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Risk analysis for rumor propagation in metropolises based on improved 8-state ICSAR model and dynamic personal activity trajectories

N. Zhang [a], H. Huang [a,*], M. Duarte [b], J. Zhang [b,c]

[a] Institute of Public Safety Research, Department of Engineering Physics, Tsinghua University, Beijing, China
[b] Duke Global Health Institute, Duke University, NC, 27708, USA
[c] Duke Kunshan University, Kunshan City, Jiangsu Province, China

HIGHLIGHTS

- We improve the ICSAR model considering personal psychology.
- Risk for rumor propagation is studied based on dynamic personal activity.
- Day 2 usually reaches the outbreak period for rumor propagation.
- Anti-rumor target at public transportation system is very effective.
- Government should invest more resources in the area with low personal resistance.

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ABSTRACT

Social media has developed extremely fast in metropolises in recent years resulting in more and more rumors disturbing our daily lives. Knowing the characteristics of rumor propagation in metropolises can help the government make efficient rumor refutation plans. In this paper, we established a dynamic spatio-temporal comprehensive risk assessment model for rumor propagation based on an improved 8-state ICSAR model (**I**gnorant, Information **C**arrier, Information **S**preader, **A**dvocate, **R**emoval), large personal activity trajectory data, and governmental rumor refutation (anti-rumor) scenarios. Combining these relevant data with the 'big' traffic data on the use of subways, buses, and taxis, we simulated daily oral communications among inhabitants in Beijing. In order to analyze rumor and anti-rumor competition in the actual social network, personal resistance, personal preference, conformity, rumor intensity, government rumor refutation and other influencing factors were considered. Based on the developed risk assessment model, a long-term dynamic rumor propagation simulation for a seven day period was conducted and a comprehensive rumor propagation risk distribution map was obtained. A set of the sensitivity analyses were conducted for different social media and propagation routes. We assessed different anti-rumor coverage ratios and the rumor-spreading thresholds at which the government started to launch anti-rumor actions. The results we obtained provide worthwhile references useful for governmental decision making towards control of social-disrupting rumors.

* Corresponding author.
E-mail address: hhong@mail.tsinghua.edu.cn (H. Huang).

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Nomenclature

$P_{RC}(t, j)$ The number of rumor carrier in the grid j at the time t.
$P_{RS}(t, j)$ The number of rumor spreader in the grid j at the time t.
$P_{RA}(t, j)$ The number of rumor advocate in the grid j at the time t.
$P_{TC}(t, j)$ The number of truth carrier in the grid j at the time t.
$P_{TS}(t, j)$ The number of truth spreader in the grid j at the time t.
$P_{TA}(t, j)$ The number of truth advocate in the grid j at the time t.
$P_{I}(t, j)$ The number of ignorant in the grid j at the time t.
$P_{IR}(t, j)$ The number of ignorant removal in the grid j at the time t.

1. Introduction

In recent years, options in the style of communication have become more abundant due to highly developed and attractive social media. But social media has also contributed to the spread of false rumors that can hinder the reach of accurate information. A rumor is defined as the information with neither a publicized confirmation nor an official refutation, but it always has a definite negative impact on social safety [1]. Rumor is a critical part of social interaction. Spreading rumors related to environmental problems and natural disasters may have a significant impact on individual lives and the societal stability [2]. For example, in 2011, the nuclear leakage caused by a serious earthquake in Japan resulted in thousands of Chinese people buying salt because they thought ionized salt would protect them from nuclear radiation [3]. In 2010, after a red river had run through the village in Hungary, a rumor spread that the mud contained high amounts of radioactive and alkaline material terrified all of the village inhabitants [4]. In Europe, thirty years ago, a rumor that ten well-known brands of food products contained toxic and cancer-causing compounds was disseminated via leaflets, leading to a public panic and reduced production of the foods [5]. Rumor interferes with our lives and may bring a lot of unnecessary disruption or disturbance to the public. Studying how to prevent or minimize rumor propagation is, hence, very important especially in metropolitan areas where the population density is high and rumor can spread rapidly and widely.

In recent years, there has been a large number of rumor propagation models derived from epidemics as rumor and epidemics are considered to have similar dissemination mechanisms. SIR (spreader–ignorant–removal) model divides people into three states: ignorant, spreader, and stifler [6]. Trpevski used SIS model (susceptible–infective–susceptible) to analyze the rumor spreading in network [7]. Zhao developed SIHR (spreader–ignorant–hibernator–removal) model that considered hibernator coming from spreader due to the forgetting mechanism to analyze rumor spreading [8]. In addition, some researchers used social network [9] and the small world hypothesis [10] to analyze and forecast rumor spreading. For example, in American schools, Lind found that the spreading time grows logarithmically with the number of friends based on BA network [11,12]. Furthermore, some mathematical models such as D-K model [13], physical models such as Potts model [14], and cellular automation model [15] were used to study rumor propagation. However, in these models, spreading mechanism is simple and fewer personal states are not enough to analyze the rumor propagation on a microcosmic scale. Furthermore, these models did not extensively consider personal characteristics and regional features to achieve a more accurate assessment of rumor propagation. Analyzing solely the number of people with these three states (ignorance, spreader, stifled) cannot fully reflect the rumor propagation risk because the rumor propagation risk is usually changed with complicated dynamic population distribution.

Considering influencing factors in rumor propagation, Allport and Treadway described that rumor is the combination of inaccuracy and importance of event [16,17]. Chorus indicated that rumor propagation is also related to judgment of people because the person who has high judgment will not be influenced by rumors [18]. However, there are some limitations in previous research, including the lack of consideration of dynamic population flow and other influencing factors such as the degree of trust of social media, spread probability of inhabitants and conformity.

To overcome the problems listed above, 8-state ICSAR model [19] was developed that separates people into 8 states, then the microcosmic change of number of the people with different states could be obtained. In this study, we improved the 8-state ICSAR model that considers more influencing factors including rumor ambiguity, governmental threshold to spread anti-rumor information, coverage ratio of government, frequency of rumor refutation, personal resistance and conformity to show the individual difference and increase the accuracy of comprehensive rumor propagation risk. In addition, dynamic personal activity trajectory is considered based on the 'big' traffic data of Beijing because information flow accords with population flow to a certain extent. Comprehensive consideration on governmental refutation of rumors contributes to reduce economic losses and unnecessary casualties. Finally, we used the improved 8-state ICSAR model to estimate the comprehensive rumor propagation risk in Beijing. The results are expected to help the government make more efficient plans to prevent rumor propagation related to environmental and natural disasters.