Example: COVID-2019 data for Italian Regions

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The data is taken from official Italian government figures [1]. This mlx. file was proposed by matteo Secli [2] but I did some modifications to it.

[1] https://github.com/pcm-dpc/COVID-19

[2] https://github.com/matteosecli

Initialisation

The parameters are here taken as constant except the death rate and the cure rate.

```
clearvars;close all;clc;

% Download the data from ref [1] and read them with the function
% getDataCOVID_ITA
tableCOVIDItaly = getDataCOVID_ITA();

time = unique(datetime(datestr(datenum(tableCOVIDItaly.Date,'yyyy-mm-DDThh:MM:ss'))));
fprintf(['Most recent update: ',datestr(time(end)),'\n'])
```

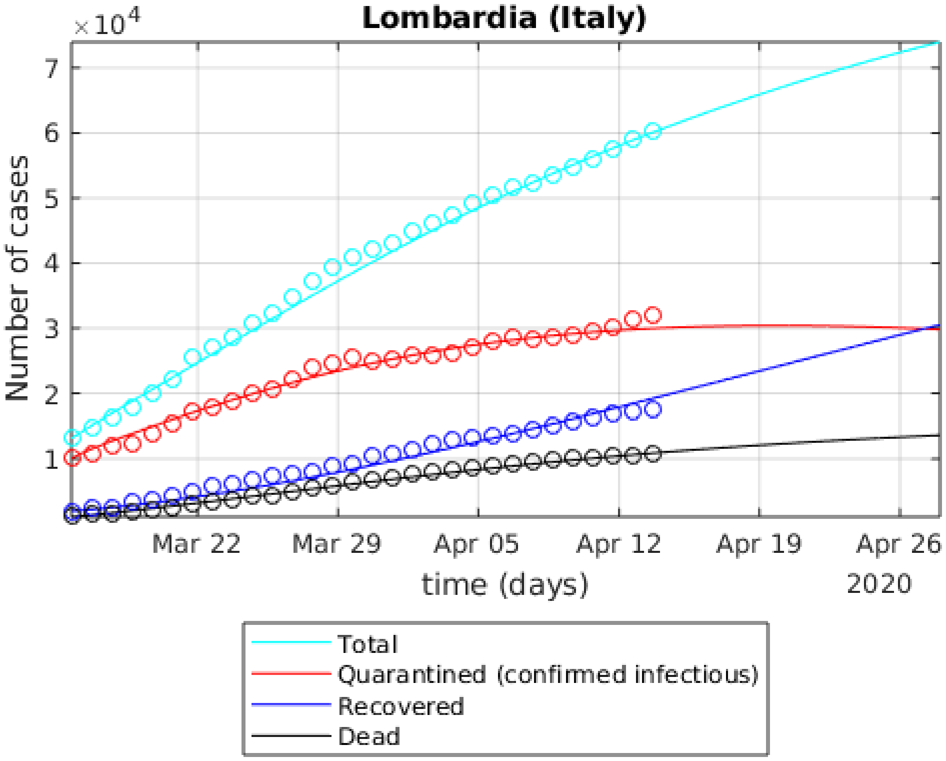
```
Most recent update: 13-Apr-2020 17:00:00
```

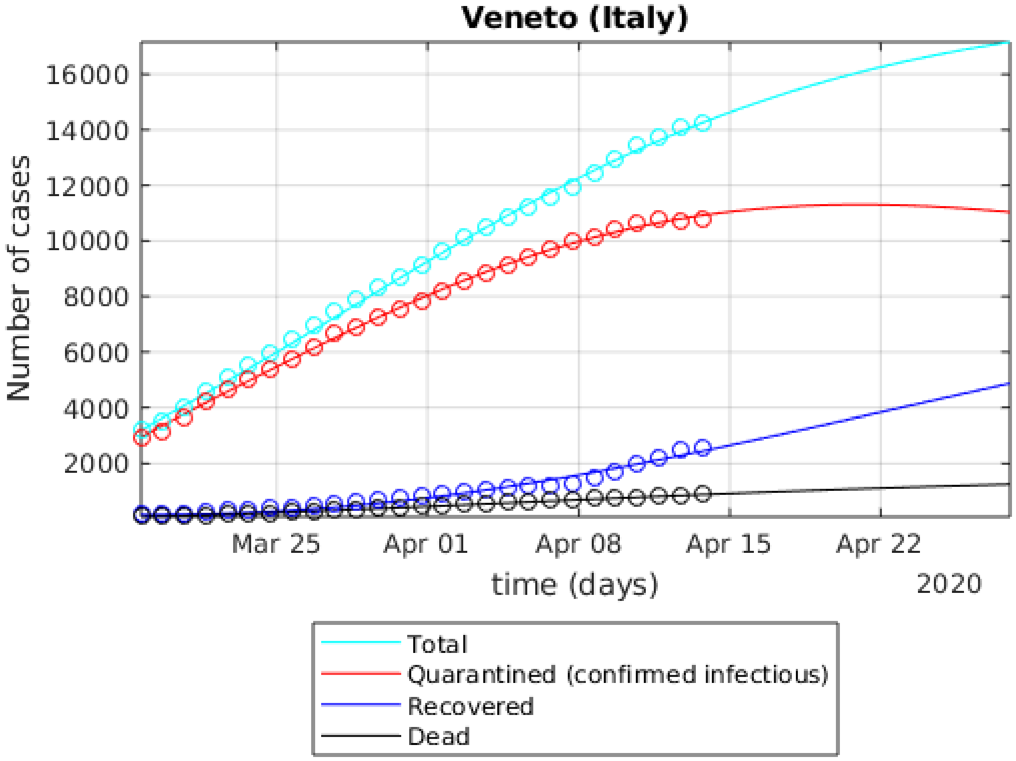
```

% Add regions and populations here to generate more plots. Eurostat 2018
% data.
Regions     = {'Lombardia', 'Veneto', 'Emilia-Romagna', 'Piemonte'};
Populations = [10.040e6   , 4.905e6 , 4.453e6         , 4.376e6   ];

% Definition of the first estimates for the parameters
alpha_guess = 0.06; % protection rate
beta_guess = 1.0; % Infection rate
LT_guess = 5; % latent time in days
Q_guess = 0.5; % rate at which infectious people enter in quarantine
lambda_guess = [0.1,0.05]; % recovery rate
kappa_guess = [0.02,0.05]; % death rate

guess = [alpha_guess,...
    beta_guess,...
    1/LT_guess,...
    Q_guess,...
    lambda_guess,...
    kappa_guess];
```

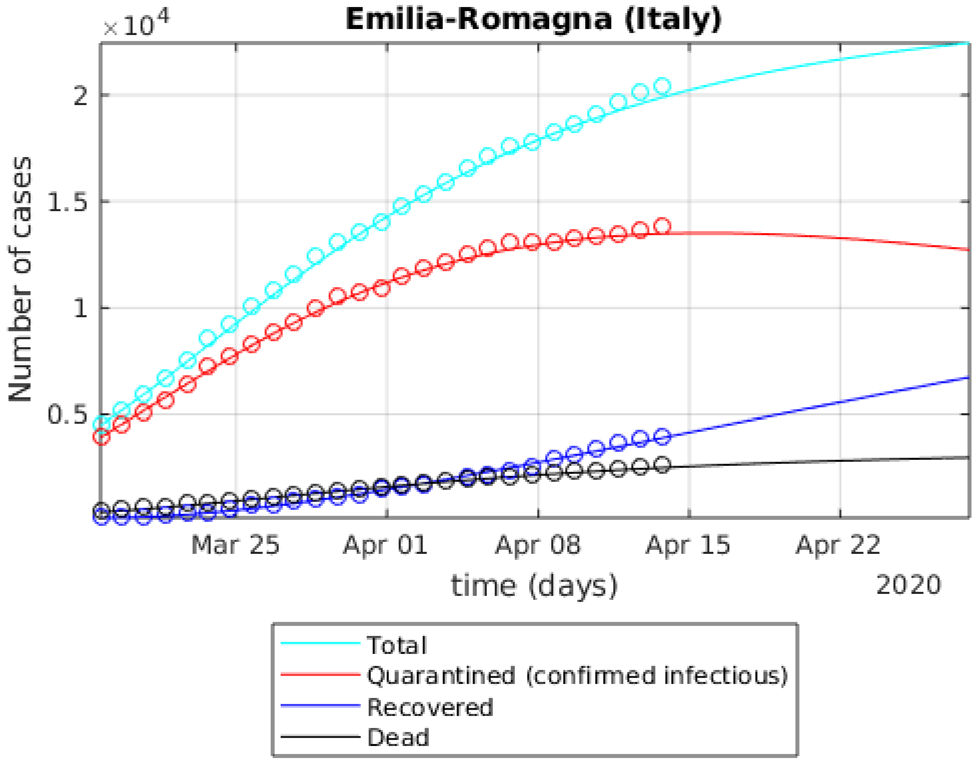
Iterative application of fit_SEIQRDP

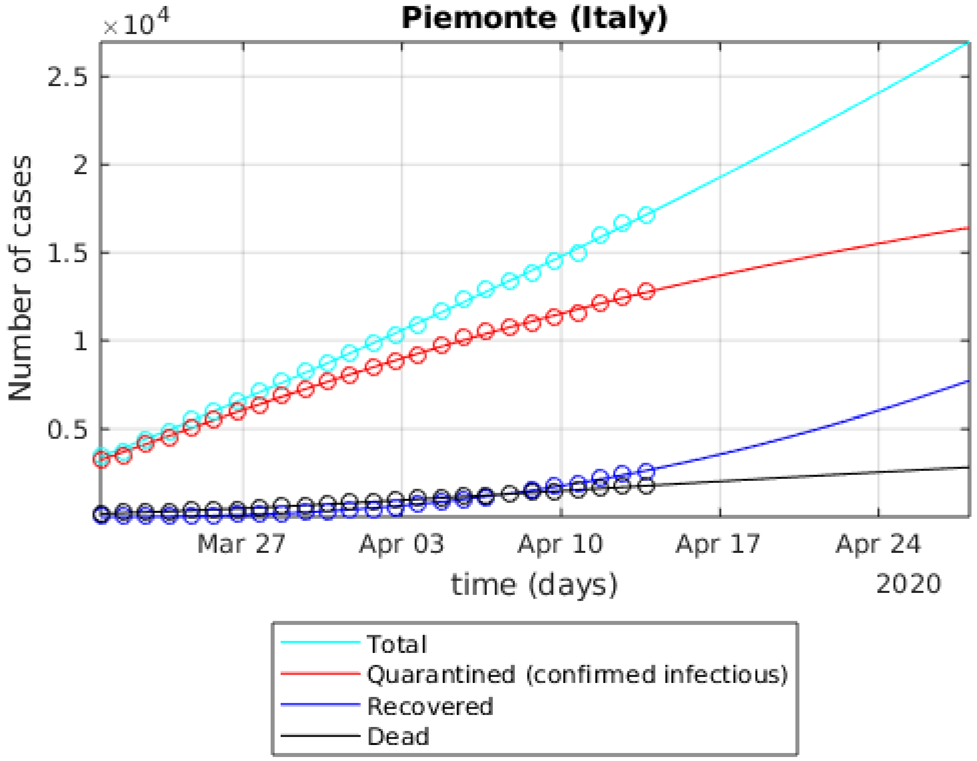
Active cases = Confirmed-Deaths-Recovered (database) = Quarantined (SEIQRDP model)

```
for regionIdx=1:numel(Regions)

    % Region definitions
    regionName = Regions{regionIdx};
    Npop       = Populations(regionIdx); % population

    try
        indLocation = find(contains(tableCOVIDItaly.RegionName,regionName)==1);
    catch exception
        searchLoc = strfind(tableCOVIDItaly.RegionName,regionName);
        indLocation = find(~cellfun(@isempty,searchLoc)) ;
    end

    % Remove the ";" at the end of the line below to show regional data
    tableCOVIDItaly(indLocation,[1,7:end]);

    Recovered   = tableCOVIDItaly.Recovered  (indLocation)';
    Deaths      = tableCOVIDItaly.Deaths     (indLocation)';
    Confirmed   = tableCOVIDItaly.Confirmed  (indLocation)';
    Quarantined = tableCOVIDItaly.Quarantined(indLocation)';
    time        = tableCOVIDItaly.Date       (indLocation)';
    time = unique(datetime(datestr(datenum(tableCOVIDItaly.Date,'yyyy-mm-DDThh:MM:ss'))



    % If the number of confirmed Confirmed cases is small, it is difficult to know whet
    % the quarantine has been rigorously applied or not. In addition, this
    % suggests that the number of infectious is much larger than the number of
    % confirmed cases
    minNum= round(0.2*max(Confirmed));
    Recovered  (Confirmed<=minNum)=[];
    Deaths     (Confirmed<=minNum)=[];
    time       (Confirmed<=minNum)=[];
    Quarantined(Confirmed<=minNum)=[];
    Confirmed  (Confirmed<=minNum)=[];

    %% To simulate the cases after fitting
    dt = 1/24; % time step
    time1 = time(1):dt:datetime(datestr(floor(datenum(now))+datenum(14)));
    N = numel(time1);
    t = [0:N-1].*dt;


    % Initial conditions
    E0 = Confirmed  (1); % Initial number of exposed cases. Unknown but unlikely to be
    I0 = Confirmed  (1); % Initial number of infectious cases. Unknown but unlikely to
    Q0 = Quarantined(1);
    R0 = Recovered  (1);
    D0 = Deaths     (1)*0.9;

    [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1] = ...
        fit_SEIQRDP(Quarantined,Recovered,Deaths,Npop,E0,I0,time,guess,'Display','off',

    % Simulate the epidemy outbreak based on the fitted parameters
    [~,~,~,Q,R,D,~] = SEIQRDP(alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R

    % Comparison of the fitted and real data
    figure
    semilogy(time1,Q+R+D,'c',time1,Q,'r',time1,R,'b',time1,D,'k');
    hold on
    set(gca,'ColorOrderIndex',1);
    semilogy(time,Confirmed,'co',time,Quarantined,'ro',time,Recovered,'bo',time,Deaths,
    % ylim([0,1.1*Npop])
    ylabel('Number of cases')
    xlabel('time (days)')
    title([regionName,' (Italy)']);
    % leg = {'susceptible','exposed','infectious','quarantined','recovered','Dead','ins
    leg = {'Total','Quarantined (confirmed infectious)','Recovered','Dead'};
    legend(leg{:},'location','southoutside')
    set(gcf,'color','w')
    grid on
    axis tight
    % ylim([1,8e4])
    set(gca,'yscale','lin')
end
```


Lombardia (Italy)
×10^4
7
6
5
4
3
2
1
Number of cases
Mar 22
Mar 29
Apr 05
Apr 12
Apr 19
Apr 26
time (days)
2020
Total
Quarantined (confirmed infectious)
Recovered
Dead


Veneto (Italy)
16000
14000
12000
10000
8000
6000
4000
2000
Number of cases
Mar 25
Apr 01
Apr 08
Apr 15
Apr 22
time (days)
2020
Total
Quarantined (confirmed infectious)
Recovered
Dead



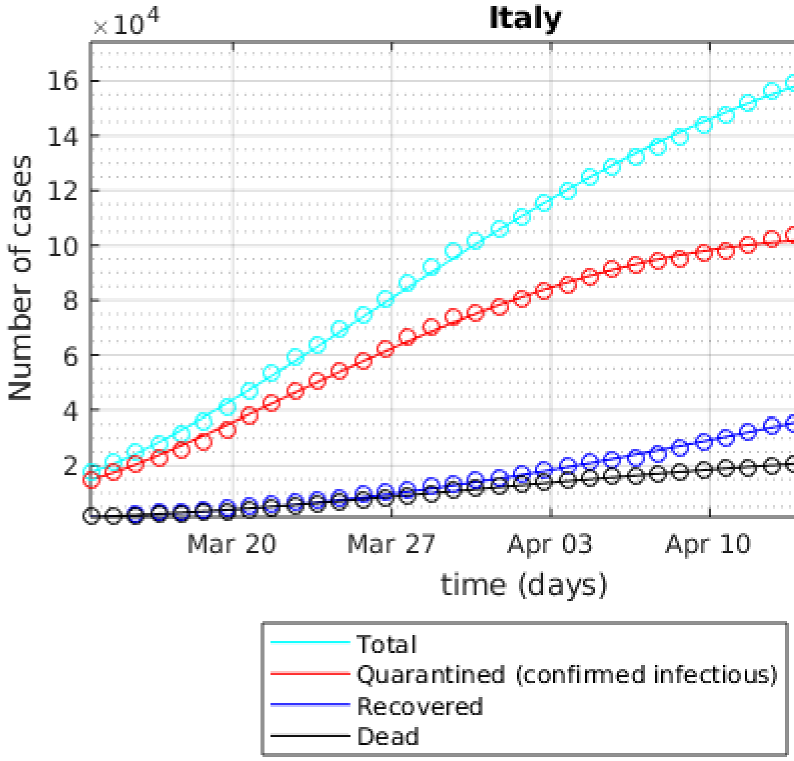


Cumulative data

Perform nation-wide statistics by summing the data of all the regions.

```
% Merge regional data for each day
tableCOVIDItaly_Tot = varfun(@sum,tableCOVIDItaly, ...
    'InputVariables',tableCOVIDItaly.Properties.VariableNames(7:end), ...
    'GroupingVariables','Date');
% Remove the 'GroupCount' variable, should total to the number of Italian regions (19 +
tableCOVIDItaly_Tot = removevars(tableCOVIDItaly_Tot,'GroupCount');
% Rename the accumulated variables with the original variable names
tableCOVIDItaly_Tot.Properties.VariableNames=[tableCOVIDItaly.Properties.VariableNames(


Npop = 60.48e6; % population

Recovered   = tableCOVIDItaly_Tot.Recovered'  ;
Deaths      = tableCOVIDItaly_Tot.Deaths'     ;
Confirmed   = tableCOVIDItaly_Tot.Confirmed'  ;
Quarantined = tableCOVIDItaly_Tot.Quarantined';
time        = tableCOVIDItaly_Tot.Date'       ;
time = unique(datetime(datestr(datenum(tableCOVIDItaly.Date,'yyyy-mm-DDThh:MM:ss'))));




% If the number of confirmed Confirmed cases is small, it is difficult to know whether
% the quarantine has been rigorously applied or not. In addition, this
% suggests that the number of infectious is much larger than the number of
% confirmed cases
minNum= round(0.1*max(Confirmed));
Recovered  (Confirmed<=minNum)=[];
Deaths     (Confirmed<=minNum)=[];
time       (Confirmed<=minNum)=[];
Quarantined(Confirmed<=minNum)=[];
Confirmed  (Confirmed<=minNum)=[];


% To simulate the cases after fitting
dt = 1/24; % time step
time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(7)));
N = numel(time1);
t = [0:N-1].*dt;

% Initial conditions
E0 = Confirmed  (1); % Initial number of exposed cases. Unknown but unlikely to be zero
I0 = Confirmed  (1); % Initial number of infectious cases. Unknown but unlikely to be z
Q0 = Quarantined(1);
R0 = Recovered  (1);
D0 = Deaths     (1);

[alpha1,beta1,gamma1,delta1,Lambda1,Kappa1] = ...
    fit_SEIQRDP(Quarantined,Recovered,Deaths,Npop,E0,I0,time,guess,'Display','off');
```

```
[S,E,I,Q,R,D,P] = SEIQRDP(alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R0,D0


% Comparison of the fitted and real data
figure
semilogy(time1,Q+R+D,'c',time1,Q,'r',time1,R,'b',time1,D,'k');
hold on
set(gca,'ColorOrderIndex',1);
semilogy(time,Confirmed,'co',time,Quarantined,'ro',time,Recovered,'bo',time,Deaths,'ko'
ylabel('Number of cases')
xlabel('time (days)')
title('Italy');
leg = {'Total','Quarantined (confirmed infectious)','Recovered','Dead'};
legend(leg{:},'location','southoutside')
set(gcf,'color','w')
grid on
grid minor
axis tight
set(gca,'yscale','lin')
```


Italy
×10^4
Number of cases
Mar 20
Mar 27
Apr 03
Apr 10
Apr 17
time (days)
Total
Quarantined (confirmed infectious)
Recovered
Dead