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Simka: fast kmer-based method for estimating the similarity between numerous metagenomic datasets

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Metagenomic

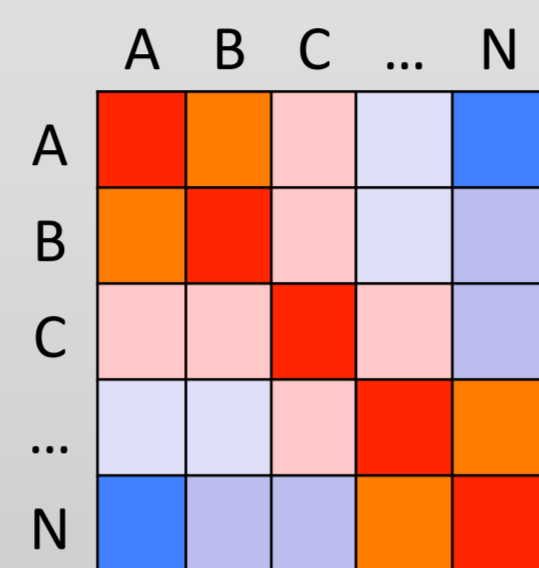


- A liter of sea water:**
- Hundred of millions of species
 - > 90% unknown species

Comparative metagenomics



N metagenomic samples
N > 1000 in Tara Oceans project



Similarity heatmap N²
with hierarchical clustering

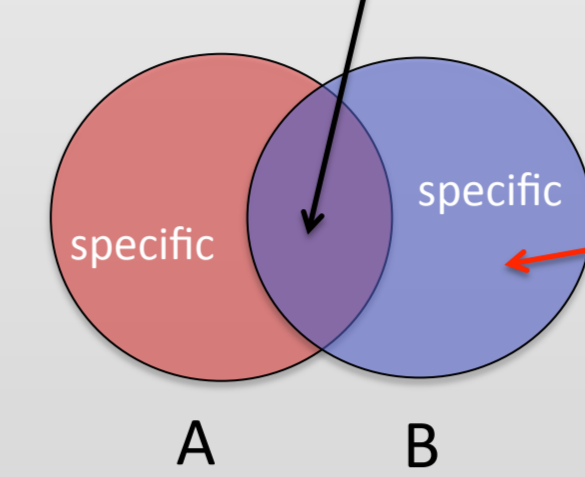


N read-sets
Usually >100M reads per dataset

Similarity between 2 read-sets

Idea: similarity is given by the size of the intersection

Intersection = number of similar reads



Similar: their alignment score > 90%

100M reads

✗ Blast-like approach required months of computation for a single intersection

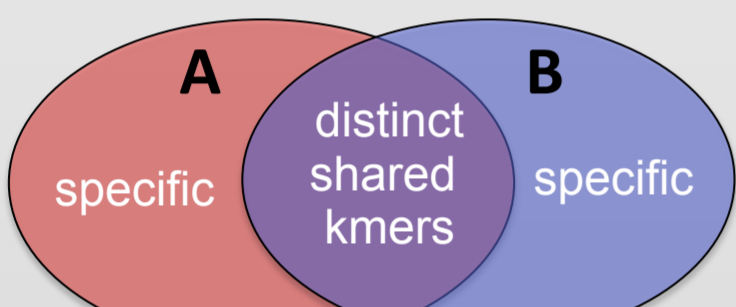
Commet [1] (state of the art)

- Heuristic: Two read are similar if they share some kmers
- Computes one intersection in few hours
- Still does not scale on large metagenomic projects
- N(N-1) intersections to compute

Kmer-based similarity functions

- We have very fast methods for indexing and querying kmers
- A read-sets is now view as a set of its kmers
- We define new pairwise similarity measures based on shared kmers

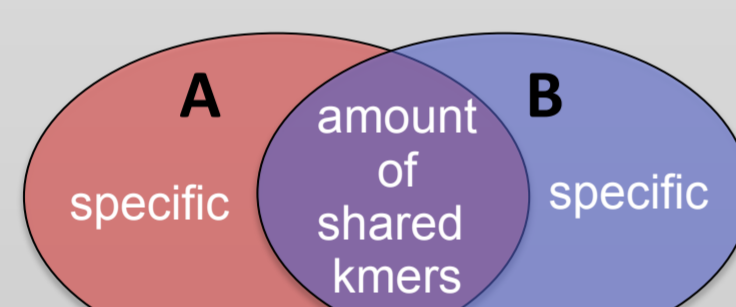
1) Presence / Absence of kmers



Similarity based on presence/absence of species

$$Jaccard(A, B) = \frac{DistinctKmers(A \cap B)}{DistinctKmers(A \cup B)}$$

2) Abundance of shared kmers



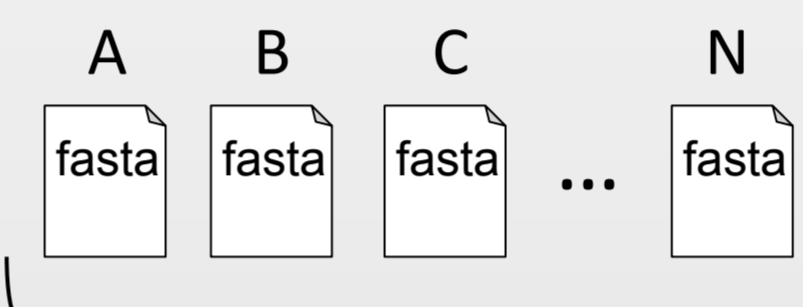
Similarity based on abundance of species

$$AbundanceJaccard(A, B) = \frac{\sum_{w \in A \cap B} N_A(w) + N_B(w)}{\sum_{w \in A \cup B} N_A(w) + N_B(w)}$$

w: kmer, Ni(w): abundance of w in read-set i

Method

To scale on N large datasets, we count the kmers of N datasets simultaneously.



GATB[2] - DSK multi-dataset kmer counting

Kmer's abundances v

	A	B	C	...	N
ACGTAT	0	4	52	...	0

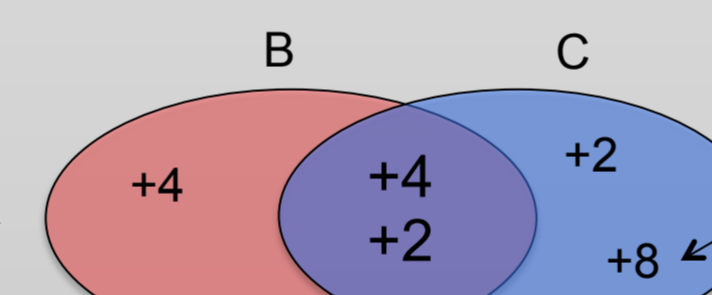
For each kmer, we get a vector of its abundances in N datasets

Is kmer solid? (optional)

Update intersections

Kmer shared by B and C

	A	B	C
ACC	0	4	2



Kmer specific to C

	A	B	C
TGC	0	0	8

Estimating similarity is now a problem of counting kmers

Execution time repartition:

- Counting kmers O(N): 75%
- Updating intersections O(N²): 25%

Filtering sequencing errors

Kmer solid:

A kmer that contains no sequencing errors

Statistics:

80% of distinct kmers appear only one time and only in a single dataset

Noisy data:

It is hard to distinguish erroneous kmers from unique genomic kmers

We defined a solidity definition that can saved some unique kmers:

Given a solidity threshold t (t=2), a kmer w is solid if:

abundance(w) in at least one dataset >= t

Examples on 4 datasets:

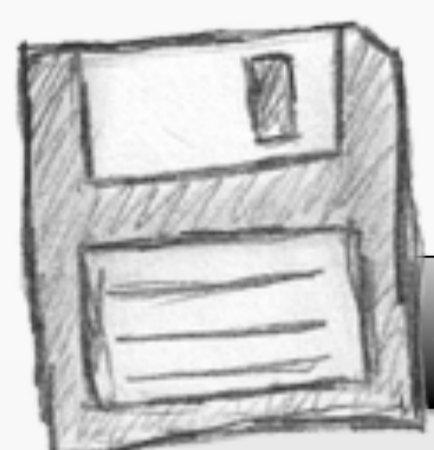
A	B	C	D
2	0	1	0

A	B	C	D
52	0	1	1

A	B	C	D
0	1	1	0

Statistics on solid 31-mers from 21 Tara Oceans samples:

- Distinct: 18G (15% of all distinct kmers)
- Abundance: 106G (49% of all kmers)



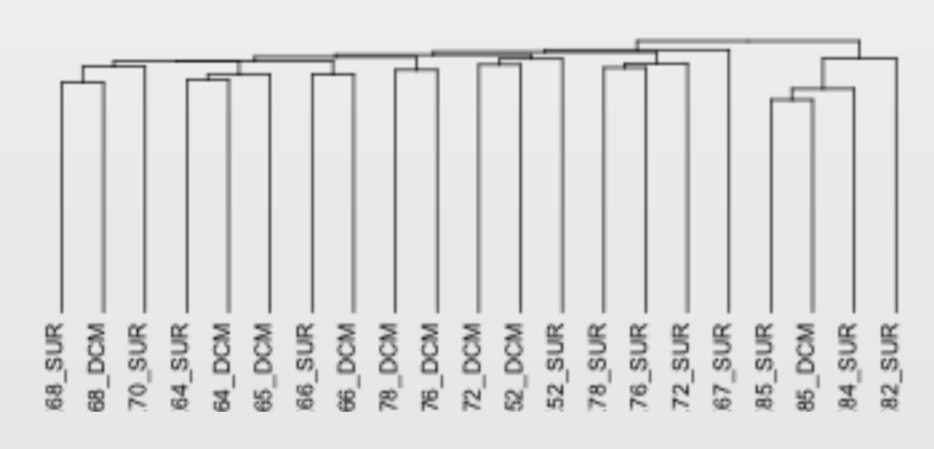
Datasets

- Simka was tested and compared to Commet[1] (state of the art) on 21 Tara Oceans samples:
- 3G reads
 - 400 GB of data
 - 219G 31-mers
 - 123G distinct 31-mers

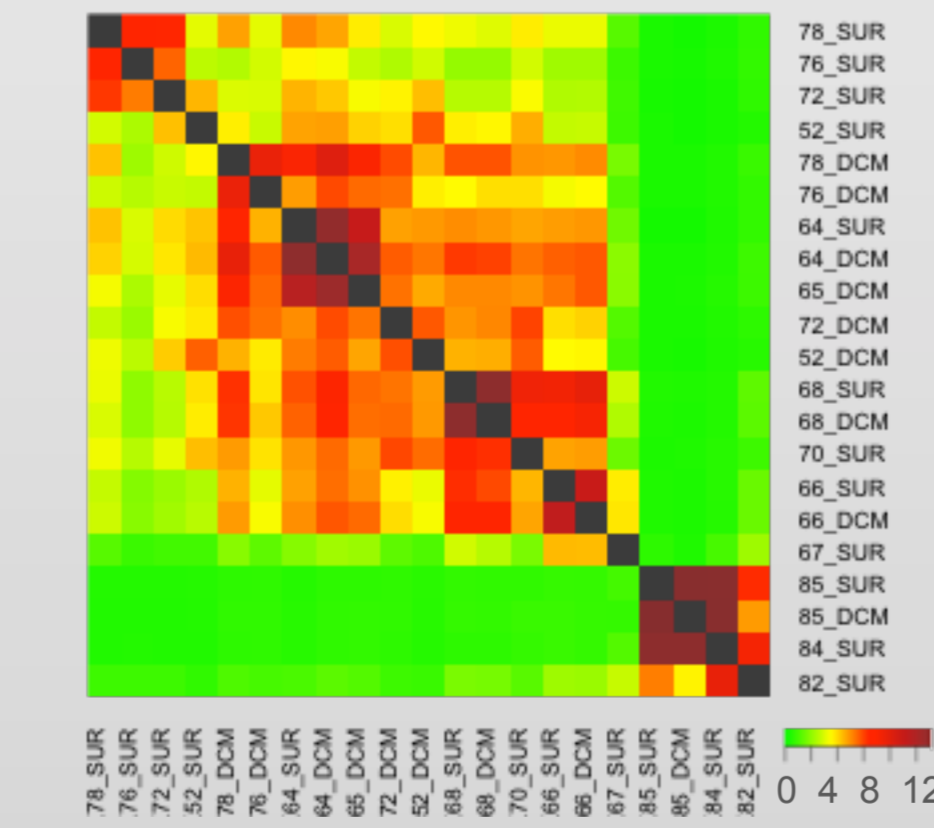


Presence / Absence of kmers

Relative similarity:



Absolute Similarity:

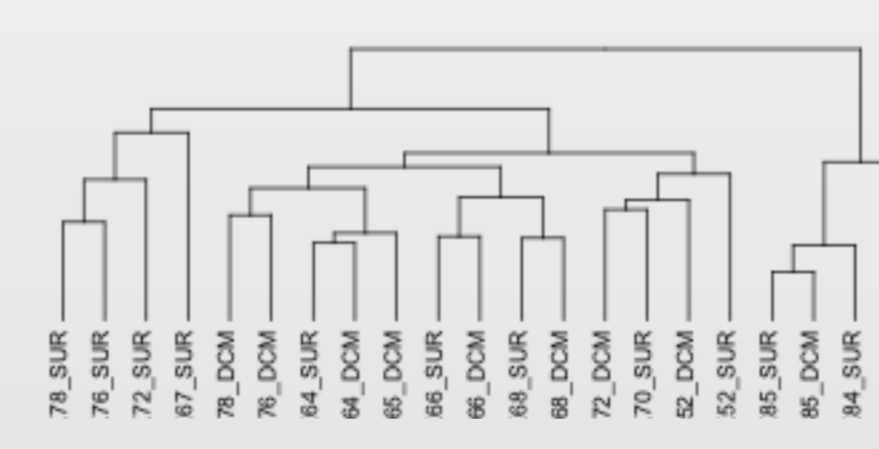


5 Hours

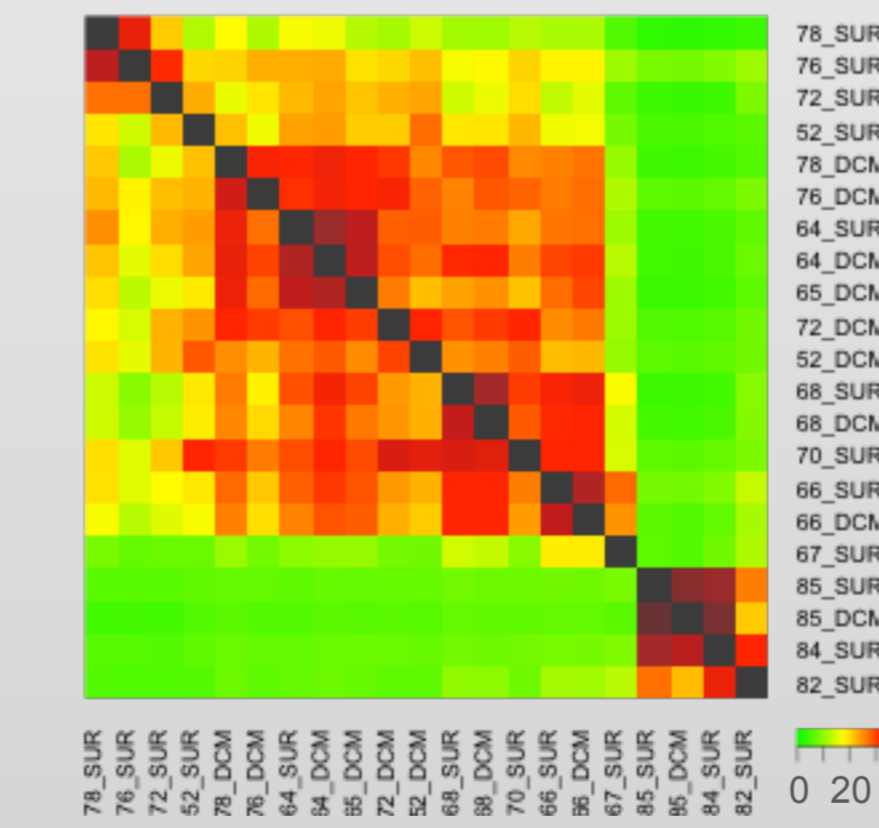
- ✗ Can differs from Commet because not based on species's abundance
- ✓ Simka is the first method to provide quickly information about presence and absence of species

Abundance with error filter

Relative similarity:



Absolute Similarity:

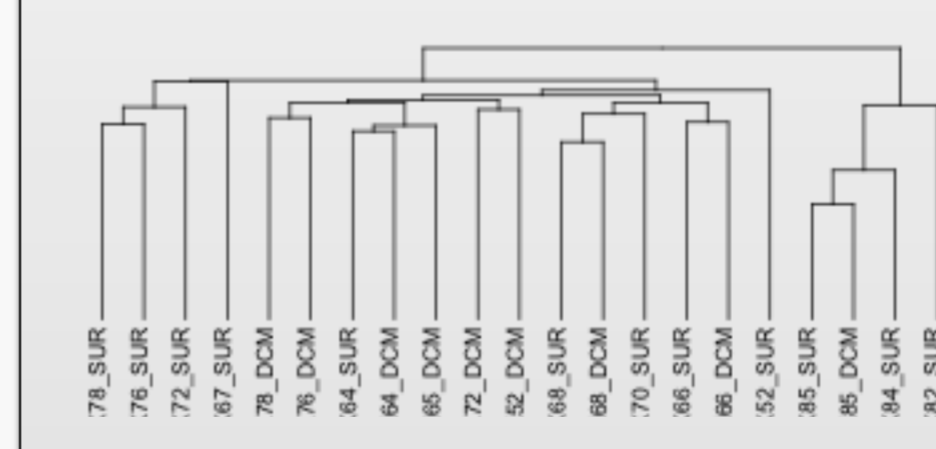


5 Hours

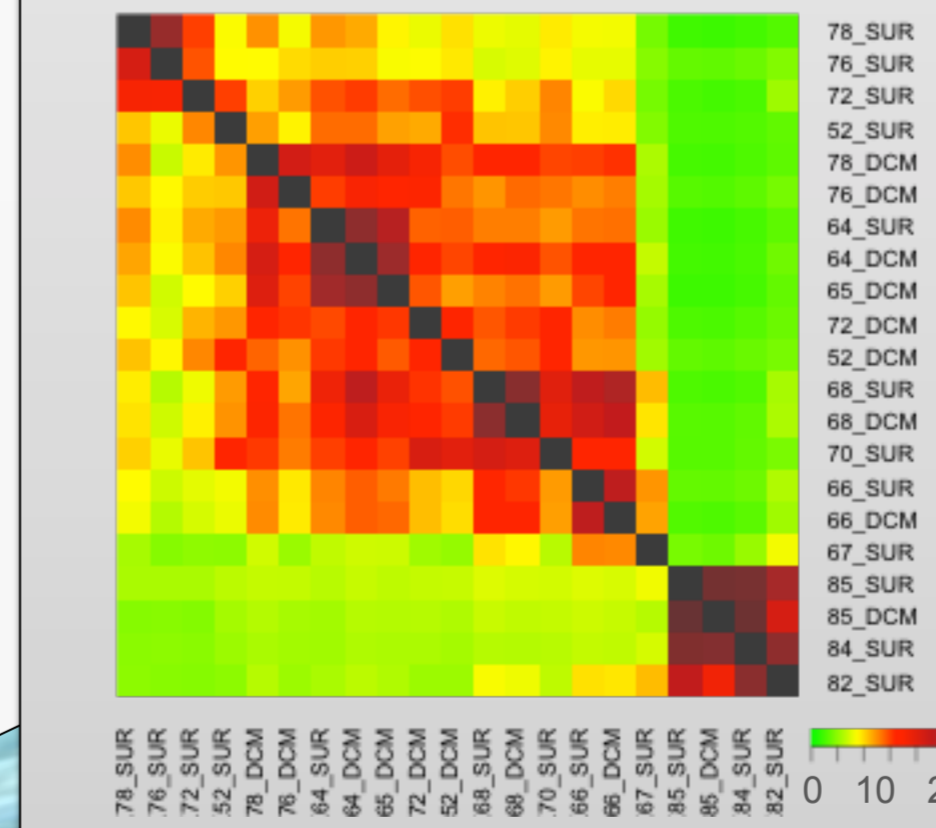
- ✓ Clustering less noisy and more readable
- ✓ Close to Commet while using only 18% of distinct kmers (half of the datasets)

Abundance of shared kmers

Relative similarity:



Absolute Similarity:

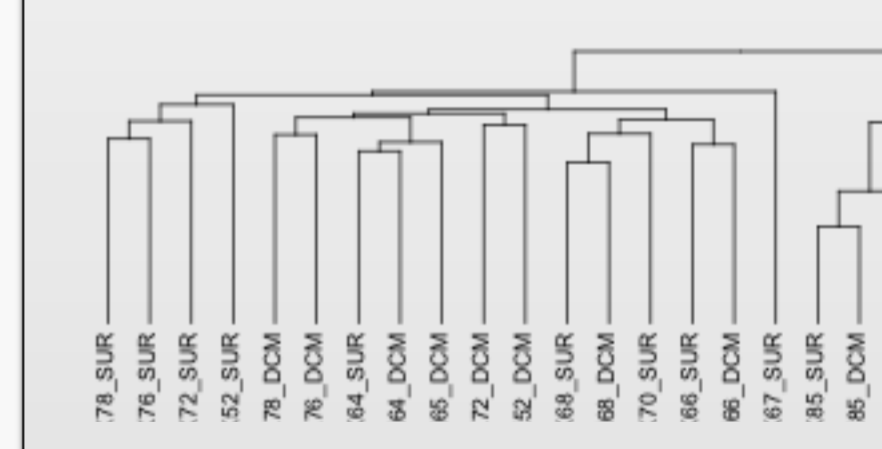


5 Hours

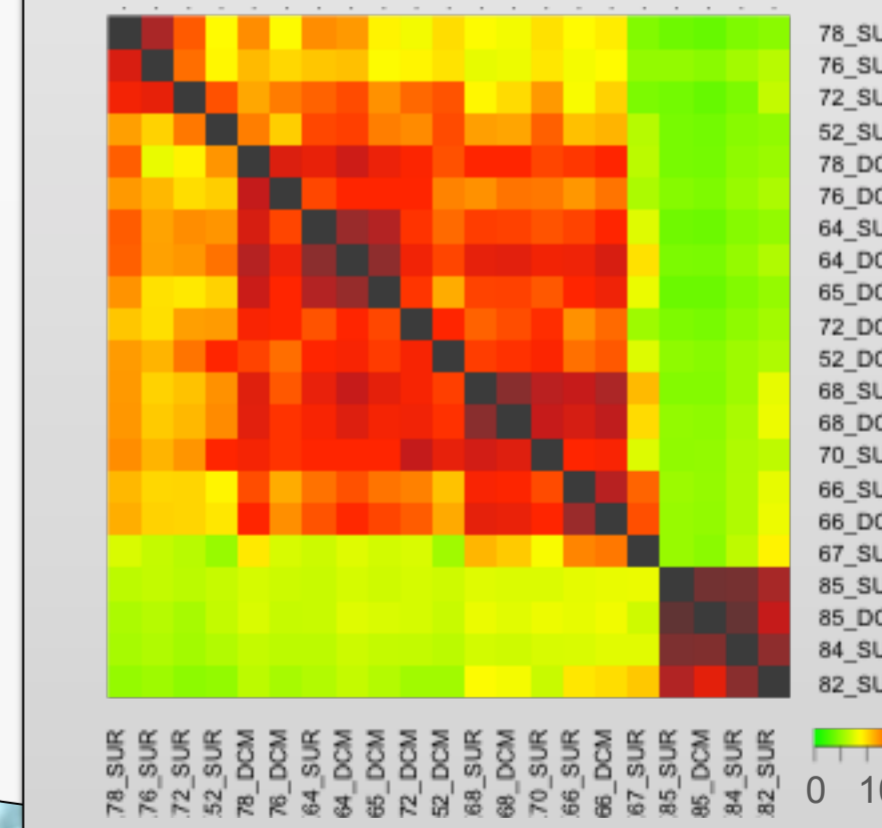
- ✓ Similarity and clustering close to read-based methods

Commet (state of the art)

Relative similarity:



Absolute Similarity:



Weeks

- ✓ Read-based
- ✗ Too slow on large metagenomic projects

Alignment based methods

Years

Perspectives

- Filtering input reads
- Provide similarity confidence intervals with bootstrap
- Selecting discriminative kmers

Simka

- ★ New similarity functions based on shared kmers
- ★ Based on abundance and presence/absence of species
- ★ Results close to read-based methods
- ★ Fast and low memory thanks to the GATB library [2]

References

- [1] COMMET: comparing and combining multiple metagenomic datasets
N. Maillet, G. Collet, T. Vannier, D. Lavenier, P. Peterlongo
IEEE BIBM, 2014
- [2] GATB: Genome Assembly & Analysis Tool Box
E. Drezon, G. Rizk, R. Chikhi, C. Delteil, C. Lemaitre, P. Peterlongo, D. Lavenier
10.1093/Bioinformatics/btu406, 2014
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