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A Study on the Classification of Exhibition Contents Based on the Agent's Behavior and the Applicability of Discrete Event Simulation in an Exhibition Space

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Abstract
Establishment and focus: Exhibition facilities should reduce unnecessary viewing time by arranging the exhibition contents efficiently. Simulation verification during the design stage can help improve these facilities, but its application is limited because of the diversity of the contents and the uncertainty and variability of exhibition facilities. Discrete event simulation is a computational model that tracks data trends over time, and it is receiving the spotlight as a useful tool for identifying risks without having to stop the system and finding optimal solutions or improvement measures through continuous feedback. However, there are difficulties in applying discrete event simulation to exhibition facilities with high uncertainty because the discrete event simulation is only applicable to spaces where the procedures are formalized and the procedures of the content and agent are fixed. Therefore, this study first classified the exhibition contents and then applied pedestrian-based discrete event simulation to an exhibition space classified by content type to examine its usefulness.

System: Based on prior studies and the visitor(agent)'s behavior, the exhibition contents were defined and divided into three categories (viewing, participatory, experiential). The method was applied to a simplified small prototype model to examine the applicability of discrete event simulation for exhibition spaces. A simulation tool was developed for measuring the time required for viewing the contents as well as the number of visitors that can be accommodated during the exhibition hours. The objective was to analyze three alternatives that included the three types of exhibition contents while changing the order of viewing them. According to the results, the layout of the exhibition contents did not have a significant effect on the overall viewing time. However, the alternatives that adjusted the services resulted in significant improvements in all three layouts. This study found that discrete event simulation can be applied to uncertain and variable exhibition facilities if the exhibition contents can be classified and pedestrian circulation can be organized. However, further research will be required to subdivide exhibition types based on more cases of exhibition contents. Moreover, variables must be defined for converting the defined types into simulation objects.

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1. Introduction

Exhibition spaces such as exhibition halls, art galleries, museums, science museums, and experience centers play a very important role in education and culture in modern society, and an unspecified number of people visit these spaces. Exhibition facilities should deliver information

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about the exhibits (contents) to visitors more efficiently by reducing inefficient space and congestions and arranging proper waiting areas during the spatial design process. If the visitor's behavior and movement according to the types of exhibits can be predicted quantitatively during this process, it will be a very effective tool for verifying the exhibition plan.

Discrete event simulation observes the flow of agents changing over time and is receiving attention as a very useful verification tool to evaluate and improve the performance of architectural spaces. This is because the simulation allows us to interpret high-dimensional social complexes where people interact with space or contents. In particular, many studies have recently begun applying pedestrian-based discrete event simulations to evaluate and improve the performance of architectural spaces.

Previous studies on discrete event simulations have been applied to spaces where the agents have clear and uniform goals or in areas where the system is clearly distinguished from the outside, such as general medical facilities[1-3] including emergency centers[4-8] and outpatient departments[9-12], or facilities with formalized procedures and manuals, such as production lines[13-15] or supply lines (logistics) [16,17].

Exhibition facilities are also procedure-oriented facilities that emphasize the use of space (uniformity). But, unlike medical or production facilities, the contents are highly diverse, the attributes and functions are unspecific, and the circulation of visitors is highly flexible depending on the story of the exhibition. Moreover, modern exhibitions are delivering information in more diverse ways than before, and many exhibitions encourage visitor participation and experience. Therefore, more scientific research is required to develop spatial strategies and plans by predicting the viewing behavior between various exhibits and unspecified visitors. Therefore, this study explored methods to classify exhibition contents and defined them as objects applicable to discrete event simulation based on the influence of exhibition contents on the visitor's behavior. From this basis, the study defined three types of contents and applied discrete event simulation to a virtual prototype space reflecting these contents to examine the effect of content layout and attributes on viewing time.

Although this is a basic study to examine the usefulness of discrete event simulation as a verification tool in the stage of planning and designing exhibition spaces, extending the scope of research to non-structured spatial systems is meaningful since its applicability as a design tool has been confirmed through studies that have integrated[18-20] or linked[21] discrete event simulation verification with BIM.

2. Materials and Methods

H Discrete event simulation has mainly been applied to facilities with formalized procedures and service manuals such as production lines and medical services. However, exhibition facilities implemented by exhibition contents and spatial presentations have unspecified and various ways of delivering information. Moreover, there are difficulties in modeling because the layout of space and contents is also very free, which is why there is a lack of studies that apply discrete event simulation to exhibition facilities from the study cases applying discrete event simulation to architectural spaces.

While the layout of exhibition spaces can be flexibly organized according to the purpose of the exhibition and the intention of the exhibition manager without following standardized manuals, the visitors show different reactions depending on the nature of the contents. In this way, the contents can be classified according to the behavior of the visitors. According to a relevant prior study[22], the visitor's viewing time is considered as the time required to acquire information related to the exhibits. That is, since it is difficult to define the contents by unspecified individuals or complex physical conditions, the process of viewing the exhibits is described by introducing the concept of a start-end structure based on the flow of time and composition, and the characteristics of viewing time are allocated accordingly. The details are as follows.

The first type is a non-limited exhibition that has no limit on the beginning of the exhibition, which consists of nonverbal (spatial) symbols such as paintings, statues, models, dioramas, and image panels. This content type is difficult for visitors to recognize the temporal order of collecting exhibition information. These mainly include exhibits where the beginning and end are unclear.

The second type is an unlimited exhibition that has a limit on the start but no limit on the end. That is, the exhibition information of exhibition contents such as explanatory panels and narrations (audio, video) need to be processed by the audiovisual effort or active will of the visitors. These exhibits usually have language-oriented exhibition information, and the end of collecting exhibition information is unclear compared to limited types.

The third type is a time-limited exhibition in which the end of the exhibition is limited in time among the same start-limited exhibitions as the second type, which has a clear concept of when to start collecting exhibition information and ends after a certain period of time. These mainly include image, audio, and operating model exhibitions and game-type touch screens that are activated by sensors and buttons, with consistent forms of termination and passive relationships with the visitors.

The fourth type is an opportunity-limited exhibition in which the end is subjected to the opportunity for visitors to see the exhibition among the start-limited exhibitions. These exhibitions require attention from the visitors to collect exhibition information (puzzles, operating models, game-type touch screens, etc.), and the viewing experience ends by completing the mission intended by the designer. Unlike the third type, this requires an active relationship because the viewing ends according to the individual's will and ability.

Based on previous studies, the types of exhibits and their viewing time according to visitor behavior can be classified into three types of exhibitions and viewing characteristics. Each type is as follows.

2.1. Viewing-type exhibition contents

Viewing types are non-limited and unlimited exhibits that consist of non-verbal symbols and languages that are classified according to the start-end structure of exhibitions mentioned in the prior studies[22]. However, this study classifies narrations (audio, video) as participatory exhibition types, which will be mentioned later, and viewing-types are defined as exhibitions where the viewing time depends purely on the will of the visitors.

Visitors recognize and view the exhibits as they move around the space, and the time required for viewing is relatively short regardless of the size and type of the exhibits. Therefore, the average viewing time and the types of exhibits are more affected by the type and number of exhibits than the size.

The minimum viewing time is the time required for the visitors to ignore and pass by each exhibit and the maximum viewing time is the sum of the time required to view each exhibit according to the intention of the exhibition content planner.

2.2. Participatory-type exhibition contents

Participatory-type exhibitions include narration (video, audio) exhibitions among time-limited and unlimited types. These exhibition types begin as the visitor directly operates the images, models,

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and kiosks, and have a clear beginning and end because the viewing time consists of the running time of the featured exhibition contents. Although some visitors may view the contents again and again, these few exceptions will not have a significant impact on the results.

As in the case of viewing-type exhibition contents, the minimum viewing time is the time required for the visitors to ignore and pass by each exhibit. However, as the time required would be exponential rather than uniform, the maximum viewing time would be the running time planned by the exhibition manager.

2.3. Experiential-type exhibition contents

Experiential exhibitions are opportunity-limited exhibitions in which visitors actively participate to acquire exhibition information. Although the minimum viewing time is the time required for the visitors to ignore and pass by each exhibit, survey results show that only a few visitors leave these types of exhibitions in the early stage.

The maximum viewing (experience) time may be estimated as the time planned by the exhibition content planner, but the total viewing (experience) time in experiential exhibitions can be simulated by dividing the estimated experience time by the number of exhibits. This is because the number of people that can be accommodated at a given time increases according to the number of exhibits (services).

3. Simulation Tests

3.1. Simulation configuration

This study prepared a prototype space of three unit spaces (5m x 5m) that are serially connected. It is a very simple configuration where the visitor enters through the entrance on the left, passes through each room, and exits through the exit on the right.

The visitors experience each of the viewing (A), participatory (B), and experiential (C) exhibition contents once, by configuring three alternatives ABC model (A→B→C), CBA model (C→B→A), BCA model (B→C→A)] according to the layout of the exhibition contents from the first unit space.

The viewing type (A) was configured to have a short viewing time (minimum: 0 min, maximum: 3 min), while the participatory type (B) requires a long fixed amount of time (20 min). The opportunity-limited experiential type (C) takes 5 to 30 minutes because the viewing time is highly variable. The initial speed and comport speed of the visitors (agents) were set to 0.3 m/sec~0.7 m/sec and 0.5 m/sec~1.0 m/sec, respectively, and the interval time of one agent to enter the simulation space was every 1-2 minutes.

The simulation time was set to 28,800 seconds (8 hours) to determine the maximum number of people that can experience the exhibition and measure how long it takes to view the exhibition. Since complex system computational models produce different values for each simulation, the final value was determined by averaging the values of ten repeated simulations.

This study used AnyLogic 8.x for the simulations and developed a program based on a Java platform supported by AnyLogic to count the agents and measure the time.

3.2. Changing the layout of the exhibition contents

Figure 1 shows the simulation results of the ABC model and the heat map indicates the density of the agents. As a result of analyzing the ABC model, the average number of agents that could complete viewing the exhibition within 8 hours was 263.3 (minimum: 261, maximum: 266). The average time required to view the exhibition was 3,706.24 sec (minimum:1,594.80 sec, maximum: 6,054.95 sec).

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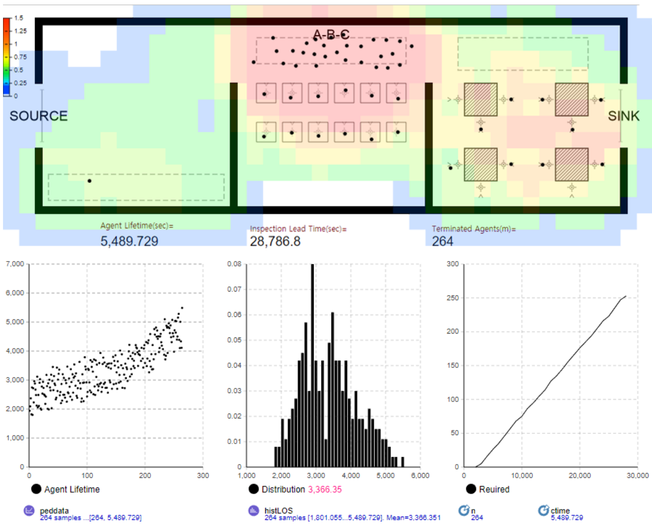

Figure 1. ABC model simulation analysis results (from the top-left: heat map, viewing time by agent, viewing time distribution, lead time)

The CBA model was analyzed to accommodate an average of 262.4 people (minimum: 261, maximum: 265), which is 0.9 more than that of ABC but this difference was insignificant. On the other hand, the time required to view the exhibition increased by 2.6% to 3,804.84 sec (minimum: 1,607.81 sec, maximum: 6,170.82 sec). Figure 2 shows the density distribution.

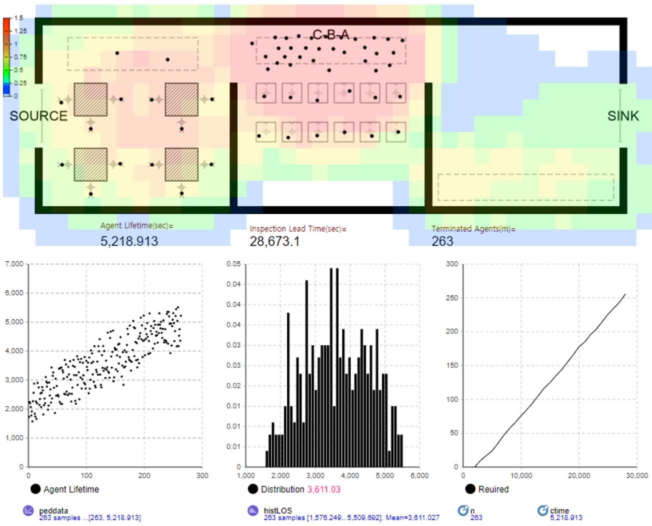

Figure 2. CBA model simulation analysis results

The BCA model figure 3 was analyzed to accommodate an average of 264.1 people (minimum: 263, maximum: 266), which is 0.8 more than that of ABC but this difference was also insignificant. The average time required to view the exhibition was 3,699.01sec (minimum: 1,665.75sec, maximum: 6,081.73sec).

In summary, changing the layout of the exhibition contents did not affect the viewing time. Therefore, the exhibition manager can feel free to arrange and organize the exhibition according to his or her intention (storytelling).

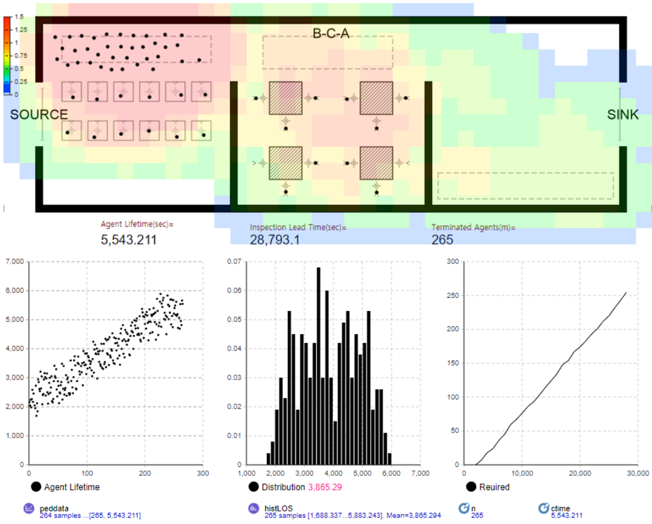

Figure 3. BCA model simulation analysis results

3.3. Adjusting the services

The second test intends to resolve queues by adjusting (allocating) the services. According to the heat maps (Figure 1-3) obtained from the previous simulations, there are no queues in the viewing-type (A), which has a short service time. However, queues occur in the participatory type (B) and experiential type (C), and more frequently in the participatory type (B) compared with the experiential type (C). Therefore, this study reduced one service from the experiential type (C) and moved it to the participatory type (B) and performed the simulations again. The names of the improved alternative models were distinguished by adding a “+” at the end of the original model. As a result of the simulations shown in figure 4, the ABC+ model was able to accommodate an average of 269.4 people (minimum: 262, maximum: 275), showing no significant difference. However, the average time

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required to view the exhibition decreased by 281.06 sec (-7.58%) to 3,425.19 sec. The maximum time also decreased by 571.88 sec (-9.44%) to 5,483.07 sec. In contrast, the minimum time increased by 63.06 sec (+12.10%) to 1,657.86 sec.

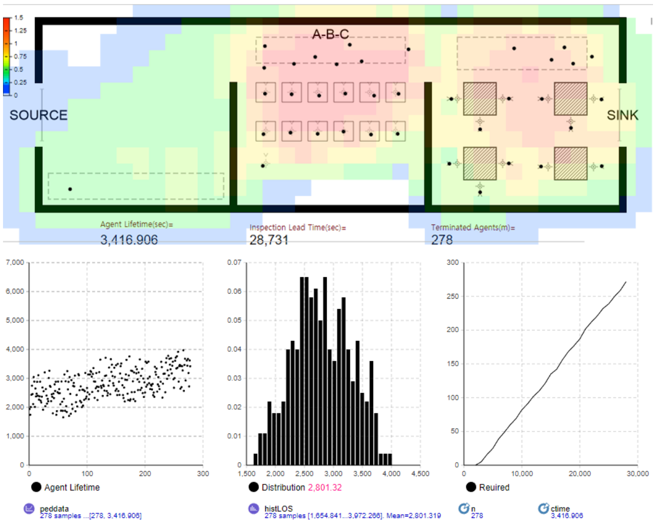

Figure 4. ABC+ model simulation analysis results

The CBA+ model could accommodate an average of 274.4 people (minimum: 267, maximum: 280), which is an increase of 12 people as shown in figure 5. The average time required to view the exhibition decreased by 315.24 sec (-8.29%) to 3,489.59 sec. The minimum time decreased by 41.71 sec (-15.62%) to 1,566.11 sec and the maximum time also decreased by 364.51 sec (-5.91%) to 5,806.31 sec.

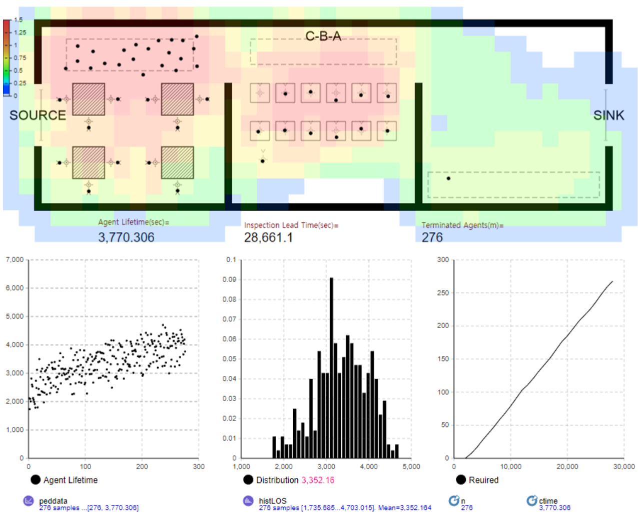

Figure 5. CBA+ model simulation analysis results

The BCA+ model could accommodate an average of 274.9 people (minimum: 267, maximum: 285), which is 10.8 more than that of BCA as shown in figure 6. The average time required to view the exhibition decreased by 433.47 sec (-11.72%) to 3,265.54 sec. The minimum time decreased by 85.96 sec (-12.76%) to 1,579.79 sec and the maximum time also decreased by 509.62 sec (-8.38%) to 5,572.11 sec.

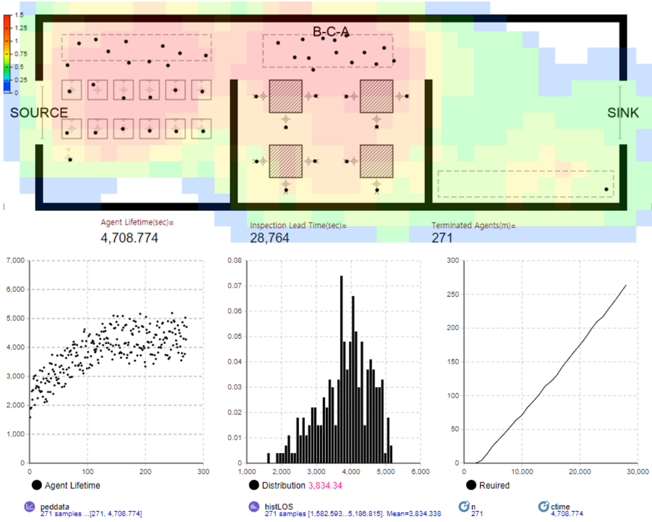

Figure 6. BCA+ model simulation analysis results

Therefore, unlike the layout of contents, adjusting the number of services was effective in reducing the viewing time and queues, and the effects may vary depending on the arrangement order. Since this study confirmed differences in a small model, the improvements in real and large spaces are expected to increase significantly

4. Conclusion

More and more studies are being conducted using discrete event simulations to reduce the service time of architectural spaces and improve efficiency by identifying risks. However, as most of the studies focus on facilities with formalized types and procedures of services, there is a lack of research on facilities that provide unstructured and flexible services such as exhibitions. Therefore, as one of the first basic studies to apply discrete event simulation to exhibition facilities that value traffic and services, this study classified the exhibition contents into viewing, participatory, and experiential types. The purpose was to examine the effects of content layout and service allocation on the functions of exhibition facilities.

According to the simulation results using a prototype virtual space, the layout of exhibition contents had no significant effect on the overall viewing time. On the other hand, it was found that adjusting the services was important because queues for a certain content affect subordinated processing. Adjusting services can have a significant effect on calculating the area of each exhibition unit and needs to be reflected in planning spaces.

In summary, the queues of each service should first be measured, and the resources on the side without queues should be moved to the side with queues to evenly distribute all of the queues. In addition, experiential exhibitions tend to require more cost and space to increase services compared with participatory exhibitions. Therefore, adjusting the number of services in the order of participatory exhibitions and viewing exhibitions based on experiential exhibitions will contribute to finding the optimal alternative.

Based on the study results, it is necessary to subdivide exhibition types based on more cases of exhibition contents and methods and an additional study on methods to define variables for converting the defined types into simulation objects is required.

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