AUTOMATIC GENERATION OF SIGNBOARDS IN LARGE-SCALE TRANSPORTATION BUILDING DRIVEN BY PASSENGERS' PATHS

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Abstract. The signage design of any large-scale transportation building is vital to its passengers' wayfinding experiences. Firstly, a set of passengers' paths should be re-designed by signage designers according to the latest requirements, which always deviates from the initial ones in large-scale projects or inevitably updates during a long-term running. Afterwards, the path design has to be transformed into the layout and content of signboards manually. It is a time-consuming and error-prone process. This study introduces a human-computer hybrid workflow keeping the flexible path design in the hands of designers and leaving the following procedures to an algorithm, which automatically generates signboard contents ready for construction. It is proved efficient with more than 3000 signboards in the project of PVG Airport, Shanghai. Furthermore, the designer got an opportunity to optimize his path design through various alternatives, which impossible traditionally.

Keywords. Design Automation; Human-Computer Hybrid; Signboard; Passenger Path; Transportation Building.

1. Introduction

Signage system design is an important part of the public buildings. Especially in large-scale transportation buildings, the design quality will significantly affect the user's wayfinding efficiency (Berger, C, 2005). The traditional signage system design method is time-consuming and laborious, and the accuracy of the design is difficult to measure. Essentially, the signage system design is a generation process based on established rules, which can be described as a programming language. Therefore, the computer-aided design method can be adopted to intervene in the designer's familiar workflow to achieve a human-computer process.

1.1. TRADITIONAL DESIGN PROCESS OF SIGNAGE SYSTEM

The traditional signage design work is a sequential process. First, obtain and analyze the expected setting of passengers' paths based on the architecture design, and draw them on the building plan (see Figure 1). Secondly, according to the relevant design specifications and design experience, decide on the locations to set signboards where needed from all potential wayfinding decision points (Han, Y, 2010), that is, to complete the layout design of the signboards. Then, think

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over passengers' paths around the location of each signboard, installation form, and specifications of font and color to design the content of the signboards (Han, Y, 2010). Finally, the construction documents are compiled to guide where to be installed.

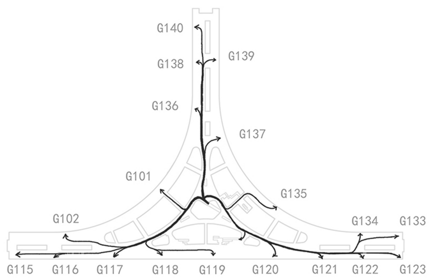

Figure 1. Passengers' paths drawn by designer.

The sequential design process means that once a modification occurs, the designer must restart the entire design, which restricts the design, update, and iteration of the signage system. In the large-scale transportation building, it contains complex passengers' paths. On the one hand, the design of the content on signboards is a tremendous workload, and it is fallible. On the other hand, although the initial passengers' paths are the most concise, they are the foundation of the whole design process, any changes to the paths will bring a series of follow-up revisions. The resulting content design and construction documents are highly repetitive and arduous.

1.2. COMPUTER AIDED DESIGN AUTOMATION

In the field of computer-aided architecture design, a direction called design automation develops rapidly in recent years. It mainly uses various algorithms to automatically complete the tasks with computable rules in the human's design process to improve design efficiency (Sun, C and Ke, X, 2016).

To aid the signage design, automation algorithms and tools are developed. Dubey, RK et al (2020) developed a tool named AUTOSIGN that automatically optimize the signboard layout with multi-criteria in office buildings. Fu, M and Liu, R (2019) found the coherence between interior main paths and the straight skeleton of its plan, with which their algorithm can generate paths from BIM models for the following automatic signage layout. Huang, H et al. (2017) proposed an automatic approach to generate a highly optimized signage layout and contents from a building plan. The idea is to involve the designer's evaluation and to adopt simulation agents to find out the design error.

Evidently, none of these algorithms or tools takes the signage designer's subjective intention on paths as a key input, which makes the automatic process a solo of computer. The requirements of a path design always deviates from the initial ones in large-scale projects or inevitably updates during a long-term running in the whole building life-time. Thus, how to involve the signage designer's key input in an automation process becomes the main question for this study.

In the following, a human-computer hybrid workflow is introduced firstly. It keeps the flexible path design in the hands of designers and leaves the following procedures to an algorithm, which automatically generates signboard contents ready for construction. It takes the satellite terminal of Shanghai Pudong International Airport (Hereinafter PVG Airport) as an example to demonstrate the whole process. In the Grasshoppers' programming environment (including GH Python), the designer inputs the passenger paths and the signboards' layout designed by himself/herself; the content of the signboard and the construction documents are automatically generated according to the relevant design specifications and standards. The automation method can be embedded into the traditional design process, saving time for designers from repetitive work. Therefore, designers can focus on the optimization design of passengers' paths and layout of signboards, and continuously improve design quality.

2. Automatic Generation Method for the Signage Driven by Passengers' Paths

2.1. HUMAN-COMPUTER HYBRID AUTOMATION DESIGN PROCESS

A design process of signboards' content with human-computer hybrid is proposed, incorporating existing automation design algorithmic efficiency and passengers' paths drawn by the designer (see Figure 2). The basic steps are consistent with the traditional method. Only the following two steps are different: the computer 'automatic generation of signboards content', and finally the computer 'automatic storage construction document'. In this way, on the premise of retaining the designer's initiative to design the passengers' paths, the efficiency of computers can be fully utilized, and the design iteration period can be greatly shortened.

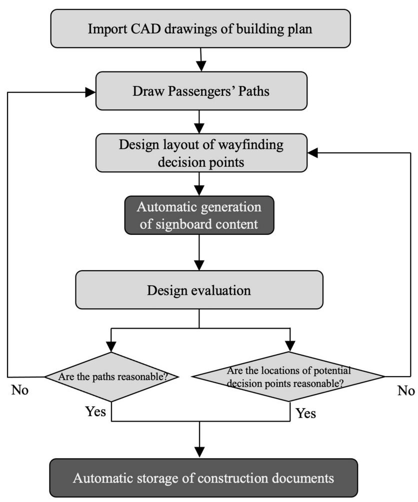

Figure 2. Human-computer hybrid workflow of signage system design (Note: dark grey - algorithm's operation, light grey - designer's operation) .

Hereafter, we take the optimization design of the signage system of the satellite terminal of PVG airport as an example to verify the feasibility and efficiency of this human-computer hybrid design process in the Grasshopper programming environment (including GH Python) of Rhino 3D.

2.2. IMPORT CAD DRAWINGS OF BUILDING PLAN

The designer imported the CAD drawings of the building plan into Rhino 3D. The Grasshopper programming identifies wall line, boarding gate names and locations, elevators, walkable area boundary and planar contour which are the corresponding geometric information in the two-dimensional building plan drawings.

2.3. DRAWING PASSENGERS' PATHS

Passengers' paths can be divided into one-direction and two-direction. Judging whether or not paths cross different floors we can classify them into vertical paths and horizontal paths. Vertical paths are usually organized by stairs, elevators, and escalators. Horizontal paths are divided into line, bifurcated line, ring, and grid type (see Figure 3). Among them, grid-type paths rarely appear in PVG airport, therefore, this research doesn't take grid-type paths into account.

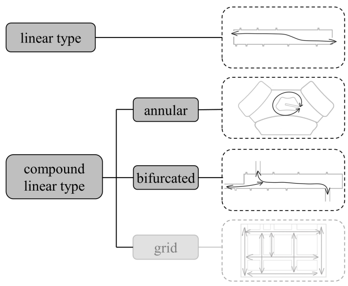

Figure 3. Classification of passenger paths.

The above several paths are combined to form the prototype of the passengers' paths in the building. The passengers' paths are the foundation of signage system design, and it is also the part that most reflects the designer's design thinking and intention. The designer uses the curve tools to draw various passengers' paths in the Rhino 3D (see Figure 1), which are read by the programming.

2.4. DESIGN LAYOUT OF WAYFINDING DECISION POINTS

After analyzing the two-dimensional building plan, designers can obtain the locations of the three types of wayfinding decision points. The target points (the black solid dot in Figure 4) are the boarding gate. The directional decision points (the gray solid dot in Figure 4) are located at the intersection of multiple paths or in a long corridor. The end decision points (the black hollow dot in Figure 4) are distributed evenly in a small corridor and look evenly distributed everywhere. On the building plan, the designer marks the wayfinding decision points location where the signboard can be installed in the future. This is equivalent to a preliminary signboards' layout design, which is generally carried out following the relevant design specification 'Guidance System for Public Information-Setting Principles and Requirements (GB/T15566.1-2007)' in China. For example, along the passengers' paths, directional decision points should be arranged at all locations where passengers may choose from which direction to go. Besides, when the distance between two wayfinding decision points on the passenger's paths is too far, the directional decision points should also be added at a visible distance for the passenger.

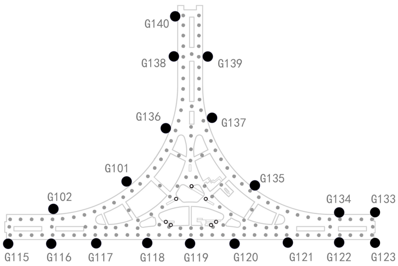

Figure 4. Decision points in international departure of satellite terminal 1 of PVG Airport (Note: black solid dots as target points; gray solid dot as directional decision points; black hollow dots as end decision points).

The algorithm contains a preset distance, when the distance between each wayfinding decision points and the passengers' paths is less than the preset distance, it is considered that the passengers' path through the wayfinding decision points. It gives designers more freedom to drawing the passengers' path in the building plan.

2.5. AUTOMATIC GENERATION OF SIGNBOARD CONTENT

Following the design specification of the signage system, the algorithm automatically generates the content of signboards according to the direction of the passengers' paths, the position of targets, and the direction of signboards.

Some signboards are fixed in their directions before the generation, such as boards under beams. In this case, the algorithm only generates their contents. While other signboards are free in direction of installation, which means the algorithm should generate not only the contents but also the directions according to visual accessibility of passengers along the paths. One signboard can show panels in two directions, and the contents in each direction are different. Therefore, a single signboard in reality is programmed as two pieces in computer programming. When the passengers' path is determined, two different algorithm situations are possible depending on whether the direction of the signboard is determined or not. The specific algorithm diagram is shown in Figure 5.

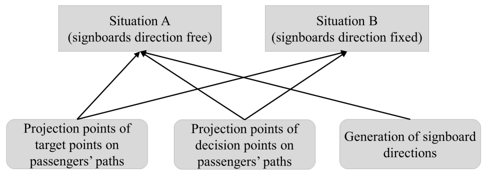

Figure 5. The algorithm of signboard generation.

2.5.1. PROJECTING THE TARGET POINTS TO THE PASSENGERS' PATHS

Due to the different attributes of the target points, their radiation range varies as well. In general, the service range of the restroom is larger than range of the boarding gate, so the radius of the restroom as a target point is larger than the latter. If there are obstacles (columns, wall, and other objects that hinder the sight) in the space, the service range of the target point will be fan-shaped. When the passenger path is within the range of the target point, the target point will be projected on his/her path (see Figure 6). When the path is bi-directional for the passengers, the both directions labeled as 'left-to-right' and 'right-to-left' in the figure should be calculated separately. According to the different directions of the passengers' path, two types of projections are created, either from right to left or from left to right. Taking G013 as an example, in the case of 'left-to-right' the algorithm will read the information of G013 before the toilet. When a signboard is located in the projection point of toilet, the content of this signboard will not contain the information of G013.

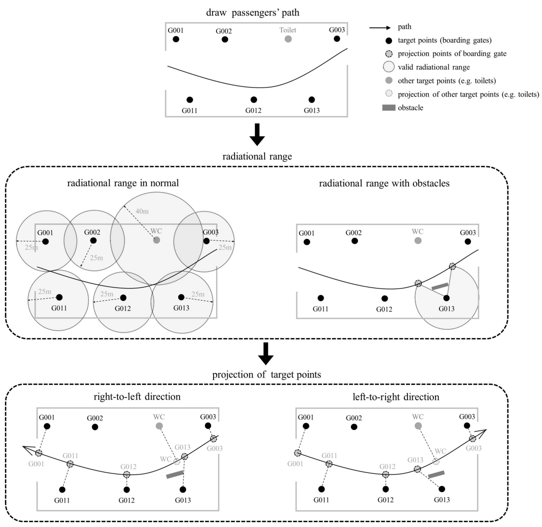

Figure 6. Projection of target points on the passengers' path.

2.5.2. PROJECTING THE DECISION POINTS TO THE PASSENGERS' PATHS

The projection of decision points has two possibilities: in situation A, the signboards' location is fixed but the direction free (see left part of Figure 7); in situation B, the signboards' location and direction are both fixed (see right part of Figure 7). Due to the variable of direction, the location of the projection of decision points will be changed accordingly.

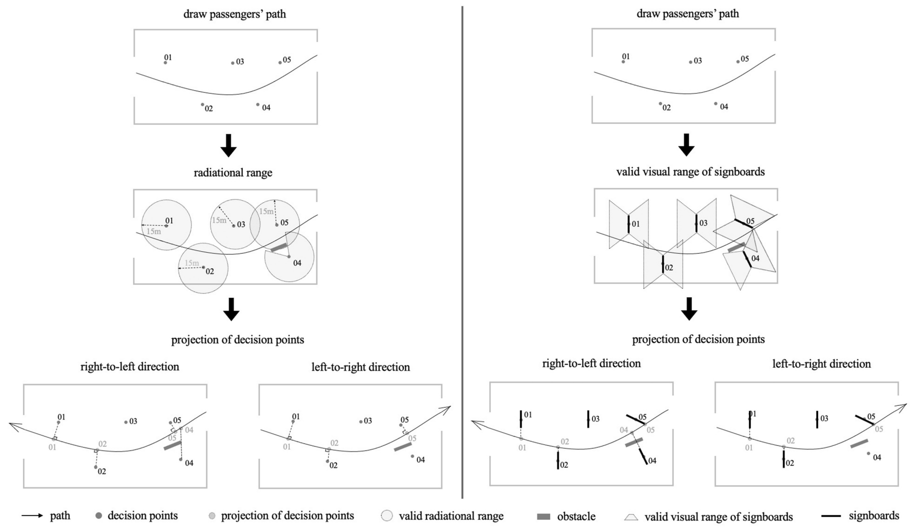

Figure 7. Projection of decision points on the passengers' path.

2.5.3. THE CONTENT OF SIGNBOARD BASED ON PASSENGER PATH AND SIGNBOARDS' DIRECTION

If the path is two-way, the front and back sides of the signboard need to be generated respectively. Based on the above generation principle, the contents of the signboard at the same decision point will alter in different directions of the signboard, namely, four results. In this section, one of the four is illustrated in Figure 8. Taking decision point 05 as an example, the direction of passengers' path is from right to the left, with the fixed signboard direction facing right. Thus, the content of signboard displays the information of the target points' projection that can be read on the path starting from point 05.

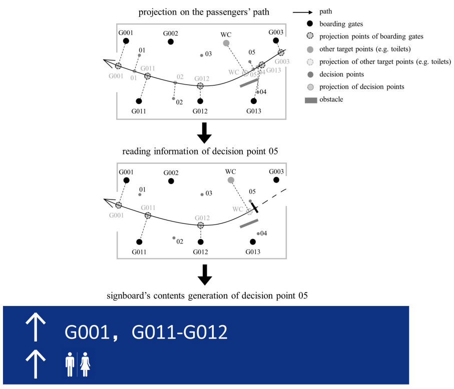

Figure 8. Decision point 05's signboard contents when signboard's direction is fixed.

2.5.4. PARAMETER OF SIGNBOARD CONTENT

The size of the font, font type, color, symbols, and format are formulated by parameters according to the local specifications. Therefore, the parameters can also be modified in accordance with the relevant specifications of various countries and regions.

2.5.5. SELECTION OF SIGNBOARDS SIZE

According to the contents generated by the algorithm, the minimum size of the signboard is estimated, and the choice is made among the common size according to the construction modules.

2.5.6. AUTOMATIC GENERATION OF SIGNBOARDS

Upon the above design and algorithm operation, the 3D signboard models are generated and can be previewed in the viewport of Rhino (see Figure 9).

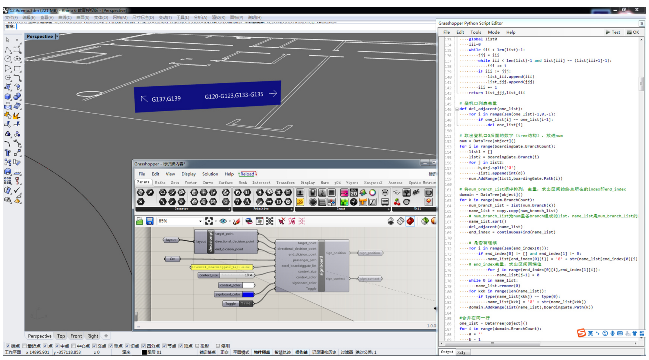

Figure 9. The algorithm and preview of automatically generated suspended signboard.

2.6. RAPID UPDATE OF PATH ADJUSTMENT

The process of path adjustment reflects the advantages of human-computer hybrid workflow. If the designer wants to adjust the passengers' paths, the contents of the signboards will also need to be modified. Meanwhile, the location of the wayfinding decision points can also be moved by the designer's intention.

For example: if the passengers' paths are changed due to the cancellation of gate G120, the designer only has to delete the path which leads to G120 (the bold black curve in Figure 10), then the content of the signboard located in the black dot position (see Figure 10) will change immediately (see Figure 11).

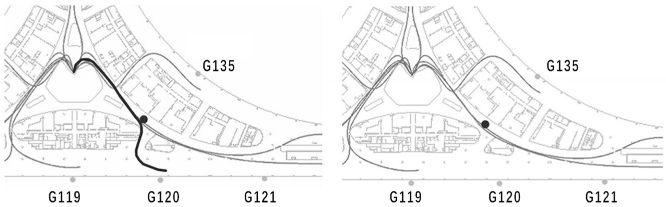

Figure 10. Passenger's path changed by the designer.

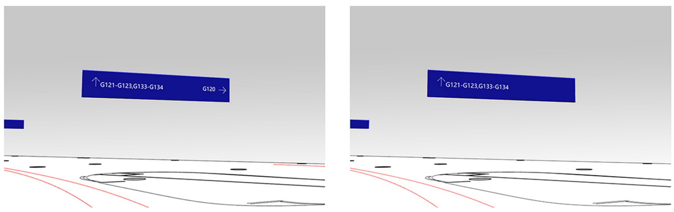

Figure 11. Content of signboard before (left) and after (right) passenger path change.

2.7. AUTOMATIC STORAGE OF CONSTRUCTION DOCUMENTS

Storage of construction documents is also automatically completed by the computer, which considerably improves the efficiency of compiling such documents, and eliminates the mistakes and omissions caused by the human operation. After the designer specifies a path to store the construction document, all signboards will be stored as the format of .bmp in the archive path. The file name is 'size + wayfinding decision points number'. For example, '3600_ 600_ 23.bmp' (see Figure 12) refers to the signboard with 3600mm in length and 600mm in height at the 23rd wayfinding decision points.

In this way, designers can quickly know the number of signboards and each signboards' size, which is convenient for designers to manage the signage system. Finally, it can also be directly delivered to people who produce and install signboards.

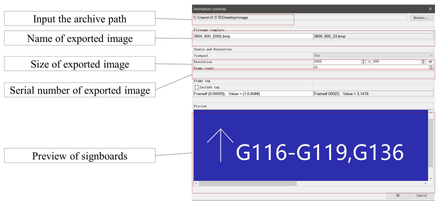

Figure 12. The export Interface of construction document.

3. Conclusion

This study provides a human-computer hybrid workflow supported by an automatic generation algorithm transforming passenger's paths into well-documented signboard contents in seconds. It reduces the labor cost significantly in large-scale projects and provides signage designers an opportunity to test various alternatives in the path design stage, which makes a quicker and better design possible.

Future research will focus on how the algorithm can automatically generate wayfinding decision points in a complex building plan through existing rules. At the same time, research will also focus on how designers can achieve an integrated human-computer hybrid workflow by adding, reducing, or moving computer-generated wayfinding decision points.

Acknowledgments

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