Research on Network Public Opinion Communication Model of Fusion Emotion

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Abstract: To effectively simulate the network public opinion dissemination process and study the evolution law of different public opinion groups under the influence of emotion intervention, we propose a group network public opinion communication model SPQNR that integrates emotions. The model divides netizens into three categories according to the sentiment value of netizens' main comments and introduces the positive rate and negative rate of netizens to design the relationship between the mutual conversion parameters between groups. Finally, this paper conducts case analysis through Anylogic simulation. The SPQNR model can effectively simulate the evolution of public opinion of different groups.

1 INTRODUCTION

As of December 2021, the number of Chinese netizens has reached 1.032 billion, and the Internet penetration rate has reached 73.0%. The number of online social platforms has increased accordingly. Netizens use various social platforms to disseminate information (Alvarez-Galvez 2016). Weibo is an information dissemination platform with a large number of users. In Weibo, many topics co-exist, and the topic information is difficult to distinguish between true and false. Netizens' comments on events can be followed and commented on by Weibo users, making the Weibo platform an essential channel for disseminating negative information. The malicious dissemination of negative public opinion on the internet will distort the truth of the incident and cause social conflicts. It has become an essential factor in social instability.

Internet public opinion information is created by netizens' subjects and spread by them. Although the government, online media, and other objects influence the dissemination of online public opinion, the emotions of netizens play a crucial role in the dissemination of online public opinion. Therefore, it is of great practical significance to build a model of public opinion dissemination and implement interventions based on the emotions of netizens to control public opinion. The infectious disease model is a top-down modeling approach, which evolved from the DK model (Daley 1964). Many scholars have found that the contagion model can simulate the spread of public opinion information, and the two transmission mechanisms are relatively similar, so scholars have proposed improved models to more accurately simulate the spread of online public opinion among groups (Liu et al. 2020; Zhang et al. 2020; Yang et al. 2018; Huo et al. 2019; Liu et al. 2019). Wang Zhiying et al. studied the dissemination interaction of solid and weak public opinion information and the dissemination pattern of emergencies under government intervention, which provided a reference for the government to develop emergency plans (Wang et al. 2020) (Li et al. 2017). Di Lan et al. established a three-divisional opinion online dissemination model under media intervention (Di et al. 2018). They determined that the media role had the most significant influence on neutrals because neutrals were the majority among netizens. MI-SEIR considered the impact of media communication and interpersonal cusps on opinion dissemination based on the SEIR model (Kumar et al 2020). Zhang et al. identified a significant effect of government intervention on the intervention effect of opinion leaders under media, opinion leaders, and government intervention (Zhang et al. 2021). Zhang

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Lin and Du Cuicui et al. studied the effects of online media and government intervention on the interactive dissemination of public opinion information from different perspectives (Zhang et al. 2022).

The above study analyzed the state transformation of different groups in online opinion dissemination under the participation of varying intervention subjects. However, the main subjects in online opinion dissemination are netizens. The government, opinion leaders, and media are all objects that affect the state transformation of netizens. They are not studied with the attributes of netizens themselves as the main subjects, so our study takes netizens themselves as the main subjects and uses their emotions as the entry point to study the dissemination process of online opinion information among different groups. Besides, the parameters of inter-group state transformation are relatively independent and cannot be related to the main body of netizens.

In this study, we propose a model of public opinion dissemination incorporating netizens' emotions. We consider that communication subjects carry personal subjective emotions in public opinion dissemination, so we divide communication subjects into positive, negative, and neutral emotion communicators. At the same time, we consider the cognitive differences of communication subjects, so we assign a positive rate to positive emotion communicators and a negative rate to negative emotion communicators, so that the group state transformation parameters form a correlation, which can more effectively simulate the law of online opinion dissemination.

2 SPQNR MODEL

2.1 The SPQNR Model of Integrating Emotion

2.1.1 Model Assumptions

Hypothesis 1: When netizens browse negative public opinion information on the Weibo platform, if they become interested in public opinion events, netizens will have personal emotional tendencies. It is assumed that there are five types of netizen groups. The unknown group $\mathcal{S}$ refers to people who pay attention to events and comments and are easily affected; The positive emotional group $\mathcal{P}$ refers to the group who pays attention to the event and makes positive comments; the neutral emotional group $\mathcal{Q}$ refers to the group who still publishes neutral comments after paying attention to the event; the negative emotional group $\mathcal{N}$ refers to the group who pays attention to the event and makes negative comments; the removed group $\mathcal{R}$ refers to people who have lost interest in the event. $\mathcal{S}$ can be converted into $\mathcal{P}$, $\mathcal{Q}$, $\mathcal{N}$, $\mathcal{R}$; $\mathcal{P}$ can be converted into $\mathcal{Q}$, $\mathcal{R}$; $\mathcal{Q}$ can be converted into $\mathcal{P}$, $\mathcal{N}$, $\mathcal{R}$; $\mathcal{N}$ can be converted into $\mathcal{Q}$, $\mathcal{R}$; the state transformation among the five groups is shown in Figure 1.

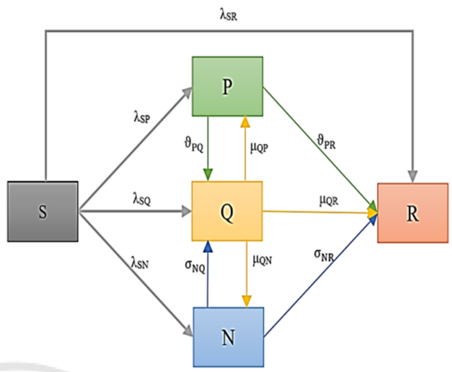

Figure 1. The model of SPQNR

Hypothesis 2: We assume that $(0,a]$、$(a,b]$、$(b,1]$ represent negative emotion interval, neutral emotion interval and positive emotion interval, where $a \in (0,0.5), b \in (0.5,1)$.

Hypothesis 3: We assume that people with positive emotions have a specific "positive rate" and will not easily transform into neutral people. The "positive rate" is expressed as (b+1)/2, and it belongs to (0.75,1).

Hypothesis 4: We assume that people with negative emotional comments have a certain "negative rate" themselves, and they will not easily transform into neutral people. The "negative rate" is expressed as 1- a/2 and belongs to (0.75,1).

2.1.2 Model Parameters

The model design process involves many parameters. To form a relationship between the parameters, we will simplify the parameters. α represents the probability that $\mathcal{S}$ may be transformed into $\mathcal{P}$ after browsing comments at a certain moment, β represents the probability that $\mathcal{S}$ may transform into $\mathcal{Q}$ after viewing comments at a certain moment, γ represents the probability that $\mathcal{S}$ may transform into $\mathcal{N}$ after viewing comments at a certain moment, and δ represents The probability that $\boldsymbol{\mathcal{S}}$ is transformed into $\boldsymbol{\mathcal{R}}$ after viewing comments at a certain moment.

In the SPQNR model, the conversion parameters among $\boldsymbol{\mathcal{P}}$, $\boldsymbol{\mathcal{Q}}$, $\boldsymbol{\mathcal{N}}$, and $\boldsymbol{\mathcal{R}}$ are set according to the positive rate and negative rate among groups. $\boldsymbol{\mathcal{Q}}$ has a weak subjective judgment, so it is assumed that $\boldsymbol{\mathcal{Q}}$ and $\boldsymbol{\mathcal{S}}$ have the same probability of conversion to other groups. The applicable conversion rates are shown in Table 1.

Table 1: The description of model parameters.

Conversion Rate	Representation	Explanation
λ_{SP}	α	*The conversion rate of $\mathcal{S}$ to $\mathcal{P}$*
λ_{SQ}	β	*The conversion rate of $\mathcal{S}$ to $\mathcal{Q}$*
λ_{SN}	γ	*The conversion rate of $\mathcal{S}$ to $\mathcal{N}$*
λ_{SR}	δ	*The conversion rate of $\mathcal{S}$ to $\mathcal{R}$*
ϑ_{PQ}	$[\frac{b+1}{2}]\beta$	*The conversion rate of $\mathcal{P}$ to $\mathcal{Q}$*
ϑ_{PR}	$[1+\frac{b+1}{2}]\delta$	*The conversion rate of $\mathcal{P}$ to $\mathcal{R}$*
μ_{QP}	α	*The conversion rate of $\mathcal{Q}$ to $\mathcal{P}$*
μ_{QN}	γ	*The conversion rate of $\mathcal{Q}$ to $\mathcal{N}$*
μ_{QR}	δ	*The conversion rate of $\mathcal{Q}$ to $\mathcal{R}$*
σ_{NQ}	$(1-a/2)\beta$	*The conversion rate of $\mathcal{N}$ to $\mathcal{Q}$*
σ_{NR}	$(2-a/2)\delta$	*The conversion rate of $\mathcal{N}$ to $\mathcal{R}$*

2.2 Model Analysis

2.2.1 Dynamic Analysis Model

Netizens have five states at time t, which are denoted by $\mathcal{S}(\mathrm{t}), \mathcal{P}(\mathrm{t}), \mathcal{Q}(\mathrm{t}), \mathcal{N}(\mathrm{t})$, and $\mathcal{R}(\mathrm{t})$, respectively. According to the conversion relationship and conversion rate among groups in the SPQNR model, the system dynamics differential equations are shown in formula (1).

$$\begin{cases} \frac{d\mathcal{S}(\mathrm{t})}{dt} = A - \alpha\mathcal{S}\mathcal{P} - \beta\mathcal{S}\mathcal{Q} - \gamma\mathcal{S}N - \delta\mathcal{S} \\ \frac{d\mathcal{P}(\mathrm{t})}{dt} = \alpha\mathcal{S}\mathcal{P} + \left(\alpha - \frac{b+1}{2} * \beta\right)\mathcal{P}\mathcal{Q} - \left(\frac{b+1}{2} * \delta\right)\mathcal{P} \\ \frac{d\mathcal{N}(\mathrm{t})}{dt} = \gamma\mathcal{S}\mathcal{N} + \left(\gamma - \left(1 - \frac{a}{2}\right) * \beta\right)\mathcal{N}\mathcal{Q} - \left(\left(1 - \frac{a}{2}\right) * \delta\right)\mathcal{Q} \\ \frac{d\mathcal{Q}(\mathrm{t})}{dt} = \beta\mathcal{S}\mathcal{Q} + \left(\frac{b+1}{2} * \beta - \alpha\right)\mathcal{P}\mathcal{Q} + \left(\left(1 - \frac{a}{2}\right) * \beta - \gamma\right)\mathcal{Q}\mathcal{N} - \delta\mathcal{Q} \\ \frac{d\mathcal{R}(\mathrm{t})}{dt} = \delta\mathcal{S} + \left(\frac{b+1}{2} * \delta\right)\mathcal{P} + \delta\mathcal{Q} + \left(\left(1 - \frac{a}{2}\right) * \delta\right)\mathcal{N} \end{cases} \quad (1)$$

In order to facilitate the solution of the equilibrium point, we simplify the formula (1), let $\tau_1 = \left(\alpha - \frac{b+1}{2} * \beta\right)$, $\tau_2 = \left(\frac{b+1}{2} * \delta\right)$, $\tau_3 = \left(\left(1 - \frac{a}{2}\right) * \beta - \gamma\right)$, $\tau_4 = \left(\left(1 - \frac{a}{2}\right) * \delta\right)$, then the above equations can be transformed into formula (2).

$$\begin{cases} \frac{d\mathcal{S}(\mathrm{t})}{dt} = A - \alpha\mathcal{S}\mathcal{P} - \beta\mathcal{S}\mathcal{Q} - \gamma\mathcal{S}N - \delta\mathcal{S} \\ \frac{d\mathcal{P}(\mathrm{t})}{dt} = \alpha\mathcal{S}\mathcal{P} + \tau_1\mathcal{P}\mathcal{Q} - \tau_2\mathcal{P} \\ \frac{d\mathcal{Q}(\mathrm{t})}{dt} = \beta\mathcal{S}\mathcal{Q} - \tau_1\mathcal{P}\mathcal{Q} + \tau_3\mathcal{Q}\mathcal{N} - \delta\mathcal{Q} \\ \frac{d\mathcal{N}(\mathrm{t})}{dt} = \gamma\mathcal{S}\mathcal{N} - \tau_3\mathcal{N}\mathcal{Q} - \tau_4\mathcal{N} \\ \frac{d\mathcal{R}(\mathrm{t})}{dt} = \delta\mathcal{S} + \tau_2\mathcal{P} + \delta\mathcal{Q} + \tau_4\mathcal{N} \end{cases} \quad (2)$$

2.2.2 Basic Reproduction Number & Equilibrium Point

The basic reproduction number R_0 is a critical parameter in the infectious disease dynamics model, representing the proportion of the number of people a contagious person can infect without any intervention. The basic reproduction number R_0 can measure whether public opinion spreads on a large scale on the network platform. When $R_0<1$, network public opinion will not spread on a large scale; when $R_0>1$, network public opinion is in a state of large-scale transmission.

Let $x = (\mathcal{P}, Q, N)^{\mathrm{T}}$, the model can be expressed as $dx = \mathcal{F}(x) - \mathcal{V}(x)$, where the expressions of $\mathcal{F}(x)$ and $\mathcal{V}(x)$ are respectively:

$$\mathcal{F}(x) = \begin{pmatrix} \alpha\mathcal{S}\mathcal{P} \\ \beta\mathcal{S}\mathcal{Q} \\ \gamma\mathcal{S}\mathcal{N} \\ 0 \end{pmatrix}, \mathcal{V}(x) = \begin{pmatrix} \tau_2\mathcal{P} - \tau_1\mathcal{P}\mathcal{Q} \\ \tau_1\mathcal{P}\mathcal{Q} + \delta\mathcal{Q} - \tau_3\mathcal{Q}\mathcal{N} \\ \tau_3\mathcal{N}\mathcal{Q} + \tau_4\mathcal{N} \\ \alpha\mathcal{S}\mathcal{P} + \beta\mathcal{S}Q + \gamma\mathcal{S}N + \delta\mathcal{S} - A \end{pmatrix} \quad (3)$$

Assuming that public opinion does not exist, there is only $\boldsymbol{\mathcal{S}}$ in the process of Internet public opinion dissemination, which is the equilibrium point of no public opinion dissemination, The Jacobian matrices of $\mathcal{F}(x)$ and $\mathcal{V}(x)$ are expressed as:

$$\boldsymbol{\mathcal{F}} = \left(\frac{\partial\mathcal{F}(x)}{\partial x}\middle| x = X_0\right) = \begin{bmatrix} \alpha\mathcal{S} & 0 & 0 & 0 \\ 0 & \beta\mathcal{S} & 0 & 0 \\ 0 & 0 & \gamma\mathcal{S} & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \left(\mathcal{S} = \frac{A}{\delta}\right) \quad (4)$$

$$\boldsymbol{\mathcal{V}} = \left(\frac{\partial\mathcal{V}(x)}{\partial x}\middle| x = X_0\right) = \begin{bmatrix} \tau_2 & 0 & 0 & 0 \\ 0 & \delta & 0 & 0 \\ 0 & 0 & \tau_4 & 0 \\ \alpha\mathcal{S} & \beta\mathcal{S} & \gamma\mathcal{S} & \delta \end{bmatrix}, \left(\mathcal{S} = \frac{A}{\delta}\right) \quad (5)$$

Thus, the spectral radius R_0 of the reproduction matrix $\boldsymbol{\mathcal{F}\mathcal{V}^{-1}}$ is obtained as:

$$R_0 = \rho(\boldsymbol{\mathcal{F}\mathcal{V}^{-1}}) = max\left(\frac{\alpha A}{\tau_2\delta}, \frac{\beta A}{\delta^2}, \frac{\gamma A}{\tau_4\delta}\right) \quad (6)$$

When $R_0<1$, the internet public opinion will not spread, so there are $\frac{\alpha A}{\tau_2\delta} < 1$, $\frac{\beta A}{\delta^2} < 1$, $\frac{\gamma A}{\tau_4\delta} < 1$.

To solve the equilibrium solution of the equation system, we set the formula (2) to be 0, then,

X_0: $\left(\mathcal{S} = \frac{A}{\delta}, \mathcal{P} = 0, \mathcal{Q} = 0, \mathcal{N} = 0\right)^T$,

X_1: $\left(\mathcal{S} = \frac{\tau_2}{\alpha}, \mathcal{P} = \frac{\alpha A - \delta\tau_2}{\alpha\tau_2}, \mathcal{Q} = 0, \mathcal{N} = 0\right)^T$,

X_2: $\left(\mathcal{S} = \frac{\delta}{\beta}, \mathcal{P} = 0, \mathcal{Q} = \frac{\beta A - \delta^2}{\delta\beta}, \mathcal{N} = 0\right)^T$,

X_3: $\left(\mathcal{S}=\frac{\tau_4}{\gamma}, \mathcal{P}=0, \mathcal{Q}=0, \mathcal{N}=\frac{\gamma A-\delta\tau_4}{\gamma\tau_4}\right)^T$.

So the Jacobian matrix at X_0 is expressed as:

$$\mathcal{J}=\begin{bmatrix} -\delta & -\alpha\frac{A}{\delta} & -\beta\frac{A}{\delta} & -\gamma\frac{A}{\delta} \\ 0 & \alpha\frac{A}{\delta}-\tau_2 & 0 & 0 \\ 0 & 0 & \beta\frac{A}{\delta}-\delta & 0 \\ 0 & 0 & 0 & \gamma\frac{A}{\delta}-\tau_4 \end{bmatrix} \quad (7)$$

We obtain the four eigenvalues as follows: $\theta_1=-\delta$, $\theta_2=\alpha\frac{A}{\delta}-\tau_2$, $\theta_3=\beta\frac{A}{\delta}-\delta$, $\theta_4=\gamma\frac{A}{\delta}-\tau_4$.

According to $\frac{\alpha A}{\tau_2\delta}<1$, $\frac{\beta A}{\delta^2}<1$, $\frac{\gamma A}{\tau_4\delta}<1$, we judge that the four eigenvalues are all negative numbers, so X_0 is the equilibrium point of no public opinion propagation.

In addition, X_1, X_2, and X_3 are local propagation equilibrium points. There are two values of 0 in each set of solutions, representing only one kind of emotional comment in the actual communication situation. The final emotional comments of statements opinion will end with positive emotions, so in the equilibrium state, $\mathcal{P}$ is not less than $\mathcal{Q}$ and $\mathcal{N}$. Therefore, when $R_0>1$, there can only be one local communication equilibrium point X_1 when network public opinion spreads.

3 SIMULATION ANALYSIS

3.1 Dataset Description

We select the "Yugou Middle School Beating Incident" on Weibo in April 2022. We first used crawler technology to crawl 6,000 valid comments on the incident from April 1 to April 14 on the Weibo platform. After data cleaning, we use the natural language processing method to get each comment's sentiment value. We set the comment value in (0, 0.35] belongs to $\mathcal{P}$, in (0.35, 0.65] belongs to $\mathcal{Q}$, in (0.65, 1] belongs to $\mathcal{N}$.

We use the Anylogic simulation platform to simulate the SPQNR model dynamically and obtain the optimal parameters after multiple calibration experiments. The relevant parameter settings after calibration are shown in Table 2.

3.1.1 Dynamic Analysis Model

Table 2: Optimal Parameter Settings.

Parameter	Value	Explanation
A	**0.0001**	The crowd input rate of concerning events
α	0.275	The conversion rate of $\mathcal{S}$ to $\mathcal{P}$
β	0.111	The conversion rate of $\mathcal{S}$ to $\mathcal{Q}$
γ	0.139	The conversion rate of $\mathcal{S}$ to $\mathcal{N}$
δ	0.248	The conversion rate of $\mathcal{S}$ to $\mathcal{R}$
b	0.65	The interval of positive score
a	0.35	The interval of negative score

3.2 Effectiveness Analysis

We use the simulation software to build the SPQNR model to obtain the population change over time, as shown in Figure 2, where Real-P\Q\N respectively represents the three groups of people $\mathcal{P}, \mathcal{Q}$, and $\mathcal{N}$ under the real data, and Sim-P\Q\N respectively represents the three groups of people $\mathcal{P}, \mathcal{Q}$, and $\mathcal{N}$ under the simulation data.

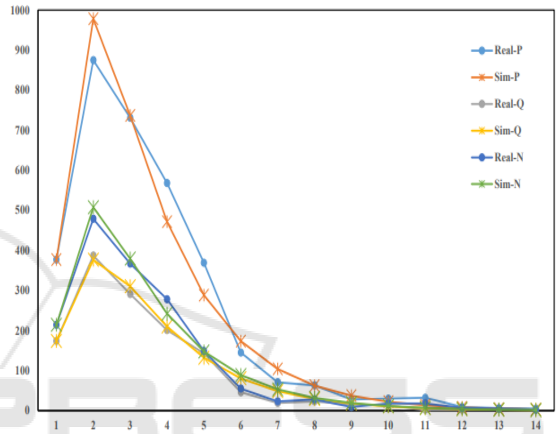

Figure 2: Comparison between simulation data and real data.

From figure 2, it can be concluded that at the initial stage of the outbreak of public opinion, S was transformed into three emotional groups, and the number of each group increased sharply. Over time, the three populations transform into each other or removers. At t = 14, the three groups of people tended to 0, and the public opinion disappeared, which is consistent with the actual situation.

The real data of the three groups of people have a high degree of fitting with the simulated data, which can well simulate real public opinion events. Therefore, the SPQNR model constructed in this paper can effectively simulate the real situation when public opinion events occur, and the model is suitable for the simulation of negative public opinion events in different situations.

3.3 Parameter Sensitivity Analysis

Since the between-group conversion parameter is linked to the parameter for conversion of $\mathcal{S}$ to other groups, we performed a sensitivity analysis on the four base conversion rates. To fix the emotional range, we mainly analyze the impact of the changes in the number of the three types of emotional groups.

(1) The sensitivity analysis of α

We only change α, and the rest of the parameters are set to $\beta: 0.111, \gamma: 0.139, \delta: 0.248, a: 0.35$, b:0.65.

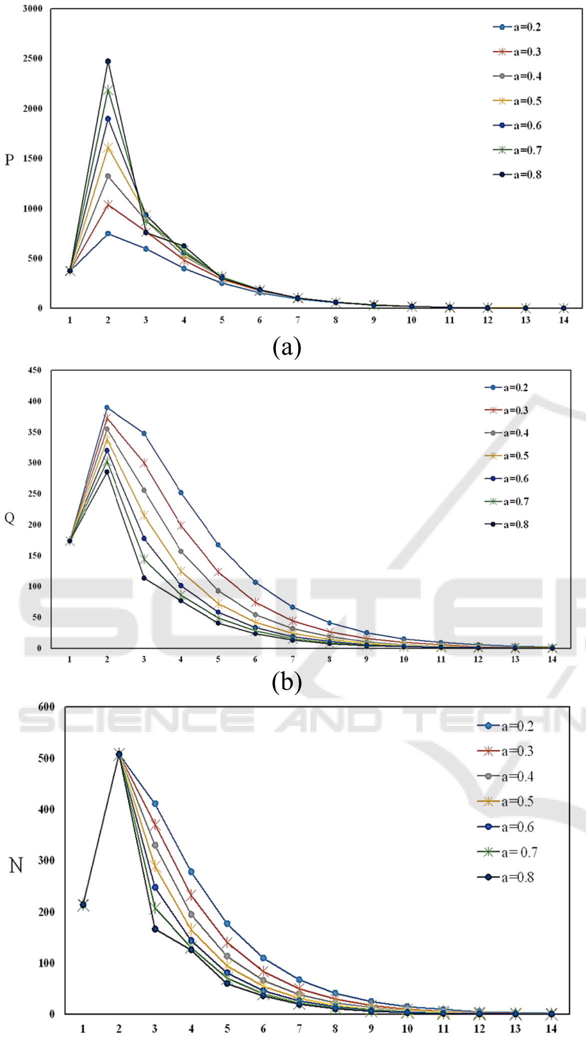

Figure 3: The number of $\mathcal{P}, \mathcal{Q}, \mathcal{N}$ groups.

It can be concluded from figure 3 that as α increases continuously, the number of $\mathcal{P}$ constantly increases, while the numbers of $\mathcal{Q}$ and $\mathcal{N}$ decrease continuously. In the time dimension, $\mathcal{P}$ and $\mathcal{N}$ drop straight after the second day, while $\mathcal{Q}$ is a neutral population in a state of gentle decline in mutual transformation. The three groups of people remained stable on the 10th day, the three groups gradually turned into the remover $\mathcal{R}$, and the public opinion gradually eased.

(2) The sensitivity analysis of γ

We only change γ, and the rest of the parameters are set to $\alpha: 0.275, \beta: 0.111, \delta: 0.248, a: 0.35$, b:0.65.

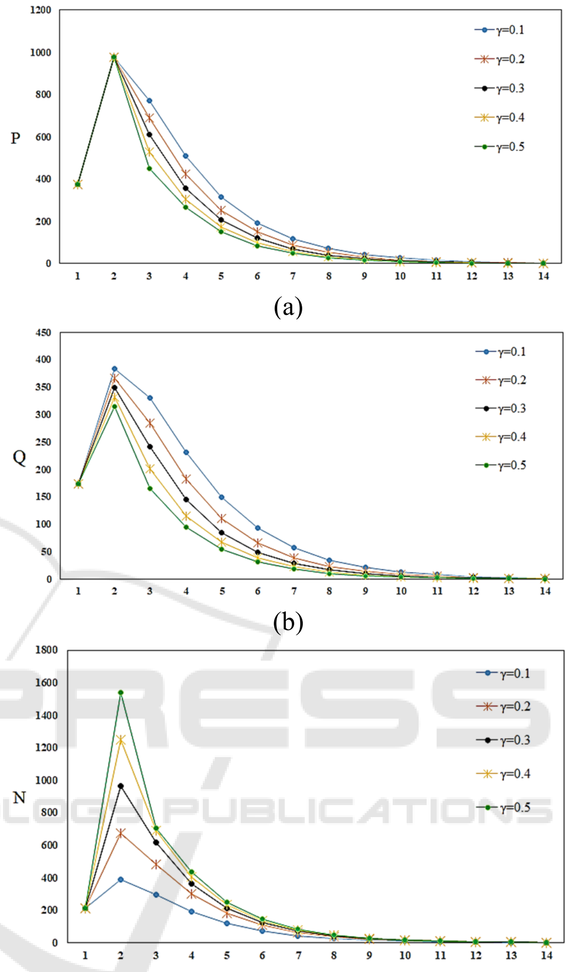

Figure 4: The number of $\mathcal{P}, \mathcal{Q}, \mathcal{N}$ groups.

It can be concluded from figure 4 that as γ continues to increase, the number of $\mathcal{P}$ and $\mathcal{Q}$ continues to decrease, and the number of $\mathcal{N}$ continues to increase, and the increase and change are apparent. In the time dimension, after the second day, the numbers of the three groups of people continued to decrease. Finally, the three groups of people remained stable on the 11th day, and public opinion gradually disappeared.

4 CONCLUSIONS

The traditional SIR model is widely used in the study of public opinion dissemination. In practice, the main subjects in the process of online opinion dissemination are netizens, and the government, opinion leaders, or media are the objects that influence the state transformation of netizens. These studies need to consider the different emotions of online communication subjects fully.

In this paper, the SPQNR model is constructed by integrating netizens' emotions and simulated by using theoretical data, which can effectively simulate the evolution trend of online opinion dissemination. Finally, combined with the actual data of the "Yugou Middle School Beating Incident" incident on Weibo, we prove that the SPQNR model matches well with the real incident and has certain universality.

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