Epidemiological Modelling and Outbreak Prediction using Hyperbolic Geometry

Shreyas Vivek, Raghav Pai

August 2024

Abstract

An epidemic can be defined as the widespread occurrence of an infectious disease in a certain group or community. In the context of the recent COVID-19 pandemic, epidemiology has taken on a heightened importance, especially regarding the field of outbreak prediction and prevention. In this research paper, we leverage hyperbolic geometry (specifically, the Poincaré disk model), group theory, and machine learning to better identify patterns in epidemic spread. By mapping social networks onto hyperbolic space, and using tools from group theory, we believed it would be possible to determine the most likely pathways for the spread and transmission with greater accuracy than traditional Euclidean outbreak prediction methods. Lastly, Python-based machine learning models will be utilised to provide a practical platform to these mathematical theories. This research and its results may have long standing benefits in planning epidemic mitigation, and using more accurate mapping tools to aid public health authorities in the containment of highly infectious diseases such as the COVID-19 outbreak.

1 Introduction

1.1 Existing outbreak models

There have been several attempts at the creation and development of mathematical models to map disease outbreak, especially during the recent COVID-19 Epidemic. They have incorporated several Machine Learning concepts and designs to map spreading of diseases, and have mainly focused on using SIR (Susceptible, Infected, Recovered) class models to calculate and predict the epidemics growth over time. Let $\boldsymbol{S(t), I(t),}$ and $\boldsymbol{R(t)}$ denote the number of people who are Susceptible, Infected, and Recovered at a time $\boldsymbol{t}$ of a whole population $\boldsymbol{N}$. Then, $s(t) = \frac{S(t)}{N}$, $i(t) = \frac{I(t)}{N}$, and $r(t) = \frac{R(t)}{N}$ so that $s(t) + i(t) + r(t) = 1$. With this in mind, the simple formulas used to describe the SIR model is this system of ordinary differential equations:

$$\frac{ds}{dt} = \beta si, \frac{di}{dt} = \beta si - \gamma i, \frac{dr}{dt} = \gamma i$$