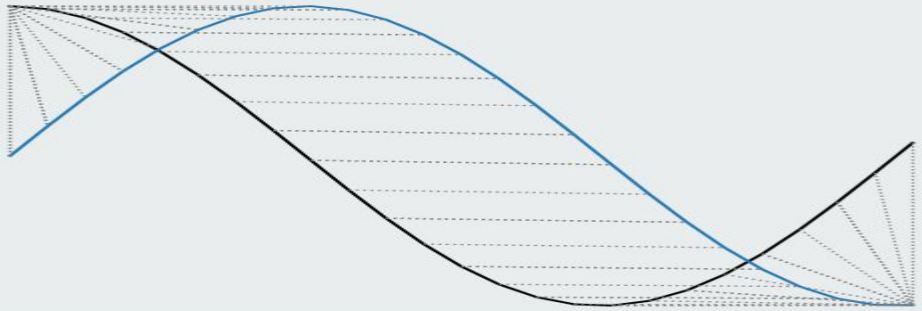
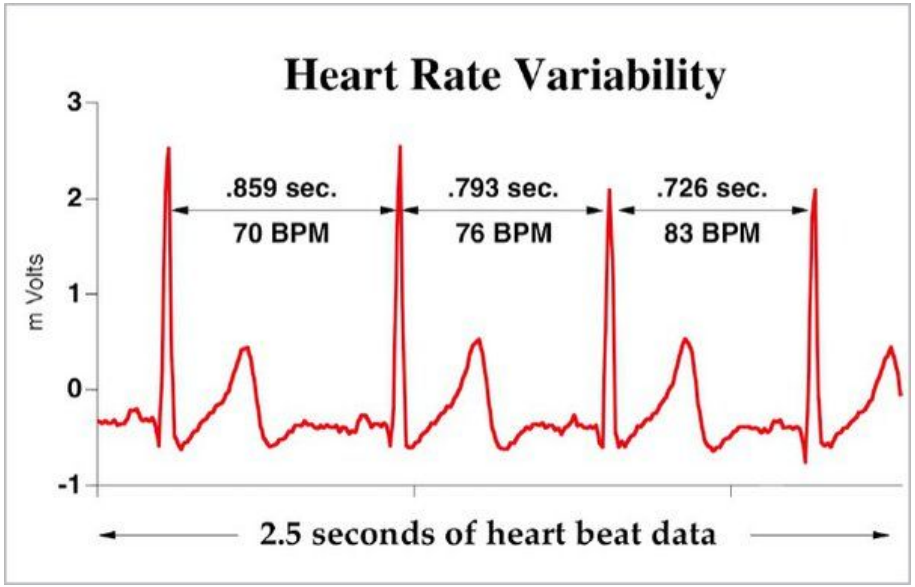
Warping Time: Using Dynamic Time Warping to Improve Machine Learning Outcomes

Kim Kraunz
ODSC West - November 2, 2023



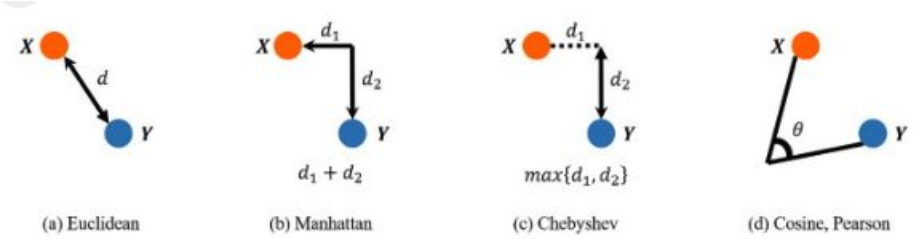
What if the time series aren't in sync?



Heart beats look very similar but have different lengths.

Goal: Measure the Similarities between Time Series

In a simple world we would calculate the distance using one of many distance measures



Traditional methods wouldn't work to align them

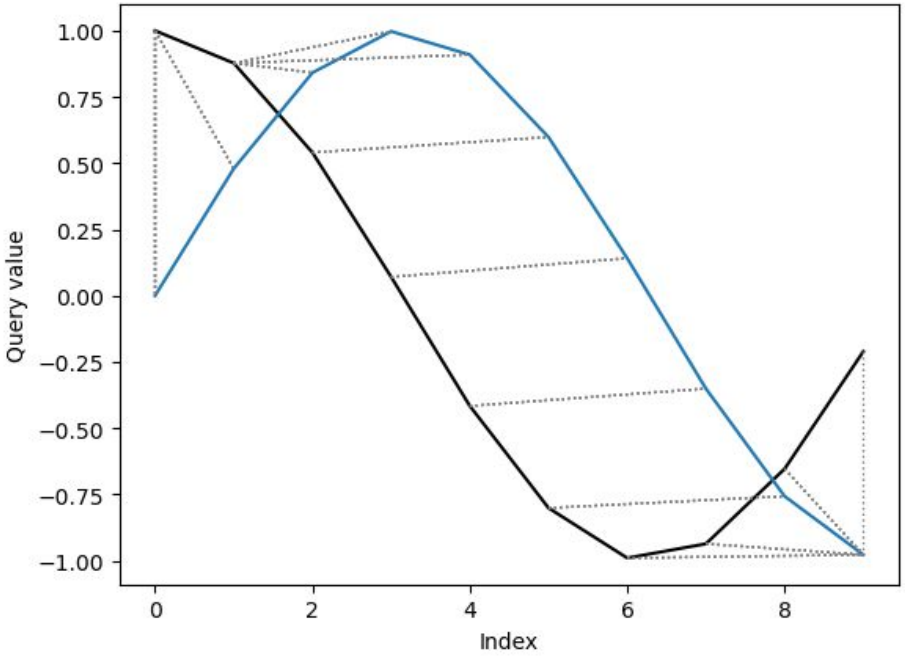
Dynamic Time Warping!

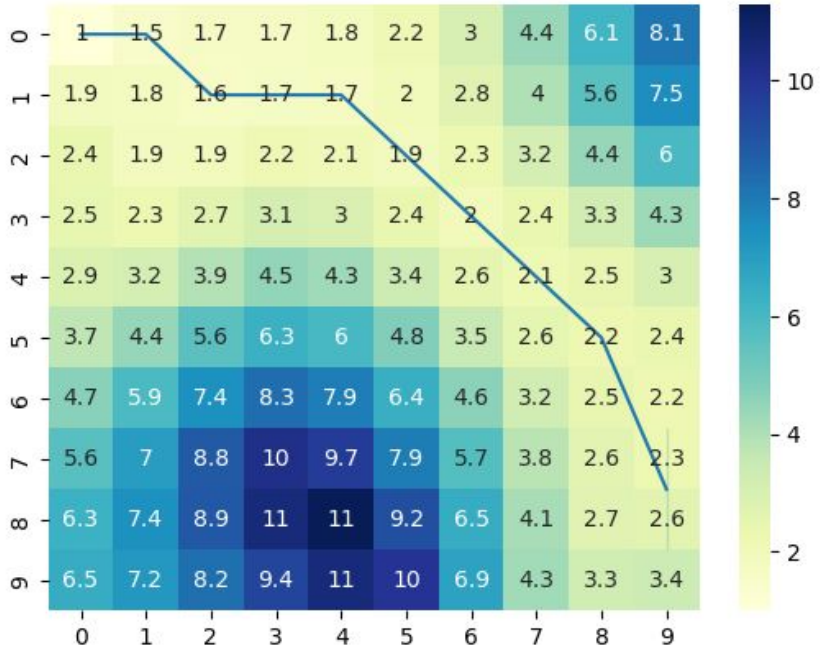
Ao Li, Cheng Fan, Fu Xiao, Zhijie Chen, Distance measures in building informatics: An in-depth assessment through typical tasks in building energy management, Energy and Buildings, Volume 258, 2022, 111817

Time Warping Calculation

1. Divide the two series into equal points.
2. Calculate the euclidean distance between the first point in the first series and every point in the second series. Store the minimum distance calculated. (this is the ‘time warp’ stage)
3. Move to the second point and repeat 2. Move step by step along points and repeat 2 till all points are exhausted.
4. Repeat 2 and 3 but with the second series as a reference point.
5. Add up all the minimum distances that were stored and this is a true measure of similarity between the two series.

Example


Query value
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
2
4
6
8
Index


0 1 1.5 1.7 1.7 1.8 2.2 3 4.4 6.1 8.1
1 1.9 1.8 1.6 1.7 1.7 2 2.8 4 5.6 7.5
2 2.4 1.9 1.9 2.2 2.1 1.9 2.3 3.2 4.4 6
3 2.5 2.3 2.7 3.1 3 2.4 2 2.4 3.3 4.3
4 2.9 3.2 3.9 4.5 4.3 3.4 2.6 2.1 2.5 3
5 3.7 4.4 5.6 6.3 6 4.8 3.5 2.6 2.2 2.4
6 4.7 5.9 7.4 8.3 7.9 6.4 4.6 3.2 2.5 2.2
7 5.6 7 8.8 10 9.7 7.9 5.7 3.8 2.6 2.3
8 6.3 7.4 8.9 11 11 9.2 6.5 4.1 2.7 2.6
9 6.5 7.2 8.2 9.4 11 10 6.9 4.3 3.3 3.4
0 1 2 3 4 5 6 7 8 9
10
8
6
4
2

Dynamic Time Warping Packages

Python

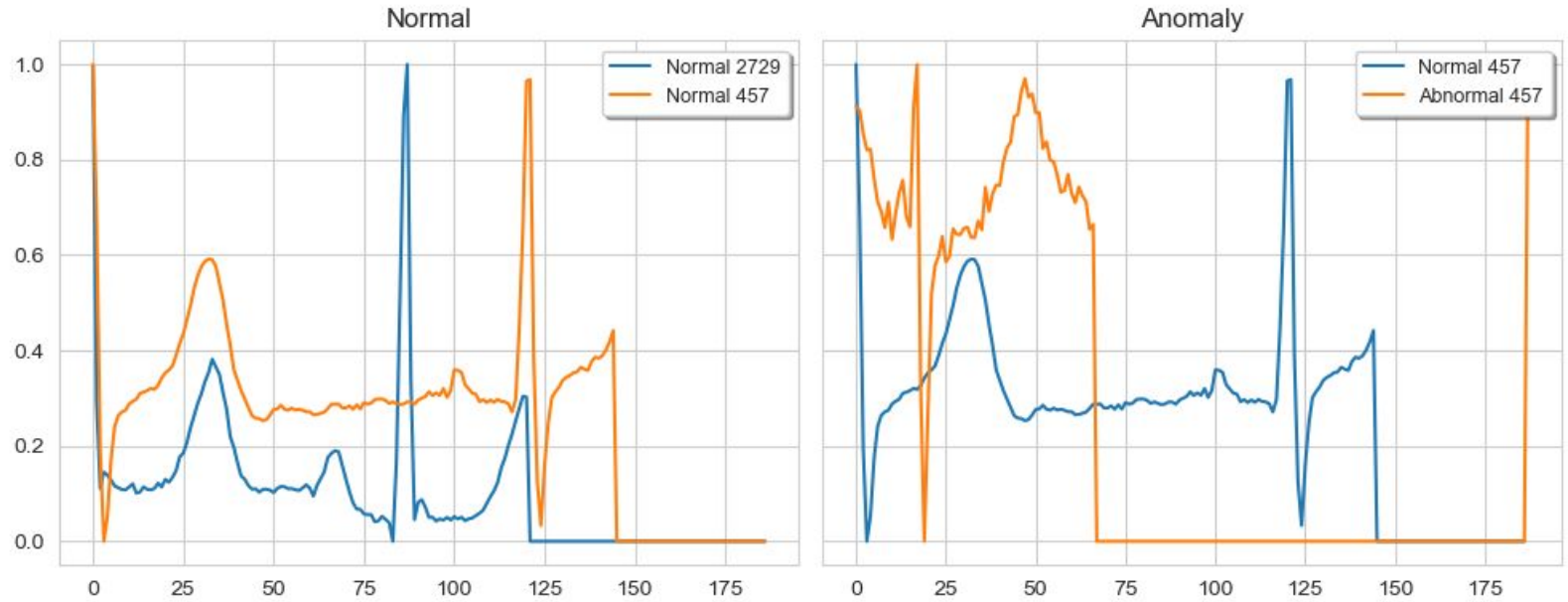
1. dtw-python
2. dtaidistance.dtw
3. TSLearn.metrics.dtw
4. pyts.metrics.dtw
5. FastDTW

R

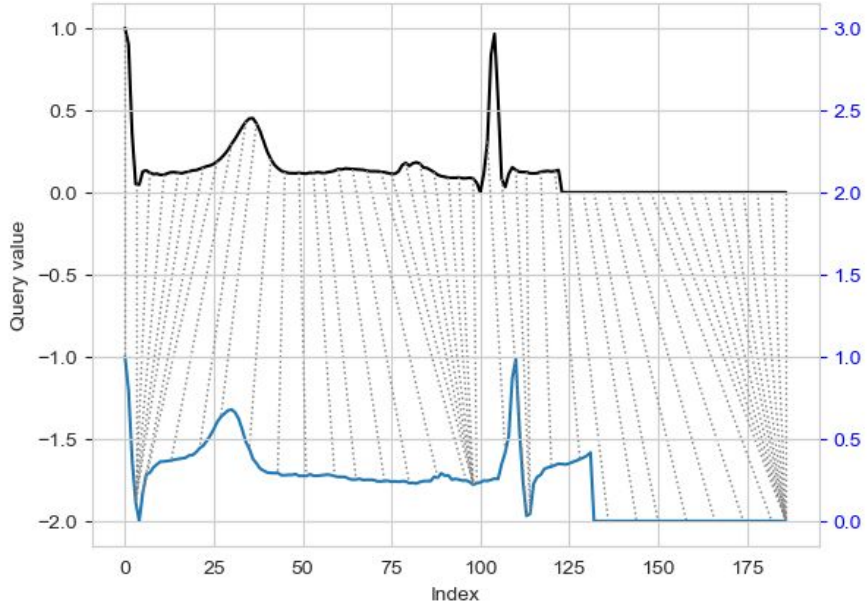
1. dtw
2. IncDTW

https://forecastegy.com/posts/dynamic-time-warping-dtw-libraries-python-examples/

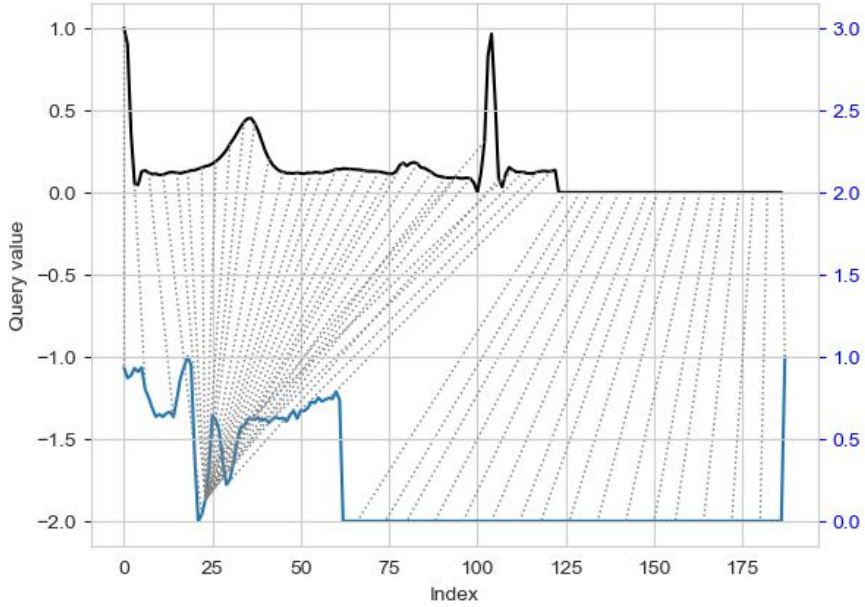
Example - EKG


Normal
Normal 2729
Normal 457
1.0
0.8
0.6
0.4
0.2
0.0
0
25
50
75
100
125
150
175
Anomaly
Normal 457
Abnormal 457
0
25
50
75
100
125
150
175

Example - Normal EKG with DTW



Example - Abnormal EKG with DTW

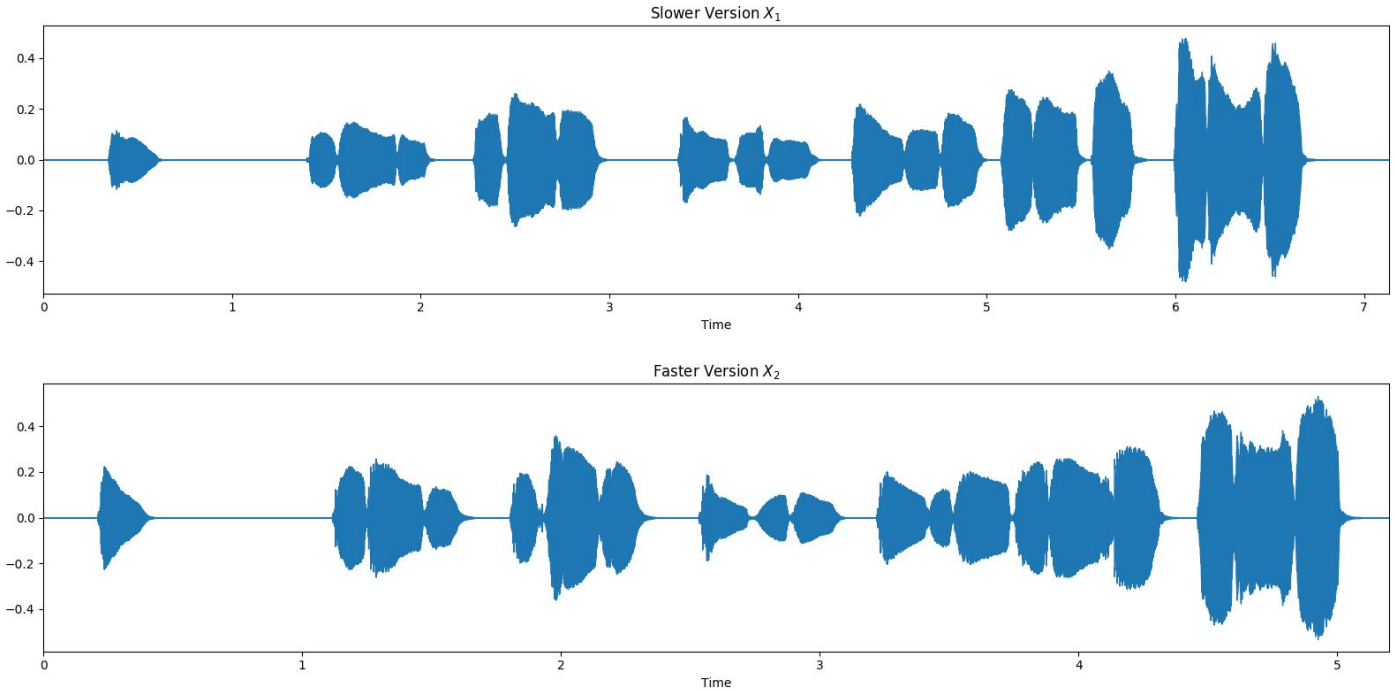


Stock Market - Tesla Momentum Pause Patterns

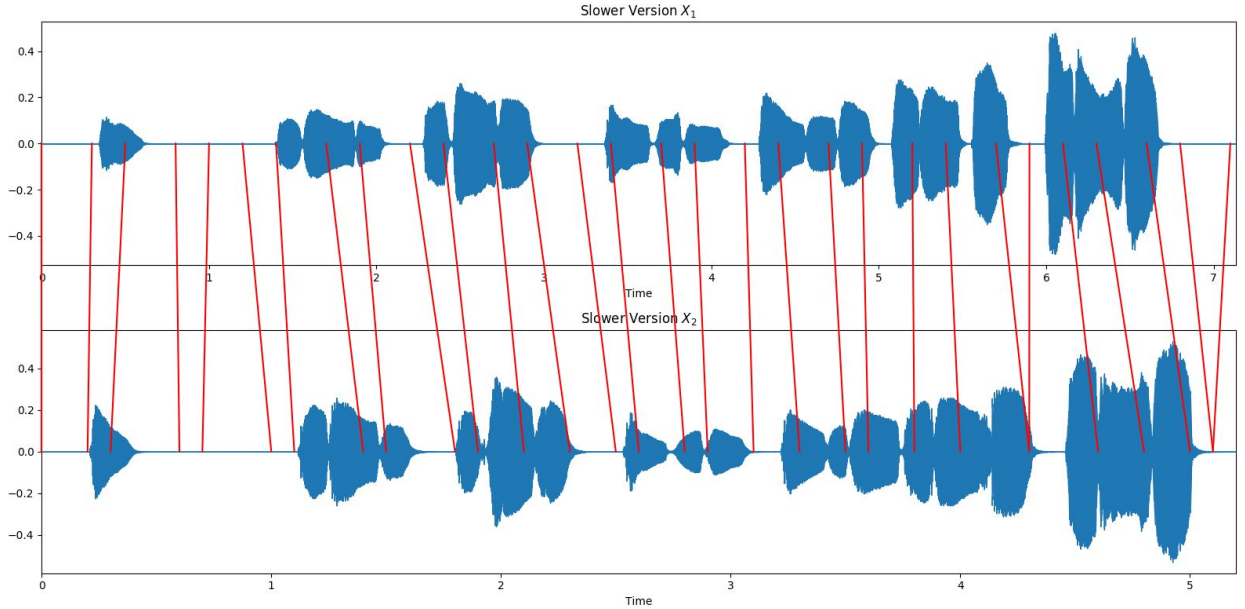
https://medium.datadriveninvestor.com/creating-a-momentum-trading-scanner-with-dynamic-time-warping-2a4e7ceb1e1c

Stock Market - Tesla Momentum Pause Patterns with DTW

Audio


Slower Version X_1
0.4
0.2
0.0
−0.2
−0.4
0
1
2
3
4
5
6
7
Time
Faster Version X_2
0.4
0.2
0.0
−0.2
−0.4
0
1
2
3
4
5
Time

Audio with DTW



https://librosa.org/librosa_gallery/auto_examples/plot_music_sync.html

Now What?

- Classification
- Clustering
  - https://nbviewer.org/github/markdregan/K-Nearest-Neighbors-with-Dynamic-Time-Warping/blob/master/K_Nearest_Neighbor_Dynamic_Time_Warping.ipynb