

Yeison Rodriguez

UTD ID: 202139026

Signals and Systems for Biomedical Engineering

Mini Project #2

February 19, 2020

### Short Report for Mini Project #2

For this project, I began the first problem by loading the two mat files provided for part a. Then I created a vector  $N$ , which holds the values 2, 3, 5 & 10. I used a vector for  $N$  rather than an int/double variable so that my code can execute the moving average filters for varying values of  $N$  more easily. I then created a for loop that runs from  $i = 1$  to  $i = 4$ . This for loop is used so that I can create the appropriate  $y[n]$  and figures for the varying values of  $N$ . I then created vector  $y1$ , which would hold the values of the noisy signal after it was transformed by the moving average filter, setting its length equal to  $N(i) + \text{the length of the noisy signal} - 1$ . I did the same for vector  $t$ , which ranges from 0 to 2 seconds.

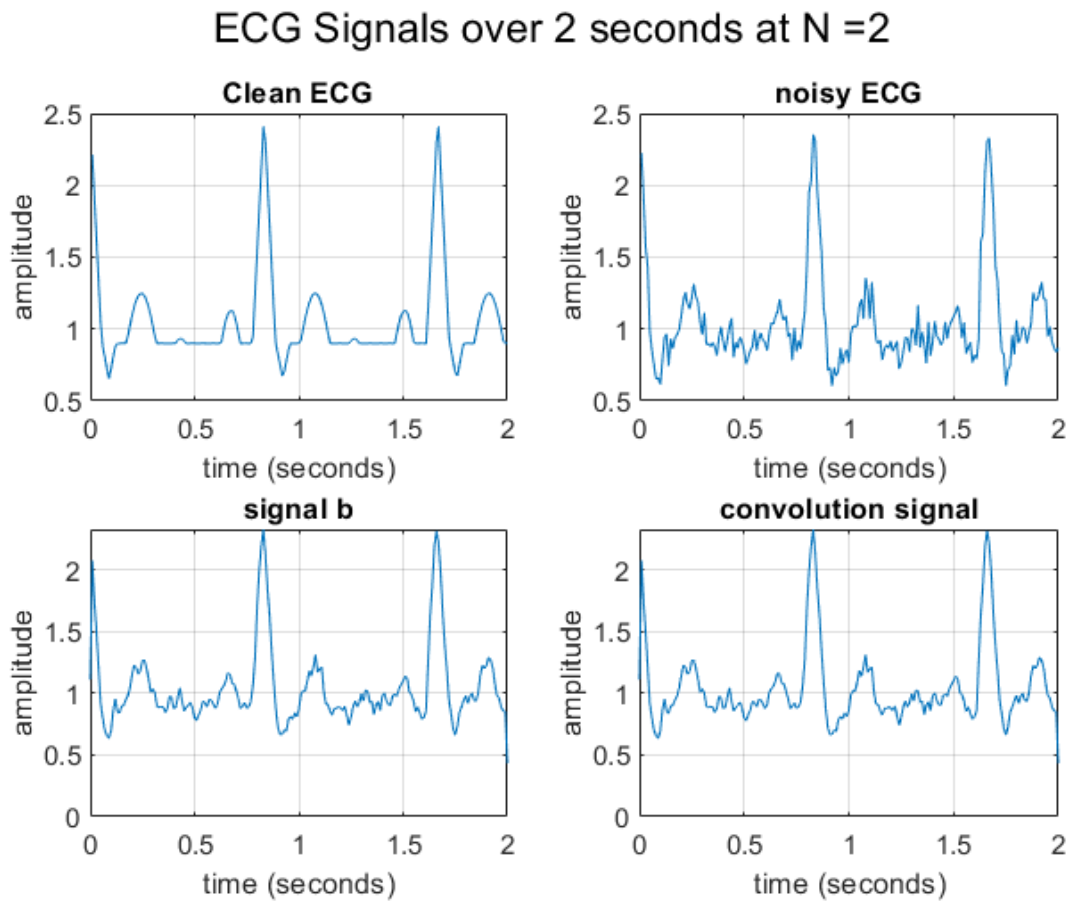
Finally, with all my variables properly initialized, I moved on to part b. I solved b by first creating a for loop, that runs from  $n = 1$  to the value of  $N(i) + \text{the length of the noisy signal} - 1$  (the length of a convoluted signal). This for loop is used to access each index of  $n$  so that we may create our new clean signal. I then created three condition statements for varying ranges of  $n$ , since I knew we had three breakpoints.

If  $n$  is less than or equal to  $N(i) - 1$ , there are not enough previous samples of  $x(n)$  accessible to process our signal through the moving average filter. Therefore, I set  $y(n)$  equal to  $y(n) + \text{noisyECG}(n-k)/N(i)$  for  $k = 0$  to  $k = n - 1$ . Since, despite not being able to access the values of the noisyECG at negative time values, I knew these values would just be equal to zero. Else, if  $n$  is greater than  $N(i) - 1$  and less than, or equal to, the length of the noisy ECG signal, we can use the general formula for the moving average filter. Therefore, I set  $y(n)$  equal to  $y(n) + (\text{noisyECG}(n-k))/N(i)$  for  $k = 0$  to  $k = N(i) - 1$ . Finally, I created my last conditional, where if  $n$  was greater than 200 there was not enough samples of  $x(n)$  available for access, since  $x(200^+)$  exceeds the size of the noisy ECG signal vector. Therefore, I set  $y(n)$  equal to  $y(n) + \text{noisyECG}(\text{the length of the noisy ECG} - k)/N(i)$  for  $k = 0$  to  $k = \text{length}(y) - n$ . Since I know that any value recorded at a time exceeding the length of the noisy ECG is zero, since it was never recorded.

Then for part c, I began by setting my equation for  $y[n]$ , the moving average filter equation, equal to the convolution between  $x[n]$  and impulse response  $h[n]$ . I transformed the convolution into the summation form, with  $h[n]$  transforming into  $h[k]$

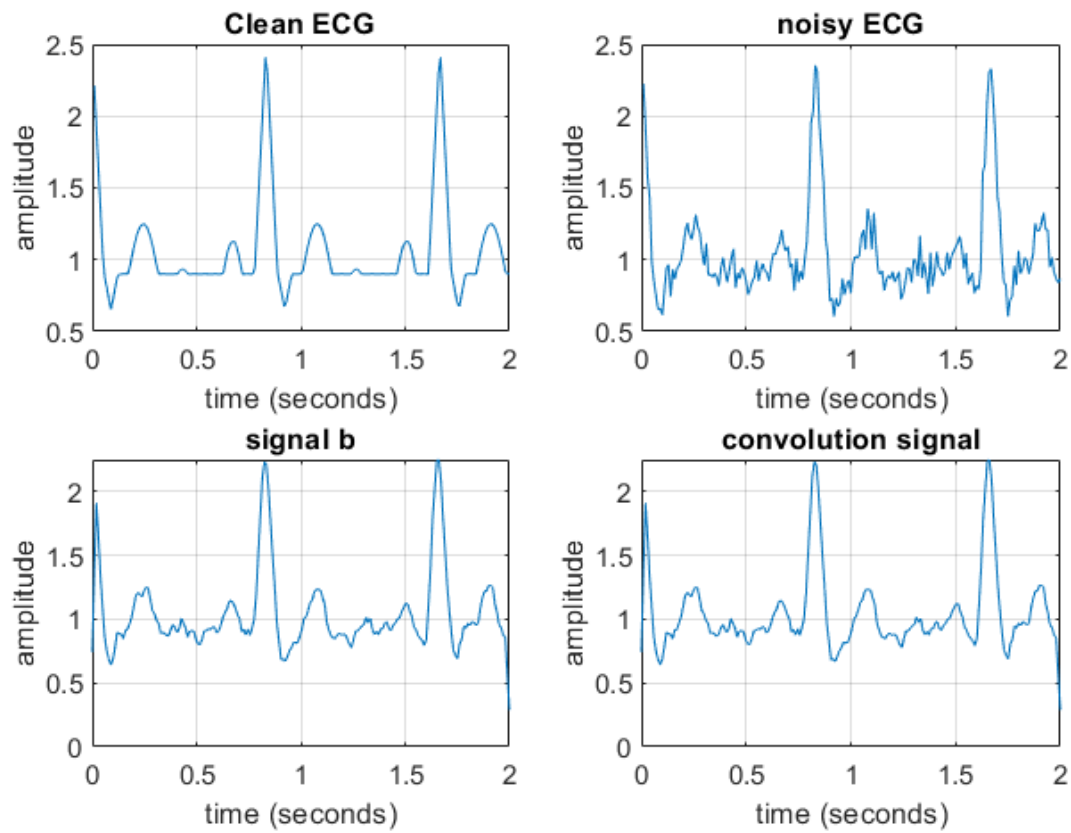
and  $x[n]$  into  $x[n-k]$ . I then observed that I had  $x[n-k]$  on both sides, which means they cancelled each other out. I then realized that I just had  $\frac{1}{N} \sum_{k=0}^{N-1} 1 = \sum_{k=-\infty}^{\infty} h[n-k]$ . Then, realizing that our bounds for  $y[n]$  indicate that  $h[n-k]$  must only have values from  $k=0$  to  $k=N-1$ , I realized that  $h[n]$  must be a form of a square function from  $n=0$  to  $n=N-1$ . My final  $h[n]$  was  $\frac{h[n]=u[n]-u[N-1]}{N}$ . This function can be expressed in MATLAB as  $h = \frac{\text{ones}(1,N(i))}{N(i)}$ . The indices were shifted over one since MATLAB does not start arrays with a zero index. Then I simply used the convolution function, built into MATLAB, to convolve the noisyECG signal with my impulse response  $h$  to get  $y_2$  for part d.

The following are the figures created for part e of problem one:



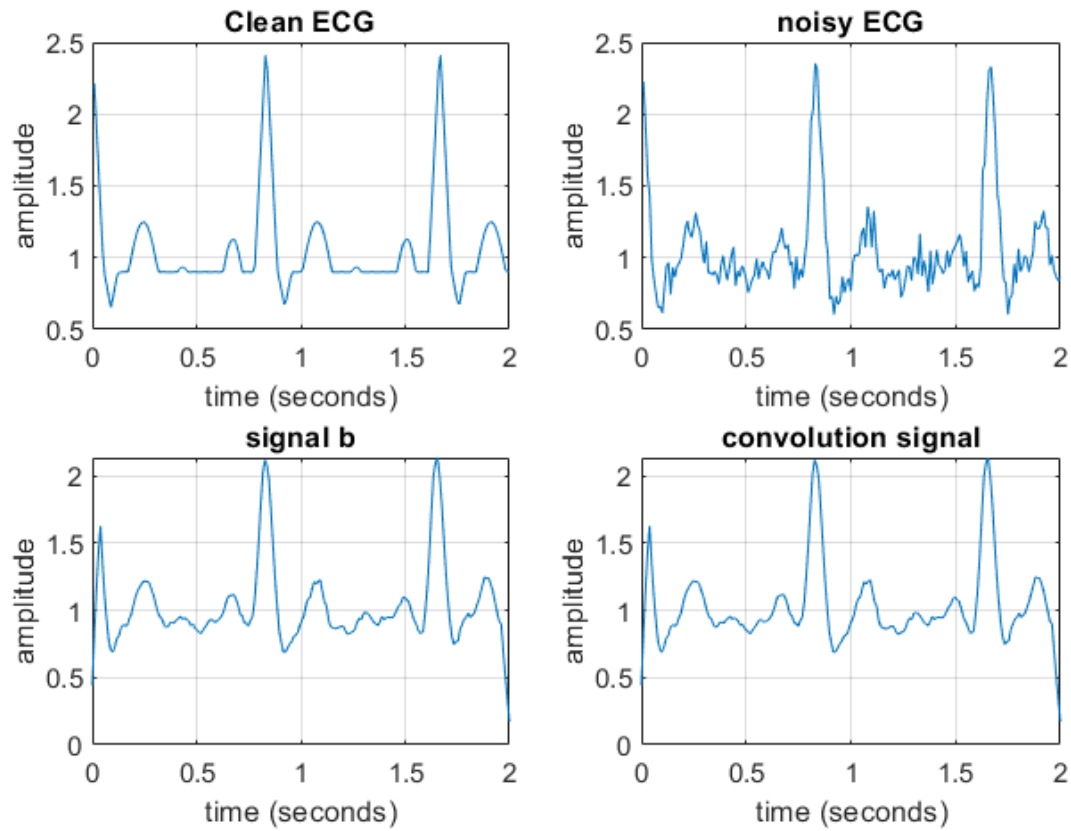
*Figure 1: The figure displays our four signals created when we used  $N=2$  samples in our moving average filter.*

## ECG Signals over 2 seconds at $N = 3$



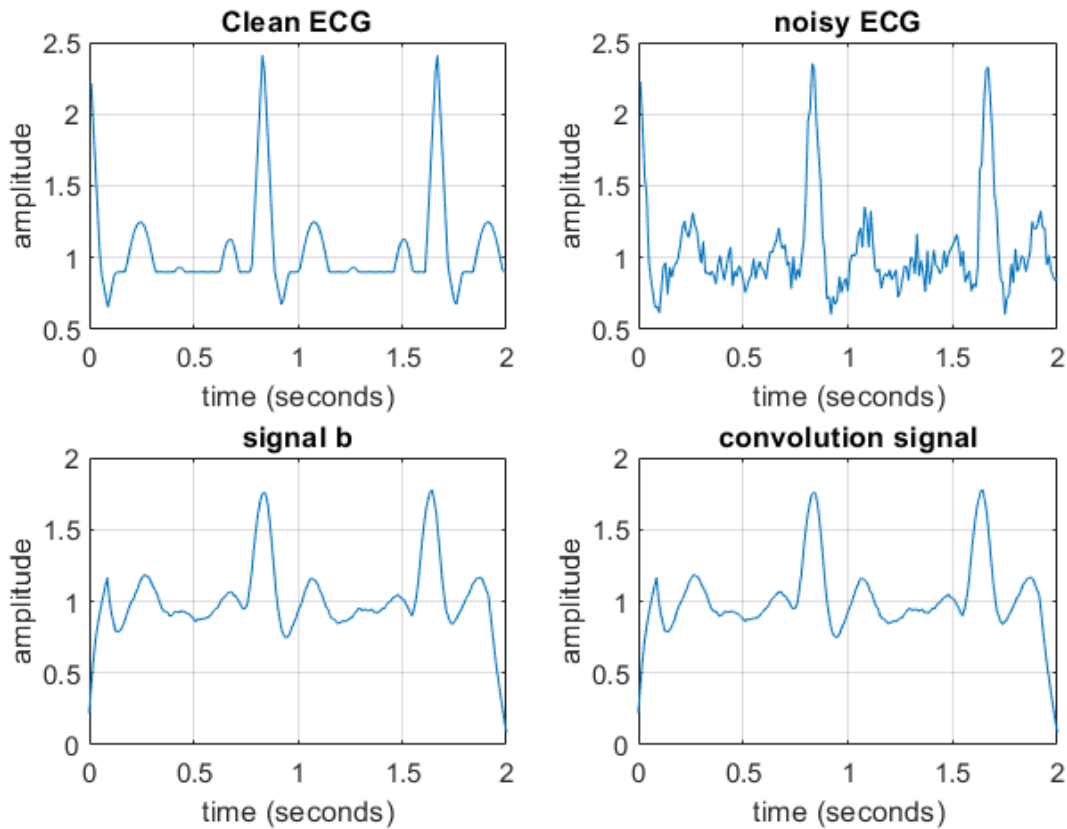
*Figure 2: The figure displays our four signals created when we used  $N = 3$  samples in our moving average filter.*

## ECG Signals over 2 seconds at $N = 5$



*Figure 3: The figure displays our four signals created when we used  $N = 5$  samples in our moving average filter.*

## ECG Signals over 2 seconds at $N = 10$

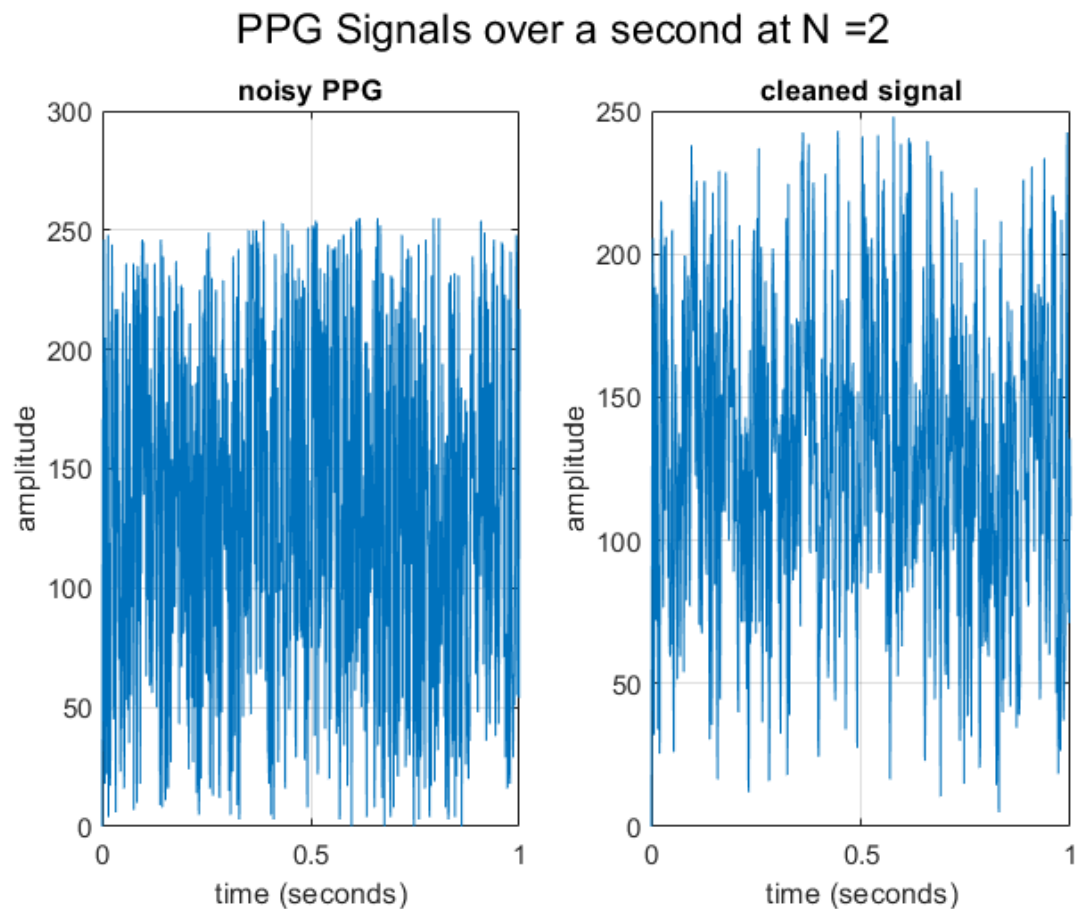


*Figure 4: The figure displays our four signals created when we used  $N = 10$  samples in our moving average filter.*

For part e, I created the figures above, using the line figure(i), for each value of  $N(i)$ , and filled the figure with four subplots. Each subplot containing either the clean ECG, the Noisy ECG, the signal from part b, or the convolution from part d at varying values of  $N(i)$ . Based on these figures, I conclude that the code used for part b was an effective representation of the moving average filter. Since the signal found in part b and the convolution in part d appear identical. One can also deduce from these figures the benefit and drawback of varying values of  $N$ . At smaller values of  $N$  samples, 2 & 3, our cleaned signals appear to retain a decent portion of noise, even after being filtered. However, a smaller value of  $N$  also causes the cleaned signals to retain a more accurate amplitude. At larger values of  $N$  samples, 10, the opposite is true. With noise being undetectable, but the amplitude of our cleaned signals being far lower than its true value (denoted from the cleaned ECG signal provided). This is likely due to the moving average filter using the concept of mean to filter out our noisy signal. As a larger number of samples means that our outlying low or high values will be averaged out. Therefore, causing our signal to appear smoother but with lower amplitude since the

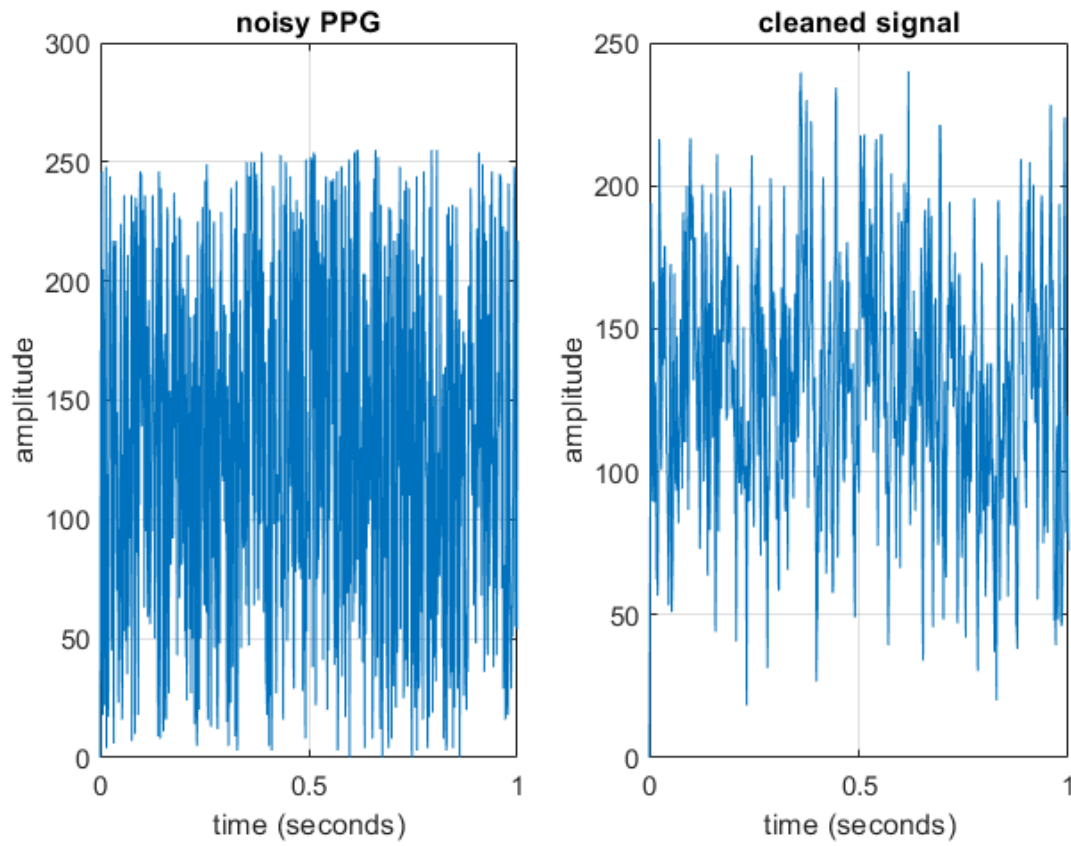
large outliers have a smaller effect when averaged out with more samples. For this problem,  $N = 5$  samples seems to be the appropriate sampling size for our moving average filter. As this allows us to keep our amplitude truer to the correct value, while also cleaning out most of the noise.

For problem 2, I ended up using a wrist photoplethysmogram (PPG) signal that was measured while a patient was walking. I was unable to find a file in .mat or .csv formatting, but this signal is still readily accessible from Physionet. It was initially recorded by Goldberger et. al [1] for the purpose of building up a database of PPG signals. The process I used to access the file in MATLAB is relatively the same as in problem one. However, I used the fread and fopen functions so that I could read the binary file. Then, I read in the values recorded (at 256 Hz) for the first second only to avoid taking too much processing time. I then largely repeated the process described above for parts b and e of problem one, to create the following graphs:



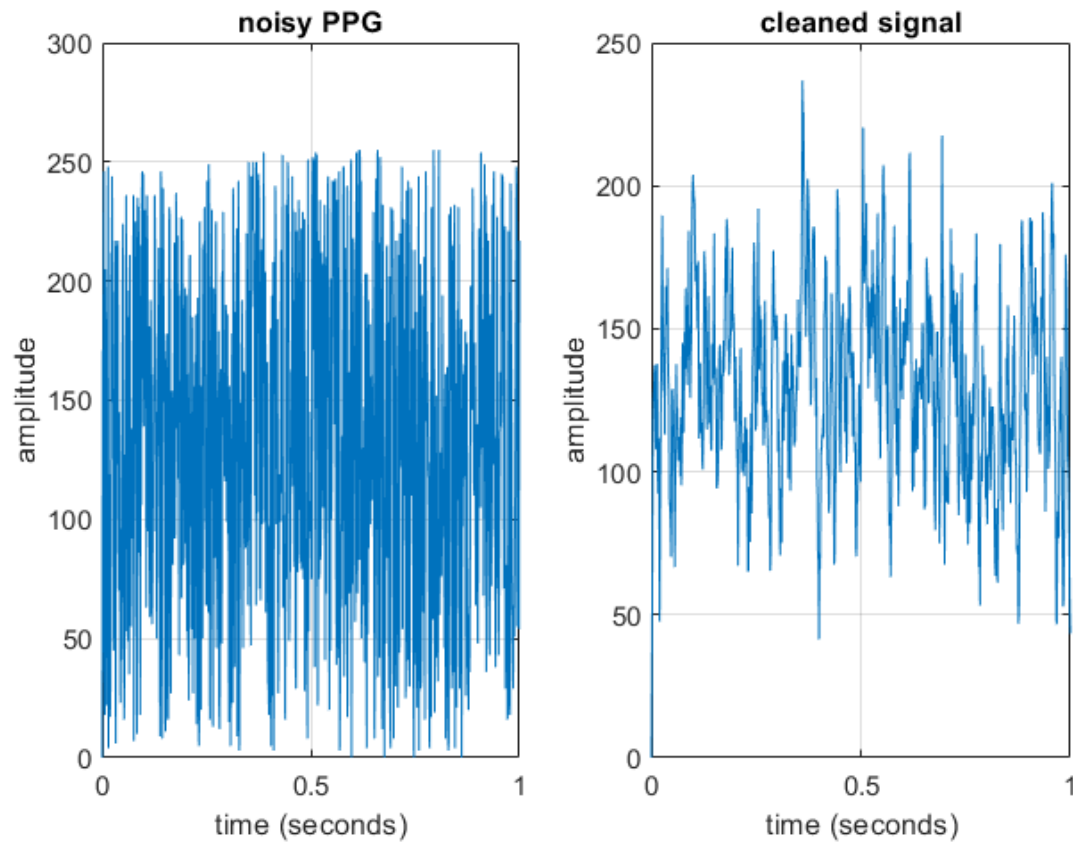
*Figure 5: The figure displays our PPG signals created when we used  $N = 2$  samples in our moving average filter.*

## PPG Signals over a second at $N = 3$



*Figure 6: The figure displays our PPG signals created when we used  $N = 3$  samples in our moving average filter.*

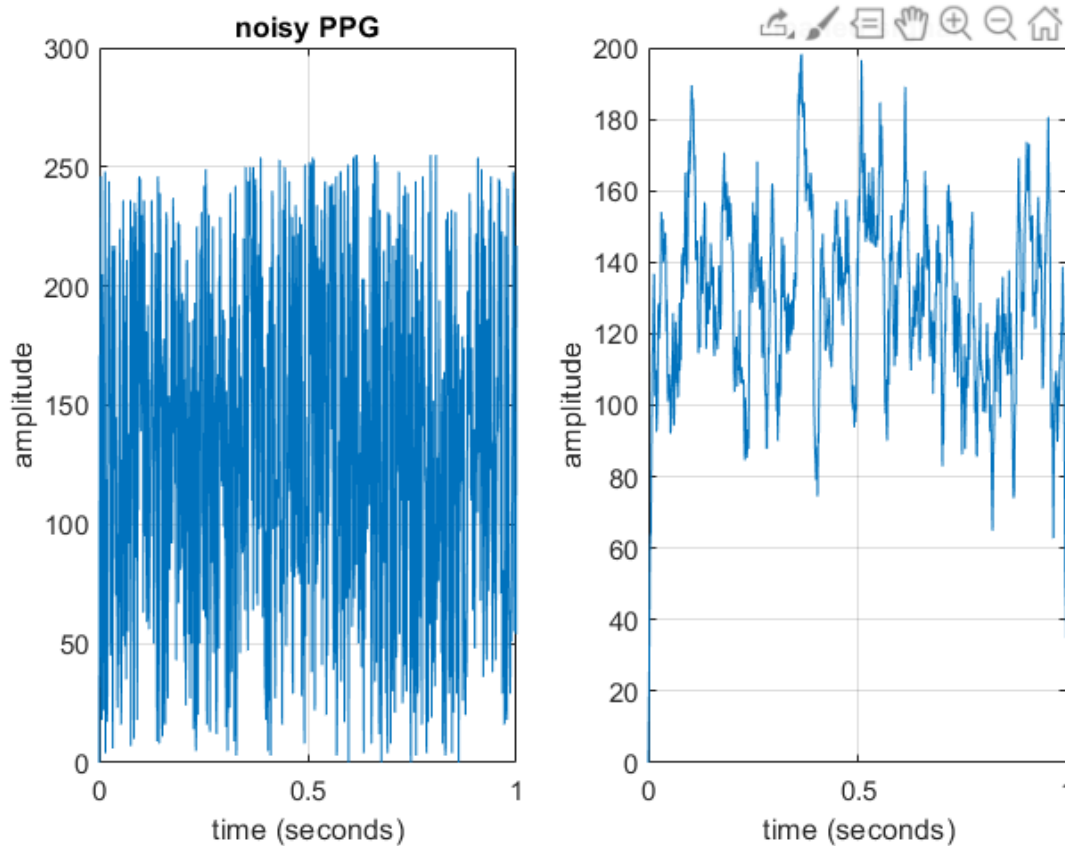
## PPG Signals over a second at $N = 5$



*Figure 7: The figure displays our PPG signals created when we used  $N = 5$  samples in our moving average filter.*



## PPG Signals over a second at N =10



*Figure 8: The figure displays our PPG signals created when we used  $N = 10$  samples in our moving average filter.*

The above figures were created using our moving average filter, at varying values of  $N$ , to clean the noisy PPG signal provided. It is easy to denote that this moving average filter is not the most effective filter available for signals such as these. Meaning, that our PPG signal had a low SNR. However, if we had to choose the moving average filter to clean the signal, the value of  $N = 10$  appears to be the most favorable.  $N = 10$  is the preferred value for  $N$  due to this being the only signal that appears to be clean enough for analysis.

Citation:

[1] Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals (2003). *Circulation*. 101(23):e215-e220.