Hindawi
Indoor Air
Volume 2023, Article ID 7068735, 11 pages
https://doi.org/10.1155/2023/7068735

Research Article

Application of Data-Driven Building Information Modeling in the Visual Simulation of Disease Transmission and Route with Pipeline System

Chen-Yu Pan,[1] **Hsieh-Chih Hsu**,[1] **Ko-Wei Huang**,[2] **and Ya-Hua Lin**[1]

[1]*Department of Architecture, National Cheng Kung University, No. 1, Daxue Rd, East Dist., Tainan 70101, Taiwan*
[2]*Department of Electrical Engineering, National Kaohsiung University of Science and Technology, No. 415, Jiangong Rd., Sanmin Dist., Kaohsiung City 807618, Taiwan*

Correspondence should be addressed to Chen-Yu Pan; panchenyusk@gmail.com

Received 8 February 2023; Revised 16 May 2023; Accepted 28 July 2023; Published 8 August 2023

Academic Editor: Xiaohu Yang

Currently, preventing epidemics is an extremely critical global topic. Using present data to quickly conduct virus simulations is a difficult but interesting problem, especially when real situations are difficult to experimentally demonstrate. In the past, most studies have used package software for disease transmission simulation, but this approach is limited by availability and software cost. Therefore, we propose a visual simulation of disease transmission using building information modeling data and a 3D model using Unity. The results show that the proposed method can effectively predict the probability and route of disease transmission; it also verifies that the vertical pipeline on the floor plane is conducive to the spread of the virus (90%), and disease transmission on the plane gradually expands outward from the starting room and has a higher probability of spreading (80%) from the opposite room. In addition, a vertical pipeline was simulated using a toilet exhaust air ventilation pipeline, from which it can be observed that the adjacent floors have a higher diffusion probability (70%). It has also been confirmed that distance is the primary factor affecting disease transmission. This framework may provide designers and managers further protection against the spread of future epidemics.

1. Introduction

COVID-19 has severely affected people in various countries. With the popularization of vaccines, defenses against the virus in each country have gradually been loosened. Although the death toll has been decreasing, the number of confirmed cases continues to increase. Therefore, reducing community-based infections is important, and corresponding protective measures should be taken for similar diseases in the future.

1.1. Abbreviations. The abbreviations shown in Table 1 are used in the article to simplify the description of related terms.

1.2. Background. Recently, large-scale epidemics have become serious. Common pathogen transmissions are divided into food-borne, blood-borne, airborne, and droplet transmissions [1]. Airborne and droplet transmissions are more difficult to prevent than the other two, and presently, both can cause most people to become infected or even die within a short period of time. For instance, the severe acute respiratory syndrome (SARS) coronavirus, discovered in 2003, is more infectious and pathogenic than the respiratory tract infection (RTI); a person infected with SARS died of pulmonary fibrosis and respiratory failure caused by the virus. According to World Health Organization (WHO) statistics, from November 2002 to July 2003, the number of infected persons worldwide reached 8,096, of which 774 died. COVID-19, discovered in 2019, was more infectious than SARS, causing many countries to be engulfed by the epidemic, with the number of global infections reaching 574 million and the death toll in July 2022 increasing to 6.4 million.

In general, in epidemic prevention, the pipeline systems of buildings are easily neglected and indirectly cause

Table 1: Abbreviation list.

Term	Abbreviation
Building information modeling	BIM
Severe acute respiratory syndrome	SARS
Genetic algorithm	GA
A star	A*
Simulated annealing	SA
Particle swarm optimization	PSO
Ant Colony optimization	ACO
Nondeterministic polynomial	NP
Industry foundation classes	IFC

infections. For example, the sewage system contains waste produced by lavatories, shower rooms, and kitchens [2, 3], and the domestic sewage discharged from toilets contains viruses [4, 5]. In addition, during the SARS epidemic in Hong Kong, the Amoy Gardens housing estate caused local cluster infections due to its pipeline system [6]. Previous studies have found that viruses are affected by temperature and humidity, and that temperature is a survival factor after the virus leaves the host [7]. Compared to other environments, the temperature in a building tube is stable and close to room temperature [8], and the tube materials are mostly metal and plastic. The infectious virus can survive for approximately 24–48 h [9, 10], and it can be confirmed whether the pipeline system will be a good way of infection within 24–48 h. The prevention and prediction of infection are a major challenges for public hygiene.

If a virus with no decreasing infectivity is transmitted in the tube through feces, it is difficult to predict the randomness and direction of the infection. Thus, a heuristic algorithm is used to solve this randomness problem using a bionic pattern. Currently, the mainstream heuristic algorithms which can be used to solve the problem of the random spread of viruses include simulated annealing (SA) [11], particle swarm optimization (PSO) [12], ant colony optimization (ACO) [13], genetic algorithm (GA) [14], and A Star (A*) [15]. However, heuristic algorithms have several applications in different fields. SA can be used to solve pipeline conflicts because there are many possible random pipeline modification methods [16]. Air particle concentration and velocity are simulated using an indoor air conditioning system, and PSO is used for localization [17]. An improved ACO is used to search for mutations in viral genes [18]. GA is used to identify cancer genes in microarray data [19]. A* is combined to plan the flight paths of an indoor unmanned aerial vehicle [20]. In summary, it can be observed that the heuristic algorithms have a positive effect on both random and route searches; therefore, they are used in this study to determine the spread probability and route of the virus in the pipeline system.

The easiest method to obtain pipeline data is to export the data stored in BIM, which is a visual model that currently contains data on the actual structure. In addition, the entire building life cycle is currently imported in the construction industry [21], in which the combination of BIM and game engines creates more possibilities [22], such as simulating the interior direction [23], improving engineering quality [24], and designing visualization reviews [25]. Therefore, through the combination of the aforementioned heuristic algorithms and BIM, the spread probability and route of the virus in the pipeline are visualized to provide hospitals or office buildings with a simulation of the virus in the pipeline system to prevent further infection.

1.3. Motivation. COVID-19 continues to cause inconvenience in daily life; as medical resources are insufficient, mild-case patients can only be isolated at home, and the risk of infection for uninfected family members or neighbors remain. Effectively simulating the trajectory and probability of infection is difficult; consequently, the required pipeline data from the BIM software (distance, diameter, and speed) is proposed. Using GA and A*, we determined the disease transmission and route, respectively. We use the Unity engine to visualize the final route. The results show that the combination of BIM, a heuristic algorithm, and Unity can predict the probability and route of disease transmission to other areas by building pipelines. This provides a reference for virus prevention and epidemic protection work in the future.

2. Materials and Methods

The COVID-19 virus is stable inside pipeline systems but is affected by the distance, diameter, and speed of the pipeline; therefore, the risk of spreading cannot be controlled. To simulate the viral spread, we made the most valuable trade-off for the factors (distance, diameter, and speed) of pipeline systems connecting various rooms. In this section, we illustrate the use of heuristic algorithms to address the details concerning the spread and route of viruses in pipeline systems.

2.1. Disease Transmission in Pipeline Systems. Heuristic algorithms are widely used today, as humans develop through the observation of certain affairs and simulate situations to solve problems encountered. For example, a GA is developed to simulate the mating processes of biological chromosomes. ACO is related to route change by observing the concentration of pheromones when ants carry food back to their colony. Current heuristic algorithms are often used to solve complicated permutation and combination problems, such as NP-Hard, NP-Complete, NP, and P problems. The knapsack problem is a type of NP problem which has extensive applications, such as discrete optimization [26], nonlinear [27], and linear [28]. Therefore, simulating the complexity of variable viruses could provide a feasible solution and allow for adapting to more complicated variables in the future.

The knapsack problem is extensively used in heuristic algorithms such as SA [29], ACO [30], PSO ([31], and the GA [32]. This study primarily discusses the knapsack problem of GA. This method solves a variety of knapsack problem types, such as the knapsack problem for dynamic environments [33], the knapsack problem after blurring

```
BEGIN
    Randomize the start population (INITIALISE)
    Evaluate each candidate (EVALUATE)
    Repeat until the end condition is satisfied (REPEAT)
        1. Choose parents (PARENT SELECT)
        2. Crossing parents (RECOMBINE)
        3. Applying mutate to the children (MUTATE)
        4. Evaluate new candidates (EVALUATE)
        5. Choose children to survive in the next generation (SURVIVOR SELECT)
END
```

Pseudocode 1: Pseudocode of research method.

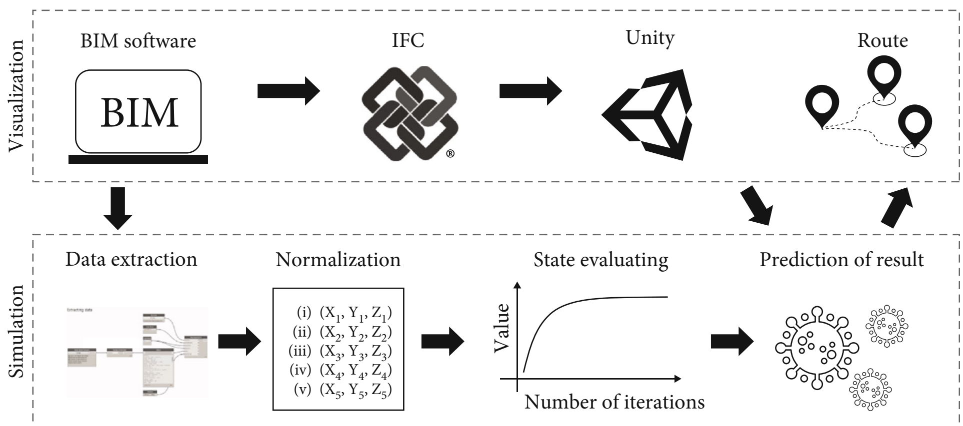


Figure 1: Architecture diagram of simulation and visualization.

[34], and the multiple-choice multidimensional knapsack problem [35]. The GA and knapsack problems were combined to solve disease transmission in pipeline systems with different variables, as shown in Pseudocode 1.

2.2. Visualization of Virus Route. Building information modeling (BIM) is a prominent science in the construction industry. Common BIM software includes Revit, AECOsim, Tekla, and ArchiCAD; these software manufacturers provide application programming interfaces (APIs) to facilitate secondary development by users [36]. Among these, Revit is currently the most commonly used BIM software, and its secondary development software is dynamo [37]. The advantage of dynamo is that it provides better use of the software and is not affected by versions. In addition, it works using the visual programming process without a need to write code, so novices can get a good understanding of it. Nevertheless, Unity has gradually shifted the application of BIM toward the development of virtual reality and augmented reality [38, 39]. The 3D model and information element (IE) can be preserved by converting between the two in the IFC file format. Thus, the necessary data for simulated visualization can be found using the information from the model. The game engine Unity is often used in simulating reality, such as in traffic simulation [40], 3D anatomy [41], and daylighting research [42]. Hanie and Rensburg [43] used Unity to explore the spread of COVID-19 in South Africa. The target search method used in the game engine was the A* search algorithm developed by Hart et al. [44], which benefits from the shortest distance selection with time and movement [45]. Finally, we used the IFC file exported from the BIM model as the basis of the Unity 3D model, which is helpful for predicting the virus route in the pipeline; the diffusion target is the result of the GA and the knapsack problem.

3. Development of Framework

This study is divided into two parts: visualization and simulative prediction. Both the knapsack problem and the GA described in Section 2.1 were used as the prediction tool, as well as the method described in Section 2.2, for visualization, as shown in Figure 1. Therefore, in this section, we sequentially introduce the predicted disease transmission and routes. Section 3.1 discusses preprediction data processing, and Section 3.2 is related to the forecast of disease transmission probability and route.

3.1. Preprediction Data Processing. The exported data can be separated into 3D models and digital data. The 3D model is to export the IFC file and import the data into Unity. For the digital data, we used dynamo, a secondary development software provided by Revit, to select model elements to extract the required pipeline data (distance, diameter, and speed). However, this experiment is primarily based on the floor plan, and we settle on a room to discuss the vertical pipeline

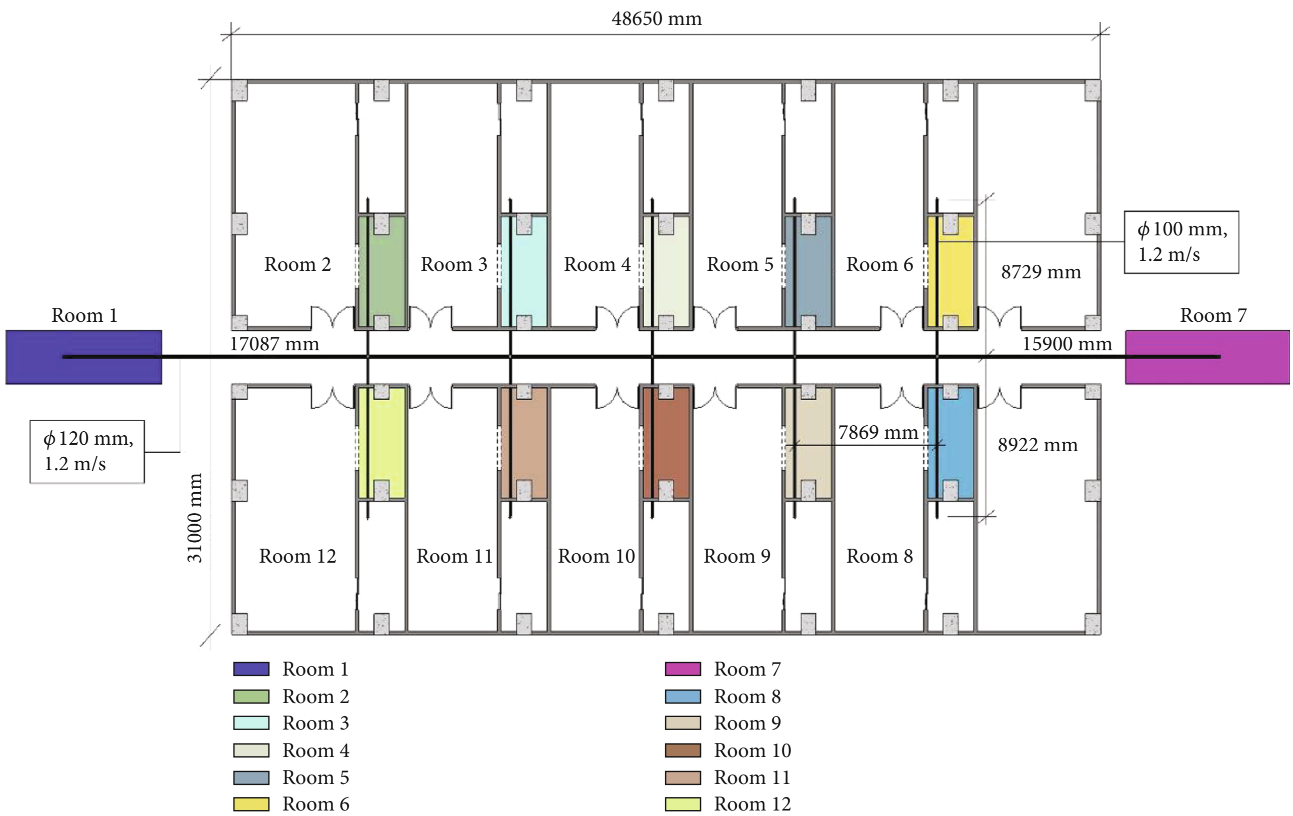


Figure 2: Plans of floor and sewage system.

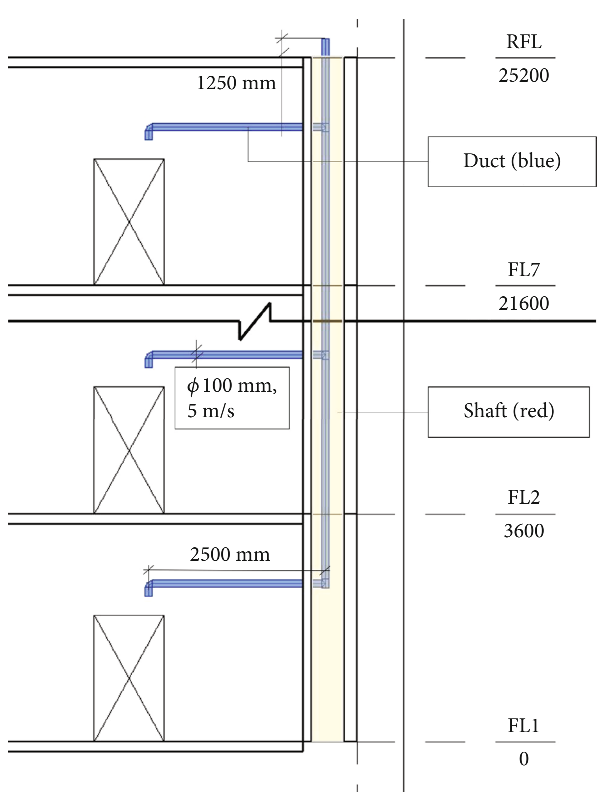


Figure 3: Cross-sectional view of floors and exhaust air ventilation system.

so that the virus is most likely to spread to the upper and lower floors. During the simulation, we standardize the pipeline data to eliminate errors and improve the accuracy of the simulation to further develop and apply the BIM data and increase the reliability of the simulation.

3.2. Route Prediction of Disease Transmission Probability. To simulate disease transmission from the pipeline to other rooms, we can obtain information on the pipeline from BIM, which helps us predict the spread probability and route in greater detail. Disease transmission from one room to another is affected by the environment and leaving the host itself. In the literature, it has been found that viruses can survive for 24–48 h. Therefore, considering the influence of viruses and pipelines, viruses cannot spread completely to every room and are forbidden from reaching some rooms. In fact, the evaluation method is that one closer to the knapsack capacity with a higher value; that is, this is an approximate current solution. Each iteration is the completion of one simulation. In this experiment, 1000 iterations are performed, and the results are added to determine the probability of virus transmission. Three variables (speed, distance, and pipe diameter) are individually simulated and added to the results. It is concluded that the virus transmitted through the pipeline with probability of occurrence reaches other rooms, which is its ultimate goal.

The viral route is important because the pipelines of building pipeline systems are complex and interconnected. With respect to disease transmission, it is difficult to

Table 2: Standards of distance, pipe diameter, and speed. (The italic filling values are used in this study; the rest are the sizes of pipeline data exported by BIM).

	Distance (mm)	Normalization	Diameter (mm)	Normalization	Speed (m/s)	Normalization
Horizontal-5F (initial point to target)						
Room 11 to room 1	*33878*	*0.70*	32	0.21	1	0.56
Room 11 to room 2	*25520*	*0.53*	40	0.27	1.1	0.61
Room 11 to room 3	*17651*	*0.36*	50	0.33	*1.2*	*0.67*
Room 11 to room 4	*25520*	*0.53*	80	0.53	1.3	0.72
Room 11 to room 5	*33389*	*0.69*	*100*	*0.67*	1.4	0.78
Room 11 to room 6	*41258*	*0.85*	*120*	*0.80*	1.5	0.83
Room 11 to room 7	*48429*	*1.00*	150	1.00	1.6	0.89
Room 11 to room 8	*41451*	*0.86*	—	—	1.7	0.94
Room 11 to room 9	*33582*	*0.69*	—	—	1.8	1.00
Room 11 to room 10	*25713*	*0.53*	—	—	—	—
Room 11 to room 11	*0*	*0.00*	—	—	—	—
Room 11 to room 12	*25713*	*0.53*	—	—	—	—
Vertical-1F~7F (initial point to target)						
Room 11 (5F) to room 11 (1F)	*16900*	*1.00*	90	0.82	4	0.67
Room 11 (5F) to room 11 (2F)	*13300*	*0.79*	*100*	*0.91*	*5*	*0.83*
Room 11 (5F) to room 11 (3F)	*9700*	*0.57*	110	1	6	1
Room 11 (5F) to room 11 (4F)	*6100*	*0.36*				
Room 11 (5F) to room 11 (5F)	*0*	*0.00*				
Room 11 (5F) to room 11 (6F)	*6100*	*0.36*				
Room 11 (5F) to room 11 (7F)	*9700*	*0.57*				
Room 11 (5F) to room 11 (RFL)	*10950*	*0.65*				

determine the behavior of the virus, especially where it disperses and other contaminated rooms. This study imports BIM (IFC) through the game engine to simulate the transmission of the disease to other rooms in the pipeline and uses the A* search algorithm, which is commonly used for controlling the route of nonplayers in role-playing games, to simulate the behavior of the virus. Using this combination of software, the virus routes in the starting and target rooms are simulated and determined.

4. Experiment Review

In this section, we demonstrate an actual case from the initial model to the final simulation of the game engine and verify the experimental results. According to the case description in Section 4.1, the probability of disease transmission in Section 4.2, and the virus route in Section 4.3, this experiment provides a feasibility diagram.

4.1. Case Description. This case concerns a student dormitory with seven floors; each floor includes ten rooms, one tearoom, and one social hall. The sewage system (discharged from toilets) is connected from 10 toilets to the middle aisle and then discharged to the sewage disposal tank in the basement, as shown in Figure 2. The exhaust air ventilation system is connected to different floors and cannot be connected to the same floor, as shown in Figure 3. In addition, this study is limited by the fact that the simulated pipeline needs to be on the same main pipe and must not limit any pipeline system. It is only necessary to consider the possibility of spread to other dorms. This study primarily uses sewage systems on the same floor and ventilation systems on different floors.

The left and right sides of Figure 2 (rooms 1 and 7) are the pipes connecting the main vertical pipes and the pipes connecting other areas, respectively. We set the two sides as the infection areas and conclude that there are 12 rooms in this experiment. Because the rooms are adjacent to each other and the sewage branch belongs to the same main pipe, the rate of infection is higher than in other areas. Simultaneously, the data show the pipeline information and the distance from one room to the others. Table 2 lists the standards of distance, pipe diameter, and speed from the initial room 11 to the other target rooms.

Figure 3 shows a cross-sectional view of the vertical simulation of the pipeline room. Room 11 on floor 5 is the main starting point for this horizontal simulation to verify the disease transmission problem of the virus on the vertical floor. Unlike the horizontal simulation (sewage system), this exhaust air ventilation system is a purely airborne disease transmission system. Figure 3 also shows that the duct is connected to the main pipeline, like the sewage system, to verify the proposed architecture method. Table 2 also lists the exhaust ventilation pipeline information exported from the BIM data.

4.2. Probability of Disease Transmission. The data from BIM standardizes the length, pipe diameter, and speed. In

Table 3: Simulation results of GA—Sewage pipeline (horizontal-5F).

Pairs	Times	1	2	3	4	5	6	7	8	9	10	11	12
Distance & diameter	1	1	1	1	1	0	0	1	0	0	0	—	1
	2	1	1	1	1	0	0	1	0	0	1	—	0
	3	1	1	1	0	0	0	1	0	0	1	—	1
	4	1	1	1	1	0	0	1	0	0	1	—	0
	5	1	0	1	1	0	0	1	0	0	1	—	1
	…	…	…	…	…	…	…	…	…	…	…	—	…
	996	1	1	1	1	0	0	1	0	0	1	—	0
	997	1	0	1	1	0	0	1	0	0	1	—	1
	998	1	1	1	1	0	0	1	0	0	0	—	1
	999	1	1	1	1	0	0	1	0	0	1	—	0
	1000	1	1	0	1	1	0	0	0	1	1	—	0
	Total	999	711	978	711	80	44	875	42	72	767	—	721
Distance & speed	1	1	1	1	1	0	0	1	0	0	0	—	1
	2	1	1	1	1	0	0	1	0	0	0	—	1
	3	1	0	1	0	1	0	0	1	0	1	—	1
	4	1	0	1	1	0	0	1	0	0	1	—	1
	5	1	0	1	1	0	0	1	0	0	1	—	1
	…	…	…	…	…	…	…	…	…	…	…	—	…
	996	1	1	1	1	0	0	1	0	0	0	—	1
	997	1	1	0	0	1	0	0	0	1	1	—	1
	998	1	1	1	1	0	0	1	0	0	1	—	0
	999	1	1	1	1	0	0	1	0	0	1	—	0
	1000	1	1	1	0	0	0	1	0	0	1	—	1
	Total	984	696	979	762	89	44	864	48	97	727	—	710
Speed & diameter	1	1	0	1	1	1	0	1	0	0	1	—	0
	2	1	0	0	0	1	1	1	0	1	1	—	0
	3	1	0	0	1	0	1	1	1	0	1	—	0
	4	1	1	0	1	0	0	1	1	0	0	—	1
	5	1	0	1	0	0	0	1	1	1	0	—	1
	…	…	…	…	…	…	…	…	…	…	…	—	…
	996	1	0	1	0	0	1	1	0	1	0	—	1
	997	1	1	0	0	1	0	1	0	1	0	—	1
	998	1	1	0	0	0	0	1	1	1	0	—	1
	999	1	0	0	1	1	0	1	0	0	1	—	1
	1000	1	0	1	0	0	1	1	0	1	0	—	1
	Total	1000	473	440	461	421	439	1000	431	441	455	—	439
Arithmetic mean (≈)		17	11	13	11	3	3	15	3	3	11	—	10

addition, we assume that the room 11 is the starting room, the other rooms are the target rooms, and that the virus is 6000 units (horizontal) and 4000 units (vertical). We then simulated the distance and diameter, distance and speed, and speed and diameter as the values and weights of the knapsack. After running 1000 iterations through the GA, the results shown in Table 3 were obtained. It can be observed that the probability of infection of the vertical pipelines connecting the upper and lower floors of room 1 and room 7 is higher than that of the other rooms (more than 90%), while those of rooms 5, 6, 8, and 9 are obviously much lower than those of the other rooms (below 20%), as shown in Figure 4. Thus far, we understand that the spreading

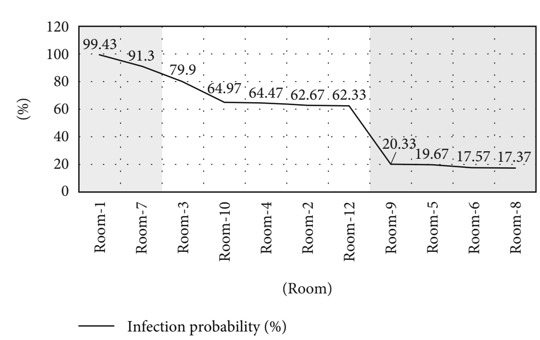


Figure 4: Probability of diffusion in each room by horizontal-5F (descending power).

Table 4: Simulation results of GA—exhaust air ventilation pipeline (vertical-1F~RF).

Pairs	Times/room11	1F	2F	3F	4F	5F	6F	7F	RF
Distance & diameter	1	0	1	0	1	—	1	1	0
	2	0	1	1	0	—	1	1	0
	3	0	0	1	0	—	1	1	1
	4	0	0	1	1	—	1	1	0
	5	0	0	0	1	—	1	1	1
	…	…	…	…	…	—	…	…	…
	996	1	0	1	1	—	1	0	0
	997	0	0	1	1	—	1	0	1
	998	1	0	0	1	—	1	1	0
	999	1	0	0	1	—	1	1	0
	1000	0	1	1	0	—	1	1	0
	Total	163	409	678	801	—	850	659	440
Distance & speed	1	0	1	0	1	—	1	1	0
	2	0	0	1	1	—	1	1	0
	3	1	0	1	1	—	1	0	0
	4	1	0	1	1	—	1	0	0
	5	0	0	1	1	—	1	1	0
	…	…	…	…	…	—	…	…	…
	996	0	1	0	1	—	1	1	0
	997	0	1	0	1	—	1	0	1
	998	0	1	0	1	—	1	0	1
	999	0	0	1	1	—	0	1	1
	1000	0	1	1	1	—	1	0	0
	Total	184	431	654	828	—	832	666	405
Speed & diameter	1	1	1	1	1	—	0	0	0
	2	1	1	1	0	—	0	1	0
	3	1	1	1	0	—	0	1	0
	4	0	1	1	1	—	0	0	1
	5	1	1	0	1	—	0	0	1
	…	…	…	…	…	—	…	…	…
	996	0	0	1	1	—	1	0	1
	997	1	1	0	0	—	1	1	0
	998	1	0	0	1	—	1	1	0
	999	1	0	1	0	—	0	1	1
	1000	0	1	1	0	—	0	1	1
	Total	561	595	570	560	—	584	567	563
Arithmetic mean (≈)		8	12	16	18	—	19	16	12

probability on the floor plan is related to the starting room and that the vertical spreading probability is 90%. In Table 4, we also find results similar to those of Cheng and Lin [2], in which the virus was gradually transmitted to other floors. As shown in Figure 5, the probability of disease on adjacent floors reached 70%, whereas on the farthest floor, 1F, this probability was approximately 30%. Therefore, it can be observed from Figures 4 and 5 that the probability of horizontal disease transmission is higher than that of vertical transmission (approximately 80% in room 3).

4.3. Route of Disease Transmission. As shown in Figures 4 and 5, the diffusion of the virus was simulated using the diffusion probabilities of each room and floor. To reduce the simulation burden on the computer, each room was

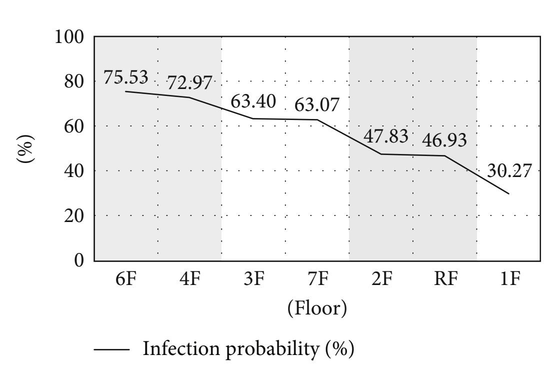
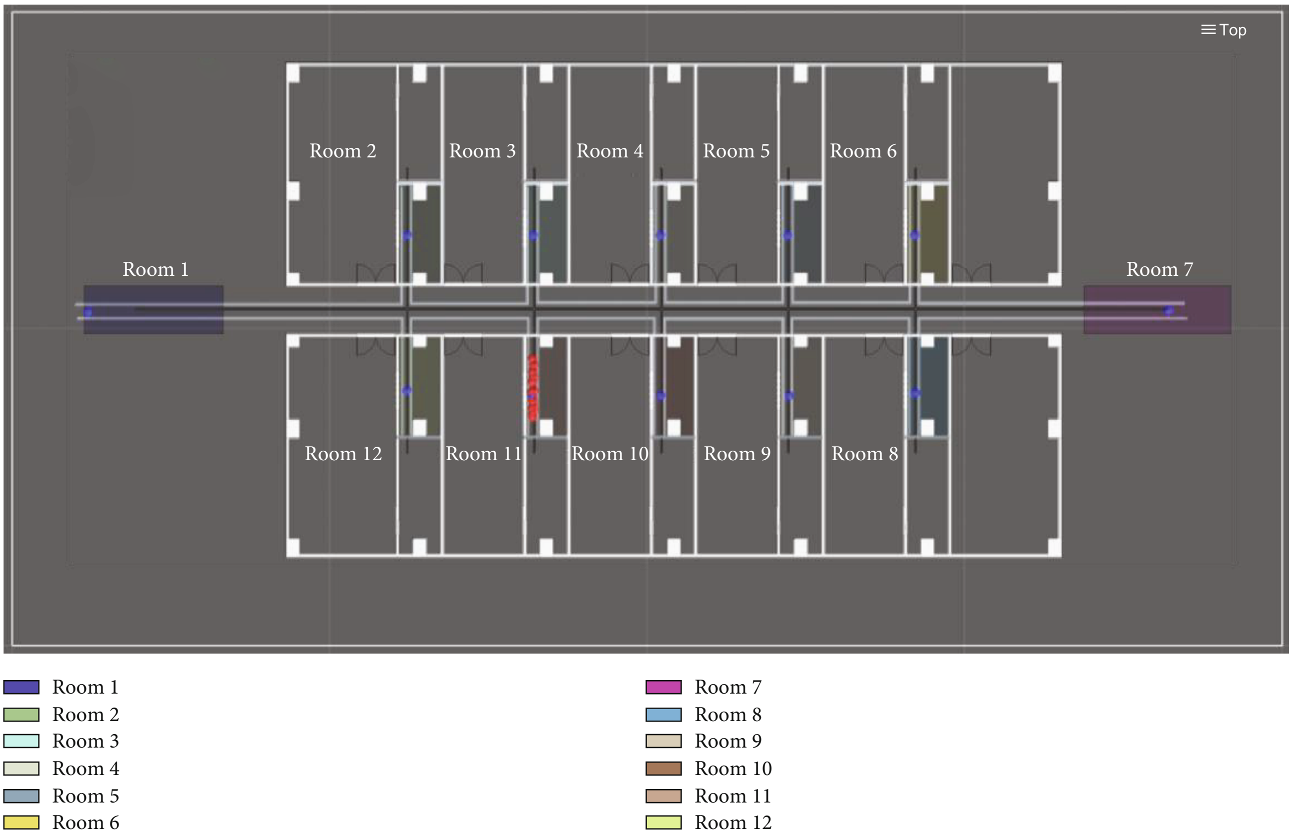
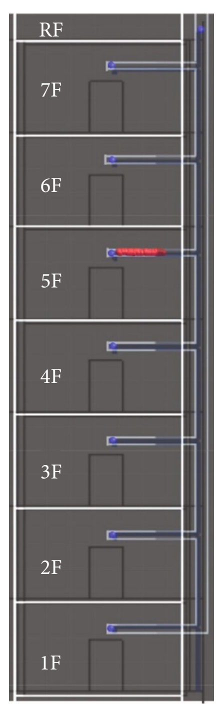


Figure 5: Probability of diffusion in each floor by vertical-1F~RF (descending power).



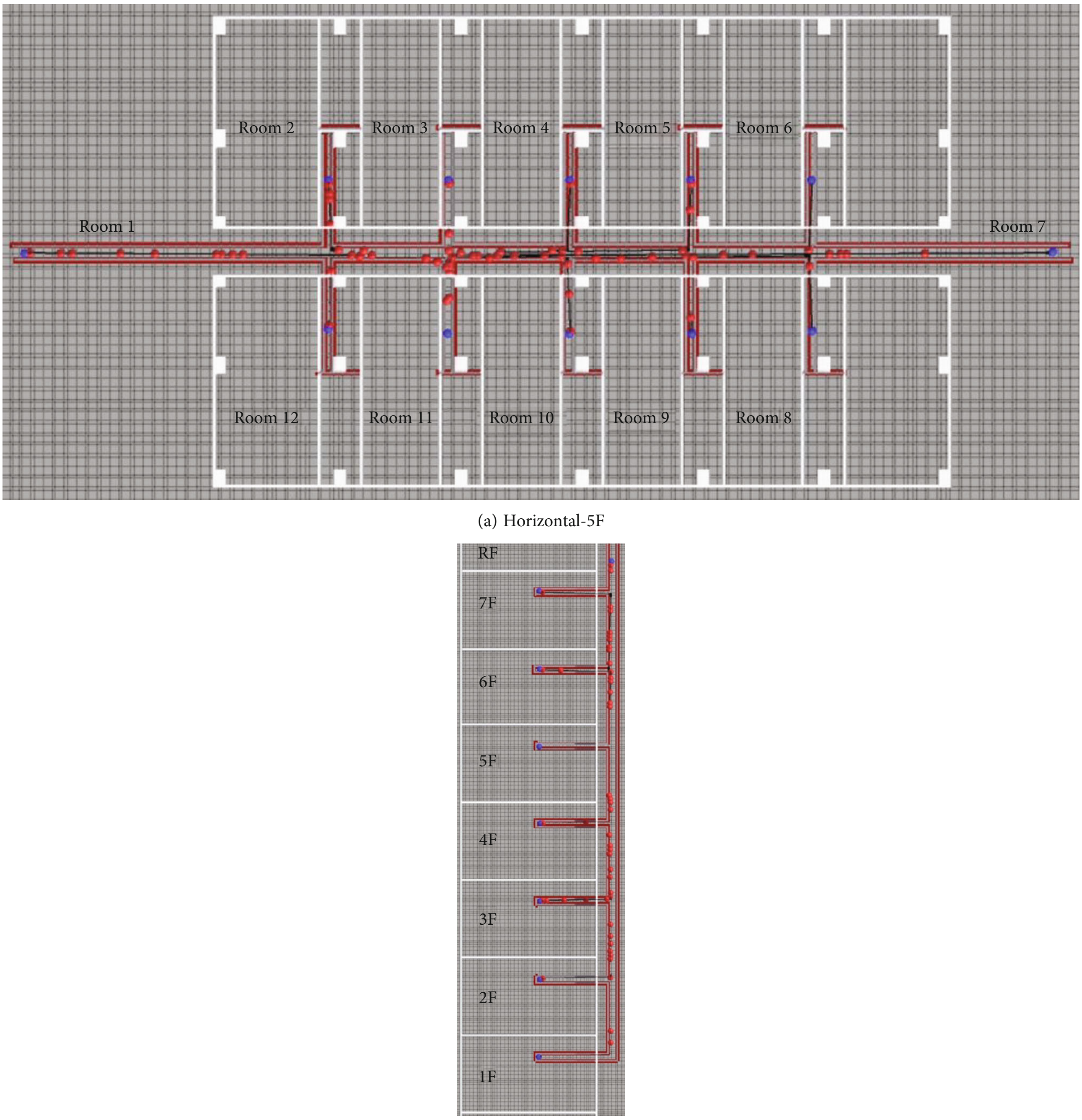
(a) Horizontal-5F



(b) Vertical-1F~RF

Figure 6: Import to Unity virus generation result.

averaged and input into Unity. To set Unity (the arithmetic means in Tables 3 and 4), it is necessary to fix the range of the virus route to ensure that the virus moves in the pipeline during the simulation. After generating the number of viruses and determining their locations, a simulation was performed. The results after the generation are shown in



(a) Horizontal-5F

(b) Vertical-1F~RF

Figure 7: Unity simulated virus route.

Figure 6. Blue indicates not only the room but also the target of the virus, and red indicates the virus. As shown in Figure 7, the pipeline with the red border is the range of the virus route that we fixed in the simulation, and the thin black line is the virus route.

5. Conclusion

The application of BIM is well known; however, it is rarely used for more in-depth information models and 3D drawings. Therefore, we propose a visualization of disease transmission probability and route prediction that combines BIM and Unity. In addition, we use the pipeline data provided by the BIM to simulate the spread, and the 3D model is imported into Unity for subsequent visualization. When simulating the probability of diffusion, we compare the number of rooms to a backpack, and the pipeline data are the values and weights. We use the GA to perform an optimization simulation with 1000 iterations. The horizontal result shows that the disease transmission probability of the vertical pipeline to the upper and lower floors is as high as 90%, while that in the initial surrounding rooms lies between 60 and 80%, and the rooms with the lowest disease probabilities are the outermost four rooms, where it is approximately 20%. Furthermore, we found that the straighter the pipeline is, the more likely viruses are to spread through it. To illustrate, the highest probability of disease transmission (80%) for all plane pipes was in room 3. Eventually, the proposed method can effectively analyze the factors of the pipeline, which is conducive to simulating disease transmission to various rooms. The vertical results show the same situation as the horizontal results, and floors farther from the starting room have a lower probability of infection. The results also show that distance has a higher influence than the other two factors; therefore, we can focus on the distance between pipelines in future work.

This study has shown good simulation results and has verified that this method can be applied to different situations of vertical or horizontal floors. However, due to the limitations of the institutional review board (IRB), medical majors, and disease transmission, the simulation cannot be compared with a real situation. This demonstrates the importance of our framework development, which will promote the application of BIM in hotels and hospitals in the future.

Data Availability

The data (Building Information Modeling Data-Driven in the Visual Simulation of Virus Spread and Path) used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authors' Contributions

Conceptualization, methodology, and writing—original draft preparation, were done by H.-C.H. and Y.-H.L.. Software, data curation, visualization, and project administration were assigned to H.-C.H. and K.-W.H.. Validation, writing—review and editing, supervision, and funding acquisition were conducted by C.-Y.P.

Acknowledgments

This work was financially supported by the National Science and Technology Council, Taiwan (grant number NSTC 112-2628-E-006-003) and the Hierarchical Green-Energy Materials (Hi-GEM) Research Center, National Cheng Kung University, Tainan 70101, Taiwan, from The Featured Areas Research Center Program within the framework of the Higher Education Sprout Project (NCKU Sustainable Interdisciplinary Integrated Project, D112-F2312) by the Ministry of Education (MOE) in Taiwan.

References

[1] N. Rosa, M. Jordão, J. Costa et al., "Experimental and numerical evaluation of a new visor concept with aerodynamic sealing to protect medical professionals from contaminated droplets and aerosols," *Indoor Air*, vol. 32, no. 9, Article ID e13114, 2022.

[2] C.-L. Cheng and Y.-Y. Lin, "CFD numerical simulation in building drainage stacks as an infection pathway of COVID-19," *International Journal of Environmental Research and Public Health*, vol. 19, no. 12, 2022.

[3] M. Gormley, T. J. Aspray, and D. A. Kelly, "Aerosol and bioaerosol particle size and dynamics from defective sanitary plumbing systems," *Indoor Air*, vol. 31, no. 5, pp. 1427–1440, 2021.

[4] M. L. Holshue, C. DeBolt, S. Lindquist et al., "First case of 2019 novel coronavirus in the United States," *New England Journal of Medicine*, vol. 382, no. 10, pp. 929–936, 2020.

[5] K.-W. Shi, Y.-H. Huang, H. Quon, Z.-L. Ou-Yang, C. Wang, and S. C. Jiang, "Quantifying the risk of indoor drainage system in multi-unit apartment building as a transmission route of SARS-CoV-2," *Science of the Total Environment*, vol. 762, article 143056, 2021.

[6] I. T. S. Yu, Y. Li, T. W. Wong et al., "Evidence of airborne transmission of the severe acute respiratory syndrome virus," *New England Journal of Medicine*, vol. 350, no. 17, pp. 1731–1739, 2004.

[7] S.-M. Duan, X.-S. Zhao, R.-F. Wen et al., "Stability of SARS coronavirus in human specimens and environment and its sensitivity to heating and UV irradiation," *Biomedical Environmental Sciences*, vol. 16, no. 3, pp. 246–255, 2003.

[8] B. Apperl, A. Pressl, and K. Schulz, "Feasibility of locating leakages in sewage pressure pipes using the distributed temperature sensing technology," *Water, Air, & Soil Pollution*, vol. 228, no. 2, p. 82, 2017.

[9] J. Biryukov, J. A. Boydston, R. A. Dunning et al., "Increasing temperature and relative humidity accelerates inactivation of SARS-CoV-2 on surfaces," *mSphere*, vol. 5, no. 4, 2020.

[10] D. E. Corpet, "Why does SARS-CoV-2 survive longer on plastic than on paper?," *Medical Hypotheses*, vol. 146, article 110429, 2021.

[11] F. Mauger, C. Chandre, and T. Uzer, "Simulated annealing algorithm for finding periodic orbits of multi-electron atomic systems," *Communications in Nonlinear Science and Numerical Simulation*, vol. 16, no. 7, pp. 2845–2852, 2011.

[12] J. A. T. Machado, S. M. A. Pahnehkolaei, and A. Alfi, "Complex-order particle swarm optimization," *Communications in Nonlinear Science and Numerical Simulation*, vol. 92, article 105448, 2021.

[13] B. Xu, Q. Chen, and Z. Wang, "Track initiation with ant colony optimization," *Communications in Nonlinear Science and Numerical Simulation*, vol. 14, no. 9-10, pp. 3629–3644, 2009.

[14] T.-Y. Huang, P.-Y. Huang, and H.-Y. Tsai, "Automatic design system of optimal sunlight-guiding micro prism based on genetic algorithm," *Developments in the Built Environment*, vol. 12, article 100105, 2022.

[15] A. R. Soltani, H. Tawfik, J. Y. Goulermas, and T. Fernando, "Path planning in construction sites: performance evaluation of the Dijkstra, a^{ss}, and GA search algorithms," *Advanced Engineering Informatics*, vol. 16, no. 4, pp. 291–303, 2002.

[16] H.-C. Hsu, S. Chang, C.-C. Chen, and I.-C. Wu, "Knowledge-based system for resolving design clashes in building information models," *Automation in Construction*, vol. 110, article 103001, 2020.

[17] Q. Feng, H. Cai, F. Li, X. Liu, S. Liu, and J. Xu, "An improved particle swarm optimization method for locating time-varying indoor particle sources," *Building and Environment*, vol. 147, pp. 146–157, 2019.

[18] B. Guan and Y. Zhao, "Self-adjusting ant colony optimization based on information entropy for detecting epistatic interactions," *Genes*, vol. 10, no. 2, p. 114, 2019.

[19] M. Ghosh, S. Adhikary, K. K. Ghosh, A. Sardar, S. Begum, and R. Sarkar, "Genetic algorithm based cancerous gene identification from microarray data using ensemble of filter methods," *Medical Biological Engineering Computing*, vol. 57, no. 1, pp. 159–176, 2019.

[20] F. Li, S. Zlatanova, M. Koopman, X. Bai, and A. Diakité, "Universal path planning for an indoor drone," *Automation in Construction*, vol. 95, pp. 275–283, 2018.

[21] R. Santos, A. A. Costa, J. D. Silvestre, T. Vandenbergh, and L. Pyl, "BIM-based life cycle assessment and life cycle costing of an office building in Western Europe," *Building and Environment*, vol. 169, article 106568, 2020.

[22] G. Edwards, H. Li, and B. Wang, "BIM based collaborative and interactive design process using computer game engine for general end-users," *Visualization in Engineering*, vol. 3, no. 1, p. 4, 2015.

[23] H. Chen, L. Hou, G. Zhang, and S. Moon, "Development of BIM, IoT and AR/VR technologies for fire safety and upskilling," *Automation in Construction*, vol. 125, article 103631, 2021.

[24] A. Sidani, F. M. Dinis, J. Duarte et al., "Recent tools and techniques of BIM-based augmented reality: a systematic review," *Journal of Building Engineering*, vol. 42, article 102500, 2021.

[25] H. Park and S. Choo, "A development of visualization technology through AR-based design checklist connection," *Applied Sciences*, vol. 12, no. 12, p. 6126, 2022.

[26] Q. Zhou, J.-K. Hao, and Q. Wu, "A hybrid evolutionary search for the generalized quadratic multiple knapsack problem," *European Journal of Operational Research*, vol. 296, no. 3, pp. 788–803, 2022.

[27] K. M. Bretthauer and B. Shetty, "The nonlinear knapsack problem - algorithms and applications," *European Journal of Operational Research*, vol. 138, no. 3, pp. 459–472, 2002.

[28] I. Deplano, C. Lersteau, and T. T. Nguyen, "A mixed-integer linear model for the multiple heterogeneous knapsack problem with realistic container loading constraints and bins' priority," *International Transactions in Operational Research*, vol. 28, no. 6, pp. 3244–3275, 2021.

[29] N. Moradi, V. Kayvanfar, and M. Rafiee, "An efficient population-based simulated annealing algorithm for 0–1 knapsack problem," *Engineering with Computers*, vol. 38, no. 3, pp. 2771–2790, 2022.

[30] J. Skackauskas, T. Kalganova, I. Dear, and M. Janakiram, "Dynamic impact for ant colony optimization algorithm," *Swarm and Evolutionary Computation*, vol. 69, article 100993, 2022.

[31] R. G. Babukarthik, C. Dhasarathan, M. Kumar, A. Shankar, S. Thakur, and X. Cheng, "A novel approach for multi-constraints knapsack problem using cluster particle swarm optimization," *Computers & Electrical Engineering*, vol. 96, article 107399, 2021.

[32] A. Rezoug, M. Bader-El-Den, and D. Boughaci, "Guided genetic algorithm for the multidimensional knapsack problem," *Memetic Computing*, vol. 10, no. 1, pp. 29–42, 2018.

[33] S. Qian, Y. Liu, Y. Ye, and G. Xu, "An enhanced genetic algorithm for constrained knapsack problems in dynamic environments," *Natural Computing*, vol. 18, no. 4, pp. 913–932, 2019.

[34] C. Changdar, R. K. Pal, G. S. Mahapatra, and A. Khan, "A genetic algorithm based approach to solve multi-resource multi-objective knapsack problem for vegetable wholesalers in fuzzy environment," *Operational Research*, vol. 20, no. 3, pp. 1321–1352, 2020.

[35] J. Yang, Y.-H. Kim, and Y. Yoon, "A memetic algorithm with a novel repair heuristic for the multiple-choice multidimensional knapsack problem," *Mathematics*, vol. 10, no. 4, p. 602, 2022.

[36] L.-C. Lien and U. Dolgorsuren, "BIM-based steel reinforcing bar detail construction design and picking optimization," *Structure*, vol. 49, pp. 520–536, 2023.

[37] G. Demirdöğen, Z. Işık, and Y. Arayici, "BIM-based big data analytic system for healthcare facility management," *Journal of Building Engineering*, vol. 64, article 105713, 2023.

[38] A. Khalili, "An XML-based approach for geo-semantic data exchange from BIM to VR applications," *Automation in Construction*, vol. 121, article 103425, 2021.

[39] T. M. O'Grady, N. Brajkovich, R. Minunno, H.-Y. Chong, and G. M. Morrison, "Circular economy and virtual reality in advanced BIM-based prefabricated construction," *Energies*, vol. 14, no. 13, p. 4065, 2021.

[40] C. Olaverri-Monreal, J. Errea-Moreno, A. Díaz-Álvarez, C. Biurrun-Quel, L. Serrano-Arriezu, and M. Kuba, "Connection of the SUMO microscopic traffic simulator and the Unity 3D game engine to evaluate V2X communication-based systems," *Sensors*, vol. 18, no. 12, p. 4399, 2018.

[41] K. M. Wesencraft and J. A. Clancy, "Using photogrammetry to create a realistic 3D anatomy learning aid with Unity game engine," in *Biomedical Visualisation*, P. M. Rea, Ed., vol. 5, pp. 93–104, Springer International Publishing, Cham, 2019.

[42] C. Moscoso, M. Nazari, and B. S. Matusiak, "Stereoscopic images and virtual reality techniques in daylighting research: a method-comparison study," *Building and Environment*, vol. 214, article 108962, 2022.

[43] R. L. Hanie and J. J. van Rensburg, "Using Reinforcement Learning Algorithms to Explore COVID-19 Spread in South Africa," in *2021 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD)*, Durban, South Africa, August 2021.

[44] P. E. Hart, N. J. Nilsson, and B. Raphael, "A formal basis for the heuristic determination of minimum cost paths," *IEEE Transactions on Systems Science and Cybernetics*, vol. 4, no. 2, pp. 100–107, 1968.

[45] B. Huang, Q. Wu, and F. B. Zhan, "A shortest path algorithm with novel heuristics for dynamic transportation networks," *International Journal of Geographical Information Science*, vol. 21, no. 6, pp. 625–644, 2007.