PH3110 : Epidemic Modelling via the Physics of the Kinetics of Crystallization

Introduction

In this computational Project, I model the spread of COVID-19 both exponentially and using the Avrami Fitting with the help of Mathematica. I use data (Reported cases of COVID-19 and deaths because of COVID-19) from The UK, England and Runnymede (which is the surrounding area around Royal Holloway) and different time periods (The first wave and the Omicron wave). The aim is to understand if Avrami fitting can be used by the Government and hospitals for future hypothetical pandemic situations to predict the severity and spread of diseases.

Exponential Fitting of COVID-19

Exponential growth is when a there's a rapid growth of quantity of the subject over time. Exponential Modelling is very good to predict the rapid growth of the virus. The exponential model can fit the initial transmission of the COVID-19 very well as there's a sudden outburst of the virus and there is a rapid spread as there no measures in the first few weeks to contain the outbreak.

Methodology

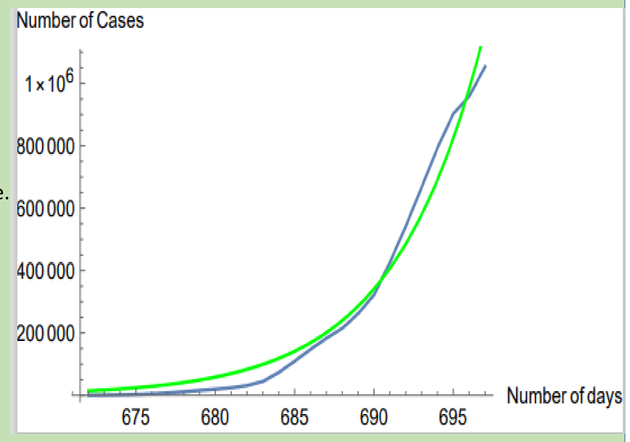
$A = a * \exp((t-t0)/\tau)$ – Exponential Growth Equation

Using mathematica, I plot this equation with respect to the data available and find τ of the data provided and multiply it by log2 which gives us the doubling time.

$\log2 * \tau = t$ (which is the doubling time)

Result

We can see that the doubling time is 3.88 days for Omicron which shows how fast the virus can spread compared to the first wave. Here is when we can use exponential model to understand the rapid spread of the virus.



Exponential fitting for the omicron variant in England between 1st December and 26th December, 2021
Green line is the exponential fit while the blue line is the actual data
(τ -> 5.67098 so Doubling time = 3.88 days

Avrami Fitting of COVID-19

The Avrami equation describes how solids transform from one phase to another at constant temperature. It can specifically describe the kinetics of crystallisation. The avrami fitting has a sigmoidal curve which is a realistic fit for our data.

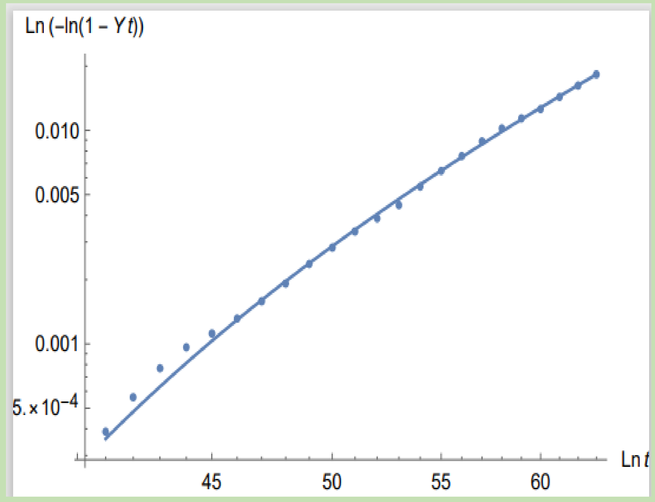
Methodology

$\ln(-\ln[1 - Y(t)]) = \ln(k) + m \ln(t)$ – Avrami Equation

Using mathematica, I plot a loglog-plot which takes log of both x and y axis and plots $\ln(-\ln(1 - Y))$ against $\ln(t)$. I use that to plot the data available accurately to me. Using the function FindFit, all the 3 parameters t0,s and m are found.

Results

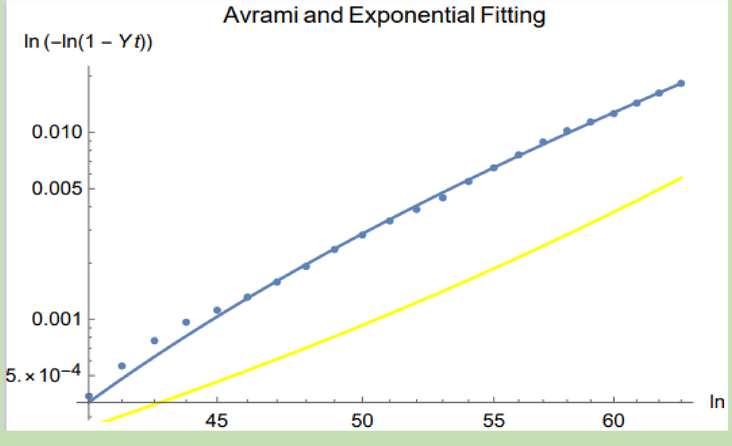
The most important parameter is 'm' which is related to space. 'm' is the effective dimension in which the spread takes place. Originally, 'm' was assumed to have an integer value between 1 and 4, reflecting the nature of the transformation under consideration. The number 4 may be considered to include contributions from three growth dimensions and one indicating a constant nucleation rate



Avrami fitting for COVID-19 cases in England between 10th March and 1st April, 2020 (m → 4.554)

Conclusion

Exponential growth models of physical events can only be applied in certain locations since unbounded development is physically impossible. Although growth may appear to be exponential at first, the modelled phenomenon will eventually enter a region when the population in England stops the spread of the virus as the population is finite. This is when the shape of the curve changes to an 'S' or sigmoidal shape and the Avrami Model which is a physical model has the ability to model the spread. For short time-frames in the initial days, it is better to consider the exponential model as it accurately predicts the growth of the virus and predicts the doubling time. However, In the long term and to better understand the spread, Avrami Modelling might be key as it can explain more than Exponential and Governments might be able to use this model to better understand the next pandemic.



Avrami(Blue) and Exponential(Yellow) fitting for the first wave in England between 10th March and 1st April,2020

All the data has been collected from the UK government website https://coronavirus.data.gov.uk/

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