Example: COVID-2019 data for Spain

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I am taking some data from John Hopkins university [1]

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

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
[tableConfirmed,tableDeaths,tableRecovered,time] = getDataCOVID();
% time = time(1:end-1);
fprintf(['Most recent update: ',datestr(time(end)),'\n'])
```

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

```
Location = 'Korea';


try
    indR = find(contains(tableRecovered.CountryRegion,Location)==1);
    indC = find(contains(tableConfirmed.CountryRegion,Location)==1);
    indD = find(contains(tableDeaths.CountryRegion,Location)==1);
catch exception
    searchLoc = strfind(tableRecovered.CountryRegion,Location);
    indR = find(~cellfun(@isempty,searchLoc)) ;

    searchLoc = strfind(tableConfirmed.CountryRegion,Location);
    indC = find(~cellfun(@isempty,searchLoc)) ;

    searchLoc = strfind(tableDeaths.CountryRegion,Location);
    indD = find(~cellfun(@isempty,searchLoc));
end

disp(tableRecovered(indR,1:2))
```

```
    ProvinceState    CountryRegion
    _____________    _____________

      <missing>      "Korea, South"
```

```
disp(tableConfirmed(indC,1:2))
```

```
    ProvinceState    CountryRegion
    _____________    _____________
```

```
      <missing>      "Korea, South"
```

```
disp(tableDeaths(indD,1:2))
```

```
    ProvinceState    CountryRegion
    _____________    _____________

      <missing>      "Korea, South"
```

```
indR = indR(1);
indD = indD(1);
indC = indC(1);

Recovered = table2array(tableRecovered(indR,5:end));
Deaths = table2array(tableDeaths(indD,5:end));
Confirmed = table2array(tableConfirmed(indC,5:end));
% If the number of 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)= [];
Confirmed(Confirmed<=minNum)=[];

if isempty(Confirmed)
    warning('"Confirmed" is an empty array. Check the value of "minNum". Computation ab
    return
end


Npop= 60e6; % population
```

Fitting of the generalized SEIR model to the real data

```
% 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 = 0.1; % rate at which infectious people enter in quarantine
lambda_guess = [0.1,0.05]; % recovery rate
kappa_guess = [0.1,0.05]; % death rate

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


% 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 zer
Q0 = Confirmed(1)-Recovered(1)-Deaths(1);
R0 = Recovered(1);
D0 = Deaths(1);

Active = Confirmed-Recovered-Deaths;
Active(Active<0) = 0; % No negative number possible
[alpha1,beta1,gamma1,delta1,Lambda1,Kappa1] = ...
    fit_SEIQRDP(Active,Recovered,Deaths,Npop,E0,I0,time,guess);
```

Iteration	Func-count	f(x)	Norm of step	First-order optimality
0	9	4.95288e+11		2.38e+13
1	18	9.12426e+10	0.0645316	3.27e+12
2	27	1.72543e+10	0.0676073	4.56e+11
3	36	3.49987e+09	0.0602724	6.92e+10
4	45	6.39795e+08	0.0588567	1.24e+10
5	54	4.77838e+08	0.0785744	5.01e+10
6	63	1.14794e+08	0.0196436	6.1e+09
7	72	6.83521e+07	0.0392872	3.64e+08
8	81	5.33164e+07	0.0785744	7.85e+09
9	90	2.87191e+07	0.0785744	6.83e+08
10	99	2.87191e+07	0.145776	6.83e+08
11	108	2.62659e+07	0.0364439	4.02e+09
12	117	2.25326e+07	0.0364439	5.68e+08
13	126	2.25326e+07	0.0728879	5.68e+08
14	135	2.16655e+07	0.018222	1.02e+09
15	144	2.05865e+07	0.0364439	3.57e+09
16	153	1.9141e+07	0.0364439	5.99e+08
17	162	1.9141e+07	0.0728879	5.99e+08
18	171	1.8785e+07	0.018222	1.03e+09
19	180	1.83104e+07	0.0364439	3.08e+09
20	189	1.76985e+07	0.0364439	5.78e+08
21	198	1.76985e+07	0.0728879	5.78e+08
22	207	1.75363e+07	0.018222	9.68e+08
23	216	1.73124e+07	0.0364439	2.71e+09
24	225	1.70234e+07	0.0364439	5.68e+08
25	234	1.70234e+07	0.0728879	5.68e+08
26	243	1.69416e+07	0.018222	9e+08
27	252	1.68312e+07	0.0364439	2.53e+09
28	261	1.66806e+07	0.0364439	5.28e+08
29	270	1.66806e+07	0.0728879	5.28e+08
30	279	1.66356e+07	0.018222	9.7e+08
31	288	1.65724e+07	0.0364439	2.38e+09
32	297	1.6487e+07	0.0364439	5.86e+08
33	306	1.6487e+07	0.0728879	5.86e+08
34	315	1.6461e+07	0.018222	1.02e+09
35	324	1.64283e+07	0.0364439	2.58e+09
36	333	1.63723e+07	0.0364439	5.58e+08
37	342	1.63723e+07	0.0728879	5.58e+08
38	351	1.63561e+07	0.018222	9.72e+08
39	360	1.63352e+07	0.0364439	2.52e+09
40	369	1.62954e+07	0.0364439	4.98e+08
41	378	1.62954e+07	0.0728879	4.98e+08
42	387	1.62832e+07	0.018222	8.4e+08
43	396	1.62651e+07	0.0364439	2.27e+09
44	405	1.62337e+07	0.0364439	4.33e+08
45	414	1.62337e+07	0.0728879	4.33e+08
46	423	1.62234e+07	0.018222	7.07e+08
47	432	1.62056e+07	0.0364439	1.97e+09
48	441	1.61788e+07	0.0364439	3.82e+08
49	450	1.61788e+07	0.0728879	3.82e+08

```
    50        459     1.61695e+07       0.018222        5.9e+08
    51        468     1.61521e+07      0.0364439       1.71e+09
    52        477     1.61105e+07      0.0728879       1.45e+09
    53        486     1.61105e+07        0.12898       1.45e+09
    54        495     1.60899e+07      0.0322451       5.19e+08
    55        504     1.60807e+07      0.0644902       5.33e+09
    56        513     1.60502e+07      0.0161225       2.77e+06
    57        522     1.60434e+07      0.0322451       1.93e+09
    58        531     1.60231e+07      0.0322451       1.13e+07
    59        540      1.6008e+07      0.0644902       4.44e+09
    60        549      1.5965e+07      0.0644902       4.38e+07
    61        558      1.5965e+07        0.12898       4.38e+07
    62        567     1.59562e+07      0.0322451       1.29e+09
    63        576     1.59256e+07      0.0644902       2.86e+08
    64        585     1.59256e+07        0.12898       2.86e+08
    65        594     1.59135e+07      0.0322451       7.06e+08
    66        603     1.58868e+07      0.0644902       9.55e+08
    67        612     1.58393e+07        0.12898       2.54e+09
    68        621     1.57775e+07       0.177703       1.37e+09
    69        630     1.57341e+07       0.172886       3.96e+09
    70        639     1.56665e+07       0.302376       7.52e+08
    71        648     1.56504e+07       0.318003       1.01e+10
    72        657     1.56128e+07      0.0795007       7.07e+05
    73        666     1.56128e+07       0.159001       7.07e+05
    74        675     1.56103e+07      0.0397504       1.12e+09
    75        684     1.56035e+07      0.0795007       9.27e+07
    76        693     1.56035e+07       0.159001       9.27e+07
    77        702     1.56005e+07      0.0397504       6.11e+08
    78        711     1.55947e+07      0.0795007       3.64e+08
    79        720     1.55874e+07       0.159001       3.84e+09
    80        729     1.55774e+07       0.159001       5.25e+07
    81        738     1.55774e+07       0.318003       5.25e+07
    82        747     1.55763e+07      0.0795007       3.09e+09
    83        756     1.55723e+07      0.0795007       5.76e+07
    84        765     1.55723e+07       0.159001       5.76e+07
    85        774     1.55711e+07      0.0397504       6.55e+08

Local minimum possible.

lsqcurvefit stopped because the final change in the sum of squares relative to
its initial value is less than the value of the function tolerance.

<stopping criteria details>
```

Simulate the epidemy outbreak based on the fitted parameters

```
dt = 1/24; % time step
time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(10)));
N = numel(time1);
t = [0:N-1].*dt;
[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

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

```
clf;close all;
figure
semilogy(time1,Q,'r',time1,R,'b',time1,D,'k');
hold on
```

```
semilogy(time,Active,'ro',time,Recovered,'bo',time,Deaths,'ko');
% ylim([0,1.1*Npop])
ylabel('Number of cases')
xlabel('time (days)')
leg = {'Active (fitted)',...
        'Recovered (fitted)','Deceased (fitted)',...
        'Active (reported)','Recovered (reported)','Deceased  (reported)'};
legend(leg{:},'location','southoutside')
set(gcf,'color','w')
grid on
axis tight
 set(gca,'yscale','lin')
```