DSP Homework 07

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Contents

Abstract

In this week's homework, there are three questions.

In question 1:I summarized the three videos of mouse principle, starch and other traditional diet, and the ecological environment of the north and south poles that I watched this week,learned and understood the cross-correlation algorithm mentioned in the first video, and realized the cross-correlation operation of the two functions through Matlab simulation software.

In question 2: In order to find the advantages and disadvantages of Shannon sampling, first of all, I put forward the evaluation criteria for the advantages and disadvantages of analog signal sampling according to my own understanding, put forward its existing problems according to the proof process of Shannon's theorem according to the proposed criteria, and summarized the advantages of the method by comparing with the sampling process of the Fourier series expansion method.

In question 3: Based on the mouse movement position determination method learned in Video 1, the position of the mobile phone in three-dimensional space is determined by comparing two adjacent pictures.

1 Write a summary of this week's video(s) and your further thoughts on the content.

1.1 The videos summary

1.1.1 Mouse introduction

The first video explains the image sensor of the mouse and the difference between a normal mouse and a gaming mouse.
Image sensor of the mouse:

The bottom of the mouse has an image acquisition system, which is composed of three parts: LED, pixel array and lens, and its general working process is as follows: through the LED emits infrared light reflected into the lens, the picture information collected by the lens is made into a pixel array, and the array obtained before and after is compared to obtain the motion coordinates of the mouse. Among them, it should be noted that the mouse itself does not capture the color and shape of the mouse pad, its image is through the LED at a very small angle of light to illuminate the bottom of the mouse to get different texture images, the image is collected every 59us, the previous image will be moved and the next image is calculated by the cross-correlation algorithm When the correlation coefficient is the largest, the position is the position of the mouse movement, and the position movement in 1ms can be obtained through the superposition of 17 position movements $(\Delta x, \Delta y)$.
The difference between a normal mouse and a gaming mouse:

The difference between gaming mice and ordinary mice is that the DPI of gaming mice is much higher than that of ordinary mice, and its value can be obtained by interpolation algorithm, in addition, the information exchange rate of gaming mice is much larger than that of ordinary mice.

1.1.2 Traditional diet

The second video illustrates the gradual decline in people's physical health since the human diet changed from traditional foods such as starch, vegetables and fruits to videos often eaten by kings and queens, such as oil and meat. In the video, the speaker talks about how due to this unbalanced eating habit, the children, soldiers, and workers are far less in good health. As a doctor, he has deeply discovered how important healthy eating habits play in maintaining good health and fighting diseases, so he calls on people to pay attention to how to eat, abandon this unbalanced eating habit, and return to a fruit, vegetable and starch diet.

1.1.3 Our planet

The third video explains to us some creatures living in the Arctic and Antarctic regions and the territories they inhabit, penguins and albatross birds living in the Antarctic region, polar bears, seals and other creatures living in the Arctic. But as glaciers melt due to global warming, their habitats have been severely damaged.

1.2 My further thoughts

In the first video, the method of determining the direction of the before and after images is mentioned through the cross-correlation algorithm. I thought of whether it was possible to calculate the delay of the input and output signals by cross-correlation algorithm, so I simulated it with MATLAB software, and the result is as follows:

First record the input signal, that is, the original signal in the picture, assuming that the signal delay 3 information bits are recorded as the theoretical output signal, that is, the delay signal in the picture, considering that the channel transmission process will be affected by noise, on the basis of the theoretical output signal superimposed noise as the output signal.

Very good. Yes, time delay can be thus estimated, as

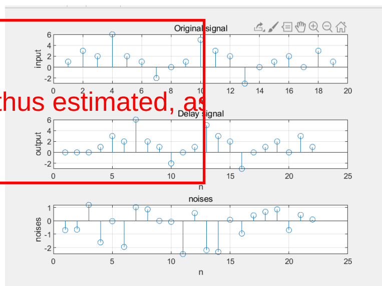


Figure 1: Input and output signals

The input signal is panned through m, and the translated signal is compared with the output signal, and the comparison result is shown in the following figure:

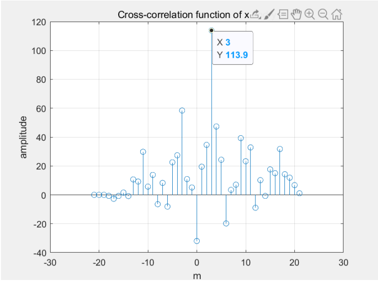


Figure 2: Cross-correlation detection

It can be observed that the number of correlations between the two signals is the largest at m = 3. Therefore, in the process of communication information transmission, an original signal can be input first, and the number of interrelationships between the input signal and the output signal can be calculated to obtain the number of delayed information m, and the original signal can be obtained by shifting the obtained signal to the corresponding position in the process of subsequent signal reception.

2 Analyze the pros and cons of the Shannon/Nyquist sampling method.

To judge the merits of sampling methods, it is necessary to set evaluation criteria or compare them with other methods, and after studying Shannon's sampling theorem and Fourier series expansion method, I propose the following criteria.

According to the specific steps of Shannon sampling, its advantages and disadvantages are summarized.

2.1 Judging criteria

Very good.

2.1.1 The range of signals that can be processed

The more types of signals a sampling method can handle, the wider and more universal it is.

2.1.2 Signals used for sampling

Whether the signal used for sampling is easy to implement is the criterion for the cost of sampling, and the easier the signal used for sampling is to achieve, the lower the cost of sampling.

2.1.3 Signal recovery

As a means of signal transmission, sampling ultimately needs to obtain the original signal, so whether the recovery process is easy to achieve, and whether the distortion of the signal after recovery is serious or not are the evaluation criteria for the advantages and disadvantages of the sampling method.

2.1.4 Information transfer after sampling

Continuous signals are changed into discrete signals by sampling for easy transmission, so whether the sampled signal is conducive to transmission is also an important criterion for sampling evaluation.

2.2 Pros of the Shannon sampling method

1. **Both periodic and non-periodic signals can be processed**: Since the Fourier series can only expand the periodic function, the Fourier series expansion method can only handle periodic signals, but the Shannon sampling uses the expansion method of the Fourier function to expand the non-periodic function.

2. **Converts continuous signals in the time domain into discrete signals in the time domain for easy transmission**: Shannon sampling samples the original signal through periodic pulses, turning the time-domain continuous signal into a time-domain discrete signal; The Fourier series expansion method turns the continuous signal in the time domain into a discrete signal in the frequency domain, which cannot be transmitted according to the information bits in the process of channel transmission, but is corresponding to $n\omega$.

3. **The signal is a continuous spectrum, which is less distorted for normal signals during recovery**: The spectrum after sampling by Shannon is a continuous spectrum, and the original signal can be obtained according to the inverse Fourier transform for limited signals in the frequency domain, and the method of Fourier series expansion has a certain discard of the coefficient due to $n \nrightarrow \infty$, resulting in distortion in the recovery process.

2.3 Cons of the Shannon sampling method

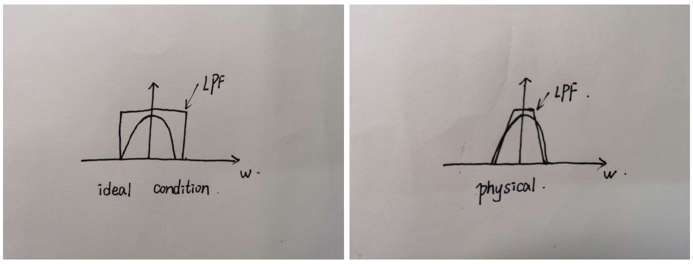
1. **Processing of time-domain finite signals creates distortion**: Due to the infinite magnitude of the time-domain finite signal in the frequency domain, there is no way to find the exact cutoff frequency f_s,Only an approximate cutoff f_s can be found, which will produce some distortion during the recovery process.

2. **Sampling of higher frequency signals is not suitable**: Since Shannon's theorem requires sampling at twice the highest frequency of the signal which is $2f_s$, sampling by Shannon's theorem for very high frequency signals will be difficult to generate due to the frequency being too high.

3. It is necessary to know the bandwidth W,otherwise it will cause distortion.

4. **The low-pass filter recovers distortion**:Consider that a low-pass filter is needed in the process of signal recovery, but the low-pass part of the actual circuit is not a steep rise and fall, but has a certain slope, as shown in the figure below, which may cause spectral filtering distortion and lead to distortion of the recovery signal.

Need more thorough deta



(a) ideal condition (b) physical

Figure 3: LPF analyse

3 Use the knowledge learnt in video 01 to solve the following problems

3.1 Problem description

3.1.1 Questions 01

Make your phone camera shoot a video clip while it moves freely in all directions (left/right, up/down, near/far) with minimal rotation. Then use the video clip alone to do the next part.

3.1.2 Questions 02

Draw the trajectory of your phone camera movement in the three dimensional (3D) space up to scaling and analyze the error.

3.2 Solving way

3.2.1 Design ideas

In this problem, we divide the movement of the mobile phone before and after the left and right and the change of the far and near distance into two aspects for discussion.

Suppose the image before moving is f_1, and after panning (a,b), the image f_2 is obtained, which is $f_2 = f_1(x + a, y + b)$.To be able to find the numbers a and b,we offset the original image with $(\Delta x_n, \Delta y_n)$,so we get $f_{\Delta n} = f_1(x + \Delta x_n, y + \Delta y_n)$.Defined by a cross-correlation function:

$$R_{ccf}(x, y) = f_{\Delta n}(x, y) * f_2(x, y)$$

It can be seen from the Fourier transformation that

$$\begin{aligned}
\widetilde{f_{\Delta n}}(u,v) &= \widetilde{f_1}(u,v)e^{-2\pi j(u\Delta x_n + v\Delta y_n)} \\
\widetilde{f_2}(u,v) &= \widetilde{f_1}(u,v)e^{-2\pi j(ua+vb)} \\
\widetilde{R_{ccf}}(u,v) &= \widetilde{f_{\Delta n}}(u,v)\widetilde{f_2}(-u,-v) \\
&= \widetilde{f_1}(u,v)e^{-2\pi j(u\Delta x_n + v\Delta y_n)}\widetilde{f_1}^*(u,v)e^{2\pi j(ua+vb)} \\
&= \widetilde{f_1}(u,v)\widetilde{f_1}^*(u,v)e^{2\pi j(u(a-\Delta x_n)+v(b-\Delta y_n))}
\end{aligned}$$

Set $\widetilde{f_1}(u,v)\widetilde{f_1}^*(u,v) = \widetilde{F}(u,v)$Inverse transform by Fourier

$$\begin{aligned}
R_{ccf}(x,y) &= F(x,y) * \Delta(x-(a-\Delta x_n), y-(b-\Delta y_n)) \\
&= F(x-(a-\Delta x_n), y-(b-\Delta y_n))
\end{aligned}$$

From the properties of the auto-correlation function, the peak value of the function $\widetilde{f_1}(u,v)\widetilde{f_1}^*(u,v)$ is at the origin, To ensure x=0,y=0,we can get that $\Delta x_n = a, \Delta y_n = b$,That is the offset of f_2 to f_1.

The envisaged treatment of the movement of equipment near and far is using $\theta = \frac{l}{h}$ to find out the shooting angle of the mobile phone,when the position h changes,record it as h_1,then $l_1 = h_1 tan\theta$,the part in the middle that is not highly affected is denoted as s,crop the image to $2l_1 + s$ length get f_2,comparison with the original image f_1 by cross-correlation algorithm to find h_1.

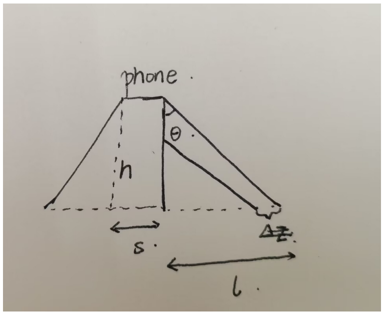


Figure 4: Altitude position measurement

3.2.2 Carry out

Since the movement of the picture in the 2D direction and the movement in the near and far direction are separated, its motion trajectory in the 2D plane and Z direction is measured in the process of coding and design, and the result is drawn.

1. **Video image extraction**:Split the video into 26 pictures via MATLAB and save it in a folder to be used.

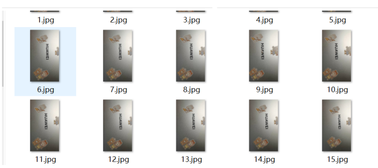
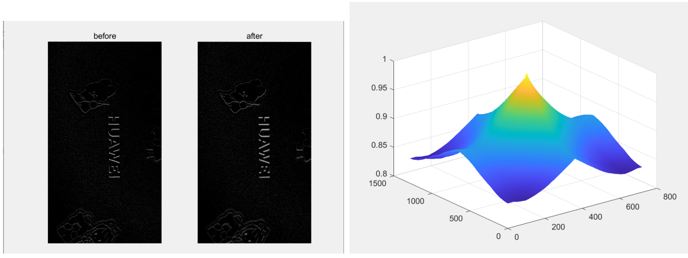


Figure 5: video cut

2. **2D image processing**:Write code to find two adjacent images' offset in 2D space through a cross-correlation algorithm.The image after moving compare as shown below the processed image figure, in order to better demonstrate his position shift process, the correlation results of each point are plotted by mesh.And we can find that$x = 535, y = 262$.



(a) compare (b) Cross-correlated image

Figure 6: 2D picture process

3. **far and near**:The length and width that can be photographed when measuring heights h_0 and h_1 are denoted as l_0 l_1 c_0 c_1 respectively.Set the shooting angle for wide direction and long direction to θ_c and θ_1.Set the length range that is not affected by height to s_l s_c.Then we can get that,

$$l_0 = s_l + 2h_0 tan\theta_1$$
$$l_1 = s_l + 2h_1 tan\theta_1$$
$$c_0 = s_c + 2h_0 tan\theta_c$$
$$c_1 = s_c + 2h_1 tan\theta_c$$

Substituting the measured data into the formula yields the parameters(Due to space constraints, specific measurement processes and data are no longer displayed).The coordinate distance and the actual moving distance (cm) are converted from the 2D image.The coding test tells the position change of its height.

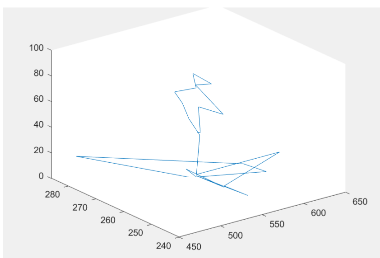
3.2.3 The result

The 2D position offset and the h direction's recorded datas are as follows:

Table 1: The functions of the P3 port multiplexing pin

direction	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
x	535	480	594	605	541	542	541	541	539	541	641	541
y	262	286	260	255	261	265	251	261	242	251	261	261
z	10	12	12	9	10	12	12	11	15	13	12	12
direction	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24
x	545	532	534	538	544	540	539	540	540	540	539	541
y	261	261	264	268	262	262	255	261	251	260	259	261
z	42	57	66	70	78	90	89	82	69	66	47	45

Put the recorded data into MATLAB to obtain the motion trajectory shown in the figure below.



Error analysis?

Figure 7: Motion trajectory

Reference

Appendix A Code Listings

```
%% signal cross-correlation
clear;
clc;
x=[1 3 2 6 2 1 -2 0 1 5 3 2 -3 0 1 2 0 3 1];
y_or=[0 0 0 1 3 2 6 2 1 -2 0 1 5 3 2 -3 0 1 2 0 3 1];
k=length(y_or);
e=randn(1,k);
y=y_or+e;
xk=fft(x,2*k);
yk=fft(y,2*k);
rm=real(ifft(conj(xk).*yk));
rm=[rm(k+2:2*k) rm(1:k)];
n = 1:k-3;
p = 1:k;
m=(-k+1):(k-1);

figure(1);
subplot(311),stem(n,x);title('Original signal');
grid on
xlabel('n')
ylabel('input')
subplot(312),stem(p,y_or);title('Delay signal');
grid on
xlabel('n')
ylabel('output')
subplot(313),stem(p,e);title('noises');
grid on
xlabel('n')
ylabel('noises')

figure(2);
stem(m,rm)
xlabel('m');
ylabel('amplitude');
title('Cross-correlation function of x and y');
grid on
hold on

%%picture apart
clc;
clear;
video_file='C:\Users\HUAWEI\Documents\Tencent Files\1418646282\Video\video.mp4';
video=VideoReader(video_file);
frame_number=floor(25 * video.FrameRate);
n=video.FrameRate*1;
k=1;
for i=1:round(n):frame_number
    image_name=strcat('C:\Users\HUAWEI\Desktop\image\',num2str(k));
    image_name=strcat(image_name,'.jpg');
    I=read(video,i);
    imwrite(I,image_name,'jpg');
    k=k+1;
    I=[];

end

%% 2-D position test
clear
tic
I1 = imread('C:\Users\HUAWEI\Desktop\image\1.jpg');
```

```
I1 = rgb2gray(I1);
FI1 = fft2(I1);
I2 = imread('C:\Users\HUAWEI\Desktop\image\2.jpg');
I2 = rgb2gray(I2);
FI2 = fft2(I2);

FR = FI1.*conj(FI2);%calculating correlation

R = ifft2(FR);
R = fftshift(R);

num = find(R==max(R(:)));
[i,j] = ind2sub(size(R), num);
offset_x = i-100
offset_y = j-100

toc

R = R/max(R(:));
figure %coefficient of correlation in spatial domain
imshow(R,[])

[m,p] = size(FI2)
[X,Y] = meshgrid(1:p,1:m);
figure
mesh(X,Y,R)

figure
subplot(1,2,1)
imshow(I1-I2);title('before registration')

subplot(1,2,2)
I3 = imtranslate(I2, [2,3]);
imshow(I1-I3);title('after registration')

clear;
clc;
%% far and near
I1 = imread('C:\Users\HUAWEI\Desktop\image\1.jpg');
I1 = rgb2gray(I1);
I2 = imread('C:\Users\HUAWEI\Desktop\image\2.jpg');
I2 = rgb2gray(I2);
FI1 = fft2(I1);
FI2 = fft2(I2);
h1 = 0;
offset_h1 = 0;
FR1 = 0;
c = 1;
k = 2;
s1 = 100;
s2 = 200;
while h1 < 100
    h1 = h1 + 1;
    rect = [c*h1 k*h1 c*h1+s1 k*h1+s2];
    I1_1=imcrop(I1,rect);
    I1_1= imresize(I1_1,size(FI2));
    FI1_1 = fft2(I1_1);

    FR = FI1_1.*conj(FI2);
    if (FR > FR1)
```

```
        offset_h1 = -h1;
    end

    I2_1=imcrop(I2, rect);
    I2_1= imresize(I2_1, size(FI1));
    FI2_1 = fft2(I2_1);
    FR = FI1.*conj(FI2_1);
    if (FR > FR1)
        offset_h1 = h1;
    end
end
fprintf('offset_h = %d.\n', offset_h1);

%% plot
x = [535,480,594,605,541,542,541,541,539,541,641,541,545,532,534,538,544,540,539,540,540,540
y = [262,286,260,255,261,265,251,261,242,251,261,261,261,261,264,268,262,262,255,261,251,260
z = [10,12,12,9,10,12,12,11,15,13,12,12,42,57,66,70,78,90,89,82,69,66,47,45];
plot3(x,y,z);
```