Instituto Universitario
de Matemática Multidisciplinar

MODELLING FOR ENGINEERING & HUMAN BEHAVIOUR 2020

July 8-10, 2020

Edited by

R. Company, J.C. Cortés,
L. Jódar and E. López-Navarro

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CIUDAD POLITÉCNICA DE LA INNOVACIÓN

Modelling for Engineering & Human Behaviour 2020

València, 8 – 10 July 2020

This book includes the extended abstracts of papers presented at XXII Edition of the Mathematical Modelling Conference Series at the Institute for Multidisciplinary Mathematics "Mathematical Modelling in Engineering & Human Behaviour".

I.S.B.N.: 978-84-09-25132-2
Version: 3-12-2020
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Edited by: R. Company, J. C. Cortés, L. Jódar and E. López-Navarro.
Credits: The cover has been designed using images from kjpargeter/freepik.

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This book has been supported by the European Union through the Operational Program of the [European Regional Development Fund (ERDF) / European Social Fund (ESF)] of the Valencian Community 2014-2020. [Record: GJIDI/2018/A/010].

Contents

Epidemiological modelling of COVID-19 in Granada, Spain: Analysis of future scenarios

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1 Introduction

COVID-19, a disease caused by the novel coronavirus SARS-CoV-2, has become a global pandemic with huge incidence in public health. The first outbreak happened at the end of December in Wuhan, China. Since then, more than two hundred countries have been affected with near four million cases worldwide [2]. The symptoms of the disease cover a broad number of possibilities, from asymptomatic patients to multiple organ failure [1]. The high number of asymptomatic patients, together with the novelty of the disease, have made possible the fast expansion of the virus [3].

In this work, a mathematical model describing the transmission dynamics of COVID-19 is presented. It is based on a modified SEIR model, with the aim at reproducing the evolution of the hospitalization pressure. Also quarantine actions have been taken into account in order to study the effect of the confinement in the spread of the disease.

Regarding to COVID-19, a person may be in different states described below and shown graphically in Figure 1 and described mathematically by the equation system (1).

- **Susceptible (S):** when the person has not the disease and has not passed though it.
- **Lockdown (Q):** when the individual is in lockdown due to public health policies.
- **Latent or exposed (L):** when the person has the disease, but he/she is not capable of infect other people.
- **Infectious (I):** when the person has the disease and he/she can infect other people with SARS-CoV-2.

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- **Recovered (R):** when the person has passed through the disease and did not need hospital treatment.
- **Hospitalized (H):** when the person is passing the disease and needs hospital treatment.
- **Intensive care unit (U):** when the person is passing the disease and needs intensive care unit (ICU) treatment.
- **Deceased (F):** when the person dies because of SARS-CoV-2.
- **After ICU (HU):** when a person moves from ICU to other non-ICU department inside the hospital once the disease has improved.
- **Discharged (A):** when the person is discharged from hospital.

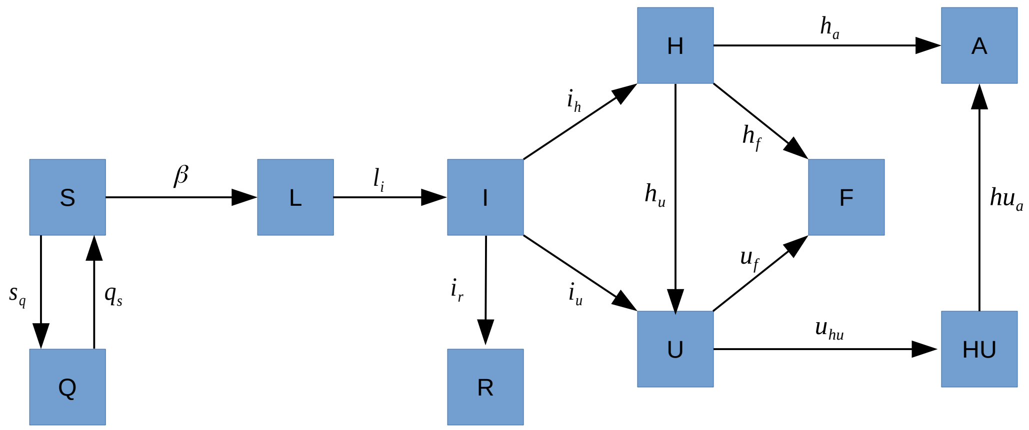

Figure 1: Diagram with the different states considered in the COVID-19 SEIR model. Arrows describe the movement from one state to another.

$$
\begin{aligned}
S(t+1) &= S(t) + q_s(t) - s_q(t) - \beta(t)S(t)\tfrac{I(t)}{P_T}, \\
Q(t+1) &= Q(t) + s_q(t) - q_s(t), \\
L(t+1) &= L(t) + \beta(t)S(t)\tfrac{I(t)}{P_T} - l_i L(t), \\
I(t+1) &= I(t) + l_i L(t) - (i_r(t) + i_h(t) + i_u(t))I(t), \\
H(t+1) &= H(t) + i_h(t)I(t) - (h_u(t) + h_f(t) + h_a(t))H(t), \\
U(t+1) &= U(t) + i_u(t)I(t) + h_u(t)H(t) - (u_f(t) + u_{hu}(t))U(t), \\
HU(t+1) &= HU(t) + u_{hu}(t)U(t) - hu_a(t)HU(t), \\
A(t+1) &= A(t) + h_a(t)H(t) + hu_a(t)HU(t), \\
F(t+1) &= F(t) + h_f(t)H(t) + u_f(t)U(t), \\
R(t+1) &= R(t) + i_r(t)I(t).
\end{aligned}
\qquad (1)
$$

2 Results and discussion

Once the model has been presented, it has been calibrated using NS algorithm [4] with data obtained from the *Hospital Universitario Virgen de las Nieves* in Granada (Spain) [5]. The province of Granada has 921511 inhabitants, and we consider this value as constant during the simulation time. Our simulations begins on 5 March 2020. The calibrated model and the data used for calibration and validation are shown in Figure 2.

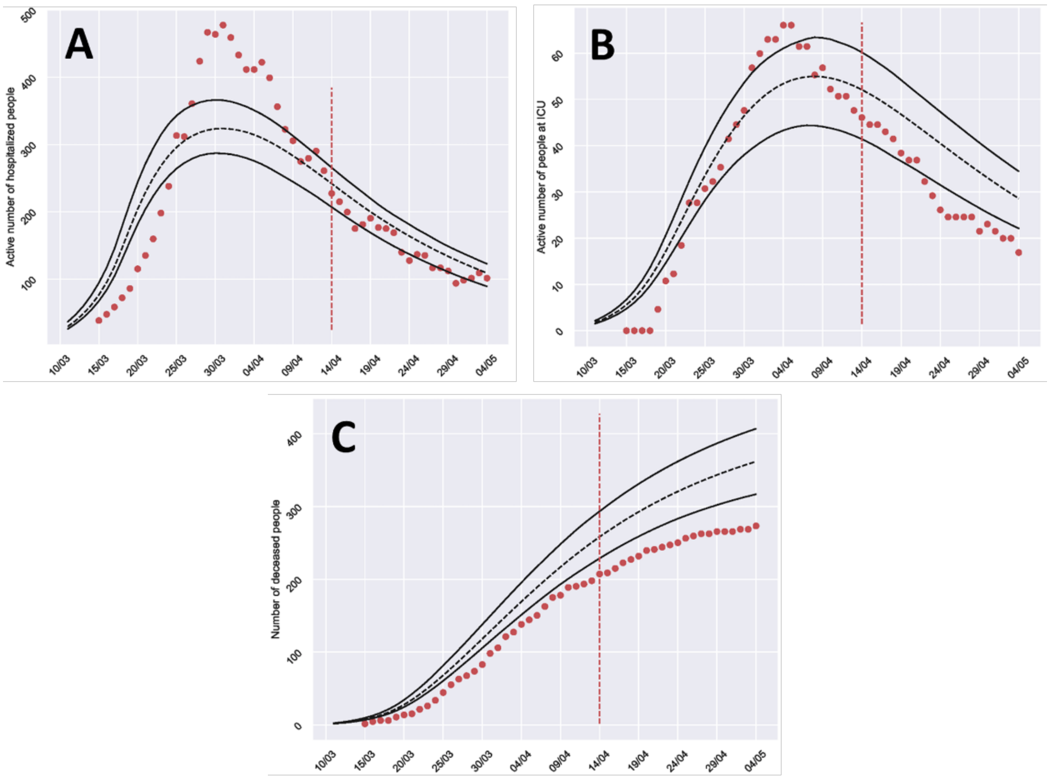

Figure 2: COVID-19 SEIR model calibration and validation for (A) Hospitalizations at ward, (B) Intensive Care Unit and (C) Deceases. The red points on the left of the vertical line of the graphics are used to calibrate the model and the red points on the right of the vertical line of the graphics are used to validate the model.

Assuming that the behaviour of the disease in the future is similar to the behaviour of the disease in the past, some scenarios are simulated in order to study different public health policies that might reduce the infections in future outbreaks of COVID-19. For the simulation, when required, we include that the exit of the quarantine is done gradually during 4 weeks on which every week 25% of people return to normal life.

The β may be modified taking into account: (i) measures avoiding social contacts: home-working, avoiding meetings, safe distancing, room ventilation, limiting the capacity of bars, restaurants, hotels and public places, (ii) measures of protection (facemasks, hand washing), response of the virus to the summer temperatures, the population immunity, etc.

Assuming an optimistic 10% viral β during 14 April – 2 September 2020, by the end of summer the number of cases would be significantly reduced. However, SARS-CoV-2 β could increase in autumn 2020 due to seasonality and other factors (schools reopening, etc.). On this basis, we assessed the analysis considering 100%, 50% or 25% of β from autumn respect to the rate registered before the quarantine.

The evolution of the pandemics depending on the β value are shown in Figure 3.

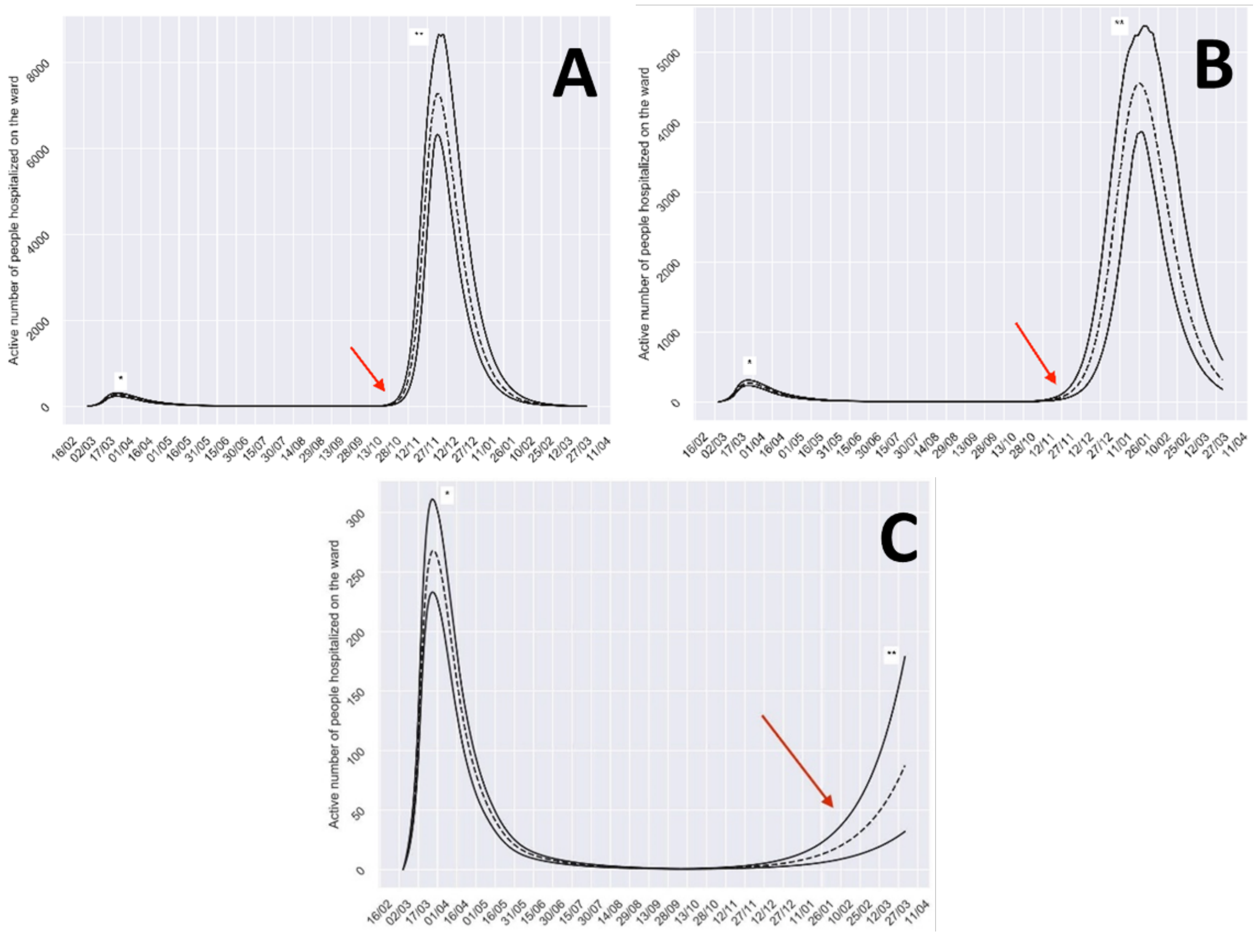

Figure 3: COVID-19 SEIR model evolution depending on the β parameter. (A) Evolution with 100% of initial β, (B) evolution with 50% of initial β and (C) evolution with 25% of initial β. Red arrows are used to point out the moment when more drastic public health measures must be implemented.

3 Conclusions and future work

The modified SEIR model presented can be a useful tool for providing insight into the transmission dynamics of SARS-CoV-2. We simulated mid-term scenarios varying the β after the current quarantine. Those predictions would provide enough time to the health systems to establish appropriate measures. The conclusions of this work suggest that social distancing, together with measures that decrease the contagion will be needed in order to control the pandemics in the next autumn. It will be also important the monitoring of the evolution of the disease in the health system in order to take more aggressive measures if the number of infected people might collapse hospitals again.

Acknowledgements

- the Spanish Ministerio de Economía, Industria y Competitividad (MINECO), the Agencia Estatal de Investigación (AEI) and Fondo Europeo de Desarrollo Regional (FEDER UE) grant MTM2017-89664-P;

- the European Union through the Operational Program of the [European Regional Development Fund (ERDF) / European Social Fund (ESF)] of the Valencian Community 2014-2020. Files: GJIDI/2018/A/010 and GJIDI/2018/A/009;
- the Ramón Areces Foundation, Madrid, Spain (CIVP18A3920).

References

[1] Fei Zhou, Ting Yu, Ronghui Du, Guohui Fan, Ying Liu, Zhibo Liu, Jie Xiang, Yeming Wang, Bin Song, Xiaoying Gu, Lulu Guan, Yuan Wei, Hui Li, Xudong Wu, Jiuyang Xu, Shengjin Tu, Yi Zhang, Hua Chen, Bin Cao. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *The Lancet*, 395:1054–1062, 2020. 10.1016/s0140-6736(20)30566-3

[2] European Centre for Disease Prevention and Control. https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases (accessed: 8-05-2020)

[3] Adam J Kucharski, Timothy W Russell, Charlie Diamond, Yang Liu, John Edmunds, Sebastian Funk, Rosalind M Eggo, Fiona Sun, Mark Jit, James D Munday, Nicholas Davies, Amy Gimma, Kevin van Zandvoort, Hamish Gibbs, Joel Hellewell, Christopher I Jarvis, Sam Clifford, Billy J Quilty, Nikos I Bosse, Sam Abbott, Petra Klepac, Stefan Flasche. Early dynamics of transmission and control of COVID-19: a mathematical modelling study. *The Lancet Infectious Diseases*: 20(5):553–558, 2020. 10.1016/s1473-3099(20)30144-4.

[4] Martínez-Rodríguez, D, Colmenar, JM, Hidalgo, JI, Villanueva Micó, R-J, Salcedo-Sanz, S. *Particle swarm grammatical evolution for energy demand estimation* Energy Sci. Eng. 8:1068–1079, 2020. 10.1002/ese3.568.

[5] Hospital Universitario Virgen de las Nieves. https://www.huvn.es (accessed 8-05-2020)