A Queue Management Approach for Social Distancing and Contact Tracing

Athanasios I. Kyritsis and Michel Deriaz
Information Science Institute, GSEM/CUI
University of Geneva
Geneva, Switzerland
Email: {$athanasios.kyritsis, michel.deriaz$}@unige.ch

***Abstract*—Social distancing is necessary to prevent the rapid spread of a highly contagious disease, such as COVID-19, at least until a vaccine is found and mass-produced. By reducing the probability of an uninfected person coming close or in physical contact with an infected one, the disease transmission in the community can be suppressed. Although social distancing is simple to comprehend, it is not always easy to implement, mainly because not all public spaces are designed with this requirement in mind. In this paper, we present a queue management tool that can be used to allow people that wait for a service practice social distancing. In our approach, people are asked to join a virtual queue, in order to avoid crowds in physical waiting rooms or long waiting queues. Machine learning is used to predict the estimated waiting time of queuers, so they are called just in time to get served. We use past data and machine learning to predict how busy a location will be so that customers can pick the best time to visit the service. Finally, we present the method we use to monitor people taking a service at any time and implement contact tracing in a privacy-preserving manner.**

***Keywords*—AI, COVID-19, machine learning, pandemic, pattern recognition, queue system, social distancing.**

I. Introduction

COVID-19 has already had dire repercussions to the global health and economy. In the first half of 2020, 213 countries and territories around the world have reported more than 10 million cases, including more than half a million deaths [1]. The IMF has projected that the ongoing recession caused by SARS-CoV-2, also known as the Great Lockdown, will eventually be the most significant economic downturn since the Great Depression [2]. About 47 million people in the USA alone have filed for unemployment from April until June 2020, increasing the national unemployment rate up to 14.7%, up from 4.4% in March [3]. The pandemic has impacted most industry sectors to varying degrees, and countries' GDPs have been shrinking. Therefore, in order to reduce the negative impacts of the disease on global health and the economy, it is of crucial importance to control the spread of the virus.

Social distancing is a valid non-pharmaceutical approach to limit the spread of a virus with increased transmissibility [4], [5]. Social distancing refers to measures taken in order to decrease the closeness and the frequency of physical contacts. With such measures, the probability of an already infected person transmitting the disease to a healthy person decreases, and the disease's spread is also decreased [6]. When implemented at the early stages of a pandemic, the infection rate is decreased, and the disease's peak is delayed, giving more time to governments and healthcare systems to take necessary precautionary measures. The challenge with highly contagious diseases comes when the number of patients exceeds the capacity of the public healthcare capacity, leading to unnecessary deaths that could have been prevented had the burden on the healthcare system been lighter. When social distancing measures are taken early, the effects of it will be higher, and the total number of cases at the end of the pandemic will be fewer.

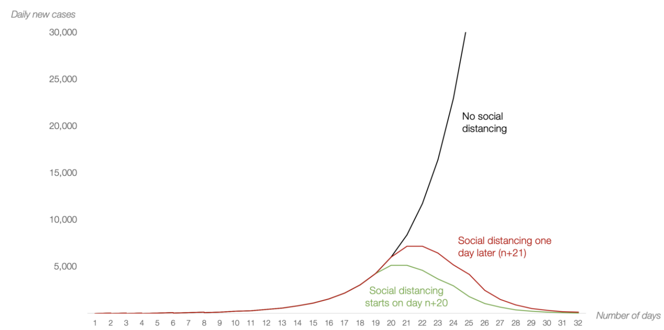

Fig. 1. Modeling the effects of social distancing [9].

Many governments around the world have implemented various measures that promote social distancing. Those measures include travel restrictions, banning large events and gatherings of many people, asking citizens to stay at home as much as possible, and keeping distances of 1.5-2 meters from each other or wearing a mask when such a distance is not possible [7], [8]. Figure 1 [9] models the exponential spread of COVID-19 and highlights that the earlier social distancing measures are implemented, the higher their effect will be. Nevertheless, people still have to go outside for essential work, for healthcare, and to get food, and it is not always easy to implement such measures. Therefore, it is crucial to develop technologies that facilitate social distancing, and that help prevent the uncontrolled and rapid spread of it.

In this paper, we are presenting a method to apply social distancing in queueing scenarios. We are extending the queue-

This work was co-financed by Innosuisse.

ing system presented in a previous work of ours [10]. We are adapting our system towards aiding the efforts to contain the pandemic. Apart from using machine learning to predict the waiting time of queuers, and so that they are called to come when it is their turn to get served, we are also predicting how busy each service will be at any moment, based on past data, so that customers plan when to join the queue. Last but not least, and in the spirit of contact tracing, our system can anonymously monitor the people that coexist in the same business for a given amount of time. In case a positive case arises in the future, we can then notify the appropriate people for potential infections.

The rest of the paper is organized as follows. In Section II, we are presenting related works on technologies that promote social distancing. We are then proposing one such system for queueing scenarios in Chapter III, that different businesses can easily use. Finally, we conclude our work in Section IV.

II. Related work

Several technologies can be used to monitor the proper implementation of social distancing measures. The physical distance between two people can be monitored using the Global Positioning System (GPS) when outdoors or indoor positioning systems when indoors. There are many technologies that can be used for indoor positioning, such as Bluetooth [11], Ultrasound [12], and Ultra-wideband (UWB) [13]. Each technology has its advantages and limitations, but in order to achieve a proper distance detection of 1.5-2 meters, the acceptable positioning error should be of a few centimeters. According to the literature, this can be achieved in a UWB setting [13]. UWB antennas, however, are not already in most mobile devices. Therefore, using such an indoor positioning system can not be easily scaled since it requires additional hardware both for the configuration and for the people that are to be positioned.

Another way to control social distancing is by monitoring and gauging the number of people inside a place. UWB sensors can be used to count people indoors even in non optimal environments [14], without needing any additional hardware on the counting objects. These environments may include supermarkets, airports and train stations, where local managers may take further actions, like scheduling more people to enter, based on the counting information. The concentration of people can also be monitored in external places. Using cellular information, mobile network operators can detect when there is a concentration of mobile devices in public spaces [15]. However, the fact that governments have demanded access to those data has raised privacy concerns and raised the prospect of state surveillance in multiple countries, especially when considering such measures may become permanent [16], [17].

In April 2020, Apple and Google have integrated the exposure notification system that offers contact tracing capabilities into their mobile operating systems [18]. Historically, in the case of an infected person, health officials would ask for a list of everyone the person has been in contact with so that these people are contacted and asked to look out for potential symptoms or to self-isolate if possible. With the developed system, when two people are in close range, they exchange anonymous Bluetooth identifiers. If an individual gets diagnosed with COVID-19, the mobile device sends to the cloud a list of all the identifiers used by the device during the last 14 days. Every other user periodically downloads the identifiers of infected people from the cloud. If there is a match of one of those keys with a recent encounter, a notification with what to do next appears.

Social distancing can also be effectively promoted by scheduling. Traditionally, workforce scheduling was about minimizing the cost of labor [19]. However, given pandemic circumstances, decreasing the number of people at the workplace to the minimum necessary, and maximizing social distancing should be the top objectives for the task. Besides workforce scheduling, healthcare services can also optimize appointments to decrease unnecessary traffic in the hospitals. There are already algorithms that minimize patient waiting times and doctor idle times [20]. Optimizing buildings for navigation may also reduce the unnecessary amount of time that patients and visitors spend in hospitals [21]. However, an additional objective to optimize against is to minimize the number of patients coming simultaneously at the hospital to maintain a level of social distancing. Home health care services can also help reduce traffic in hospitals in our context [22].

The motivation behind writing this paper and presenting the queueing system lies in its ease of use and in the social distancing policy that can be easily applied with its use. Customers join virtual queues, and they do not increase traffic on the premises of the business. Customers can also schedule when to join the queue based on past information on how busy the service is. The number of people in the service is monitored and gauged by the queue manager. Last but not least, potential customer interactions are being traced, and any confirmed case will notify the corresponding customers that coexisted at the same service at the same time. All these can be achieved with a web application and the requirement that people comply with using their mobile phones to join the queue. There is no need for any additional hardware on the premises of businesses.

III. System overview

In our previous publication, we presented QueueForMe [10], a platform in which anyone can register as a creator, and open virtual queues by defining queue specific parameters with predefined responses. Each client that joins the queue responds to all the necessary parameters. Based on the current state of the queue, a queue-specific machine learning model predicts the client's waiting time. When the queue manager calls queuers to get served, the clients either receive a notification on the web application, or an SMS if the clients opt to. The machine learning model predicting waiting times is continuously adapting to changes in queue patterns by using data from past clients.

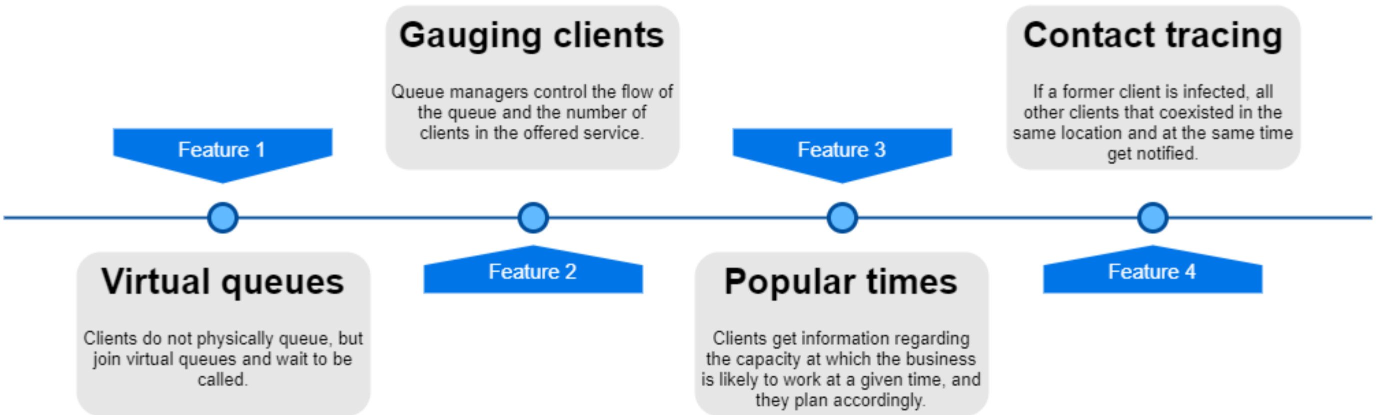

Fig. 2. Summary of the features of the presented system.

When a client joins a queue, a unique and random identifier is created and stored in the database, and by the web application on the client's device. When the queue manager calls a client to be served, and the client shows up at the service, e.g. when the client enters the supermarket, this timestamp is also saved. At the time of exit from the service, e.g., when the client exits the supermarket, the client has to report this timestamp to the web application manually or by scanning a QR code installed on the premises. With this information, each business knows the number of people being served at any time. Having this information, the queue manager can monitor in real-time and gauge the number of people in the business to limit access and promote social distancing.

Having this kind of information also enables the application of contact tracing. The client application can access all the identifiers that were used in a given device. When a client tests positive for the virus, the client can voluntarily input this information in our system, and all identifiers that were created the past days and belong to the client will be marked as infected. The backend will then mark all the rest identifiers of other clients that coexisted in the same service for a given amount of time as "potentially infected". So next time another client that owns a "potentially infected" identifier uses the application, the client will be asked to look out for potential symptoms. From a privacy perspective, each client is anonymous to the application. The phone number that can be used for the SMS notification is immediately erased from the backend as soon as the client leaves the service. Nothing is linking an identifier to a client and the list of identifiers created by the same client, is only stored on the device that the client has used.

By monitoring in real-time the number of people in a public space, and the number of people that have joined the queue, we can also build a model to predict the busy times of the service. Google has popularized this concept by showing popular times, live visit information, wait times, and typical visit duration in various businesses on Google Maps [23]. However, this service requires that clients have opted in the use of location history in the mobile phone, which is not always the case. To achieve this, we can train a demand forecasting model using past queue and service trend data to predict the capacity at which the business is likely to work at a given time in the future. Customers can then plan to join the queue at optimal times that will lead to less waiting time and minimum unnecessary human contact. Figure 2 summarizes the features of the system we have presented.

IV. Conclusion

Social distancing is considered a crucial measure to limit the spread of COVID-19, allowing more time to governments and healthcare systems to take appropriate measures, and pharmaceutical research to advance towards developing a vaccine. In this paper, we have presented a system that allows social distancing in queueing scenarios and contact tracing for clients that use this system. Nonetheless, the system is not perfect since it can be easily abused. On the one hand, there is no authentication for clients that join queues, and therefore their identity remains private. On the other hand, however, there is no verification that the inputted infected clients are indeed infected people and not malicious users. It would require socially responsible clients for our approach to work. To deal with malicious users that abuse the social tracing feature of our system, we would have only to allow professional healthcare institutions to input clients' infected status, like in the Exposure Notification system developed by Apple and Google, and of course, that would require a higher level of collaboration.

References

[1] World Health Organization, "Who coronavirus disease (covid-19) dashboard," https://covid19.who.int/, 2020, [Online; accessed June 30, 2020].

[2] International Monetary Fund, "World economic outlook, april 2020: The great lockdown," https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020, 2020, [Online; accessed June 30, 2020].

[3] The Guardian, "Us unemployment and employment statistics," https://www.theguardian.com/business/us-unemployment-and-employment-statistics, 2020, [Online; accessed June 30, 2020].

[4] N. M. Ferguson, D. A. Cummings, C. Fraser, J. C. Cajka, P. C. Cooley, and D. S. Burke, "Strategies for mitigating an influenza pandemic," *Nature*, vol. 442, no. 7101, pp. 448–452, 2006.

[5] N. M. Ferguson, D. A. Cummings, S. Cauchemez, C. Fraser, S. Riley, A. Meeyai, S. Iamsirithaworn, and D. S. Burke, “Strategies for containing an emerging influenza pandemic in southeast asia,” *Nature*, vol. 437, no. 7056, pp. 209–214, 2005.

[6] C. Fraser, S. Riley, R. M. Anderson, and N. M. Ferguson, “Factors that make an infectious disease outbreak controllable,” *Proceedings of the National Academy of Sciences*, vol. 101, no. 16, pp. 6146–6151, 2004.

[7] Centers for Disease Control and Prevention, U.S. Department of Health & Human Services, “Social distancing,” https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html, 2020, [Online; accessed June 30, 2020].

[8] Federal Office of Public Health, Switzerland, “New coronavirus: Measures and ordinances,” https://www.bag.admin.ch/bag/en/home/krankheiten/ausbrueche-epidemien-pandemien/aktuelle-ausbrueche-epidemien/novel-cov/massnahmen-des-bundes.html, 2020, [Online; accessed June 30, 2020].

[9] Tomas Pueyo, “Coronavirus: Why you must act now,” https://medium.com/@tomaspueyo/coronavirus-act-today-or-people-will-die-f4d3d9cd99ca, 2020, [Online; accessed June 30, 2020].

[10] A. I. Kyritsis and M. Deriaz, “A machine learning approach to waiting time prediction in queueing scenarios,” in *2019 Second International Conference on Artificial Intelligence for Industries (AI4I)*. IEEE, 2019, pp. 17–21.

[11] G. G. Anagnostopoulos, C. M. de la Osa, T. Nunes, A. Hammoud, M. Deriaz, and D. Konstantas, “Practical evaluation and tuning methodology for indoor positioning systems,” in *2016 Fourth International Conference on Ubiquitous Positioning, Indoor Navigation and Location Based Services (UPINLBS)*. IEEE, 2016, pp. 130–139.

[12] A. Hammoud, A. I. Kyritsis, M. Deriaz, and D. Konstantas, “Enhanced still presence sensing with supervised learning over segmented ultrasonic reflections,” in *2017 International conference on indoor positioning and indoor navigation (IPIN)*. IEEE, 2017, pp. 1–8.

[13] J. Tiemann, F. Schweikowski, and C. Wietfeld, “Design of an uwb indoor-positioning system for uav navigation in gnss-denied environments,” in *2015 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*. IEEE, 2015, pp. 1–7.

[14] J. W. Choi, D. H. Yim, and S. H. Cho, “People counting based on an ir-uwb radar sensor,” *IEEE Sensors Journal*, vol. 17, no. 17, pp. 5717–5727, 2017.

[15] P. N. Pathirana, A. V. Savkin, and S. Jha, “Location estimation and trajectory prediction for cellular networks with mobile base stations,” *IEEE Transactions on Vehicular Technology*, vol. 53, no. 6, pp. 1903–1913, 2004.

[16] Swissinfo, “Mobile phone data show swiss are keeping their distance,” https://www.swissinfo.ch/eng/coronavirus_mobile-phone-data-show-swiss-are-keeping-their-distance-/45644704, 2020, [Online; accessed June 30, 2020].

[17] Reuters, “Vodafone, deutsche telekom, 6 other telcos to help eu track virus,” https://www.reuters.com/article/us-health-coronavirus-telecoms-eu/vodafone-deutsche-telekom-6-other-telcos-to-help-eu-track-virus-idUSKBN21C36G, 2020, [Online; accessed June 30, 2020].

[18] Apple and Google, “Covid-19 notifications,” https://www.google.com/covid19/exposurenotifications/, 2020, [Online; accessed June 30, 2020].

[19] I. Castillo, T. Joro, and Y. Y. Li, “Workforce scheduling with multiple objectives,” *European Journal of Operational Research*, vol. 196, no. 1, pp. 162–170, 2009.

[20] G. C. Kaandorp and G. Koole, “Optimal outpatient appointment scheduling,” *Health care management science*, vol. 10, no. 3, pp. 217–229, 2007.

[21] G. G. Anagnostopoulos, M. Deriaz, J.-M. Gaspoz, D. Konstantas, and I. Guessous, “Navigational needs and requirements of hospital staff: Geneva university hospitals case study,” in *2017 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*. IEEE, 2017, pp. 1–8.

[22] A. Trautsamwieser and P. Hirsch, “Optimization of daily scheduling for home health care services,” *Journal of applied operational research*, vol. 3, no. 3, pp. 124–136, 2011.

[23] Google, “Popular times, wait times, and visit duration,” https://support.google.com/business/answer/6263531, 2020, [Online; accessed June 30, 2020].