



Analysis of the impact of education rate on the rumor spreading mechanism



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HIGHLIGHTS

- A more realistic rumor spreading model, called SEIR, is derived.
- Two groups of ignorants: educated and non-educated individuals are considered.
- Population's education rate is incorporated as the rumor control factor.
- Impact of the population's education rate on the rumor dynamics is examined.
- The more there are educated individuals, the weaker is the rumor influence.

ARTICLE INFO

Article history:

Received 30 April 2014
Received in revised form 8 July 2014
Available online 17 July 2014

Keywords:

Rumor
Education rate
Educated ignorant individual
Rumor spreading control coefficient

ABSTRACT

Education remains one of the fundamental factors in people's lives. The education rate of a population reflects the degree of vulnerability of a typical individual to any kind of information. In general, one distinguishes two types of individuals in a population: educated individuals and non-educated individuals. Unlike an educated individual, a non-educated individual has a high chance to accept any untrue information (rumor). In this study, the classical SIR rumor spreading model is extended to consider the forgetting mechanism and population's education rate, to thus yield the SEIR rumor spreading model. A system of nonlinear ordinary differential equations that describes the dynamical behavior of the SEIR rumor spreading model is derived. Further, analyses of our model are carried out to determine the rumor final size and to investigate the impact of education rate on the rumor final size. Our analytical and numerical results show that the more there are educated individuals within a population, the smaller is the rumor final size. In brief, education significantly contributes to the rumor spreading cessation.

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1. Introduction

The study on the rumor spreading mechanism began in the 1960s with the classical SIR model, known as the DK model, developed by Daley and Kendal [1]. They developed a model that analyzes a rumor spreading mechanism by considering a population which they compartmentalized into three distinct groups with respect to the rumor as follows: people who know and are transmitting the rumor (spreaders), people who do not know the rumor and are susceptible to be "infected" (ignorant individuals), and people who know but do not transmit the rumor (stiflers) [2]. In the DK model the authors assumed that the rumor is transmitted through peer-wise contacts of a spreader with ignorant individuals. As a cornerstone, the DK model has been modified and extended by many researchers in order to get insight into the rumor spreading mechanism.

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Maki and Thompson [3] extended the DK model leading to a model, known as the MK model, suggesting an additional hypothesis. In the MK model, the authors assumed that whenever two individuals who know the rumor have contact, one of them (the initial one) will inevitably abandon the rumor and thus will not spread it any further (turning into a stifler). Based on these two early models, several studies on the rumor spreading process and its applications have been carried out through different approaches such as mathematical theory [4], physical theory [5], and stochastic theory [6–8]. However, some shortcomings were revealed in the DK and MK models as their formalization did not take into account the topological properties of the networks considered and in addition, their applications are only limited to small-scale social networks [2]. Hence, many factors and concepts that may contribute to rumor spreading and the rumor spreading control were gradually pointed out by scholars, thus yielding several distinct rumor spreading models for analyses through different approaches.

Moreno et al. [6–8] analyzed a rumor spreading model on a scale-free network through a stochastic approach. Their results showed that the uniformity of the network has a great impact on the rumor spreading mechanism. Zanette [9,10] considered a small-world network for the analysis of the dynamical behavior of rumor spreading and found that there exists a threshold beyond which the rumor is not disseminated. Isham et al. [11] analyzed the final distribution size of the rumor on a general network. Han et al. [5] formalized a model called the Energy model through physical theory. They postulated that the energy that each spreader possesses to communicate the rumor differs between individuals, and that this energy gradually diminishes as time goes. Castellano et al. [12] made use of statistical physics to present a rumor spreading model. Nekovee et al. [13] extended the classical SIR rumor spreading model taking into account the forgetting mechanism. Zhao et al. [14] refined the model in Ref. [13] by introducing the remembering mechanism in addition to the forgetting mechanism previously used in Ref. [13]. In both these latter models, the forgetting rate was assumed to be constant. Zhao et al. [2] insisted that the forgetting rate is a function depending on time. Their results showed that the final size of the rumor is much larger when the forgetting rate changes over time, compared to the case where the forgetting rate is constant. The forgetting rate is thus added to the stifling factor as a component of the control factors in the rumor spreading analysis.

As noticed from the previous studies, the rumor spreading cessation relies mostly on these two factors: the stifling and the forgetting mechanisms [1,3,13]. However, we believe that besides these two influential factors, the population's education rate is also an influential factor in rumor spreading cessation. This hypothesis spans from the plausible observations that the more an individual is educated, the stronger is his/her ability to evaluate the credibility of the rumor, and the quicker is his/her disinclination or forgetfulness of the rumor. Education can then be considered to catalyze the forgetfulness and the stifling mechanisms. One could even say that the forgetting factor and the stifling factor are components of the education factor. In short, educational influence on rumor spreading needs to be considered when talking about rumor spreading control. We thus extend the classical Spreader–Ignorant–Stifler rumor spreading model [13] to include the three factors: the forgetting rate, the stifling rate, and the education rate of the population considered. Given that the first two factors have been analyzed in the previous studies, we will then focus on the third factor in this paper. As a result, we develop a rumor spreading model, the SEIR model, based on the studies in Refs. [3,13], considering a closed homogeneously mixed population that we compartmentalize into four distinct rumor-classes: the spreaders class (S), the educated ignorant individuals class (E), the non-educated ignorant individuals class (I), and the stiflers class (R).

We structured this paper as follows. In Section 2, we give a description of our model and we derive a system of nonlinear ordinary differential equations that describe the interactions and progression dynamics of individuals from one rumor-class to another. In Section 3, extensive calculations are performed to investigate the contribution of the education rate on rumor spreading cessation. In the last section, numerical simulations are carried out for better understanding of the dynamic behavior of the rumor spreading mechanism and the impact of the education rate on rumor influence.

2. Model formulation

Rumors generally propagate via the direct contact of a spreader with other individuals who have never heard the rumor, namely ignorant individuals. So, an ignorant is aware of the rumor when s/he contacts a spreader and both end up in any form of discussion about the rumor. In that situation, the ignorant individual becomes a spreader when s/he is convinced of the truth of the rumor and then decides to inform others. However, note that “a convinced” ignorant can possibly refuse to spread the rumor, or alternately a spreader can lose interest in the rumor and then decide not to spread the rumor any further. In these two situations, both become stiflers. A stifler is therefore either an individual who knows the rumor but who is not spreading it or a spreader who, with time, loses interest and is no longer spreading the rumor. Furthermore, one can notice that the tendency of accepting a rumor as credible information differs from one ignorant to another. This can be explained by the strong background knowledge that some of the ignorant individuals possess. These types of ignorant individuals, once aware of the rumor, generally raise some reasonable questions and/or logical arguments in order to assess the credibility or the validity of the rumor. We hence distinguish a new group of individuals that are educated ignorant individuals. Education is therefore among the factors that also contribute to the cessation of a rumor spreading and is an important aspect that has not been considered in previous studies.

In order to contribute to the rumor spreading process studies, we make use of the classical SIR rumor spreading model with consideration of forgetting mechanism [13] and incorporate a new factor that is education rate of population. As a result, a new rumor-class is introduced into the SIR rumor spreading model to yield the SEIR rumor spreading model. The SEIR rumor spreading model is formulated as follows.

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