The Effect of Weekend Curfews on Epidemics: A Monte Carlo Simulation

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Abstract: The ongoing COVID-19 pandemic is being responded with various methods, applying vaccines, experimental treatment options, total lockdowns or partial curfews. Weekend curfews is one of the methods to reduce the amount of infected persons and this method is practically applied in some countries such as Turkey. In this study, the effect of weekend curfews on reducing the spread of a contagious disease, such as COVID-19, is modeled using a Monte Carlo algorithm with a hybrid lattice model. In the simulation setup, a fictional country with three towns and 26,610 citizens were used as a model. Results indicate that applying a weekend curfew reduces the active cases significantly and is one of the efficient ways to fight the epidemic. The results also show that applying

personal precautions such as social distancing is important for reducing the number of cases and deaths.

Key words: Monte Carlo simulation, epidemic, curfew, SIR, COVID-19

1. Introduction

The Coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is currently ongoing since December 2019. To the best of our knowledge, there is no approved specific antiviral drug treatment for SARS-CoV-2 (Tarighi et al. 2021) and vaccination efforts are conducted worldwide. The spread of the disease is ongoing and various countries are applying nationwide and/or local measures for preventing the spread of the disease.

As of May 2021, different countries and communities follow different ways to combat the disease: Vaccination, partial curfews and full quarantines. Among the examples, Turkey applies a partial curfew which applies a travel ban for all citizens (except for mandatory duties) on weekends. This 2-day curfew is applied at least to the end of May 2021.

By the means of in silico and computational methods, many scientists are working on discovering the genome analysis and mutations (Ugurel et al. 2020, Eskier et al. 2021), using epidemiological simulation. By the means of epidemiological data fitting and simulation there are two main approaches: The first one is to fit the data with mathematical models and the second one is to simulate and generate data in consistency with the real clinical data (Maltezos and Georgakopoulou 2021). Previously, several studies on modeling infectious diseases by the means of random walk and stochastic processes have been reported (Filipe and Gibson 1998, 2001, Draief and Ganesh 2011, Bestehorn et al. 2021). Monte Carlo (MC) simulation is one of the efficient methods for generation of a decision making tool (Xie 2020). Different MC studies have been reported for COVID-19 spread, such as analyzing different scenarios for selected countries (Vyklyuk et al. 2021), age-structured mobility data for simulation of the pandemic spread in selected cities (De Sousa et al. 2020) and random-walk proximity-based infection spread (Triambak and Mahapatra 2021).

The aim of this paper is to observe the effects of disease detection rate and the chance of recovery for a contagious disease under a weekend curfew scenario, similar to the one applied in Turkey. In the model, three different towns with a total population of 26,610 were modeled in a hybrid model of susceptible, infected and recovered (SIR) model (Kermack and Mckendrick 1927, Huppert and Katriel 2013, Shu et al. 2016), lattice model (Liccardo and Fierro 2013) and spin-1 Ising model (Berker and Wortis 1976, Hoston and Berker 1991).

2. Methods

The Monte Carlo model used in this study is written in the C & C++ language by the authors. A fictional country with a population of 26,610 and three separate towns (namely A, B and C, as shown in Figure 1) are generated. Each person in the towns are placed randomly on an Ising-like model where the neighbors of each particle can be another person or a void space (as shown in Figure 2). In order to improve the randomness in movement, there are also "obstacles" which are simply lattice points which are impossible to be on.

FIGURE 1

FIGURE 2

The following attributes are possible for each particle: a) Healthy, b) sick and undiagnosed, c) sick and in quarantine, d) recovered (cured), e) dead. Option b “sick and undiagnosed” is used for simulation of both undiagnosed persons and asymptomatic cases.

In each Monte Carlo step, particles are selected and a random possible direction is assigned to this particle as the movement. After selecting and checking the movement of all possible particles, this is called one Monte Carlo step and named as “day” in the simulation. In the following “day”, the process is repeated for all particles.

On day 7, a randomized person gets infected on Town A and starts spreading the disease (patient zero). On day 15, the disease spreads to a random position in Town B. On day 22, the disease spreads to a random position in Town C.

An infected person can spread the disease at a certain probability P_{spread} and the sickness is detected at a probability of $P_{detection}$.

If the person is diagnosed with the disease, then the rate of successful treatment is $P_{treatment}$. This person goes to quarantine, which means the person is immobile and cannot transmit the virus ($P_{spread} = 0$) until the disease is cured.

If the disease in the person is not properly diagnosed, then the rate of the survival is $P_{survival}$. In both cases, the person either gets cured or dies (based on $P_{treatment}$ or $P_{survival}$) after 28 days.

The government applies a curfew on weekends like Turkey, beginning on day 13, which is 6 days after the first detection. On curfew, persons are immobile and are not able to spread the disease. On weekdays (5 days), all persons are mobile and can spread the virus except the persons under quarantine. A cured person can not be reinfected and does not spread the virus.

Spread of the virus and infection is modeled by the generation of a random number r on each Monte Carlo step. If $r > P$, then the aforementioned event occurs. For instance, if day > 28 and $r > P_{treatment}$, then the person gets recovered.

3. Results and Discussion

Figure 3 shows the spread of the disease on days 0, 11 and 24. The ill persons are marked with red, indicating the random movement of the ill persons as well as the spread of disease at a probability of P_{spread}.

FIGURE 3

In order to test the model, a SIQR - susceptible, infected, in quarantine and recovered – plot is generated as shown in Figure 4. In the test model, nobody dies because of the disease and accordingly, with the onset of the infection, the sums of the ratios of each case is always 1.0, indicating the model works for the given simulation setup.

FIGURE 4

The effect of weekend curfews is shown in Figure 5. This figure indicates the start day of the weekend curfews when compared to the case without the weekend curfews, where all plots were obtained at a detection probability of 0.3 for comparison. As indicated in the plot, starting the weekend curfew early as day 14 decreases the ratio of ill persons from 0.22 to 0.15, as well as widening the peak. Reducing the amount of ill persons at a given time is very important for reducing the workloads of health professionals and efficiently using capacities of intensive care units (Farsalinos et al. 2021). Therefore, the effect of curfews are clearly visible in the given simulation. Prolonging the starting day of the weekend curfews slowly shifts the curve to the left, i.e. to the case without any curfew/nationwide lockdown.

FIGURE 5

In the second part of the study, the effect of varying P_{spread} on the death rate was investigated. Here, P_{spread} varied from 0.1 to 1.0, with an increase of 0.1 and the simulation repeated for different P_{spread} values, with an assumption of asymptomatic cases always recover, where weekend curfews continue. The result of this simulation is shown in Figure 6. It is clear that reducing the P_{spread} decreases the death ratio significantly, which demonstrates the importance of social distancing, wearing masks and complying with other hygiene precautions in combating the spread of the disease.

FIGURE 6

Conclusion

By applying a weekend curfew e.g., two-day alternating lockdowns and five-day free motion on particles being simulated in this study, it is found that the ratio of infected decreases by 68% at the peak point. It is also evident that starting this curfew is more efficient when started earlier (day 14 in this study). Turkey also observed a similar pattern of case decrease by following the weekend curfews for combating COVID-19. Monte Carlo simulations remain as a strong tool not only for predicting the spread of contagious diseases, but also for modeling the alternative precaution measures. Further and detailed studies might show the effects of disobeying the curfew, age, gender and other parameters as well as the effect of vaccines altogether for modeling the epidemic/pandemic.

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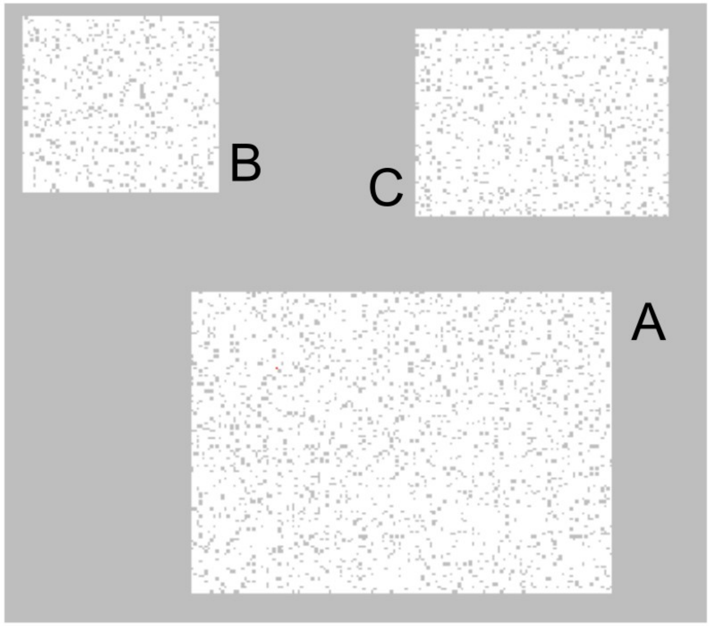

Figure 1 Three fictional towns A, B, C which hold 26,610 persons in this study.

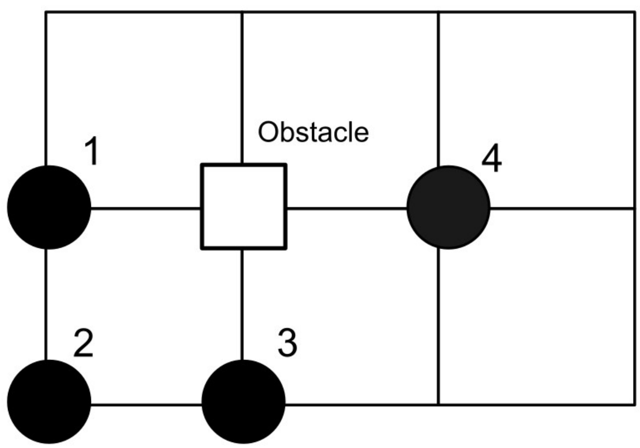

Figure 2 An example to the four of the particles in the given lattice, where each particle represents a person in the simulation. The obstacle is a forbidden lattice point.

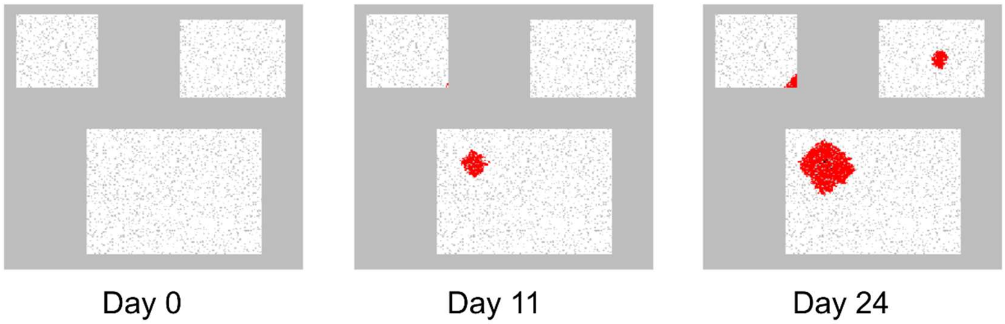

Figure 3 Increase in the number of ill persons on three different days, which includes both the spread of the disease and movement of the persons.

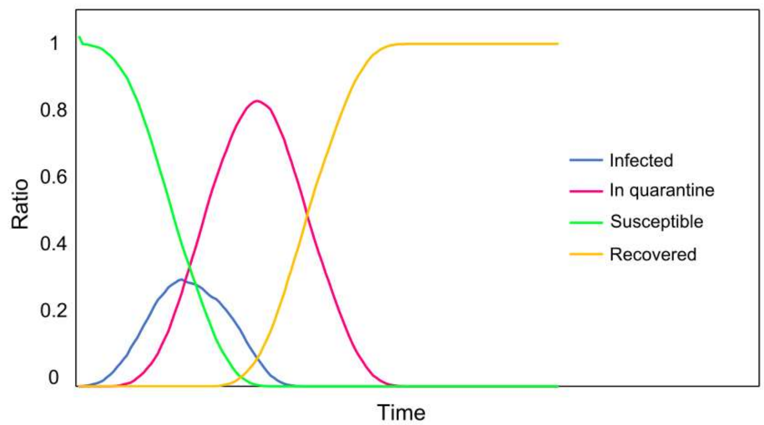

Figure 4 Ratios of susceptible, infected, in quarantine and recovered in this model.

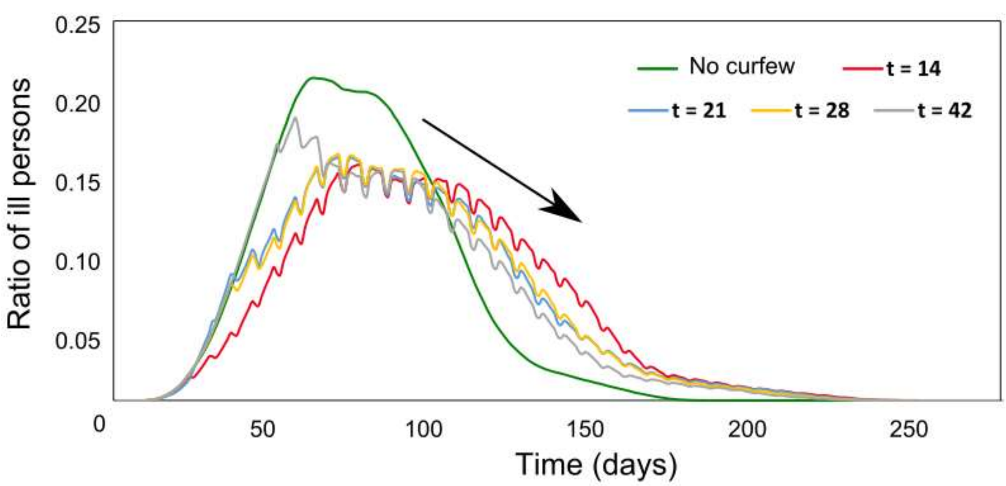

Figure 5 Ratio of ill persons for five different cases: No curfew is applied (green), weekend curfews starting on day 14 (red), day 21 (blue), day 28 (yellow) and day 42 (gray).

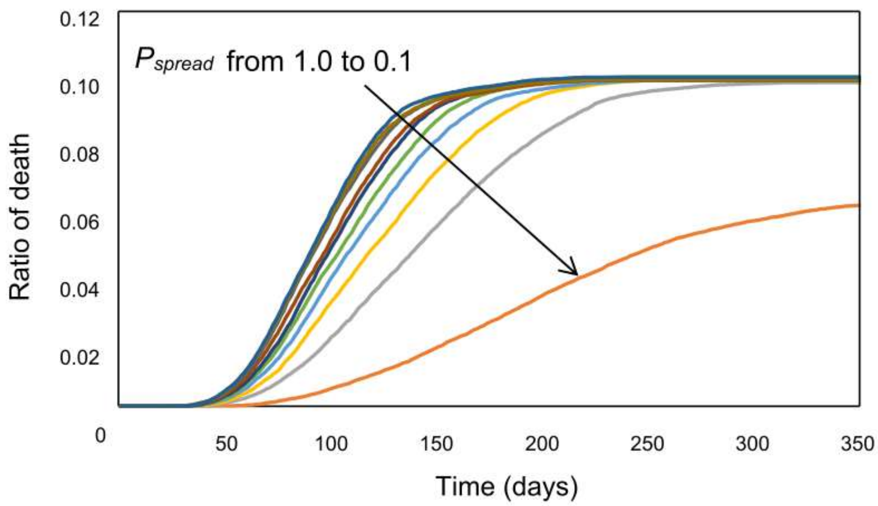

Figure 6 Effect of the spread probability P_{spread} on the death ratio, where decreasing the probability gives the lower ratio (orange curve).