairwise distances Rips with inverse map returned.

bats.**RipsHom**(*arg0:* bats.topology.SetDiagram, *arg1:* bats.dense.DataSet, *arg2:* bats.topology.Euclidean, *arg3:* *List[float]*, *arg4: int*, *arg5:* bats.linalg_f2.F2) → *bats.linalg_f2.F2Diagram*

class bats.**SetDiagram**

Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.topology.SetDiagram, *arg0: int*, *arg1: int*, *arg2: List[int]*) → int

add_node(*self:* bats.topology.SetDiagram, *arg0: Set[int]*) → int

edge_data(*self:* bats.topology.SetDiagram, *arg0: int*) → List[int]

edge_source(*self:* bats.topology.SetDiagram, *arg0: int*) → int

edge_target(*self:* bats.topology.SetDiagram, *arg0: int*) → int

nedge(*self:* bats.topology.SetDiagram) → int

nnode(*self:* bats.topology.SetDiagram) → int

node_data(*self:* bats.topology.SetDiagram, *arg0: int*) → Set[int]

set_edge(*self:* bats.topology.SetDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3: List[int]*) → None

set_node(*self:* bats.topology.SetDiagram, *arg0: int*, *arg1: Set[int]*) → None

bats.**SierpinskiDiagram**(*arg0: int*) → bats::Diagram<bats::CellComplex, bats::CellularMap>

Diagram of Sierpinski triangle iterations.

class bats.**SimplicialComplex**
Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.SimplicialComplex, *arg0: List[int]*) → *bats.topology.cell_ind*
add simplex

add_recursive(*self:* bats.topology.SimplicialComplex, *arg0: List[int]*) → List[*bats.topology.cell_ind*]
add simplex and missing faces

boundary(*self:* bats.topology.SimplicialComplex, *arg0: int*) → CSCMatrix<int, unsigned long>

find_idx(*self:* bats.topology.SimplicialComplex, *arg0: List[int]*) → int

get_simplex(*self:* bats.topology.SimplicialComplex, *arg0: int*, *arg1: int*) → List[int]

get_simplices(**args*, ***kwargs*)
Overloaded function.

1. get_simplices(self: bats.topology.SimplicialComplex, arg0: int) -> List[List[int]]

Returns a list of all simplices in given dimension.

2. get_simplices(self: bats.topology.SimplicialComplex) -> List[List[int]]

Returns a list of all simplices.

maxdim(*self:* bats.topology.SimplicialComplex) → int
maximum dimension simplex

ncells(**args*, ***kwargs*)
Overloaded function.

1. ncells(self: bats.topology.SimplicialComplex) -> int

number of cells

2. ncells(self: bats.topology.SimplicialComplex, arg0: int) -> int

number of cells in given dimension

class bats.**SimplicialComplexDiagram**
Bases: pybind11_builtins.pybind11_object

add_edge(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*, *arg1: int*, *arg2:* bats.topology.CellularMap) → int

add_node(*self:* bats.topology.SimplicialComplexDiagram, *arg0:* bats.topology.SimplicialComplex) → int

edge_data(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*) → *bats.topology.CellularMap*

edge_source(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*) → int

edge_target(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*) → int

nedge(*self:* bats.topology.SimplicialComplexDiagram) → int

nnode(*self:* bats.topology.SimplicialComplexDiagram) → int

node_data(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*) → *bats.topology.SimplicialComplex*

set_edge(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*, *arg1: int*, *arg2: int*, *arg3:* bats.topology.CellularMap) → None

set_node(*self:* bats.topology.SimplicialComplexDiagram, *arg0: int*, *arg1:* bats.topology.SimplicialComplex) → None

bats.**SimplicialMap**(**args*, ***kwargs*)
Overloaded function.

1. SimplicialMap(arg0: bats.topology.SimplicialComplex, arg1: bats.topology.SimplicialComplex) -> bats.topology.CellularMap

Inclusion map of simplicial complexes

2. SimplicialMap(arg0: bats.topology.SimplicialComplex, arg1: bats.topology.SimplicialComplex, arg2: List[int]) -> bats.topology.CellularMap

simplicial map extended from function on vertices

bats.**TriangulatedProduct**(*arg0:* bats.topology.SimplicialComplex, *arg1:* bats.topology.SimplicialComplex) → *bats.topology.SimplicialComplex*

bats.**UELP**(*arg0:* bats.linalg_f3.F3Mat) → Tuple[*bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*, *bats.linalg_f3.F3Mat*]

UELP factorization

bats.**U_EU_commute**(*arg0:* bats.linalg_f3.F3Mat, *arg1:* bats.linalg_f3.F3Mat) → *bats.linalg_f3.F3Mat*

U, E_U commutation

class bats.**UpdateInfoFiltration**

Bases: pybind11_builtins.pybind11_object

filtered_info(*self:* bats.topology.UpdateInfoFiltration, *arg0: List[List[int]]*) → None

if the cells in filtration are not sorted by their filtration values, we find filtered updating information

class bats.**UpdateInfoLightFiltration**

Bases: pybind11_builtins.pybind11_object

filtered_info(*self:* bats.topology.UpdateInfoLightFiltration, *arg0: List[List[int]]*) → None

if the cells in filtration are not sorted by their filtration values, we find filtered updating information

bats.**WitnessFiltration**(*arg0: bats::DataSet<double>*, *arg1: bats::DataSet<double>*, *arg2: bats.topology.Euclidean*, *arg3: float*, *arg4: int*) → *bats.topology.FilteredSimplicialComplex*

bats.**ZigzagBarcode**(**args*, ***kwargs*)

Overloaded function.

1. ZigzagBarcode(arg0: bats.topology.ZigzagCubicalComplex, arg1: int, arg2: ModP<int, 2u>) -> List[List[bats::zigzag::ZigzagPair<double>]]

2. ZigzagBarcode(arg0: bats.topology.ZigzagCubicalComplex, arg1: int, arg2: ModP<int, 2u>, arg3: bats::extra_reduction_flag) -> List[List[bats::zigzag::ZigzagPair<double>]]

3. ZigzagBarcode(arg0: bats.topology.ZigzagSimplicialComplex, arg1: int, arg2: ModP<int, 2u>) -> List[List[bats::zigzag::ZigzagPair<double>]]

4. ZigzagBarcode(arg0: bats.topology.ZigzagSimplicialComplex, arg1: int, arg2: ModP<int, 2u>, arg3: bats::extra_reduction_flag) -> List[List[bats::zigzag::ZigzagPair<double>]]

class bats.**ZigzagCubicalComplex**

Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.ZigzagCubicalComplex, *arg0: float*, *arg1: float*, *arg2: List[int]*) → *bats.topology.cell_ind*

add_recursive(*self:* bats.topology.ZigzagCubicalComplex, *arg0: float*, *arg1: float*, *arg2: List[int]*) → List[*bats.topology.cell_ind*]

complex(*self:* bats.topology.ZigzagCubicalComplex) → *bats.topology.CubicalComplex*

levelset(*self:* bats.topology.ZigzagCubicalComplex, *arg0: float*, *arg1: float*) → *bats.topology.CubicalComplex*

maxdim(*self:* bats.topology.ZigzagCubicalComplex) → int

ncells(*self:* bats.topology.ZigzagCubicalComplex, *arg0: int*) → int

vals(**args*, ***kwargs*)
Overloaded function.

1. vals(self: bats.topology.ZigzagCubicalComplex) -> List[List[List[Tuple[float, float]]]]
2. vals(self: bats.topology.ZigzagCubicalComplex, arg0: int) -> List[List[Tuple[float, float]]]

class bats.**ZigzagPair**
Bases: pybind11_builtins.pybind11_object

birth(*self:* bats.linalg.ZigzagPair) → float

birth_ind(*self:* bats.linalg.ZigzagPair) → int

death(*self:* bats.linalg.ZigzagPair) → float

death_ind(*self:* bats.linalg.ZigzagPair) → int

dim(*self:* bats.linalg.ZigzagPair) → int

length(*self:* bats.linalg.ZigzagPair) → float

mid(*self:* bats.linalg.ZigzagPair) → float

bats.**ZigzagSetDiagram**(*arg0: List[Set[int]]*) → *bats.topology.SetDiagram*
Create a zigzag diagram of sets and pairwise unions.

class bats.**ZigzagSimplicialComplex**
Bases: pybind11_builtins.pybind11_object

add(*self:* bats.topology.ZigzagSimplicialComplex, *arg0: float*, *arg1: float*, *arg2: List[int]*) → *bats.topology.cell_ind*

add_recursive(*self:* bats.topology.ZigzagSimplicialComplex, *arg0: float*, *arg1: float*, *arg2: List[int]*) → List[*bats.topology.cell_ind*]

complex(*self:* bats.topology.ZigzagSimplicialComplex) → *bats.topology.SimplicialComplex*

levelset(*self:* bats.topology.ZigzagSimplicialComplex, *arg0: float*, *arg1: float*) → *bats.topology.SimplicialComplex*

maxdim(*self:* bats.topology.ZigzagSimplicialComplex) → int

ncells(*self:* bats.topology.ZigzagSimplicialComplex, *arg0: int*) → int

vals(**args*, ***kwargs*)
Overloaded function.

1. vals(self: bats.topology.ZigzagSimplicialComplex) -> List[List[List[Tuple[float, float]]]]
2. vals(self: bats.topology.ZigzagSimplicialComplex, arg0: int) -> List[List[Tuple[float, float]]]

bats.**approx_center**(**args*, ***kwargs*)
Overloaded function.

1. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: int, arg3: int) -> int
2. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: int, arg3: int) -> int
3. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: int, arg3: int) -> int
4. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: int, arg3: int) -> int
5. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: int, arg3: int) -> int

6. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: int, arg3: int) -> int
7. approx_center(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: int, arg3: int) -> int

bats.**barcode**(**args*, ***kwargs*)

Overloaded function.

1. barcode(arg0: bats.linalg_f2.F2HomDiagram, arg1: int) -> List[bats.linalg.PersistencePair_int]
2. barcode(arg0: bats.linalg_f2.F2HomDiagram, arg1: int, arg2: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
3. barcode(arg0: bats.linalg_f2.F2HomDiagram, arg1: int, arg2: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
4. barcode(arg0: bats.linalg_f2.F2HomDiagram, arg1: int, arg2: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
5. barcode(arg0: bats.linalg_f2.F2HomDiagramAll) -> List[bats.linalg.PersistencePair_int]
6. barcode(arg0: bats.linalg_f2.F2HomDiagramAll, arg1: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
7. barcode(arg0: bats.linalg_f2.F2HomDiagramAll, arg1: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
8. barcode(arg0: bats.linalg_f2.F2HomDiagramAll, arg1: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
9. barcode(arg0: bats.linalg_f2.F2DGHomDiagram, arg1: int) -> List[bats.linalg.PersistencePair_int]
10. barcode(arg0: bats.linalg_f2.F2DGHomDiagram, arg1: int, arg2: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
11. barcode(arg0: bats.linalg_f2.F2DGHomDiagram, arg1: int, arg2: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
12. barcode(arg0: bats.linalg_f2.F2DGHomDiagram, arg1: int, arg2: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
13. barcode(arg0: bats.linalg_f2.F2DGHomDiagramAll) -> List[bats.linalg.PersistencePair_int]
14. barcode(arg0: bats.linalg_f2.F2DGHomDiagramAll, arg1: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
15. barcode(arg0: bats.linalg_f2.F2DGHomDiagramAll, arg1: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
16. barcode(arg0: bats.linalg_f2.F2DGHomDiagramAll, arg1: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
17. barcode(arg0: bats.linalg_f2.F2Diagram, arg1: int) -> List[bats.linalg.PersistencePair_int]
18. barcode(arg0: bats.linalg_f2.F2Diagram, arg1: int, arg2: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
19. barcode(arg0: bats.linalg_f2.F2Diagram, arg1: int, arg2: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
20. barcode(arg0: bats.linalg_f2.F2Diagram, arg1: int, arg2: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
21. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> > > > >) -> List[bats.linalg.PersistencePair_int]

22. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> > > > >, arg1: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
23. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> > > > >, arg1: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
24. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 2u>, unsigned long> > > > >, arg1: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
25. barcode(arg0: bats.linalg_f3.F3HomDiagram, arg1: int) -> List[bats.linalg.PersistencePair_int]
26. barcode(arg0: bats.linalg_f3.F3HomDiagram, arg1: int, arg2: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
27. barcode(arg0: bats.linalg_f3.F3HomDiagram, arg1: int, arg2: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
28. barcode(arg0: bats.linalg_f3.F3HomDiagram, arg1: int, arg2: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
29. barcode(arg0: bats.linalg_f3.F3HomDiagramAll) -> List[bats.linalg.PersistencePair_int]
30. barcode(arg0: bats.linalg_f3.F3HomDiagramAll, arg1: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
31. barcode(arg0: bats.linalg_f3.F3HomDiagramAll, arg1: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
32. barcode(arg0: bats.linalg_f3.F3HomDiagramAll, arg1: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
33. barcode(arg0: bats.linalg_f3.F3DGHomDiagram, arg1: int) -> List[bats.linalg.PersistencePair_int]
34. barcode(arg0: bats.linalg_f3.F3DGHomDiagram, arg1: int, arg2: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
35. barcode(arg0: bats.linalg_f3.F3DGHomDiagram, arg1: int, arg2: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
36. barcode(arg0: bats.linalg_f3.F3DGHomDiagram, arg1: int, arg2: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
37. barcode(arg0: bats.linalg_f3.F3DGHomDiagramAll) -> List[bats.linalg.PersistencePair_int]
38. barcode(arg0: bats.linalg_f3.F3DGHomDiagramAll, arg1: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
39. barcode(arg0: bats.linalg_f3.F3DGHomDiagramAll, arg1: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]
40. barcode(arg0: bats.linalg_f3.F3DGHomDiagramAll, arg1: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]
41. barcode(arg0: bats.linalg_f3.F3Diagram, arg1: int) -> List[bats.linalg.PersistencePair_int]
42. barcode(arg0: bats.linalg_f3.F3Diagram, arg1: int, arg2: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]
43. barcode(arg0: bats.linalg_f3.F3Diagram, arg1: int, arg2: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]

44. barcode(arg0: bats.linalg_f3.F3Diagram, arg1: int, arg2: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]

45. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> > > > >) -> List[bats.linalg.PersistencePair_int]

46. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> > > > >, arg1: bats.linalg.divide_conquer) -> List[bats.linalg.PersistencePair_int]

47. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> > > > >, arg1: bats.linalg.rightward) -> List[bats.linalg.PersistencePair_int]

48. barcode(arg0: bats::Diagram<unsigned long, std::vector<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> >, std::allocator<ColumnMatrix<SparseVector<ModP<int, 3u>, unsigned long> > > > >, arg1: bats.linalg.leftward) -> List[bats.linalg.PersistencePair_int]

bats.**bivariate_cover**(*arg0: List[Set[int]]*, *arg1: List[Set[int]]*) → Tuple[List[Set[int]], List[int], List[int]]

class bats.**cell_ind**
Bases: pybind11_builtins.pybind11_object

class bats.**clearing_flag**
Bases: pybind11_builtins.pybind11_object

class bats.**compression_flag**
Bases: pybind11_builtins.pybind11_object

class bats.**compute_basis_flag**
Bases: pybind11_builtins.pybind11_object

class bats.**divide_conquer**
Bases: pybind11_builtins.pybind11_object

bats.**enclosing_radius**(*arg0: A<Dense<double*, *RowMaj> >*) → float
Enclosing radius from matrix of pairwise distances

bats.**extend_zigzag_filtration**(*arg0: List[float]*, *arg1:* bats.topology.SimplicialComplex, *arg2: float*) → *bats.topology.ZigzagSimplicialComplex*

class bats.**extra_reduction_flag**
Bases: pybind11_builtins.pybind11_object

bats.**force_repel_rp**(*arg0: bats::DataSet<double>*, *arg1: float*) → None

bats.**greedy_landmarks**(**args*, ***kwargs*)
Overloaded function.

1. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.Euclidean, arg3: int) -> bats::DataSet<double>

2. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.L1Dist, arg3: int) -> bats::DataSet<double>

3. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.LInfDist, arg3: int) -> bats::DataSet<double>

4. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.CosineDist, arg3: int) -> bats::DataSet<double>

5. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.RPCosineDist, arg3: int) -> bats::DataSet<double>

6. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.AngleDist, arg3: int) -> bats::DataSet<double>

7. greedy_landmarks(arg0: bats::DataSet<double>, arg1: int, arg2: bats.topology.RPAngleDist, arg3: int) -> bats::DataSet<double>

bats.**greedy_landmarks_hausdorff**(**args*, ***kwargs*)

Overloaded function.

1. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.Euclidean, arg2: int) -> Tuple[List[int], List[float]]

2. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.L1Dist, arg2: int) -> Tuple[List[int], List[float]]

3. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.LInfDist, arg2: int) -> Tuple[List[int], List[float]]

4. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.CosineDist, arg2: int) -> Tuple[List[int], List[float]]

5. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.RPCosineDist, arg2: int) -> Tuple[List[int], List[float]]

6. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.AngleDist, arg2: int) -> Tuple[List[int], List[float]]

7. greedy_landmarks_hausdorff(arg0: bats::DataSet<double>, arg1: bats.topology.RPAngleDist, arg2: int) -> Tuple[List[int], List[float]]

8. greedy_landmarks_hausdorff(arg0: A<Dense<double, RowMaj> >, arg1: int) -> Tuple[List[int], List[float]]

bats.**hausdorff_landmarks**(**args*, ***kwargs*)

Overloaded function.

1. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.Euclidean, arg3: int) -> bats::DataSet<double>

2. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.L1Dist, arg3: int) -> bats::DataSet<double>

3. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.LInfDist, arg3: int) -> bats::DataSet<double>

4. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.CosineDist, arg3: int) -> bats::DataSet<double>

5. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.RPCosineDist, arg3: int) -> bats::DataSet<double>

6. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.AngleDist, arg3: int) -> bats::DataSet<double>

7. hausdorff_landmarks(arg0: bats::DataSet<double>, arg1: float, arg2: bats.topology.RPAngleDist, arg3: int) -> bats::DataSet<double>

bats.**landmark_cover**(**args*, ***kwargs*)

Overloaded function.

1. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.Euclidean, arg3: int) -> List[Set[int]]

2. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.L1Dist, arg3: int) -> List[Set[int]]
3. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.LInfDist, arg3: int) -> List[Set[int]]
4. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.CosineDist, arg3: int) -> List[Set[int]]
5. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPCosineDist, arg3: int) -> List[Set[int]]
6. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.AngleDist, arg3: int) -> List[Set[int]]
7. landmark_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPAngleDist, arg3: int) -> List[Set[int]]

bats.**landmark_eps_cover**(**args*, ***kwargs*)

Overloaded function.

1. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.Euclidean, arg3: float) -> List[Set[int]]
2. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.L1Dist, arg3: float) -> List[Set[int]]
3. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.LInfDist, arg3: float) -> List[Set[int]]
4. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.CosineDist, arg3: float) -> List[Set[int]]
5. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPCosineDist, arg3: float) -> List[Set[int]]
6. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.AngleDist, arg3: float) -> List[Set[int]]
7. landmark_eps_cover(arg0: bats::DataSet<double>, arg1: bats::DataSet<double>, arg2: bats.topology.RPAngleDist, arg3: float) -> List[Set[int]]

class bats.**leftward**

Bases: pybind11_builtins.pybind11_object

bats.**lower_star_backwards**(*arg0: List[List[float]]*, *arg1: List[List[int]]*, *arg2: List[List[int]]*) → List[float]

compute gradient on function from gradient on lower star filtration diagram

bats.**lower_star_filtration**(**args*, ***kwargs*)

Overloaded function.

1. lower_star_filtration(arg0: bats.topology.SimplicialComplex, arg1: List[float]) -> Tuple[List[List[float]], List[List[int]]]

extend function on 0-cells to filtration

2. lower_star_filtration(arg0: bats.topology.LightSimplicialComplex, arg1: List[float]) -> Tuple[List[List[float]], List[List[int]]]

extend function on 0-cells to filtration

3. lower_star_filtration(arg0: bats.topology.CubicalComplex, arg1: List[List[float]]) -> List[List[float]]

extend function on 0-cells to filtration

4. lower_star_filtration(arg0: bats.topology.CubicalComplex, arg1: List[List[List[float]]]) -> List[List[float]]

extend function on 0-cells to filtration

class bats.**no_optimization_flag**
Bases: pybind11_builtins.pybind11_object

bats.**persistence_barcode**(*ps*, *remove_zeros=True*, *tlb=0.0*, *tub=inf*, *essential_color=None*, *figargs={}*, *lineargs={'linewidth': 1}*)
plot a persistence barcode for pairs in ps. Each barcode is a pyplot axis. Barcodes are stacked horizontally in figure.

Parameters:

ps: List of PersistencePair

remove_zeros: flag to remove zero-length bars (default: True)

tlb: lower bound on filtration parameter to display. (default: 0.0)

tlb: upper bound on filtration parameter to display. (default: inf)

essential_color: color for essential pairs (defualt: 'r')

figargs - passed onto pyplot subplots construction (default {})

lineargs - passed onto hlines construction (default {"linewidth":1})

Returns: fig, ax - pyplot figure and axes

bats.**persistence_diagram**(*ps*, *remove_zeros=True*, *show_legend=True*, *tmax=0.0*, *tmin=0.0*, ***kwargs*)

bats.**random_landmarks**(*arg0: bats::DataSet<double>*, *arg1: int*) → bats::DataSet<double>

bats.**reduce**(**args*, ***kwargs*)
Overloaded function.

1. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedF2ChainComplex
2. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedF2ChainComplex
3. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex
4. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedF2ChainComplex
5. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedF2ChainComplex
6. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex
7. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f2.ReducedF2ChainComplex

8. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex

9. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedF2ChainComplex

10. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedF2ChainComplex

11. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex

12. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedF2ChainComplex

13. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedF2ChainComplex

14. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex

15. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedF2ChainComplex

16. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedF2ChainComplex

17. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex

18. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f2.ReducedF2ChainComplex

19. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex

20. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedF2ChainComplex

21. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedF2ChainComplex

22. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex

23. reduce(arg0: bats.linalg_f2.F2ChainComplex) -> bats.linalg_f2.ReducedF2ChainComplex

24. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedF2ChainComplex

25. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex
26. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedF2ChainComplex
27. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedF2ChainComplex
28. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex
29. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.extra_reduction_flag) -> bats.linalg_f2.ReducedF2ChainComplex
30. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex
31. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedF2ChainComplex
32. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedF2ChainComplex
33. reduce(arg0: bats.linalg_f2.F2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedF2ChainComplex
34. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedF3ChainComplex
35. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedF3ChainComplex
36. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex
37. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedF3ChainComplex
38. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedF3ChainComplex
39. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex
40. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f3.ReducedF3ChainComplex
41. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex
42. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedF3ChainComplex

43. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedF3ChainComplex

44. reduce(arg0: bats.topology.SimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

45. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedF3ChainComplex

46. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedF3ChainComplex

47. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

48. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedF3ChainComplex

49. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedF3ChainComplex

50. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

51. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f3.ReducedF3ChainComplex

52. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

53. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedF3ChainComplex

54. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedF3ChainComplex

55. reduce(arg0: bats.topology.LightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

56. reduce(arg0: bats.linalg_f3.F3ChainComplex) -> bats.linalg_f3.ReducedF3ChainComplex

57. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedF3ChainComplex

58. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

59. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedF3ChainComplex

60. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedF3ChainComplex

61. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

62. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.extra_reduction_flag) -> bats.linalg_f3.ReducedF3ChainComplex

63. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

64. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedF3ChainComplex

65. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedF3ChainComplex

66. reduce(arg0: bats.linalg_f3.F3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedF3ChainComplex

67. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

68. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

69. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

70. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

71. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

72. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

73. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

74. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

75. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

76. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

77. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

78. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

79. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

80. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

81. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

82. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

83. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

84. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

85. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

86. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

87. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

88. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

89. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f2.F2) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

90. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

91. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

92. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

93. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f2.F2, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

94. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex) -> bats.linalg_f2.ReducedFilteredF2ChainComplex

95. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.standard_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
96. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
97. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
98. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
99. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
100. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.extra_reduction_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
101. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
102. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
103. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
104. reduce(arg0: bats.linalg_f2.FilteredF2ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f2.ReducedFilteredF2ChainComplex
105. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
106. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
107. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
108. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
109. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
110. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
111. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex
112. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

113. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

114. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

115. reduce(arg0: bats.topology.FilteredSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

116. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

117. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

118. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

119. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

120. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

121. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

122. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

123. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

124. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

125. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

126. reduce(arg0: bats.topology.FilteredLightSimplicialComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.extra_reduction_flag, arg3: bats.linalg.compression_flag, arg4: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

127. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f3.F3) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

128. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

129. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

130. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

131. reduce(arg0: bats.topology.FilteredCubicalComplex, arg1: bats.linalg_f3.F3, arg2: bats.linalg.standard_reduction_flag, arg3: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

132. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

133. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.standard_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

134. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

135. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

136. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

137. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.standard_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

138. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.extra_reduction_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

139. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

140. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.clearing_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

141. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

142. reduce(arg0: bats.linalg_f3.FilteredF3ChainComplex, arg1: bats.linalg.extra_reduction_flag, arg2: bats.linalg.compression_flag, arg3: bats.linalg.compute_basis_flag) -> bats.linalg_f3.ReducedFilteredF3ChainComplex

bats.**reduce_matrix**(**args*, ***kwargs*)
Overloaded function.

1. reduce_matrix(arg0: bats.linalg_f3.F3Mat) -> List[int]

2. reduce_matrix(arg0: bats.linalg_f3.F3Mat, arg1: bats.linalg.extra_reduction_flag) -> List[int]

3. reduce_matrix(arg0: bats.linalg_f3.F3Mat, arg1: bats.linalg_f3.F3Mat) -> List[int]

4. reduce_matrix(arg0: bats.linalg_f3.F3Mat, arg1: bats.linalg_f3.F3Mat, arg2: bats.linalg.extra_reduction_flag) -> List[int]

class bats.**rightward**
Bases: pybind11_builtins.pybind11_object

bats.**rips_union_find_pairs**(*arg0: List[int]*, *arg1: List[float]*) → List[*bats.linalg.PersistencePair*]
find Rips pairs

bats.**sample_sphere**(*arg0: int*, *arg1: int*) → bats::DataSet<double>

class bats.**standard_reduction_flag**
Bases: pybind11_builtins.pybind11_object

bats.**union_find_pairs**(**args*, ***kwargs*)
Overloaded function.

1. union_find_pairs(arg0: bats.linalg_f2.FilteredF2ChainComplex) -> List[bats.linalg.PersistencePair]
2. union_find_pairs(arg0: bats.linalg_f3.FilteredF3ChainComplex) -> List[bats.linalg.PersistencePair]

bats.**zigzag_levelsets**(**args*, ***kwargs*)
Overloaded function.

1. zigzag_levelsets(arg0: bats.topology.ZigzagCubicalComplex, arg1: float, arg2: float, arg3: float) -> bats::Diagram<bats::CubicalComplex, bats::CellularMap>
2. zigzag_levelsets(arg0: bats.topology.ZigzagSimplicialComplex, arg1: float, arg2: float, arg3: float) -> bats::Diagram<bats::SimplicialComplex, bats::CellularMap>

bats.**zigzag_toplex**(*arg0: List[List[List[float]]]*) → *bats.topology.ZigzagCubicalComplex*

1.6 About BATS

Python bindings for BATS

People who have contributed to BATS.py:

- Brad Nelson
- Yuan Luo

1.6.1 Citing BATS

If you find this code useful, please consider citing one of the following papers, depending on your use case:

- Persistent and Zigzag Homology: A Matrix Factorization Viewpoint by Gunnar Carlsson, Anjan Dwaraknath, and Bradley J. Nelson.
- Accelerating Iterated Persistent Homology Computations with Warm Starts by Yuan Luo and Bradley J. Nelson

CHAPTER

TWO

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