Numerical Simulation of COVID-19 in Brazil

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1 SIR 2 3
4 SIR

	3.30	4.07	4.15	4.23	5.01	5.09	5.17	5.25	6.02	6.10
	4256	12341	25758	46348	87187	147003	233511	363211	526447	707412

1:

2

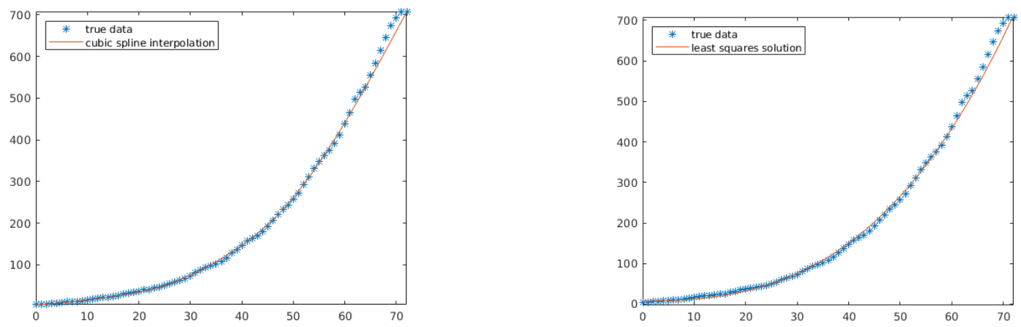
$(x_i, y_i), 1 \leq i \leq n$ $S(x)$

$$S(x_i) = y_i, \quad 1 \leq i \leq n, \quad S(x)|_{[x_i, x_{i+1}]} \in \mathbb{P}_3, \quad 1 \leq i \leq n-1, \quad S(x) \in \mathcal{C}^2[x_1, x_n],$$

x_i (not-a-knot) :

$$s'''(x)\ x = x_2 \ \ x = x_{n-1} \ .$$

$[x_i, x_{i+1}]$ matlab spline 3 30 y_i 1000
1(a)



(a) (b)

1:

3

$(x_i, y_i), (1 \le i \le n)$, $p(x) = \sum_{j=0}^{n} a_j x^j$ p

$$\min_{q\in\mathbb{P}_n} \sum_{i=1}^{n} |p(x_i) - y_i|^2.$$

QR matlab

$$p_3(x) = 6.6933 + 0.1910x + 0.0243x^2 + 0.0015x^3,$$

1(b).

4 SIR

SIR Susceptible Infected Recovered $S(t), I(t)$ $R(t)$

-
$$N(t) = S(t) + I(t) + R(t) = N, \quad \forall t \ge 0.$$
- β
$$\frac{\mathrm{d}S(t)}{\mathrm{d}t} = -\beta \frac{I(t)}{N(t)} S(t).$$
- γ
$$\frac{\mathrm{d}R(t)}{\mathrm{d}t} = \gamma I(t)$$

$$\frac{\mathrm{d}I(t)}{\mathrm{d}t} = \beta \frac{I(t)}{N(t)} S(t) - \gamma I(t).$$

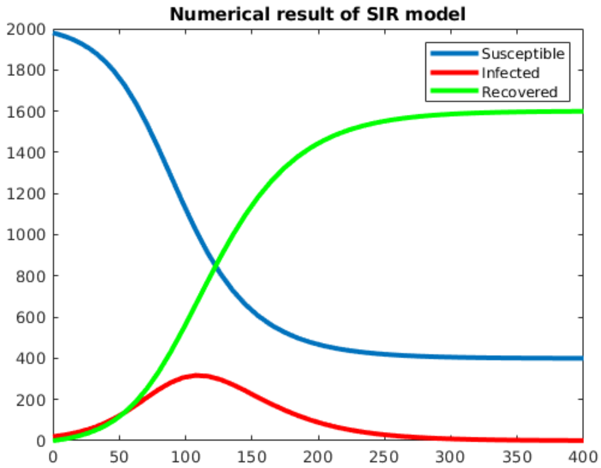
$$\begin{aligned}
\frac{\mathrm{d}S(t)}{\mathrm{d}t} &= -\beta \frac{I(t)}{N(t)} S(t)\\
\frac{\mathrm{d}I(t)}{\mathrm{d}t} &= \beta \frac{I(t)}{N(t)} S(t) - \gamma I(t)\\
\frac{\mathrm{d}R(t)}{\mathrm{d}t} &= \gamma I(t),
\end{aligned}$$

$$S(0) = S_0, I(0) = I_0, R(0) = 0,$$

, S_0 I_0

$$S_0 + I_0 = N.$$

ODE matlab ODE ode45 ode23s $N = 2000, \beta = 0.08, \gamma = 0.04, I_0 = 20, S_0 = N - I_0 = 1980$



2: SIR

β, γ

5

```
% true data
xx = linspace(0,72,73)';
yy = [203;366;492;734;865;977;979;1582;
   2231;2631;3450;4381;5656;5298;4144;6051;
   7788;8581;13086;16766;19660;20398;22609;23937;
   25173;22348;25141;25146;19872;19923;21582;19831;
   17332;16407;15861;15698;20634;19657;16983;15319;
   11956;9330;9545;8932;7084;6606;5395;4722;
   4390;4024;3961;3760;3625;2780;1259;1305;
   1869;1487;1203;869;746;759;637;770;
   784;570;503;422;343;290;219;131;
   93]/100;
plot(xx,yy,'*')
axis([0 72 4.2 708])
hold on
% data points for interpolation
x = linspace(0,72,10)';
y = [4256; 12341; 25758; 46348; 87187; 147003;
   233511; 363211; 526447; 707412]/1000;
u = linspace(0,72)'; % for plotting
% Perform cubic spline interpolation
v = spline(x,y,u);
```

```
plot(u,v,’-’)
hold off
legend(’true data’, ’cubic spline interpolation’, ’Location’, ’NorthWest’)
```

```
% true data
xx = linspace(0,72,73)’;
yy = [4256;4681;5861;7011;8165;9216;10431;11298;
    12341;14152;16238;18176;19943;21042;22625;23955;
    25758;29015;30891;34485;36925;39144;40814;43592;
    46348;50512;54043;59479;63328;67446;73235;80246;
    87187;92630;96559;101826;108620;116299;127389;137309;
    147003;156604;163510;170021;179457;192081;206507;220291;
    233511;244052;257396;271885;291579;310087;330890;347398;
    363211;374898;391222;411821;438238;465166;498440;514849;
    526447;555383;584016;614941;646006;673587;691758;707412;
    707412]/1000;
plot(xx,yy,’*’)
axis([0 72 -3.2 708])
hold on
x = linspace(0,72,10)’;
y = [4256; 12341; 25758; 46348; 87187; 147003;
    233511; 363211; 526447; 707412]/1000;
A = [x.^0 x.^1 x.^2 x.^3];
a = A\y;
u = linspace(0,72)’;
plot(u,a(1)+a(2)*u+a(3)*u.^2+a(4)*u.^3,’-’)
hold off
legend(’data points’,’least squares solution’,’Location’,’NorthWest’)
```

SIR :

```
N = 2000; % total population
beta = 0.08; gamma = 0.04;
SIRfunc = @(t, y) [ -beta*y(2)/N*y(1);
    beta*y(2)/N*y(1)-gamma*y(2);
    gamma*y(2)];
t0 = 0; tfinal = 400;
% initial conditions
I0 = 20; S0 = N-I0; R0 = 0;
y0 = [S0; I0; R0];
[t, y] = ode45(SIRfunc,[t0,tfinal],y0);
plot(t,y(:,1),’-’,t,y(:,2),’r-’,t,y(:,3),’g-’,’LineWidth’,3);
legend(’Susceptible’,’Infected’,’Recovered’)
title(’Numerical result of SIR model’)
```