Wheeze Detection: Reproducing Results of Emrani, Gentimis, and Krim

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Content

Environment and Reference

Computer operating system: Windows 10
Computer programming language: Python
Third-party library: gudhi
Theoretical basis: persistence homology, sliding window embedding

Reference:

[1] Emrani S, Gentimis T, Krim H. Persistent homology of delay embeddings and its application to wheeze detection. IEEE Signal Processing Letters, 21(4):459–463, 2014

[2] _____, Topological time series analysis, Notices of the American Mathematical Society 66 (2019), no. 5.

[3] Edelsbrunner, H., & Harer, J. (2008). Persistent homology—a survey. In Goodman, J.E., & Pach, J. (Eds.) American Mathematical Society, (Vol. 453 pp. 257–282). Providence.

Key Points and Solutions

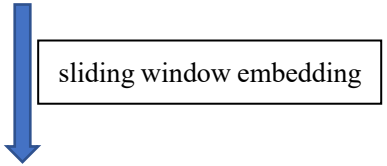
Consider using sliding window embedding to embed time series into high-dimensional Euclidean space, and then analyze the topological properties of the embedded point cloud by the form of barcode or diagram.

■Choice of Parameter:

delay: τ skip: σ

Time series:

$$x_1, x_2, x_3, \cdots, x_n, \cdots$$



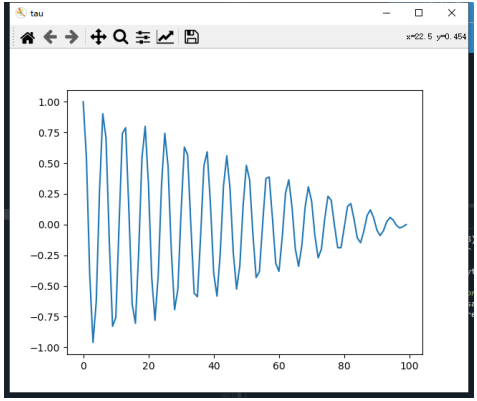
The embedded point cloud:

$$(x_1, x_{1+\tau}), (x_{1+\sigma}, x_{1+\sigma+\tau}), \cdots, (x_{1+n\sigma}, x_{1+n\sigma+\tau})$$

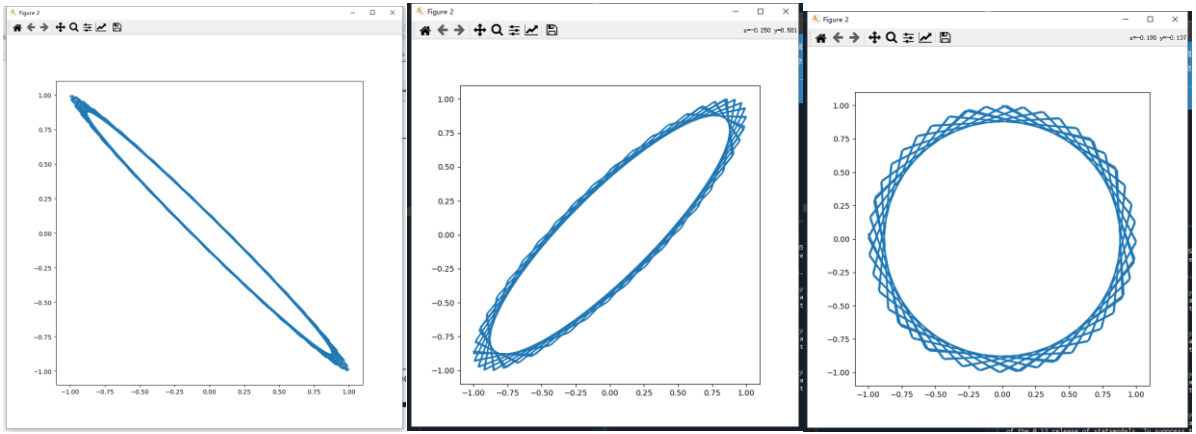
Results of different parameters

Key: Autocorrelation Function: $R_f(\tau) = \int_{-\infty}^{+\infty} f(x+\tau) f^*(x) dx$

For example: $f(x) = \sin x$



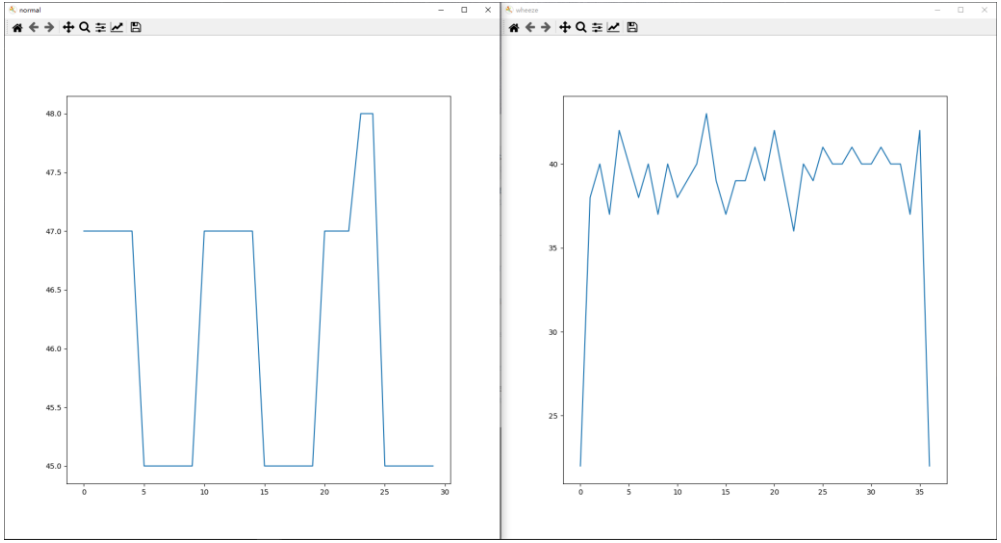
Autocorrelation coefficient



delay=3; delay=0.5; delay =pi/2

It can be seen that when the delay value τ s.t. $R_f(\tau) = 0$, sliding window embedding can best reflect the topological characteristics of $\sin x$(that is, the hole in the picture is "maximum").

The abscissa is the audio files number, the ordinate is the recommended delay value of audio files.

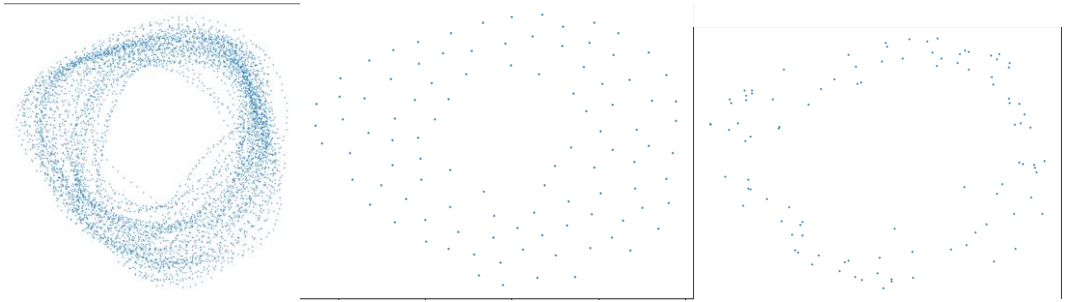


normal wheeze

■Methods of Subsampling

Recommended method: Maxmin Subsampling; Random Subsampling; Lazy Method: Capture a piece of audio in sequence.

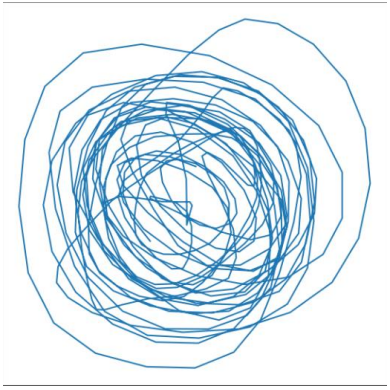
The differences caused by different subsampling are described in detail in the last section.



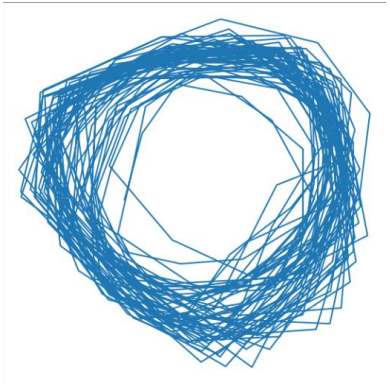
Crude Maxmin Random

■Classification Standard

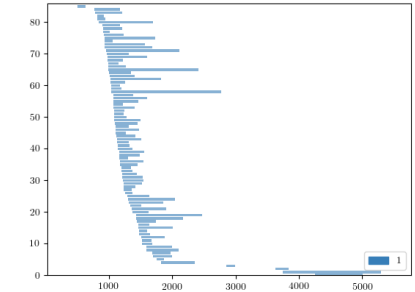
Comparing barcode of wheeze.wav and normal.wav, we can clearly find the huge difference between them. This difference is reflected in the embedded image, that is, whether the hole in the picture has been filled.

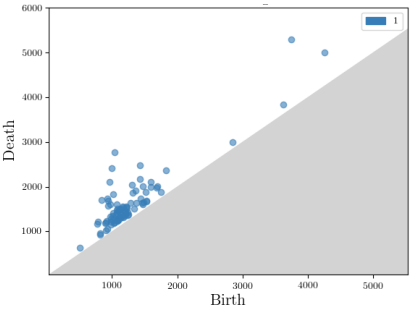


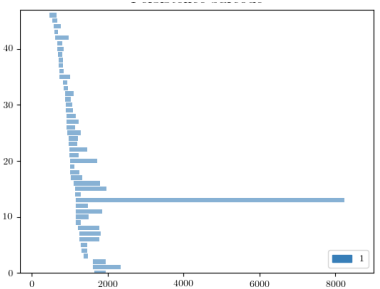
normal



wheeze


1


1
Death
Birth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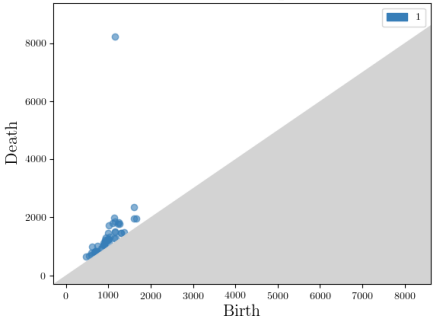
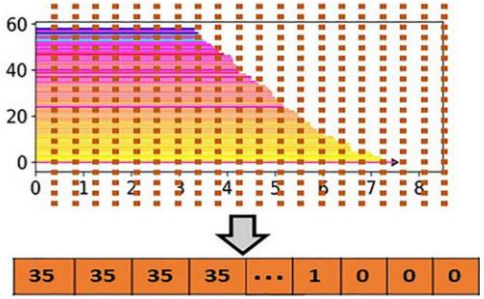

1
Death
Birth

■Methods of Classification

●Through calculation, we try to distinguish the outliers and the points close to the diagonal in one-dimensional diagram.

●Consider doing the following operation on barcode to get a fixed dimension vector, and then use machine learning.

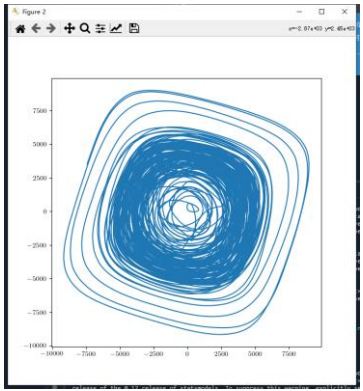


●Transforming diagram into persistence image, and then classified by machine learning.

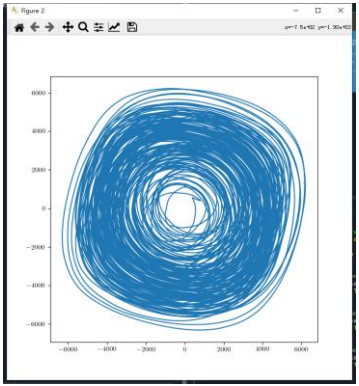
●Methods be not considered.

Outliers:

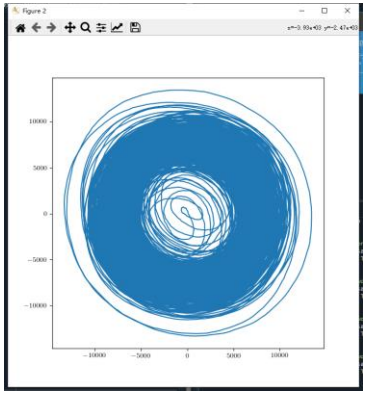
wheeze (11), wheeze (17), wheeze (19), wheeze (23), wheeze (28)



wheeze(11)

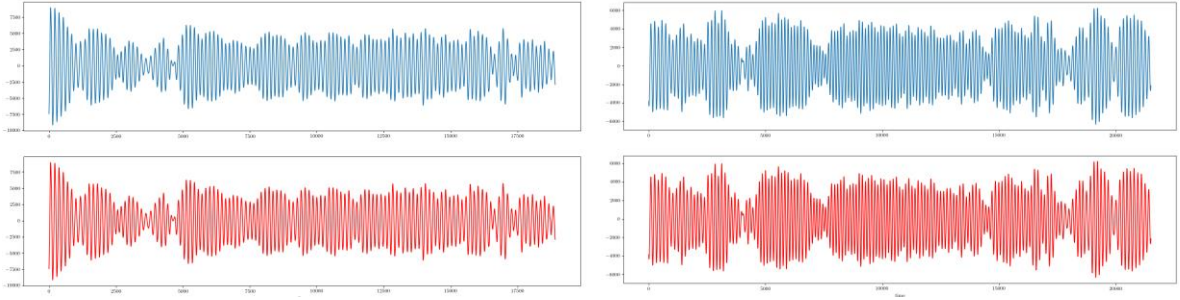


wheeze(23)



wheeze(28)

■Causes of outliers

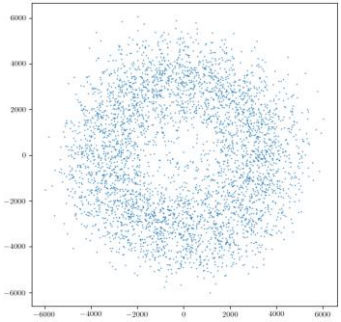


I guess the reason for the abnormal sign is that normal sign (i.e. breathing) is mixed with wheeze sign (i.e. wheezing).

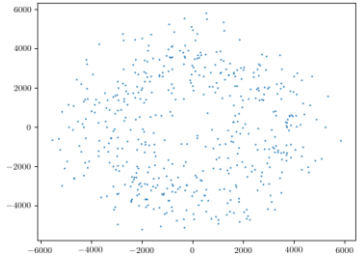
■Possible Improvement

- ●Using different sampling methods.
- ●Dividing the same audio into several segments and choose the best one.
- ●Morse function. (I guess that the effect of using Morse function is similar to that of random sampling.)

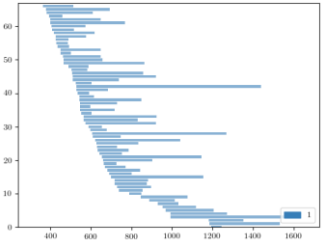
■For example wheeze (19)



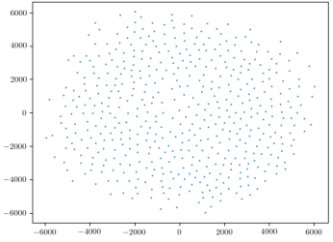
Crude



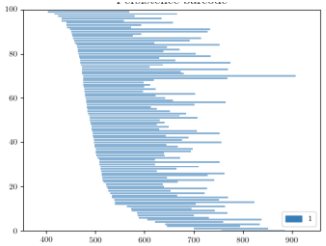
Random(point cloud)



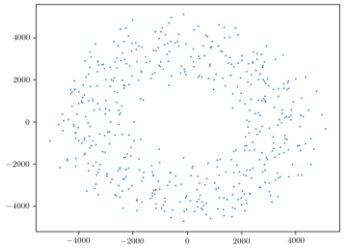
Random(barcode)



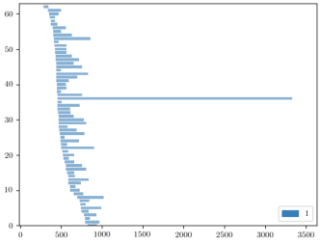
Maxmin(point cloud)



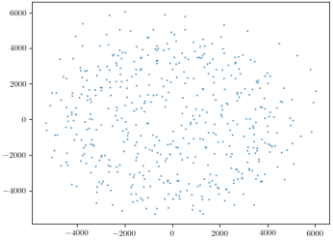
Maxmin(barcode)



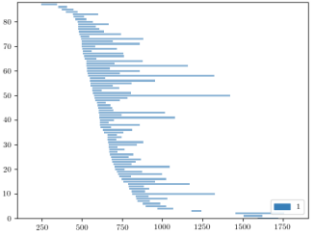
Lazy method([500:1000])(point cloud)



Lazy method(barcode)



Lazy method([0:500])(point cloud)



Lazy method(barcode)

Thank you