EE525 - Lab Project 1

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Due: 10/8/2021

Objective:

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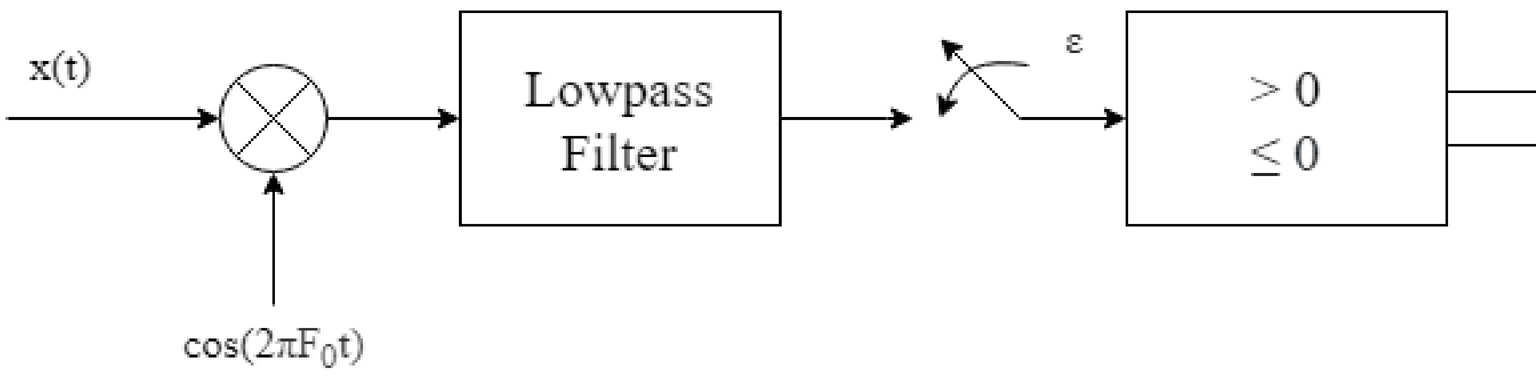
Part 1. Digital Communications

Problem Statement

In a phase-shift keyed (**PSK**) digital communication system, a binary digit (also termed a bit), which is either a "**0**" or a "**1**", is communicated to a receiver by sending either $s_0 = A\cos(2\pi F_0 t + \pi)$ to represent a "0" or $s_1 = A\cos(2\pi F_0 t)$ to represent a "1", where $A > 0$. The receiver that is used to decode the transmission is shown in the figure below. The receiver that is used to decode the transmission is shown in the figure below.



The input to the receiver is the noise corrupted signal or $x(t) = s_i(t) + w(t)$, where $w(t)$ represents the channel noise. It can be shown that in the absence of noise, the output of the lowpass filter is

$$\zeta = \begin{cases} -\frac{A}{2} & \text{for } a \text{ "0"} \\ \frac{A}{2} & \text{for } a \text{ "1"} \end{cases}$$

The receiver decides a "1" was transmitted if $\zeta > 0$ and a "0" if $\zeta \leq 0$. To model the channel noise we assume that the actual value of ζ observed is

$$\zeta = \begin{cases} -\frac{A}{2} + W & \text{for } a \text{ "0"} \\ \frac{A}{2} + W & \text{for } a \text{ "1"} \end{cases}$$

where W is the Gaussian random variable, $W \sim \mathrm{N}(0, 1)$.

1. Analytically determine the probability of error P_e, and plot it versus A.
2. Use computer simulation to plot P_e versus A on the same graph as in 1 above.
3. How should one choose A so that the error probability does not exceed 0.01 (use the analytical result)?

1 - Analytical Solution

```
clc;
clear;
clf;
syms A W x
P_0 = 0.5
```

```
P_0 = 0.5000
```

```
P_1 = 0.5;

Guass_Norm_pdf = 1/sqrt(2*pi) * exp((-(x)^2)/2);

Zeta_0_pdf = subs(Guass_Norm_pdf, x, (A/2 + W));
Zeta_1_pdf = subs(Guass_Norm_pdf, x, (A/2 - W));

P_e_given_0 = 1 - int(Zeta_0_pdf,W,-inf,0);
P_e_given_1 = int(Zeta_1_pdf,W,-inf,0);

P_e_analytical = P_e_given_0*P_0 + P_e_given_1*P_1;
```

Computer Simulation

```
% n = 100; % Sample Size
% Astep = 20;
%
% A = [-5:10/Astep:5];
% errors = zeros(length(A), 1);
% for k = 1:length(A)
%     dist = normrnd(A(k)/2, 1, [1 n]);
%     for m = 1:n
%         if dist(m) <= 0
%             errors(k) = errors(k) + 1;
%         end
%     end
```

```
% end
%
% P_e_simulation_100 = errors/n;
%
% n = 1000000
% A = [-5:10/Astep:5];
% errors = zeros(length(A), 1);
% for k = 1:length(A)
%     dist = normrnd(A(k)/2, 1, [1 n]);
%     for m = 1:n
%         if dist(m) <= 0
%             errors(k) = errors(k) + 1;
%         end
%     end
% end
% P_e_simulation_100k = errors/n;
```

Plot

```
% figure
% hold on
% fplot(P_e_analytical, 'Color', [0 0 0])
% plot(A,P_e_simulation_100, '.', 'MarkerSize', 12, 'Color', [0.8750 0.2780 0.3840])
% plot(A,P_e_simulation_100k, '^', 'MarkerSize', 5, 'Color', [0 0.4470 0.7410], 'MarkerFaceColo
% hold off
%
% legend('Analytical', 'Simulation, n=100', 'Simulation, n=100k')
% title("Cumulative Density Function of Flipped-Bit Error versus Magnitude of A")
% xlabel("Signal Magnitude, {\itA} [-]")
% ylabel("Probability of Error, {\itP_e} [-]")
```

Part 2. COVID-19 Data Analysis

Problem Statement

In this assignment, you will analyze the data to understand the Coronavirus pandemic, in particular, you will study the factors that might impact the mortality rate of COVID-19. You can find the dataset provided by *Our World in Data* here. It provides daily numbers on confirmed cases and deaths, testings, vaccinations, and other metrics for over 100 countries. For this study, consider the following data: *new_deaths_per_million* for the month of September 2021, *new_tests_per_thousand* for the same period, *people_vaccinated_per_hundred*, *aged_70_older*, *gdp_per_capita, cardiovasc_death_rate, diabetes_prevalence*. If a country misses any of the data, remove that country in this study.

1. Plot the distribution of death rates for all countries. Compute the average death rates and the variance (Don’t use MATLAB built-in functions). What do these numbers tell us? Describe anything else you observe from the data.
2. Study all other metrics. Plot their distributions, compute and interpret the average values and variances.
3. Compute the correlation coefficients between the death rates and other metrics. What factor(s) affect the mortality rate the most? Plot the scatter diagram to support your argument. Describe anything else you observe from the data.

Part 1

```
clc
clear
clf

raw_covid_data = readtable('owid-covid-data.csv');

countries = unique(raw_covid_data.location);

random_variable = {'avg_new_deaths_per_million', 'avg_new_tests_per_thousand', 'avg_people_vacc
                   'avg_aged_70_older', 'avg_gdp_per_capita', 'avg_cardiovasc_death_rate', 'avg
                   'var_new_deaths_per_million', 'var_new_tests_per_thousand', 'var_people_vacc
                   'var_aged_70_older', 'var_gdp_per_capita', 'var_cardiovasc_death_rate', 'var
```

```
random_variable = 1×14 cell
'avg_new_deaths_per_million'   'avg_new_tests_per_thousand'   'avg_people_vaccin ···
```

```
x = zeros(length(countries), length(random_variable))
```

```
x = 233×14
    0    0    0    0    0    0    0    0    0    0    0    0    0 ···
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0
    ⋮
```

```
for k = 1:length(countries)
    new_deaths_per_million = raw_covid_data.new_deaths_per_million(string(raw_covid_data.locati
                                                                   raw_covid_data.date >= '1-Se
                                                                   raw_covid_data.date <= '30-S
                                                                   ~isnan(raw_covid_data.new_de
    new_tests_per_thousand = raw_covid_data.new_tests_per_thousand(string(raw_covid_data.locati
                                                                   raw_covid_data.date >= '1-Se
                                                                   raw_covid_data.date <= '30-S
                                                                   ~isnan(raw_covid_data.new_te
    people_vaccinated_per_hundred = raw_covid_data.people_vaccinated_per_hundred(string(raw_cov
                                                                                 ~isnan(raw_cov
    aged_70_older = raw_covid_data.aged_70_older(string(raw_covid_data.location) == countries(k
                                                                                 ~isnan(raw_cov
    gdp_per_capita = raw_covid_data.gdp_per_capita(string(raw_covid_data.location) == countries
                                                                                 ~isnan(raw_cov
    cardiovasc_death_rate = raw_covid_data.cardiovasc_death_rate(string(raw_covid_data.location
                                                                                 ~isnan(raw_cov
    diabetes_prevalence = raw_covid_data.diabetes_prevalence(string(raw_covid_data.location) ==
                                                                                 ~isnan(raw_cov
    rv_vector = {new_deaths_per_million, new_tests_per_thousand, people_vaccinated_per_hundred,
```

```
                        gdp_per_capita, cardiovasc_death_rate, diabetes_prevalence};

    x(k,:) = [transpose(first_moment(rv_vector)), transpose(second_moment(rv_vector))];
end

t = array2table(x,'RowNames',countries,'VariableNames',random_variable)
```

t = 233×14 table

...

	avg_new_deaths_per_million	avg_new_tests_per_thousand
1 Afghanistan	0.0719	NaN
2 Africa	0.3429	NaN
3 Albania	2.3204	NaN
4 Algeria	0.4057	NaN
5 Andorra	0	NaN
6 Angola	0.3144	NaN
7 Anguilla	NaN	NaN
8 Antigua and Barbuda	11.8170	NaN
9 Argentina	2.4609	0.6032
10 Armenia	5.3345	1.9166
11 Aruba	NaN	NaN
12 Asia	0.6315	NaN
13 Australia	0.3864	8.3364
14 Austria	0.8737	39.0196
15 Azerbaijan	2.8986	1.5741
16 Bahamas	14.8647	1.0742
17 Bahrain	0.0191	10.6501
18 Bangladesh	0.2635	0.1647
19 Barbados	2.7807	NaN
20 Belarus	1.2816	2.2106
21 Belgium	0.6363	3.8349
22 Belize	4.2808	NaN
23 Benin	0.0830	NaN
24 Bermuda	NaN	NaN
25 Bhutan	0	2.5440
26 Bolivia	0.7974	0.4376
27 Bonaire Sint Eustatius and S...	NaN	NaN
28 Bosnia and Herzegovina	8.2020	1.0066

	avg_new_deaths_per_million	avg_new_tests_per_thousand
29 Botswana	1.4878	NaN
30 Brazil	2.5446	NaN
31 British Virgin Islands	NaN	NaN
32 Brunei	2.4915	NaN
33 Bulgaria	9.5990	NaN
34 Burkina Faso	0.0202	NaN
35 Burundi	0	NaN
36 Cambodia	0.8181	NaN
37 Cameroon	0.1335	NaN
38 Canada	0.8098	2.4236
39 Cape Verde	1.5425	1.6684
40 Cayman Islands	NaN	NaN
41 Central African Republic	0	NaN
42 Chad	0	NaN
43 Chile	0.9212	2.6300
44 China	0	NaN
45 Colombia	0.8804	0.8909
46 Comoros	0	NaN
47 Congo	0.0589	NaN
48 Cook Islands	NaN	NaN
49 Costa Rica	5.7079	1.3645
50 Cote d'Ivoire	0.2257	0.1502
51 Croatia	2.4990	2.1905
52 Cuba	6.2823	NaN
53 Curacao	NaN	NaN
54 Cyprus	1.5764	61.0986
55 Czechia	0.1708	6.7030
56 Democratic Republic of Congo	0.0090	NaN
57 Denmark	0.4128	7.0968
58 Djibouti	0.3326	NaN
59 Dominica	7.3898	NaN
60 Dominican Republic	0.1156	NaN
61 Ecuador	0.9653	0.1313
62 Egypt	0.1902	NaN

	avg_new_deaths_per_million	avg_new_tests_per_thousand
63 El Salvador	1.6160	NaN
64 Equatorial Guinea	0.4828	1.5000
65 Eritrea	0.0370	NaN
66 Estonia	1.6350	4.2354
67 Eswatini	3.3836	NaN
68 Ethiopia	0.2564	0.0662
69 Europe	2.2970	NaN
70 European Union	1.2319	NaN
71 Faeroe Islands	NaN	NaN
72 Falkland Islands	NaN	NaN
73 Fiji	4.7257	NaN
74 Finland	0.3004	2.8847
75 France	1.2571	8.0229
76 French Polynesia	NaN	NaN
77 Gabon	0.2926	12.0665
78 Gambia	0.2546	NaN
79 Georgia	12.8818	12.9405
80 Germany	0.5903	NaN
81 Ghana	0.1262	NaN
82 Gibraltar	NaN	NaN
83 Greece	3.8763	15.1402
84 Greenland	NaN	NaN
85 Grenada	40.9975	NaN
86 Guatemala	2.9918	0.5879
87 Guernsey	NaN	NaN
88 Guinea	0.1036	NaN
89 Guinea-Bissau	0.2645	NaN
90 Guyana	6.9169	NaN
91 Haiti	0.0693	NaN
92 Honduras	3.0707	NaN
93 Hong Kong	0.0044	NaN
94 Hungary	0.4567	1.6902
95 Iceland	0	5.0044
96 India	0.2230	1.1294

	avg_new_deaths_per_million	avg_new_tests_per_thousand
97 Indonesia	1.0754	0.5718
98 International	NaN	NaN
99 Iran	4.9529	1.3034
100 Iraq	1.1575	0.6794

⋮

1 - Death Rates in September

```
figure
histogram(t.avg_new_deaths_per_million)
title('Average new death rates per million by country for the month of September')
ylabel('New deaths per million')
xlabel('Countries')
```