Network Milestone - Alexander Wang (aw3494), Nick Fiorovanti (nef46)

Step 1. Set up Network Representation

```
% Number of individuals
N = 100;

% Random symmetric matrix
network = randi([0, 1], N);
network = triu(network, 1);
network = network + network';

% Initialize the state of individuals (0 = Susceptible, 1 = Infected)
state = zeros(N, 1);

% Create random ages for individuals in contact network
age = ones(N,1);
for p = 1:size(age,1)
    age(p) = randi(80);
end

% Randomly assign a few individuals as Infected
num_initially_infected = 0.05*N;
infected_indices = randperm(N, num_initially_infected);
state(infected_indices) = 1;

% Initial stats:
initial_infected_proportion = sum(state)/N;
initial_susceptible_proportion = sum(state==0)/N;
```

Step 2. Simulate

```
% CUSTOMIZE PARAMETERS %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
num_days = 365;                                 % days
expose_prob = 0.05;                             % exposure prob
infect_prob = 0.04;                             % infection prob (4% was given in paper)
recover_prob = 0.1;                             % recovery prob
num_exposed = zeros(num_days, 1);               % Vector of exposed individuals each day
num_infected = zeros(num_days, 1);              % Vector of infected individuals each day
hospitalization_rate = 0.15;                    %https://gis.cdc.gov/grasp/COVIDNet/COVID19_3.H
% positive_rate = 0.12875/7;  % by week          % Percent Positive Testing: averaged peaks of
% MAKE ASSUMPTION - IF EACH EXPOSED INDIVIDUAL AT-HOME TESTS, AND THEN TESTS POSITIVE, THEY
% SOCIAL DISTANCE AND CANNOT INFECT OTHERS
% ORRRRRR
socialdist_prob = [0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1];  % no statistic for social distanc
% 0.75 - quarantining rate  - https://thehill.com/changing-america/well-being/medical-advances/
% find quarantining rate to find acceptable loss of individuals
```

```
% Hosp death rate approximated from:
% https://www.cdc.gov/nchs/covid19/nhcs/hospital-mortality-by-week.htm
hosp_death_rate_29 = 0.03/7;
hosp_death_rate_59 = 0.07/7;
hosp_death_rate_plus = 0.18/7;
```

Other rates

% hospitalization_rate = 0.0015; % hospitalization rate https://www.nytimes.com/interactive/2023/us/covid-cases.html

%hospitalization_rate = 1.2/100000; % https://www.nytimes.com/interactive/2023/us/covid-cases.html

% hospitalization_rate = 0.3; % https://www.economist.com/graphic-detail/2021/03/13/our-covid-19-model-estimates-odds-of-hospitalisation-and-death

% death_rate = 0.1625; % percent deaths: averaged peaks of % death attributed to covid https://covid.cdc.gov/covid-data-tracker/#trends_weeklyhospitaladmissions_testpositivity_00

% death_rate = 0.3/100000 % https://www.nytimes.com/interactive/2023/us/covid-cases.html

% death_rate = 1.1/100 % https://coronavirus.jhu.edu/data/mortality

% death_rate = 0.06; % https://ourworldindata.org/mortality-risk-covid

% hosp_death_rate = 0.10/7; % by week, % https://www.cdc.gov/nchs/covid19/nhcs/hospital-mortality-by-week.htm

% death_rate = 0.0028; % OLD DEATH RATE: gross mortality rate https://www.worldometers.info/coronavirus/coronavirus-death-rate/

% quarantining_rate = 0.75; % quarantining rate - https://thehill.com/changing-america/well-being/medical-advances/491760-3-in-4-americans-say-they-are-self-isolating-in/#:~:text=Approximately%2075%20percent%20of%20U.S.%20residents%20are%20self-isolating,coronavirus%20and%20is%20being%20enforced%20across%20the%20country.

```
% Store infected/susceptible state to recall for all iterations
state_orig = state;

% RECAP: SUSCEPTIBLE = 0, INFECTED = 1, EXPOSED = 2, HOSPITALIZED = 3,
% RECOVERED/IMMUNE = 4, DEAD = NaN
for c = 1:11
        % Repeat model for 10 iterations to average findings
        for l = 1:10

            % initialize the iteration state of susceptible and infected to original state of i
            state = state_orig;

            % For each day in the year
            for day = 1:num_days

                % For each individual in the contact network
```

```
            for i = 1:N

                % If the individual is infected
                if state(i) == 1

                    % Find the other individuals in the network they are in
                    % contact with
                    contacts = find(network(i, :));

                    % For all contacts in network
                    for j = contacts

                        % Randomly generate a number to decide chance of
                        % contact becoming exposed if susceptible
                        exposed_diceroll = rand;

                        % If contact is susceptible
                        if state(j) == 0

                           % generate random chance for not social distancing
                           social_dist_diceroll = rand;

                           % If individual didn't social distance
                           if social_dist_diceroll > socialdist_prob(c)

                                % See if the probability is within the expected for
                                % exposure
                                if exposed_diceroll < expose_prob

                                    % If so, susceptible individual becomes exposed
                                    % to COVID
                                    state(j) = 2;
                                end
                           end
                        end
                    end

                    % now move onto the current infected patient

                    % Since the patient is infected, there is a chance they
                    % will recover

                    % Randomly generate this chance
                    recovery_diceroll = rand;

                    % Randomly generate a chance for hospitalization as well
                    hospitalized_diceroll = rand;
                    % IMMUNITY LASTS ABOUT 500 DAYS (well within sim) https://www.medicaln
                    % If recovery chance is within expected probability
                    if recovery_diceroll < recover_prob
```

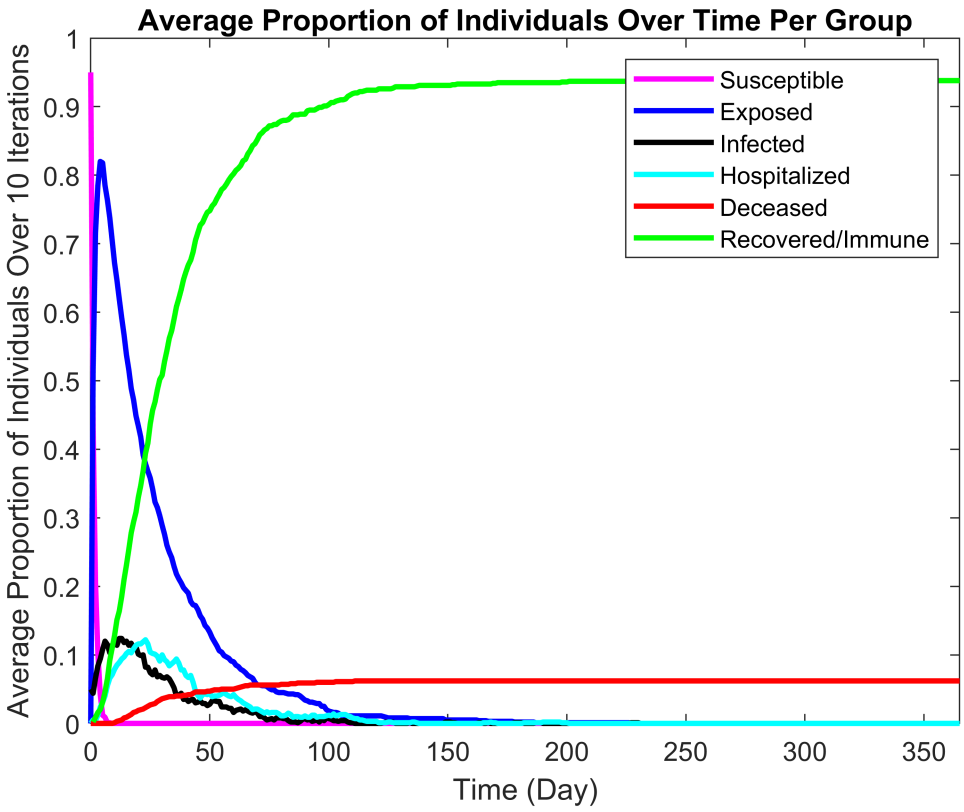
```
                    % Infected individual becomes susceptible again
                    % (disregard short-term immunity as individuals have
                    % been found to get covid multiple times)
                    state(i) = 4;

                    % MAKE ASSUMPTION THAT IF PEOPLE ARE SICK, THEY'LL GO
                    % TO HOSPITAL - ONLY PLACE THEY WOULD DIE
%                 % If chance is not within recovery and expectation for death
%                 elseif recovery_diceroll > (1-death_rate) && hospitalized_diceroll >
%
%                     % individual gets removed from the network
%                     state(i) = NaN;
%
                % if chance not within recovery and hospitalization is
                % probable
                elseif recovery_diceroll > recover_prob && hospitalized_diceroll < hosp

                    % infected individual instead becomes hospitalized
                    state(i) = 3;
                end

            % If the individual is not infected, but is exposed,
            elseif state(i) == 2

                % Generate random chance for individual to become infected
                infected_diceroll = rand;

                % If chance is within expected
                if infected_diceroll <  infect_prob

                    % Convert exposed individual to infected
                    state(i) = 1;
                end

            % If individual is hospitalized
            elseif state(i) == 3

                % Generate random recovery chance
                recovery_diceroll = rand;

                % Generate random hospitalization chance
                hospitalized_diceroll = rand;

                % Generate random death chance
                reaper_diceroll = rand;

                % IMMUNITY FOR 500 days (well within sim) https://www.medicalnewstoday.
                % If recovery is expected
                if recovery_diceroll < recover_prob
```

```
                    % Hospitalized individual becomes susceptible and can
                    % go home
                    state(i) = 4;

                % If individual is still symptomatic and expected by chance
                elseif hospitalized_diceroll < hospitalization_rate

                    % Remain in hospital
                    state(i) = 3;
                end

                if age(i) <= 29
                    if reaper_diceroll < hosp_death_rate_29
                        state(i) = NaN;
                    end
                elseif age(i) <= 59
                    if reaper_diceroll < hosp_death_rate_59
                        state(i) = NaN;
                    end
                else
                    if reaper_diceroll < hosp_death_rate_plus
                        state(i) = NaN;
                    end
                end
%                 % If individual is hospitalized, and expected for death
%                 elseif reaper_diceroll < hosp_death_rate
%                     state(i) = NaN;
%                 end

            % If susceptible,
            elseif state(i) == 0
                social_dist_diceroll = rand;
                if social_dist_diceroll > socialdist_prob(c) % then did not social dist
                    state(i) = 2;
                end
            end
        end
        % Record the number of exposed and infected individuals
        num_susceptible(day) = sum(state == 0);
        num_infected(day) = sum(state == 1);
        num_exposed(day) = sum(state == 2);
        num_hospitalized(day) = sum(state == 3);
        num_immune(day) = sum(state == 4);
        num_deceased(day) = sum(isnan(state));
    end

    % Store all of the simulated data for this iteration in the accumulation
    % variables
    num_exposed_accumulated(l,:) = num_exposed';
```

```
        num_infected_accumulated(l,:) = num_infected';
        num_susceptible_accumulated(l,:) = num_susceptible';
        num_deceased_accumulated(l,:) = num_deceased';
        num_hospitalized_accumulated(l,:) = num_hospitalized';
        num_immune_accumulated(l, :) = num_immune';
        end

    if c == 6
    fprintf('This figure displays the maxima along the \nmean of 10 simulation iterations for e
    % Plot the number of exposed and infected individuals over time
    figure;

    % Plot susceptible
    plot(0:num_days, [initial_susceptible_proportion mean(num_susceptible_accumulated)/N], 'Col
    hold on
    % Plot exposed proportion
    plot(0:num_days, [0 mean(num_exposed_accumulated)/N], 'Color', 'Blue', 'DisplayName', 'Expo

    % Plot infectious proportion
    plot(0:num_days, [initial_infected_proportion mean(num_infected_accumulated)/N], 'Color', '

    % Plot hospitalized proportion
    plot(0:num_days, [0 mean(num_hospitalized_accumulated)/N], 'Color', 'Cyan', 'DisplayName',

    % Plot deceased proportion
    plot(0:num_days, [0 mean(num_deceased_accumulated)/N], 'Color', 'Red', 'DisplayName', 'Dece

    % Plot immune proportion
    plot(1:num_days, mean(num_immune_accumulated)/N, 'Color', 'Green', 'DisplayName', 'Recovere
    % Label figure
    xlabel('Time (Day)');
    ylabel('Average Proportion of Individuals Over 10 Iterations');
    xlim([0 num_days])
    title('Average Proportion of Individuals Over Time Per Group')
    legend()
    end

% Mean Peak Susceptible
avg_susceptible = mean(num_susceptible_accumulated);
% Mean Peak Exposed
avg_exposed = mean(num_exposed_accumulated);
% Mean Peak Infected
avg_infected = mean(num_infected_accumulated);
% Mean Peak Deceased
avg_deceased = mean(num_deceased_accumulated);
% Mean Peak Hospitalized
avg_hospitalized = mean(num_hospitalized_accumulated);
% Mean Peak Immune
avg_immune = mean(num_immune_accumulated);
```

```
% % Mean Peak Susceptible
% peak_susceptible = mean(max(num_susceptible_accumulated));
% % Mean Peak Exposed
% peak_exposed = mean(max(num_exposed_accumulated));
% % Mean Peak Infected
% peak_infected = mean(max(num_infected_accumulated));
% % Mean Peak Deceased
% peak_deceased = mean(max(num_deceased_accumulated));
% % Mean Peak Hospitalized
% peak_hospitalized = mean(max(num_hospitalized_accumulated));
% % Mean Peak Immune
% peak_immune = mean(max(num_immune_accumulated));


max_susceptible = max(avg_susceptible);
max_exposed = max(avg_exposed);
max_infected = max(avg_infected);
max_deceased = max(avg_deceased);
max_hospitalized = max(avg_hospitalized);
max_immune = max(avg_immune);
time_susceptible = find(avg_susceptible == max_susceptible);
time_exposed = find(avg_exposed == max_exposed);
time_infected = find(avg_infected == max_infected);
time_deceased = find(avg_deceased == max_deceased);
time_hospitalized = find(avg_hospitalized == max_hospitalized);
time_immune = find(avg_immune == max_immune);

max_c(:,c) =[max_susceptible/N;max_exposed/N; max_infected/N; max_deceased/N; max_hospitalized/
time_c(:,c) = [time_susceptible(1); time_exposed(1);time_infected(1); time_deceased(1); time_ho
    if c == 6
        fprintf('This table displays the maxima along the \nmean of 10 simulation iterations fo
        t1 = table([max_susceptible/N; time_susceptible(1)], [max_exposed/N; time_exposed(1)],
        t1.Properties.VariableNames = {'Max Susceptible', 'Max Exposed', 'Max Infected', 'Max D
        t1.Properties.RowNames = {'Proportions Across Simulation', 'Times for Max Average Propo
        disp(t1)
    end
end
```

```
This table displays the maxima along the
mean of 10 simulation iterations for each group
and the times in which they occur
for quarantining rate of 0.5.
```

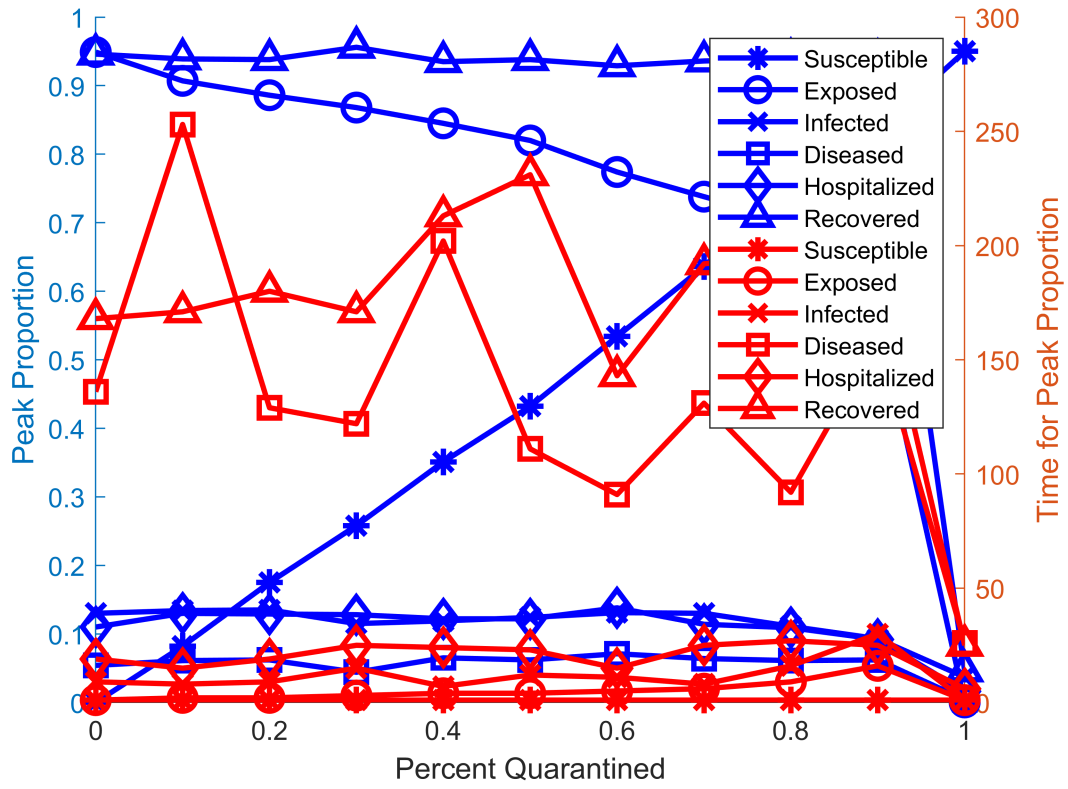


This table displays the maxima along the
mean of 10 simulation iterations for each group
and the times in which they occur
for quarantining rate of 0.5.

	Max Susceptible	Max Exposed	Max Infected	Max Deceased	Max Hospi
Proportions Across Simulation	0.432	0.82	0.124	0.062	0.12
Times for Max Average Proportions	1	4	12	111	2

```
figure
hold on
for k = 1:6
    if k == 1
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-b*', 'LineWidth', 2,'DisplayName', 'Susceptible', '
        yyaxis right
        plot(socialdist_prob, time_c(k,:),'-r*','LineWidth', 2, 'DisplayName', 'Susceptible', '
    elseif k == 2
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bo','LineWidth', 2,'DisplayName', 'Exposed', 'Marke
        yyaxis right
        plot(socialdist_prob, time_c(k,:),'-ro', 'LineWidth', 2, 'DisplayName', 'Exposed', 'Mar
    elseif k == 3
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bx','LineWidth', 2,'DisplayName', 'Infected', 'Mark
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-rx','LineWidth', 2, 'DisplayName', 'Infected', 'Ma
```

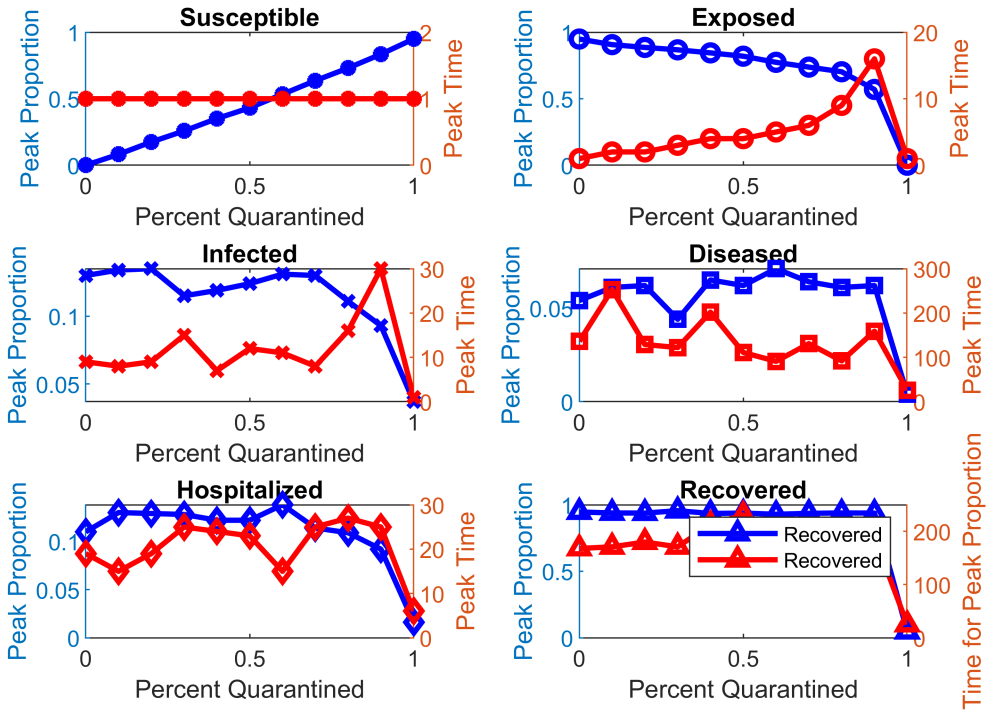
```
    elseif k == 4
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bs','LineWidth', 2,'DisplayName', 'Diseased', 'Mark
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-rs','LineWidth', 2, 'DisplayName', 'Diseased', 'Ma
    elseif k == 5
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bd','LineWidth', 2,'DisplayName', 'Hospitalized',
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-rd','LineWidth', 2, 'DisplayName', 'Hospitalized',
    elseif k == 6
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-b^','LineWidth', 2,'DisplayName', 'Recovered', 'Mar
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-r^','LineWidth', 2, 'DisplayName', 'Recovered', 'M
    end
end
xlabel('Percent Quarantined')
legend
yyaxis left
ylabel('Peak Proportion')
yyaxis right
ylabel('Time for Peak Proportion')
hold off
```



```
figure
sgtitle('Parametric Analysis of Groups by Quarantined Percentage')
hold on
for k = 1:6
    if k == 1
        subplot(3,2,1)
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-b*', 'LineWidth', 2,'DisplayName', 'Susceptible')
        ylabel('Peak Proportion')
        yyaxis right
        plot(socialdist_prob, time_c(k,:),'-r*','LineWidth', 2, 'DisplayName', 'Susceptible')
        xlabel('Percent Quarantined')
        ylabel('Peak Time')
        title('Susceptible')
    elseif k == 2
        subplot(3,2,2)
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bo','LineWidth', 2,'DisplayName', 'Exposed')
        ylabel('Peak Proportion')
        yyaxis right
        plot(socialdist_prob, time_c(k,:),'-ro', 'LineWidth', 2, 'DisplayName', 'Exposed')
        xlabel('Percent Quarantined')
        ylabel('Peak Time')
        title('Exposed')
    elseif k == 3
        subplot(3,2,3)
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bx','LineWidth', 2,'DisplayName', 'Infected')
        ylabel('Peak Proportion')
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-rx','LineWidth', 2, 'DisplayName', 'Infected')
        xlabel('Percent Quarantined')
        ylabel('Peak Time')
        title('Infected')
    elseif k == 4
        subplot(3,2,4)
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bs','LineWidth', 2,'DisplayName', 'Diseased')
        ylabel('Peak Proportion')
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-rs','LineWidth', 2, 'DisplayName', 'Diseased')
        xlabel('Percent Quarantined')
        ylabel('Peak Time')
        title('Diseased')
    elseif k == 5
        subplot(3,2,5)
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-bd','LineWidth', 2,'DisplayName', 'Hospitalized')
        ylabel('Peak Proportion')
        yyaxis right
```

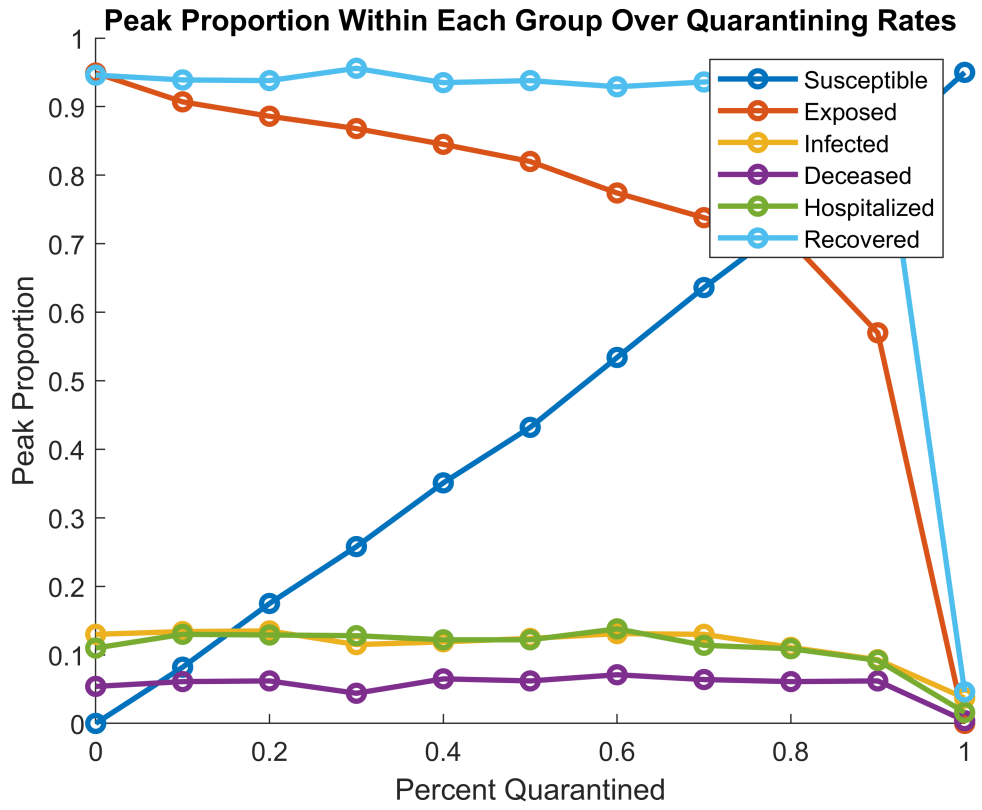
```
        plot(socialdist_prob, time_c(k,:), '-rd','LineWidth', 2, 'DisplayName', 'Hospitalized')
        xlabel('Percent Quarantined')
        ylabel('Peak Time')
        title('Hospitalized')
    elseif k == 6
        subplot(3,2,6)
        yyaxis left
        plot(socialdist_prob, max_c(k,:), '-b^','LineWidth', 2,'DisplayName', 'Recovered')
        ylabel('Peak Proportion')
        yyaxis right
        plot(socialdist_prob, time_c(k,:), '-r^','LineWidth', 2, 'DisplayName', 'Recovered')
        xlabel('Percent Quarantined')
        ylabel('Peak Time')
        title('Recovered')
    end
end
xlabel('Percent Quarantined')
legend
yyaxis left
ylabel('Peak Proportion')
yyaxis right
ylabel('Time for Peak Proportion')
hold off
```

Parametric Analysis of Groups by Quarantined Percentage




```
figure
```

```
hold on
for k = 1:6
    if k == 1
        plot(socialdist_prob, max_c(k,:), '-o','LineWidth', 2,'DisplayName', 'Susceptible')
    elseif k == 2
        plot(socialdist_prob, max_c(k,:),'-o', 'LineWidth', 2,'DisplayName', 'Exposed')
    elseif k == 3
        plot(socialdist_prob, max_c(k,:),'-o', 'LineWidth', 2,'DisplayName', 'Infected')
    elseif k == 4
        plot(socialdist_prob, max_c(k,:),'-o', 'LineWidth', 2,'DisplayName', 'Deceased')
    elseif k == 5
        plot(socialdist_prob, max_c(k,:),'-o', 'LineWidth', 2,'DisplayName', 'Hospitalized')
    elseif k == 6
        plot(socialdist_prob, max_c(k,:), '-o', 'LineWidth', 2,'DisplayName', 'Recovered')
    end
end
xlabel('Percent Quarantined')
legend
ylabel('Peak Proportion')
title('Peak Proportion Within Each Group Over Quarantining Rates')
hold off
```




```
figure
hold on
for k = 1:6
    if k == 1
```

```
        plot(socialdist_prob, time_c(k,:), '-o','LineWidth', 2, 'DisplayName', 'Susceptible')
    elseif k == 2
        plot(socialdist_prob, time_c(k,:),'-o', 'LineWidth', 2, 'DisplayName', 'Exposed')
    elseif k == 3
        plot(socialdist_prob, time_c(k,:), '-o','LineWidth', 2, 'DisplayName', 'Infected')
    elseif k == 4
        plot(socialdist_prob, time_c(k,:), '-o','LineWidth', 2, 'DisplayName', 'Deceased')
    elseif k == 5
        plot(socialdist_prob, time_c(k,:), '-o','LineWidth', 2, 'DisplayName', 'Hospitalized')
    elseif k == 6
        plot(socialdist_prob, time_c(k,:), '-o','LineWidth', 2, 'DisplayName', 'Recovered')
    end
end
xlabel('Percent Quarantined')
legend
ylabel('Time for Peak Proportion')
title('Time @ Peak Proportion Over Quarantining Rates')
```