Modeling the Dynamics of Spreading Rumors and Fake News through Online and Social Media

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Abstract

A sensitive manipulated news which is well-known as rumors may derive a person, group or nation into a wrong direction. Sometimes it can even make a massacre among the mass people. By the progress of digital online and social media , any news can easily be manipulated and spreads dynamically. Sometimes it gets tougher for people to identify whether a news or information on online media is manipulated or not. Nowadays the act of forgery done by internet is increasing and some subtle people are using these online media for spreading rumors and fake or manipulated information regarding sensitive issues for serving their own purposes. Once any rumor is created and available on online media, it become spreading very quickly by sharing and discussing about that rumor by other anonymous people intentionally or accidently without verifying the fact in details. Some people wants to verify and if find something wrong about that news, some people want to take actions against the propaganda and the people or group liable for it too. We've modeled the dynamics of spreading rumor on online media by using a system of four ODEs. This problem is studied as the dynamics of diffusing of misinformation over the online media using these ODEs as four compartments of the model. We have used them to describe the change of population liable for spreading rumor, who are preventing it from spreading, population acts neutral and may participate in spreading rumors without verifying. For validating and evaluating the system we did necessary qualitative and quantitative analysis like equilibria and stability of the model . Then he analytical findings have been validated with the numerical simulations. After performing all necessary calculations we've proposed strategies can be used for prevent or minimize the rumor diffusion on the online media.

Keywords
Mathematical Modeling, Modeling Rumor Spreading, The Role Of Online Media

1. Introduction

If anyone or a group of people start spreading any news fake or real but sensitive and should not be speeded then it causes severe losses on a countries economy, safety, conflicts, violation and many more. We've assumed that some people exists for spreading news's for serving their personal agenda and other help them knowing or without knowing the fact. According to human behavior, there exists different types of people in any society and of different thinking line . So they spread the news in different ways . Some people defined as protestor is concerned about the consequences and causes of spreading this types of news and always do their best for resisting others.

If we want to solve the problem firstly we've to crack down the whole system to understand . Then we'll be able to solve the problem . Here we've modeled the system of spreading rumor or fake news using a system of ordinary differential equations .Then we analyzed the equilibrium, stability, boundedness and positivity of our model for validating and verifying our model. We discussed the dynamics of the system like changes over the time, influential factors, limitations and solutions as well. By simulating our model numerically we have visualized the results and findings for better understanding.

2. Model Formulation

Susceptible (S) represents a user who has not heard about the news yet but can be informed anytime. Exposed (E) represents a user who has received the news via any user but has taken some time, an exposure delay, prior to posting. Infected (I) denotes a user who has shared about the news intentionally , they can create or share the news after knowing or before knowing. Protestors (Z) is a user who has heard about the news but want to verify and validate the authenticity . If they find it wrong they take proper steps for preventing the spreading. The system dynamics of transmission of rumor among these compartments are shown in Figure 1. The whole system is represented using a transmission diagram in Figure 2.

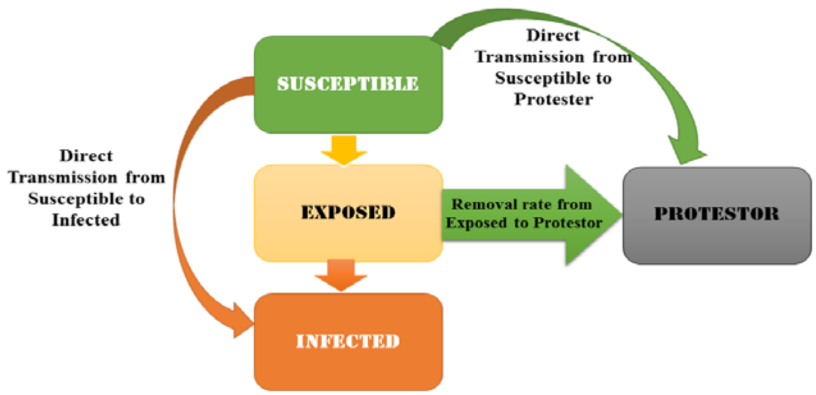

Figure 1: System Dynamics

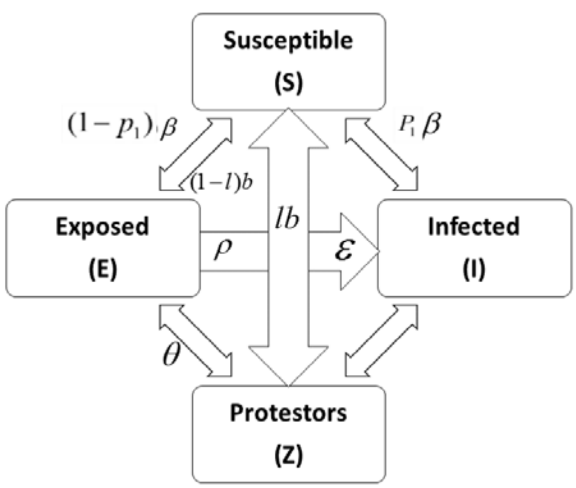

Figure 2: Model Diagram

By considering the above assumptions the whole system is mathematically represented by the following system of ODEs.

$$\frac{dS}{dt} = -IS\beta - SZb = 0 \;.....(1)$$

$$\frac{dE}{dt} = -E\epsilon - \theta EZ - EI\rho + IS\beta\left(p_1 - 1\right) + SZb\left(l - 1\right) \;.....(2)$$

$$\frac{dI}{dt} = E\epsilon + EI\rho + IS\beta\, p_1 \;.....(3)$$

$$\frac{dZ}{dt} = \theta EZ + SZbl \;.....(4)$$

For $S(0) > 0, E\left(0\right) > 0,\ I\left(0\right) \geq 0\ , Z\left(0\right) \geq 0$

the solutions S, E, I, Z are all non-negative .

Table 1: Parameter Description

Variables	*Description*
β	S-I contact rate
b	S-Z contact rate
ρ	E-I contact rate
ε	Incubation rate
θ	E-Z Contact Rate
bl	Transmission rate of S -> Z
$\beta\rho$	Transmission rate of S -> I
$b(1-l)$	Transmission rate of S -> E via contact with Z
$\beta(1-p_1)$	Effective rate of S -> E via contact with I
l	S->Z Probability given contact with Protestors
$1-l$	S->E Probability given contact with Protestors
p_1	S->I Probability given contact with Infected
$1-p_1$	S->E Probability given contact with Infected

3. The Equilibrium Points

The equilibrium points for the model can be obtained by considering $\frac{dS}{dt} = \frac{dE}{dt} = \frac{dI}{dt} = \frac{dZ}{dt} = 0$

$$E^*(S^*, E^*, I^*, Z^*) = \left\{-\frac{\theta}{bl}, 1, -\frac{b\epsilon l}{bl\rho - \beta p_1\theta}, \frac{\beta\epsilon l}{bl\rho - \beta p_1\theta}\right\}$$

For $S(0) > 0, E\left(0\right) > 0,\ I\left(0\right) \geq 0\ , Z\left(0\right) \geq 0$

the solutions S, E, I, Z are all non-negative .

The equilibrium point is locally asymptotically stable if $\lambda \leq 1$ and unstable if $\lambda \geq 1$.

$$\det\left|J - \lambda I\right| = C_0\lambda^4 + C_1\lambda^3 + C_2\lambda^2 + C_3\lambda = 0$$

$$C_0 = \frac{b^2 l^2 \rho - b\beta l p_1 \theta}{bl(bl\rho - \beta p_1 \theta)}$$

$$C_1 = -\frac{b^2 l^2 \rho^2 - \varepsilon b\beta l^2 \theta - 2b\beta l p_1 \rho\theta + \varepsilon b\beta l p_1 \theta + \beta^2 p_1^2 \theta^2}{bl(bl\rho - \beta p_1 \theta)}$$

$$C_2 = -\frac{\varepsilon b^2 \beta l^2 \theta - \varepsilon p_1 b\beta^2 l\theta + \varepsilon\rho b\beta l^2 \theta - \varepsilon b\beta l\theta^2 - \varepsilon p_1 \beta^2 l\theta^2 + \varepsilon p_1 \beta^2 \theta^2}{bl(bl\rho - \beta p_1 \theta)}$$

$$C_3 = \frac{\varepsilon\rho b^2 \beta l^2 \theta - \varepsilon p_1 b\beta^2 l\theta^2 - \varepsilon\rho b\beta l\theta^2 + \varepsilon p_1 \beta^2 \theta^3}{bl(bl\rho - \beta p_1 \theta)}$$

All the roots have negative real parts for the condition $C_1 C_2 > C_0 C_3$

4. Basic Reproduction Number

The basic reproduction number R_0 is a threshold parameter for the stability of Epidemic/Rumor free equilibrium. If $R_0 > 0$, the rumor diffusion will increase at a high rate and as a result it's consequences prevails for a long period of time. Otherwise, the diffused rumor will disappear within a shortest possible time.

$$R_0 = \frac{\beta(1-p_1) + b(1-l)}{\theta + \varepsilon + \rho}$$

The above parameters are considered as most influential factors for rumor diffusion.

5. Numerical Simulation

Numerical Simulation has been performed for validating the analytical findings. The numerical simulation has been carried out using Runge-Kutta (4, 5) method with the following parameter values.

Table 2: Parameter values for numerical simulation

Variables	**Values**
β	0.6
p_1	0.2
b	0.4
l	0.4
ρ	0.2
ε	0.03
θ	0.5
S(0)	0.4
E(0)	0.3
I(0)	0.2
Z(0)	0.1

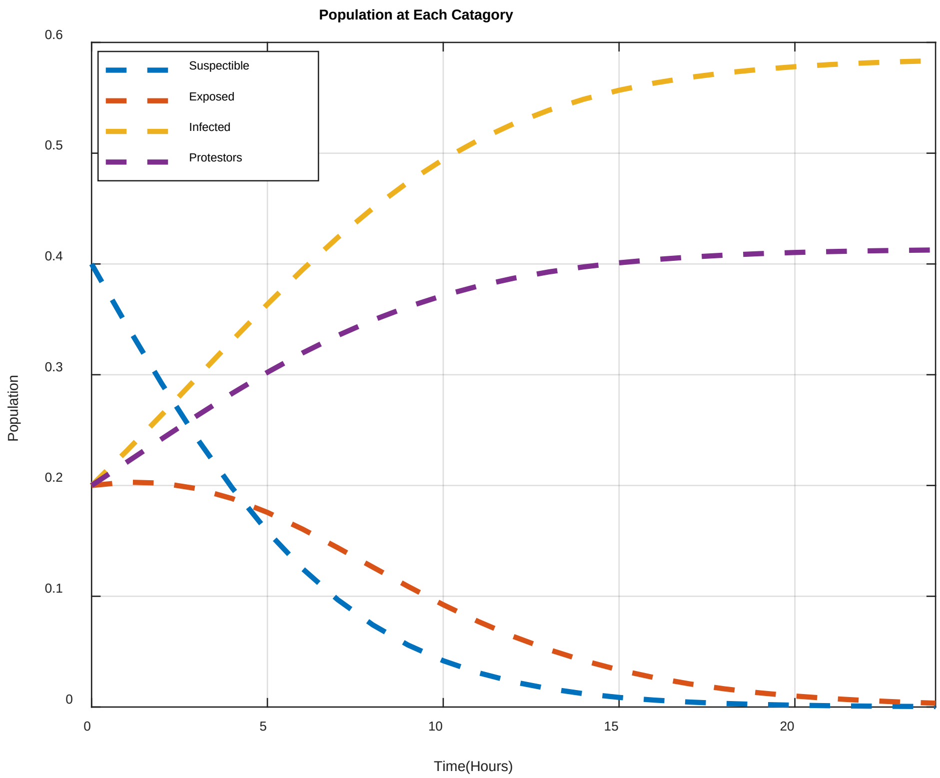

Figure 3: Population of each types when initially Protestors , Infected and Exposed all are 0.2

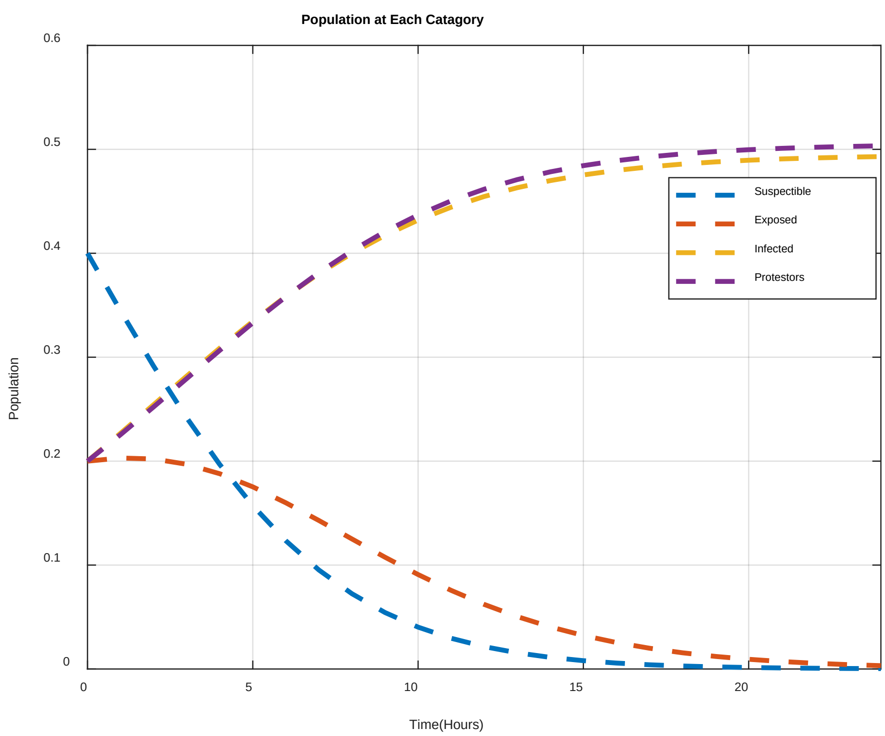

Figure 4: Population of each types when initially Protestors, Infected and Exposed all are 0.2

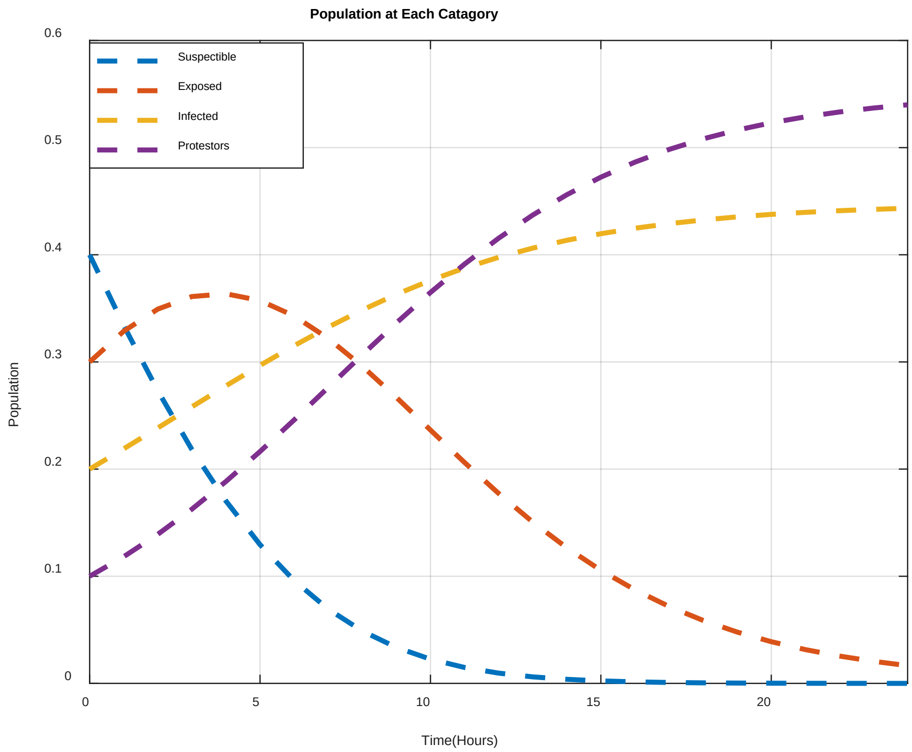

Figure 5: Population of each types when initially Protestors, Infected and Exposed all are 0.1, 0.2 and 0.3 respectively

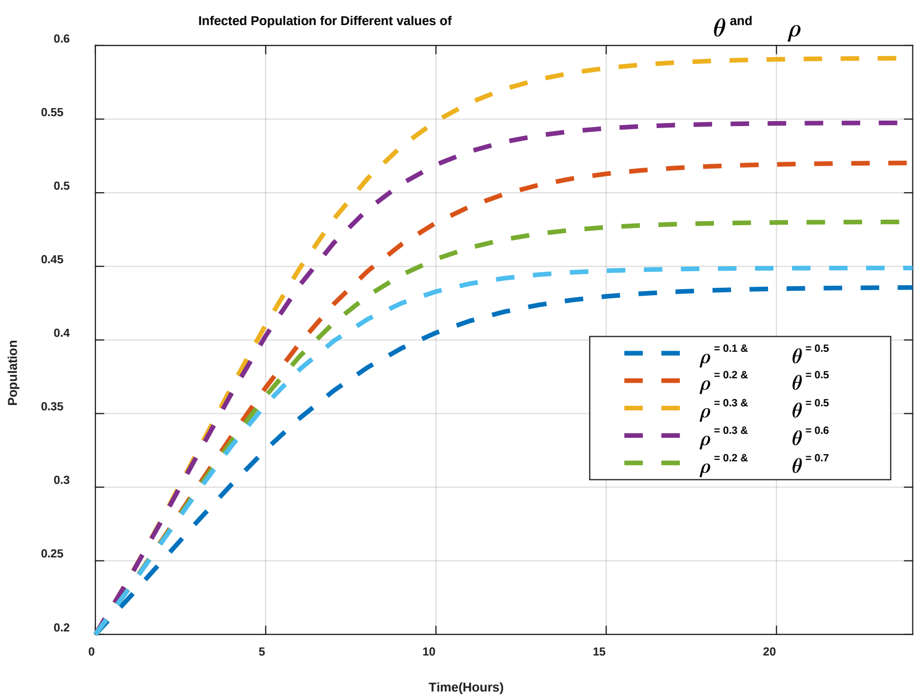

Figure 6: Infected population for different values of E-Z, E-I contact rate

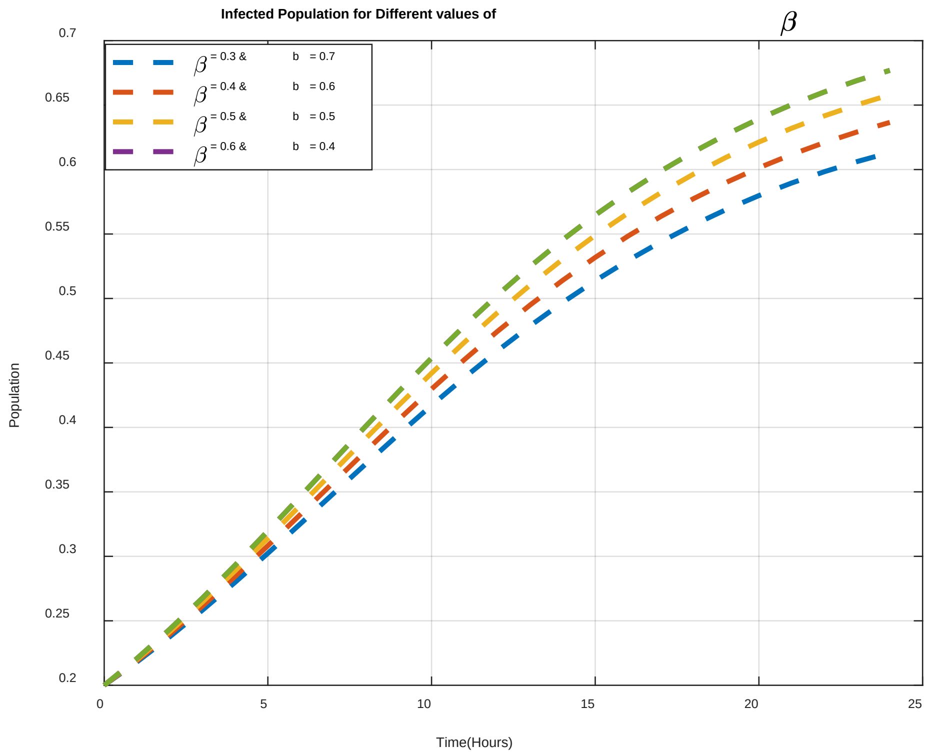

Figure 7: Infected population for different values of S-Z and S-I contact rate

From the figures 6 and 7 we can see that With initial population 0.1 of the protestor and the double of infected 0.2 , after a few hours with a medium rate of E-Z contact and usual rate of E-I contact effectively decreased infected population and spreading rumor as well where S-I contact rate and S-Z contact rate can contribute very little.

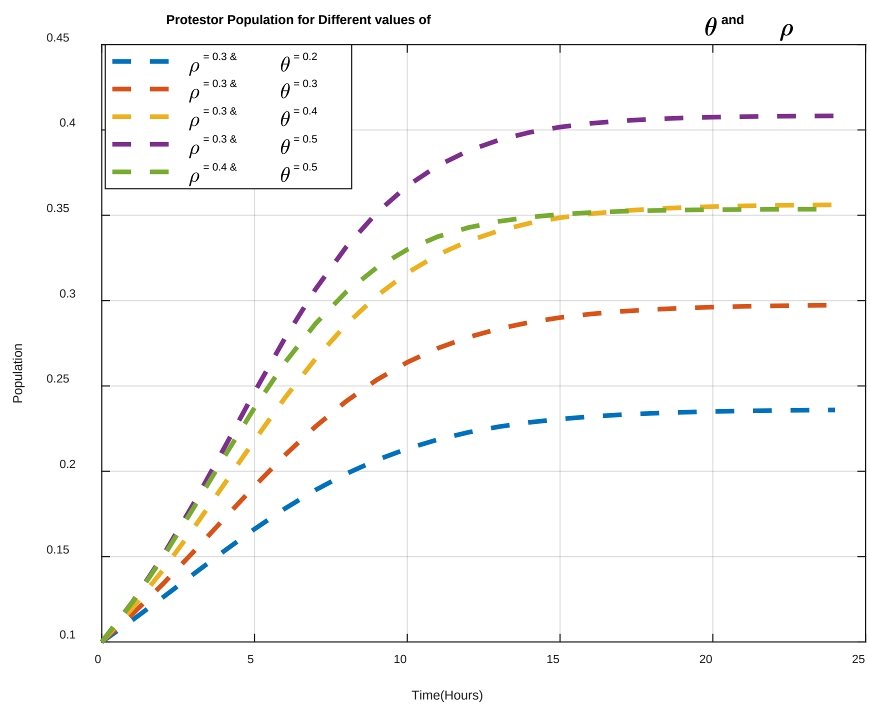

Figure 8: Protestor population for different values of E-Z, E-I contact rate

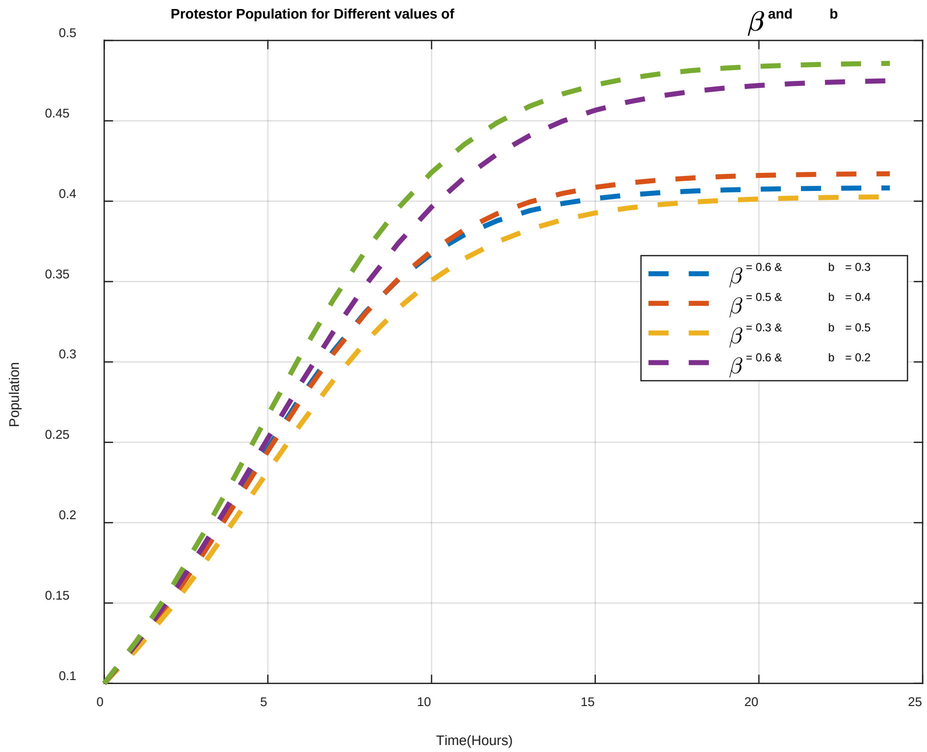

Figure 9: Protestor population for different values of S-Z, S-I contact rate

Since we've noticed that S-I and S-Z contact rate can't change the system dynamics significantly , But after contacting with protestors and infected , they can contribute in decreasing infected population.

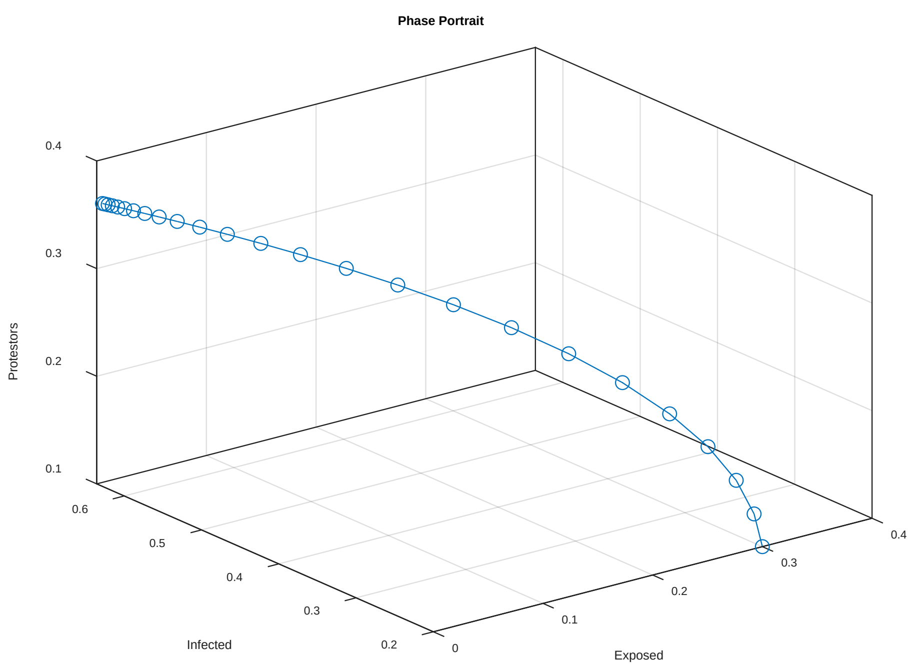

Figure 10: Phase Portrait

From phase portrait and this figure it is clear that , when after a few time protester population grows and reach near at .5-.6, the increment of infected stopped then. From phase portrait we can see after a certain population of protesters like 0.55, the curve become parallel to the infected axis means population isn't increasing there.
From Fig 3-7 , it's clear that is mostly responsible for changing the system . If the E-I contact ρ rate decreased and E-Z contact rate θ increased by a significant rate the diffusion of rumor will be vanished soon. A larger S-I contact rate β can spread any rumor instantly but if protestor population is large enough then it'll never affect the society and country.

6. Conclusion

From the above figures and analysis now we can describe and define the solution. As increasing Protestor and decreasing infected is our main concern, this task can be carried out by using several strategies we've seen before.
From basic reproduction number we found most influential parameters for changing our system dynamics. From them we've selected those parameters ($\theta, \varepsilon, \rho, \beta$) which have significant contribution in reducing infected and increasing protestors. Since no population is subtracting from infected, there will be some population at this state always, but without the help of innocents or vulnerable population they have nothing to do with a rumor.

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Biographies

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