COVID Information Commons (CIC) Research Lightning Talk

Transcript of a Presentation by Xin Zan (University of Florida), July 26, 2023

Title: Data-driven Adaptive Testing Resource Allocation Strategies for Real-time Monitoring of Infectious Diseases

YouTube Recording with Slides

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Transcript

Slide 1

Xin Zan:

My name is Xin Zan and I'm a Ph.D. candidate in the department of Industrial and Systems Engineering at the University of Florida. This is a joint work with Dr. Hall, Dr. Hladish, and Dr. Xian in multiple departments at University of Florida. Today, I'm going to share our work about data-driven adaptive testing resource allocation strategies for real-time monitoring of infectious diseases.

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As everybody knows, infectious disease, including the COVID-19 pandemic, has continued to be a major global public health threat due to the increasing cost of health care and the cost of deaths. So it is very critical for us to detect the disease outbreaks as early as possible to support timely implementation of public health interventions and to contain the rapid spread of infectious diseases at an early stage. We know that mass testing is key to tracking the spread of pandemics based on diagnostic tests.

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The challenge is that testing availability is limited, especially at the early stage of novel or infectious disease. This will lead to insufficient testing data. Insufficient testing data will impede our analysis of the spread of infectious diseases and also impede the effective monitoring of the infectious diseases.

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In the current literature, there are many works about the modeling and monitoring methods in epidemiology to monitor the infectious diseases. Unfortunately, they are not handling the inadequate data, so the models are unreliable. To deal with limited testing availability, there are a lot of pooled testing strategies to handle. This will increase the overall testing efficiency, but it will but it will increase reporting delays and lower testing sensitivity. This will impede our real-time monitoring. In this research work, we focused on individual diagnostic tests. There are many works about resource allocation strategies to help us implement the test allocation, like MAB map (Multi-Armed Bandit) techniques. But all of these methods are applicational agnostic. How to deal - how we can integrate these techniques into our problem is still challenging.

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So in this work, our goal is to integrate some physical information with the insufficient testing data to help us to properly characterize spatial and temporal transmission patterns of infectious diseases. Based on that, we will develop our data-driven test allocation strategies for quick disease outbreak detection.

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Here is an overview of our proposed methodology. Our first step is to collect the testing data based on the diagnostic test allocated. In this work we have based on - we are focusing on updates - the test allocation based on the geographic unit of census block groups. Within each block group, we assume the random sampling. After we collect all the testing data from all the block groups, we combine these testing data though limited with the physical information to assess the appropriate health risk. We will combine physical information associated with the transmission dynamics and the health disparity of infectious diseases. The transmission pattern - the transmission dynamics will help us to identify the positive cases. The health disparity will help us to pay more attention to the vulnerable population groups. After we assess the health risk, we will update our test allocation. Along the time we will also - it will also help us to detect the possible disease outbreaks. Along the time, we will do these steps iteratively.

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And first of all I would like to introduce our physics-informed model. We modeled the infection rates using the patient framework and to account for the future change we will also model the prospective infection risk using symmetric transmission metrics. Here, the transmission metric is decomposed into two patterns. One is about the local transmission patterns and another one is imported transmission patterns.

The first one, the local transmission pattern, will characterize the transmission within each group and it will characterized by the local condition risk scores. For the imported transmission patterns, it will characterize the transmission among all the groups, so it will be characterized by the connected scores. All these scores will be evaluated by some associated factors that will lead to the spread of the infectious diseases. For the possible factors, I will introduce them in a few slides.

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Apart from the infection risks, we also account for the severity risk measures, which is intuitive that the population groups that were at the higher risk of getting severely infected will definitely be drawn more attention. Similarly, it will be characterized by this severity risk score. For this part it can account for the health disparity measure.

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By combining these two risks - the infection risks and the severity risk - we will assess the risk levels for each group. By using this, we will update our test allocation. The basic idea is to balance between the exploitation and exploration. That is, we will allocate more tests to the block groups that have the highest risk levels. We will allocate more tests to the block groups that lack the test so their risk levels will be of the high uncertainty. Balancing these two, we will intelligently update our limited tests. Apart from this informative statistic, we will also update the allocation proportional to the population. This is intuitive because the groups that that has a larger population will definitely be allocated more tests even they have the same risks.

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After that, we will simultaneously monitor the infection rates over all the groups. The basic steps is when we first estimate the risks and then diagnose the most suspected block groups that are at the highest risk and the update our monitoring statistic. We then guide our detection decision.

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We have done some simulation motivated by the COVID-19 pandemic in north central Florida, which includes nearly 600 block groups. Here is how we evaluate the scores of the three types of scores in our physics informed model, which is pre-evaluated based on the medical geographic analysis. We use the population density and the community infection rates to characterize the local contagion rate, measuring the neighborhood condition risk within each group. And we use the point distance and the stay at home rate, which is the proxy factor for mobility score. This will measure how frequently the two groups interact. Also we use the ADI, the Aerial Deprivation Index, which indicates a socio-economic deprivation in a geographic area to measure the severity risk. All this data, all these factors are publicly ready and available.

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In the simulation, we generate three different transmission cases regarding different social distancing adherence. In the case where there is very limited adherence and in the case when the positive rates will reach a steady state and in the case that there will be a second wave.

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We will evaluate our method regarding different perspective of the performance. Regarding the model estimation, the calibration of our physics informed model we can see that regarding the accuracy and the convergence the estimation is pretty good.

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For our allocation, we compare it with some competing algorithms and we find out that compared to other algorithms, our method can achieve robust - overall robust - and satisfactory performance regarding the number of positive cases.

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For the monitoring part, the performance is generally consistent with our allocation performance which is intuitive because better allocation performance will lead us to collect higher quality testing data. Based on higher quality testing data, we can project the transmission patterns better and then we can detect the the outbreaks in an effective way. So our proposed method can achieve the shortest detection delay in detecting the disease outbreaks.

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So, in summary, we developed a data-driven test allocation strategy and by leveraging the physical information into model with the limited testing data to properly project and describe the spatial and transmission patterns. Based on this we can use this for quickly detecting the disease outbreaks and we also investigate our method in a theoretical and empirical way and to guarantee the capability of the allocation and the monitoring.

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So that is my presentation and I'm open to your questions and comments. Thank you for your attention!