The mathematics behind shouldistayhome.de

The objective is to calculate the number of people whose lives could be saved by social distancing in your local city. To do this estimatimation we assume the following:

- With "city" we also include neighboring cities in the same Landkreis (e.g. when the user enters "München" cities like Garching are also included)
- No inter-city travel in Germany
- No overload of hospital capacity possible (i.e. no deaths resulting from missing hospital beds), deaths only caused by virus mortality rate.
- The infection rate is independent of the density of the city.
- The mortality rate of Covid19 is 2%, regardless of the demographics of the city (estimate from https://www.worldometers.info/coronavirus/coronavirus-death-rate/)
- The number of confirmed cases in the city is the real number of all total cases, i.e. all infected people have been tested (this will give us the minimum number of people saved). In the future we will give an upper estimate by estimating the "Dunkelziffer" with a factor of 10.
- Since we do not know the number of people who are still infectious, we estimate the number by looking at the percentage of recovered people in the state where the city is located (e.g. when estimating the number of infectious people in Munich, we will assume that if 45% are still infectious in Bavaria, 45% are also still infectious in Munich). This data is obtained from https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4

Our simulation is based on the SIR model, where the number of susceptible + infected + removed = 1. We assume the reader is familiar with the three differential equations associated with this simple but powerful model. After the user has chosen a city (included in the fusionbase dataset), say it is called Musterstadt and is in Bavaria, we know the number of total cases (say 1000) and the total population (say 100.000).

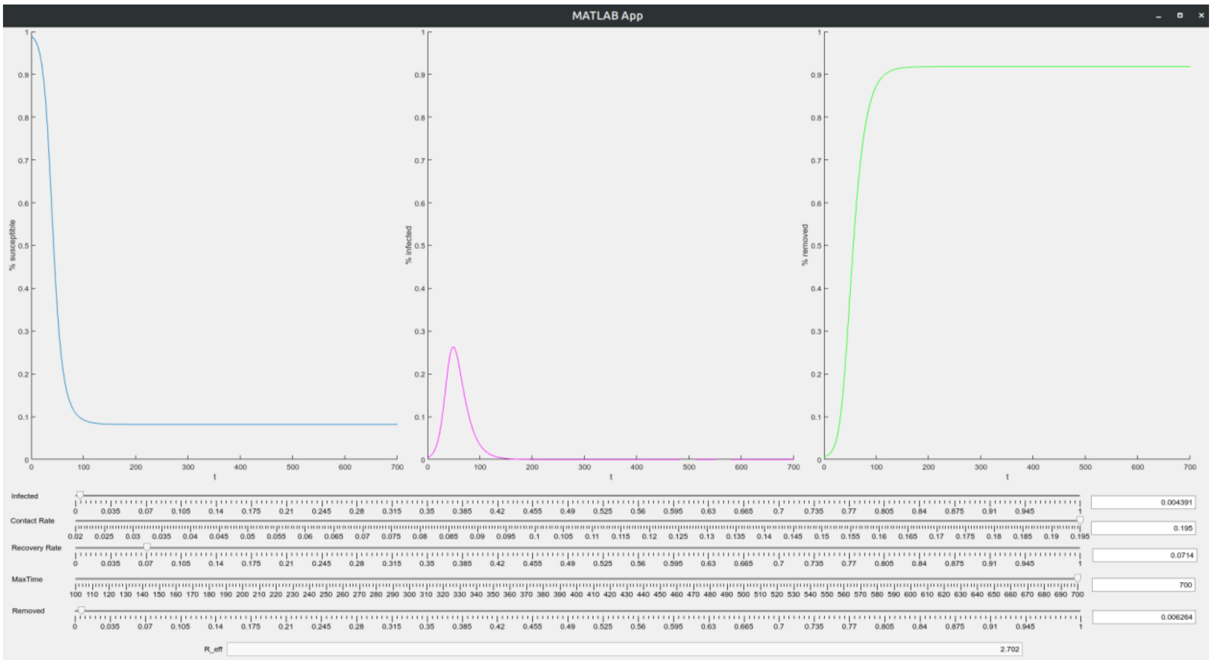
Now we can estimate the number of recovered people in Musterstadt (since we can find out the percentage of recovered people in Bavaria). Say the the recovery rate in Bavaria is 55%. We can therefore estimate 55% * 1000 = 550 are at least in the removed category. Another 2% * 1000 = 20 are in the removed category because they passed away. Therefore we have 570 in removed, 1000 – 570 = 430 in infected and 100.000 – 1000 = 99.000 in susceptible. These are are going to be the starting values (*Anfangswerte*) for the differential equations. Note that our model will work with percentages, so instead of e.g. using I = 430 we will use I = 430 / 100.000.

Note that the we still have to set the two parameters a and b used in the SIR model, where **a** is the contact rate and **b** is the recovery rate. The recovery rate can be calculated as „b = 1 / Average days to recover", in our case b = 1 / 14 (roughly). On the other hand, **a** will depend on how infectious Covid19 is and how much social distancing is practiced. Fortunately, we know that **R_{eff} = R_0 * (Susceptible / TotalPopulation) = (a / b) * (Susceptible / TotalPopulation).** This paragraph is based on information from https://www.lewuathe.com/covid-19-dynamics-with-sir-model.html .

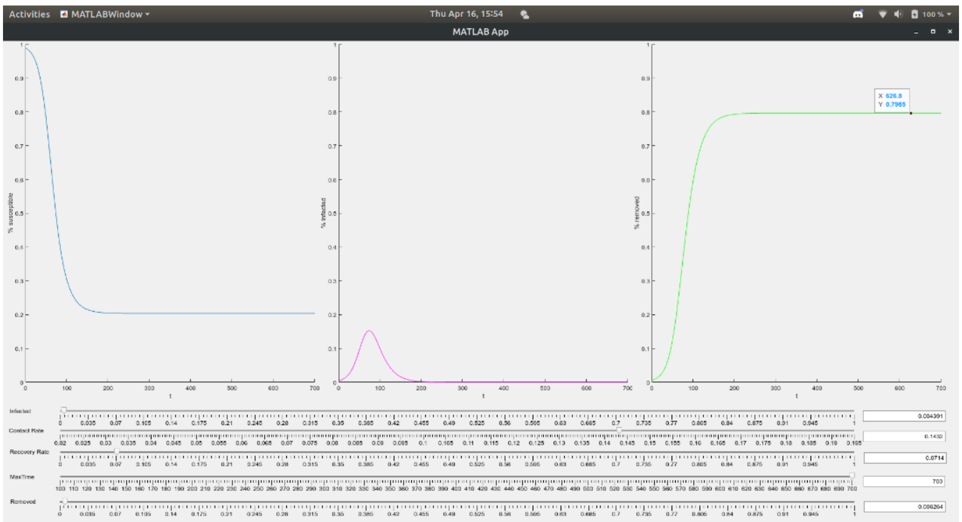
We can assume that 0% social distancing (schools open, parties and concerts allowed, etc.) will lead to R_0 = 2.7 and R_{eff} = 2.7 (rough estimation for Covid19), which means a = (2.7 * TotalPopulation * b)/Susceptible. At the same time, if we would social distance by 100% (total lockdown like in China), we estimate that R_{eff} = 0.3 (based on https://qz.com/1834700/rt-the-real-time-r0-guiding-how-to-lift-coronavirus-lockdowns/). This leads to a = (0.3 * TotalPopulation

* b) / Susceptible. That's it! When the user moves the social distancing slider, all the user is doing is changing the parameter **a** such that R_{eff} is between 2.7 and 0.3. If you want to know which values would apply in our case, here are the final results based on the above calculation: if R_{eff} = 2.7 we would have a = 0.195, if R_{eff} = 0.3 we would have a = 0.0216.

Still the question remains: how many lives can be saved by social distancing? The number is now easy to obtain. First, start simulating with the SIR-model to look at the number of people in the removed category for the parameters which correspond to 0% social distancing (in our example a = 0.195, S = 99.000 / 100.000 , I = 430 / 100.000, R = 570, …) and look at which percentage the number of removed people converges (see example below created with our custom built MATLAB applet).



We can see that 0% social distancing leads to roughly 92% of the population receiving the disease, i.e. to a total of 92% * 100.000 = 92.000. Since we estimate a 2% mortality rate, this leads to the death of 1840 people in Musterstadt. On the other hand, let's say we want to find out how many lives can be saved by a social distancing factor in the population of 30%. We first have to find the contact rate **a**, which can be calculated with the following formula via classic linear interpolation: (0.0216 – 0.195) * x + 0.195 = -0.1734 * x + 0.195. Therefore, for a 30% social distancing factor we obtain -0.1734 * 0.3 + 0.195 = 0.143. Inserting this into our simulation tool (see picture below), we obtain that 80% of the population will have Covid19 in Musterstadt.



This would result in 2% * 80% * 100.000 = 1600 deaths. We're finally there! How many lives can 30% social distancing save? Easy! We simply calculate 1840 – 1600 = 240 people. Since this model is very simplistic, our website will simply show that roughly 200 people have been saved.

That's it. It is interesting to note that as soon as R_{eff} approaches 1 or is smaller than one, the number of people in the removed category reduces **drastically.** The users will see this as soon as they start increasing the social distancing factor. This is due to the exponential behavior of disease spreading. Hopefully the users can take away from this experience that little social distancing in a city / town can save lives and strong social distancing measures are extremely effective, although they pose extreme challenges and difficulties.