

गुठी GUDHI



*Geometric Understanding in Higher Dimensions*

# What will be new in GUDHI library version 2.0.0

Jean-Daniel Boissonnat, Paweł Dłotko, Marc Glisse, François Godi, Clément Jamin, Siargey Kachanovich, Clément Maria, Vincent Rouvreau and David Salinas

*DataShape, Inria Saclay and Sophia-Antipolis*

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*Geometric Understanding in Higher Dimensions*

*inria*  
informatics mathematics

**GUDHI is a five years project** supported by a Grant of the European Research Council and hosted by INRIA



- develop and understand geometrical data structures
- develop associated statistical, geometric and topological functions

## Geometric Understanding in Higher Dimensions

W Topological data an... x +

https://en.wikipedia.org/wiki/Topological\_data\_analysis

Search

**Workflow** [edit]

The basic workflow in TDA is:<sup>[14]</sup>

point cloud → nested complexes → persistence module → barcode or diagram

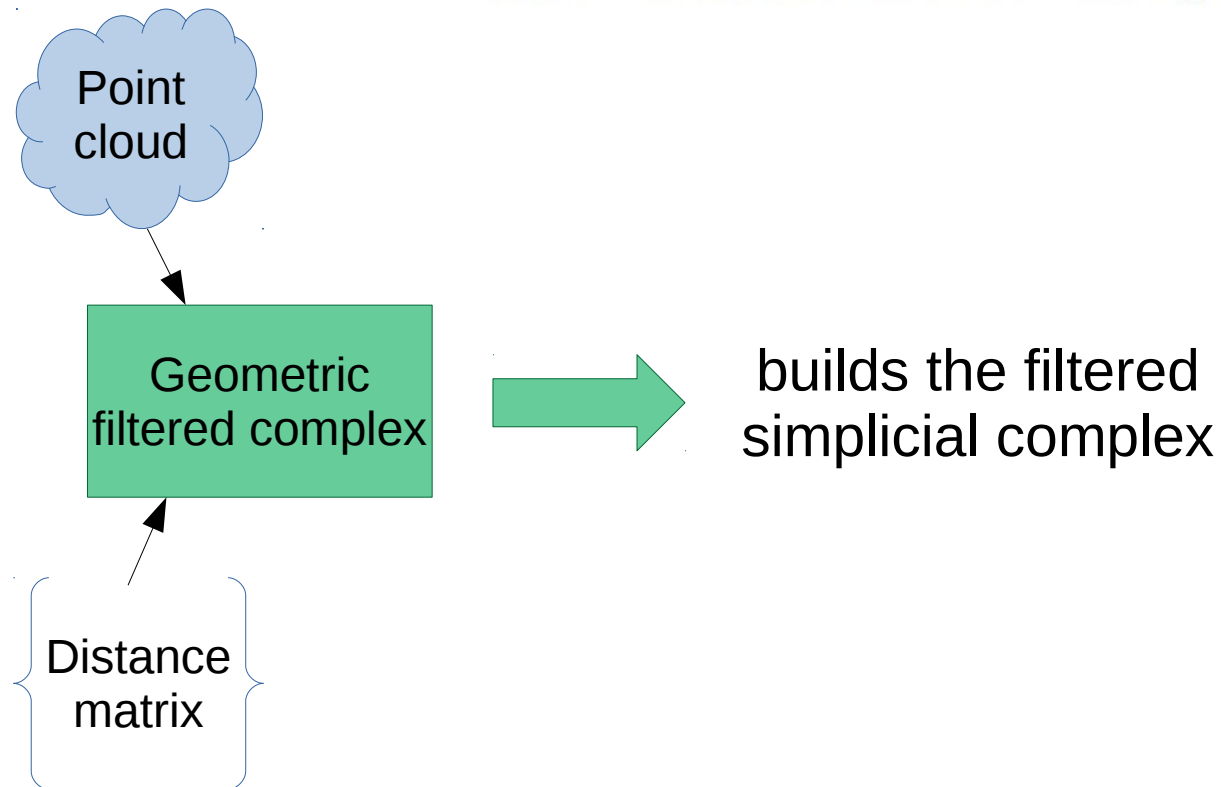
1. If  $X$  is a point cloud, replace  $X$  with a nested family of **simplicial complexes**  $X_r$ , (such as the Čech or Vietoris-Rips complex). This process converts the point cloud into a filtration of simplicial complexes. Taking the homology of each complex in this filtration gives a persistence module
 
$$H_i(X_{r_0}) \rightarrow H_i(X_{r_1}) \rightarrow H_i(X_{r_2}) \rightarrow \dots$$
2. Apply the structure theorem to provide a parameterized version of **Betti number**, **persistence diagram**, or equivalently, **barcode**.

Graphically speaking,

A usual use of persistence in TDA <sup>[15]</sup>

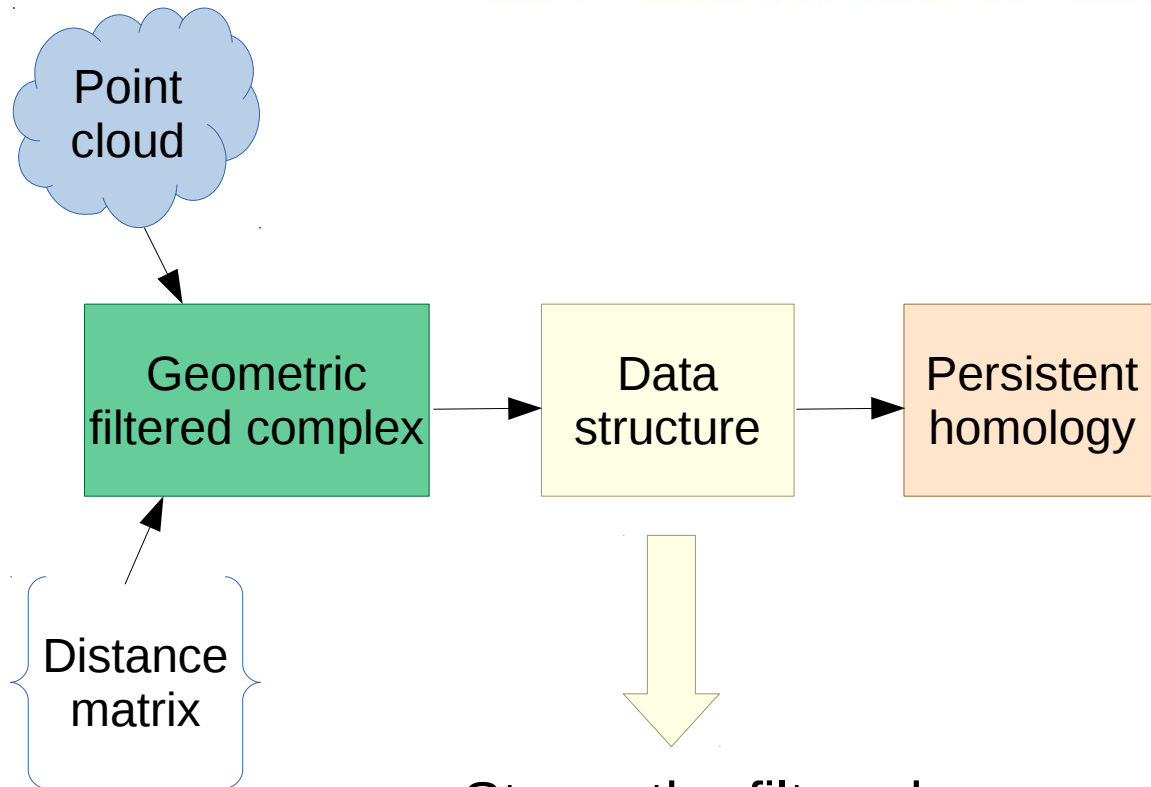
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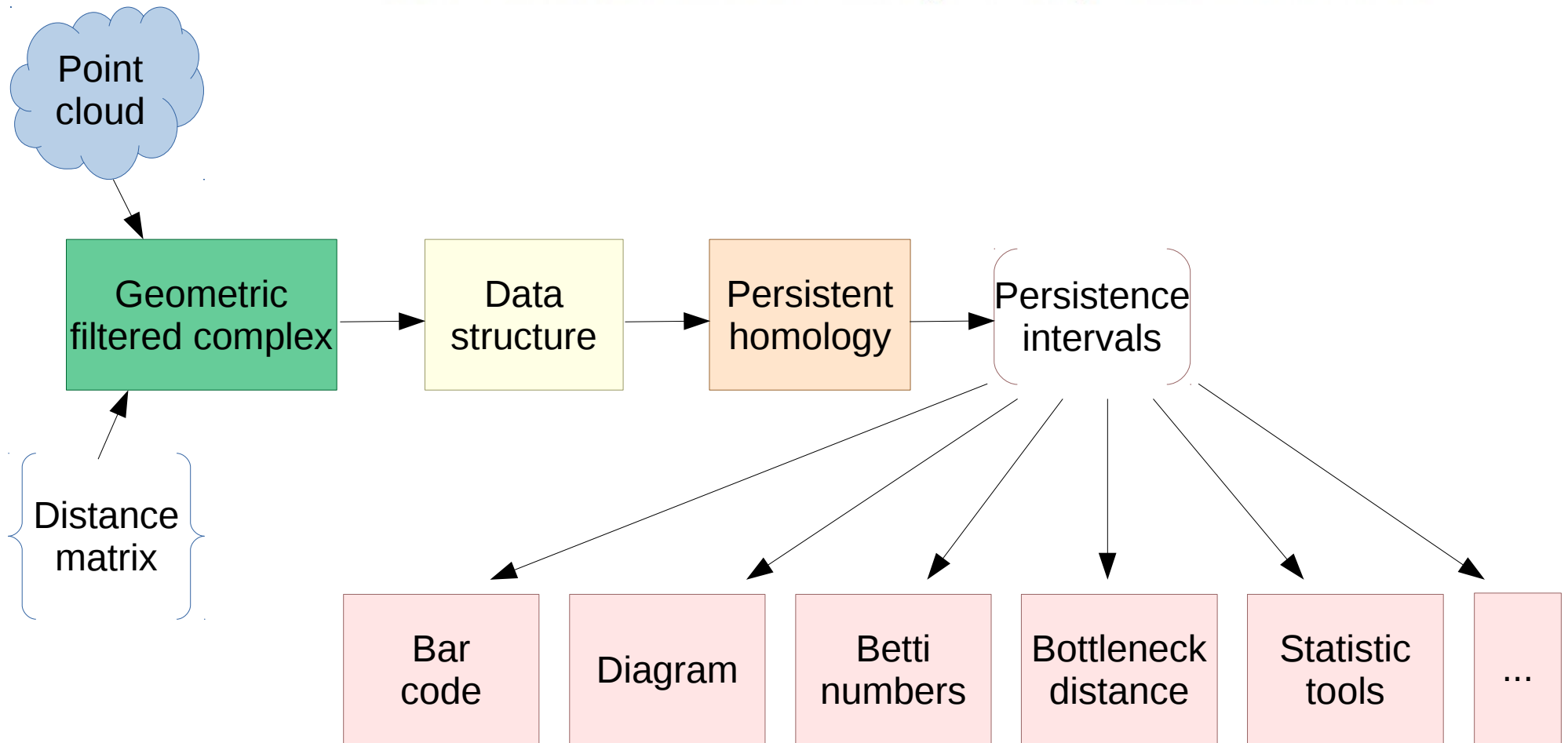
## Geometric Understanding in Higher Dimensions



- Stores the filtered simplicial complex
- Interfaces with persistence modules

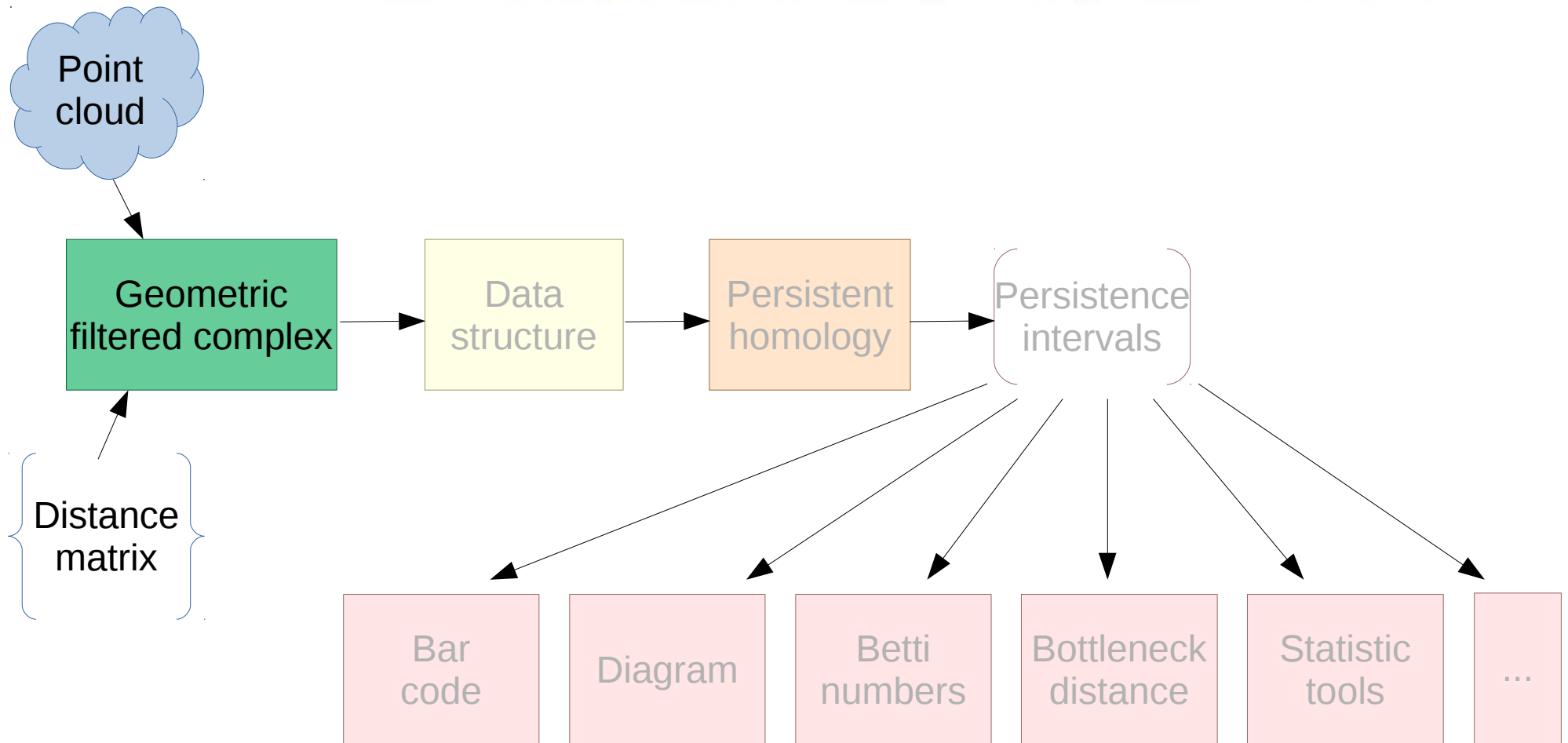
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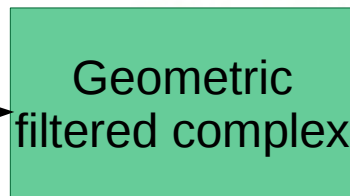
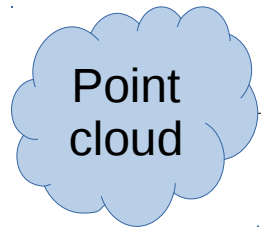
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## Geometric Understanding in Higher Dimensions

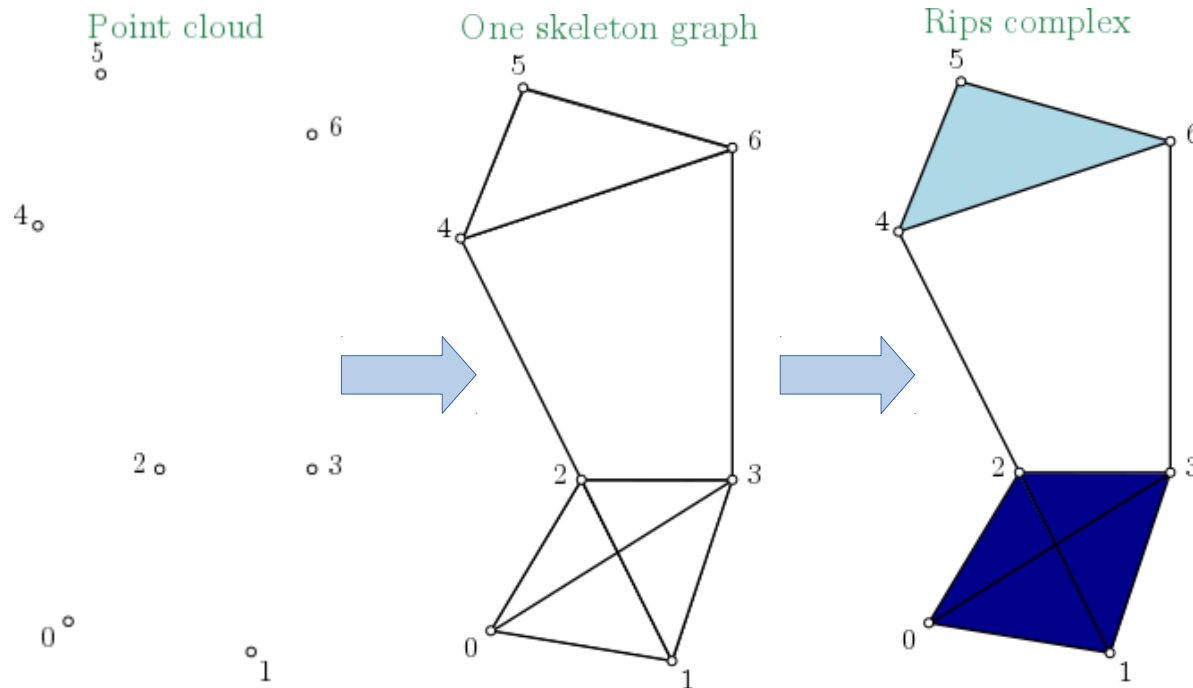


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## Geometric Understanding in Higher Dimensions



Geometric filtered complex – Rips from a point cloud





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## Geometric Understanding in Higher Dimensions

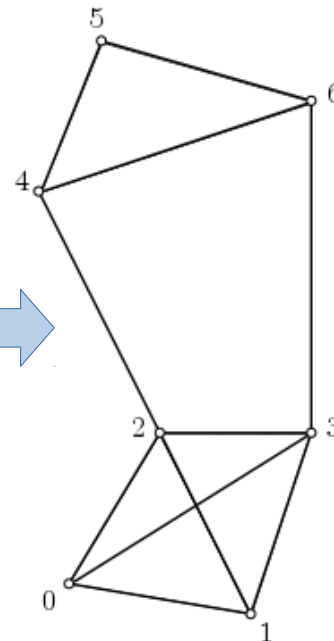
### Geometric filtered complex – Rips from a distance matrix

Distance matrix

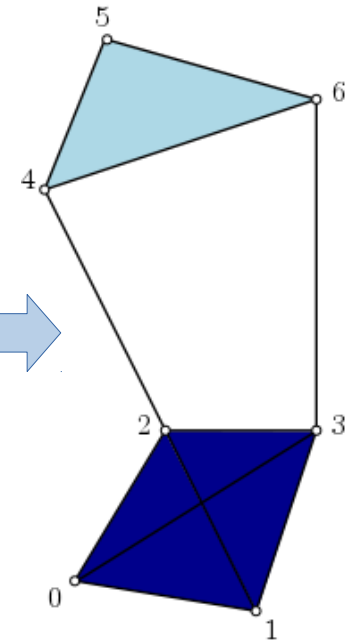
Geometric filtered complex

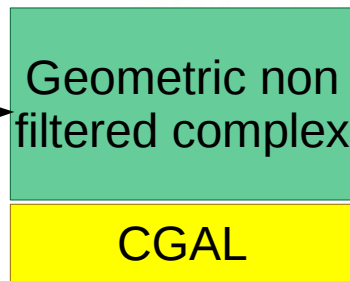
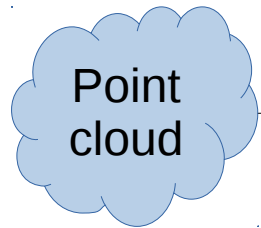
0	6.08	5.83	9.43	13.04	18.03	17.89
6.08	0	6.71	6.32	15.65	19.65	17.12
5.83	6.71	0	5	8.94	13.15	12.08
9.43	6.32	5	0	12.04	14.76	11
13.04	15.65	8.94	12.04	0	14.76	9.49
18.03	19.65	13.15	14.76	5.38	0	7.28
17.89	17.12	12.08	11	9.49	7.28	0

One skeleton graph

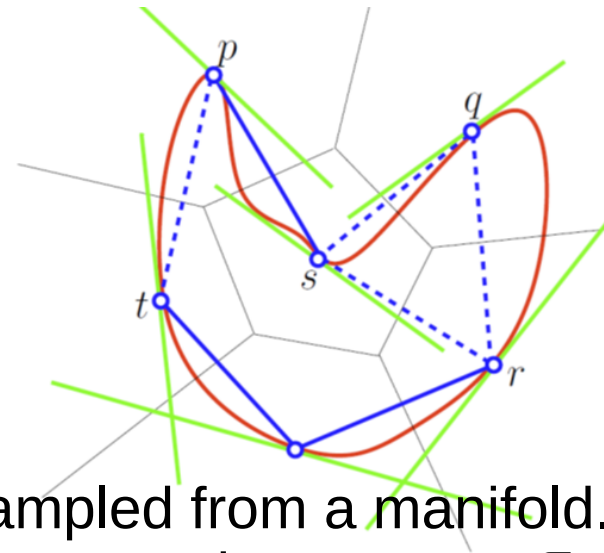
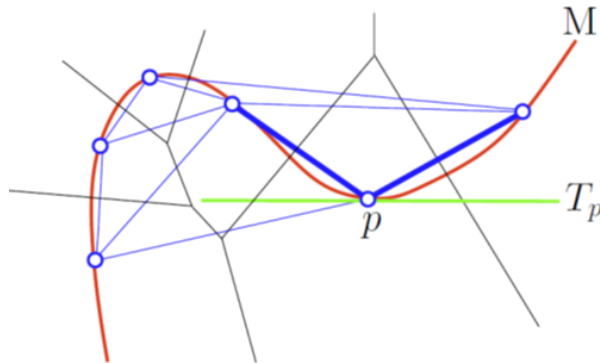


Rips complex





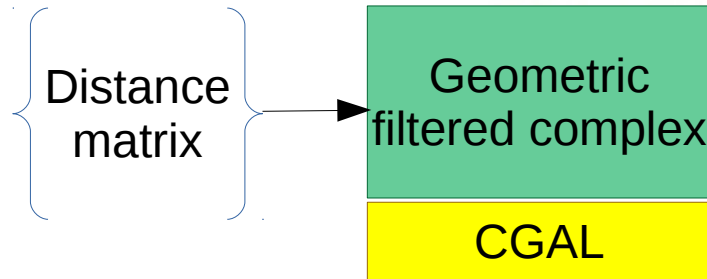
### Geometric non filtered complex – Tangential complex



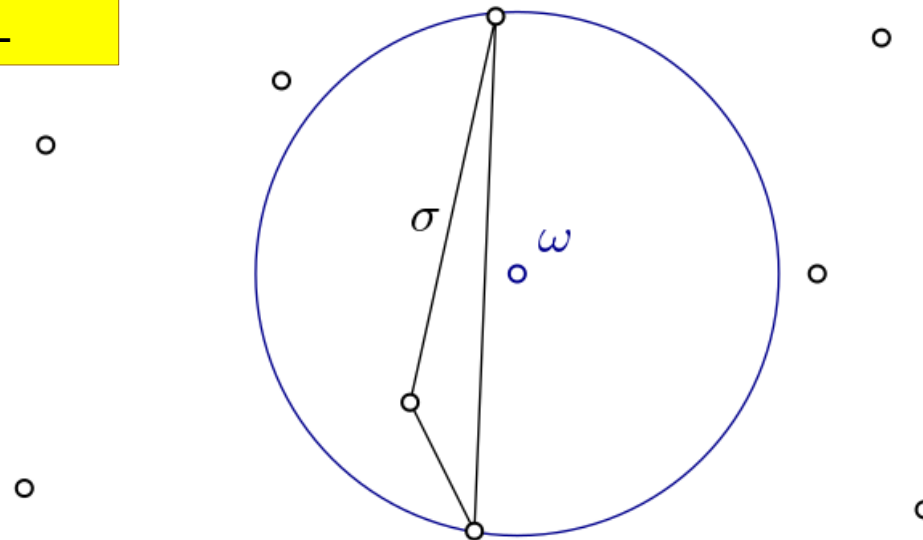
- Suppose we have a set of points sampled from a manifold.
- For every point construct tangent space at that every  $p \in L$ .
- For every  $p \in L$ , construct its star and glue the stars of neighbouring points if they agree.
- Based on *Jean-Daniel Boissonnat and Arijit Ghosh Manifold reconstruction using Tangential Delaunay Complexes.*

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Geometric filtered complex –  
Witness complex

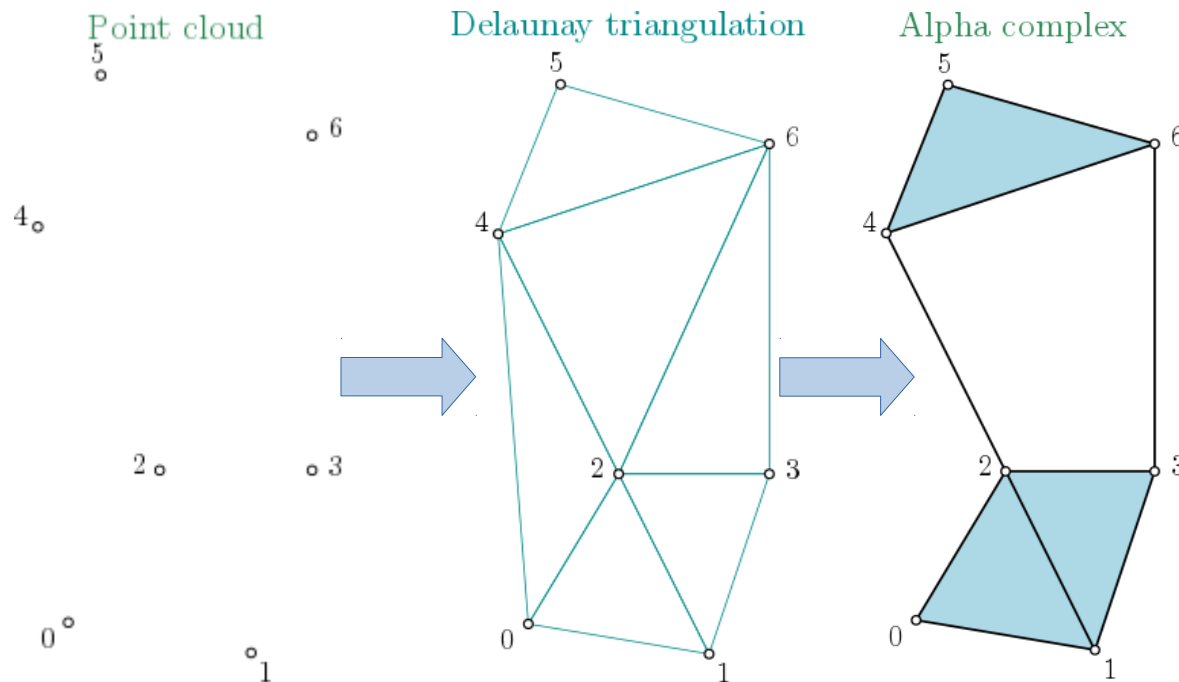
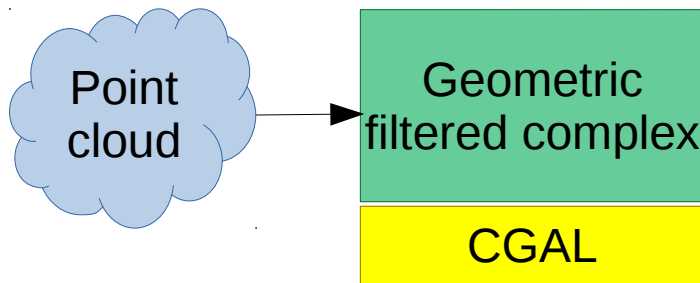


- For large point clouds, select small, representative collection of points  $L$  called landmarks.
- Build a complex on landmark points. Add a simplex if a witness exists.
- Version with and without filtration.

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### Geometric filtered complex – Alpha from a point cloud

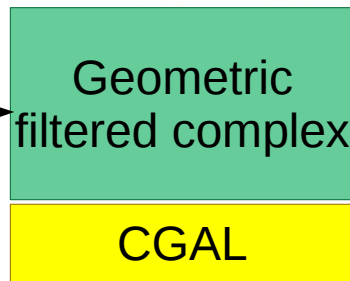
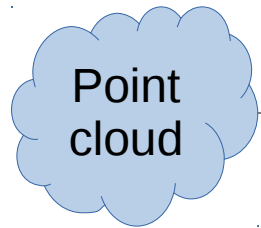


+ Periodic, exact and weighted alpha complexes in dimension 3.

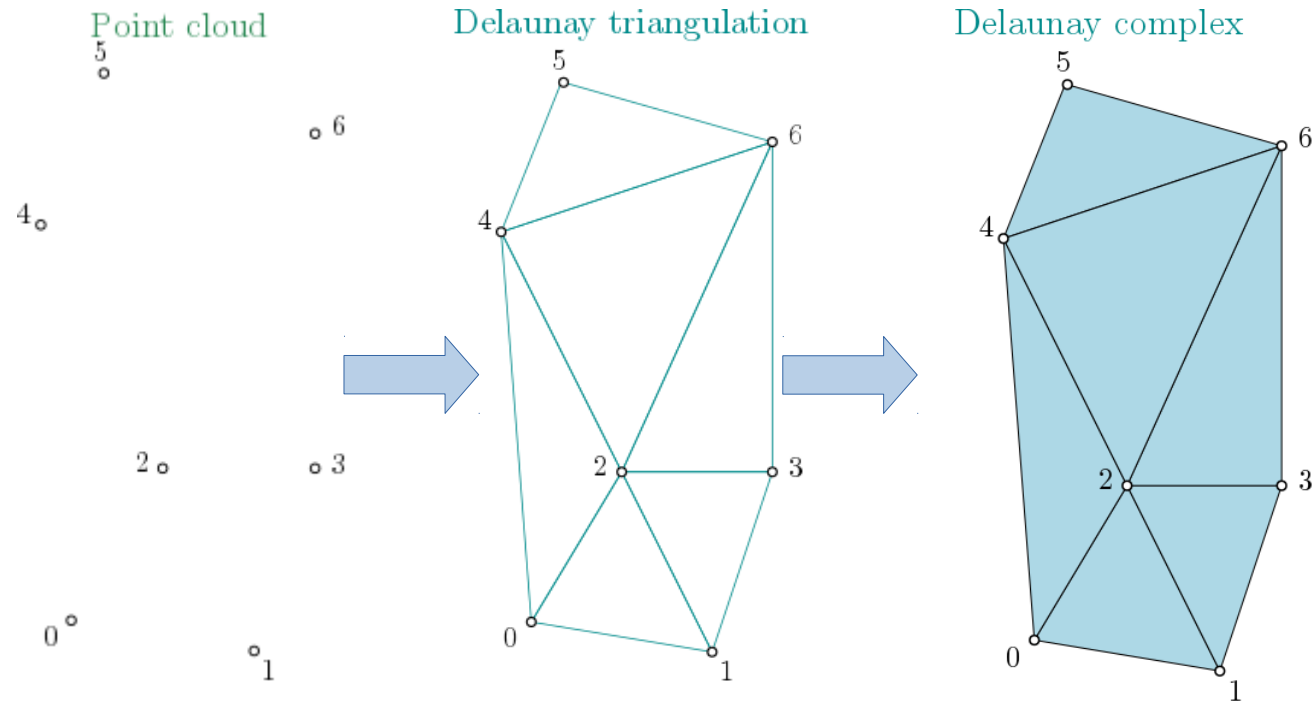
by Marc Glisse & Vincent Rouvreau

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Geometric Understanding in Higher Dimensions



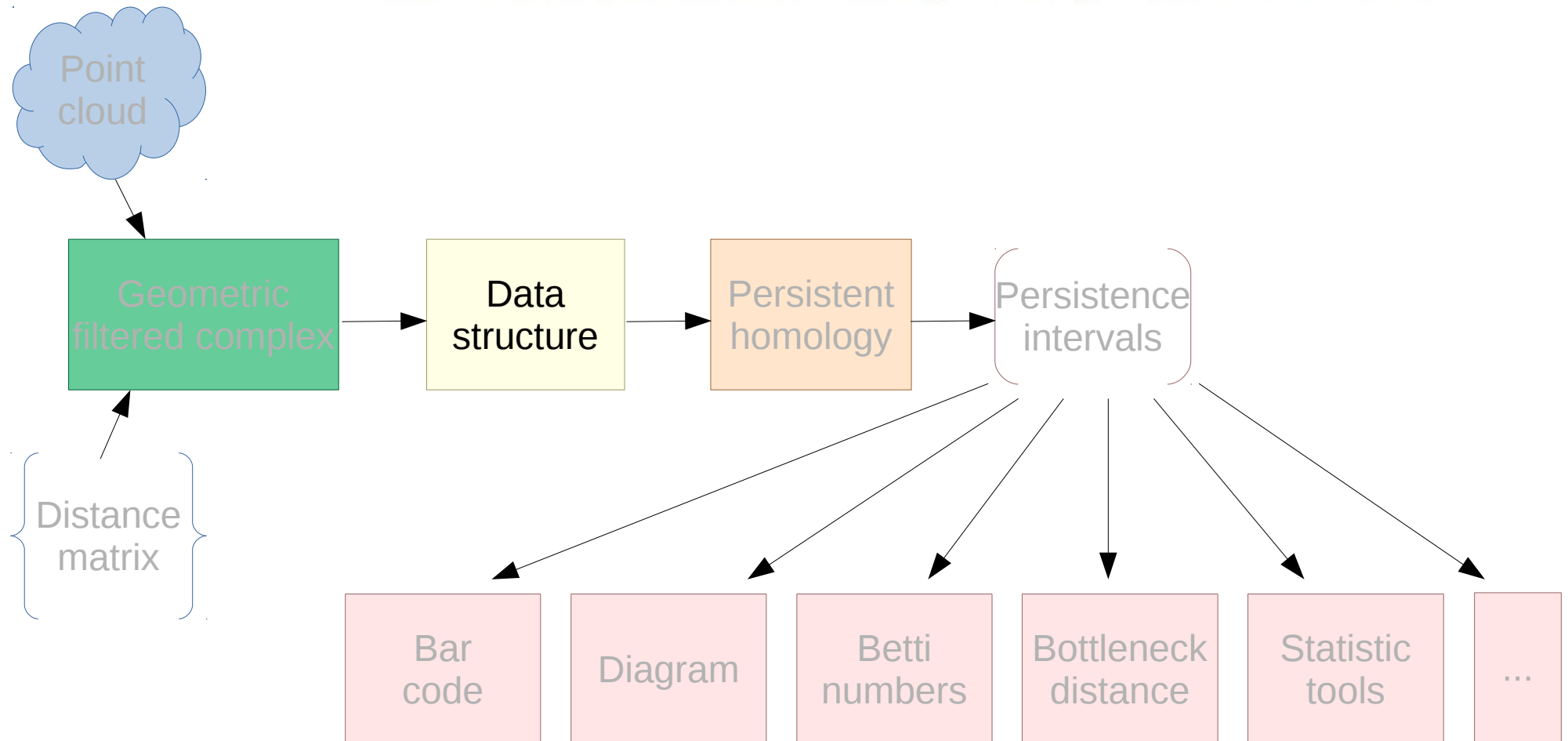
## Geometric filtered complex - Delaunay from a point cloud



by Marc Glisse &  
Vincent Rouvreau

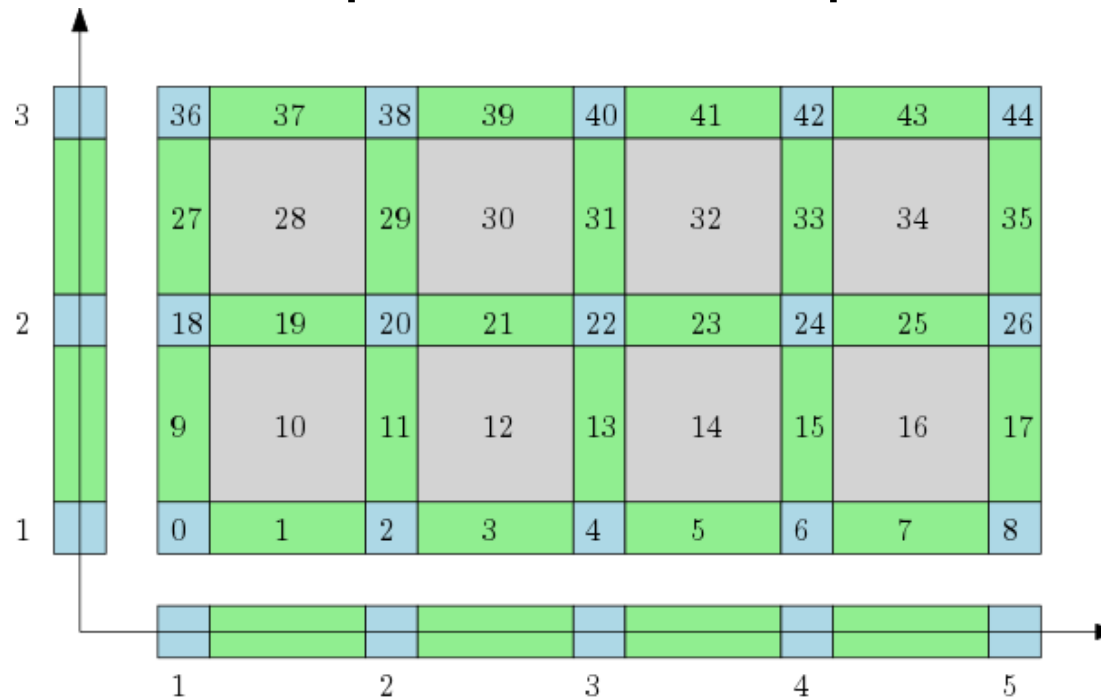
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## Geometric Understanding in Higher Dimensions



Data  
structure

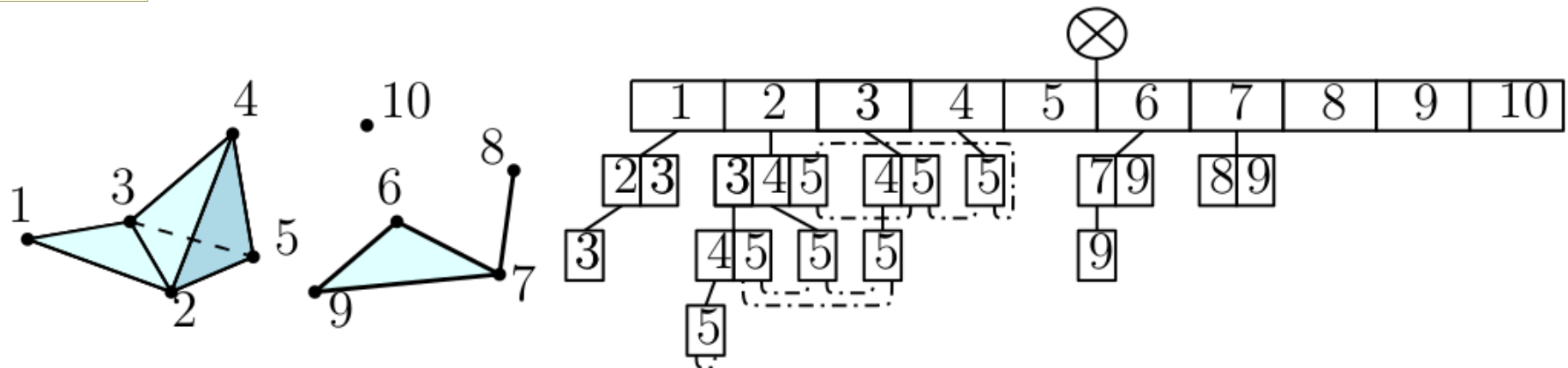
### Cubical complexes – bitmap



- Represented as a vector of filtration values.
- (Co)boundary computed based on the position in this vector.
- Used in analysis of grid-type data.

Data structure

### Filtered simplicial complexes – Simplex tree

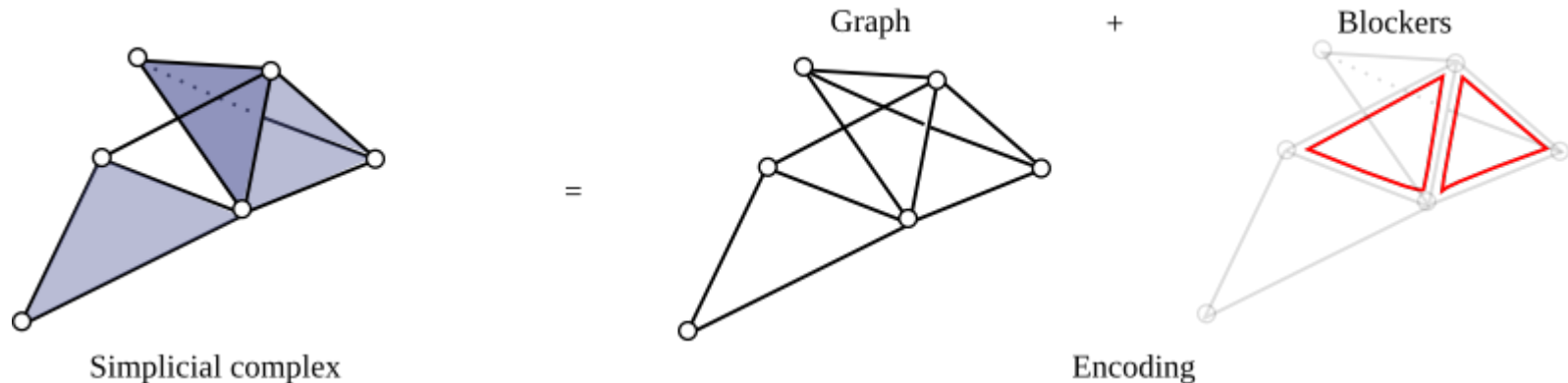


- Memory and time-efficient data structure to store simplicial complexes.
- Every simplex is a word stored in the tree.
- The nodes corresponding to simplices of the same dimension having the same maximal vertex are stored in a cyclic list.
- It is a base of all algorithms to compute persistence of weighted simplicial complexes in GUDHI.



Data  
structure

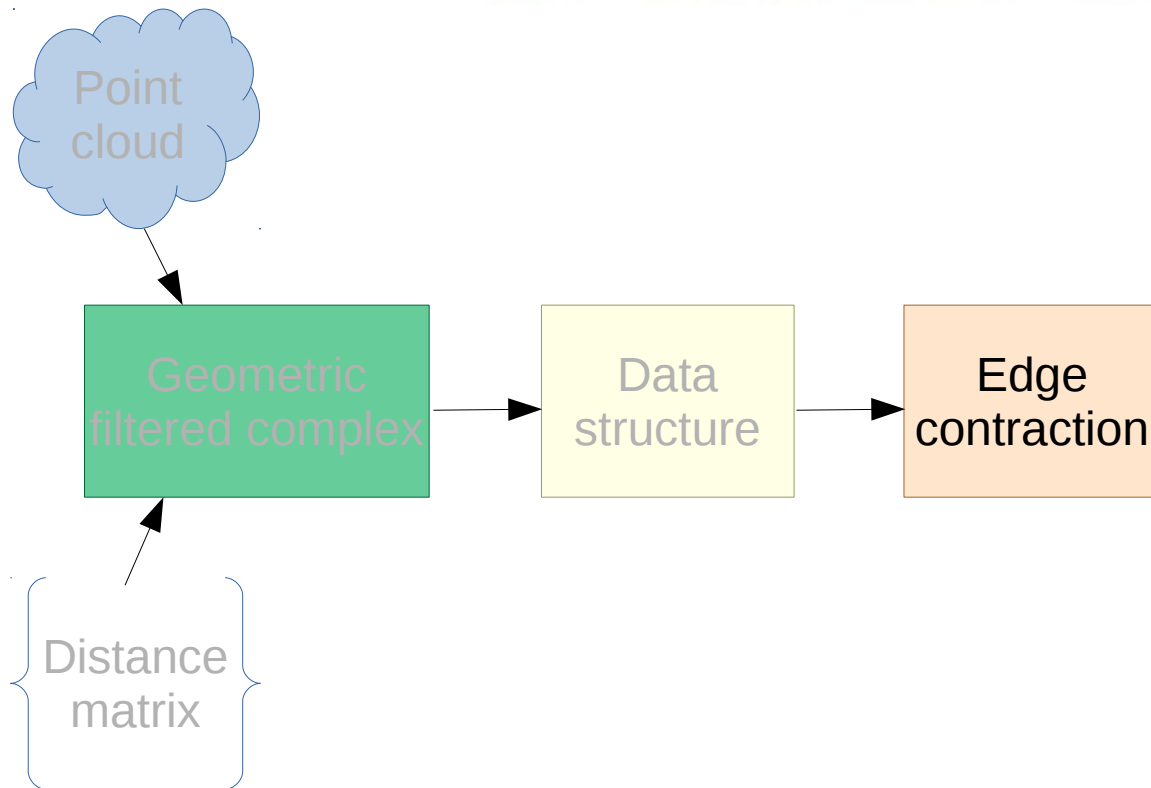
### Simplicial complexes – Skeleton blocker



- A data structure for very large simplicial complexes.
- We store the 1-skeleton and the minimal simplices which are not present in the complex.
- The rest is generated from cliques in the 1-skeleton.
- Used in edge contraction toolbox (details later).

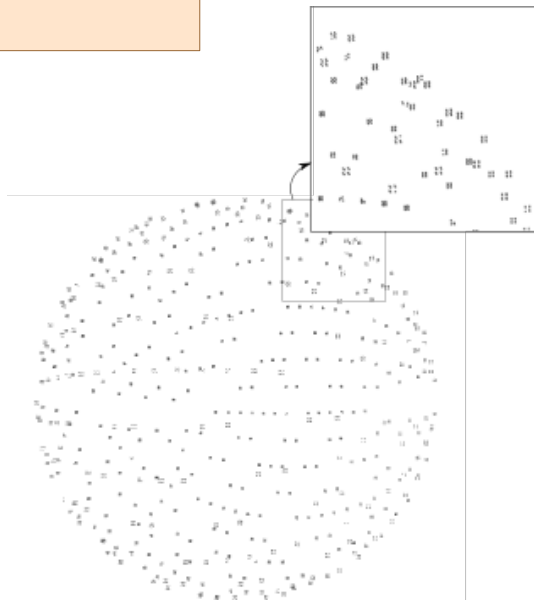
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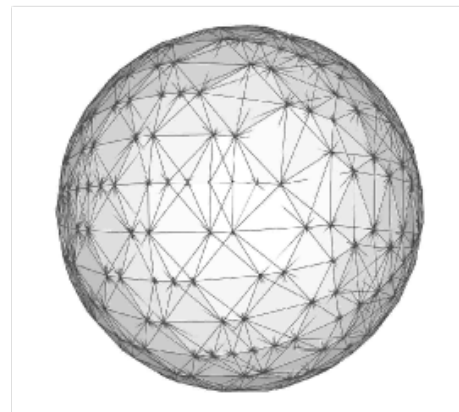


Edge  
contraction

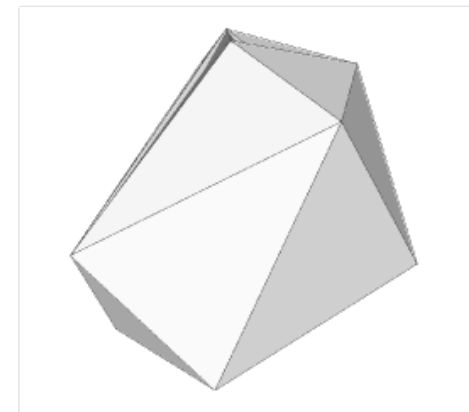
### Toolbox – edge contraction



Point cloud sampling  $S^3$   
(points are in  $\mathbb{R}^9$  but projected into  $\mathbb{R}^3$   
for visualization)



Rips complex built upon these points  
20 millions simplices

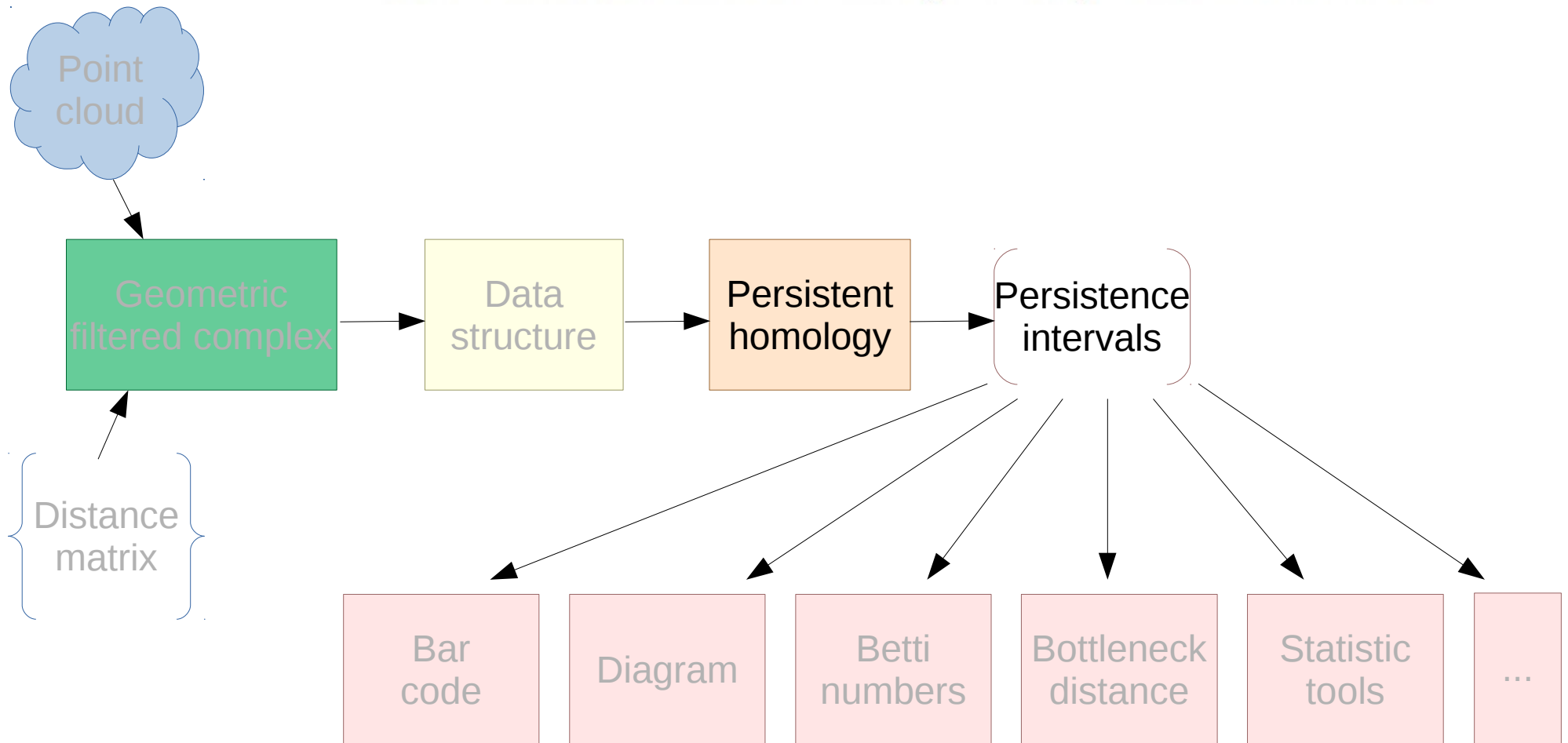


Simplicial complex obtained after simplification  
714 simplices

- Efficient on a skeleton blocker data structure.

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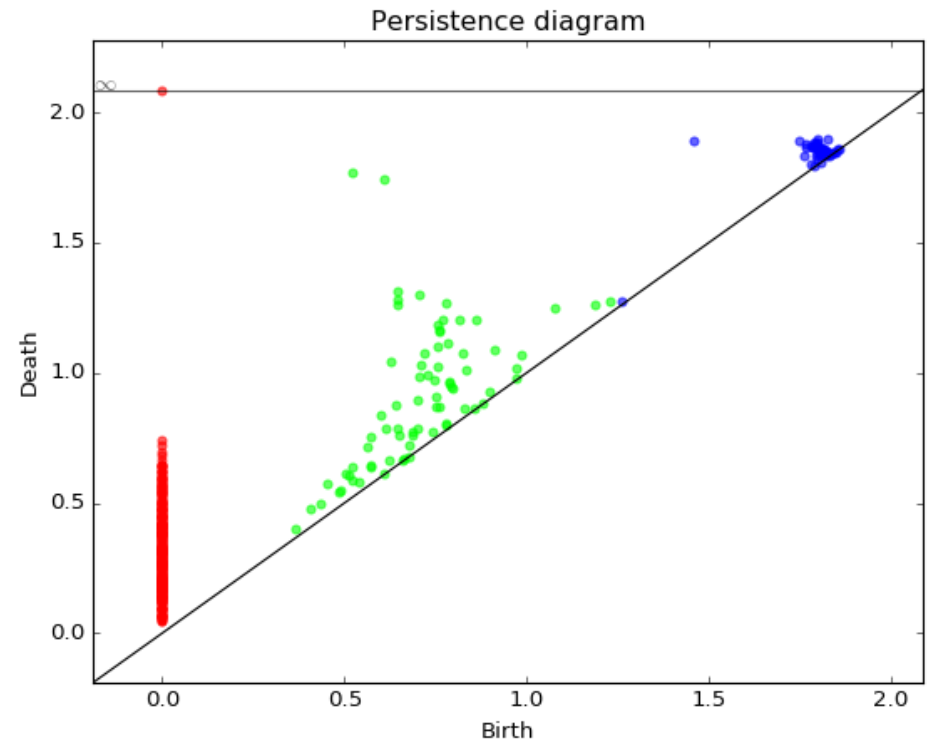
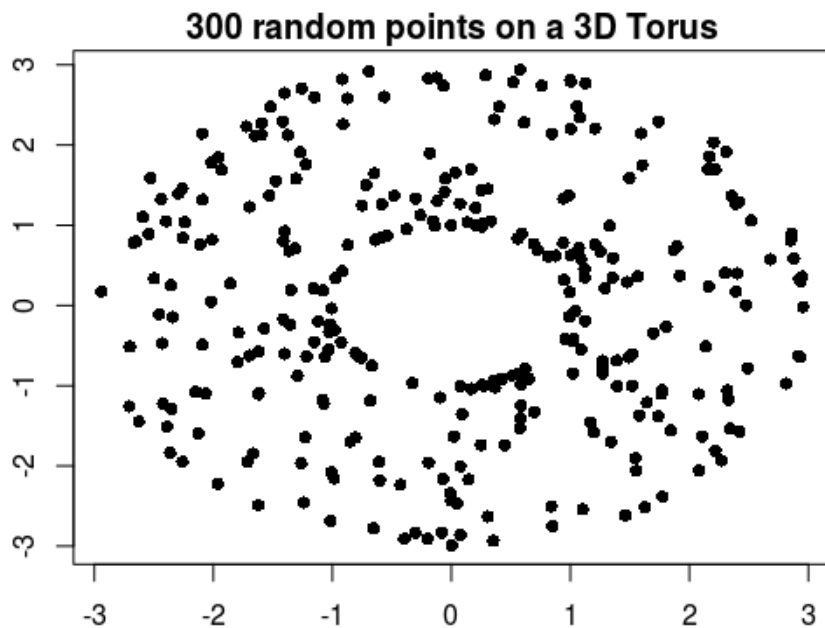
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Persistent  
homology

Persistence  
intervals

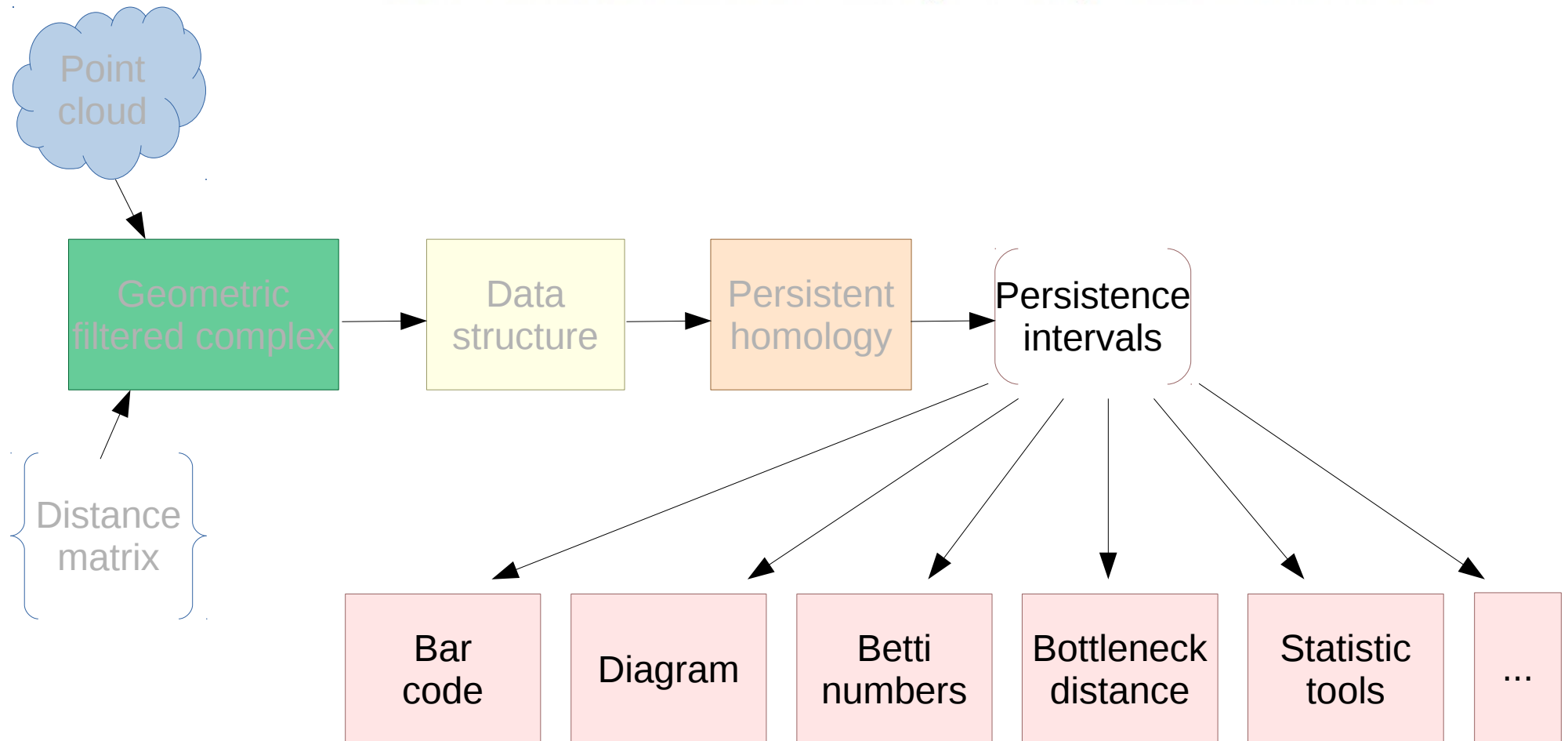
### Toolbox – Persistence cohomology



- Standard persistence cohomology computations by using compressed annotation matrix.
- Multi-field persistence (detection of torsion coefficients).

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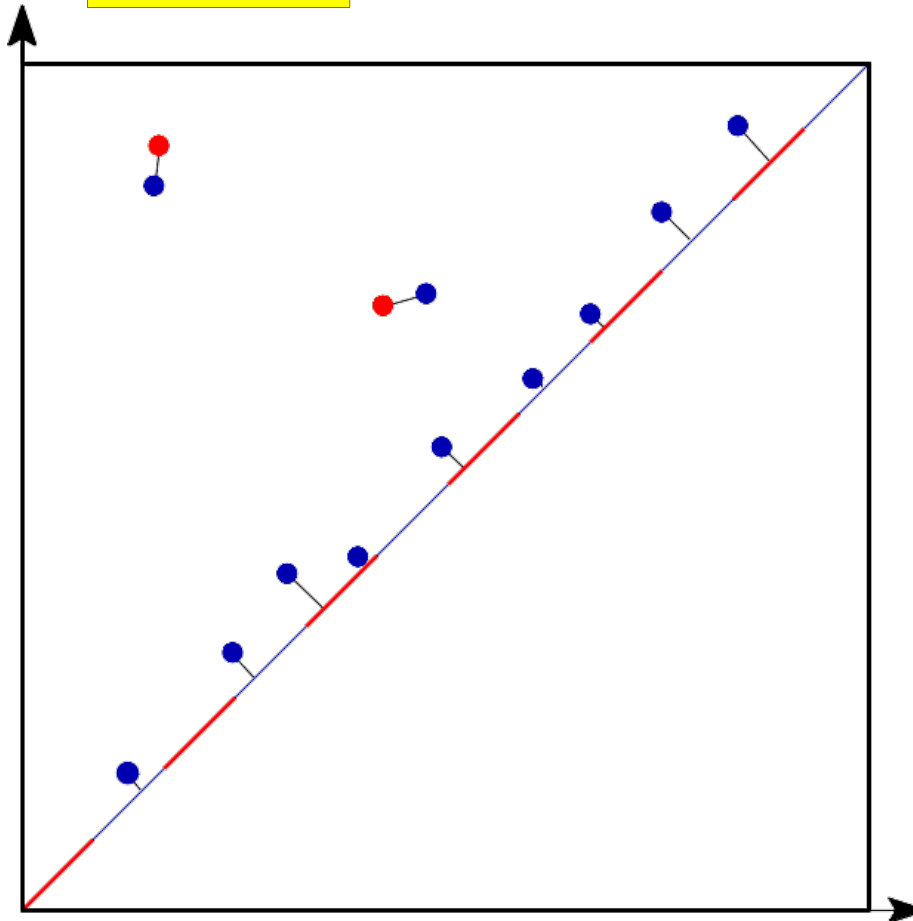
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Persistence intervals

Bottleneck distance

CGAL

Toolbox – Bottleneck distance



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Our website:

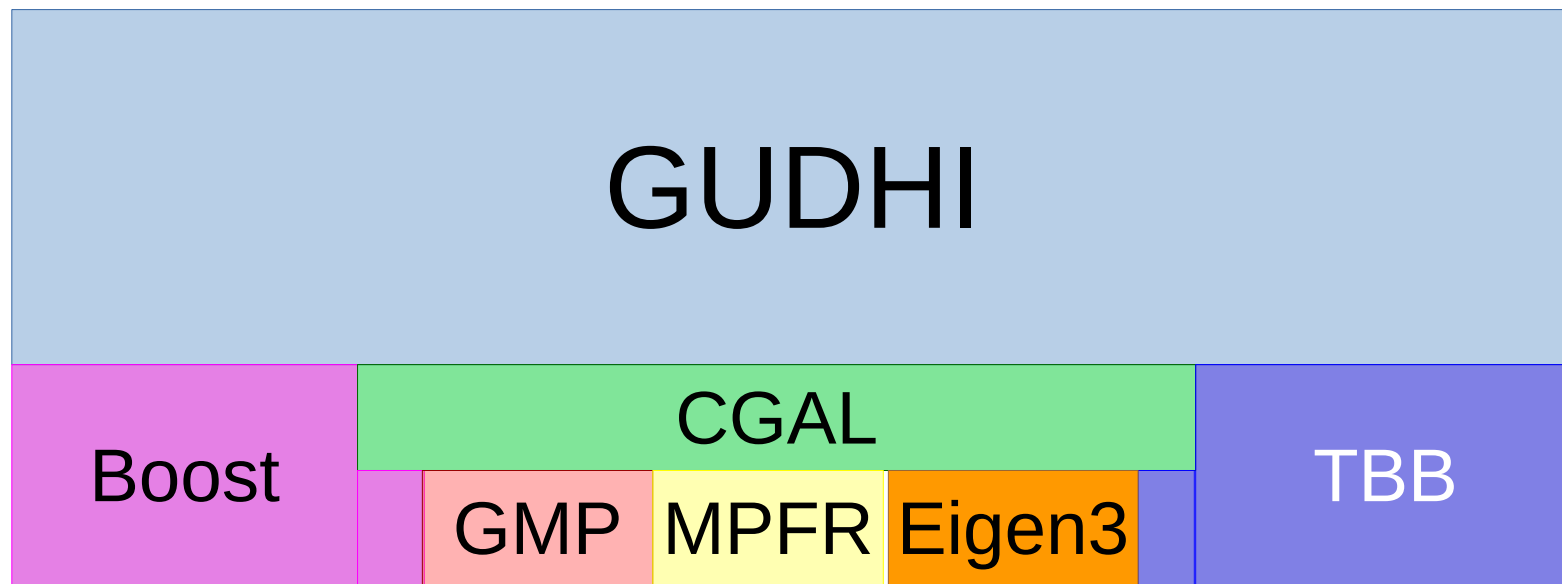
<http://gudhi.gforge.inria.fr>

Documentation will be available here:

<http://gudhi.gforge.inria.fr/doc/latest/> <sup>BETA</sup>



## Third party libraries



Installing GUDHI:

<http://gudhi.gforge.inria.fr/doc/latest/installation.html> <sup>BETA</sup>

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If you want to join the GUDHI users community:

<http://gudhi.gforge.inria.fr/keepintouch/> **BETA**

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in Higher Dimensions

## Keep in touch

Please help us improving the quality of the GUDHI library. You may [contact us](#) to report bugs or suggestions.

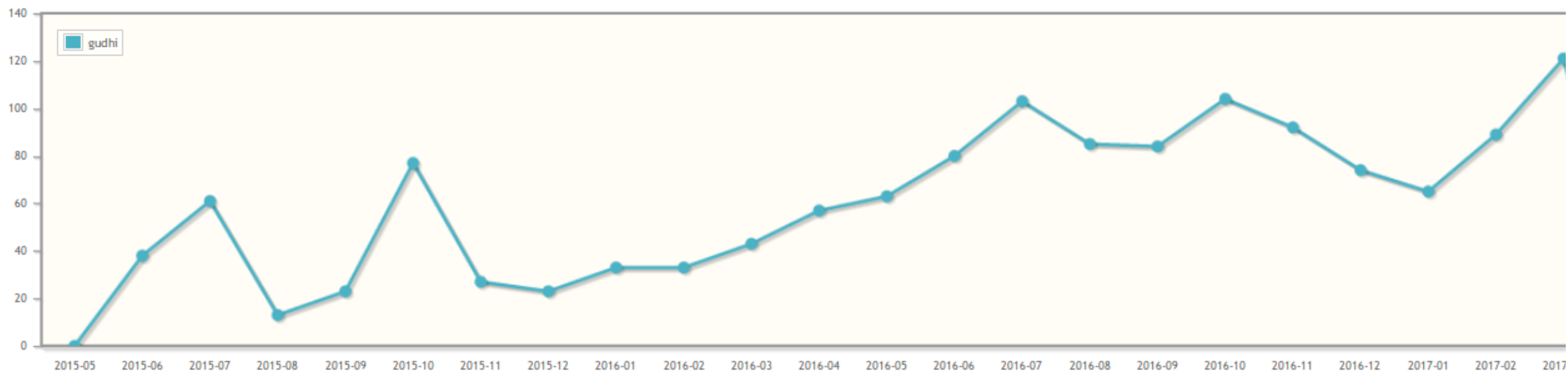
GUDHI is open to external contributions. If you want to join our development team, please read carefully the [GUDHI Editorial Policy](#) and contact us.

[Subscribe to the GUDHI users mailing-list >](#)

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## Geometric Understanding in Higher Dimensions

GUDHI downloads:





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GUDHI is open to external contributions.

- Examples driven development
- Documentation is required
- Unitary tests are required
- Some conventions to write code
- Peer review process
- All the packages come with the names of their authors

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## Geometric Understanding in Higher Dimensions

Dashboard [Jenkins] x +

https://ci.inria.fr/gudhi/ Search

Jenkins search vincent.rouvreau@inria.fr | log out

Jenkins ENABLE AUTO REFRESH [add description](#)

- New Item
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**Build Queue** -

No builds in the queue.

**Build Executor Status** -

- gudhi-centos764**  
1 idle
- gudhi-fedora32**  
1 idle
- gudhi-osx109**  
1 idle
- gudhi-win764**  
1 idle
- gudhi-windows732**  
1 idle

S	W	Name ↓	Last Success	Last Failure	Last Duration
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		<a href="#">BRANCH_build-and-test-centOS764-random-cgal</a>	6 days 2 hr - <a href="#">#1</a>	N/A	25 min
		<a href="#">BRANCH_build-and-test-MacOS</a>	14 days - <a href="#">#39</a>	N/A	11 min
		<a href="#">BRANCH_build_and_test_win32</a>	14 days - <a href="#">#53</a>	N/A	4 min 51 sec
		<a href="#">BRANCH_build_and_test_win64</a>	14 days - <a href="#">#55</a>	28 days - <a href="#">#51</a>	24 min
		<a href="#">BRANCH_generate-and-build-centOS764</a>	6 days 5 hr - <a href="#">#267</a>	6 days 6 hr - <a href="#">#258</a>	2 min 4 sec
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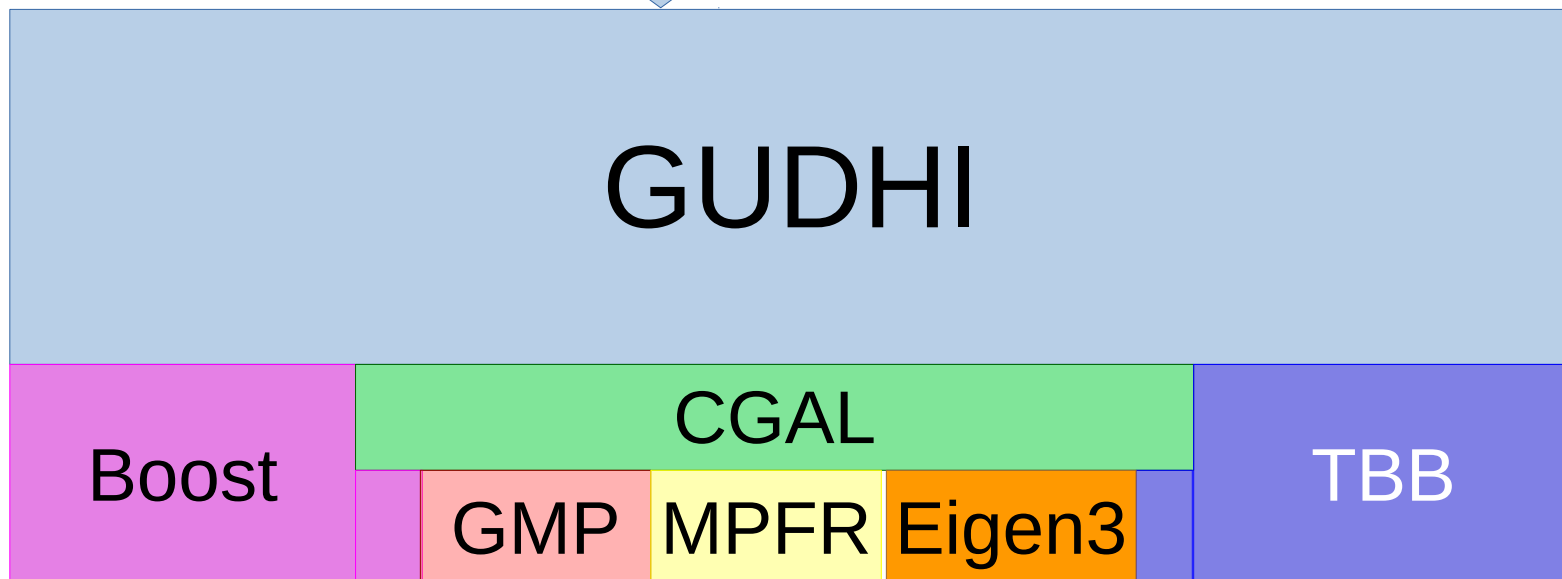
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Legend [RSS for all](#) [RSS for failures](#) [RSS for just latest builds](#)

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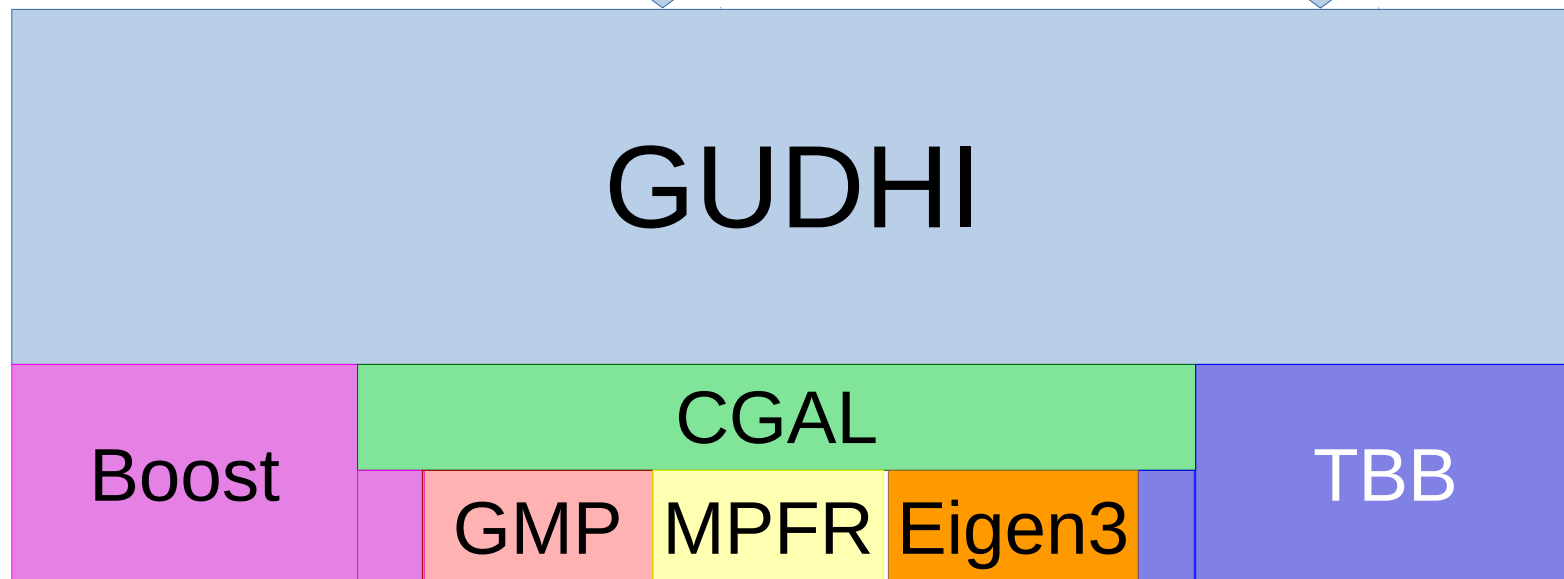
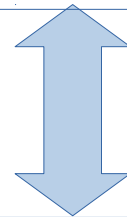
Interfaces



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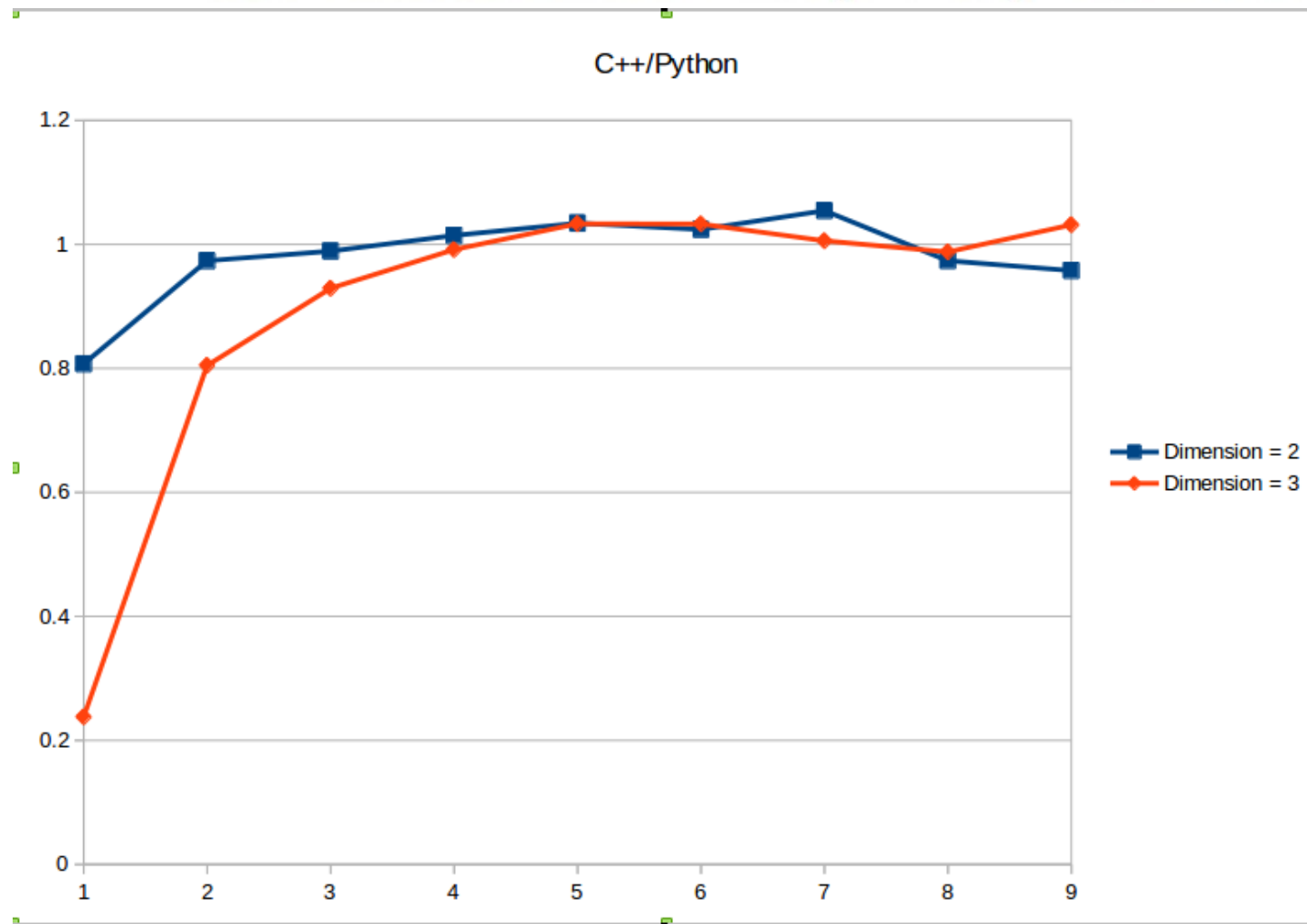
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Interfaces



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## Geometric Understanding in Higher Dimensions



Dim2: random cubical complex  $400 \times 400$  to  $3600 \times 3600$ ,  $dx = 400$

Dim3: random cubical complex  $20 \times 20 \times 20$  to  $180 \times 180 \times 180$ ,  $dx = 20$



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- Documentation will be available here:

<http://gudhi.gforge.inria.fr/cython/latest/> BETA

- Documentation will be available here:

<http://gudhi.gforge.inria.fr/cython/latest/installation.html> BETA

What will arrive after GUDHI 2.0.0 ?

- S.A.L.
- GUDHI stat
- Zig zag persistence
- Phat persistence interface
- Graph induced complex
- Nearest neighbor

Thank you !