

Qiang Zhu<sup>1</sup>, Xin Tian<sup>1</sup>, Chau-Wai Wong<sup>2</sup>, and Min Wu<sup>1</sup>

<sup>1</sup> Electrical and Computer Engineering, University of Maryland, College Park <sup>2</sup> Electrical and Computer Engineering, North Carolina State University

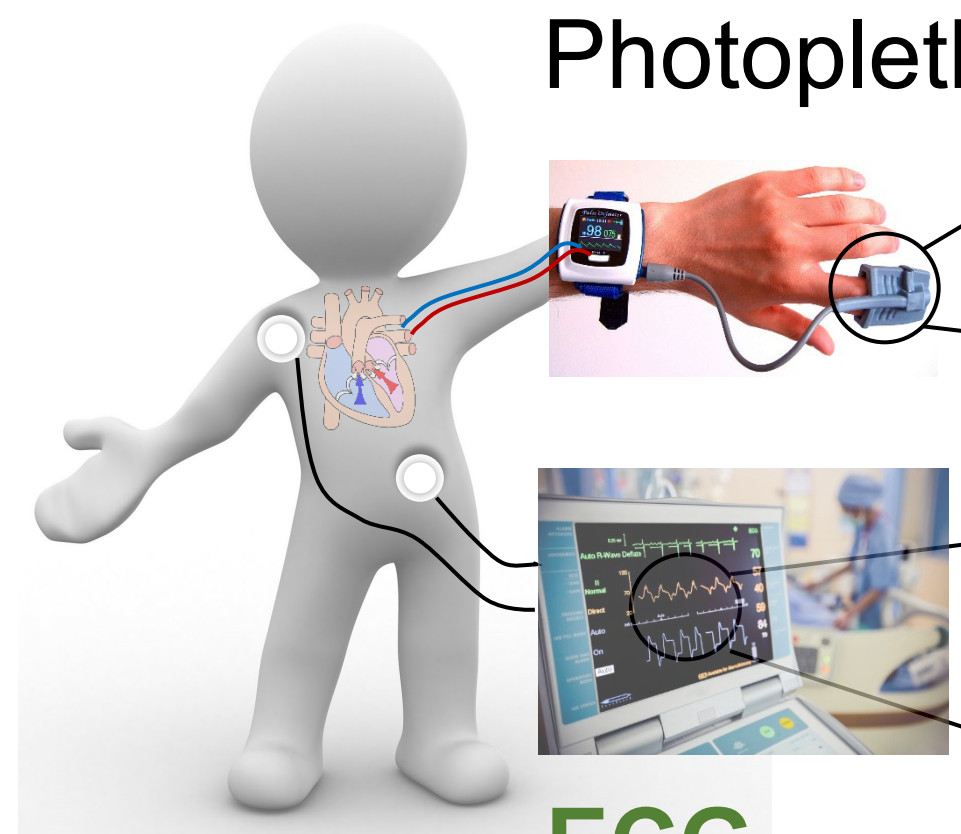
## Motivation

### Continuous Cardiovascular Monitoring

**PPG**

Photoplethysmogram

Less direct cardiac information  
More user-friendly and cheaper



**ECG**

Electrocardiogram

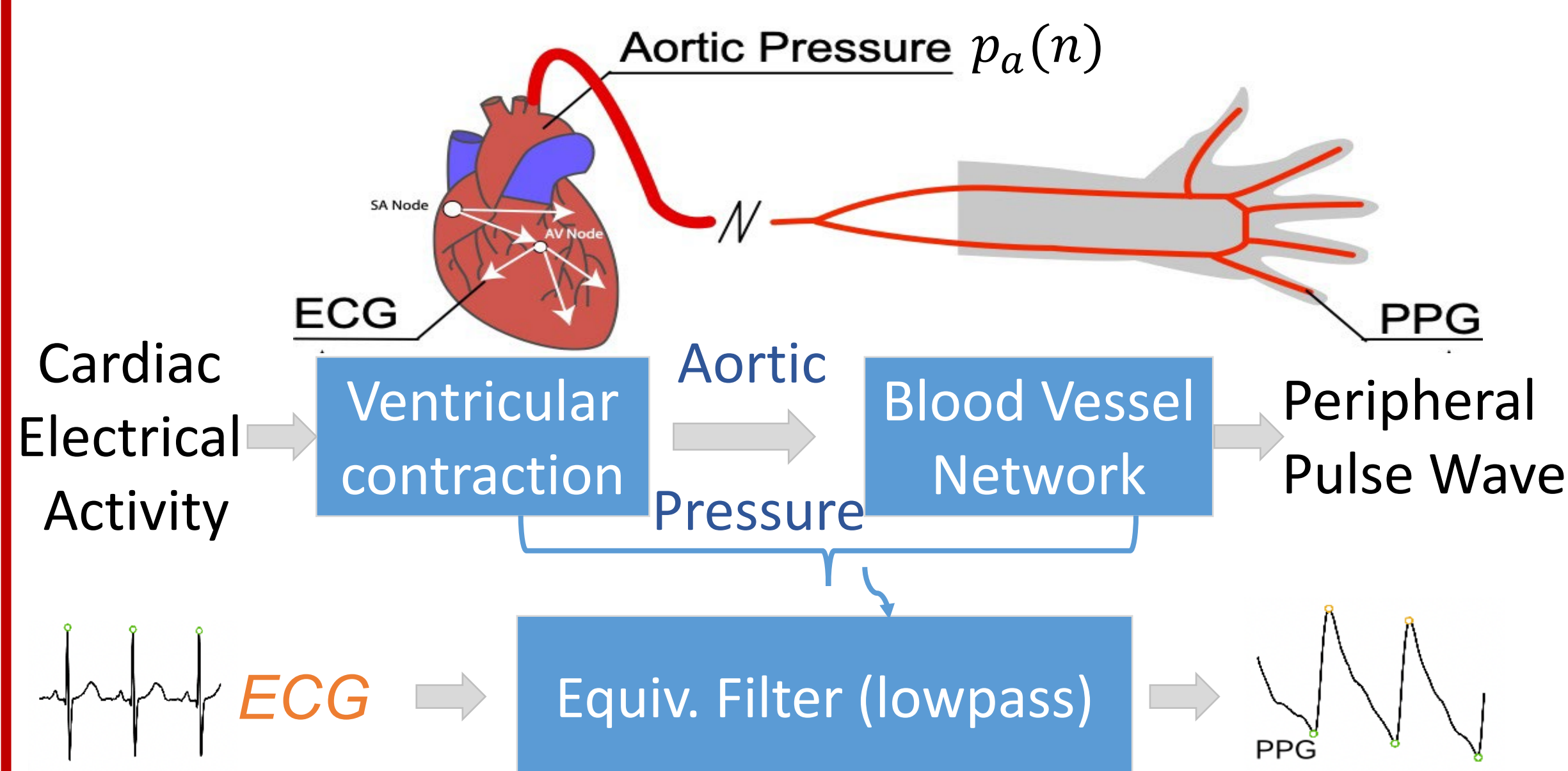
Clinical gold standard  
Restrictive; uncomfortable

### Infer ECG from PPG?



Knowledge Base Low Cost Continuous Real-time User Friendly Digital Twins Monitoring

## Proposed Signal Model



### Mathematical model:

From electrical, biomechanical, and optophysiological principles

$$C_y = FC_x + C_0 + V$$

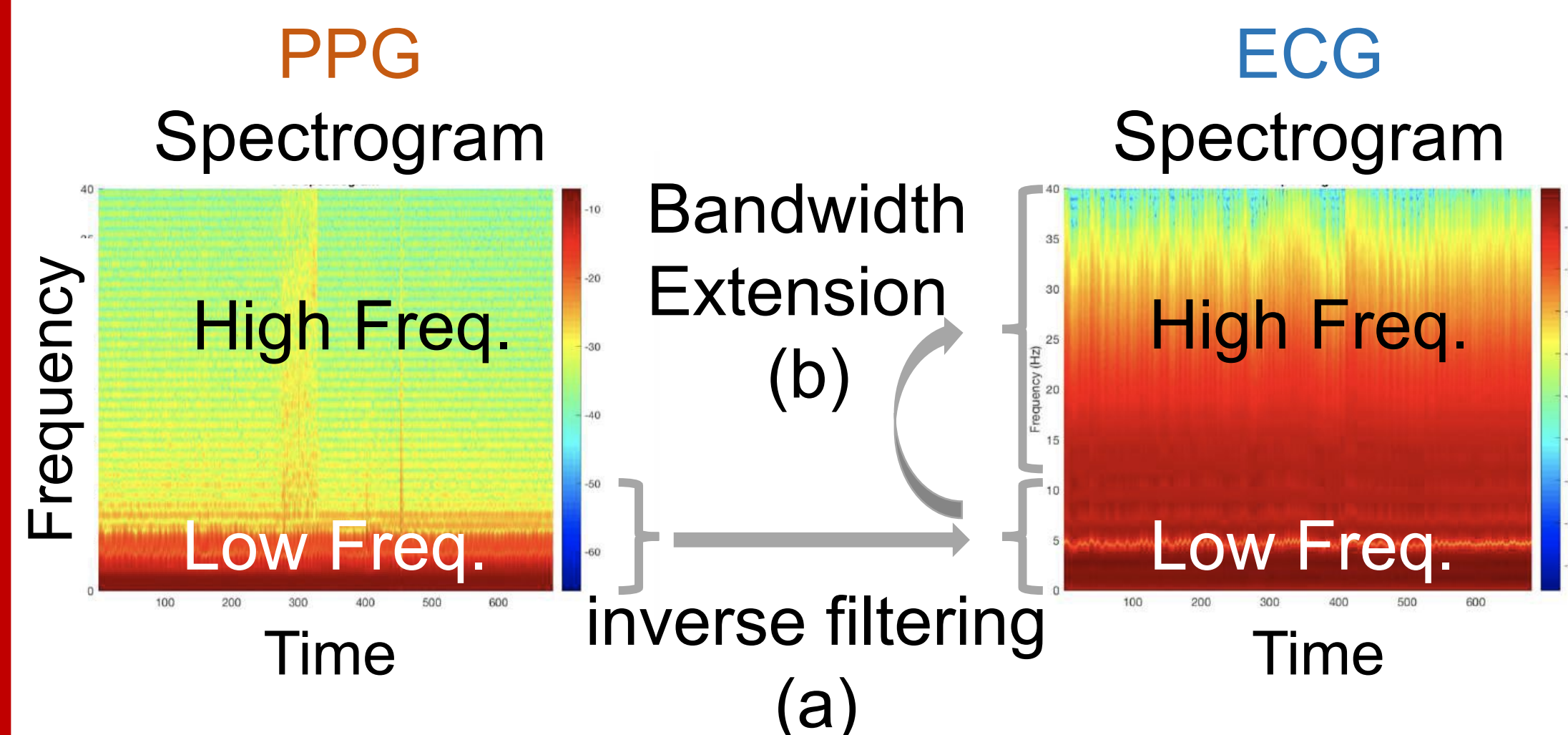
Linear model in DCT domain

where  $C_x, C_y$ : DCT coefficients of PPG and ECG

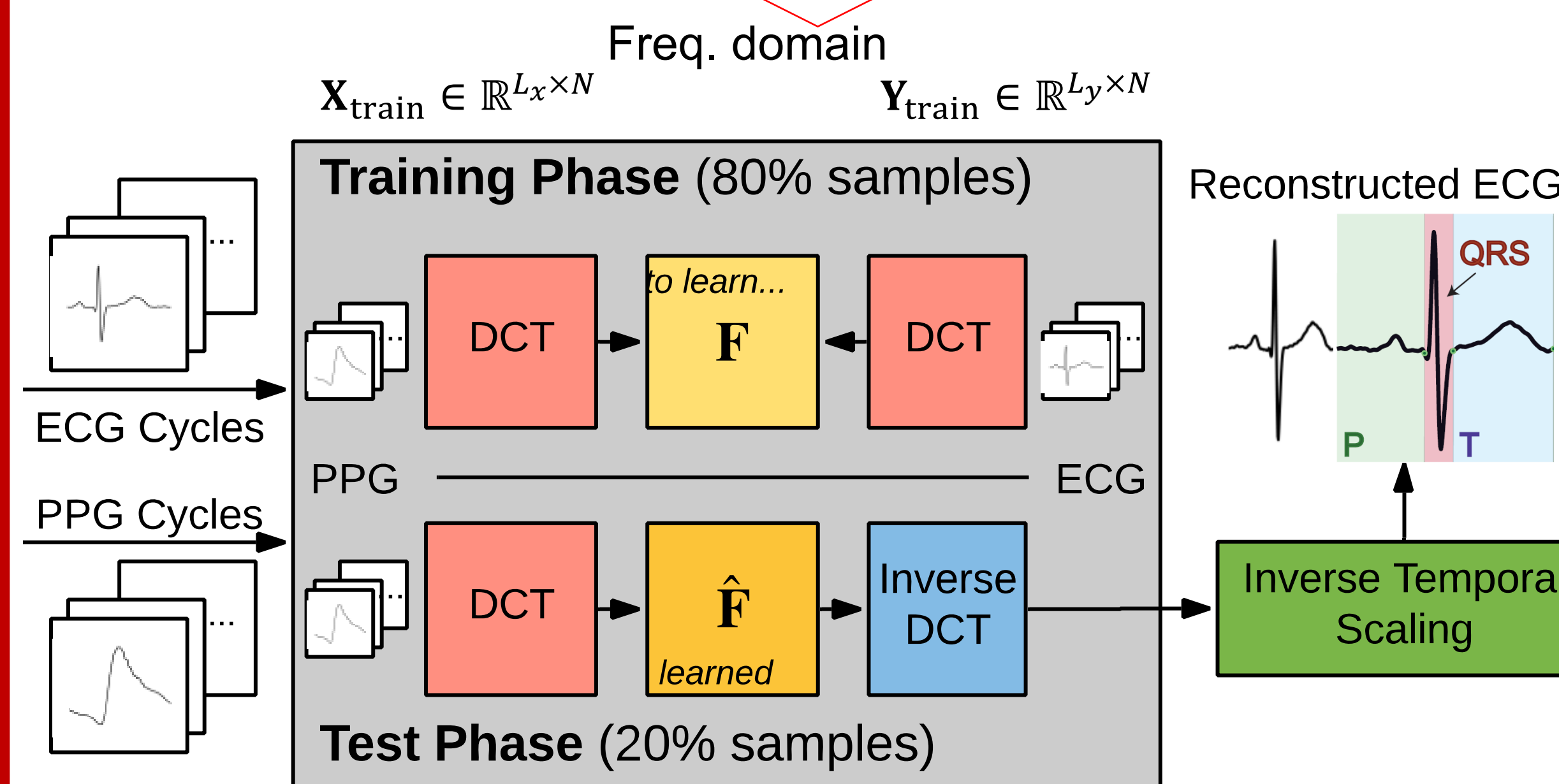
$F, C_0$ : signal path from the heart to skin surface and peripheral ends

$V$ : noise along the signal path

## Proposed Learning Framework



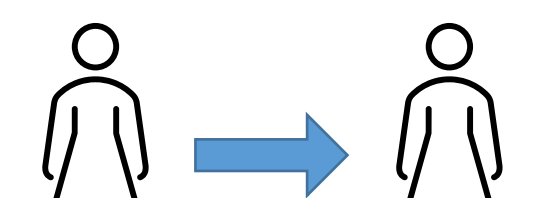
(a) + (b) => model + data supported learning



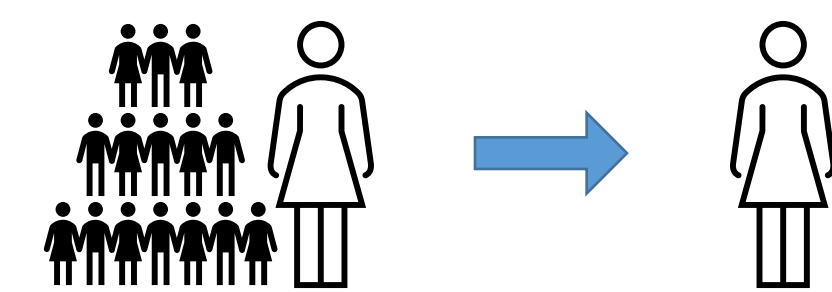
$$\hat{F} = \underset{F}{\operatorname{argmin}} \|FX_{train} - Y_{train}\|_F^2 + \gamma \|F\|_F^2$$

### Two training setups:

1. Subject-Specific Model (SM)



2. Group Model (GM)



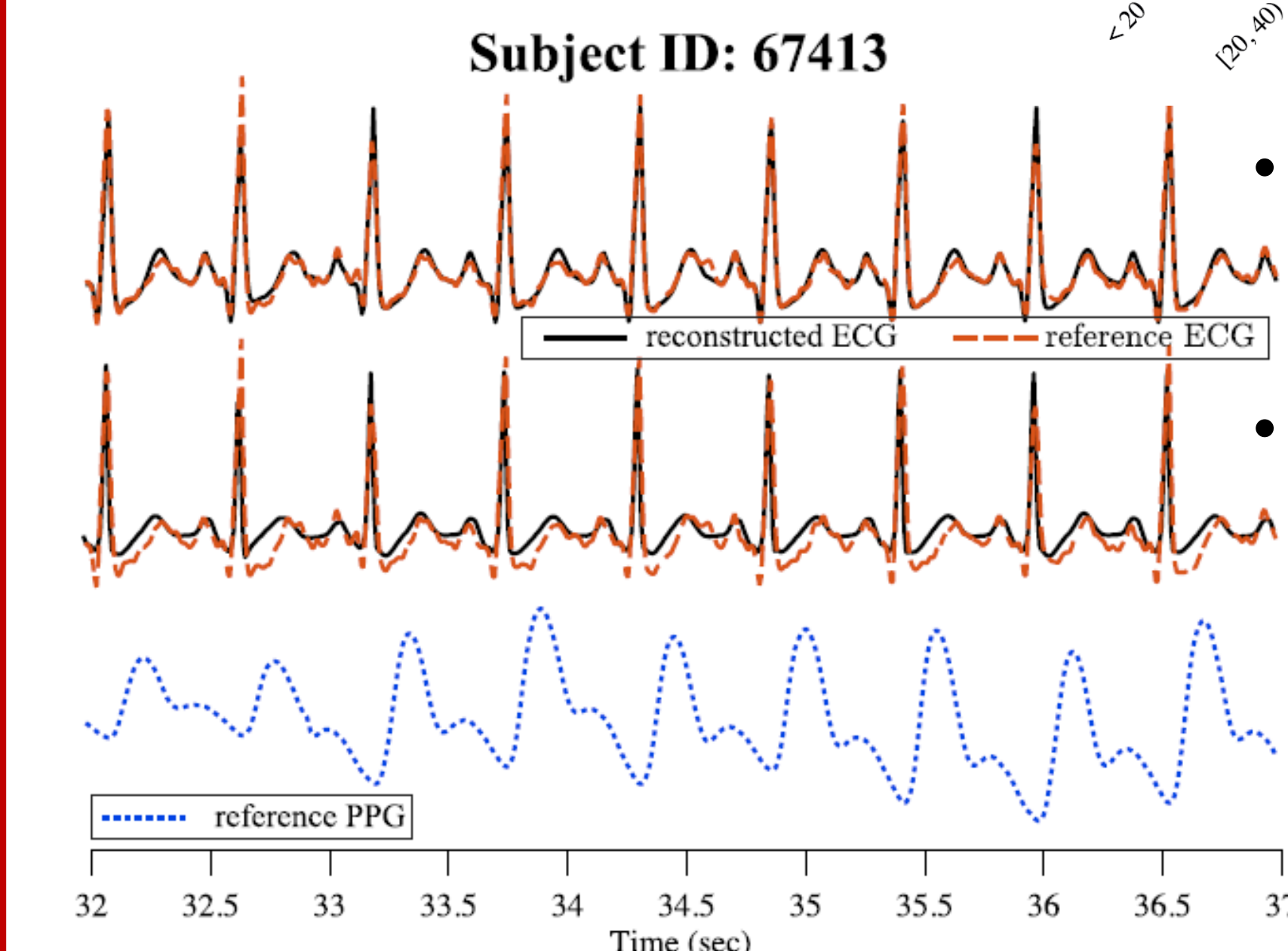
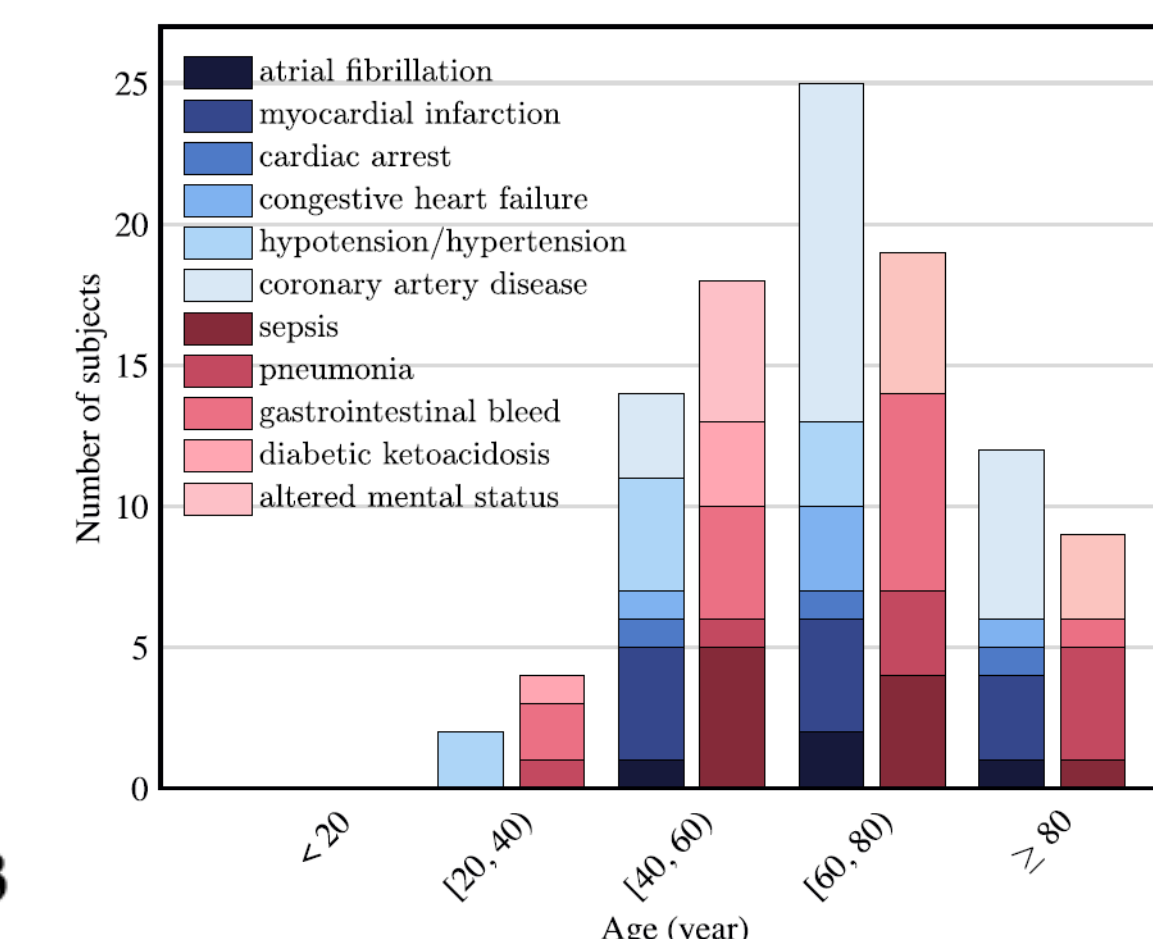
## Results

	SM				GM			
<b>TBME-RR dataset (29 Children and 13 adults)</b>								
Average	P	QRS	T	all	P	QRS	T	all
rRMSE	0.27	0.13	0.28	0.17	0.52	0.36	0.72	0.42
$\rho$	0.87	0.99	0.92	<b>0.98</b>	0.69	0.94	0.71	<b>0.91</b>
<b>UMD dataset ( Two UMD students)</b>								
Average	P	QRS	T	all	P	QRS	T	all
rRMSE	0.66	0.28	0.57	0.43	0.72	0.30	0.59	0.45
$\rho$	0.58	0.97	0.84	<b>0.90</b>	0.50	0.96	0.83	<b>0.89</b>

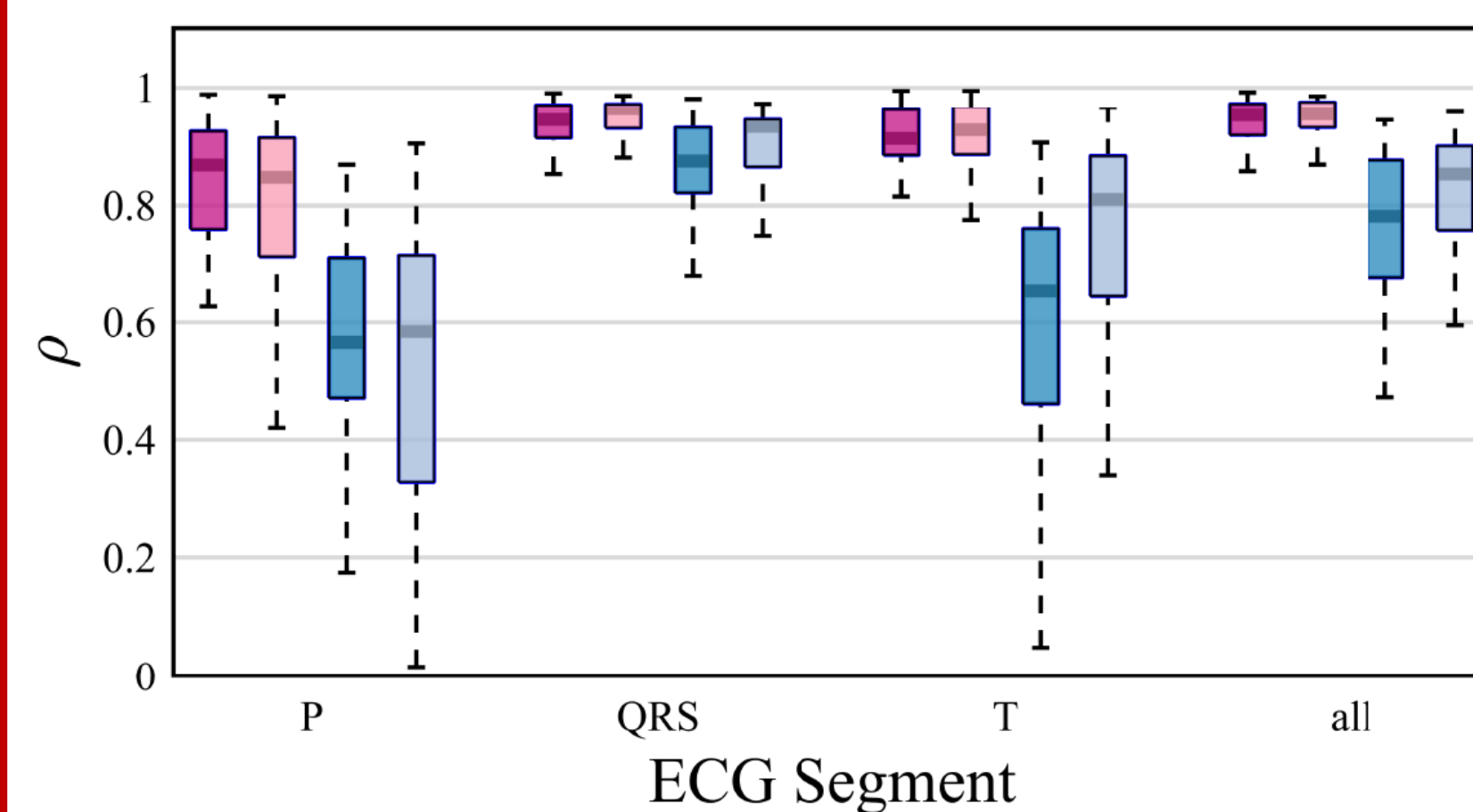
## Results

Mini-MIMIC dataset:  
Selected from MIMIC III database:

- 50 Cardiac Patients
- 53 Non-cardiac Patients



- Congestive heart failure patient.
- Pearson's correlation:
  - SM 0.959
  - GM 0.881



- Noncardiac > Cardiac
- SM > GM

### Accuracy for Cardio Disease Classification

Ref. ECG	Recon. ECG	Ori. PPG
99.6%	99.3%	76.6%

## Conclusion

- Proposed: a PPG-to-ECG physiological model;
- Developed: a principled learning framework for accurate ECG reconstruction;
- Suggested: a user-friendly, low-cost, continuous, and long-term cardiac monitoring;
- Enrich: the knowledge base for PPG from clinical ECG knowledge.