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PPG Sensors

ECG Reconstruction via PPG: A Pilot Study

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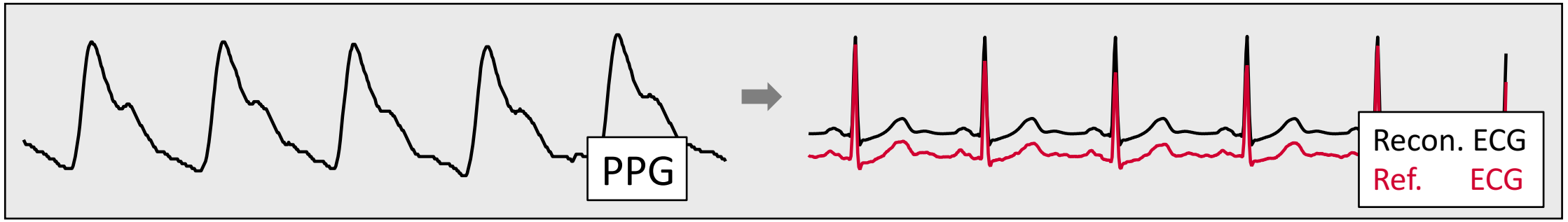
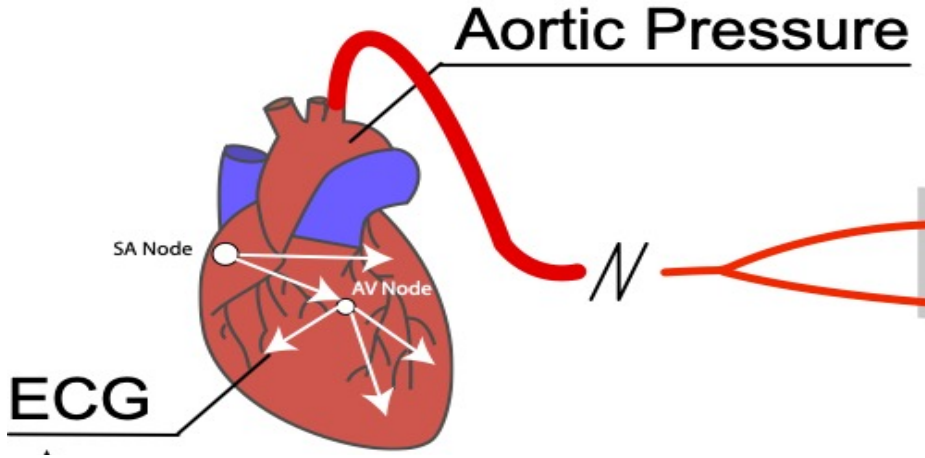
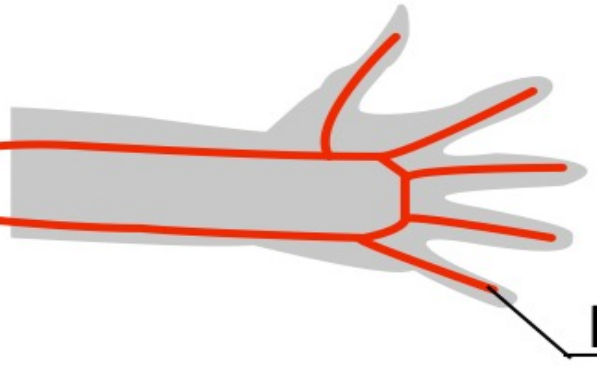


ECG vs. *PPG* — Pros and Cons





Clinical Gold Standard	Rapid Growth of Wearable Tech
Rich Knowledge Base	Limited Knowledge Base
User-unfriendly	User-friendly and Cheaper

ECG from PPG — Benefits and Research Problems

Knowledge Base

Low Cost

Continuous Real-time

User Friendly

Two major research problems:

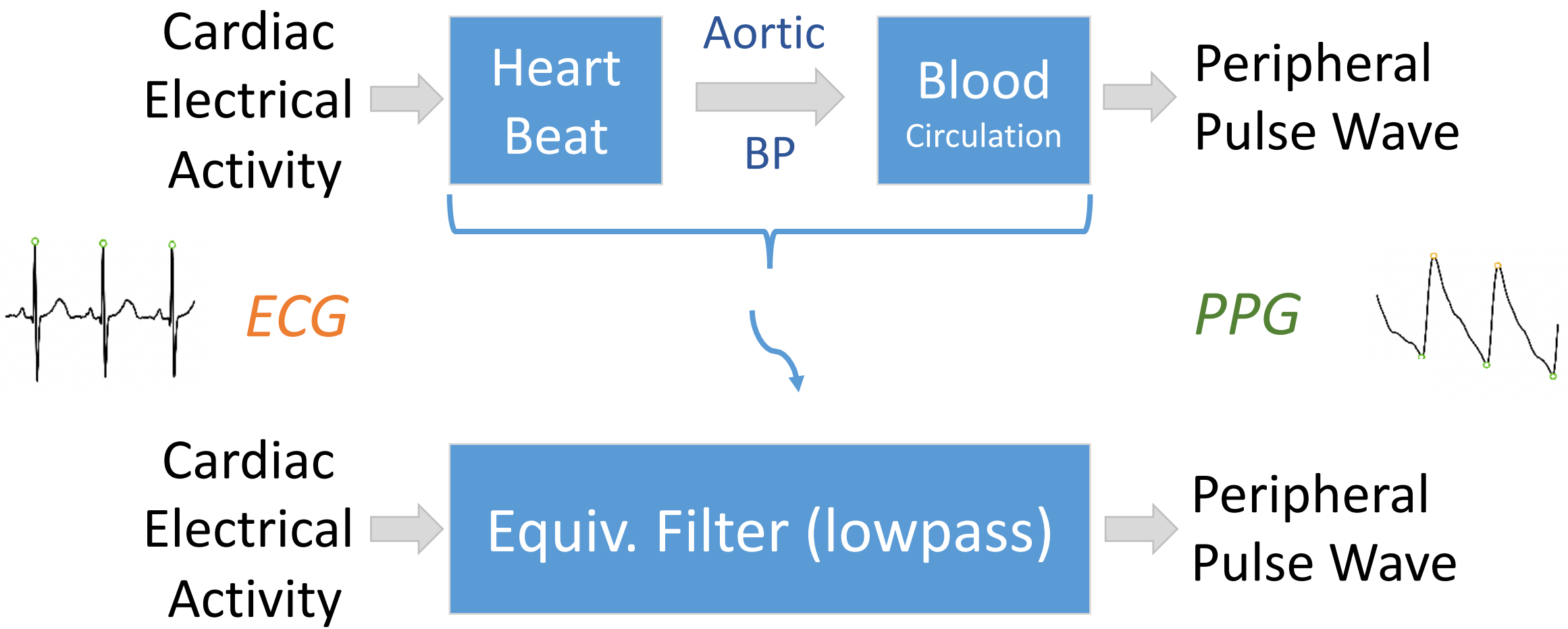
1. Infer ECG from *clean* PPG?

Fundamental & our focus

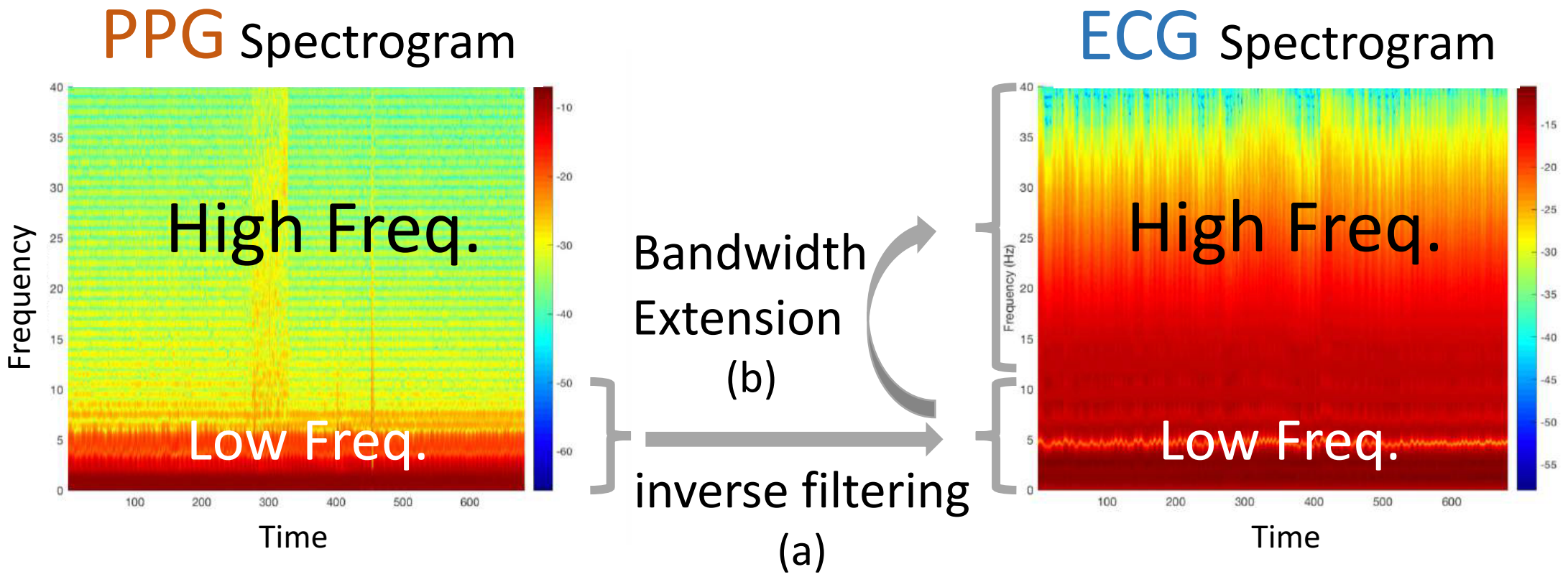
2. Clean up noisy PPG due to movement etc.?

   - Leverage multiple sensors (e.g., accelerometers)

A System Model from ECG to PPG



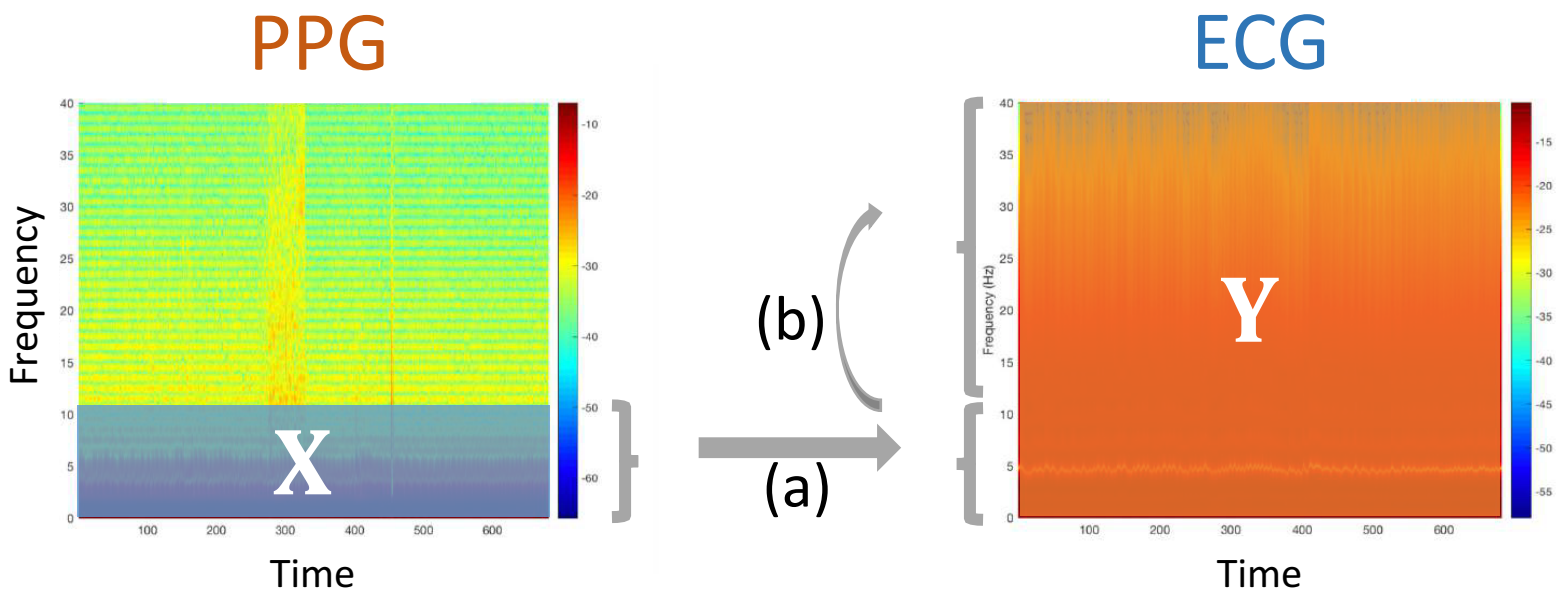
PPG to ECG: Methodology At-a-Glance



- Combine (a) and (b) with *model + data supported learning*

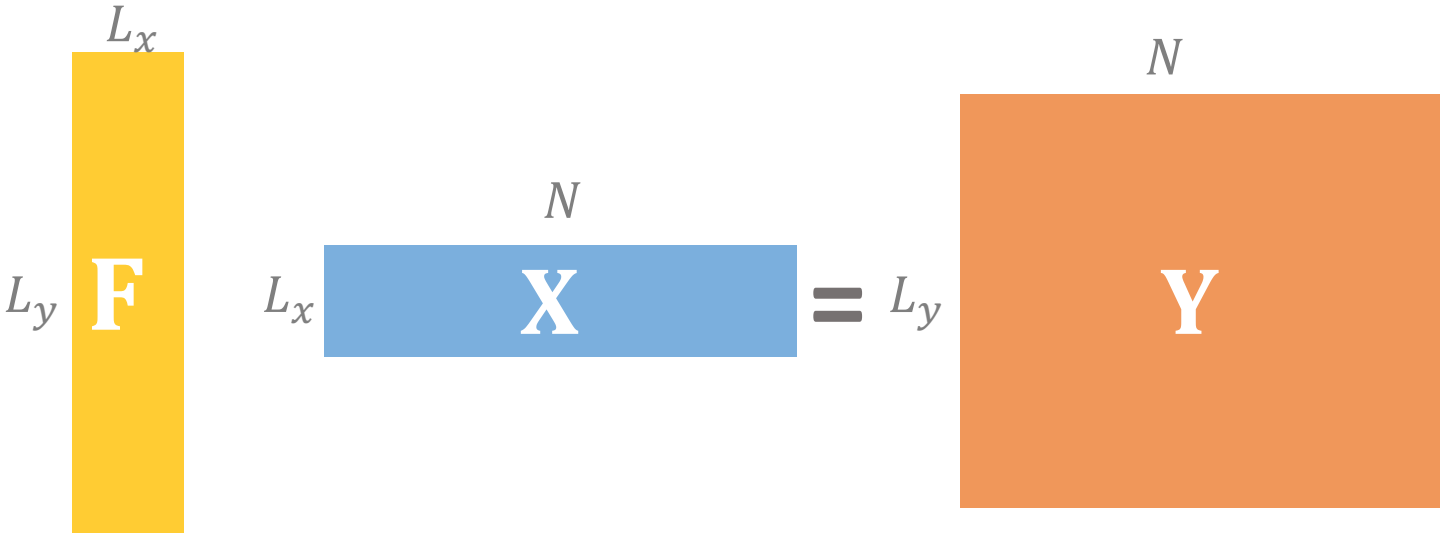
PPG to ECG: Methodology At-a-Glance (cont.)

Combine (a) and (b) with model and data learning



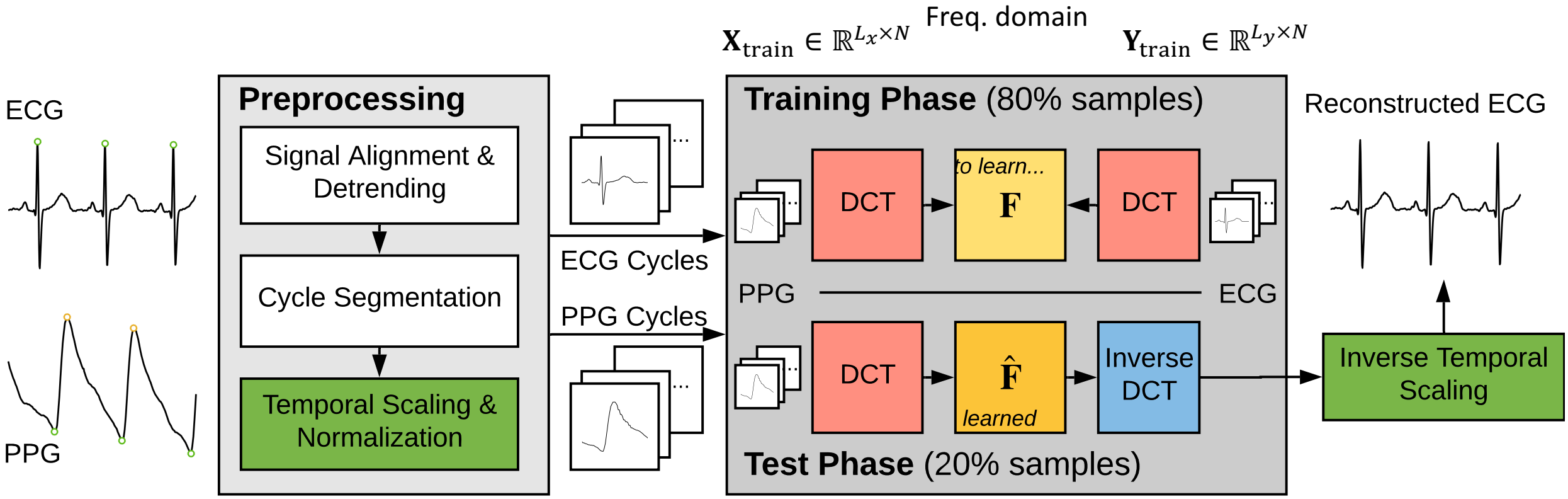
Model in freq. domain

Linear transform $\mathbf{F}$:



- L_x: # PPG freq. Coeffi.
- L_y: # ECG freq. Coeffi.
- N: # time indices

A Cycle-based Learning Framework



$$\hat{\mathbf{F}} = \underset{\mathbf{F}}{\operatorname{argmin}} \|\mathbf{F}\mathbf{X}_{\text{train}} - \mathbf{Y}_{\text{train}}\|_F^2 + \gamma \|\mathbf{F}\|_F^2$$

A linear transform f learned by *ridge regression*

Two Datasets for System Evaluation

Capnobase TBME-RR (by UBC, publicly available) [1]

- http://part.cfri.ca (UBC Pediatric Anesthesia Research)
- 29 Children (0.8-16.5 yr, median 8.7), 13 adults (26.2-75.6 yr, median 52.4)
- 300Hz ECG, 100Hz PPG

New

Mini-MIMIC (selected data from MIT MIMIC III database [2])

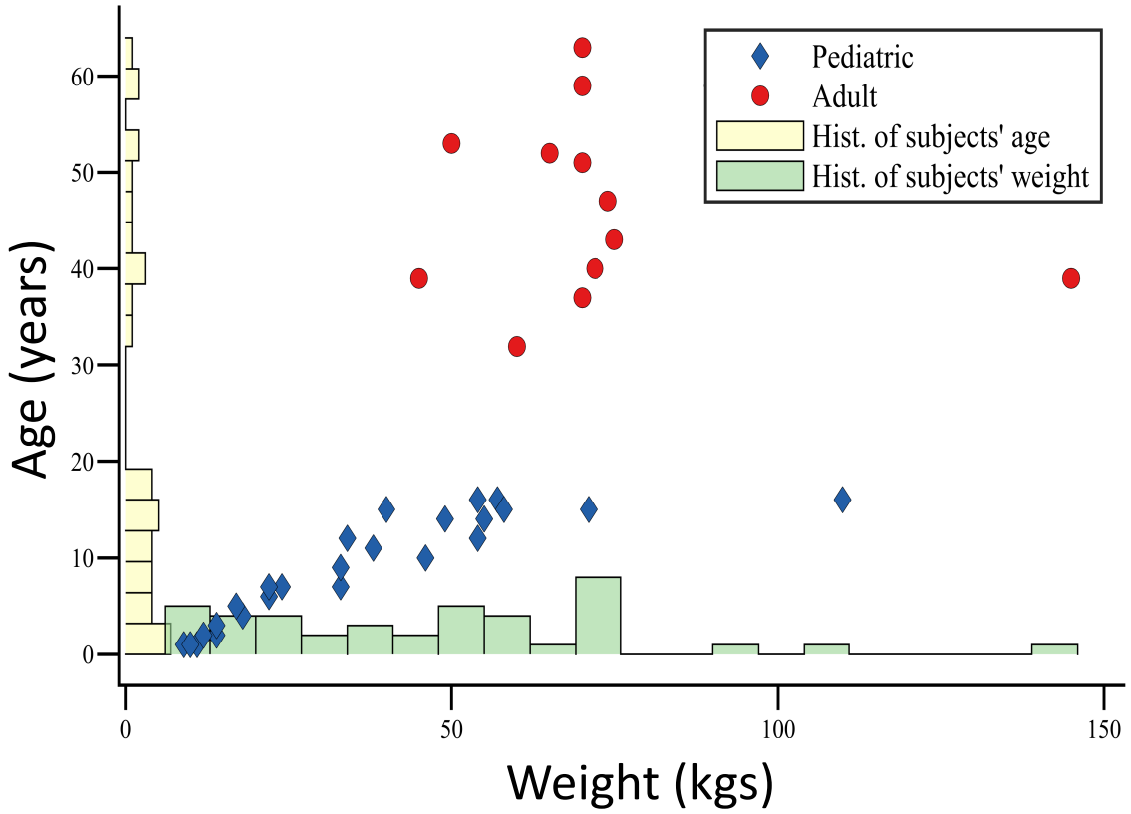
- ICU data with various cardio patients and non-cardio ones

[1]. Karlen, W., Raman, S., Ansermino, J. M., & Dumont, G. A. (2013). Multiparameter Respiratory Rate Estimation from the Photoplethysmogram. IEEE Transactions on Biomedical Engineering, 60(7), 1946-1953.

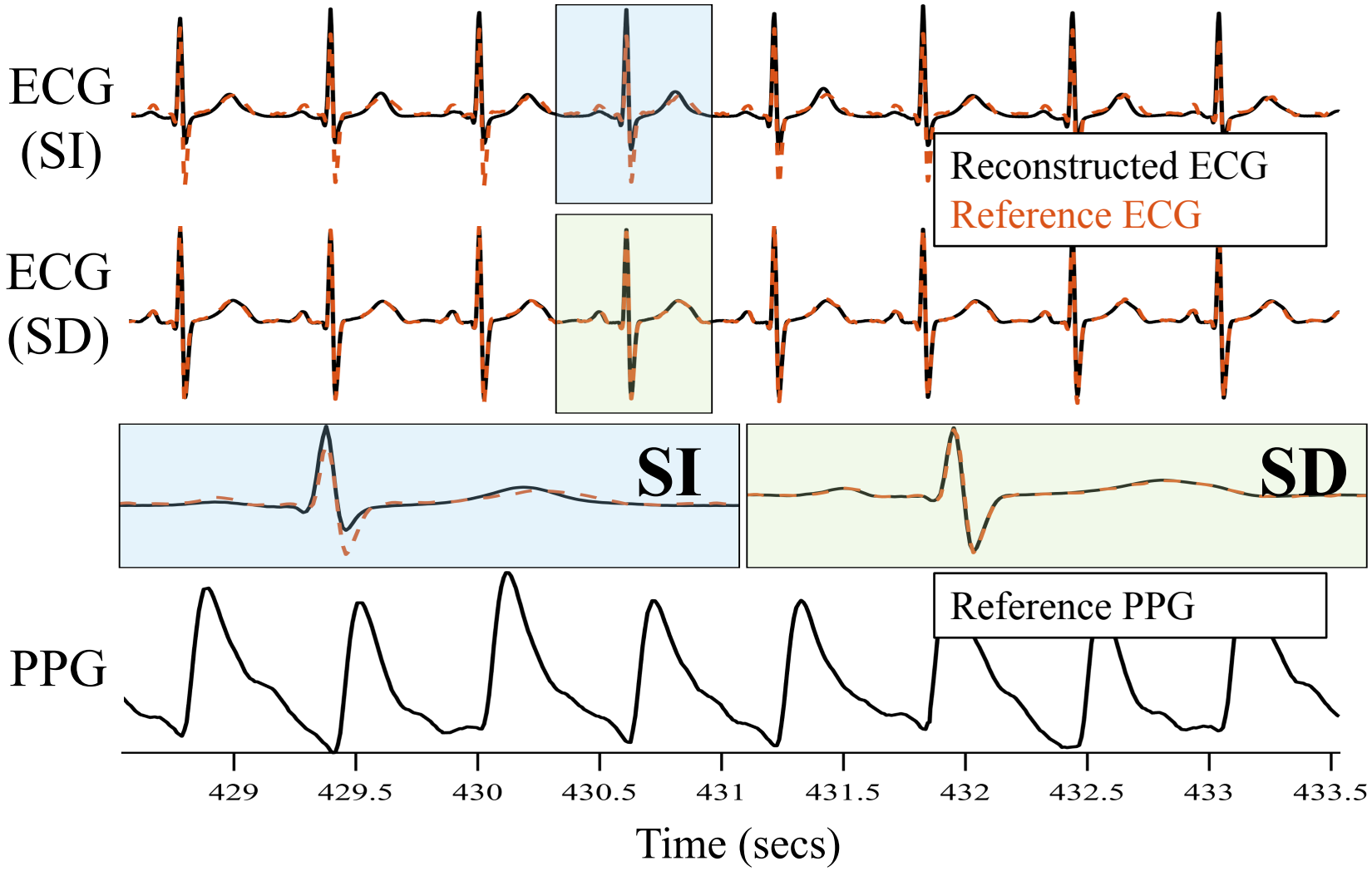
[2]. Johnson, A. E., Pollard, T. J., Shen, L., Li-wei, H. L., Feng, M., Ghassemi, M., ... & Mark, R. G. (2016). MIMIC-III, a freely accessible critical care database. Scientific data, 3, 160035.

Dataset 1— Capnobase TBME-RR

- **Capnobase TBME-RR** (by UBC, publicly available) [1]
  - 29 Children, 13 adults
  - 300Hz ECG, 100Hz PPG
- **Training Types**
  - *Sub. Dep.* (SD):
    Train and Test on each subject
  - *Sub. Indep.* (SI) :
    Train and Test over the dataset



Subject Dependent (SD) vs. Independent (SI) Model



- One example
  4 years old, 18 kg
- Pearson's correlation coeff.
  SD: 0.991
  SI: 0.883

Quantitative Results

Two Evaluation *Metrics*

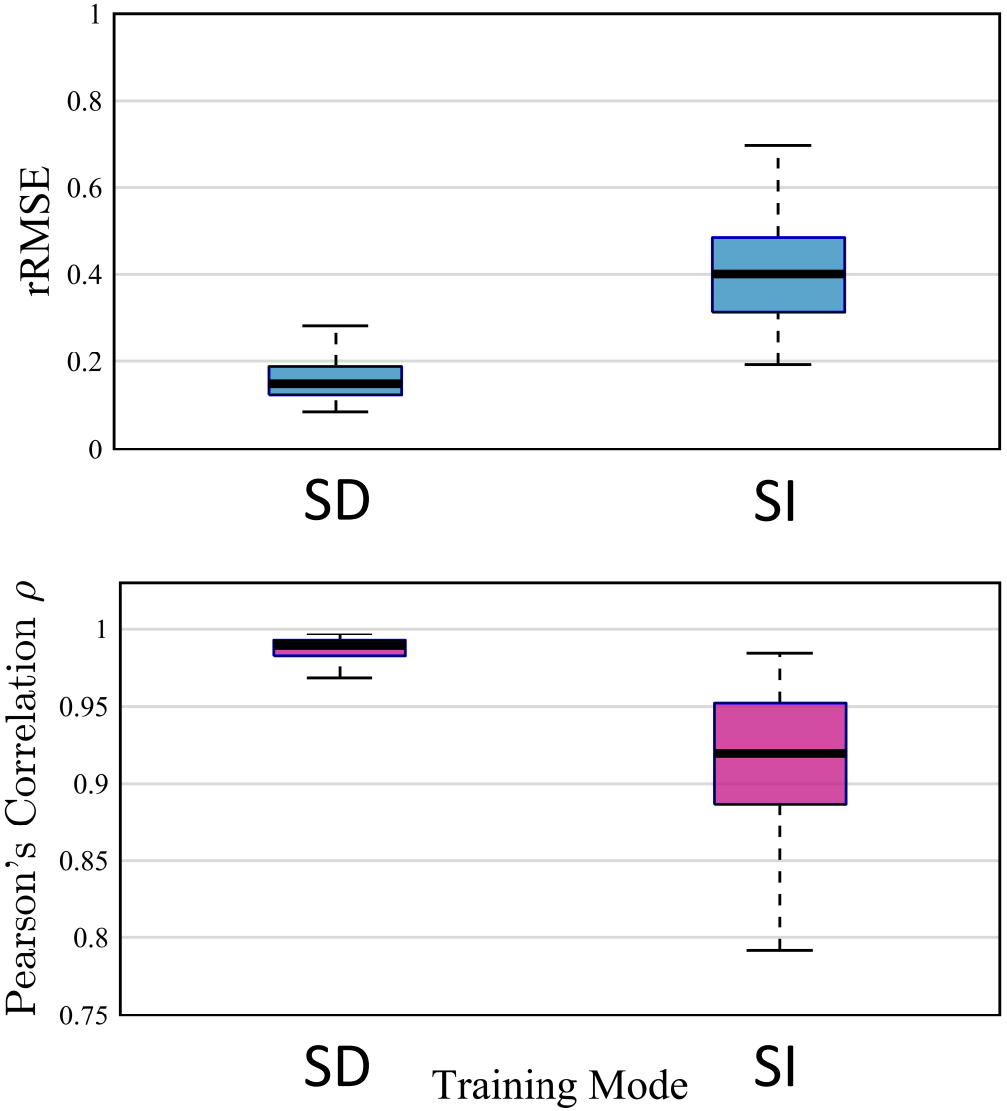
- Relative Root Mean Square Error

$$\mathrm{rRMSE} = \frac{\|\boldsymbol{y} - \hat{\boldsymbol{y}}\|_2}{\|\boldsymbol{y}\|_2}$$

- Pearson's Correlation Coefficient

$$\rho = \frac{(\boldsymbol{y} - \bar{y})^{\mathrm{T}}(\hat{\boldsymbol{y}} - \bar{\hat{y}})}{\|\boldsymbol{y} - \bar{y}\|_2 \|\hat{\boldsymbol{y}} - \bar{\hat{y}}\|_2}$$

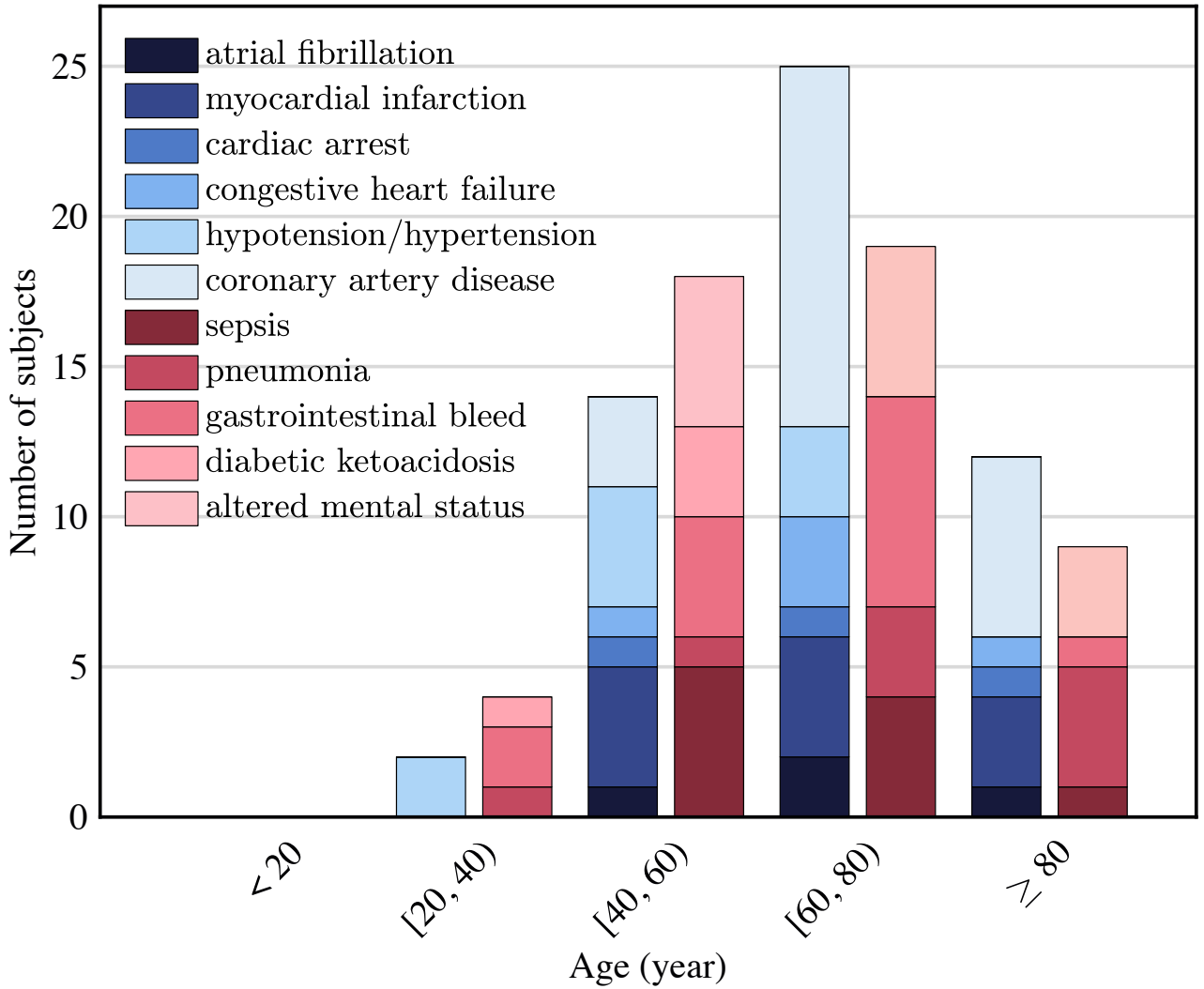
Average	SD	SI
rRMSE	0.17	0.42
ρ	0.98	0.91



Dataset 2: Mini-MIMIC III

Selected PPG and ECG data from MIMIC III database [2]

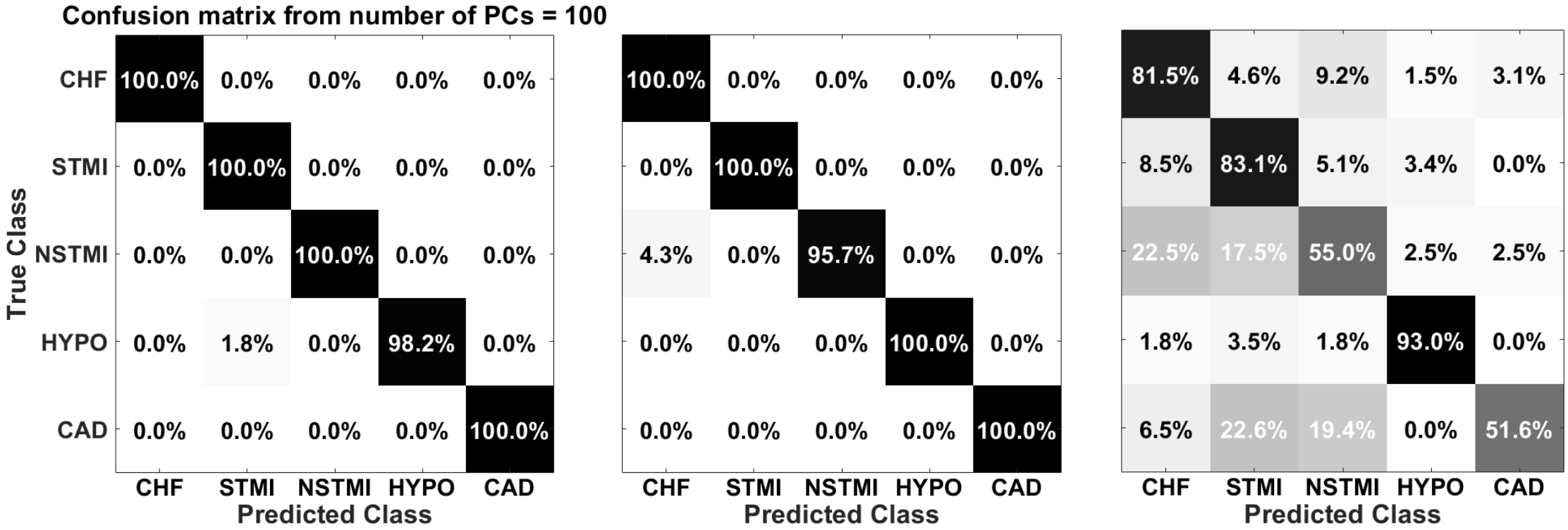
- 50 Cardiac Patients
- 53 Non-cardiac Patients



Prelim Result: Cardio Disease Classification

Confusion matrices & classification accuracy of SVM (w/ polynomial kernel) on …

	Ori. ECG (ref.)	**Recon. ECG (Proposed)**	**Ori. PPG**
Accuracy:	99.6%	**99.3%**	76.6%



Summary and Conclusion

- Combine physio. model with bio-insight and data
- Encourage accuracy of ECG reconstruction tested on two public datasets
- Facilitate explainable AI on cardio-related wearables
- Leverage rich ECG knowledge base
- Support public health in the big picture

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