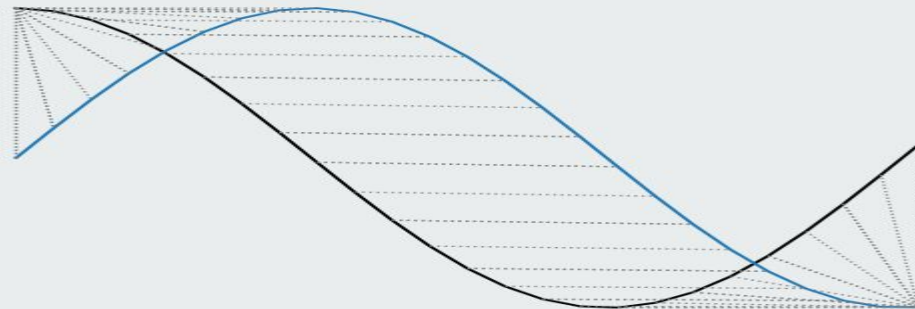


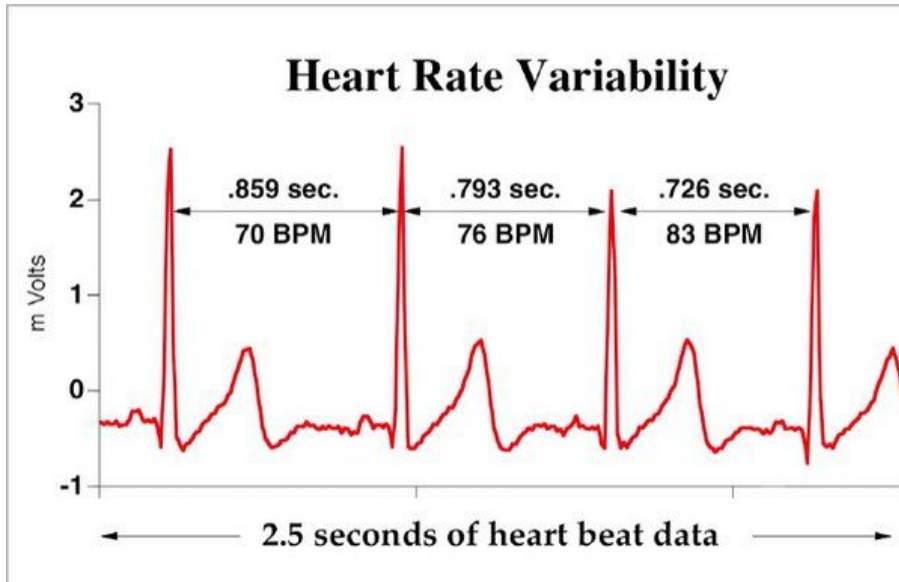


Warping Time: Using Dynamic Time Warping to Improve Machine Learning Outcomes

Kim Kraunz
ODSC West - November 2, 2023



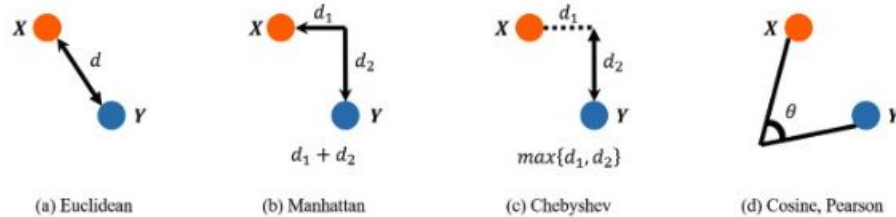
What if the time series aren't in sync?



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

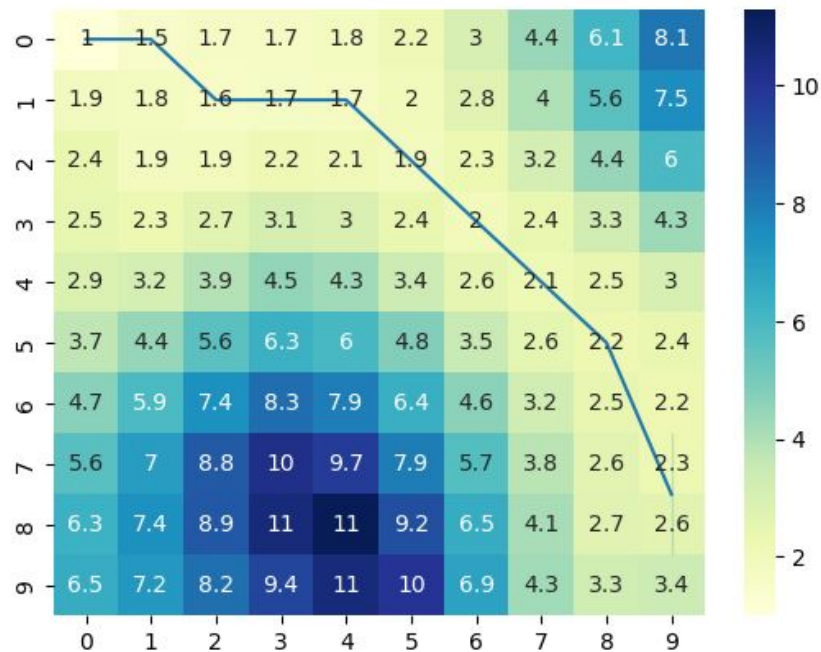
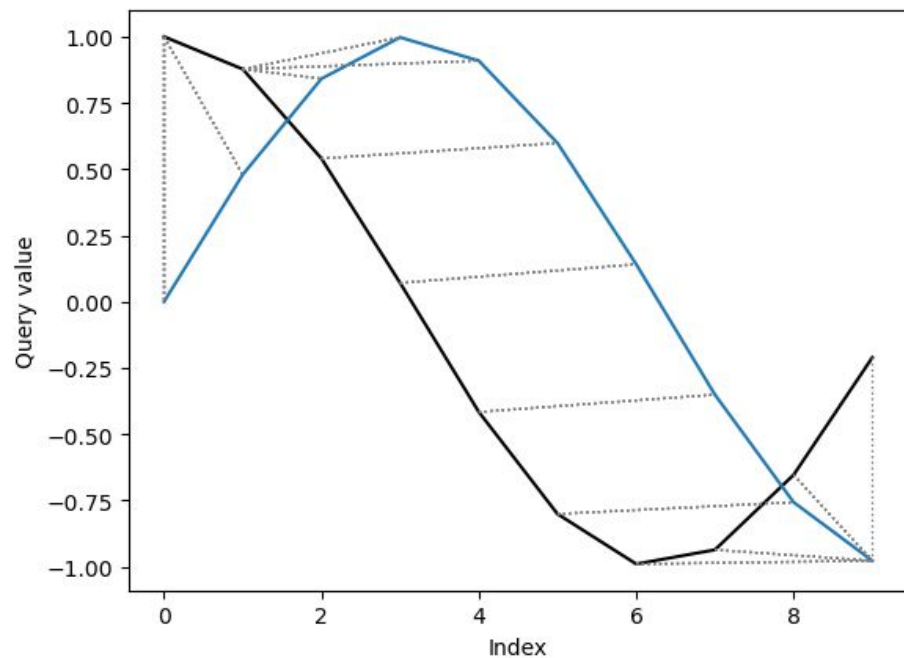
Dynamic Time Warping!



Time Warping Calculation

1. Divide the two series into equal points.
2. Calculate the distance (usually euclidean) 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





Dynamic Time Warping Packages

Python

1. [dtw-python](#)
2. [dtaidistance.dtw](#)
3. [TSLearn.metrics.dtw](#)
4. [pyts.metrics.dtw](#)
5. [FastDTW](#)

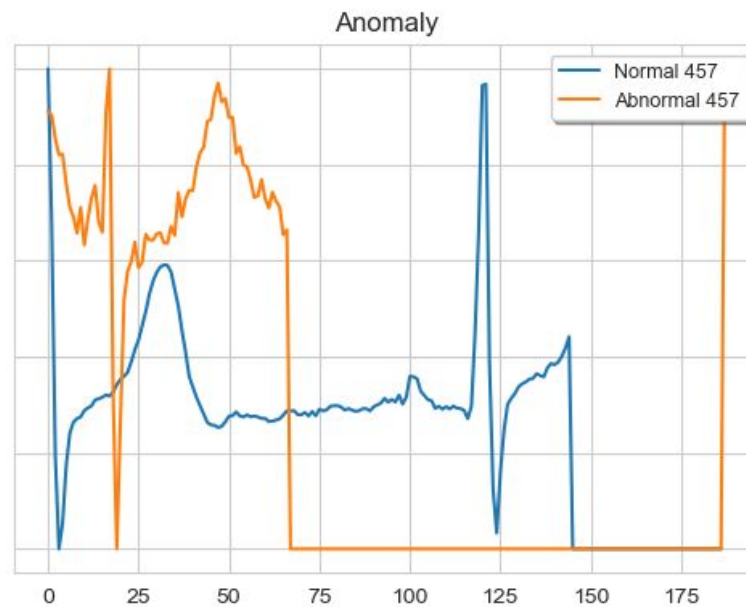
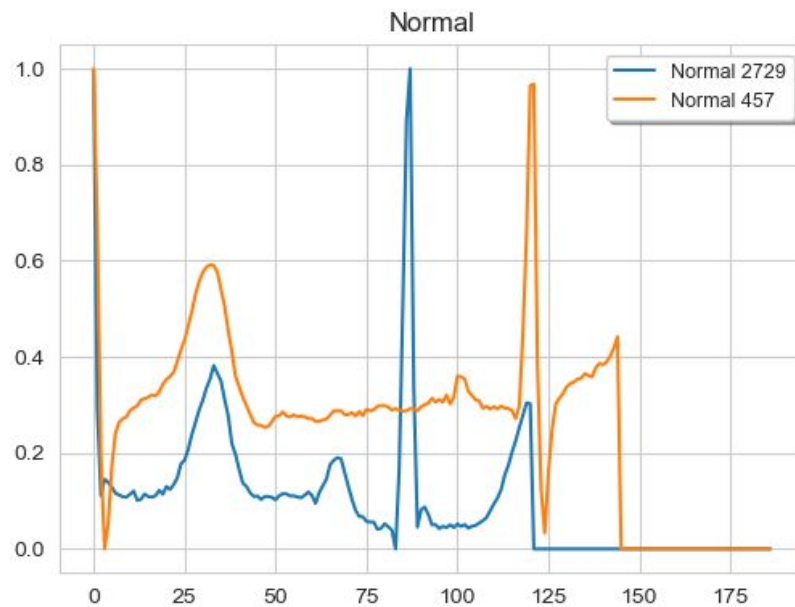
R

1. [dtw](#)
2. [IncDTW](#)

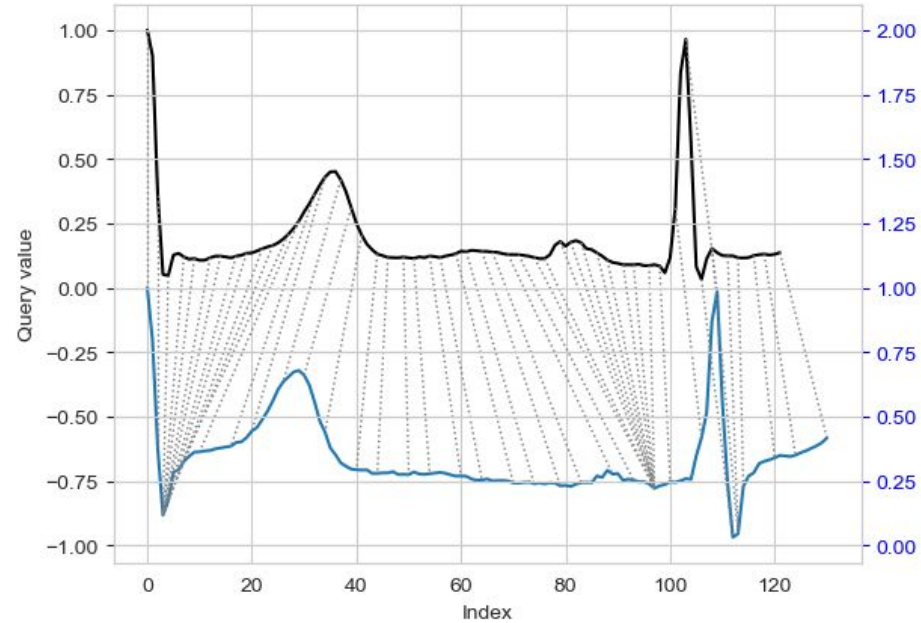
<https://forecastegy.com/posts/dynamic-time-warping-dtw-libraries-python-examples/>

Use Cases for Dynamic Time Warping

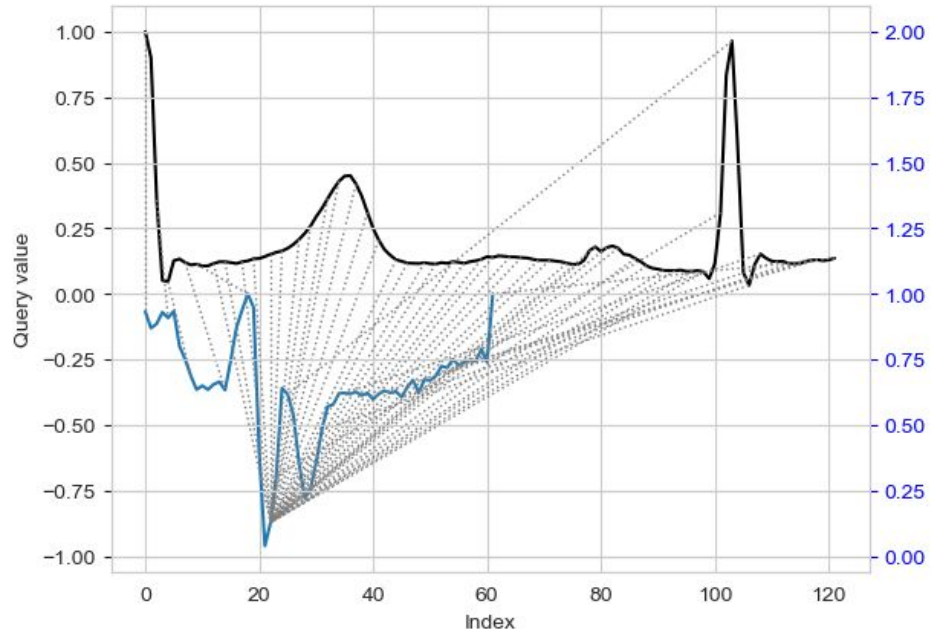
Example - ECG



Example - Normal EKG with DTW



Example - Abnormal EKG with DTW

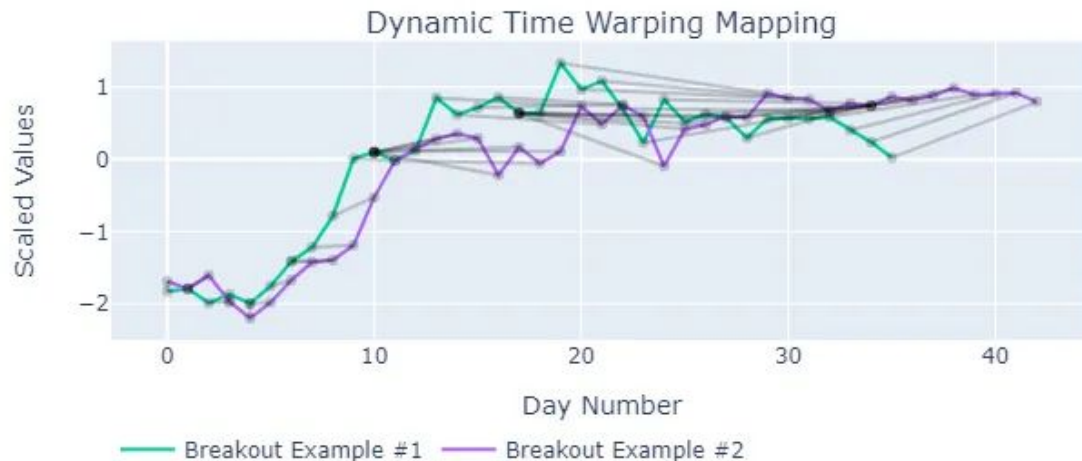


Stock Market - Tesla Momentum Pause Patterns



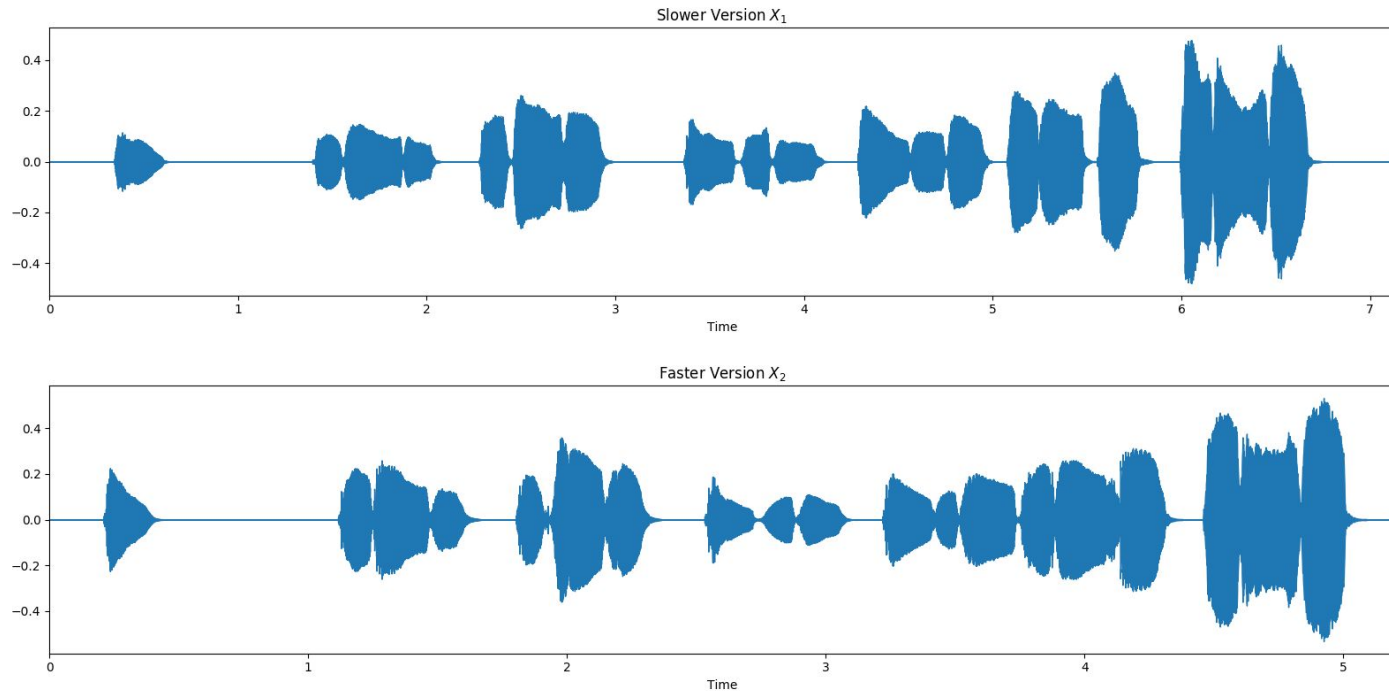
<https://medium.datadriveninvestor.com/creating-a-momentum-trading-scanner-with-dynamic-time-warping-2a4e7ceb1e1c>

Stock Market - Tesla Momentum Pause Patterns with DTW

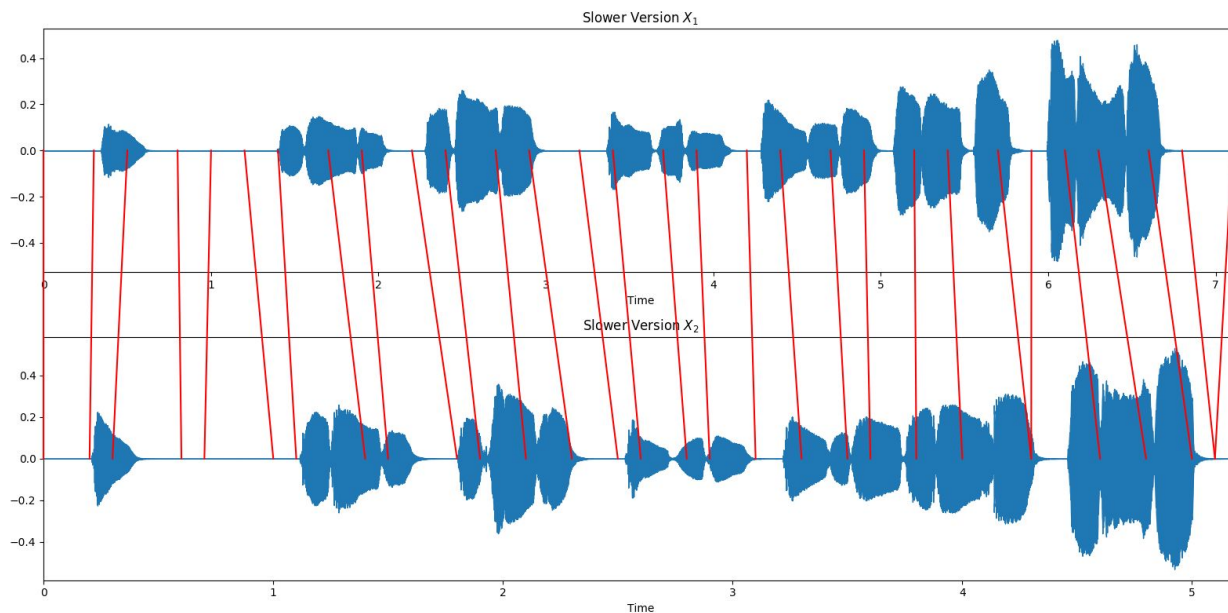




Audio



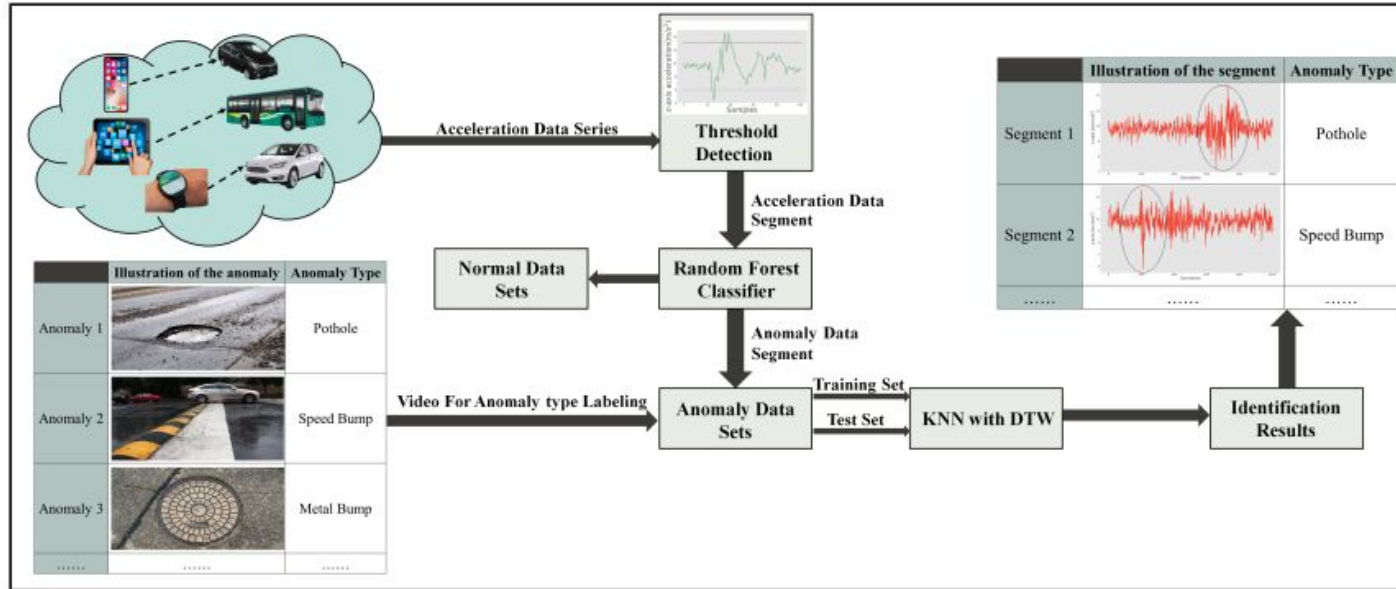
Audio with DTW



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

Machine Learning Applications

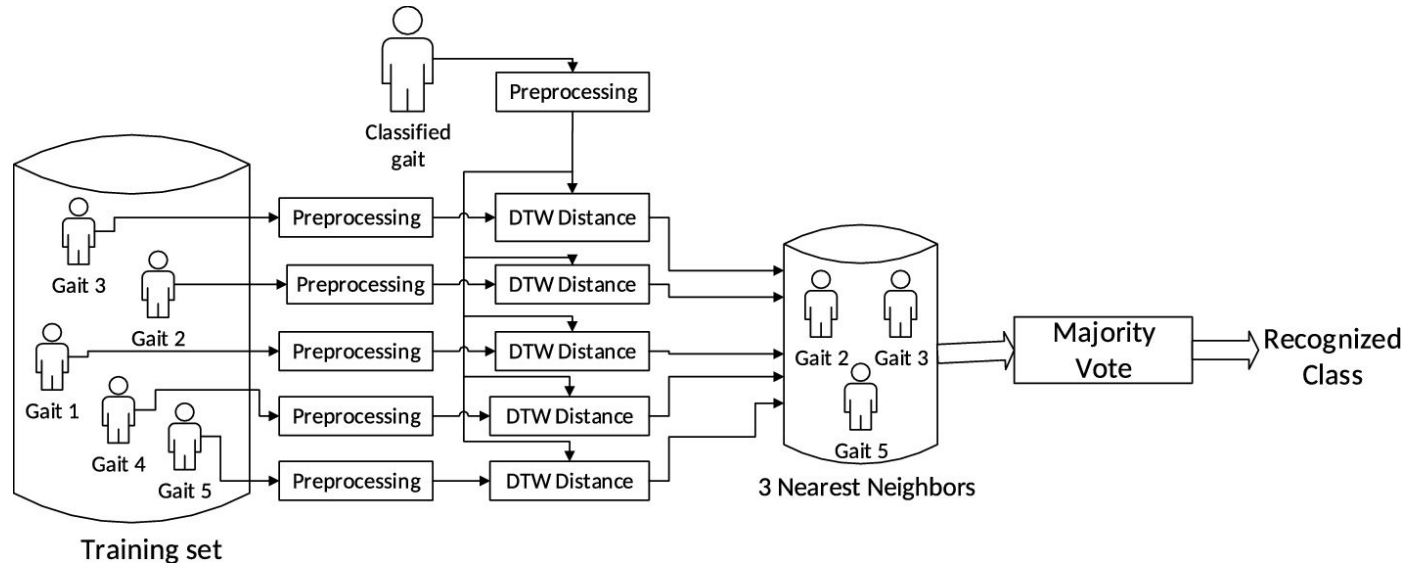
Road Anomaly Detection



Z. Zheng et al., "A Fused Method of Machine Learning and Dynamic Time Warping for Road Anomalies Detection," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 2, pp. 827-839, Feb. 2022, doi: 10.1109/TITS.2020.3016288.

Motion Capture Data

Switonski, A., Josinski, H. & Wojciechowski, K. Dynamic time warping in classification and selection of motion capture data. *Multidim Syst Sign Process* **30**, 1437–1468 (2019). <https://doi.org/10.1007/s11045-018-0611-3>





Assessment of Pulsatile Signals

Li, Qiao, and Gari D. Clifford. "Dynamic time warping and machine learning for signal quality assessment of pulsatile signals." *Physiological measurement* 33.9 (2012): 1491.

1. Resampled heartbeats to same length
2. Calculated correlation between beats
3. Used correlation as a feature in a neural network to assess the clinical utility of the waveforms

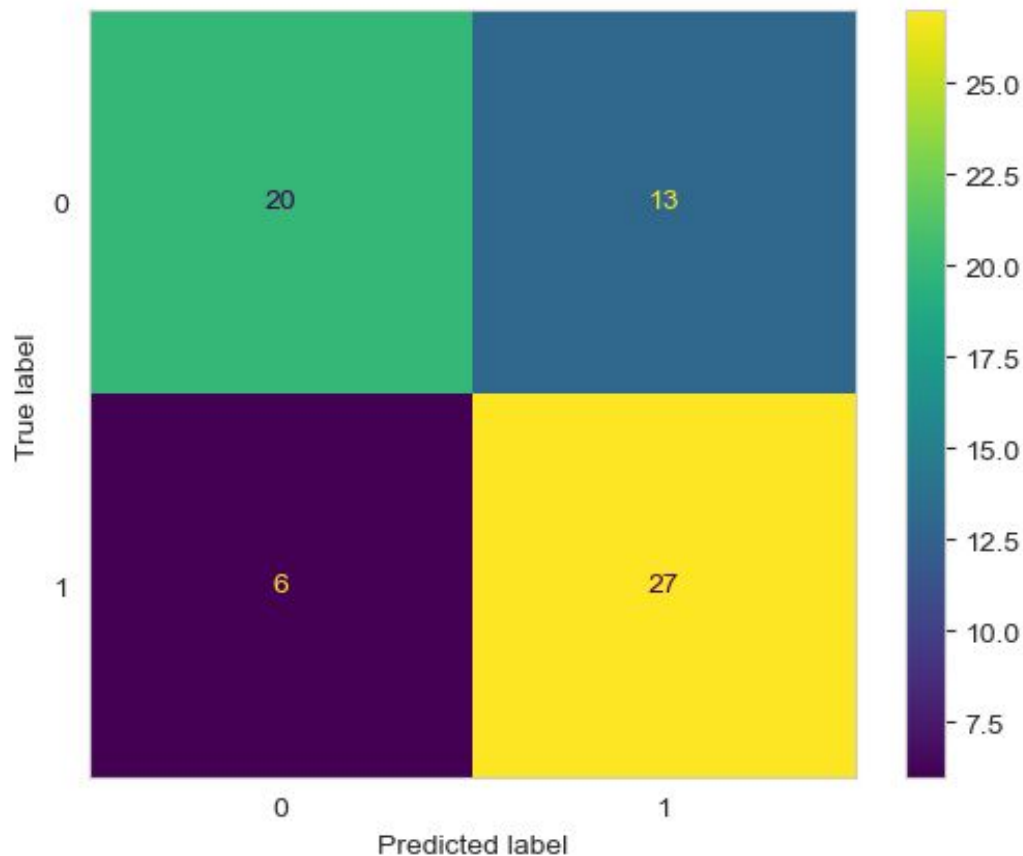


Classification as normal or abnormal EKG using data above

1. One 'normal' and one 'anomaly' heartbeat per patient
2. Limited dataset to first 100 patients
3. Calculated median dynamic time warping distance between each 'normal' and all other 'normal' patients
4. Calculated median dynamic time warping distance between each 'abnormal' and all other 'normal' patients
5. Optimized k in k nearest neighbors using recall

Results

Accuracy: 0.712
Precision: 0.675
Recall: 0.818
F1: 0.74



Questions?