COVID-19 Spread Prevention by Minimising Overcrowding

Subjects: Transportation Science & Technology

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COVID-19 has become a pandemic which has resulted in measures being taken for the health and safety of people. The spreading of this disease is particularly evident in indoor spaces, which tend to get overcrowded with people. One such place is the airport where a plethora of passengers gather in common places, such as coffee shops and duty-free shops as well as toilets and gates. Guiding the passengers to less overcrowded places within the airport may be a solution to reduce disease spread.

COVID-19 overcrowding virus passenger

1. Introduction

COVID-19 and other airborne-transmitted diseases have significant impacts on human health, even leading to death. COVID-19 is considered a highly transmissible disease [1]. Particularly in enclosed spaces, areas with crowding often increase the risk of epidemic spread of infections. Airports are crowded places where people move around duty-free shops, restaurants, and gates. Therefore, there is a need to organize people's movement within the airport to avoid crowding. Two recent studies demonstrated modeling the spread and human behavior for the transmission of COVID-19 in indoor spaces, respectively [2][3]. The virus transmission occurs either through droplets or via direct contact of an individual with another person [4].

To prevent the transmission of COVID-19 through the air, it is necessary to maintain a specific number of individuals per square meter. Consequently, it is important to organize the passenger flow heading towards or already present in various areas of the airport in order to minimise the risk of virus transmission. Passenger counting can be conducted from the moment they disembark the plane or perform check-in and can continue throughout their journey to different airport areas.

The investigation of passenger flow in airport terminals involves various methods. The conventional method primarily relies on on-site surveys, including passenger counting and questionnaires, which are used to validate model results or signals from sensors [5]. However, this approach demands extensive work, particularly in large airports. To address this, indoor sensors and technologies like Wi-Fi information [6], mobile phone data [7], RFID [8], motion sensors [9], PIR sensors [10], and surveillance videos [11] have been employed in airports and other buildings. Simulation models have also been developed to analyze and predict passenger flow in airport terminals.

The flow of passengers in an airport terminal comprises two main components: service counters where passengers stay and movements between these counters. Queuing theory is used to describe how passengers wait in line at service counters like at check-in, security, and boarding [12]. The transfer conditional probability table is a common mathematical method to analyze interactions and transfer probabilities between each counter [13][14].

Routing of passengers can be of extreme importance in indoor spaces in order to avoid overcrowding. As such, an efficient scheme is mandatory to guide passengers in airports to particular common spaces in a manner that promotes sparsity. Since passengers flow through the airport in large numbers, attempting to keep them safe and distanced in common spaces is of the utmost importance.

2. COVID-19 Spread Prevention by Minimising Overcrowding

Due to the complexity and size of airport terminals, agent-based simulation (ABS) models are employed to understand continuous changes in passenger flow and distribution. ABS treats each passenger as an individual research subject, using a social force model to control their movements [15].

In [13], simulation has proven instrumental in understanding and assessing passenger movement during airport departure procedures. The authors' methodology not only facilitates the evaluation but also the prediction of airport operational efficiency. Its application supports airport management in identifying operational bottlenecks, specifically related to challenges in flight schedule planning. Furthermore, it provides precise insights into how changes in infrastructure and operations impact airport functionality. In that study, they used simulation to examine various load factors associated with diverse flight schedules. The outcomes of the simulation emphasize the significant influence of the flight schedule on passenger flows. The proposed simulation framework and model show promise in foreseeing the effects of different flight schedules, serving as a proactive tool to refine them before implementation. These findings suggest that integrating the creation of flight schedules with passenger simulation analysis could effectively address challenges in managing passenger flow within airport terminals.

In [16], the AnyLogic software serves to simulate human behavior within specific building structures, generating valuable data on people flow. These data are pivotal in establishing a people flow model, subsequently applied to estimate human occupancy through the utilization of a Kalman filter. An initial simulation involving a single room and corridor demonstrates the superior performance of the Kalman filter estimation, based on the identified model, compared to estimations relying solely on sensors. Furthermore, this methodology is substantiated through a real-world experiment where authentic cameras and beam sensors are installed in a corridor and room. The results of this practical experiment reinforce the efficacy of the estimation technique which combines the Kalman filter and AnyLogic, surpassing the performance of exclusive reliance on sensors. This proposed method offers a viable solution to the challenge of model identification for estimating building occupancy, particularly in scenarios where real data on people flow are limited.

In [17], the authors utilized AnyLogic to analyze passenger flow at the entrance of Wulin Station. By comparing various quantities of ticket windows based on different pedestrian arrival rates, they reached a conclusion: during high-traffic hours (with a pedestrian arrival rate of 2500/h), it is more efficient to open four ticket windows. Conversely, during low-traffic hours (with a pedestrian arrival rate of 1500/h), it is preferable to operate two ticket windows. It is important to note that due to time constraints and the closure of other subway lines in Hangzhou, the precise statistics regarding pedestrian arrival rates during peak and off-peak hours were not determined in this article. The simulation model employed in that study can not only be applied to other subway entrances but is also easily adaptable for altering the pedestrian arrival rate.

In [18], the paper introduces a methodology aimed at modeling the movement of entities within a hub airport, demonstrated through the simulation of the New Barcelona International Airport, a comprehensive and intricate case study. The principles delineated in this approach are transferable to other airports with similar configurations. The simulation of entities' movement within a hub airport heavily relies on accurately interpreting diverse data types. The article meticulously delineates the categorizations of these components, the primary model parameters, and their role in establishing a presentation format for incoming entities. To simulate the movement of these entities within the airport, the proposal involves employing a Simple Reflexive agent, providing a detailed analysis of the time and delays arising from their actions. The methodological approach leans on the Specification and Description Language (SDL), a widely acknowledged formal graphical and standard language. In the highlighted case study, SDL played a crucial role, acting as a primary facilitator for effective communication among all stakeholders.

In [19], researchers introduced a simulation approach employing AnyLogic software to simulate the movement patterns of passengers both entering and exiting a metro station, with a specific emphasis on a specific line. The simulation logic was divided into three core components: the inflow of passengers, outflow of passengers, and the arrival of trains. Train arrivals were synchronized with the generation of passengers using hourly flow distributions. Different scenarios of passenger flow distributions were tested to determine the optimal number of functioning ticket windows. Selection criteria focused on ensuring that ticket level waiting times aligned with train intervals and that ticket offices utilized their staff efficiently. The simulation employed both 2D and 3D perspectives to visualize pedestrian behavior and identify congested areas. Analyzing these flow patterns led to suggestions for optimizing exit and entrance gates. The model effectively demonstrated its ability to evaluate the overall operational status while also proposing practical improvements for the organization and layout of the facility.

In [20], the authors address the effective management of an Emergency Department (ED) which involves navigating a highly intricate landscape, given the admission of patients with a spectrum of ailments and varying degrees of urgency. This complexity demands the coordination of diverse activities, encompassing both human and medical resources. The nuanced nature of ED management poses challenges, notably overcrowding, which can adversely impact the quality and accessibility of healthcare services.

The aforementioned study strategically employs Process Mining techniques within a tangible case study, focusing on the operations of the ED. Leveraging the ED database, advanced discovery techniques are applied to unravel potential patient pathways based on information acquired during the triage process. The overarching goal is to generate precise process models that not only facilitate the replication of ED workflows but also enable the prediction of patient trajectories within this dynamic healthcare setting.

References

1. Li, G.; Hu, R.; Gu, X. A close-up on COVID-19 and cardiovascular diseases. Nutr. Metab. Cardiovasc. Dis. 2020, 30, 1057–1060.
2. Cuevas, E. An agent-based model to evaluate the COVID-19 transmission risks in facilities. Comput. Biol. Med. 2020, 121, 103827.
3. Harweg, T.; Bachmann, D.; Weichert, F. Agent-based simulation of pedestrian dynamics for exposure time estimation in epidemic risk assessment. J. Public Health 2021, 31, 221–228.
4. Chen, L.; Ban, G.; Long, E.; Kalonji, G.; Cheng, Z.; Zhang, L.; Guo, S. Estimation of the SARS-CoV-2 transmission probability in confined traffic space and evaluation of the mitigation strategies. Environ. Sci. Pollut. Res. 2021, 28, 42204–42216.
5. Liu, X.; Li, L.; Liu, X.; Zhang, T.; Rong, X.; Yang, L.; Xiong, D. Field investigation on characteristics of passenger flow in a Chinese hub airport terminal. Build. Environ. 2018, 133, 51–61.
6. Nikoue, H.; Marzuoli, A.; Clarke, J.P.; Feron, E.; Peters, J. Passenger flow predictions at sydney international airport: A data-driven queuing approach. arXiv 2015, arXiv:1508.04839.
7. Zhong, G.; Wan, X.; Zhang, J.; Yin, T.; Ran, B. Characterizing passenger flow for a transportation hub based on mobile phone data. IEEE Trans. Intell. Transp. Syst. 2016, 18, 1507–1518.
8. Li, N.; Calis, G.; Becerik-Gerber, B. Measuring and monitoring occupancy with an RFID based system for demand-driven HVAC operations. Autom. Constr. 2012, 24, 89–99.
9. Soltanaghaei, E.; Whitehouse, K. Practical occupancy detection for programmable and smart thermostats. Appl. Energy 2018, 220, 842–855.
10. Benezeth, Y.; Laurent, H.; Emile, B.; Rosenberger, C. Towards a sensor for detecting human presence and characterizing activity. Energy Build. 2011, 43, 305–314.
11. Zou, J.; Zhao, Q.; Yang, W.; Wang, F. Occupancy detection in the office by analyzing surveillance videos and its application to building energy conservation. Energy Build. 2017, 152, 385–398.
12. McKelvey, F.X. Use of an analytical queuing model for airport terminal design. In Transportation Research Record; Transportation Research Board: Washington, DC, USA, 1988.
13. Alodhaibi, S.; Burdett, R.L.; Yarlagadda, P.K. Framework for airport outbound passenger flow modelling. Procedia Eng. 2017, 174, 1100–1109.

14. Wu, P.P.Y.; Pitchforth, J.; Mengersen, K. A hybrid queue-based Bayesian network framework for passenger facilitation modelling. Transp. Res. Part C Emerg. Technol. 2014, 46, 247–260.
15. Wu, P.P.Y.; Mengersen, K. A review of models and model usage scenarios for an airport complex system. Transp. Res. Part A Policy Pract. 2013, 47, 124–140.
16. Li, K.; Zhang, K.; Li, X.; Xi, J.; Fang, H.; Jia, Z. Building occupancy estimation with people flow modeling in AnyLogic. In Proceedings of the 2016 12th IEEE International Conference on Control and Automation (ICCA), Kathmandu, Nepal, 1–3 June 2016; pp. 669–672.
17. Yang, Y.; Li, J.; Zhao, Q. Study on passenger flow simulation in urban subway station based on anylogic. J. Softw. 2014, 9, 140–146.
18. i Casas, P.F.; Casanovas, J.; Ferran, X. Passenger flow simulation in a hub airport: An application to the Barcelona International Airport. Simul. Model. Pract. Theory 2014, 44, 78–94.
19. Ghali, H.S.; Essawy, Y.A.; Abdullah, A.; Nassar, K. Analyzing Passenger Flow Lines and Optimizing the Facility Layout Management for Cairo Metro Elevated Stations. In Proceedings of the Construction Research Congress 2022, Arlington, VA, USA, 9–12 March 2022; pp. 1327–1336.
20. Duma, D.; Aringhieri, R. Mining the patient flow through an emergency department to deal with overcrowding. In Proceedings of the Health Care Systems Engineering: HCSE, Florence, Italy, 3 May 2017; Springer: Berlin/Heidelberg, Germany, 2017; pp. 49–59.