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Article

Numerical Analysis of Susceptible Infected Meme Transmission Epidemic Model

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Abstract: This paper is devoted for the numerical study of susceptible infected Stifler (SIZ) epidemic model of meme dynamics. This model is solved numerically with three different numerical techniques, Forward Euler, Runge-Kutta Scheme (RK-4) and the proposed Non-Standard Finite difference (NSFD) techniques. The proposed NSFD technique becomes more efficient and reliable numerical technique than forward Euler and RK-4 techniques. NSFD technique retains all essential characteristics of continuous SIZ epidemic model like positivity, stability of equilibria while well-known forward Euler and RK-4 techniques cannot sustain these characteristics. Further- more, the proposed technique is independent of time step size while forward Euler and RK-4 depend on the time step size. The numerical simulations with the aid of a numerical test is presented for the validations of all the traits.

Keywords: Meme; SIZ epidemic model; Numerical modeling; Positivity and convergence analysis.

1. Introduction

Richard Dawkins coined the term "meme" in his 1976 book The Selfish Gene, and it has since become a neologism. To some extent, Dawkins' own position is debatable. He invited N. K. Humphrey's suggestion that memes should be viewed as "really dwelling in the brain," rather than only allegorically. Dawkins agreed with Humphrey's assessment and welcomed Susan Blackmore's 1999 assignment to provide a coherent hypothesis of memes, complete with forecasts and observational / empirical support [1] Dawkins highlights that development occurs at whichever point these variables coexist, and that advancement isn't limited to natural components like as genes. He considered memes to have the same traits that are required for evolution, and hence views meme evolution as a genuine process subject to the laws of normal choice, rather than merely comparable to DNA evolution. As different thoughts / concepts move from one generation to the next. Dawkins noted that they may either increase or decrease the endurance of those who acquire such thoughts, or have an impact on the endurance of the real thoughts [2]. Impersonation is used to convey social/cultural facts via memes. Inside culture memes can take a variety of forms, including a thinking, an expertise, a behavior/conduct, or a certain design or style [3]. When one person repeats a unit of cultural knowledge, such as a meme from someone else, this is known as meme replication and transmission [4]. The transmission process is primarily performed through verbal, visual, or electronic correspondence, ranging from books and discussions to television, email, and other Internet-based communication. Memes that are the most successful at being copied and spread become the most popular in a culture [5]. Explanation of the link between social development, social transmission, and impersonation has sparked some fascinating meme theories [6]. Different perspectives have emerged on the nature of memes, such as whether they are beneficial, neutral, or destructive.Memes may be regarded as innately destructive because, according to some experts, memes are mental parasites or diseases; once absorbed into the human psyche, the central motive turns into their own replication, with humans having little or no control over them [7]. A few memes, while beneficial, can also be hazardous since they lend themselves to being exploited or manhandled once they have been cultivated in the human brain. For example, while memes associated with religious or political beliefs may benefit those who have them, when imposed on those who have different religious or political beliefs, those memes may cause harm.For example, religious heritage or social or political stability may be lost [8]. As in the case of religious cults or extremist groups, memes associated with religious or political ideologies can

be exploited, resulting in the killing of persons. Beneficial memes, on the other side, can include those that enhance human health and survival, such as hygiene memes [9].
This paper is formulated as. Section 2 shows the model formulation. Section 3, presents equilibrium states, stability and threshold analysis of the model. In section 4 numerical simulation and discussion of the result are presented and section 5 showing the result of paper.

2. Mathematical Model

The system of non linear differential equation for the model is given by

$\frac{dS}{dt} = B + \eta Z - \alpha SI - \mu S$

$\frac{dI}{dt} = \alpha\theta SI - \beta I^2 - \gamma IZ - \mu I$

$\frac{dZ}{dt} = \alpha(1-\theta)SI + \beta I^2 + \gamma IZ - \eta Z - \mu Z$

Assumption are $N(t) = S(t) + I(t) + Z(t)$

For the study of disease the whole human population at time t, denoted as N(t), is divided into three disjoint epidemiological subpopulations: susceptible population S(t), infected population I(t), and stifler Z(t).
$N(t) = S(t) + I(t) + Z(t)$
The model is governed by following nonlinear differential equation. **Mathematical Model**

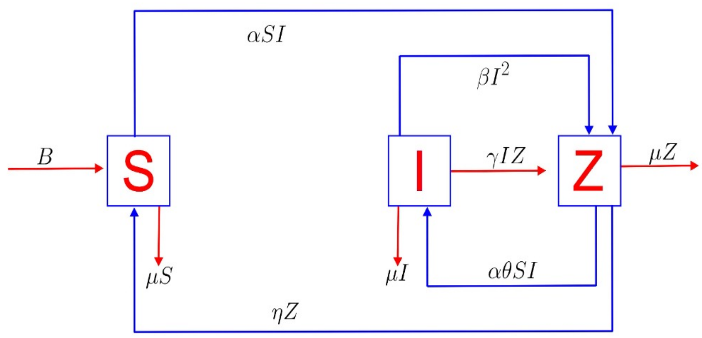


Figure 1

2.1. Variable and parameters of compartmental model

S =Susceptible Human
I =Infectious Humans
Z =Stifler Humans
N=Total population
B=The total of the population's birth and emigration rates;
μ= The death rate and emigration rates of the population are added together;
α= The rate at which susceptibles shift from one meme class to another;
β= By contacting each other, the rate at which spreaders become stiflers;
γ= The rate at which spreaders become stiflers by contacting with stiflers;
θ=The proportion of susceptiblesăpeople who become spreaders(at rate α)

2.2. Analysis of the Model

This model has two equilibrium point meme free equilibrium point and endemic equilibrium point.
The meme free equilibrium point
The meme free balance factors is the situation there are no diseases in the populace[7]. At the upset free

harmony, there is no contamination subsequently no recovery that is, $I = Z = 0$. Thusly at the balance, we have
$E_0(S, I, Z) = (\frac{B}{\mu}, 0, 0)$
Endemic equilibrium point
$E^*(S^*, I^*, Z^*), = (\frac{1}{\alpha I^*}[\mu I^* + Z^*(\mu+\eta)], \frac{\alpha\theta S^* - \gamma Z^* - \mu}{\beta}, \frac{-\mu I^*}{(\alpha I^* + \mu) + \eta}(\frac{\alpha I^*}{\mu} + 1 - \frac{\alpha B}{\mu^2})$

2.3. Basic Reproductive Number

Important prereation number of model is genrated by detect the cutting edge grid of the model [20]. Let, $F_i(x)$ is a work that restain the pace of new contaminating at section 'I' also, $V_i(x)$ is a part that include the pace of move of people between the compartment 'I' with $x = (I, Z)$ from framework. (1) We have,

$$F(x) = \begin{bmatrix} \alpha\theta SI \\ \alpha(1-\theta)SI \\ 0 \end{bmatrix}$$

$$V(x) = \begin{bmatrix} \beta I^2 + \gamma IZ + \mu I \\ = \beta I^2 - \gamma IZ + \eta Z + \mu Z \\ -B - \eta Z + \alpha IS + \mu S \end{bmatrix}$$

Differentiating equation and evaluating at E_0 gives the following matrix F and V,

$$F = (\frac{dF_i}{dx_j}(E_0)) = \begin{bmatrix} \alpha\theta S_0 & 0 \\ \alpha(1-\theta)S_0 & 0 \end{bmatrix}, V = (\frac{dV_i}{dx_j}(E_0)) = \begin{bmatrix} \mu & 0 \\ 0 & \eta+\mu \end{bmatrix}$$

Inverse of matrix$V(E_0)$is

$$V^{-1}(E_0) = \frac{adjV(\xi_0)}{det(V(E_0))}$$

$$V^{-1} = \begin{bmatrix} \frac{1}{\mu} & 0 \\ 0 & \frac{1}{\mu+\eta} \end{bmatrix}$$

Using matrix F and V^{-1} we get the next generation matrix

$$FV^{-1} = \begin{bmatrix} \alpha\theta S_0 & 0 \\ \alpha(1-\theta)S_0 & 0 \end{bmatrix} * \begin{bmatrix} \frac{1}{\mu} & 0 \\ 0 & \frac{1}{(\mu+\eta)} \end{bmatrix}$$

$$FV^{-1} = \begin{bmatrix} \frac{\alpha\theta S_0}{\mu} & 0 \\ \frac{\alpha S_0(1-\theta)}{\mu} & 0 \end{bmatrix}$$

Put the value of $E_0 = (\frac{B}{\mu}, 0, 0)$

$$FV^{-1}(E_0) = \begin{bmatrix} \frac{\alpha\theta B}{\mu^2} & 0 \\ \frac{\alpha(1-\theta)B}{\mu^2} & 0 \end{bmatrix}$$

Now, we find the eigenvalues of the matrix to solve the basic reproduction number,R_0 numbered as the spectral radius (dominant eigenvalue) of the matrix. This is calculated by $det(FV^{-1} - \lambda I) = 0$ the place. A is the matrix and 'I' is the 2x2 identity matrix.

$$det(FV^{-1}) = \begin{bmatrix} \frac{\alpha\theta B}{\mu^2} & 0 \\ \frac{\alpha(1-\theta)B}{\mu^2} & 0 \end{bmatrix} - \begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix}$$

$$det(FV^{-1}) = \begin{bmatrix} \frac{\alpha\theta B}{\mu^2} - \lambda & 0 \\ \frac{\alpha(1-\theta)B}{\mu^2} & 0 - \lambda \end{bmatrix}$$

$$0 = \begin{bmatrix} \frac{\alpha\theta B}{\mu^2} - \lambda & 0 \\ \frac{\alpha(1-\theta)B}{\mu^2} & 0 - \lambda \end{bmatrix}$$

$$-\lambda(\frac{\alpha\theta B}{\mu^2}) + \lambda^2 = 0$$

$$\frac{\alpha\theta B}{\mu^2} = \frac{-\lambda^2}{-\lambda}$$

$$\lambda = \frac{\alpha\theta B}{\mu^2}$$

FV^{-1} is called the next generation matrix. The spectral radius of FV^{-1} is equal to R_o. R_o is the maximum Eigenvalue of matrix FV^{-1}. Therefore,

$$R_o = (\frac{\alpha\theta B}{\mu^2})$$

3. Local Stability of Equilibrium States

Theorem 1: If $R_0 < 1$, the meme free equilibrium point E_0 is locally asymptotically stable.

Proof: The issue free equilibrium centers from the model are unequivocal as follows. We will find the strength of the ailment free equilibrium centers which are brought out through linearizing the plan of differential conditions with the assistance of getting the Jacobian at ailment free equilibrium [12,16]. $(\frac{B}{\mu}, 0, 0)$ The Jacobian of the framework of a differential condition is demonstrated as.

$$J = \begin{pmatrix} \frac{dS}{dS} & \frac{dS}{dI} & \frac{dS}{dZ} \\ \frac{dI}{dS} & \frac{dI}{dI} & \frac{dI}{dZ} \\ \frac{dZ}{dS} & \frac{dZ}{dI} & \frac{dZ}{dZ} \end{pmatrix}$$

$$J = \begin{pmatrix} -\alpha I - \mu & \alpha S & \eta \\ \alpha\theta I & \alpha\theta S - 2\beta I - \gamma Z - \mu & -\gamma I \\ \alpha(1-\theta)I & \alpha(1-\theta)S + 2\beta I + \gamma Z & \gamma I - \eta - \mu \end{pmatrix}$$

Put $(\frac{B}{\mu}, 0, 0)$ So the stability will be intended the usage of the Jacobian matrix at the disease-free equilibrium by using discovery the factor of the matrix. Then we have

$$J(\frac{B}{\mu}, 0, 0) = \begin{pmatrix} -\mu & -\frac{\alpha B}{\mu} & \eta \\ 0 & \frac{\alpha\theta B}{\mu} - \mu & 0 \\ 0 & \frac{\alpha(1-\theta)B}{\mu} & -(\eta + \mu) \end{pmatrix}$$

$$det(J-\lambda I)=\begin{pmatrix} -\mu & -\frac{\alpha B}{\mu} & \eta \\ 0 & \frac{\alpha\theta B}{\mu}-\mu & 0 \\ 0 & \frac{\alpha(1-\theta)B}{\mu} & -(\eta+\mu) \end{pmatrix} - \lambda \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} = 0$$

$$|J-\lambda I| = \begin{vmatrix} -\mu-\lambda & -\frac{\alpha B}{\mu} & \eta \\ 0 & \frac{\alpha\theta B}{\mu}-\mu-\lambda & 0 \\ 0 & \frac{\alpha(1-\theta)B}{\mu} & -(\eta+\mu)-\lambda \end{vmatrix} = 0$$

Hence, the eigenvalues by expanding the jacobian at the ailing free equilibrium. We can find out the eigenvalue at the disease-free equilibrium.
$\lambda_1 = -\mu < 0, \lambda_2 = -(\eta+\mu) < 0$
$\lambda_3 = \frac{\alpha\theta B}{\mu} - \mu < 0 = \mu(\frac{\alpha\theta B}{\mu^2} - 1) < 0$

$$\mu(R_0 - 1) < 0$$

$$R_0 < 1$$

So E_0 is locally stable.

4. Numerical Modeling

The investigation of strategies for discovering rough answers for differential conditions is known as Numerical Modeling. Because of the flexibility of demonstrating measures in different fields, mathematical arrangements of defer differential conditions have become progressively significant as of late [10]. A great arrangement was needed for a few actual frameworks including defer differential conditions that had actual marvels, for example, populace sizes, fixation, thickness, and pressing factor. The mathematical technique used to address these frameworks should keep the defer differential conditions in a positive state. Tracking down a mathematical answer for these frameworks is a troublesome undertaking since they show some huge actual characteristics that should be safeguarded by a mathematical strategy. We propose a powerful mathematical strategy for settling postponed sir pandemic models in this paper. This technique saves the entirety of the central elements of ceaseless sveir scourge frameworks, including inspiration, balance point steadiness, etc[11]. To approve the adequacy of our recommended method, we further develop the euler procedure for the gave consistent framework.

4.1. Forward Euler Method

Forward Euler system is an eminent time forward Finite Difference plot which is express in nature. This Finite Difference strategy is created for the framework as,
forward uler's method for continuous model is given by:
$S^{n+1} = S^n + h(B + \eta Z^n - \alpha S^n I^n - \mu S^n)$
$I^{n+1} = I^n + h(\alpha\theta S^n I^n - \beta I^{2n} - \gamma I^n Z^n - \mu I^n)$
$Z^{n+1} = Z^n + h(\alpha(1-\theta) S^n I^n + \beta I^{2n} + \gamma I^n Z^n - \eta Z^n - \mu Z^n)$

Numerical Experiment We can perform numerical experiment by using the value of parameters given in this table below

Table 1. Values of parameters

Parameters	S	I	Z	μ	β	B	γ	η	α	θ
Values	0.3890	0.8540	0.5360	0.34	0.05 (DFP) 0.5 (EP)	2	0.015 (DFP) 0.15 (EP)	0.023	0.0125	0.33

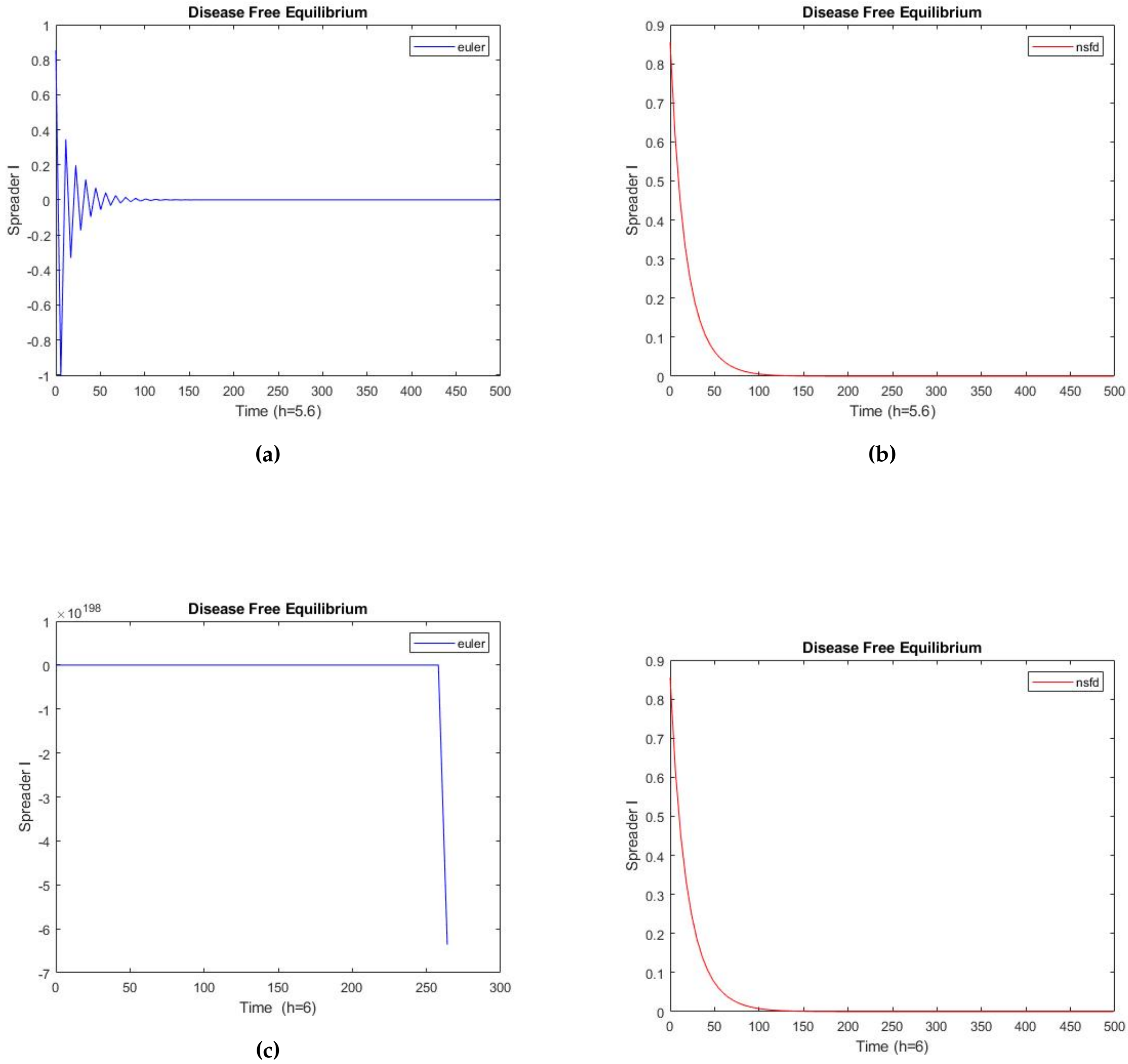


Figure 2. Comparison of forward euler and proposed NSFD at different time step size.

In spreader, when the step size is h=5.6, euler give oscillation and negative behavior, whereas the NSFD shows the convergent solution, positive behavior, and maintains the stability of disease-free equilibrium at the same step size. When h=6 and the step size is the same, the euler approach shows divergence, while the proposed nonstandard finite difference method shows the convergent solution, positive behavior, and preserves all essential values at disease-free equilibrium.

4.2. Fourth Order Runge-Kutta Scheme

RK-4 is in like manner an outstanding time forward express Finite Difference plot. RK-4 Finite Difference plot for the system is

Step 1

$k_1 = h(B + \eta Z^n - \alpha S^n I^n - \mu S^n)$

$m_1 = h(\alpha\theta S^n I^n - \beta I^{2n} - \gamma I^n Z^n - \mu I^n)$

$n_1 = h(\alpha(1-\theta) S^n I^n + \beta I^{2n} + \gamma I^n Z^n - \eta Z^n - \mu Z^n)$

Step 2

$k_2 = h(B + \eta(Z^n + \frac{n_1}{2}) - \alpha(S^n + \frac{k_1}{2})(I^n + \frac{m_1}{2}) - \mu(S^n + \frac{k_1}{2}))$

$m_2 = h(\alpha\theta(S^n + \frac{k_1}{2})(I^n + \frac{m_1}{2}) - \beta(I^{2n} + \frac{m_1}{2}) - \gamma(I^n + \frac{m_1}{2})(Z^n + \frac{n_1}{2}) - \mu(I^n + \frac{m_1}{2})$

$n_2 = h(\alpha(1-\theta)(S^n + \frac{k_1}{2})(I^n + \frac{m_1}{2}) + \beta(I^{2n} + \frac{m_1}{2}) + \gamma(I^n + \frac{m_1}{2})(Z^n + \frac{n_1}{2}) - \eta(Z^n + \frac{n_1}{2}) - \mu(Z^n + \frac{n_1}{2}))$

Step 3

$k_3 = h(B + \eta(Z^n + \frac{n_2}{2}) - \alpha(S^n + \frac{k_2}{2})(I^n + \frac{m_2}{2}) - \mu(S^n + \frac{k_2}{2}))$

$m_3 = h(\alpha\theta(S^n + \frac{k_2}{2})(I^n + \frac{m_2}{2}) - \beta(I^{2n} + \frac{m_2}{2}) - \gamma(I^n + \frac{m_2}{2})(Z^n + \frac{n_2}{2}) - \mu(I^n + \frac{m_2}{2})$

$n_3 = h(\alpha(1-\theta)(S^n + \frac{k_2}{2})(I^n + \frac{m_2}{2}) + \beta(I^{2n} + \frac{m_2}{2}) + \gamma(I^n + \frac{m_2}{2})(Z^n + \frac{n_2}{2}) - \eta(Z^n + \frac{n_2}{2}) - \mu(Z^n + \frac{n_2}{2}))$

Step 4

$k_4 = h(B + \eta(Z_n + n_3) - \alpha(S_n + k_3)(I_n + m_3) - \mu(S_n + k_3))$

$m_4 = h(\alpha\theta(S^n + k_3)(I^n + m_3) - \beta(I^{2n} + m_3) - \gamma(I^n + m_3)(Z^n + n_3) - \mu(I^n + m_3)$

$n_4 = h(\alpha(1-\theta)(S^n + k_3)(I^n + m_3) + \beta(I^{2n} + m_3) + \gamma(I^n + m_3)(Z^n + n_3) - \eta(Z^n + n_3) - \mu(Z^n + n_3)$

So the final result of RK4

$S^{n+1} = S^n + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$

$I^{n+1} = I^n + (m_1 + 2m_2 + 2m_3 + m_4)$

$Z^{n+1} = Z^n + \frac{1}{6}(n_1 + 2n_2 + 2n_3 + n_4)$

Numerical Experiment

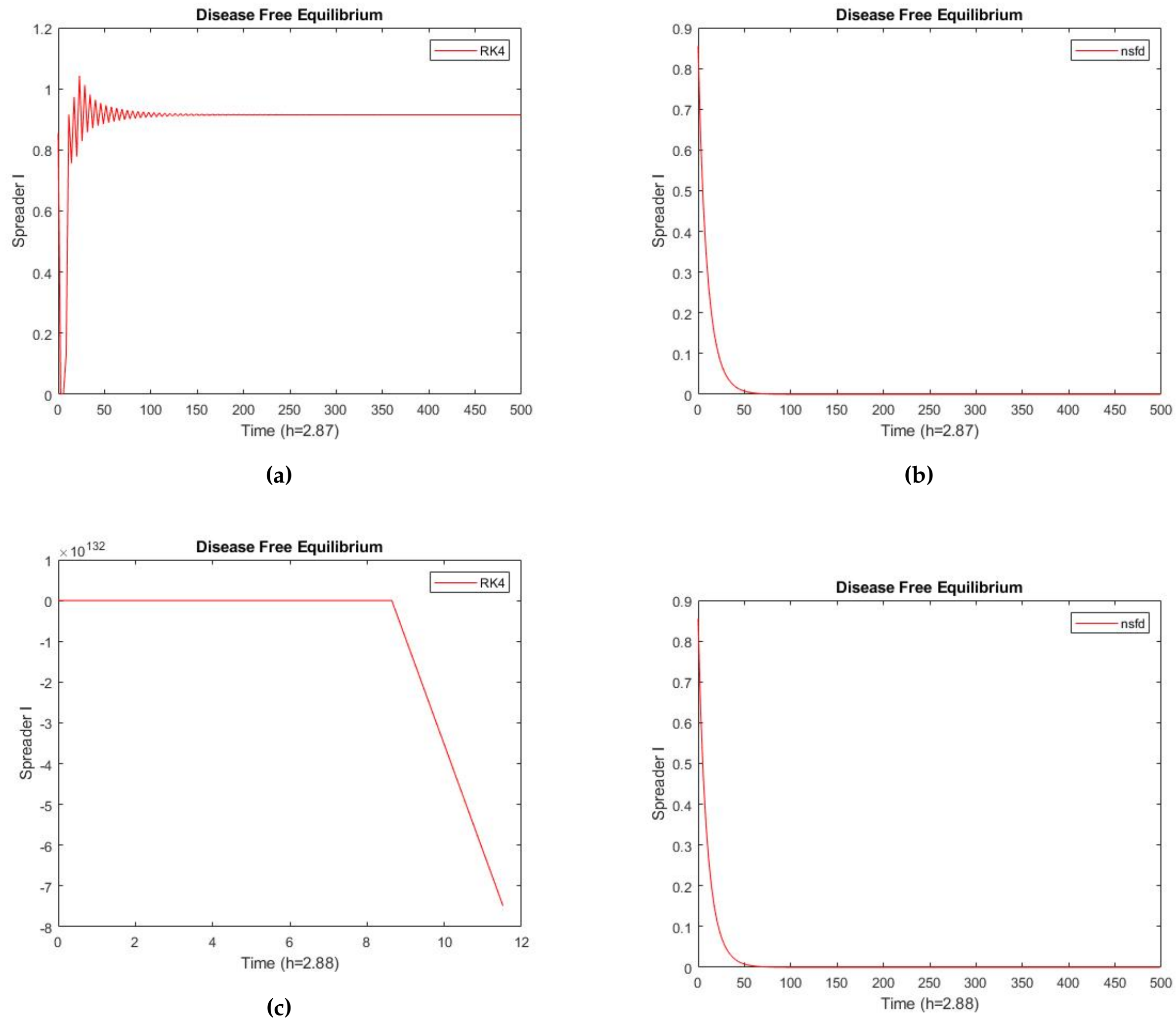


Figure 3. Comparison of RK-4 and purposed NSFD at different time step sizes.

In sp, when stepping size h=2.87, the Rk-4 technique shows oscillation, but when h=2.87, the suggested nonstandard finite difference method converges to a positive solution, preserving the stability of the disease-free equilibrium point. When h=2.88, the RK-4 and proposed nonstandard finite difference methods are compared at the same step size. The RK-4 technique shows divergence, while the proposed nonstandard finite difference method shows convergence, positive behavior, and preserves all essential values at disease-free equilibrium.

4.3. Non Standard Finite Difference Model

A Nonstandard Finite difference method depends on the arrangement of rules pointed toward saving the most dynamical properties of the related constant time model, like boundedness, inspiration of arrangements, security of consistent states, preservation laws, and bifurcations [12]. All in all, the principle benefit of these Nonstandard Finite difference method is to protect the huge properties of their nonstop analogs and thus give dependable mathematical outcomes [13]. Then again, the development of these Nonstandard Finite difference method isn't generally a direct errand and there are no broad standards for their development, and these might be considered as significant downsides for Nonstandard limited distinction plans.

$$\frac{df(t)}{dt} = \frac{f(t+h) - f(t)}{h} + 0(h) \quad (1)$$
$$as\ h \longrightarrow 0$$

S^n, I^n *and* Z^n are the approximation. Here h is time step size. For satisfying natural nature of comprising time model S^n, I^n *and* Z^n ought not be negative.
let $\phi(h) = h; \phi(h) = 1 - exp^{-h}; h\epsilon(0,1)$
$\frac{S^{n+1}-S^n}{h} = B + \eta Z^n - \alpha S^{n+1} i^n - \mu S^{n+1}$
$S^{n+1} - S^n = h(B + h\eta Z^n - h\alpha S^{n+1} I^n - h\mu S^{n+1}$
$S^{n+1} + h\alpha S^{n+1} I^n + h\mu S^{n+1} = h(B + \eta Z^n + S^n$
$S^{n+1} = \frac{h(B+\eta Z^n+S^n)}{1+h\alpha I^n+h\mu}$
Same as the other equation
$I^{n+1} = \frac{I^n+h\alpha\theta S^n I^n}{1+h\beta I^n+h\gamma Z^n+h\mu}$
$Z^{n+1} = \frac{Z^n+h\alpha(1-\theta)S^n i^n+h\beta I^2 n+h\gamma I^n Z^n}{1+h\eta+h\mu}$

4.4. Convergence Analysis of NSFD Technique

In this part the stability investigation of the $NSFD$ plan of the $SVEIR$ model will be done at infection free harmony point(DFE), $E_0(S, I, Z) = (\frac{B}{\mu}, 0, 0)$ by Taking the equation
$F = S^{n+1} = S^{n+1} = \frac{h(B+\eta Z^n+S^n)}{1+h\alpha I^n+h\mu}$
$G = I^{n+1} = \frac{I^n+h\alpha\theta S^n I^n}{1+h\beta I^n+h\gamma Z^n+h\mu}$
$H = Z^{n+1} = \frac{Z^n+h\alpha(1-\theta)S^n i^n+h\beta I^2 n+h\gamma I^n Z^n}{1+h\eta+h\mu}$
Taking partial derivative of F,G,H with respect to S,I and Z,we have, For meme free equilibrium $E_0 = (\frac{B}{\mu}, 0, 0)$ to get the following matrix

$$J(E_0) = \begin{bmatrix} \frac{1}{1+h\mu} - & \frac{-h\alpha(S+hB)}{(1+h\mu)^2} & 0 \\ 0 & \frac{\mu+h\alpha\theta\beta}{\mu(1+\mu)} & 0 \\ 0 & \frac{h\alpha(1-\theta)}{1+h\eta+h\mu} & \frac{1}{1+h\eta+h\mu} \end{bmatrix}$$

Now we calculate the eigenvalues of the matrix to decide the basic reproduction number,R_0 described as the spectral radius (dominant eigenvalue) of the matrix. This is computed by $det(J - \lambda I) = 0$ the place. J is the matrix and 'I' is the 3×3 identity matrix.

$$det(J_0 - \lambda I) = \begin{vmatrix} \frac{1}{1+h\mu} - \lambda & \frac{-h\alpha(S+hB)}{(1+h\mu)^2} & 0 \\ 0 & \frac{\mu+h\alpha\theta\beta}{\mu(1+\mu)} - \lambda & 0 \\ 0 & \frac{h\alpha(1-\theta)}{1+h\eta+h\mu} & \frac{1}{1+h\eta+h\mu} - \lambda \end{vmatrix} = 0$$

From the above matrix, to find out the basic reproduction number which is the maximum eigen value of matrix's diagonal.
For λ_1. $h, \mu > 0$

$$\frac{1}{1+h\mu} < 1$$

Similarly , for $\lambda_2 . h, \mu > 0$

$$\frac{1}{1+h\eta+h\mu} < 1$$

For λ_3

$$\frac{\mu + h\alpha\theta\beta}{\mu(1+\mu)} < 1$$

For meme free equlubrium point
$R_o = \frac{\alpha\theta B}{\mu^2}$.
$\implies \alpha\theta B = \mu^2$ Put the value of $\mu^2 = \alpha\theta B$
$\mu + h\mu^2 = \mu(1+\mu)$
$\mu + h\mu^2 < \mu + \mu^2$
$\lambda_3 < 1$
where $h = \phi(h)$,and that is less than 1
$R_0 < 1$
which is true, because$R_0 > 0$
Absolute eigenvalues of matrix is less than 1

4.5. Numerical Experiment

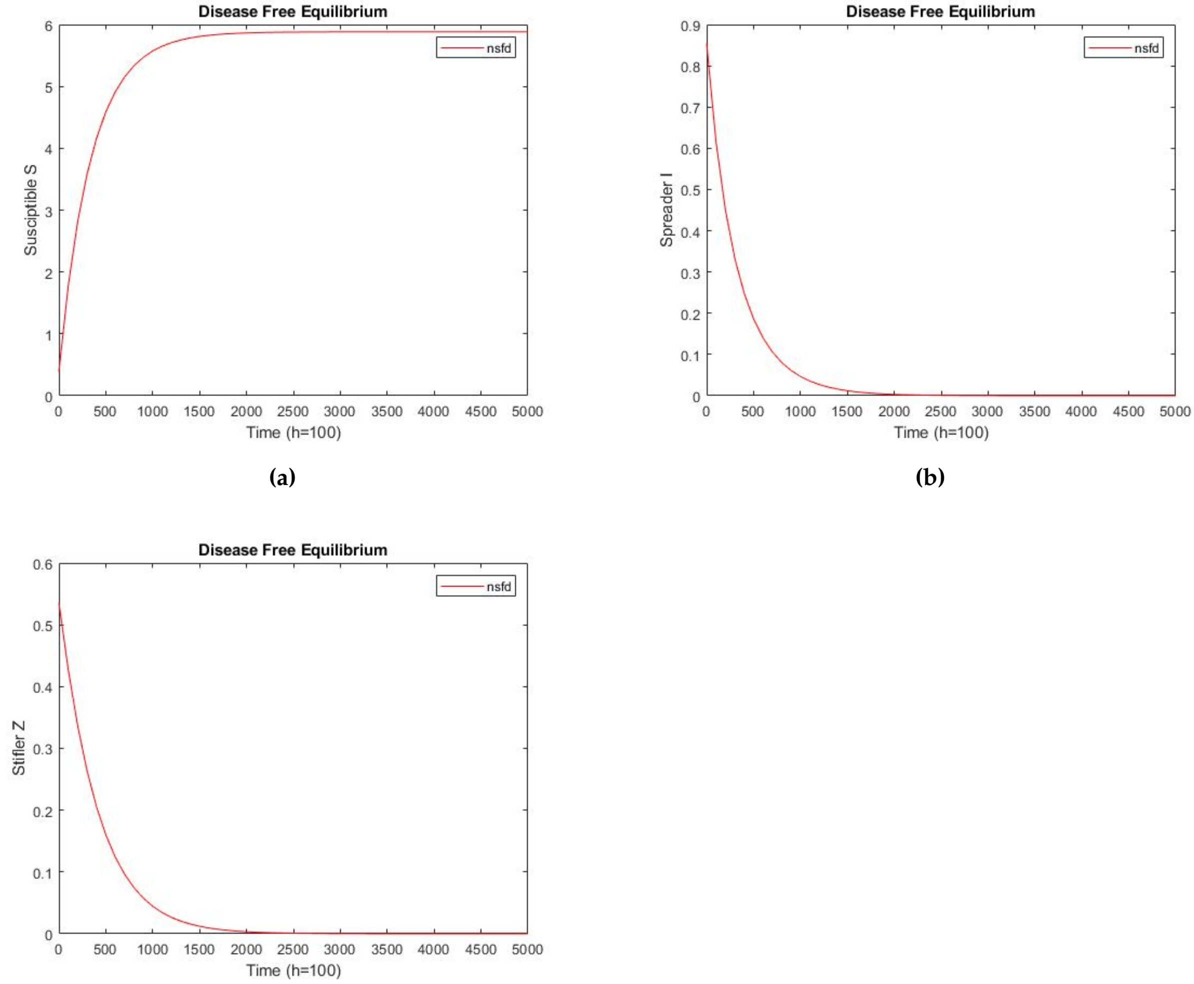
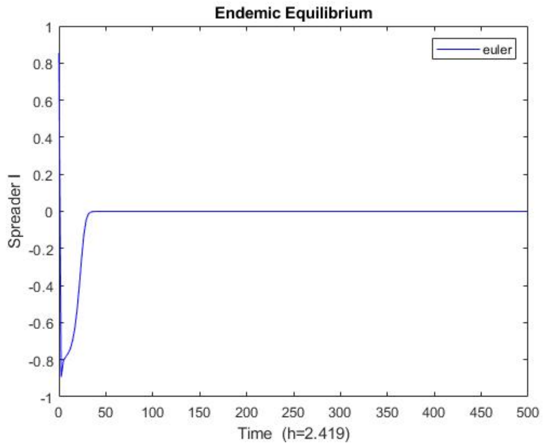


Figure 4. Purposed NSFD at different step size

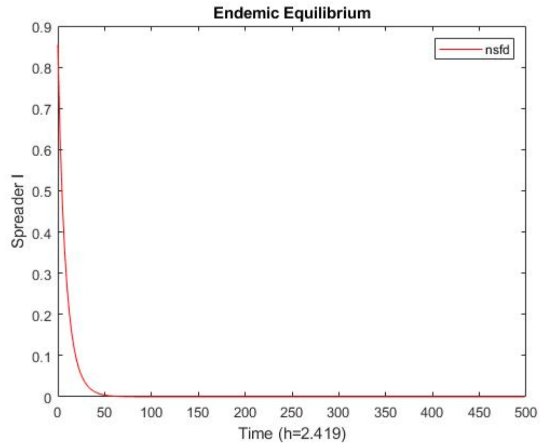
The above figure show that our purposed NSFD method give convergent solution at very large step size h=100.

4.4. Endemic Equilibrium

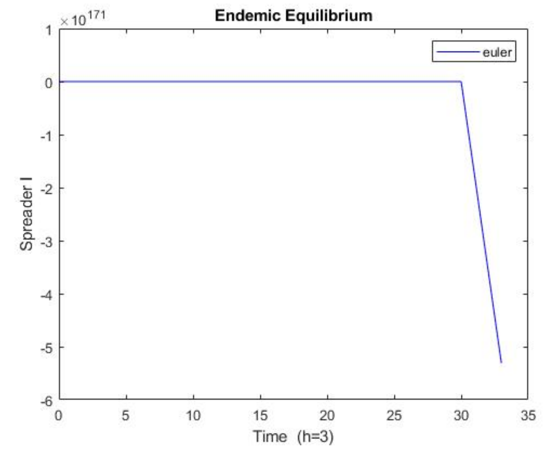
Where sickness continues in a populace is known as the endemic balance point. The study of disease transmission is a numerical consistent state.


Endemic Equilibrium
euler
Spreader I
Time (h=2.419)

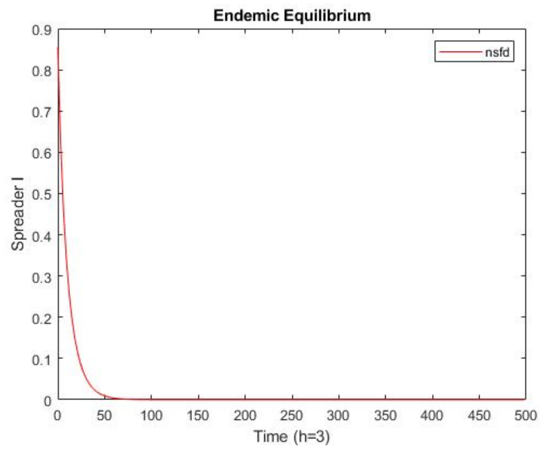
(a)


Endemic Equilibrium
nsfd
Spreader I
Time (h=2.419)

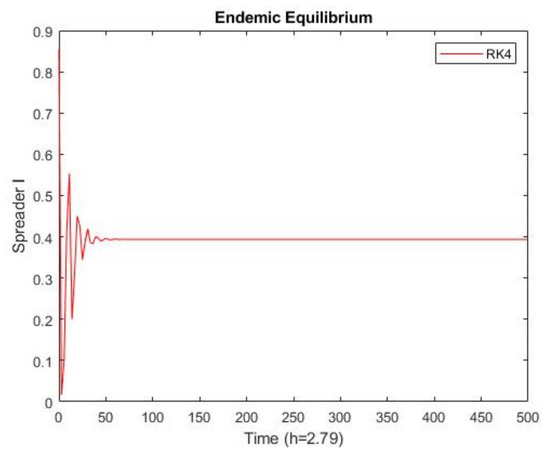
(b)


Endemic Equilibrium
×10^171
euler
Spreader I
Time (h=3)

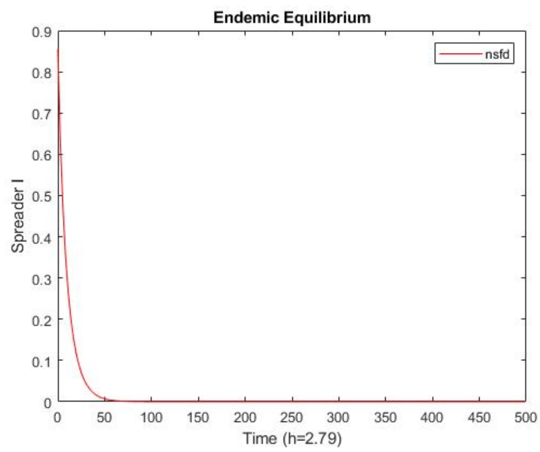
(c)


Endemic Equilibrium
nsfd
Spreader I
Time (h=3)

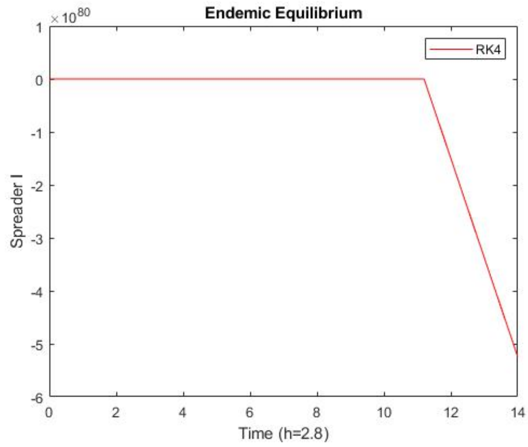
(d)


Endemic Equilibrium
RK4
Spreader I
Time (h=2.79)

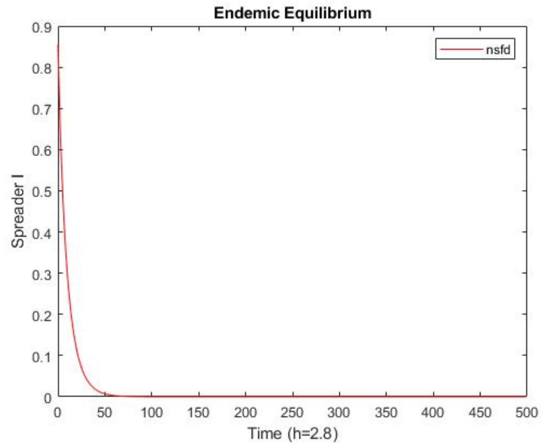
(e)


Endemic Equilibrium
nsfd
Spreader I
Time (h=2.79)

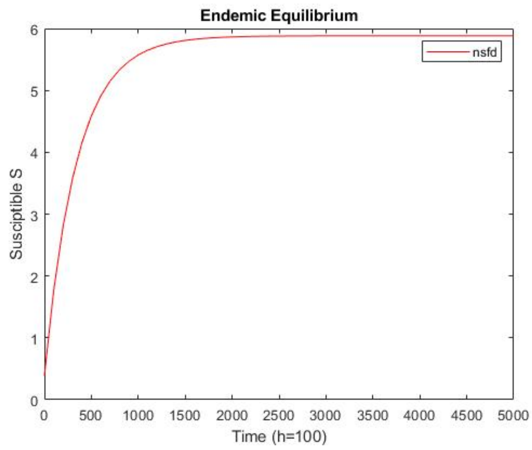
(f)



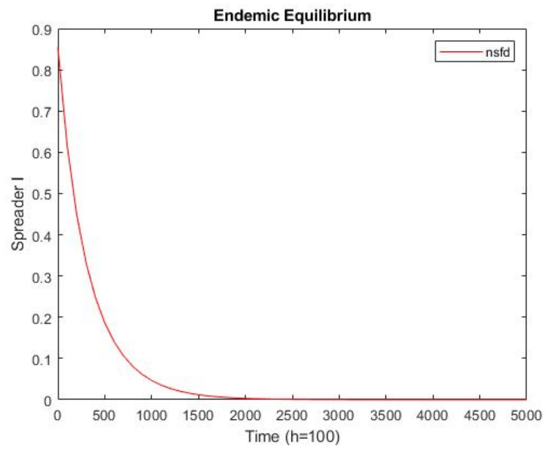
(g)



(h)



(i)



(j)

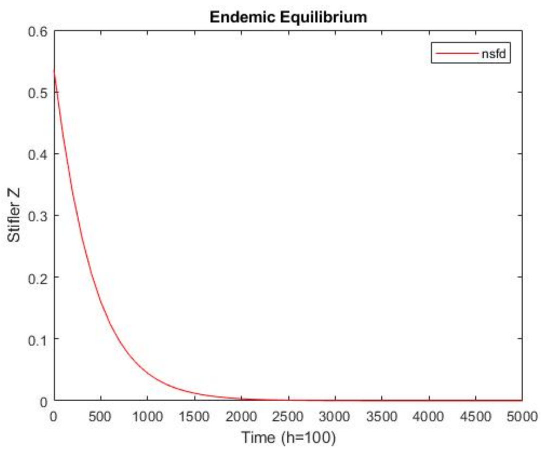


Figure 5. Comparison of NSFD with other technique at different time step sizes of endemic equilibrium.

The graph of all the procedures under investigation is shown in the diagram above. The forward Euler approach, as can be observed,shows negative behavior and divergence. Nonstandard finite difference technique shows positive behavior. RK-4 also shows osculation and diverges at very small step sizes, as can be seen in the above graph. However, the suggested NSFD technique yields a convergent solution, shows positive behavior, and maintains the disease-free equilibrium point's stability. In endemic equilibrium, the NSFD approach provides an accurate and stable solution even at a very large step size of h = 100.

5. Conclusion

Using a Non-standard finite difference method, this thesis provides an accurate and reliable numerical solution for a Meme epidemic model. All of the fundamental aspects of the meme epidemic model are preserved by the suggested technique, demonstrating its efficacy. The proposed method is compared to the forward Fuler method and the RK-4 method. The simulations show that both traditional well-known approaches fail to provide reliable solutionsăăată everyăstep sizes.

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