PPG SIGNAL RECONSTRUCTION

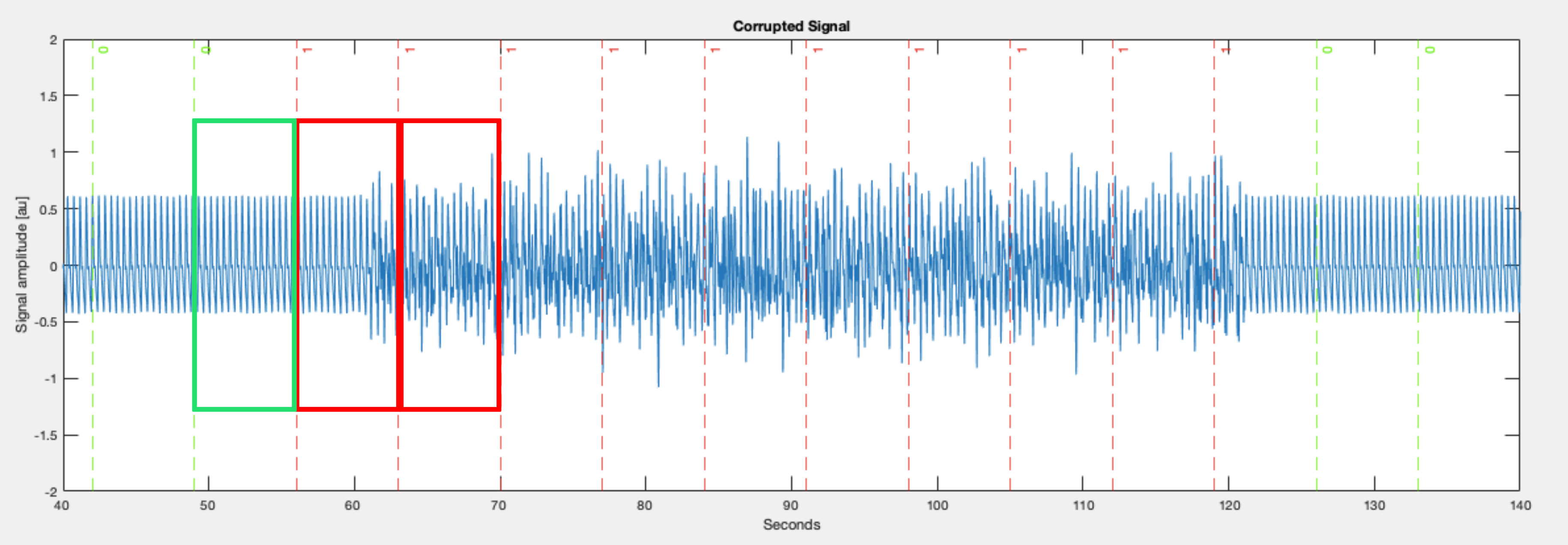
Motion and Noise Artifact Removal

PULSE OXIMETRY

- A sensor is placed on a thin part of the patient's body, usually a fingertip or earlobe.
- The device sends light for two wavelengths through the body part to a photodetector. It measures the absorbance that is made to vary on each of the wavelengths, allowing it to determine the absorbances due to pulsating arterial blood alone.

IMAR ALGORITHM INPUT

- Corrupted and filtered signal
- Labels



STEP 1

- Compute SVD on both corrupted data segments and their most prior adjacent data segments

$$T_x = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_K \end{bmatrix} = \begin{bmatrix} x_1 & x_2 & \dots & x_L \\ x_2 & x_3 & \dots & x_{L+1} \\ \vdots & \vdots & \ddots & \vdots \\ x_K & x_{K+1} & \dots & x_N \end{bmatrix}$$

SVD

- The Singular Value Decomposition is a factorization of a matrix based on the use of eigenvalues and eigenvectors.

$$A = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{pmatrix} = \underbrace{\begin{pmatrix} u_{11} & u_{12} & \dots & u_{1r} \\ u_{21} & u_{22} & \dots & u_{2r} \\ \vdots & \vdots & \ddots & \vdots \\ u_{m1} & u_{m2} & \dots & u_{mr} \end{pmatrix}}_{\substack{\text{U} \\ \text{orthonormal matrix}}} \cdot \underbrace{\begin{pmatrix} s_1 & 0 & \dots & 0 \\ 0 & s_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & s_r \end{pmatrix}}_{\substack{\text{S} \\ \text{diagonal matrix}}} \cdot \underbrace{\begin{pmatrix} v_{11} & v_{12} & \dots & v_{1n} \\ v_{21} & v_{22} & \dots & v_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ v_{r1} & v_{r2} & \dots & v_{rn} \end{pmatrix}}_{\substack{\text{V'} \\ \text{conjugate transpose of a} \\ \text{unitary matrix}}}$$

STEP 2

- Keep the top 5% of the clean and corrupted components, based on the eigenvalues being sorted from largest to smallest

$$U: K \times L \longrightarrow U: K \times 50$$

$$S: L \times L \longrightarrow \sqrt{\lambda}: 1 \times 50$$

$$V: L \times L \longrightarrow V: L \times 50$$

STEP 3

- Replace the corrupted eigenvalues with corresponding clean eigenvalues

$$\sqrt{\lambda}\ \text{corrupted} \leftarrow \sqrt{\lambda}\ \text{clean}$$

STEP 4

- Among the clean and corrupted components, only choose those with frequency within the heart rate frequency range of $0.66 < F_S < 3$ Hz

$$Uf \longleftarrow U \text{ in the frequency domain}$$

$$0.66 < Uf < 3 \text{ Hz}$$

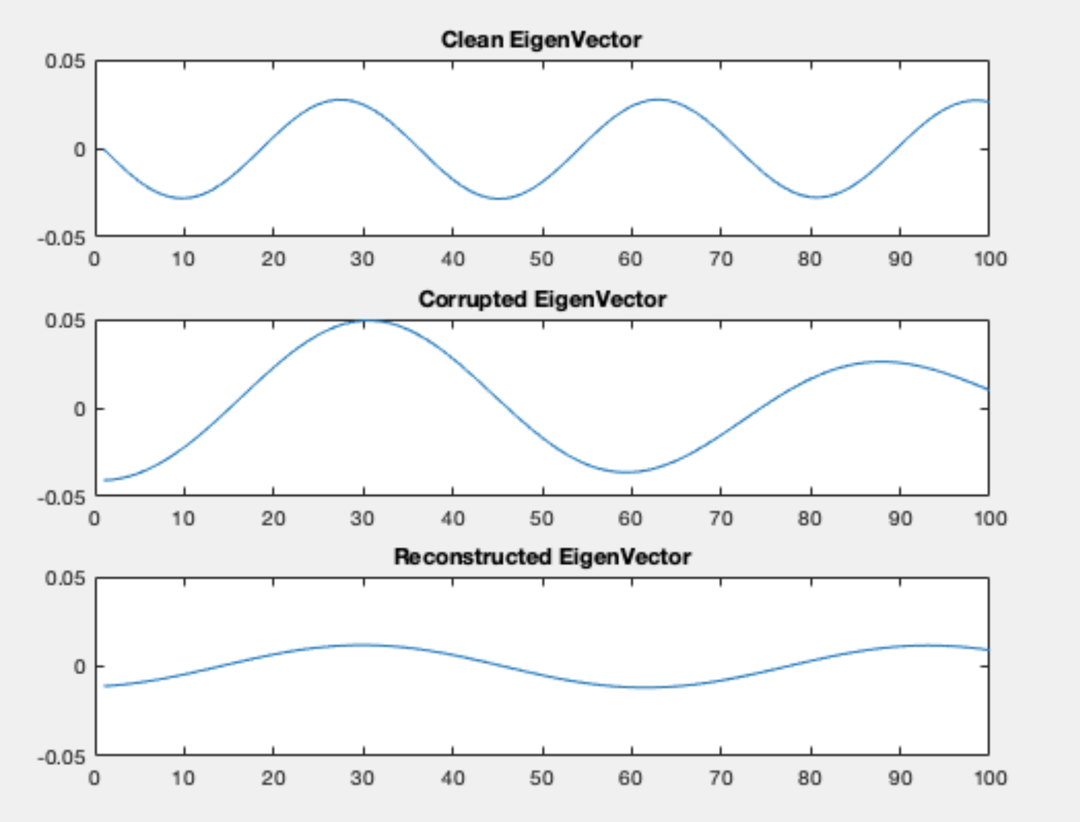
STEP 5

- Apply frequency matching to discard those corrupted components with different frequencies compared to clean components’ frequencies

| Uf_clean – Uf_corrupted | < 0.5

STEP 6

- Remove corruption from each component by applying the basic SSA algorithm iteratively



SSA

The Singular Spectrum Analysis is a non-parametric spectral estimation method composed by:

- Singular Decomposition
  - Embedding
  - Singular Value Decomposition

- Spectral Reconstruction
  - Grouping
  - Diagonal averaging

STEP 6.a

- Calculate the discarding metric for components achieved from SSA iterations and their counterpart clean components

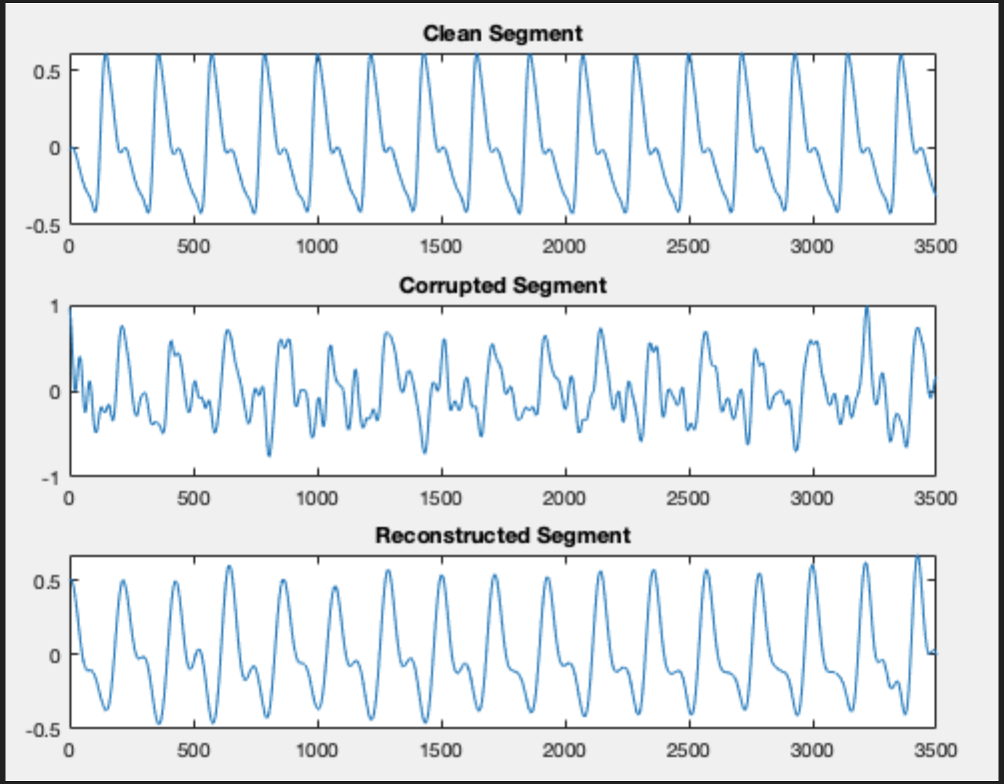
$$DM = \sum \frac{|u|}{L(u)}$$

STEP 6.b

- Select those processed components with the closest DM and frequency value to the corresponding clean component’s DM and frequency value

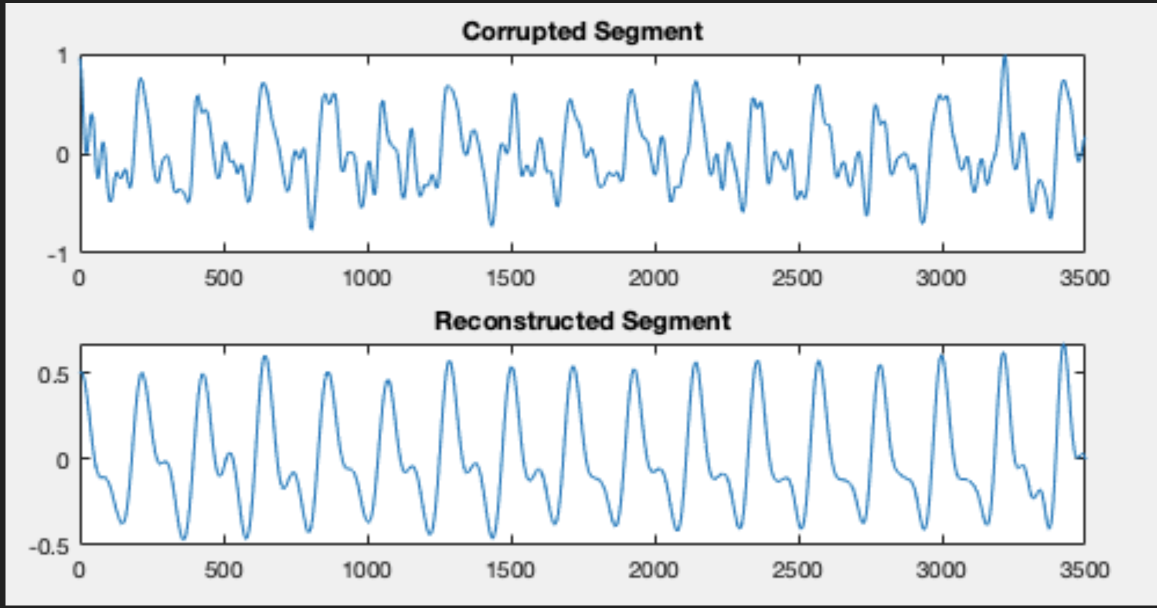
STEP 7

- Reconstruct the corrupted PPG segment based on the components achieved from the previous step

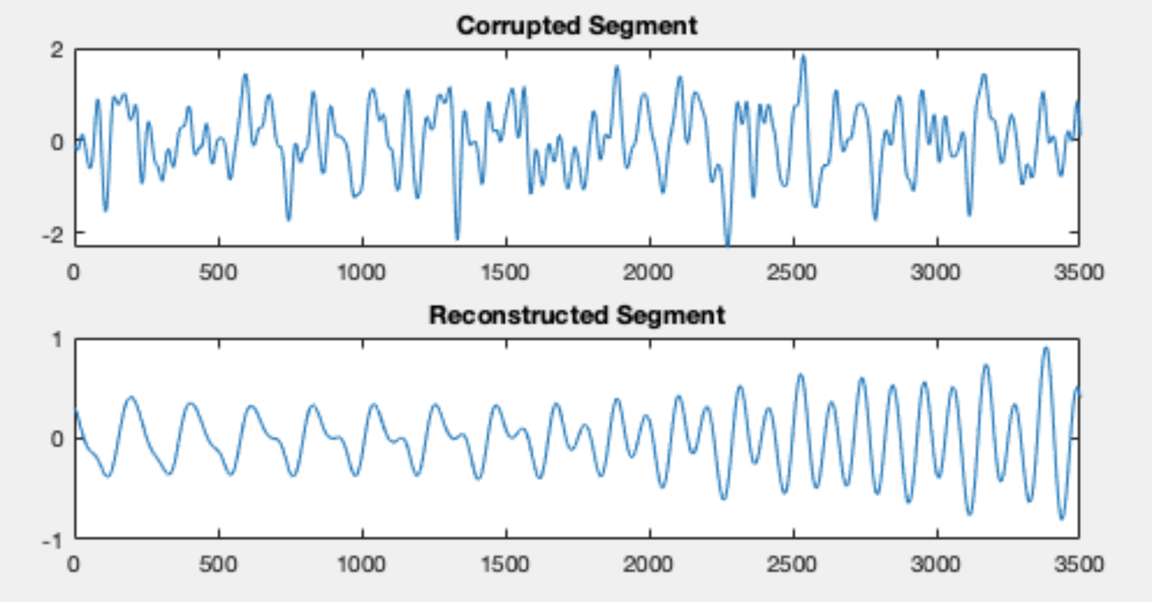


SNR

- SNR = -10dB



- SNR = -20dB



END

Thank you for the attention