**Assignment 3**

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# 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.**

A graph with a line

Description automatically generated with low confidenceFigure 1 Φ1 VS time after using the GM\_Bases function

A picture containing text, plot, line, number

Description automatically generatedFigure 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

A picture containing text, line, diagram, plot

Description automatically generated

## 1.3 Signal Space Representation with adding AWGN

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

**Case 1**:

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

A picture containing text, line, plot, diagram

Description automatically generated

**Case 2**:

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

A picture containing text, line, number, diagram

Description automatically generated

**Case 3**:

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

A graph with green and blue dots

Description automatically generated with low confidence

## 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 increases, the effect of noise becomes more prominent.

# Specifically, as 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