MITIGATING COVID-19 TRANSMISSION IN SCHOOLS WITH DIGITAL CONTACT TRACING

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ABSTRACT—Precision mitigation of COVID-19 is in pressing need for postpandemic time with the absence of pharmaceutical interventions. In this study, the effectiveness and cost of digital contact tracing (DCT) technology-based on-campus mitigation strategy are studied through epidemic simulations using high-resolution empirical contact networks of teachers and students. Compared with traditional class, grade, and school closure strategies, the DCT-based strategy offers a practical yet much more efficient way of mitigating COVID-19 spreading in the crowded campus. Specifically, the strategy based on DCT can achieve the same level of disease control as rigid school suspensions but with significantly fewer students quarantined. We further explore the necessary conditions to ensure the effectiveness of DCT-based strategy and auxiliary strategies to enhance mitigation effectiveness and make the following recommendation: social distancing should be implemented along with DCT, the adoption rate of DCT devices should be assured, and swift virus tests should be carried out to discover asymptomatic infections and stop their subsequent transmissions. We also argue that primary schools have higher disease transmission risks than high schools and, thereby, should be alerted when considering reopenings.

Index Terms— Asymptomatic infection, COVID-19, digital contract tracing, mitigation strategy, social distancing, susceptible-exposed-infectious-removed (SEIR).

I. INTRODUCTION - Manuscript received January 25, 2021; revised March 26, 2021; accepted April 11, 2021. This work was supported in part by the National Natural Science Foundation of China under Grant 61773091, Grant 11875005, Grant 61976025, and Grant 11975025; in part by the Liaoning Revitalization Talents Program under Grant XLYC1807106; in part by the Natural Science Foundation of Liaoning Province, China under Grant 2020-MZLH-22; and in part by the Major Project of the National Social Science Fund of China under Grant 19ZDA324. (Hao-Chen Sun and Xiao-Fan Liu are co-first authors.) (Corresponding authors: Xiao-Ke Xu; Ye Wu.) Hao-Chen Sun and Xiao-Ke Xu are with the College of Information and Communication Engineering, Dalian Minzu University, Dalian 116600, China (e-mail: 2332697351@qq.com; xuxiaoke@foxmail.com). Xiao-Fan Liu is with the Web Mining Laboratory, Department of Media and Communication, City University of Hong Kong, Hong Kong (e-mail: xf.liu@cityu.edu.hk). Zhan-Wei Du is with the WHO Collaborating Centre for Infectious Disease Epidemiology and Control, School of Public Health, LKS Faculty of Medicine, The University of Hong Kong, Hong Kong, and also with the Laboratory of Data Discovery for Health, Hong Kong Science and Technology Park, Hong Kong (e-mail: duzhanwei0@gmail.com). Ye Wu is with the Computational Communication Research Center, Beijing Normal University, Zhuhai 519087, China, and also with the School of Journalism and Communication, Beijing Normal University, Beijing 100875, China (e-mail: yewu@bnu.edu.cn). Digital Object Identifier

10.1109/TCSS.2021.3073109 and 600 thousand COVID-19-related cases and deaths as of July 2020 [1], albeit a mass of social distancing orders that have been enacted worldwide [2]. In the absence of pharmaceutical interventions, measures to reduce the overall burden of viral infection—including social distancing [3], case isolation [4], quarantine of susceptible [5], closure of public places [6], and increased availability of diagnostics— are paramount in planning for the months ahead [7]. Given the epidemiological disparity of strategies with the substantial economic and societal costs to sustain the virus transmission [8], there is a clear need for precision mitigation to alleviate the persistent burden of epidemics and prevent and respond effectively to future pandemics [9], [10]. Mass education is an indispensable foundation of modern society. Nevertheless, schools and universities, where teachers and students have long-term and intimate connections, are particularly risky areas for disease transmission [11]. To prevent campus outbreak, school suspension and closure of classes and grades are generally considered feasible approaches that can effectively reduce the number of infections [12]–[14]. However, school suspension or parts thereof can also result in a large number of students quarantined, either concentrated or at home, causing substantial socioeconomic costs and psychological problems [15]. Therefore, the critical question in effective retention lies in the selection of an effective mitigation strategy while inflicting a minimum cost to the society and economy [16]. Since large-scale human experiments with disease control measures are costly and risky to conduct, mathematical modeling offers a viable way to examine the impact of these measures with varying rates of controls [17]. Traditional transmission models are built upon mechanistic ones, such as the susceptible-infectious-removed (SIR) or susceptible-exposedinfectious-removed (SEIR) models [18]. However, the parameter settings of the models can vary among different diseases. Recently, animal experiments on cynomolgus macaques inoculated with the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) have shown that the virus shedding can be presymptomatic and volatile [19]. Based on this finding, we propose an SEIR model with a variable infection rate that takes into account the frequent shift of SARS-CoV-2 from infections hence their transmissibility.

II. LITERATURE SURVEY

A. Mitigating COVID-19 Transmission in Schools With Digital Contact Tracing

Haoxuan Sun, Xiao-Fan Liu, +2 authors Ye Wu Published in IEEE Transactions on… 28 April 2021

Precision mitigation of COVID-19 is in pressing need for postpandemic time with the absence of pharmaceutical interventions. In this study, the effectiveness and cost of digital contact tracing (DCT) technology-based on-campus mitigation strategy are studied through epidemic simulations using high-resolution empirical contact networks of teachers and students. Compared with traditional class, grade, and school closure strategies, the DCT-based strategy offers a practical yet much more efficient way of mitigating COVID-19 spreading in the crowded campus. Specifically, the strategy based on DCT can achieve the same level of disease control as rigid school suspensions but with significantly fewer students quarantined. We further explore the necessary conditions to ensure the effectiveness of DCT-based strategy and auxiliary strategies to enhance mitigation effectiveness and make the following recommendation: social distancing should be implemented along with DCT, the adoption rate of DCT devices should be assured, and swift virus tests should be carried out to discover asymptomatic infections and stop their subsequent transmissions. We also argue that primary schools have higher disease transmission risks than high schools and, thereby, should be alerted when considering reopenings.

B. Control Strategies for the COVID-19 Infection Wave in India: A Mathematical Model Incorporating Vaccine Effectiveness

Namitha A. Sivadas, Pooja Panda, A. Mahajan Published in IEEE Transactions on… 1 December 2023

The waning effectiveness of the coronavirus disease-2019 (COVID-19) vaccines and the emergence of new variants have given rise to the possibility of future outbreaks of the infection. COVID-19 has caused more than 43 million reported cases and 526,000 deaths in India so far, and the disease spread is active again despite mass vaccinations. In this article, we present a compartmental epidemiological model incorporating vaccinations with dose-dependent effectiveness. We study a possible sudden outbreak of SARS-CoV2 variants in India, bring out the associated predictions for various vaccination rates, and point out optimum control measures. Our model simulation numbers for the total infected are close to the seroprevalance data in August 2021, and our results show that second dose vaccine effectiveness is the most sensitive parameter in the future evolution of the disease. A combination of vaccination and social distancing is the key to tackling the current situation and for the coming few months. Our simulation shows that social distancing measures show better control over disease spread than higher vaccination rates, and disease spread does not appear to rise sharply in the near future unless a new variant emerges.

C. Detecting the Community Structure and Activity Patterns of Temporal Networks: A Non-Negative Tensor Factorization Approach

L. Gauvin, A. Panisson, C. Cattuto Published in PLoS ONE 3 August 2013

The increasing availability of temporal network data is calling for more research on extracting and characterizing mesoscopic structures in temporal networks and on relating such structure to specific functions or properties of the system. An outstanding challenge is the extension of the results achieved for static networks to time-varying networks, where the topological structure of the system and the temporal activity patterns of its components are intertwined. Here we investigate the use of a latent factor decomposition technique, non-negative tensor factorization, to extract the community-activity structure of temporal networks. The method is intrinsically temporal and allows to simultaneously identify communities and to track their activity over time. We represent the time-varying adjacency matrix of a temporal network as a three-way tensor and approximate this tensor as a sum of terms that can be interpreted as communities of nodes with an associated activity time series. We summarize known computational techniques for tensor decomposition and discuss some quality metrics that can be used to tune the complexity of the factorized representation. We subsequently apply tensor factorization to a temporal network for which a ground truth is available for both the community structure and the temporal activity patterns. The data we use describe the social interactions of students in a school, the associations between students and school classes, and the spatio-temporal trajectories of students over time. We show that non-negative tensor factorization is capable of recovering the class structure with high accuracy. In particular, the extracted tensor components can be validated either as known school classes, or in terms of correlated activity patterns, i.e., of spatial and temporal coincidences that are determined by the known school activity schedule.

IMPLEMENTATION

Modules

Service Provider

In this module, the Service Provider has to login by using valid user name and password. After login successful he can do some operations such as Login, Browse Data Sets and Train & Test, View Trained and Tested Accuracy in Bar Chart, View Trained and Tested Accuracy Results, View All Antifraud Model for Internet Loan Prediction, Find Internet Loan Prediction Type Ratio, View Primary Stage Diabetic Prediction Ratio Results, Download Predicted Data Sets, View All Remote Users.

View and Authorize Users

In this module, the admin can view the list of users who all registered. In this, the admin can view the user's details such as, user name, email, address and admin authorizes the users.

Remote User

In this module, there are n numbers of users are present. User should register before doing any operations. Once user registers, their details will be stored to the database. After registration successful, he has to login by using authorized user name and password. Once Login is successful user will do some operations like REGISTER AND LOGIN, PREDICT PRIMARY STAGE DIABETIC STATUS, VIEW YOUR PROFILE.

CONCLUSION

DCT with wearable hardware is a new and effective epidemic mitigation strategy that could be used to fight against highly infectious diseases, such as COVID-19. In this study, we proposed to examine its effectiveness and cost, quantified by the numbers of infections and quarantined individuals, respectively, in controlling disease spreading on campus. Two empirical high-resolution on-campus interpersonal close contact data sets and a modified SEIR model with a variable infection rate setting are employed to simulate epidemics. Compared to traditional mitigation strategies, such as the closure of classes, grades, and the whole school, the DCT quarantine strategy can achieve a similar effect as more rigid strategies but with a much smaller cost. Several factors can strongly affect the mitigation effectiveness of the DCT-based strategy. First when the probability of asymptomatic is high, the prevention and control effects of various strategies will be weakened as they can transmit the disease for an extended period than symptomatic infections, who are isolated as soon as they show any symptom. Second, community-introduced infections can jeopardize the efforts made by any mitigation strategy. Third, the adoption rate of teachers and students profoundly affects the effectiveness of the DCT-based strategy. Fourth, social distancing can help with the mitigation strategy and further increase its effectiveness. In light of the above results, we make the following recommendations to the on-campus mitigation of COVID-19. First, a DCT-based strategy is encouraged in schools. Second, the strategy's adoption rate must be monitored and assured continuously. Third, whenever an infection is detected on campus, rigid virus testings must be carried out to a larger extent of the population for asymptomatic or community-introduced case discovery. Fourth, social distancing measures must be placed in schools to minimize the probability of disease spreading. Note that the density of the primary school empirical contact network is much higher than that in the high school. Although the contact data are collected from two individual schools in a particular period, we argue that this phenomenon can be universal, as pupils in primary schools are more physical activity-intensive (i.e., having more physical contacts) than students in the high schools, who are in contrast more academic activity-intensive. Therefore, we warn that primary schools have a higher risk than high schools in disease transmission, thereby less suitable for pushing school reopens. Our findings also have an extensible impact on all the densely contacting communities, such as universities, military barracks, and prisons. Individuals in these environments spend much time in close contact (e.g., sitting and living in the same room) so that the virus can have sufficient time to transmit among humans. Using DCT technology to trace the possible epidemic spreading routes and quarantine the higher risk groups (e.g., direct contacts) can help prevent a pandemic in the entire community but with minimum cost, compared to a full-scale shutdown. Accordingly, we suggest that the concerned organizations with sufficient economic status resources should consider adopting DCT technology to prevent disease spreading while maintaining their regular operations.

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