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Digital Moving Average Filter for De-noising the Ultrasonic Signals Utilized in COVID-19 PreventionApplications

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Abstract:- This research paper presents a digital moving av- erage filter for noise removal of the ultrasonic signal which plays a major role in COVID-19 prevention applications such as social distance detection systems and sensor-based handwashing systems. The goal of the above-mentioned filter is to improve the accuracy of distance measurements. The filter design procedure was carried out mainly using software called Matrix Labora-tory with the assistance of hardware components such as the Arduino development board, ultrasonic sensor, and breadboard. Furthermore, a comprehensive analysis was conducted between the original signal and the filtered signal to verify the effectivenessof the filter.

***Keywords*:-** *Arduino development board, Digital Moving Average Filter, Matrix Laboratory, Noise removal, Ultrasonic sensor.*

I. INTRODUCTION

The occurrence of the COVID-19 pandemic has led us towards various techniques for reducing the spread of the disease. These techniques include maintaining a safer distance recommended by the World Health Organization (WHO), detecting high-risk areas, contact tracing, analyzing various symptoms, using automation techniques for handwashing and sanitization, using face masks, and others. Since physical contacts contribute majorly to the spread, the innovations such as wearable social distance detection system which is the main focus of [1], and low-cost sensor-based handwashing system developed by the authors of [2] have been drawn into the spotlight.

Many applications including the above-mentioned ones, usea certain sensor type for getting inputs. These inputs can bea temperature value, a distance value, or any other parameter. As far as distance is concerned, the most used sensor is the Ultrasonic sensor due to its long lifetime and easiness of interfacing with micro-controllers. The working principle of Ultrasonic sensors has three main steps namely, the emission of high-frequency sound waves, sensing the reflected signal and, calculating the distance using the time lapse betweenthe signal transmission and retrieval. Using this mechanism, they constantly perform distance measurements to facilitatethe functioning of social distance detection systems as wellas the automated handwashing systems used for COVID-19 prevention. But, just like any other sensor, the ultrasonic sensor can also show poor performance due to the addition of two kinds of noises: man-made noise, and natural noise. It will lead to inaccurate and fluctuating distance measurements. Due to these fluctuations, the commands that will be givento the Servo motors that dispense the water and soap as explained in the working principle of the low-cost sensor- based handwashing system [2] will get affected causing the overall performance of that application to reduce. Since the system will be operating when the hands are kept within a specified limit, the above-mentioned issue will frequently happen if the hands are positioned near the edge. This is dueto the reason that the system is unable to correctly recognize the presence of the hand when positioned near the edge.

Apart from this, some countries strictly follow the safe distance, as a rule, to prevent the kids and other high- risk groups of people from getting affected by COVID-19. Therefore, inaccurate distance measurement could become a serious issue when it comes to safe distance maintenance as well. Hence, an effective solution has to be obtained to remove the noise components in the ultrasonic signal.

This research paper describes the development of a Digital Filter using the Moving Average technique to remove the noisecomponents that are present in the ultrasonic signal thereby improving the accuracy of distance measurements, and ulti- mately, improving the performance of COVID-19 prevention applications such as social distance detection systems andautomated low-cost handwashing systems.

The Moving Average Filter is a simple and effective Finite impulse response (FIR) filter based on computing the average of adjacent points [3]. It operates by averaging several points from the input signal according to specified window size,in order to generate each output point of the output signal [4]. Therefore, this type of filtering is effective for reducing random noise while retaining a sharp step response as

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stated in[4]. There are several types of moving average (MA) filters; thesimple MA (SMA), the cumulative MA (CMA), the weighted MA (WMA), and the exponential MA (EMA) [3]. In thisresearch, the SMA method is used to develop the filter.

The SMA filter can be implemented in two ways. It canbe either implemented as a one-sided point type or as a Symmetric type. The one-sided MA filter considers only the present and past input values for computing the average. But, the Symmetric type filter considers the future values as well. Moreover, the one-sided filters will produce a phase shift between the input and output signals whereas the Symmetric type filters will not produce a phase shift and are called zero-phase shift filters. Our particular interest here is to design a Symmetric MA filter in order to avoid any phase shifts between the input and output signals.

Considering all these facts, the following section clearly explains the materials and methodologies that are used to implement the Simple Symmetric Moving Average filter.

II. MATERIALS AND METHODS

The implementation of the filter was carried out with the help of software and hardware. Two types of software namely, MATLAB and Arduino IDE were used. Similarly, hardware components namely, Arduino Uno microcontroller board, Breadboard, jumper wires, Ultrasonic sensor (HC–SR04), and laptop were used. The design procedure was categorized into three parts which are hardware development, software development, and testing.

A. Hardware implementation

In the hardware implementation stage, the Arduino Uno mi- crocontroller board, breadboard, jumper wires, and Ultrasonic sensor were used. The ultrasonic sensor model was HC-SR04 and it has 4 pins: Supply voltage (Vcc), Trigger, Echo, and ground. The Vcc pin powers the sensor, the Trigger pin acts as an input pin and initializes measurement by transmitting ultrasonic waves, the Echo pin acts as an output pin and goes high for a period of time that will be equal to the time taken for the signal to return back, and the ground pin connects the sensor to the system ground. The above-mentioned information about the pins was extracted from the device datasheet obtained from [5].

As the first step, all the necessary connections were madeto interface the ultrasonic sensor with the Arduino Uno board in order to facilitate distance measurement. The Vcc pin was connected to the 5 V power supply of Arduino, the trigger pin and echo pin were connected to digital pins in the Arduino board, and the ground pin was connected to the Arduino ground. Similarly, the Arduino board was connected to the laptop via the USB port. Fig.1 shows the components and necessary setup that was implemented.

B. Software Implementation

After making the necessary hardware setup, the code forthe Arduino microcontroller board was written to facilitate constant distance measurement and analysis. At the same time, the Arduino serial monitor was linked with the MATLAB software in order to process the obtained echo signal and to design the filtering mechanism in real-time. Here the important requirement is to have the Arduino support package installed in the MATLAB software.

In order to develop the code for the filtering process, a particular window size has to be defined. This window size corresponds to the number of samples we take in order to get the average. If the window size is large, the noise reduction capability will be high. In other words, the accuracy of distance measurement will be high. But if the window sizeis too large, the response time will increase.

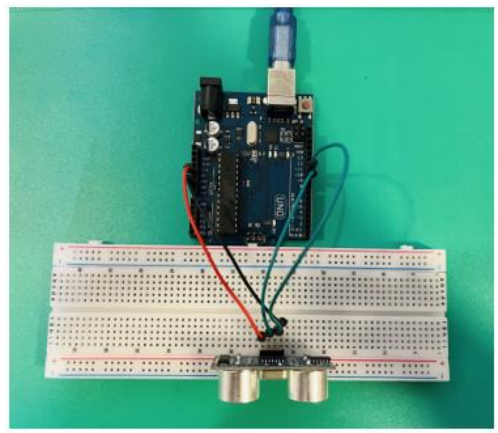

Fig. 1:- Implemented setup

```
float distance;
int duration;
int triggerPin = 9;
int echoPin = 10;

void setup() {
pinMode(triggerPin,OUTPUT);
pinMode(echoPin,INPUT);
Serial.begin(9600);
}

void loop()  {
digitalWrite(triggerPin,LOW);
delay(2);
//clearing the trigger.

digitalWrite(triggerPin,HIGH);
delay(10);
digitalWrite(triggerPin,LOW);

duration = pulseIn(echoPin,HIGH);
distance = duration*0.034/2;
Serial.println(distance);
delay(100);
}
```

Fig. 2:- Code developed for distance measurement

Fig.2 shows the code written in the Arduino IDE. This code will make sure that the ultrasonic sensor measures the distancein a proper way. Similarly, the MATLAB codes related to filterdesign are also given.

```
%moving average filter designing part
windowsize = 15;
t2 = ones(1,windowsize);
num = (1/windowsize)*t2; %numerator of transfer function
den = [1]; %denominator of transfer function
Y = filter(num,den,y);
```

Fig. 3:- MATLAB code for filter designing part

```
clc;
clear;
close all;

if ~isempty(instrfind)
    fclose(instrfind);
    delete(instrfind);
end

port = 'COM3';
Baud_Rate = 9600;
Data_Bits = 8;
Stop_Bits = 1;
%serial object
s = serial('COM3', 'BaudRate', Baud_Rate,...
'DataBits',Data_Bits,'StopBits', Stop_Bits);
fopen(s); %open serial port

%creating array
y = [];
t =[];
```

Fig. 4:- MATLAB code for interfacing serial port

```
for i = 1:350
    data=str2double(fscanf(s));
    if data > 400
        data=400;
    end
    y = [y data];
    t = [t i];

    %plotting original signal
    subplot (2,1,1)
    plot(t,y)
    ylim([20,30])
    xlim([0,350])
    yticks(20:2:30)
    ylabel('Distance (cm)')
    xlabel('Time (s)')
    title('Original signal')
```

Fig. 5:- MATLAB code for plotting the original signal

```
    %plotting filtered signal
    subplot (2,1,2)
    plot(Y,'r')
    title('filtered signal')
    ylim([20,30])
    xlim([0,350])
    ylabel('Distance (cm)')
    xlabel('Time (s)')
    yticks(20:2:30)
    pause(0.01)
end
```

Fig. 6:- MATLAB code for potting the filtered signal

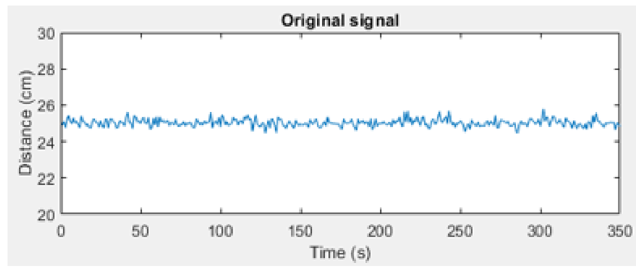

Fig. 7: - Original signal for case I

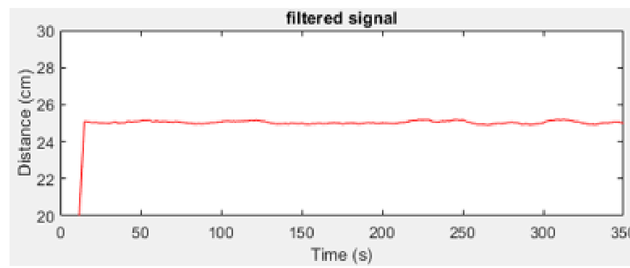

Fig. 8:- Filtered signal for case I

C. Testing

In this stage, the implemented SMA filter was tested by measuring the distance of an object from the Ultrasonic sensor in real-time. This phase was implemented in two steps. In the first step, the object was kept stable. But, in the second step, the object was moving. The results of the tests are separately analyzed for both the above-mentioned conditions in the next section.

III. RESULTS AND DISCUSSION

As mentioned previously, this section focuses on the resultsthat we have obtained by testing the filter. In the first case, wewill consider the object to be stable, and in the next case, we will consider it to be moving.

A. Case I

The object was kept at a distance of 20 – 30 cm fromthe sensor and the relevant original waveform and filtered waveform were obtained from the MATLAB output window. Fig.7 and Fig.8 shows the original and filtered signal for the window size of 15. By analyzing Fig.7 and Fig.8, we cansee that the noise present in the original signal is almost got filtered. If we increase the window size even further, the denoising capability will increase. But, we cannot increase thewindow size to any value since it will affect the response time of the filter as well as the sensitivity of the filter to immediate changes in the original signal.

B. Case II

In this case, the object was not stable at a particular distancefrom the sensor. It was moved in an irregular fashion. The relevant waveform obtained for the second case are Fig.9 and Fig.10, respectively.

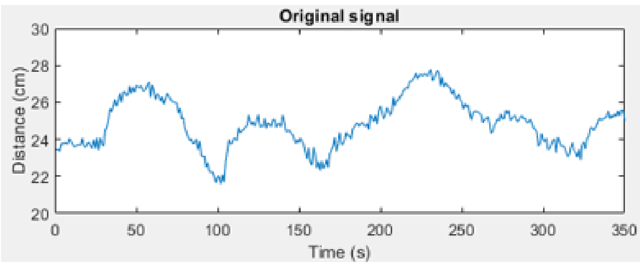

Fig. 9:- Original signal for case II

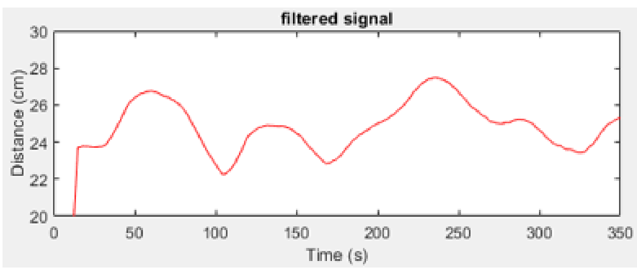

Fig. 10:- Filtered signal for case II

Considering Fig.9 and Fig.10, it is clear that the noise components of the signal are almost filtered out while maintaining the filter in a way that it responds to quick changes in the object's distance as well. Therefore, this filter shows good performance when it comes to detecting and measuring distance of moving as well as stable objects in an efficient way.

IV. CONCLUSION

In this study, I have presented a different implementation ofDigital FIR filter based on Moving Average method in order to improve the performance of existing COVID-19 prevention applications such as social distance detection systems and sensor-based handwashing systems. Since ultrasonic sensors are frequently used in the above-mentioned applications, I have particularly focused on noise removal of ultrasonic signals using the principle of moving average. The filter implementation was conducted using Matrix Laboratory and Arduino IDE, followed by a detailed comparison between original signal and filtered signal. From the comparative analysis, it was observed that the noise present in the original ultrasonic signal was almost got removed. But, in my point of view, even though the implemented filter is of good performance and efficiency, there exists room for further improvements and developments as well. As an example, we could be able to further improve the accuracy of filtering mechanism by using genetic algorithms, and some ways of calculating the feasible window size for the filter. This will be the future concerns of this study.

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REFERENCES

[1]. F. A. Naqiyuddin, W. Mansor, N. Sallehuddin, M. M. Johari, M. Shazlan, and A. Bakar, "Wearable social distancing detection system," in *2020 IEEE International RF and Microwave Conference (RFM)*. IEEE, 2020, pp. 1–4.

[2]. A. G. Yadessa and A. O. Salau, "Low cost sensor based hand washing solution for covid-19 prevention," in *2021 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT)*. IEEE, 2021, pp. 93–97.

[3]. A. Al-Odienat and A. Al-Mbaideen, "Optimal length determination of the moving average filter for power system applications," *Biomedicine*, vol. 10, 2015.

[4]. J. L. Guiñón, E. Ortega, J. García-Antón, and V. Pérez-Herranz, "Moving average and savitzki-golay smoothing filters using mathcad," *Papers ICEE*, vol. 2007, pp. 1–4, 2007.

[5]. "Hc-sr04 ultrasonic sensor." [Online]. Available: https://components101. com/sensors/ultrasonic-sensor-working-pinout-datasheet