PARAMETER STUDY OF COVID19 - A REPORT
(FINAL PROJECT)

PATTERN RECOGNITION

CSE 555

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ABSTRACT

The outbreak of coronavirus has been proving to be a massive threat to global public health with adverse impacts on the socio-economic status of affected countries. Predictive modeling helps essentially to identify the crucial preventive measures to undertake the flattening of pandemic spread. Traditional SIR (Susceptible-Infectious-Recovered) model has been a basis for understanding the paradigm of epidemics. Still, it cannot undertake many critical metrics and denies certain vital aspects like the evaluation of the incubation period, lockdown and social distancing measures, asymptotic infections, and several stages of an infected population. The addition of these key metrics also play a crucial role in optimizing the observations based on the notion of a traditional model. The massive rate of transmission of the novel coronavirus denies underlying assumptions of the classical kinetic systems, henceforth this report discusses a modified epidemic model to predict and analyze the changing trend of the epidemic situation, then analyze the parameters involved in the infection dynamics model. Acknowledging that COVID-19 situation has been varying from time to time, several assumptions false out over a period with new reports getting published; it is challenging to model realistic situations with no assumptions; however, the dataset that's being acted upon makes a significant difference in evaluating the epidemic. The report discusses some of the key metrics that can help in uniquely identifying the epidemic situation without relying on many assumptions.

1. INTRODUCTION

Since first identified, the outbreak of coronavirus(COVID-19) has been recently rapidly spreading across many regions now. The infections are of the same category as SARS, which emerged in 2003, spreading to many countries and becoming a state of crisis. It lies in the Middle East Respiratory 29 Syndrome (MERS). As of May 11, 2020, COVID-19 had affected all continents, including island nations, with the total number of cumulative infections 36 globally standing at 4,181,146 cases and 283,868deaths [1], and the number is still increasing. All the countries are working together to fight this pandemic situation and improving the means of corporate preventive measures for its people. Likely some have announced the "lockdown" of the city, and the city's urban bus, subway, ferry, and long-distance passenger transportation were suspended; for no particular reason, citizens should not leave their premises. The passages out of the location through any means, airport, and railway station are temporarily closed for the safety of people. There are many factors involved which have an effect over the control of an epidemic. Although many models and articles have been published related to the crisis it's too early to point with certainty how much a factor contributes. Also to what extent it is related directly to the problem, here's a try to discuss some of the factors involved in the "Early Stage" of an epidemic. Though the constituents of a model keep changing with a variable change in its component too, therefore, a study for a generalized model will include some future work.

2. DISCUSSING A VIABLE DATASET

While there are several published datasets on epidemic, of which few are country specific and a few based on regional interpretations. An epidemiology study to understand the growth of infections and fatalities helps in better understanding of the preventive measures to be undertaken and factors required to be controlled. Hence, a mathematical model definitely aids in simulating the epidemic, but it is more essential to understand whether the dataset metrics being used are apt to justify the situation. Considering key metrics like identifying rate of transmissions, population under attack etc, analysing the below list of measures can aid in forming an ideal dataset.

2.1 Transmission rate

- How effectively the virus spreads by cough
- How long the virus survives on surfaces
- Super spreader events (identifying mitigation and public transport, tracking mass gatherings especially grocery stores etc.)
- Symptomaticity ratio (Asymptotic population / Symptotic Population)

2.2 Infection rate

- Incubation Period (Defined on basis of symptoms)
- How infectious the virus is
    1. Depends on virus biology
    2. Immune system variance
- How is the transmission rate (Following Sec 2.1)
- Contact Rate
    1. Isolation Measures (Lockdown/Social Distancing, Business services)

    2. Location (Based on the geography, population density, residents density
- Dealing with duration of being infectious (Quarantine period)

2.3 Defining Susceptible population
- Number of people not infected
- Immunity of recovered people
- Vaccination control or measure done to the population
- Age groups of the population (Understanding age demographics helps to more accurately identify the predictive measures varying from infants to elderly)
- Understanding the Comorbid conditions (people whose health is serious not owing to virus, for appropriate identification of fatalities due to epidemic)
- Record of past respiratory diseases (or records of habits causing respiratory issues)

2.4 Fatality rate
- Hospital capacity
    1. Available staff (Can be measure on patient:staff ratio)
    2. Available ICU beds (Additionally can be measured as avg duration availability)
    3. Available Ventilators
- Treatment Quality (Measured on recoveries per day or per cycle)
- Number of known deaths
- Number of people tested positive of known cases

3. MATHEMATICAL MODEL AS A SOLUTION

Specific features are relevant for process modeling -
1) The condition stands that this is a new situation to everyone, and no cure or vaccination has been found, so trying out best with the preventive measures is what will increase the possibility of sustaining our immunity.

2) The major portal of entry of the virus in the body is the tissue lining the T-zones of the face (including the nose, eyes, and mouth). The infection is characterized by loss of the sense of smell, taste, and poor appetite. Although every affected person does not necessarily show these conditions but symptoms like fever and cough are common. Additionally, it is very crucial to know the dynamics of the virus to formulate the antiviral treatment or vaccination or its control and help identify if the public health control measures are having a measurable effect or not?

3) Understanding the transmission method and the potential risk it stands for the population are very important to know the future growth of the virus. Thus, approaching it through a mathematical model can help understand the common patterns and systems. However, there are several challenges to determine accurately at this early stage of pandemic how these pathogens-based factors may change.

4) Like other respiratory viruses, coronavirus also spreads from the infected person, as some particles that are released from coughing and sneezing may land on the clothes or other objects nearby. A study supports that a virus can live up to 2-3 days on the surface of steel or plastic[2]. This implies that unaffected individuals can also acquire the virus through them.

5) Also, Reinfection by the family of coronavirus is possible, as indicated[3,4]. Even though we cannot predict how much time it takes to recover and improve the immunity against the virus, it seems reasonable at this stage to consider the SIRS situation for epidemiological model formulation.

6) So following the preventive measures that are recommended by WHO is the right solution, but again it is limited and not put to any tests. The population-level mechanism also varies from region to region, as in some places, social distancing is enforced voluntarily, and in some places, the government places some rules for the population to follow. Therefore, the level of adherence to these rules is not uniform.

7) In the past, there have been some such cases where people have adopted specific measures like wearing masks, avoiding public places, and public gatherings to have less contact. This behavior change towards the preventive measure of the virus also depends upon the fatality rate of the virus and the way by which the disease is transmitted. People aware of such situations come out gracefully without demonstrating some risky behavior while the individuals who are not aware of these conditions fall out as prey to it. In the model, we assume the " awareness" is driven by the number of incidents reported each day. Recent history plays a significant role in the behavioral change in the population, especially at the early outbreak of such pandemic.

8) One of the critical factors is the mitigation and traffic control policies in areas with a high population. There are two cases where one stands with less population, and one with a high population where this factor plays a significant role as they travel through air, land or rail will affect the spread of the virus. Even though it can be said that this will not have a significant impact in areas with less population but moving and coming in contact with public places or transport will only put danger to the safety of people.

Finally, the mathematical model for the transmission dynamics of the spread of viruses are as follows:

S(t): at any t day, the number of susceptible people

I(t): at any t day, number of infected people

R(t) : at any t day, number of recovered people

Ro : the total number of people an infected person infects for d days.

υ : the number of people getting infected per day

μ : the proportion of infected recovering per day

N: total population

E : all exposed component(contaminated objects)

δ : rate for everyone's exposure

For our purpose reproductive number was adopted as:

$$R_0(t) = \frac{R_{0_{start}} - R_{0_{end}}}{1 + e^{-k(-x+x_0)}} + R_{0_{end}}$$

Therefore,by considering all means of transmission the force of infection spread can be given as-

$$\Phi = A_1 \frac{I + C \cdot m}{N} + A_2 \frac{E}{E_c}$$

Where, m is the modification parameter from C to I

E_c is the change in environment by some novel increment/decrement of virus

A_1 is Rate of disease transmission from humans

A_2 is Rate of disease transmission from environment

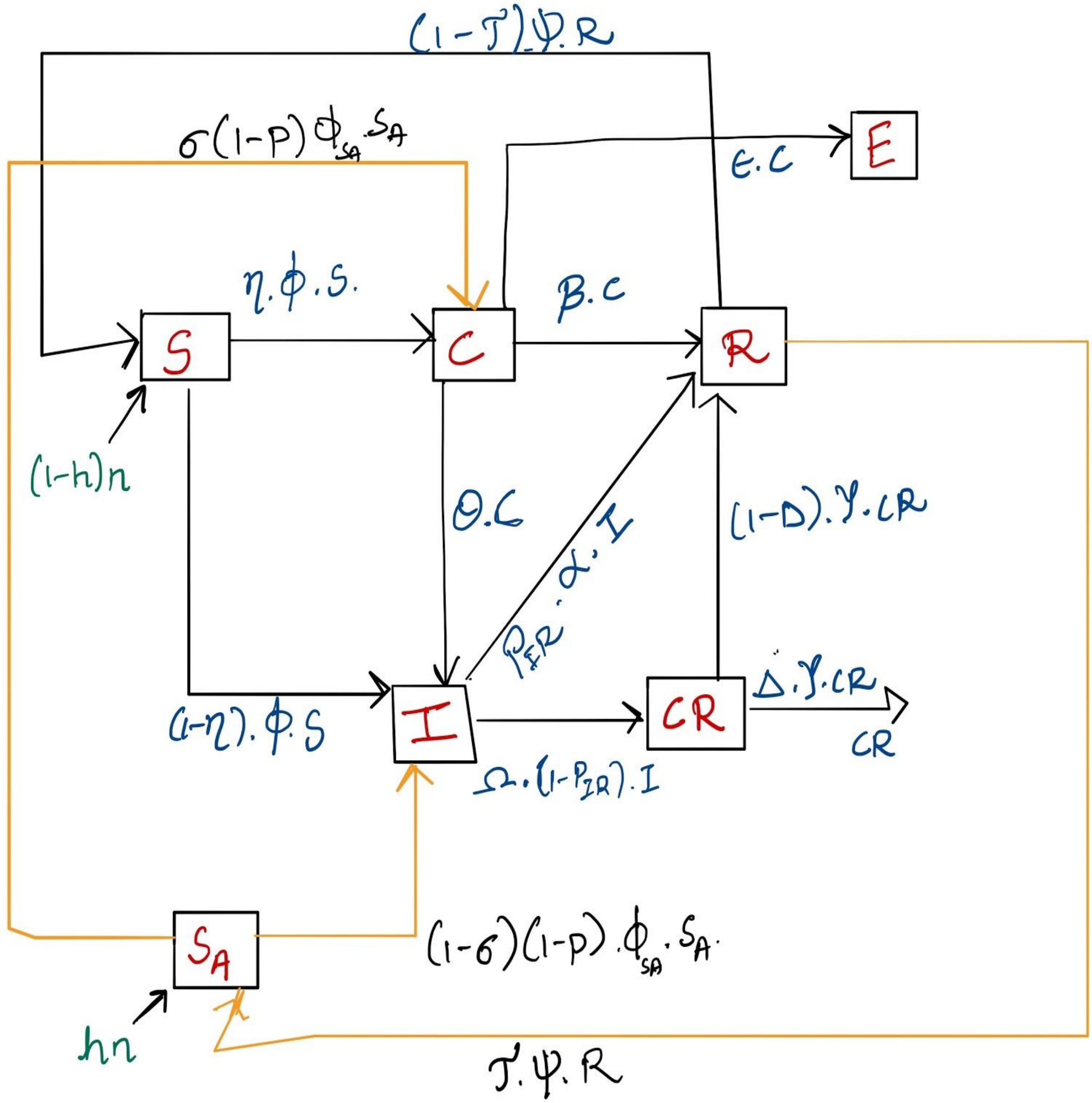
N is S+ S_a + I + C + R.

S_a is the population that is aware of epidemic and takes preventive measures

S is the population that is unaware of preventive measures and risks of epidemic

The proposed flow diagram of transmission dynamics is depicted in Fig1 while the description of parameters is given in table 1.

Figure 1


(1-J).ψ.R
σ(1-p) ϕ_{SA}.S_A
E.C
E
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(1-h)n
θ.C
(1-D).γ.CR
P_{IR}.α.I
Δ.γ.CR
CR
(1-η).ϕ.S
I
CR
Ω.(1-P_{IR}).I
S_A
(1-σ)(1-p).ϕ_{SA}.S_A.
hn
J.ψ.R

Table1

Parameters	Description
n	Rate of adding to susceptible individual
h	Fraction of addition to S_a because of past history
η	Probability of susceptible people becoming carrier
σ	Probability of S_a becoming infected and becoming carrier
p	Effectiveness existing of preventive measures(avg.)
β	Rate of recovery of carrier individuals
θ	Rate of transfer of carrier individuals to infected class
ε	Shedding rate from Carrier to environment
α	Rate of recovery from infected class
γ	Death rate due to virus
ω	Virus decay rate from environment
ψ	Rate of losing immunity after recovery
τ	Probability of people moving to S_a class after recovery
Ω	Rate of Infected people becoming critical

The dynamics of the pandemic is described using the following set of differential equations:

S' = (1-h)n - $(\varphi\eta S)$ + (1- τ) ψ R ....(A)

S_a' = hn -((1-p) φ S) + τ ψ R ....(B)

C' = η φ S + σ (1-p) φ S_a -(θ , β, ε) C ....(C)

I' = (1- η) φ S + (1- σ)(1-p) φ $S_a + \theta C$ -($\alpha I p_{IR}$) .... (D)
R' = αI + (1- Δ) $CR + \beta C - \psi R$ ....(E)
CR' = (1- p_{IR}) $\Omega \cdot I$ - ($\Delta \cdot \gamma \cdot CR$) - (1- Δ) γCR ....(F)
E' = εC ....(G)

4. ANALYSIS OF PARAMETERS

To determine the equilibrium solution we set all the above equations to 0, as-

(1-h)n - ($\varphi\eta S$) + (1- τ) ψ R = 0
hn -((1-p) φ S) + τ ψ R = 0
η φ S + σ (1-p) φ S_a -(θ , β, ε)C = 0
(1- η) φ S + (1- σ)(1-p) φ $S_a + \theta C$ -(αI) = 0
αI + (1- γ) $C_r + \beta C - \psi R$ = 0
εC = 0

Then disease free equilibrium is obtained as
E_0 = ($\frac{(1-h)\pi}{n}$, $\frac{h\pi}{n}$, 0, 0, 0, 0, 0).

Using the next generation matrix we are going to determine the basic reproduction number which is necessary for model analysis[5,6]. For the model we are evaluating we use the notation X=(C,I,E) and we have the vector functions as:

$$\mathcal{G}(X) = \begin{cases} \eta R_0 S + \sigma(1-p)\phi S_a \\ (1-\eta)\phi S + (1-\sigma)(1-p)\phi S_a \\ 0 \end{cases}$$

and

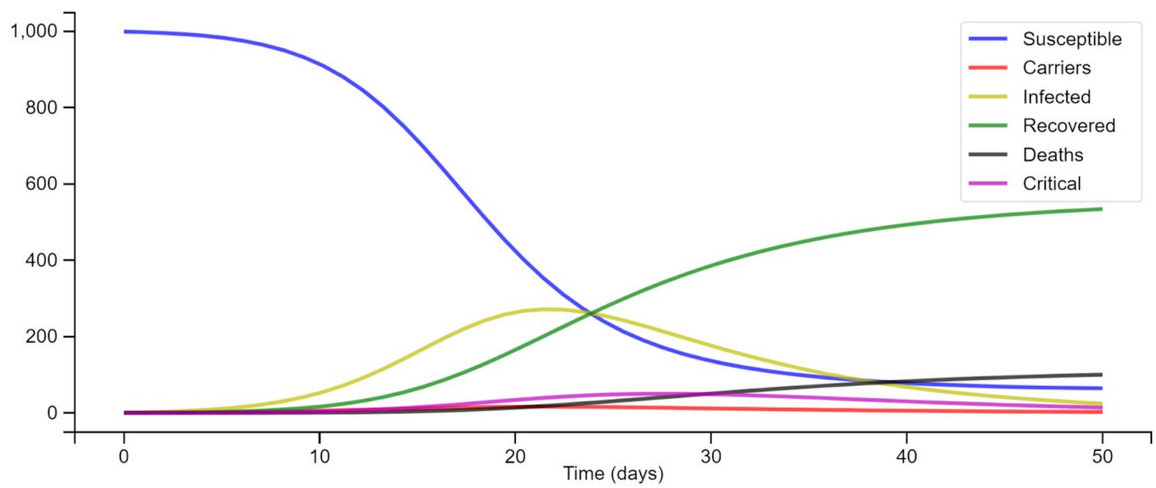
$$\mathcal{V}(X) = \begin{cases} z_1 C \\ -\theta C + z_2 I| \\ -\varepsilon C + wE \end{cases}$$

where z_1 is $\theta + \beta + \varepsilon$ and z_2 is $\alpha + \gamma$. Then the next generation matrix is B = $J_f(J_v)^{-1}$ and we can calculate the relation of reproductive number..

As it is evident that with a poor personal hygiene and increase person-person contact will increase A_1 and this can also lead to shedding infections in environment and so A_2 increases, which ultimately leads to increase of R_0 Therefore, it is very clear that infection can be easily prevented by avoiding any contacts and practicing social distancing, which is why lockdown is a good way to slow down the spread of viruses. Also good hygiene practices like not touching surfaces, washing hands with soap, using sanitizer and those who are sick with symptoms like cough and flu, ought to use masks, when they cough or sneeze use sanitary tissue and dispose off properly which ultimately will result in less chances of pathogens interaction.

5. A SIMPLE SIMULATION ON SCIR(CR)D MODEL

For a given population of N=1000, using a simplistic version of the above listed mathematical model, following are the observations. However, fine tuning the metrics as infection rate, transmission rate, Rate of reproduction R, and using time dependent variables can yield more realistic estimations. Given that, using differential delay equations for example, resembling the death rate as D(t- τ), where τ can be defined as delay in the transition from infected to death are observed to me more realistic.



6. CONCLUSION

We presented a mathematical model for the dynamics of the viruses. The model incorporates a change in behavior change to account for the people who are aware and take precautionary measures and adhere to it. Also, it considers a proportion of individuals with history/knowledge from the past and takes precautionary measures from the beginning. The model also accounts for asymptomatic carriers of the virus as well as the concentration of viruses in the environment. The basic properties of the model as such the disease-free equilibrium and its stability, model basic reproduction number were examined, and it can be more researched into.To estimate the parameter values, the model was fitted to be valued, and for our assumption, we used the reproductive number is in the form of the equation given above. From our sensitivity analysis simulations, we observed that for some given parameter combinations, the values of R0 could be reduced to below 1which will account for a smooth curve, and similarly to values much higher than 4, a steep curve.

In addition to the above study, there is scope for filling the gaps in terms of replacing the constant factors with time-dependent variables. Modeling based on Delay Difference Equations can be proven to show better results. However, as a conflict to the modeling based as a time-dependent factor, in an pandemic situation like COVID-19, the rates of fatalities and infections are more promisingly based on the existing number of active cases rather than a period. This can be potential future research on identifying all key metrics as a rate of change with respect to the active number of cases (d/dN, instead of d/dt).

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