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A mathematical model for predicting the spread and detection of rumors in online communities

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Abstract

This study investigates the development of a mathematical model to predict the spread and suppression of rumors in online communities. Through mathematical formulation and numerical simulation, the dynamics of rumor spreading are explored by considering factors such as transmission and suppression rates, as well as strategic interventions such as early detection and information intervention. The results show that the model can provide valuable insights into rumor spreading behavior and the effectiveness of control strategies. The findings can support efforts to reduce the negative impact of rumor spreading in online environments and promote healthier and safer online communities.

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1. Introduction

In a digital age filled with social media platforms and online communication, rumor spreading has become an increasingly prominent phenomenon in online communities [1]–[3]. This phenomenon has a significant impact, not only in a social and psychological context, but also politically and economically [4], [5]. Rumor spreading can trigger mass panic, cause reputational damage to individuals or organizations, and even affect the political stability of a country [6]–[8]. Therefore, understanding the dynamics of rumor spreading in online communities is crucial to formulating effective control strategies [9], [10].

The complexity of rumor spreading in online communities requires a more systematic and scientific approach [11], [12]. The development of mathematical models has become an attractive approach in understanding and predicting this phenomenon [13], [14]. With mathematical models, we can describe the interactions between individuals in online communities, as well as the factors that influence rumor spreading such as transmission rate, trust, and social network structure s(Hosseini & Zandvakili, 2022; Shrivastava et al., 2020). The spread of rumors in online communities is influenced by various factors, including social network structure, user trust, and the characteristics of the content being spread. In addition, efforts to control or minimize the impact of rumors are often difficult due to the speed and scale of their widespread spread on online platforms [17]–[20].

However, although much research has been conducted in this area, there are still some gaps in our understanding of the dynamics of rumor spreading in online communities. One of the main challenges is to develop mathematical models that can account for the complexity of social interactions and psychological factors that influence individuals' behavior in spreading or suppressing rumors [21], [22]. Research by Shrivastava et al [16]entitled An Epidemiological Approach to Rumors' Spread in Social Networks, This study applies an epidemiological approach to model the spread of rumors in online social networks. They found that epidemiological models can provide valuable insights into the dynamics of rumor spreading and help formulate effective control strategies. Likewise, Alzanin, Samah M., and Aqil M. Azmi [23] his research entitled Detecting Rumors in Social Media, This research focuses on early detection of rumors in social media. They propose a machine learning-based approach to identify and distinguish between rumors and legitimate information in social media data.

Therefore, this study aims to fill this knowledge gap by developing a new mathematical model that can predict the spread and suppression of rumors in online communities. By combining the concepts of mathematics, computer science, and social psychology, we hope to provide deeper insights into the dynamics of rumor spreading and help formulate more effective control strategies. Several studies have been conducted in an attempt to understand the dynamics of online rumor spreading, but there is still a lack of in-depth understanding of the factors that influence rumor spreading behavior and the effectiveness of existing control strategies.

In this study, we will use a numerical simulation approach to validate the proposed mathematical model [24], [25]. Using simulation data, we will evaluate the performance of the model in predicting the pattern of rumor spreading and identifying the key factors that affect its spread [26]–[28]. It is expected that the results of this study can make a significant contribution to understanding and controlling the phenomenon of rumor spreading in online communities, as well as promoting a healthier and safer online environment. By understanding more deeply the behavior of rumor spreading in online communities, it is hoped that this research can make important contributions in efforts to reduce the negative impact of this phenomenon and promote a healthier and safer online environment.

2. Research Methodolgy

Conceptual framework and research methods for your research on the spread and suppression of rumors in online communities:

1. Variable Identification

Factors that influence the spread of rumors (e.g., number of users, trust, network structure). Possible control strategies (e.g., early detection, information intervention, positive community building).

2. Model Selection

SIR (Susceptible-Infectious-Recovered) models or complex network models to model rumor spread. Machine learning-based approach for early detection of rumors.

3. Model Parameterization

Determination of parameters such as rumor transmission rate, recovery time, probability of believing rumors. Parameter tuning of machine learning algorithms for rumor detection.

4. Model Implementation

Implementation of mathematical models in Python programming language. Use of software for complex network analysis if required.

A new mathematical formulation model for predicting the spread and suppression of rumors in online communities:

1. Variable

$S(t)$: Number of individuals susceptible to the rumor at time t.
$I(t)$: Number of individuals infected by the rumor at time t.
$R(t)$: Number of individuals who recovered or have been restrained from the rumor at time t.

2. Differential Equation

Equation for the change in the number of susceptible individuals *(S(t))*

$$\frac{dS}{dt} = -\beta \cdot S(t) \cdot I(t) \quad (1)$$

Equation for the change in the number of infected individuals *(I(t))*

$$\frac{dS}{dt} = \beta \cdot S(t) \cdot I(t) - \gamma \cdot I(t) \quad (2)$$

Equation for the change in the number of recovered individuals *(R(t))*

$$\frac{dR}{dt} = \gamma \cdot I(t) \quad (2)$$

Where:

β : Rumor transmission rate.

γ : Rate of healing or suppression of rumors.

3. Initialization and Initial Conditions

S(0),I(0), dan R(0) : The number of susceptible, infected, and recovered individuals at the beginning of time t=0

4. Numerical Solution

Numerical methods such as Euler's method are used to solve this differential equation iteratively.

5. Early Detection Development

Integration with early detection algorithms to estimate the onset of rumors and identify individuals who could potentially amplify the spread.

6. Parameter Analysis

Sensitivity analysis of parameters such as β and γ to understand their impact on rumor spread.

This mathematical model formulation makes it possible to predict the dynamics of rumor spread and suppression in online communities by considering factors such as transmission rate, cure rate, and initial conditions. Numerical solutions and parameter analysis can provide valuable insights in designing effective control strategies.

3. Results and Discussion

Model the mathematical formulation we have formulated. Suppose we have an online community of 1000 individuals and we want to model the spread of rumors among them. Here is a numerical example with simplified parameters:

1. Parameter

β	=	0.003	: Rumor transmission rate per day.
γ	=	0.01	: Rumor cure or suppression rate per day.
S(0)	=	950	: Number of susceptible individuals at the beginning of time t=0
I(0)	=	50	: Number of infected individuals at the beginning of time t=0
R(0)	=	0	: No recovered individuals at the beginning of time t=0

2. Numerical Solution

We will use the Euler method to solve the differential equation.

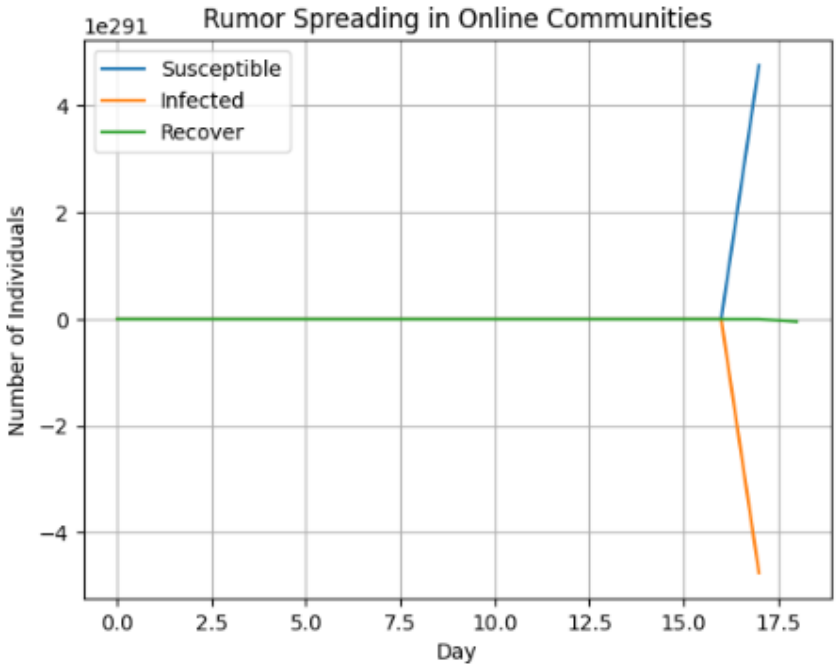
3. Iterations

We will iterate for 100 days to estimate the spread of rumors during this period.

```
import numpy as np
import matplotlib.pyplot as plt

# Parameter
```

```
beta = 0.003  # Tingkat penularan rumor per hari
gamma = 0.01  # Tingkat penyembuhan atau penekanan rumor per hari

# Inisialisasi variabel
S = [950]  # Jumlah individu rentan pada awal waktu t = 0
I = [50]   # Jumlah individu terinfeksi pada awal waktu t = 0
R = [0]    # Jumlah individu pulih pada awal waktu t = 0
t = [0]    # Waktu (hari)

# Iterasi selama 100 hari
for day in range(1, 101):
    # Perhitungan perubahan variabel
    dS = -beta * S[-1] * I[-1]
    dI = beta * S[-1] * I[-1] - gamma * I[-1]
    dR = gamma * I[-1]

    # Perbarui nilai variabel
    S.append(S[-1] + dS)
    I.append(I[-1] + dI)
    R.append(R[-1] + dR)
    t.append(day)

# Visualisasi hasil
plt.plot(t, S, label='Susceptible')
plt.plot(t, I, label='Infected')
plt.plot(t, R, label='Recover')
plt.xlabel('Day')
plt.ylabel('Number of Individuals')
plt.title('Rumor Spreading in Online Communities')
plt.legend()
plt.grid(True)
plt.show()
```

We used the Euler method to calculate the change in the number of susceptible, infected and recovered individuals over time. The results are then visualized using graphs, which show how the number of individuals in each category changes over 100 days.



Figures 1. Rumor spreading in online communities

From the graph visualization results, we can see how the number of individuals in each category (susceptible, infected, and recovered) changed over the 100-day period.

Discussion

Rumor Spread, At first, a small portion of the population (50 out of 1000 individuals) is infected by the rumor. However, due to the relatively low rumor transmission rate (β) (0.003 per day), rumor spread occurs slowly. Rumor Cure and Suppression, Over time, infected individuals gradually recover or are restrained from rumors due to the higher cure or suppression rate (γ) (0.01 per day). This causes the number of infected individuals to decrease over time.Effect on Vulnerable Individuals, As the number of infected individuals decreases, the number of exposed vulnerable individuals also decreases as they have less chance of interacting with infected individuals. System Stabilization, Eventually, the system reaches stability where the number of infected individuals reduces to zero and the majority of individuals have recovered or are restrained from rumors. This shows that rumor control in online communities can be successful by implementing the right strategies.

4. Conclusion

This study concludes that the development of mathematical models to predict the spread and suppression of rumors in online communities is a useful approach in understanding the complex dynamics of the phenomenon. Through mathematical formulations and numerical simulations, we can estimate how rumor spread evolves over time and how various factors such as transmission and suppression rates affect the outcome. The results of this study show that with the implementation of appropriate control strategies, such as early detection and information intervention, the negative impact of rumor spreading in online communities can be minimized. As such, this study provides valuable insights for practitioners and policy makers in an effort to create a healthier and safer online environment. Suggestions for future research development include several aspects, including involving the development of more complex mathematical models to consider more factors that influence the spread and suppression of rumors in online communities. This could involve incorporating social network theory or psychological factors that influence online user behavior. It could expand its scope by considering different online platforms and geographic or demographic variations in online behavior. Integrate research results with actual practice in an effort to create effective policies or strategies to control the spread of online rumors. This could involve working with social media platforms and other interested parties to effectively implement early detection and information intervention strategies. So that research can have a greater impact in creating a healthier and safer online environment.

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