Study of the “Chirpyness” of an ECG signal

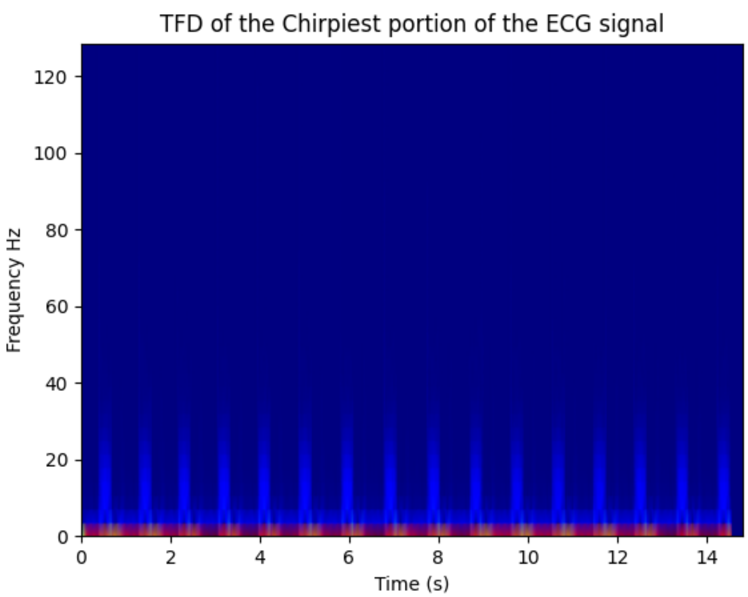
In order to calculate the chirpyness of the ECG signal I implemented the Polynomial Chirplet Transform (PCT) algorithm described in [1] (see polynomial_chirp_trans.py). The only difference is that the threshold check has no been completed – hence the threshold value for the ‘Run’ method plays no part in the output of the system. The program is designed to work for any order polynomial but in order to calculate the chirpyness the system was built and ran on a polynomial of order 2. A gaussian window of size 75 was used with an overlap of 65 units. These specific sizes were used due to the effectiveness of previous work in using PCT for ECG signal analysis [2].

Preprocessing

The ECG data from the file ‘ECOG_15’ was passed through a low pass butterworth filter with cutoff of 40 Hz, passband ripple of 3 dB, and stop band attenuation of 60 dB. The goal of the filter was to remove any artifacts due to power line interference [3]. See filter_ecg_data.py for the python implementation.

Analysis

The first 1000 data points were ignored due to its messy behaviour. The remaining data sectioned into 50 segments of 3980 samples. For each segment the PCT was performed for 3 iterations using the parameters described above. Section of data that was found to be the most chirpy were samples in the range (95520, 99500) which corresponds to the time 1:00:01 to 1:02:30.



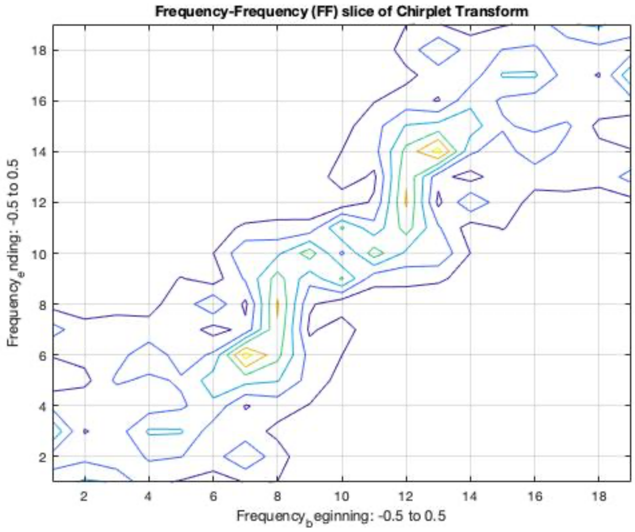
Chirpiest TFD:

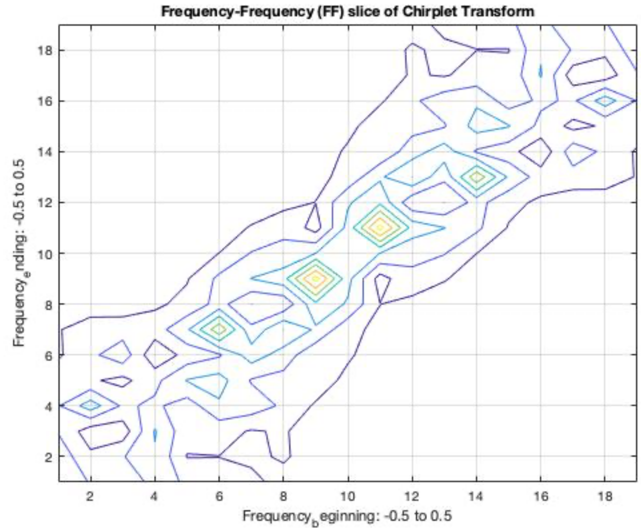
Other chirping segments included:

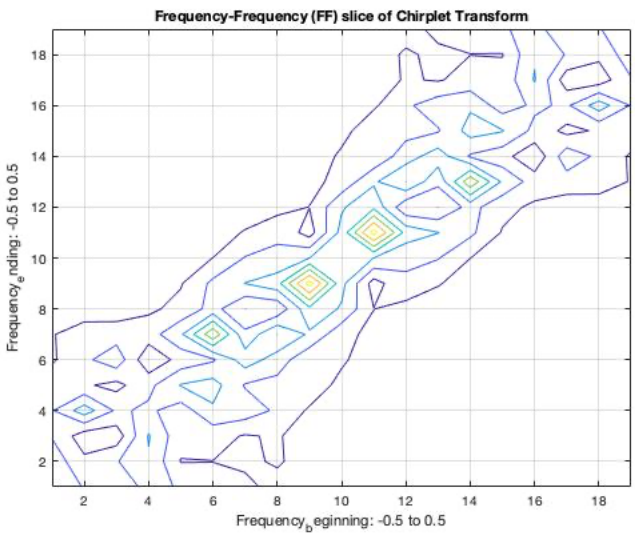
1. (0:03:05, 0:05:34)
2. (0:05:34, 0:08:02)
3. (0:10:31, 0:13:00)
4. (0:55:04, 0:57:33)
5. (0:57:33, 1:00:01)
6. (1:00:01, 1:02:30)
7. (1:02:30, 1:04:59)
8. (1:04:59, 1:07:27)
9. (1:09:55, 1:12:24)
10. (1:12:24, 1:14:53)

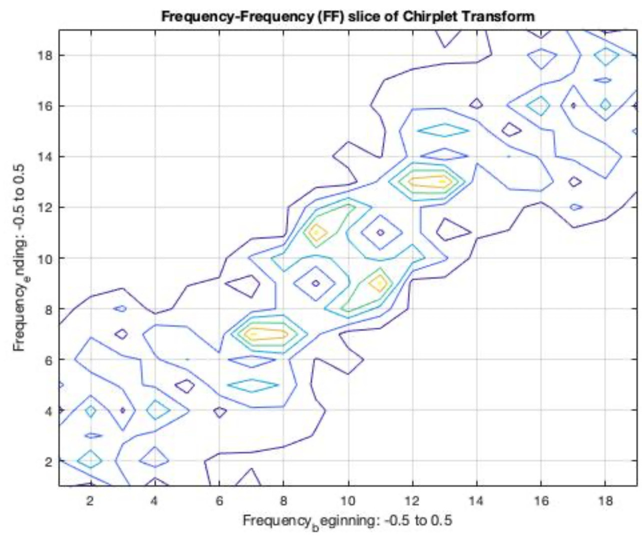
ff plane computations

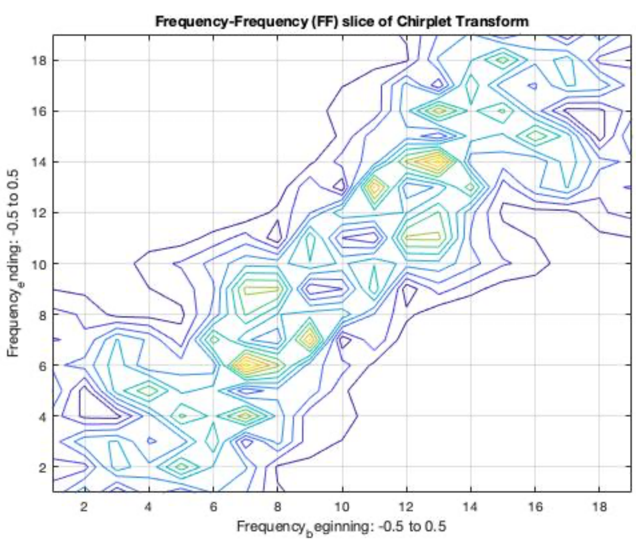
Using ff.m >> a matlab file created by Steve Mann to build a Frequency Frequency plot, the FF planes for all the above segments.

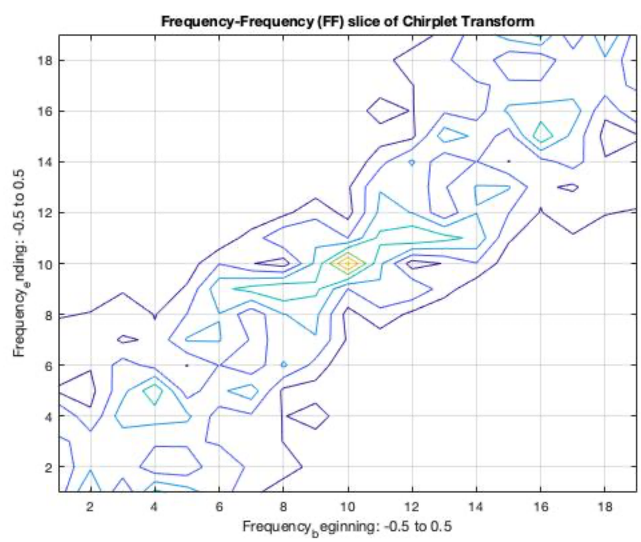

Frequency-Frequency (FF) slice of Chirplet Transform
Frequency$_e$nding: -0.5 to 0.5
Frequency$_b$eginning: -0.5 to 0.5

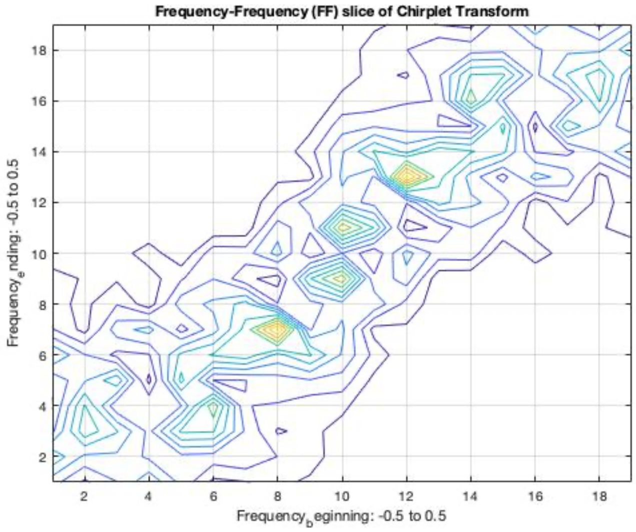

Frequency-Frequency (FF) slice of Chirplet Transform
Frequency$_e$nding: -0.5 to 0.5
Frequency$_b$eginning: -0.5 to 0.5

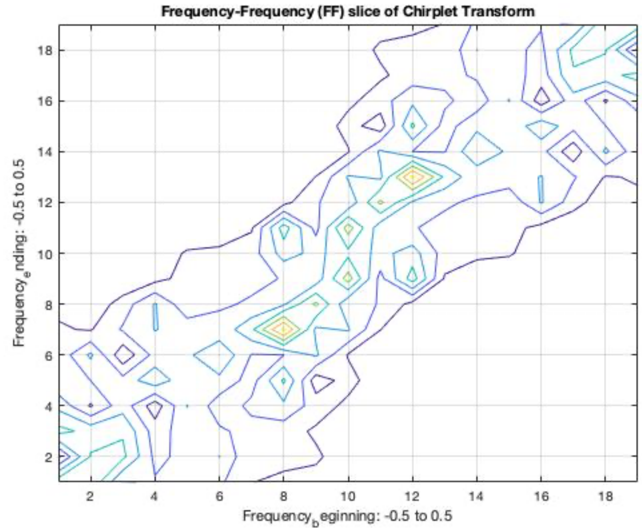

Frequency-Frequency (FF) slice of Chirplet Transform
Frequency$_e$nding: -0.5 to 0.5
Frequency$_b$eginning: -0.5 to 0.5


Frequency-Frequency (FF) slice of Chirplet Transform
Frequency$_e$nding: -0.5 to 0.5
Frequency$_b$eginning: -0.5 to 0.5


Frequency-Frequency (FF) slice of Chirplet Transform
Frequency$_e$nding: -0.5 to 0.5
Frequency$_b$eginning: -0.5 to 0.5

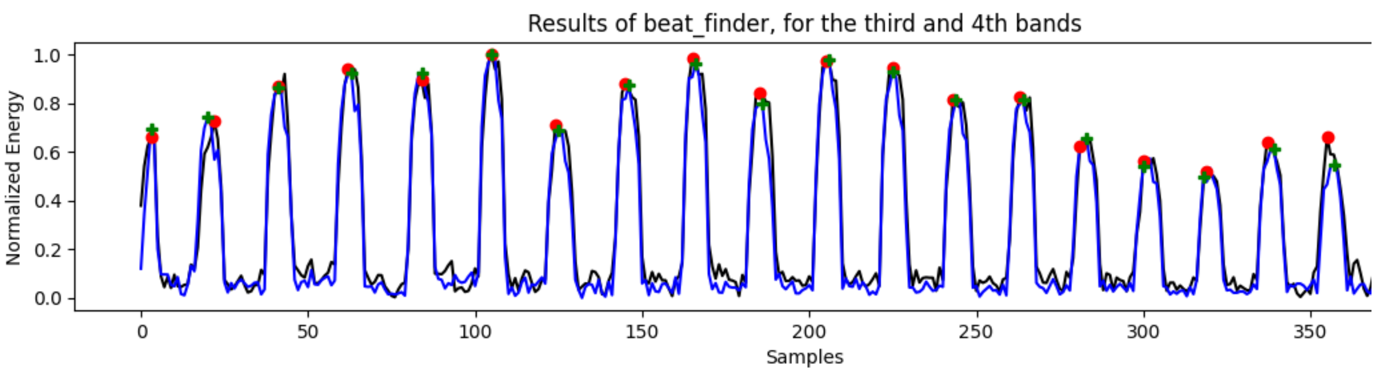

Frequency-Frequency (FF) slice of Chirplet Transform
Frequency$_e$nding: -0.5 to 0.5
Frequency$_b$eginning: -0.5 to 0.5

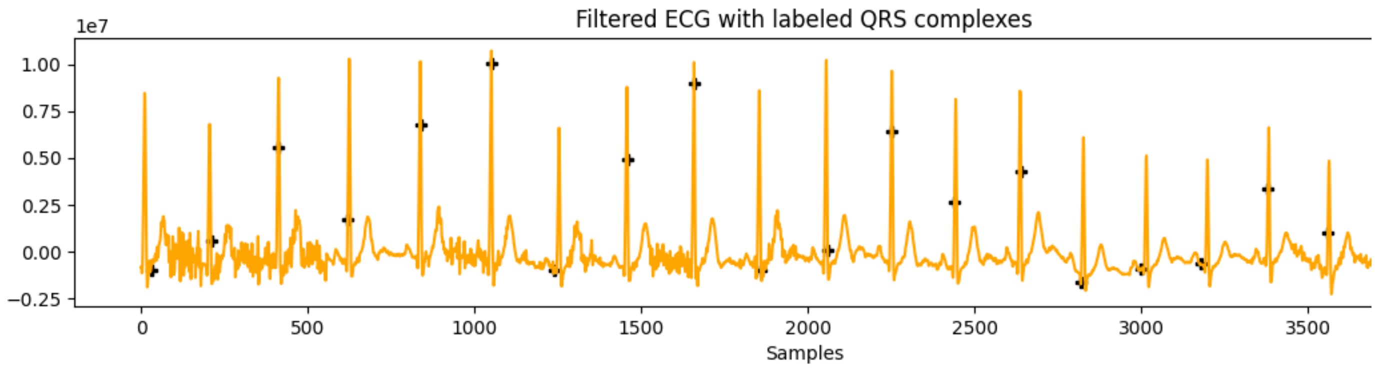




Heartbeat detector (Bonus)

Using the time-frequency distribution (TFD) calculated from a (PCT) it became possible to complete the work suggested in [2] to develop a QRS complex detector for a given ECG waveform. An adaptive threshold was used to find peaks in the 3 and 4 frequency bands of and ECG TFD. The TFD was created using the same window and overlap described above. The 3rd and 4th frequency bands were chosen because these contained the frequencies relevant to an ECG signal [2]. The adaptive threshold was initially suggested in [4] and slightly altered in [2]. A peak in an ECG signal is considered a beak if and only if the QRS complexes found in the 3rd and 4th energy match (to some degree of error). For the implementation of the threshold see 'adap_threshold.py'. For an example of how to find QRS complexes see, 'sample_heartbeat_classifier.py'. Some results for the chirpiest waveform are shown below.





References

[1] Z. Peng, G. Meng, F. Chu, Z. Lang, W. Zhang, and Y. Yang, â€œPoly- nomial chirplet transform with application to instantaneous frequency estimation,â€ IEEE Transactions on Instrumentation and Measurement, vol. 60, no. 9, pp. 3222â€"3229, 2011.

[2] G. V. S. S. K. R. Naganjaneyulu, B. S. Shaik and A. V. Narasimhadhan, "R peak delineation in ECG signal based on polynomial chirplet transform using adaptive threshold," 2016 11th International Conference on Industrial and Information Systems (ICIIS), Roorkee, India, 2016, pp. 856–860, doi: 10.1109/ICIINFS.2016.8263058.

[3] B. S. Shaik, G. V. S. S. K. R. Naganjaneyulu and A. V. Narasimhadhan, "A novel approach for QRS delineation in ECG signal based on chirplet transform," 2015 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), Bangalore, India, 2015, pp. 1–5, doi: 10.1109/CONECCT.2015.7383914.

[4] J. Pan and W. J. Tompkins, â€œA real-time QRS detection algorithm,â€ IEEE Transactions on Biomedical Engineering, vol. BME-32, pp. 230â€“ 236, March 1985.