**EPIDEMIC CASCADING PREVENTION WITH PARTIAL KNOWLEDGE OF THE SPREADING NETWORK**

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1. **Abstract**

Epidemic cascading and prevention is an interesting study in network analysis. Understanding a cascade’s spreading pattern and developing a practical immunization strategy will be helpful in preventing a major outbreak and reducing the economic loss from quarantine, medical costs, etc.

Scholars have developed several spreading models and immunization strategies regarding the spreading of epidemics in social networks. While proven to be helpful in understanding epidemic spreading, they require full knowledge of the network, which in most cases is not practical. Therefore, if an immunization strategy could be developed based upon partial knowledge of the network, while still proving to be effective, it would be more practical than vaccinating strategies based upon full network knowledge in terms of implementation in a real world where the full graph of a network is usually inaccessible.

Our project is a study in development of an effective targeted immunization strategy when only partial network knowledge is available. The targets of vaccination will be decided based upon node characteristics such as centrality scores of the known subgroup instead of upon the whole network. There strategies will then be applied in an epidemic spreading simulation based upon human contact in a network constructed from human interaction data collected in an American high school by Stanford researchers[1]. Effectiveness will then be evaluated by comparison with random immunization.

1. **Introduction**

Contagious diseases are still among the greatest threats to the world, even in the 21st century. Although the mortality rate has decreased significantly thanks to the enhancement in medical care, epidemic cascades are still the cause of considerable loss when facilities such airports, factories, schools and others are forced to shut down or operate at limited capabilities. Therefore, stopping an epidemic at an early stage can be of great value.

Vaccination has proven to be an effective mechanism against infectious diseases since Edward Jenner invented the cowpox vaccine. However, due to logistical and economic factors, and the fact that vaccines can sometimes carry their own risks, it may be infeasible to vaccinate all of the susceptible population [2]. Therefore, development of strategies to prevent an epidemic outbreak with only targeted vaccination are ongoing. However, to implement these partial vaccination strategies one still needs the full network knowledge, which may be unavailable to prohibitively expensive to obtain.

This predicament leads to the necessity of developing immunization strategies with only partial knowledge of the network. Here “partial knowledge” means the designer of the vaccination strategy will only know a subset of vertices in the network. The goal for our project is to develop an effective vaccination strategy with only partial network knowledge. An effective strategy means is one in which targeted vaccination gives a considerably better result in preventing a major outbreak in a simulation when compared to random vaccination with the same level of coverage.

The rest of the report will consist of three sections:

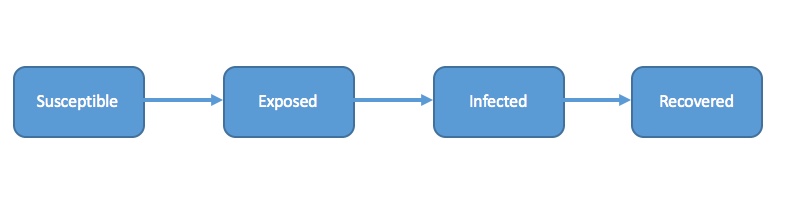
The first part will be introducing the modeling of the epidemic cascading and of the human contact network on which we are studying. The epidemic cascading model will be the SEIR model with network edge weights derived from the human contact network from an epidemic study conducted in 2010 by Stanford researchers. There the human contacts data related to disease transmission, Close Proximity Interactions, are recorded with wireless sensors during a typical day in an America high school with a population of approximately 800 students, teachers, faculty, and staff.

The second part will be a discussion upon the relationship of a structure of a network and its robustness against epidemic spreading.

The third part will be the strategies developed upon partial knowledge of the network. There we will decide which vertices (persons) have the highest risks to spread the disease by examining different centrality scores. Partial vaccination will be applied, and a cascade simulation will be conducted upon the network. The experimental results will then be evaluated by comparison with the effects of random vaccination.

1. **Modeling of the epidemic and of the transmission network**

In this project the epidemic model used is the SEIR model. In this model, progression of a disease is divided into four major phases: Susceptible, Exposed, Infectious and Recovered [Figure 1]. This model is useful because many diseases exhibit a significant incubation period, during which an individual is a disease carrier, but is not contagious or showing any symptoms.



Capturing the contact network related to infectious disease is a key element in a reliable epidemic study. Previous data gathering methods include using surveys, socioecological networks, and mobile devices like cell phones. None of them are able to capture interpersonal contact data directly related to the transmission of disease.

For diseases like influenza and SARS, one of the major transmission vectors is water droplets spreading from one to another when two people are in close proximity (usually under 3 meters). In this report, this kind of interaction is referred to as Close Proximity Interactions(CPIs). The longer time two persons are within close proximity, the higher the transmission probability.

Therefore, a human contact network with this CPI data is more suitable for an epidemic study compared to an unweighted network. Since the possibility of disease transfer from one person to another is proportional to the amount of time in which they are in close proximity, it is reasonable to put the total amount of time of such CPIs as the weight of edges between these two vertices in the network. For example, if a student had lunch for 15 minutes with his teacher seated at an adjacent table and then went to office hours and talked with the same teacher for 30 minutes, the weight of the edge between them should be 45.

Thanks to modern wireless sensor technology, the CPI data can now be collected with ease. The Stanford scholars requested every individual in an American high school wear a wireless sensor for a day. When two sensors were within certain distance(3m), the sensor tracks the length of time during which the sensors are in close proximity. Researchers collected 762,868 CPIs at a maximal distance of 3 m among 788 individuals [1].

This data will be used to construct the human contact network in our project, and the effectiveness of the proposed immunization strategy will be evaluated by the proportion of the population infected after the epidemic is complete.

**Reference**

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[2] J. Rushmore, D. Caillaud, R. J. Hall, R. M. Stumpf, L. A. Meyers, and S. Altizer, "Network-based vaccination improves prospects for disease control in wild chimpanzees," *Journal of The Royal Society Interface*, vol. 11, no. 97, pp. 20140349–20140349, May 2014.