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Mathematical modelling of social consciousness to control the outbreak of COVID-19

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Abstract:
Background. The world, now in an emergency of preventing the drastic spread of COVID-19. After the infection was first reported in December 2019, almost every country did not pay attention to this highly contaminated disease and failed to react swiftly. Now the whole universe is in an vulnerable state, loosing a great loss of lives and facing difficulties in all socio-economic aspects. That is why we have the urge to develop an efficient mathematical model (quarantine) based on social consciousness to control the epidemic.
Methods. This is a quarantine mathematical model. The outcome of the system is dependent on social consciousness. We have calculated the awareness level by considering various socio-economic factor of each country. In our model, the parameters are Education Index, GDP per capita, population density, high literacy and stable economy. To maximize the efficiency of the model, it has to be implemented in initial stage. However, strict application of the method in vigorous stage of epidemic will also bring a satisfactory outcome.
Results. Higher social consciousness will decrease the number of infected population dramatically while minimal or lower awareness will do a outburst.
Conclusion. Outbreak will be in control of health care system, lower the death rate and will ensure social and economic stability.

Keywords: Coronavirus; COVID-19; consciousness; data analysis; mathematical model; control.

1 Introduction

The coronavirus disease pandemic caused by SARS-CoV-2 is having a devastating impact across the world. Almost every country is a victim with 15,21,809 reported cases on April 09, 2020 and this is a global health emergency [1, 2]. The virus is related to the coronavirus

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responsible for the SARS outbreak of 2003 named SARS-CoV-1, and the virus is zoonotic [3]. In March 13, 2020, the World Health Organization considered Europe as hot spot of the 2019–20 coronavirus pandemic, and by April 09 (2020), 47 countries of Europe are affected by the outbreak [1, 2, 4]. The daily reported cases are being doubled over periods of 2 to 4 days by country across Europe [5], and the phenomenon has drawn a lot of attention.

In this paper, we have studied three European countries Spain, Italy and France; all these territories have higher socio-economic index [4, 6, 7]. So generally we can say people of these habitat are well aware of any given situation. In COVID-19 pandemic, they are apparently unprepared or might did not pay well attention.

This literature offer an ordinary differential equation (ODE) model to drag down the spread of COVID-19, with the influence of social consciousness towards the epidemic. Our prescribed model also determines the ongoing social response, the model also project the scenario of COVID-19 when handled with a higher social consciousness level. In the following manners, we have discovered the main novelty of our work:

- The model is designed for any types of contaminated diseases when it required to handle without medication.
- This determines the consciousness level for any given time and the percentage of social awareness required to gain the best control against the outbreak.
- The outcome of this model is applicable at any stage of epidemic with distinct outcome.
- If the solution is applied in initial stage of contamination, the disease will be in control of health care system and will not affect socio-economic context.
- We would be able to handle any future viral outbreak without or with less loss of lives or damaging the economy, and will be able to buy us some more time to investigate medication.

The paper is designed as follows. Mathematical Model is elaborately discussed in section 2. Solution of the Model is described in section 3. Section 4 is accomplished the data analysis in three subsections: Cases in Spain 4.1, Cases in Italy 4.2 and Cases in France 4.3. Finally, section 5 outlines the summary and discussion of the results.

In the following section, we will discuss our mathematical model elaborately.

2 Mathematical Model

In the literature, various types of mathematical models are developed due to the demand of time to cure or prevent the disease. In case of infectious disease modelling, the classical SIS, SIR, and SEIR etc. models allow the determination of critical condition of disease development asymptotically in the population [8, 9, 10, 11]. Since there is no proper medication

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or vaccine for disease COVID-19, prevention is only and main methodology to protect it, we propose the following ODE model based on quarantine and social consciousness:

$$Q' = \gamma Q - \alpha Q^2, \tag{2.1}$$

$$I' = rI\left(1 - \frac{I}{K}\right) - \beta Q, \tag{2.2}$$

for $t \in (0, \infty)$ with initial conditions

$$Q(0) = a, \quad I(0) = I_0, \tag{2.3}$$

where, the social consciousness level $\gamma \propto (eg)/d$, and e, g, d are the Education Index, GDP per capita and Population density of the considering country respectively as, a stable economy and high rate of literacy may help people to be more responsible to society. This implies

$$\gamma = \sigma \frac{eg}{d} \tag{2.4}$$

and σ is a constant, introducing as the mass social responsibility index of a certain country which may vary from nation to nation.

Here, $I(t)$ is the number of infected individuals at time t in unit of day and $Q'(t)$ is the increasing rate of change of social consciousness like as doing quarantine, hand washing, social distancing *etc.* due to COVID-19 pandemic situation caused by coronavirus in recent times. And α is a parameter that is very small respect to $\gamma \equiv (eg)/d$ (i.e. $\gamma >> \alpha$) making an correction over the exponential growth of $Q(t)$. The parameter r is the intrinsic growth rate and β is the rate of influence of social consciousness to pull down the propagation scene. Also in (2.2), we consider the logistic growth function to make the infection bounded [12].

This model shows the importance of social consciousness to control such a contagious infection of COVID-19. This model evaluates the current consciousness level in society to fight back the attack of COVID-19 and also measure the effective consciousness level that could pull down the outbreak at the primary stage if it could be imposed in time at the perfect level.

Now, it's time to get the solution of (2.1)-(2.3).

3 Solution of the Model

We are concern about the control of the infection growth presented in the second equation (2.2) of the model. To determine the change in $I(t)$ we first evaluate the solution of the first equation (2.1) and then place the solution of $Q(t)$ in the second equation (2.2).
From the first equation (2.1) of the system we get

$$\frac{\mathrm{d}Q(t)}{\mathrm{d}t} = \gamma Q(t) - \alpha Q^2(t)$$

$$\Rightarrow \frac{\mathrm{d}Q(t)}{\gamma Q(t) - \alpha Q^2(t)} = \mathrm{d}t,$$

Now, integrating the equation on both sides, we have

$$\int_{Q(0)}^{Q(t)} \frac{1}{\gamma Q(t) - \alpha Q^2(t)} \, \mathrm{d}Q(t) = \int_{t_0}^{t} \mathrm{d}t$$

$$\Rightarrow \int_{a}^{Q(t)} \frac{-\frac{\gamma}{Q^2(t)}}{\frac{\gamma}{Q(t)} - \alpha} \, \mathrm{d}Q(t) = -\gamma \int_{0}^{t} \mathrm{d}t$$

which yields

$$Q(t) = \frac{\gamma}{\left(\frac{\gamma}{a} - \alpha\right) e^{-\gamma t} + \alpha} \tag{3.1}$$

Now, the second equation (2.2) gives

$$\frac{\mathrm{d}I(t)}{\mathrm{d}t} = rI(t)\left(1 - \frac{I(t)}{K}\right) - \beta Q(t)$$

After few steps of mathematical simplification, we obtain

$$\frac{\mathrm{d}I(t)}{(I(t) - K)^2 + K\left(\frac{\beta}{r}Q(t) - K\right)} = -\frac{r}{K}\mathrm{d}t$$

Integrating within the reasoning limits gives

$$\int_{I_0}^{I(t)} \frac{\mathrm{d}I(t)}{(I(t) - K)^2 + K\left(\frac{\beta}{r}Q(t) - K\right)} = -\frac{rt}{K} \tag{3.2}$$

The solution of integral equation (3.2) is not straightforward since the denominator contains $Q(t)$ which is depending on time function (see (3.1) for details) and it can be an open problem to find the solution. Hence we solve the problem (3.2) numerically to find the solution of $I(t)$. As $I(t)$ being the number of infected individuals, $I(t) \geq 0$.

We will now estimate the parametric values to illustrate the numerical results for application as decorated in the following section.

4 Numerical validation

In the last of March, and first of April, 2020; Spain, Italy and France have hit the top positions of confirmed coronavirus (COVID-19) cases. This manuscript takes the data of these three countries up to 06 April, 2020 from *wordometer* [1] and check the model control prediction for these areas using the Runge-Kutta fourth order method.

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4.1 Cases in Spain

This following figure 1 shows that the current COVID-19 situation in Spain matches the model data at the average social consciousness level 49%.

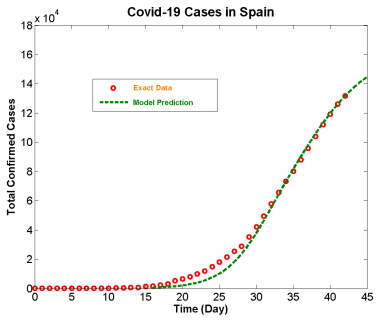

Figure 1: Model data coincides exact data at 49% social consciousness level.

From, resources published by European Union and other sources [4, 6, 7], for Spain we consider the parameter values as

$$e = 0.824, \quad g = 28.156 \text{ (thousand USD)}, \quad \text{and} \quad d = 91.4 \text{ (per square km)},$$

which shows the 49% social consciousness. It gives

$$\gamma = \sigma \frac{0.824 \times 1.311}{91.4},$$
$$\Rightarrow \sigma = 1.9304.$$

The model is also able to show in figure 2 what could happen without social consciousness and with rapid implementation of social consciousness at before community transmission or initial stage (phase 2) of infection propagation.

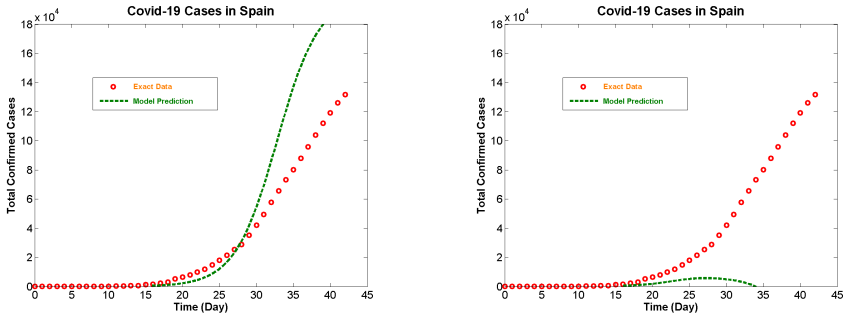

Figure 2: Model simulation at 0% and 65% social consciousness level respectively.

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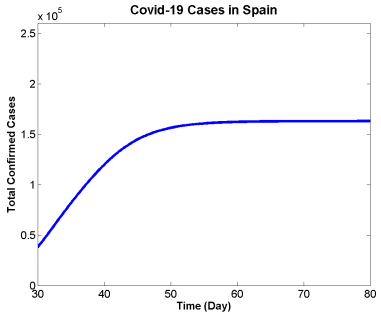

Figure 3: Model solution (data) predicts the control of COVID-19 in Spain.

The above figure 3 indicates that if the people of Spain be able to continue holding this social awareness level, there will be no new infection after the 69-th day of finding the first confirmed case of COVID-19.

4.2 Cases in Italy

Figure 4 resembles the running COVID-19 situation in Italy that coincides with the model data at the level of 57.6% social consciousness in average with mass social responsibility index 4.6518.

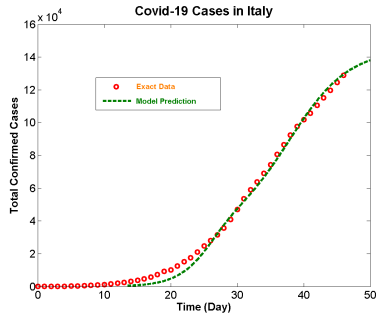

Figure 4: Model data coincides exact data at 57.6% social consciousness level.

The figure 5 shows what could happen without social consciousness and with rapid implementation of social consciousness at before community transmission or initial stage (phase 2) of infection propagation.

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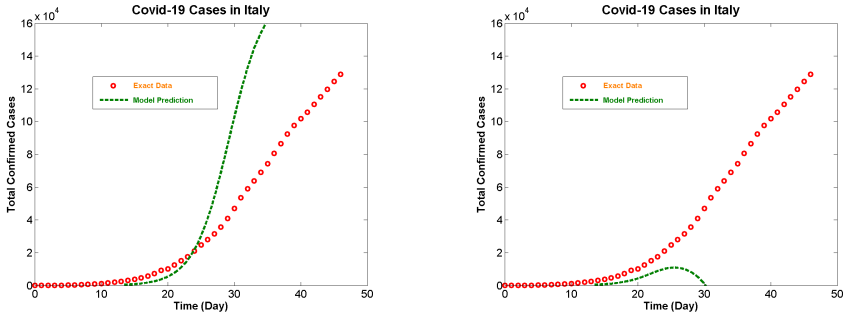

Figure 5: Model simulation at 0% and 66% social consciousness level respectively.

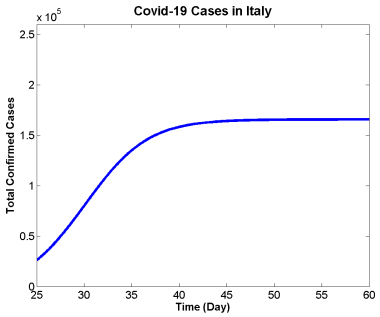

Figure 6: Model solution (data) predicts the control of COVID-19 in Italy.

This figure 6 resembles that the current social awareness level can make the pandemic to infect no new case in Italy after the 57-th day, since the fist suspected individual tested COVID-19 positive.

4.3 Cases in France

The current COVID-19 situation in France with the model data at the average social consciousness level 47.5% and mass social responsibility index 1.8203 is presented in figure 7.

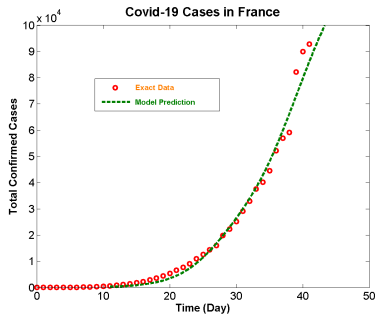

Figure 7: Model data coincides exact data at 47.5% social consciousness level.

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The impact of no social consciousness and rapid implementation of social consciousness level before community transmission or initial stage (phase 2) of infection propagation is shown in figure 8.

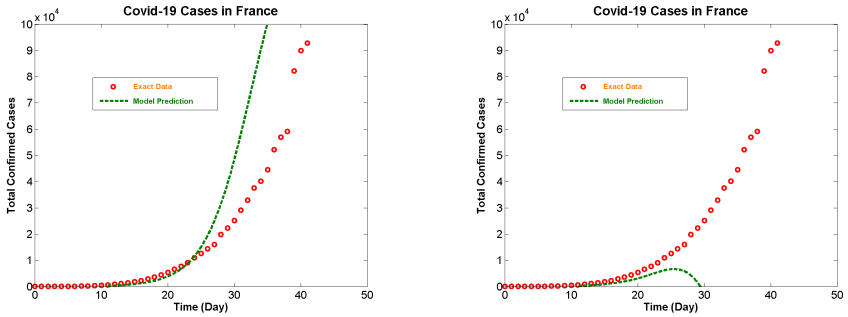

Figure 8: Model simulation at 0% and 52% social consciousness level respectively.

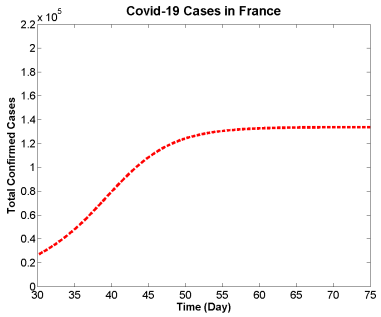

Figure 9: Model solution (data) predicts the control of COVID-19 in France.

Figure 9 presents the scenario that after the 71-st day of facing COVID-19 outbreak, no new cases will be found if the French people can continue their present social consciousness level.

5 Conclusion

Mathematical and computational models can help to understand biological scenarios and can predict epidemiological aspects. In this paper, we proposed a model to interpret the importance of social consciousness. The proposed mathematical model validates the ongoing viral cluster of Spain, Italy and France, and shows the current consciousness level in these countries. It also describes the possible outcome of the pandemic, when social consciousness raised 16% (Spain), 9% (Italy) and 5% (France) more for the respected countries. It can be said that on average only 10% increased social consciousness could possess a significant impact on disease control for any given country. The manuscript also describe the effectual outcome of disease propagation when social consciousness improved on any n^{th} day (at any stage of outbreak).

We hope that our modelling of social consciousness will assist in greater aspects. These findings will motivate the mankind to understand the importance of rapid social consciousness action. Rapid social awareness can help us to fight back this type of highly cognitive disease in the current time or in near future. This way the scientist will be able have some time in inventing medication.

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Declarations

Ethics approval and consent to participate

The ethical approval or individual consent was not applicable.

Availability of data and materials

All data and materials used in this work were publicly available.

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Authors' Contributions
MSM and MK derived the mathematical model, designed the study and the first draft of the manuscript. MSM, MK and JJ carried out the data analysis, some numerical simulations and the parameter estimations. JJ and MSI provided the literature review and final drafting. All authors contributed to the reviewing of the manuscript. All authors read and approved the final manuscript.