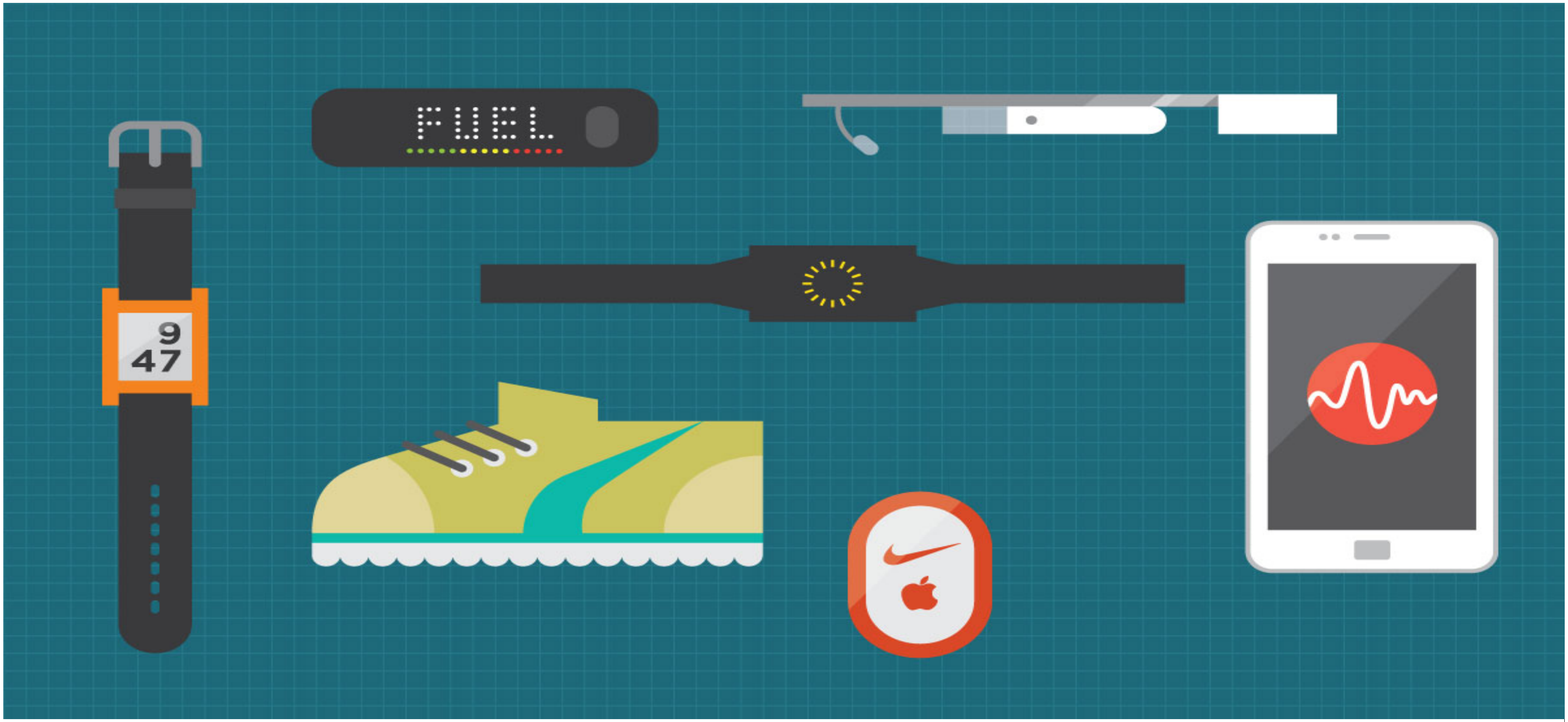

Simulation of the Electrocardiograms (ECGs) and their relation to understanding Wearable Technology

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CSE 6730

Outline

- Background
- Problem statement
- Simulation description
- Heart Rate
- Electrocardiograms (ECG)
- Future work

Background

- Wearable technology has seen tremendous growth In the past several years. One of the main drawbacks it faces is lack of accuracy in specific measurements such as heart rate.

- In this project we will simulate the Electrocardiography (ECG) which is the measurement of the electrical activity of the heart.

- The data generated from the model can then be used to compare with heart rate data obtained from heart rate wearable's such as fit bit in order to determine signal abnormality which will function as an active health monitoring system hence improve the overall wearable technology.

Problem Statement

- Simulate the Electrocardiography (ECG) of the heart. A discrete event simulation will be used to compute the average heart rate of a person based on different levels of activities. The average heart rate is then fed into a dynamical model to compute the ECG.

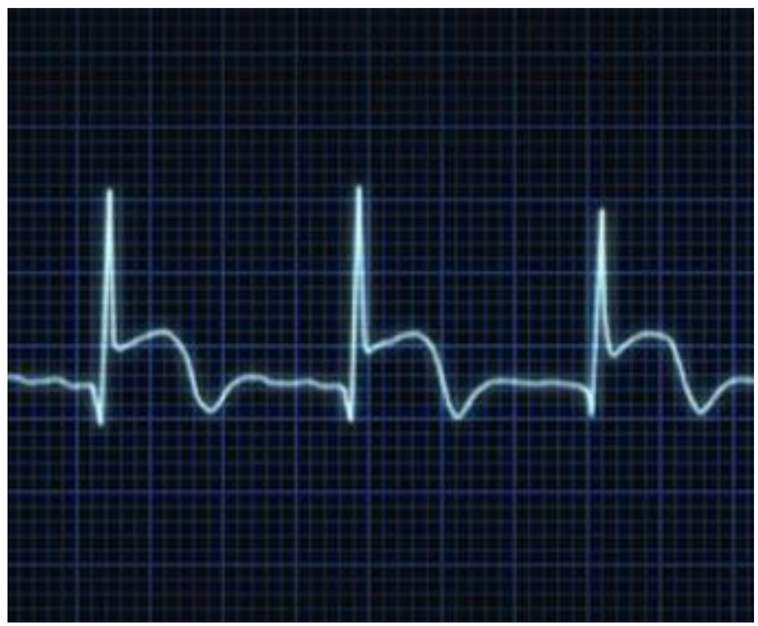


Figure 1. Example of a typical ECG signal

Simulation Description

Discreet Event Simulation to obtain heart rate for different activities

↓

Dynamical System to obtain the ECG Signal

↓

Use information to compare with wearable data

Discreet Event Simulation

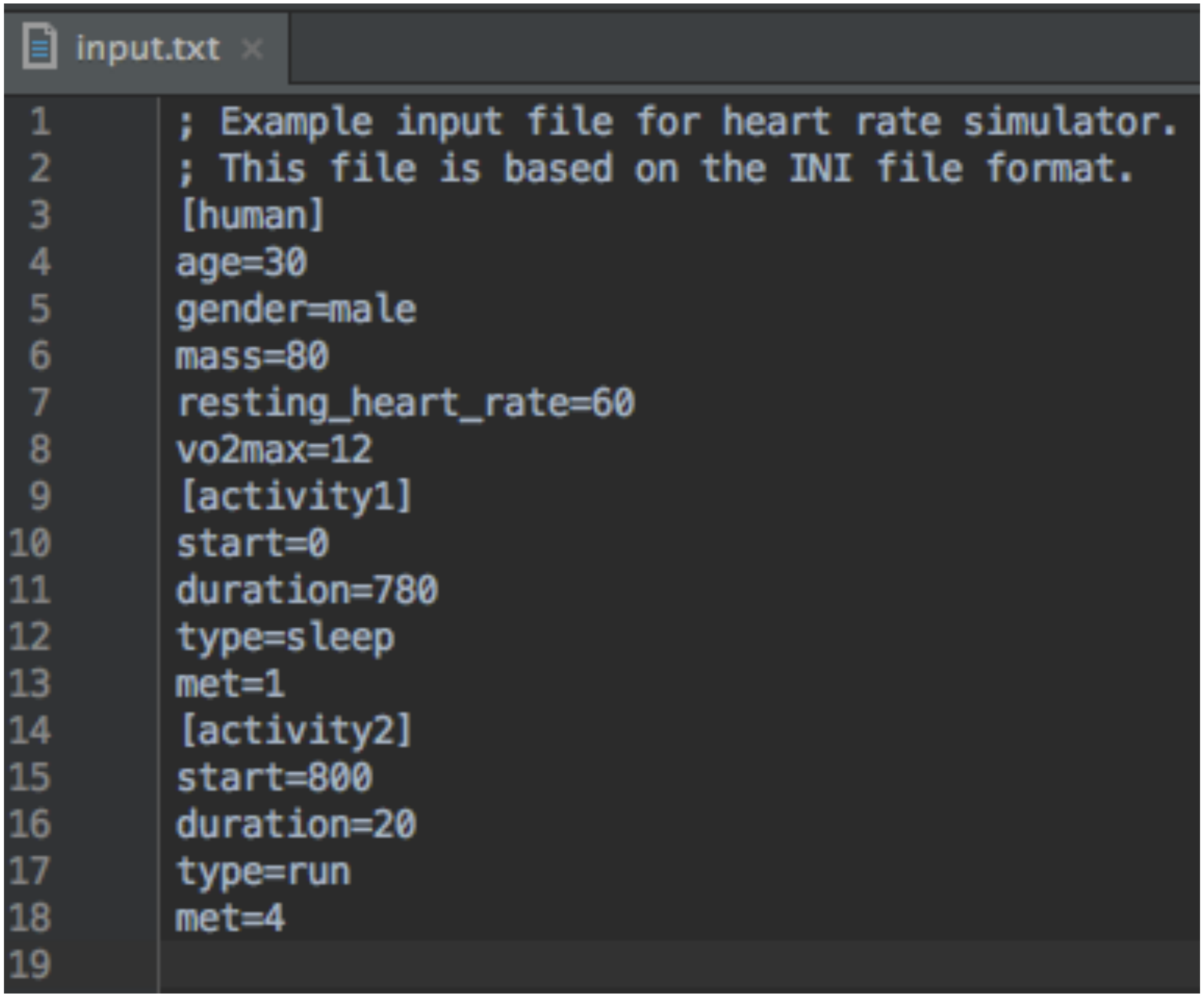
Read input file which describes events and human parameters

↓

Queue events (ensure time stamp order)

↓

Process events from the queue in time stamp order



input.txt

```
; Example input file for heart rate simulator.
; This file is based on the INI file format.
[human]
age=30
gender=male
mass=80
resting_heart_rate=60
vo2max=12
[activity1]
start=0
duration=780
type=sleep
met=1
[activity2]
start=800
duration=20
type=run
met=4
```

Heart Rate Calculation

- Calculate HR based on required oxygen consumption for activity [15]
  - In the cardiovascular model, heart rate is driven by oxygen need.
  - the level of exercise combined with the body mass of the subject determines how much oxygen is needed, and heart rate will increase or decrease to meet this need
  - Cardiac Output = Stroke Volume × Heart Rate
- Events:
  - Activity start (resting, running, etc.)
  - HR transition
  - HR steady state
- Model HR changes as linear transitions taking two minutes[13] [18] [19] – simplification!

ECG Simulation

A dynamical model for generating realistic synthetic ECG signal using a set of state equations that generates a three-dimensional (3-D) trajectory in a 3-D state space with coordinates (*x*, *y*, *z*) was adopted [13]. The dynamical equations of motion are given by a set of three ordinary differential equations in Cartesian coordinates as follows:

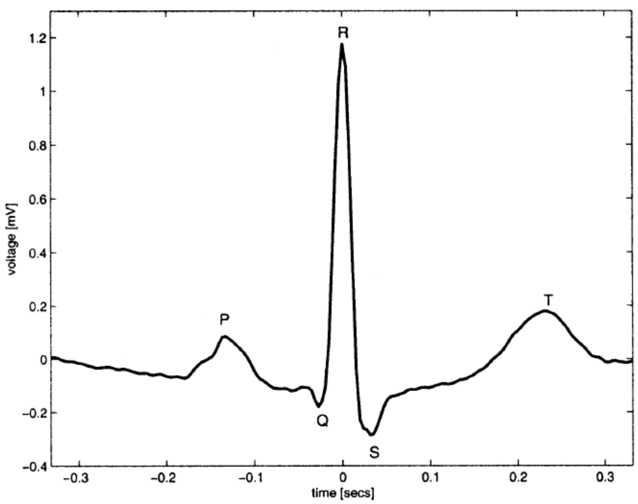


Figure 2. ECG signal [13]

$$\dot{x} = \gamma x - \omega y$$

$$\dot{y} = \gamma y - \omega x$$

$$\dot{z} = -\sum_{i \in \{P,Q,R,S,T\}} a_i \Delta\theta_i \exp\left(-\frac{\Delta\theta_i^2}{2b_i^2} \right) - (z - z_0)$$

$$\gamma = 1 - \sqrt{x^2 + y^2}$$

$$\Delta\theta_i = (\theta - \theta_i) \bmod 2\pi$$

$$\theta = a\tan 2(y, x)$$

ECG Simulation

Initial results from the model is shown in Figure 2, 3. Note that the model will use heart beat for different activity from the discrete event simulation. In this case we used HR = 70 bear per minute (BPM). As shown, the model enables the user to include noise in the data to simulate actual measurement systems.

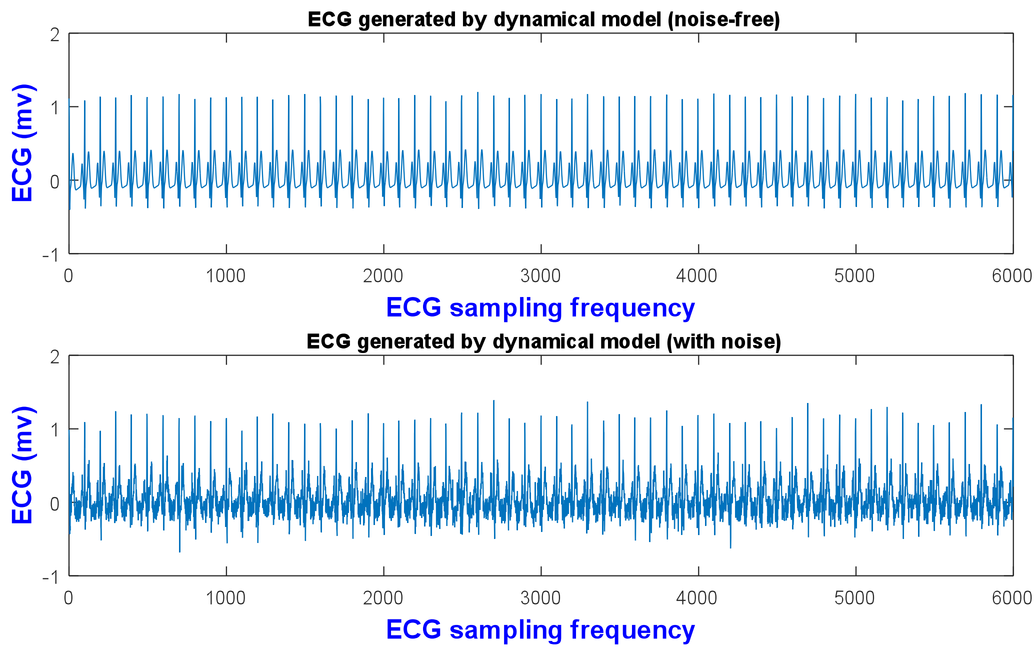


Figure 4. ECG Signal for 70 BPM as function of freq

ECG Simulation

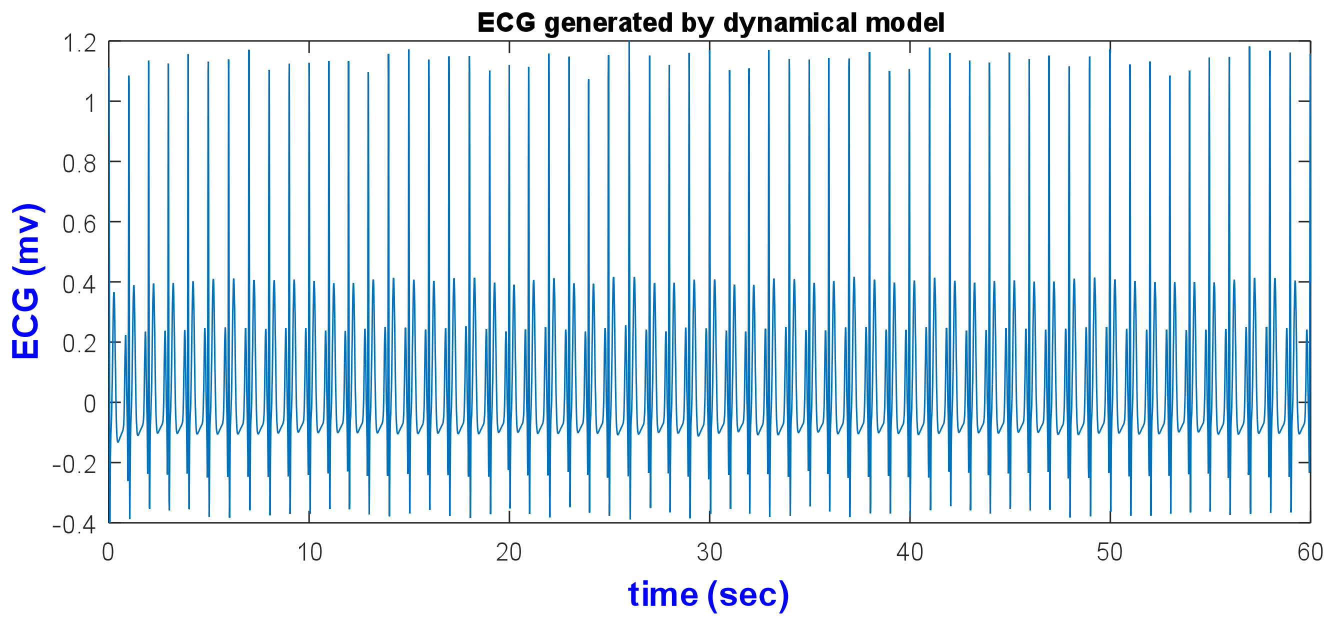
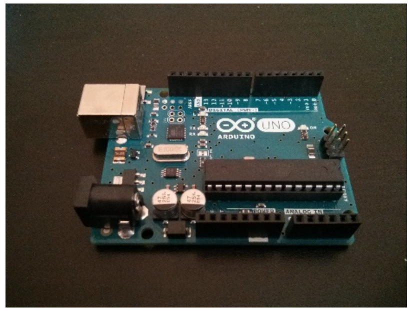


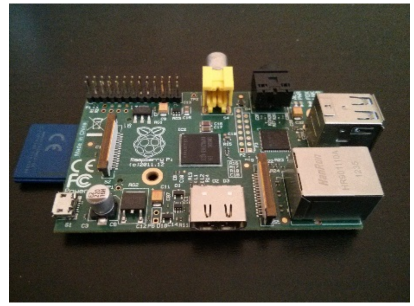
Figure 5. ECG Signal for 70 BPM as function of time

Experimental Data

9V portable battery supply

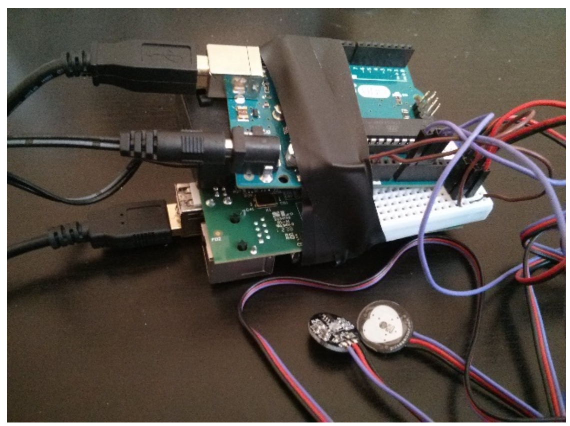


Arduino



Raspberry pi

Pulse Sensor



Combined System

ECG Simulation

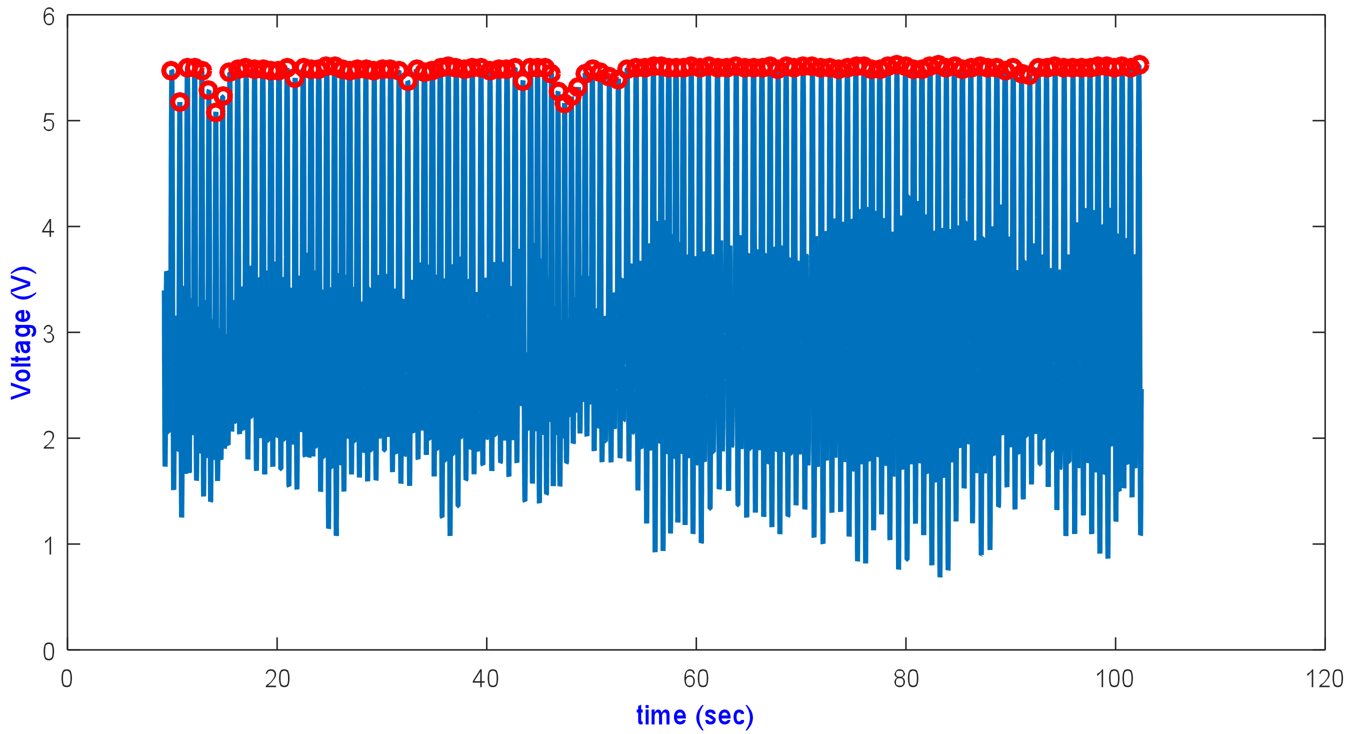


Figure 6. ECG from experimental data

Future Work

- Finalize the Heart rate and ECG simulations
  - Verification and Validation
- Perform additional studies to see the influence of different variables on the ECG output

QUESTIONS???

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