Assignment 3

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1. Part One

1.1

The function performs **the Gram-Schmidt orthogonalization** process to find two orthogonal basis functions that span the same subspace as the input signals, ensuring that **phi1** and **phi2** are orthogonal to each other and capture the essential characteristics of **s1** and **s2.**

Figure 1 Φ1 VS time after using the GM_Bases function

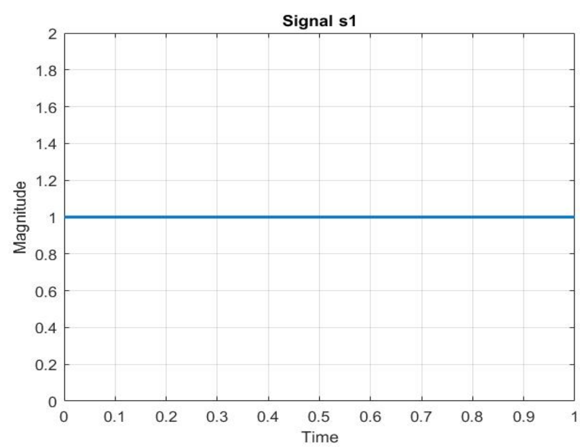
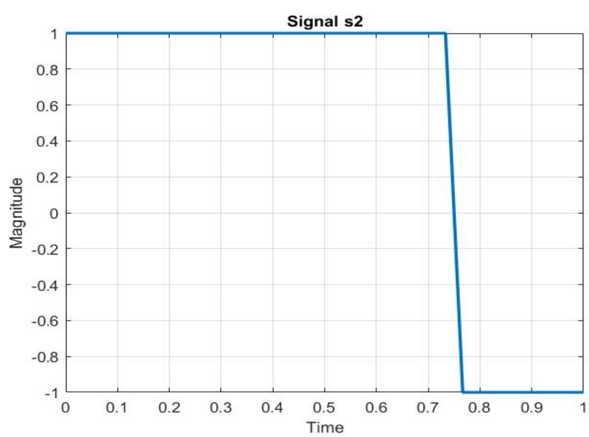


Figure 2 Φ2 VS time after using the GM_Bases function

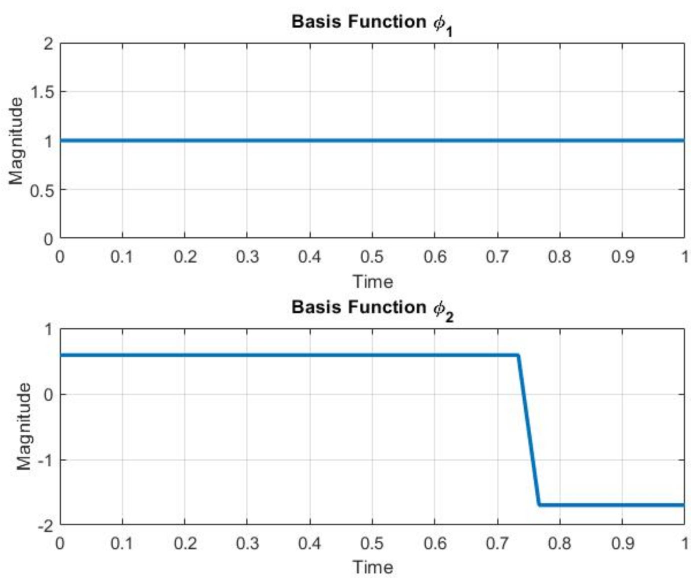


1.2 Signal Space Representation

Here we represent the signals using the base functions.

The signal_space function measures **the correlations** between the input signal s and the basis vectors **phi1** and **phi2**. It provides a way to represent the signal s in terms of the contributions from the two basis vectors.

Figure 3 Signal Space representation of signals s1,s2

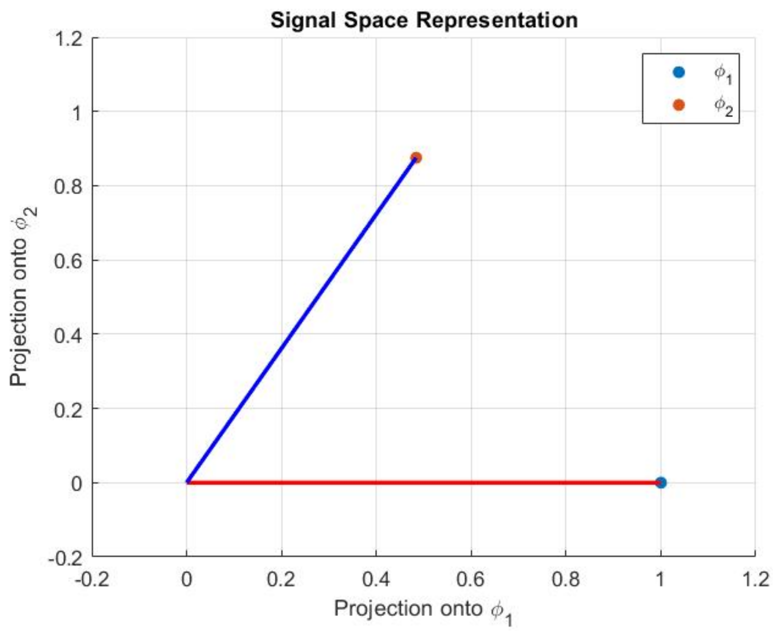


1.3 Signal Space Representation with adding AWGN

-the expected real points will be solid and the received will be hollow

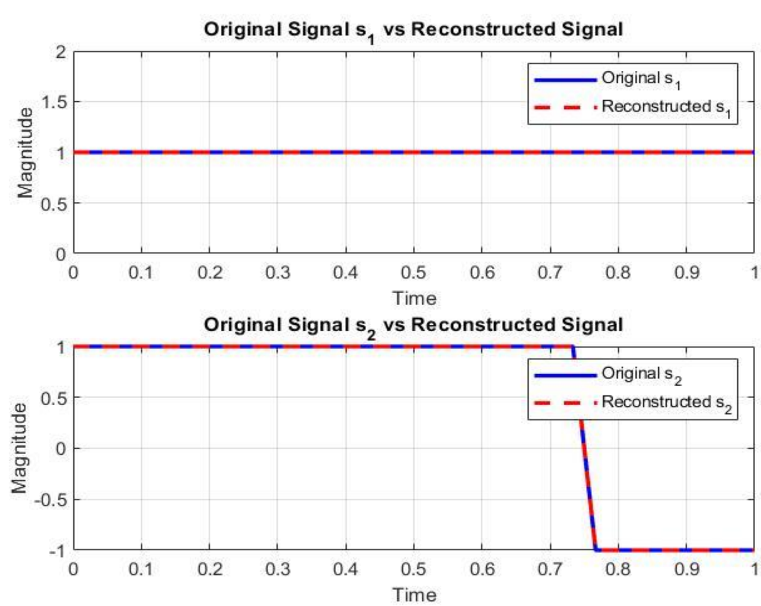
Case 1: $10\,log(E/\sigma^2) = 10\,dB$

Figure 4 Signal Space representation of signals s1,s2 with E/σ¬2 =10dB



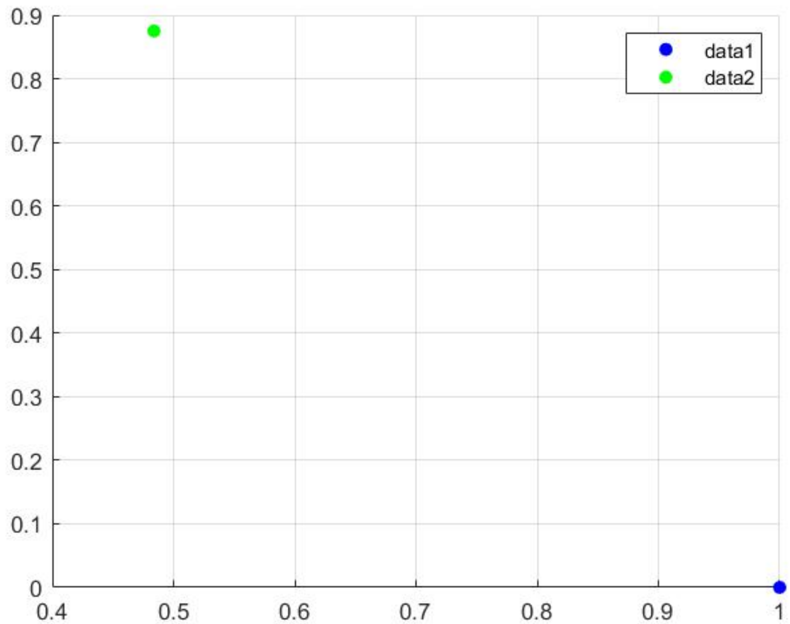
Case 2: $\mathbf{10\ log(E/\sigma^2)\ =\ 0\ dB}$

Figure 5 Signal Space representation of signals s1,s2 with E/σ¬2 =0dB



Case 3: $\mathbf{10}\ \boldsymbol{log(E/\sigma^2)} = \mathbf{-5}\ \boldsymbol{dB}$

Figure 6 Signal Space representation of signals s1,s2 with E/σ¬2 =-5dB



1.4 Noise Effect on Signal Space

2. The noise in the signal affects the signal space representation by introducing additional variability and spreading out the signal points. When the noise variance σ^2 increases, the effect of noise becomes more prominent.

Specifically, as σ^2 increases:

The spread of the signal points in the signal space increases. This is because higher noise levels cause more uncertainty in the signal measurements, leading to larger variations in the signal projections onto the basic functions.

The signal points become more dispersed and less concentrated around the ideal positions determined by the original signals and basic functions. The noise introduces randomness, causing the signal points to deviate from the expected positions. The distinction between different signal points becomes less clear. With higher noise levels, the signal points may overlap or cluster together, making it more challenging to distinguish between different signals or determine their relative positions in the signal space.

Appendix A: Codes for Part One:

A.1 Code for Gram-Schmidt Orthogonalization

```
function [phi1, phi2] = GM_Bases(s1, s2)
    % Check if the input signals have the same length
    if length(s1) ~= length(s2)
        error('Input signals must have the same length');
    end

    N = length(s1); % Length of the input signals

    % Initialize the basis functions
    phi1 = zeros(1, N);
    phi2 = zeros(1, N);

    % Calculate the first basis function (phi1)
    phi1 = s1 / (norm(s1/(N.^0.5)));

    % Calculate the projection of s2 onto phi1
    proj = dot(s2, phi1) * phi1/N;

    % Calculate the second basis function (phi2)
    phi2 = s2 - proj;
    phi2 = phi2 / norm(phi2/(N.^0.5));

    % Set phi2 to a zero vector if s1 and s2 have one basis function
    if norm(s2 - proj) == 0
        phi2 = zeros(1, N);
    end
end
```

A.2 Code for Signal Space representation

```
function [v1, v2] = signal_space(s, phi1, phi2)
    % Check if the input vectors have the same length
    if length(s) ~= length(phi1) || length(s) ~= length(phi2)
        error('Input vectors must have the same length');
    end

    % Calculate the projections (correlations) of s over phi1 and phi2
    v1 = dot(s, phi1) / length(phi1);
    v2 = dot(s, phi2) / length(phi2);
end
```

A.3 Code for plotting the bases functions

```
% Obtain the basis functions using GM_Bases function
[phi1, phi2] = GM_Bases(s1, s2);
%[phi1_s2, phi2_s2] = GM_Bases(s2, s1);

% Plot the obtained basis functions for s1
figure;
subplot(2, 1, 1);
plot(t, phi1, 'LineWidth', 2);
xlabel('Time');
ylabel('Magnitude');
title('Basis Function \phi_1');
grid on;

subplot(2, 1, 2);
plot(t, phi2, 'LineWidth', 2);
xlabel('Time');
ylabel('Magnitude');
title('Basis Function \phi_2');
grid on;
```

A.4 Code for plotting the Signal space Representations

```
% Calculate the signal space representation of s1
[v1_s1, v2_s1] = signal_space(s1, phi1, phi2);

% Calculate the signal space representation of s2
[v1_s2, v2_s2] = signal_space(s2, phi1, phi2);

% Plot the signal space representation for s1 and s2 as scatter plot
figure;
scatter(v1_s1, v2_s1, 'filled');
hold on;
scatter(v1_s2, v2_s2, 'filled');
hold on;
% Plot a line connecting the origin to the specified point
plot([0, v1_s1], [0, v2_s1], 'r','LineWidth', 2);
hold on;
% Plot a line connecting the origin to the specified point
plot([0, v1_s2], [0, v2_s2], 'b','LineWidth', 2);
xlabel('Projection onto \phi_1');
ylabel('Projection onto \phi_2');
xlim([-0.2,1.2]);
ylim([-0.2,1.2]);
title('Signal Space Representation');
legend('\phi_1', '\phi_2');
grid on;
```

A.5 Code for effect of noise on the Signal space Representations

```
% Effect of AWGN on signal space representation
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Define the SNR levels (in dB)
SNR_levels = [-5, 0, 10];
% Generate samples of r1(t) and r2(t) for each SNR level
for i = 1:length(SNR_levels)
    figure;
    grid on;
    hold on;
    % Plot the signal points
    scatter(v1_s1, v2_s1,'b', 'filled');
    scatter(v1_s2, v2_s2,'g', 'filled');

    for j = 1:100
        % Calculate the noise variance based on the SNR level
        SNR_dB = SNR_levels(i);

        % Generate samples of r1(t) and r2(t) using awgn
        r1 = awgn(s1, SNR_dB, 'measured');
        r2 = awgn(s2, SNR_dB, 'measured');

        % Calculate the signal space representation of r1(t) and r2(t)
        [v1_r1, v2_r1] = signal_space(r1, phi1, phi2);
        [v1_r2, v2_r2] = signal_space(r2, phi1, phi2);

        % Plot the signal points
        scatter(v1_r1, v2_r1,'r');
        scatter(v1_r2, v2_r2,'m');
    end
    xlabel('\phi_1');
    ylabel('\phi_2');
    title(['SNR = ' , num2str(SNR_dB)]);

    % Add legends
    legend('signal 1', 'signal 2','signal 1 + noise','signal 2 + noise');
end
```