Modeling the Spread of Covid-19 with 2-D Cellular Automata
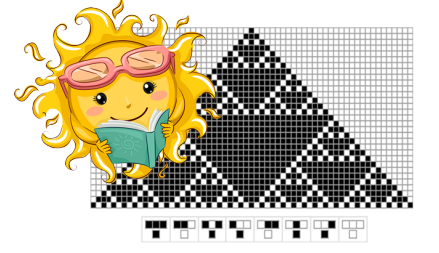
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This project focuses on developing a model that can accurately simulate COVID-19's global dissemination patterns. We utilize cellular automaton (CA) to build such a model. In this project, a new variant of CA called *Temporary Stochastic Cellular Automata* (TSCA) is used, where two rules is being utilized, one of which serves as a default rule and the other of which is a probabilistic rule that is applied with some probability. To consider the mutation of the COVID-19 rule, we employ a set of TSCAs. Each TSCA is considered as $(f,g)[\tau]$ and at a time the applied TSCA is chosen from the set. The model evolves using two TSCA rules f and g, where f is represented as the propagation of the virus, g is represented as recovery function and g is applied with probability τ. The model is validated on the basis of a real-time dataset of spreading Coronavirus (SARS-COVID-19) over the world. This proposed model depicts the spreading scenario of the novel Coronavirus which has caused a global pandemic.

We consider periodic boundary condition, where the first and last row of cells are neighbors to each other, whereas, the first and last column of cells are neighbors to each other. Temporally stochastic cellular automata (TSCA) where at a time step, a cell can be updated using one of the two rules f and g. Here, f is the *virus spreading* rule for the CA, whereas, g is the *immunity* and is applied with some probability. That is, rule g is applied with probability $\tau \in [0,1]$ whereas the rule f is applied with probability $(1-\tau)$. We call τ as the *rate of immunity*. This way of looking at these rules makes both of them temporally stochastic. Therefore,

$$y = \begin{cases} G_g(x) & \text{with probability } \tau \\ G_f(x) & \text{with probability } 1-\tau \end{cases}$$

where, $G_g(x)|_i = g(s_1, s_2, s_3, \cdots, s_{10})$ and $G_f(x)|_i = f(s_1, s_2, s_3, \cdots, s_{10})$. The proposed system specification is written as $(f,g)[\tau]$. The rate of transmission of the virus varies depending on the time of year, sometimes being quite high and other times being very low. As a result, we have considered a set of TSCAs and each of the TSCAs that we have employed for varying periods of time represents $(f,g)[\tau]$ in our model. We have used a set of TSCA rules, to simulate our model, $(f_1,g_1)[0]$, $(f_1,g_1)[0.3]$, $(f_2,g_2)[0.3]$, $(f_3,g_1)[0.3]$, $(f_3,g_3)[0.3]$.

We assume that, initially, the state of all the cells is considered to be 0 and only one cell is set to state 1. Here, we consider *white cell* for *state 0*, *black cell* for *state 1*, Fig. 1a shows the initial configuration for the model. Fig. 1b, Fig. 1c and Fig. 1d show the intermediate configurations for the simulation which demonstrates several COVID-19 spread scenarios at various time. *white cell* indicates un-infected cells whereas *black cell* indicates infected cells. Fig **??** shows the graph representation of our simulation, where Fig 1e shows the growing of infected cells (switches to *state 1*) with respect to time. Fig 1f depicts the number of infected cells over the grid for different time period.

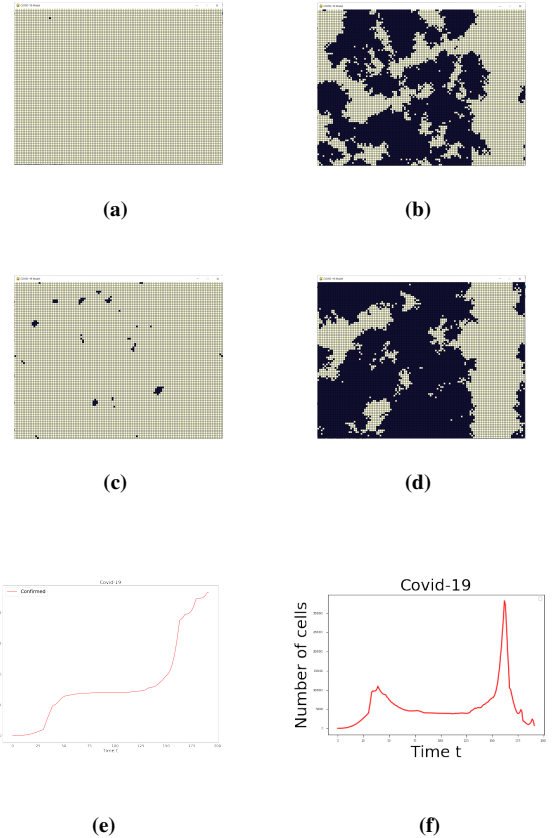For the study, we choose COVID-19 spreading data set which are taken from https://www.kaggle.com/datasets/imdevskp/corona-virus-report

Figure 1: (a) Initial configuration of the CA; (b) Configuration shows the first wave of spreading virus; (d) Configuration shows the rising of second wave; (e) Number of confirmed cases (switches to *state 1*); (f) Shows the wave of spreading the virus;

, we employed three cases: confirmed cases, recovered cases and the wave. The spreading accuracy of the proposed model is compared with real time data sets. We observed that our proposed TSCA model displays the identical circumstance like a real-time scenario and it becomes effective and performs effectively for other circumstances as well.

We may consider this model as a generalized model of spreading of this sort of viruses in future by only changing the set of TSCA rules (tune the parameters f, g, τ to form a TSCA).