Rumor Dissemination in Complex Networks

(CS785A: Multi-agent systems project report)

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(Dated: April 22, 2017)

Rumor is indeed a very important aspect of social interaction. Its so important that it can even shape public opinion. In the light of it, a canard can quite easily cause social panic and impact the well being of the society. The way rumors have spread over the years has changed drastically. From mouth to mouth, to telephone,messages,e-mail,blogs and specially through social network. With the increasing prevalence of new media, which has simplified the process of create,modify and share. People can now acquire as well as spread the word with much faster velocity.

I. INTRODUCTION

Rumors are an important form of social communications, and their spreading plays a significant role in a variety of human affairs. The spread of rumors can shape the public opinion in a country, greatly impact financial markets and cause panic in a society during wars and epidemics outbreaks. The information content of rumors can range from simple gossip to advanced propaganda and marketing material. Rumor like mechanisms form the basis for the phenomena of viral marketing, where companies exploit social networks of their customers on the Internet in order to promote their products via the so-called 'word-of-email' and 'word-of-web'.

The rumor is propagated through the population by pair-wise contacts between spreaders & rest. Any spreader involved in a pair-wise meeting attempts to 'infect' the other individual with the rumor. If the person is ignorant he then becomes a spreader. An important shortcoming of the above model is that they either do not take into account the topology of the complex social network or use highly simplified models of the topology. Such a model may thrive if the only way to spread a rumor would be to be physically present but, such is no longer the scenario in the current world where social media dominates the gathering and spreading of rumors.

In the rumor diffusion scenario, spreaders must bear the risk of punishment. When the diffusion increases more than the threshold, the rumor must bear the 'risk' of being punished so as to control further divergence. In addition, individuals' behavior and decisions are often influenced by many external factors, such as the opinions of friends, the perceived punishment risk, and personal knowledge. Interestingly, this effect is similar to the "prisoner's dilemma" in the game theory. The diffusion of rumor can be made a 'decision making problem'. Players imitate strategies of neighbors, i.e after a round of rumor diffusion, each individual selects one of his neighbors to compare payoffs and then decides whether or not to take the selected neighbors strategy. In general, if the strategy of the selected neighbor can help him to gain higher payoff than his strategy in the past round, then the neighbors strategy would be adopted with a higher probability and then the game begins.

The following explains the model in much more detail.

II. MODEL

This is a **N** player game with the whole population divided into four groups including Ignorant, Spreaders, Immunes (Vaccination) and Recovered, that could be denoted by **I**,**S**,**V** and **R**, respectively. Ignorant are the people who never heard the rumor or heard the rumor but not spread it temporarily (note that if the ignorant who have heard the rumor heard rumor again, he may spread it. This is because the so-called social reinforcement). Spreaders are those who are spreading the rumor. Immunes are the people who heard the rumor but never diffuse it. Recovered are those individuals who refuse to diffuse the rumor after they successfully diffuse the rumor. Some assumptions regarding each round is as follows:

1. A diffusion round of rumor is defined as - from there exists one initial spreader in the network until no diffused individuals.

2. Initially (round-1), when the ignorant heard the rumor, he will decide whether or not to diffuse rumor with equal probability, i.e. diffusion rate is 1/2 at the first round.

3. In the evolutionary game, individuals are allowed to adopt their neighbors strategy after each round. When a node **j** heard the rumor from a spreader **i**, the individual will not diffuse the rumor with probability **p**, or imitate his neighbors strategy with probability **1-p**. In general, node **i** knows the previous round payoff of his neighbors, so he will decide whether or not to take his friends previous round strategy.

To calculate tie strength we use the following formula :

$$w_{ij} = (k_i k_j)^{\theta} \tag{1}$$

Here θ is a constant

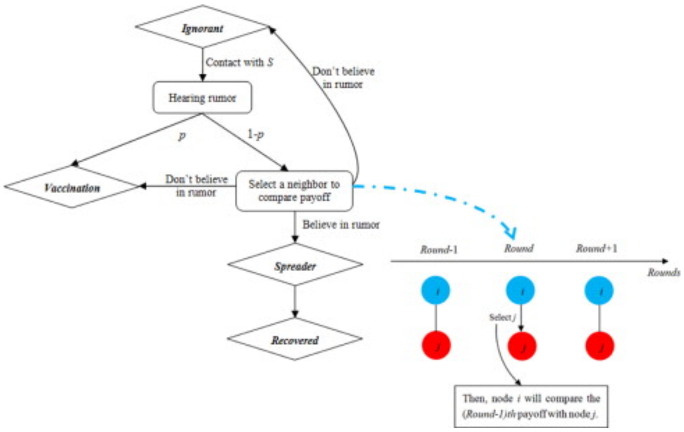

FIG. 1. Schematic diagram of the diffusion of rumor and strategy imitation. In every round, when an individual heard rumor, he will decide whether or not to spread the rumor by evaluating the benefit.

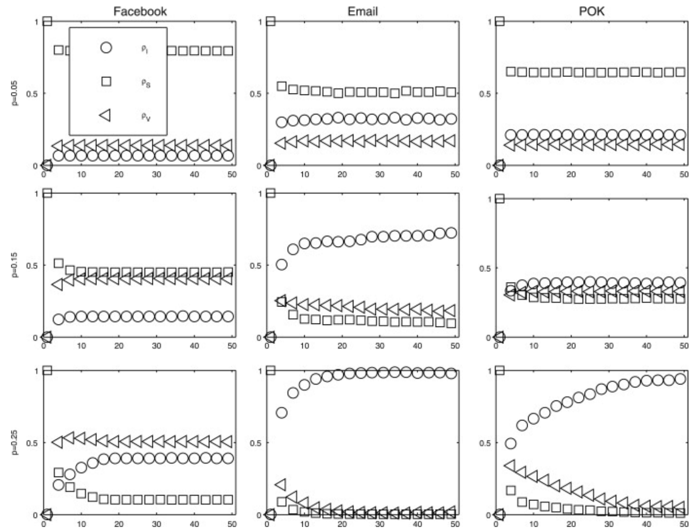

FIG. 2. The evolution of the fraction of ignorant, spreaders and vaccination with the rounds of the evolutionary dynamics. Parameters are set as =1,=0.1,b=1. At the end of every rumor process round, randomly select $\zeta = 0.1$ fraction of spreaders to be punished. Top row corresponds to the **p=0.05**. Middle row corresponds to the **p=0.15**. Bottom row corresponds to the **p=0.25**

An individual **j** will select a neighbor **k** to update his strategy, and the neighbor **k** is selected with probability:

$$P_k = \frac{\vec{\omega}_{jk}^{\alpha}}{\sum_{k\epsilon_{N_j}} \vec{\omega}_{jk}^{\alpha}} \qquad (2)$$

here $\vec{\omega}_{jk}^{\alpha}$ shows tie-strength and α shows tie strength. $\alpha > 0$ shows stronger ties and $\alpha < 0$ weaker ties. $\alpha = 0$ implies a random select of neighbor strategy.

An individual spreading a rumor also bears the risk of punishment, successful spread gives a payoff of **+1**, not spreading gives **0** payoff but, caught while spreading induces a punishment hence a **-l** payoff. While rumor spreads, punishment must be entailed to control/curb it otherwise it can go viral. We adapt three different strategies for punishment

1. Randomly select ζ fraction of spreaders to be punished, where $0 \leq \zeta \leq 1$

2. Spreaders are ranked by the degree from large to small, and select the first ζ fraction to be punished.

3. Spreaders are ranked by the degree from small to large, and select the first ζ fraction to be punished.

III. RESULTS

Three kinds of datasets were used namely, Facebook New Orleans, Email dataset And POK community dataset. All the datasets could be obtained from the Levich Institute and Department of Physics of the City College of the City University of New York.

Fig.2 shows the fractions after 50 rounds of simulation for different population types. The interesting part to look at is the spreaders ratio. The data points seemed to stabilized around 50 rounds therefore only those have been shown. Also simulating for more rounds indulged a lot of computational time hence we restricted ourselves to only 50 rounds. When the punishment strategy is taken, that leads to a progressive decrease of the spreaders but all the while some spreaders still thrive. Clearly data with more nodes had more spreaders ratio i.e Facebook with so many more nodes than E-mail had more spreaders even after 50 rounds. We notice that regardless of the complexity of the node system the ratio of spreaders decreases with increase in **p** but, it should also be noted that the extremes of this cannot be applied in real life as enforcing very high punishment costs can cause part of population to retaliate and can influence unbalance.

It is quite clear in Fig.3 that the punishment cost should be a deterministic variable in calculating for the spreaders fraction. Ideally, should the punishment cost increase the ratio of spreaders should decrease and the number of ignorant should increase but only up to a certain limit as the more and more neighbor nodes have had a punished previous round, the node in consideration would defer to follow the same strategy more and more. Following a punished spreaders strategy makes it feel most likely to be punished . The previous discussion to some tries to imitate the real society but clearly not on the extreme ends.

We even ponder on the fact that how α (variable to determine the tie-strength between neighbor node) can affect the distribution of spreaders, immunes and ignorants (see Fig.4). Note that in cases of $\alpha < 0$ the fraction of spreaders increases whereas fraction of ignorant decreases. People rarely indulge in strategies of those who are not close to them (which is the physical meaning of tie-strength). Coherently when $\alpha > 0$ the ratio

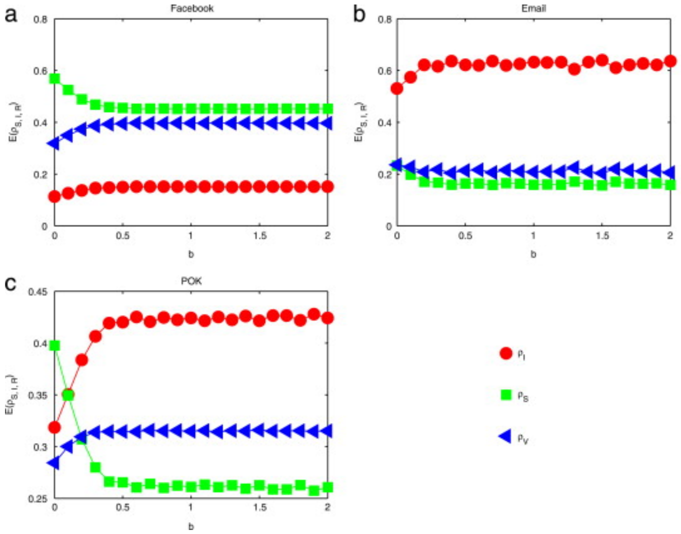

FIG. 3. The evolution of the fraction of ignorant, spreaders and vaccination for different punishment cost **b** on the first 50 rounds. Parameters are $\alpha = 1$,$\beta = 0.1$,**p=0.1**. After every round ζ is chosen to be **0.3**, which decides the part of spreader population to punish.

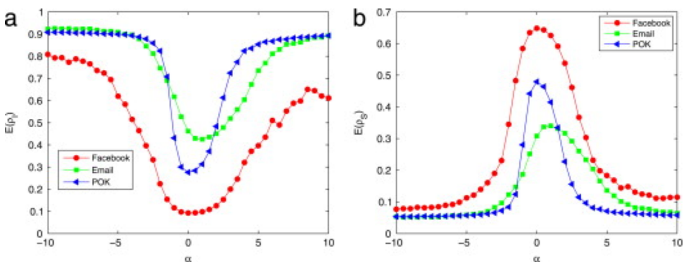

FIG. 4. The average final fraction of ignorant and spreaders as the function of α in different social networks. Each data point is obtained by averaging the first 50 rounds. The results were implemented with $\beta = 0.1$,**b=1**,**p=0.1**. ζ is chosen to be **0.1**.

of spreaders and ignorants were decreasing and increasing respectively. People tend to follow the strategies of neighbors with better relationships and hence try imitating their strategies (Our aim was to imitate basic human behavior). If α were to be removed from the equation then nodes would randomly chose their strategies, which leads to very large number of spreaders.

We analyze the results of different punishment strategies in Fig.5. We notice that upon punishing nodes randomly or with lower degree doesn't really curb the fraction of spreaders instead does exactly opposite as the nodes with higher degree have 'more' friends and therefore continue spreading the rumor at an extravagant rate. However punishing a node with higher degree is quite effective in curbing the fraction of spreaders which in turn reduces the rate of diffusion of rumor considerably.

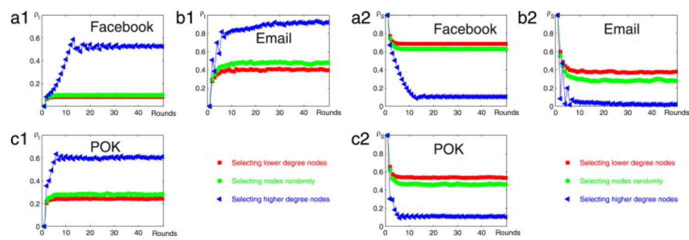

FIG. 5. The final fraction of spreaders and ignorant for different punishment strategies for 50 rounds. Parameters were **p=0.1**,$\alpha = 1$,$\beta = 0.1$,$\zeta = 0.1$,**b=1**. a1,b1&c1 are for the ratio of ignorant where a2,b2&c2 are for the ratio of spreaders.

IV. CONCLUSION

We tried to introduce and control parameters which would help imitate the way a real rumor diffuses in the social network like the punishment factor ζ and risk coefficient β which determines when the punishment should initiate. However we noticed that the punishment factor was much more effective than β. We also thought of assigning payoff to different nodes differently and similarly to punish higher degree and lower degree nodes differently but came to a different conclusion. We thought whether a lower degree node getting punished less & a higher degree node getting punished severely can be assumed to be normalized to a single value hence a **-1** payoff. A similar argument can be provided for the payoff during successful spread. We tried our best to inculcate the idea of rumor diffusion as an evolutionary game where a player can check his neighbor's history and tie-strength to decide whether to imitate his strategy or not. Conclusively we would like to thank **Professor Hernan Makse**, Levich Institute, Steiman Hall 1M12, City College of New York, New York, NY 10031 **hmakse@lev.ccny.cuny.edu** for his data on Facebook New Orleans, E-mail and POK community.

V. REFERENCES

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