Title: Behavioral Modeling for Epidemic Planning and Response

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Summary: This research develops novel methods that leverage recent advances in social media, online-labor markets and pervasive computing to infer individual and collective behaviors and study their impact on epidemic planning and response. It investigates new methods that use online-labor markets, in particular mobile phone based markets, Amazon mechanical turks and other social media data such as twitter to collect information about individual and collective behavior. The work is based on three novel ideas: (i) Use of model-based methods for providing highly disaggregated socio-temporal information on the state of the epidemic, (ii) concept of active learning for directed surveillance and situation assessment to improve how, where and what behavioral information would be collected, and (ii) extension of active learning to distributed crowd-sourced active learning environment to produce what we call "mood and behavioral weather map". The data is then used to obtain better models that provide more accurate state assessment and forecasts. The following illustrative studies demonstrate the applicability of our methods.

(1) Social Distancing Versus Vaccination Behavior Study

Intervention strategies such as social distancing and vaccination are challenging because many parameters such as vaccine efficacy, vaccine uptake, compliance with social distancing, extent of social distancing and delay in implementation come into play. This work focuses on the extent of social distancing, and its effects on the epidemic dynamics, for a given level of vaccination rate and vaccine efficacy. In particular, we are interested in understanding how vaccination and social distancing interact. While there has been some work on optimal policy design that combines both approaches, this has not been fully understood, especially in networked models. Highlights of our results are stated below. These can help policy makers decide which intervention to enforce given a wide range of values for these parameters:

(i) The extent of social distancing turns out to have a significant impact on how effective the intervention is. The benefits depend on the parameter space, with maximum benefits in the intermediate ranges of the social distancing rate. The benefits of social distancing increase as the efficacy of the vaccine decreases. Further, the effect of vaccine efficacy increases as the vaccination rate increases. (ii) When one intervention is fixed, the mean infection rate appears to have two distinct regimes. Specifically, there exists a critical social distancing rate, q^*, such that the mean infection rate is a concave function of q below q^*, but it becomes a convex function when q is above q^*. Further, the rate of change in the mean infection is minimized at q^*. (iii) Social distancing, when applied with a high compliance rate, can be highly effective in controlling the spread of infections. However, even a small delay of one day, can render the intervention ineffective. (iv) For vaccination to be an effective intervention, both the efficacy of the vaccine and the rate of vaccination must be at least 50%. (v) If the vaccination rate is low and the vaccine efficacy is low, then it needs to be combined with immediate social distancing with a compliance rate of 20% or more.

(2) Online Surveys for Disease Surveillance

The recent experience with Ebola epidemic highlights the need for surveillance and early detection and early warning. Typically, active data collection is one of the most expensive sources of data since it requires health care providers to regularly monitor the citizens but it is also the most useful type of data. It also requires a lot of trained personnel, resources and high level of coordination among hospitals and institutions that collect data, making it challenging to implement in developing countries like India. We study the potential utility of online surveys for epidemic surveillance of diseases like Influenza. In many developing countries, services like Amazon Mechanical Turks (AMT) are quite popular and used by large sections of the society. However, the demographics of AMT workers is quite different from the general population. Understanding how to use data from such surveys for epidemic surveillance is a challenging problem. We develop a simulation based approach for evaluating the use of AMT for epidemic state inference.