Ryerson University

Department of Electrical & Computer Engineering

BME 632 - Signals & Systems II

Lab Report - PPG

Lab Number: 1

Instructor: April Khademi

Section: 2

Due Date: January 24th, 2020

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Before submitting your report, your TA asks questions about your report. If there is no consistency between your oral answer and your report, you will lose 50% of your total mark. For this part, Pass or fail will be circled next to your name accordingly.

Introduction:

Pulse oximetry and blood pressure are important biomedical signals which are repeatedly checked and monitored in a medical environment. Pulse oximetry, and in turn oxygen saturation (Sp02) levels (which is the main data point measured by pulse oximetry) can provide information on; the efficiency of pulmonary gas exchange, adequacy of alveolar ventilation, blood-gas transport, and tissue oxygenation. Pulse oximetry was created in the early 1980's and replaced the previous invasive method of measuring Sp02 levels which included taking blood samples at regular intervals. This new, non-invasive approach to measuring Sp02 levels uses and LED(s) and the property of hemoglobin to measure the saturation levels. Naturally (in the human body) hemoglobin as two states; oxygenated hemoglobin and deoxygenated hemoglobin. Each of these two variants have inversely related specific properties about which types of light they absorb and reflect. Oxygenated hemoglobin absorbs infrared light (940nm) and transmits (reflects) red light (660nm), while inversely, deoxygenated hemoglobin absorbs red light and transmits infrared light. These properties can be used when we have an apparatus that is put on the end of the index finger, and contains an LED and sensors to receive the signal. The machine pulses at around 480 times per second, to create extremely accurate results. Normal oxygen saturation levels are anywhere between 95% to 100%.

Blood pressure is the force of the circulating blood on the walls of the blood vessels in your body. There are many diseases and problems linked to both high and low blood pressure, making it a very important biomedical signal to monitor. Blood pressure signals consists of two major parts; systolic pressure and diastolic pressure. Systolic pressure occurs when the ventricles contract (higher number) and the diastolic pressure occurs when the ventricles relax (smaller number). Normal ranges for systolic and diastolic pressures are 120 mmHg to 130 mmHg and 80 mmHg to 85 mmHg respectively. To measure blood pressure we use either a manual for automatic pressure cuff. (To relate to the lab the description of manual cuff will be discussed, and the pulse oximeter will be used instead of a stethoscope to check the pulse of the individual.) The pressure cuff is placed on the arm of the individual with the two tubes running parallel with the forearm and brachial artery, and tighten to the point of fit but not constriction. The oximeter is placed on the finger of the individual to monitor the heartbeat. The cuff is then puffed up slowly, but consistently, until the heart beat of the individual is not found. The pressure is recorded and the pressure is released. This is the systolic pressure,and the diastolic pressure is the pressure where the heart beat is found.

Pre-lab Questions:

1) A pulse oximetry signal is the ratio of the transmitted red and infrared light which is obtained when an LED shines these same colours into the skin. This signal is created by hemoglobin in it's two natural states; deoxygenated hemoglobin and oxygenated hemoglobin. Hemoglobin is the molecule in the blood which holds oxygen molecules, hence the names oxygenated and deoxygenated. Oxygenated hemoglobin absorbs infrared light and transmits red light, while deoxygenated hemoglobin absorbs red light

and transmits infrared light. These signals are collected using photodiodes. Pulse oximetry is used to measure arterial oxygen saturation (Sp02) levels. Sp02 levels can be used to monitor many different physiological processes in the body.

2) PPG is an optically obtained plethysmogram (instrument for measuring changes in volume within an organ) that can be used to detect blood volume changes in the microvascular bed of tissue. It is obtained using a pulse oximeter.

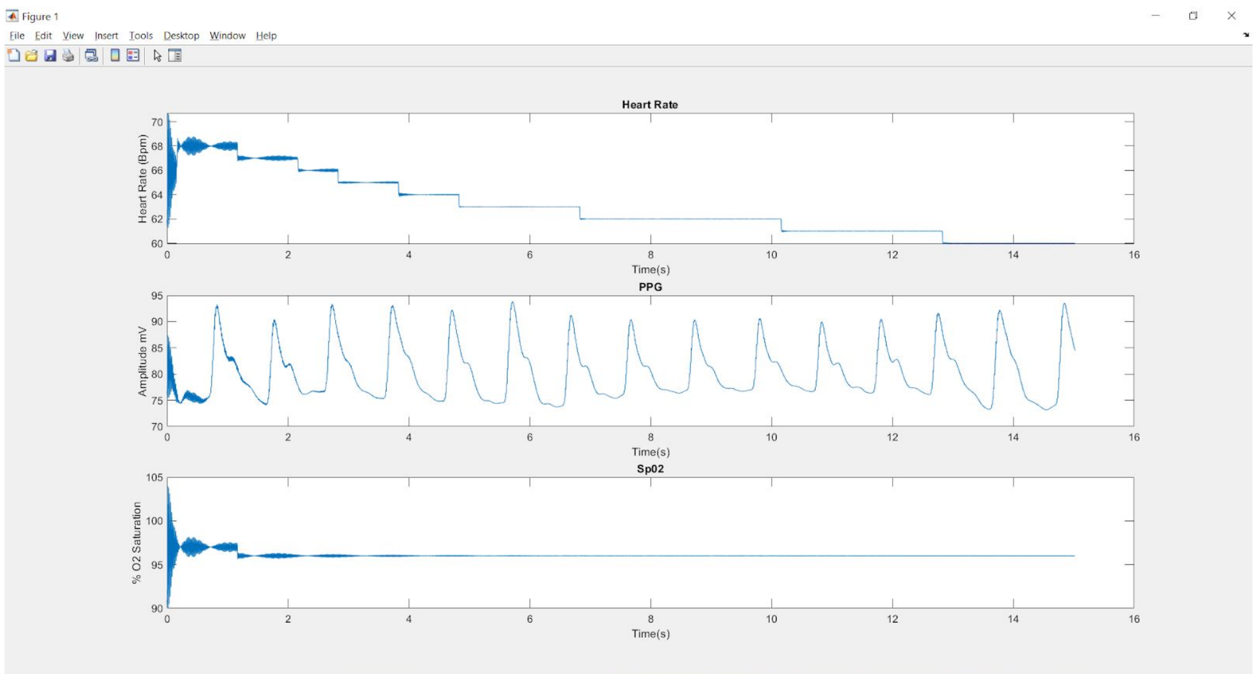

Figure 1. Plot of HR, PPG, and Sp02 for when the individual was at rest.

Table 1. Mean and standard deviations of the variables; Sp02, HR, and PPG, for resting experiment. All values were calculated in Matlab.

	Mean	Standard Deviation
Sp02	96.076	95.3886
PPG	80.0826	80.0502
HR	62.9491	65.3056

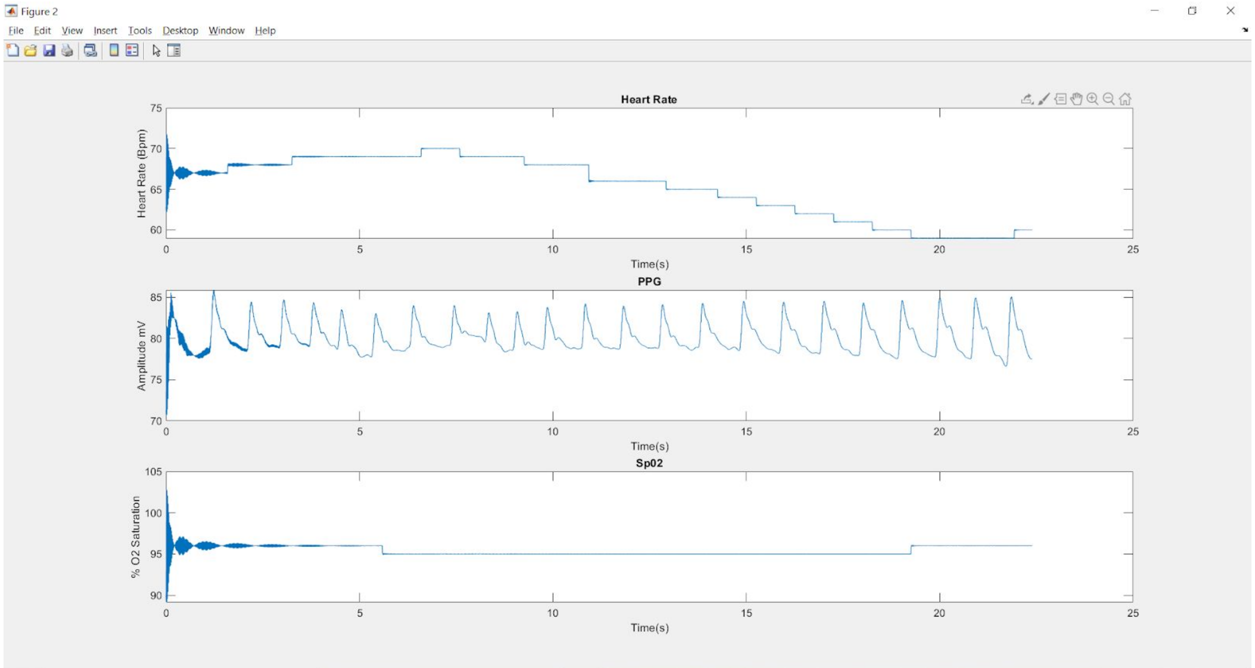

Figure 2. Plot of HR, PPG, and Sp02 for when the individual held their breath.

Table 2. Mean and standard deviations of the variables; Sp02, HR, and PPG, for holding breath experiment. All values were calculated in Matlab.

	Mean	Standard Deviation
Sp02	96.076	95.3886
PPG	80.0826	80.0502
HR	62.9491	65.3056

Exercise 2.1 Questions:

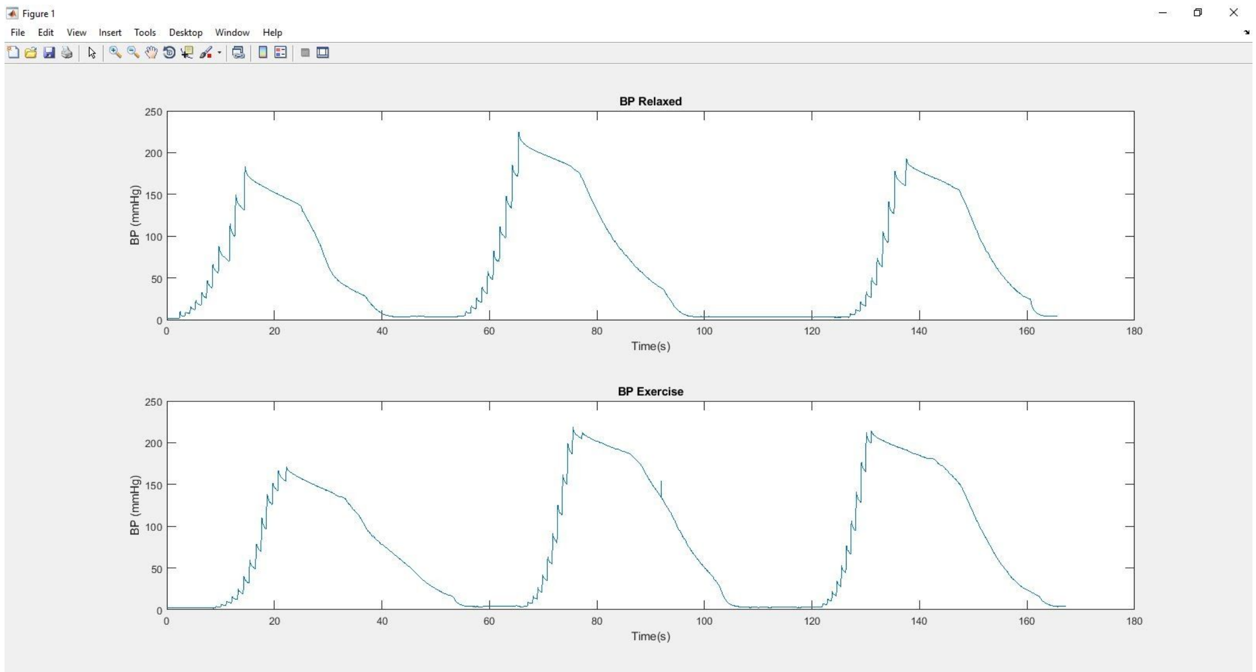

Figure 3: Plots for BP during relaxation and exercise

2,3,4.

	Systolic (mm Hg)	Diastolic (mm Hg)	MAP (mm Hg)
Relaxed			
Wave 1	130	75	93.34
Wave 2	157.5	62.5	94.17
Wave 3	139	53	81.67
Exercise			
Wave 1	125	60	81.67
Wave 2	160	85	110
Wave 3	150	88	108.67

MAP = [SBP + 2 (DBP)] / 3

Post Lab Questions:

a) **Heart Rate**: Heart rate is an interesting signal to watch during this experiment. Both figures show a drop in heart rate throughout the tests, which is consistent with basic knowledge. The individual was relaxed and not performing any physical activity, therefore their heart rate should not increase, and should slowly decrease until a plateau. However, in Figure 2 there was an interesting spike in heart rate before the slow decline, and this spike happened near the time when the individual held his breath. This is curious. Also to note in Figure 2, the decline in heart rate is not as gradual as in Figure 1, but is steeper. Back to the spike, this could be due to the fact that the body just intaked more air than usual (because instead of breathing to just stop, a larger breath was taken and then held) therefore the body had to compensate for the extra volume of air.

PPG: Interestingly, at first it was difficult to notice any differences between the two figures. But with further inspection there is a noticeable difference. Notice, during the time when the individual held their breath, the distances between the peaks of each, which is due to an increase in the trough lengths of each wave. Like in HR, this could be due to the heart compensating for the lack of new oxygen present/ no breathing. We also notice that the magnitude in the exercise graph is lower than the magnitude of the resting graph. The magnitude in Figure 1 is around 93mV - 94 mV, while in Figure 2 the magnitude is around 84mV - 85mV. This 10mV difference could be due to the lack of new air entering the body, but to note the initial values of the two figures are different, so there might just be a small difference between experiments. More experiments would have to be done to see if this is a trend or a natural occurrence.

Sp02: Out of all three signals measured during the first experiment, this signal provides the most visual representation of when the individual was holding his breath. The beginning of both signals (from Figure 1 and Figure 2) start at around 95% saturation and in Figure 1 this stays constant. However, in Figure 2 an evidently small dip is there, which dips to around 94% saturation. This dip is there for about 12 seconds, which is around the amount of time he held his breath. This is accurate to basic knowledge. Since the body is not inhaling new, fresh oxygen, the saturation levels will drop, but not too dramatically because that could be fatal.

b) The average systolic blood pressure for the resting trials was 142.17 mmHg, while the average diastolic blood pressure was 63.50 mmHg.
The average systolic blood pressure for the exercise trials was 143.34 mmHg, while the average diastolic blood pressure was 77.67 mmHg.
The average values for the exercise trials were found to be higher. This is because since the testing subjects were exposed to a few minutes of vigorous physical activity, it increased their blood pulses, pressure physiologically. Thus when the BP was measured, the restricted and released blood flow had more intensity which resulted in higher amplitudes and thus higher blood pressures. Yes, this is what we expected.

c) The automated blood pressure monitoring system, in the absence of a clinician would be operated on the principle of oscillation. In this system, the cuff is wore and inflated on the left upper arm. When the cuff is inflated, there is no blood flow through the artery. However, as the cuff is eventually deflated, the accumulated blood starts to flow again and gains momentum until it finally resumes its normal flow. While it restarts flowing, it sets up a detectable vibration at the artery, which is essentially an oscillation. These oscillations then pass through the arterial wall, into the cuff, and enter a transducer embedded in the cuff that converts the mechanical oscillations into signals.

Appendix:

Exercise 1:

```
%% Experiment 1.1 Resting
m = readtable('restinSp02.csv'); %creating variable m which is a table created from the csv file

tx1 = m(:,1); %creating variable tx1 which exstracts the time column from table m
tx1 = tx1{:,:}; %making the variable tx1 into a matrix, which can be used in the plot function
HRx1 = m(:,2); %creating variable HRx1 which exstracts the Heart Rate column from table m
HRx1 = HRx1{:,:}; %making the variable HRx1 into a matrix, which can be used in the plot
function
PPGx1 = m(:,3); %creating variable PPGx1 which exstracts the PPG column from table m
PPGx1 = PPGx1{:,:}; %making the variable PPGx1 into a matrix, which can be used in the plot
function
SP02x1 = m(:,4); %creating variable SP02x1 which exstracts the Sp02 column from table m
SP02x1 = SP02x1{:,:}; %making the variable SP02x1 into a matrix, which can be used in the
plot function

timex1 = 0 : length(tx1) - 1;
timex1 = timex1 * 0.004; %conversion of time array to take into the account the sampling rate
(250Hz)

%Part A

figure(1); %figure for HR, PPG, and Sp02 signals when resting
%Heart Rate
subplot(311);
plot(timex1,HRx1);
xlabel('Time(s)');
ylabel('Heart Rate (Bpm)');
title('Heart Rate');
subplot(312);
%PPG
plot(timex1,PPGx1);
xlabel('Time(s)');
ylabel( 'Amplitude mV');
title('PPG');
%Sp02
```

```
subplot(313);
plot(timex1,SP02x1);
xlabel('Time(s)');
ylabel('% O2 Saturation');
title('Sp02');

%Part B

sumHRx1 = sum(HRx1); %summing the whole HR column
sumPPGx1 = sum(PPGx1); %summing the whole PPG column
sumSp02x1 = sum(SP02x1); %summing the whole Sp02 column

sizeHRx1 = size(HRx1); %counting the amount of data points in the array
sizeHRx1 = sizeHRx1(:,1); %taking away the second column to create an integer value (this
value is the same for HR, PPG, and Sp02)

meanHRx1 = sumHRx1 / sizeHRx1; %mean of HR
meanPPGx1 = sumPPGx1 / sizeHRx1; %mean of PPG
meanSp02x1 = sumSp02x1 / sizeHRx1; %mean of Sp02

stdHRx1 = std(HRx1); %standard deviation of HR
stdPPGx1 = std(PPGx1); %standard deviation of PPG
stdSp02x1 = std(SP02x1); %standard deviation of Sp02

%% Experiment 1.2 Hold

n = readtable('holdSpO2.csv'); %creating variable n which is a table created from the csv file

tx2 = n(:,1); %creating variable tx2 which exstracts the time column from table m
tx2 = tx2{:,:}; %making the variable tx2 into a matrix, which can be used in the plot function
HRx2 = n(:,2); %creating variable HRx2 which exstracts the Heart Rate column from table m
HRx2 = HRx2{:,:}; %making the variable HRx2 into a matrix, which can be used in the plot
function
PPGx2 = n(:,3); %creating variable PPGx2 which exstracts the PPG column from table m
PPGx2 = PPGx2{:,:}; %making the variable PPGx2 into a matrix, which can be used in the plot
function
SP02x2 = n(:,4); %creating variable SP02x2 which exstracts the Sp02 column from table m
SP02x2 = SP02x2{:,:}; %making the variable SP02x2 into a matrix, which can be used in the
plot function

timex2 = 0 : length(tx2) - 1;
timex2 = timex2 * 0.004; %conversion of time array to take into the account the sampling rate
(250Hz)
```

```
figure(2); %figure for HR, PPG, and Sp02 signals when holding breath
%Heart Rate
subplot(311);
plot(timex2,HRx2);
xlabel('Time(s)');
ylabel('Heart Rate (Bpm)');
title('Heart Rate');
subplot(312);
%PPG
plot(timex2,PPGx2);
xlabel('Time(s)');
ylabel('Amplitude mV');
title('PPG');
%Sp02
subplot(313);
plot(timex2,SP02x2);
xlabel('Time(s)');
ylabel('% O2 Saturation');
title('Sp02');

%Part B

sumHRx2 = sum(HRx2); %summing the whole HR column
sumPPGx2 = sum(PPGx2); %summing the whole PPG column
sumSp02x2 = sum(SP02x2); %summing the whole Sp02 column

sizeHRx2 = size(HRx2); %counting the amount of data points in the array
sizeHRx2 = sizeHRx2(:,1); %taking away the second column to create an integer value (this
value is the same for HR, PPG, and Sp02)

meanHRx2 = sumHRx2 / sizeHRx2; %mean of HR
meanPPGx2 = sumPPGx2 / sizeHRx2; %mean of PPG
meanSp02x2 = sumSp02x2 / sizeHRx2; %mean of Sp02

stdHRx2 = std(HRx2); %standard deviation of HR
stdPPGx2 = std(PPGx2); %standard deviation of PPG
stdSp02x2 = std(SP02x2); %standard deviation of Sp02
```

<u>Exercise 2:</u>

```
m = readtable('exercise.csv');
m2 = readtable('relaxed.csv');
```

```
tx1 = m(:,1);
tx1 = tx1{:,:};
bp = m(:,2);
bp = bp{:,:};

tx2 = m2(:,1);
tx2 = tx2{:,:};
bp2 = m2(:,2);
bp2 = bp2{:,:};

timex1 = 0: length(tx1)-1;
timex2 = timex1*0.004;

time2x1 = 0: length(tx2)-1;
time2x2 = time2x1*0.004;

figure(1);
%bp
subplot(212);
plot(timex2,bp);
xlabel('Time(s)');
ylabel('BP (mmHg)');
title('BP Exercise');
%bp2
subplot(211);
plot(time2x2,bp2);
xlabel('Time(s)');
ylabel('BP (mmHg)');
title('BP Relaxed');
```