A Study of Sight Area Rate Analysis Algorithm on Theater Design

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ABSTRACT

This paper proposes a new quantitative sight area rate analysis algorithm based on the "sight area rate" of a stage from the audience seats in the theater. The current sightline analysis checks whether a sightline from a seat is blocked by front-row seats from a cross-sectional and plane view at the center of a theater. Although this method is a commonly accepted practice, it is not uncommon to find people who have their view blocked by the front-row seats in a theater. The newly proposed algorithm analyzes and quantifies the actual view area from each seat. The sight area rate is the actual sight area divided by the total unblocked sight area (or screen area) from each seat. The proposed algorithm provides quantitative results which make it easier to design a theater. Since the proposed algorithm can derive sight area at the early design stage of theater utilizing a set of plan and cross section drawings, it can be applied to analyze view of audiences though a 3D BIM model is not fully developed.

Keywords: sightline, theater, sight area rate, analysis, quantitative

INTRODUCTION

Sightline is a 'line of sight' between the viewpoint of stage and audience at theater (Burris-Meyer and Cole 1964; DCMS 2008; Ham 1987; Izenour 1996; John and Sheard 2000). Viewpoint locates at the edge of stage and is the lowest and closest point that every audience can see (Shows in Figure 2). Existing theater design

manuals (Burris-Meyer and Cole 1964; DCMS 2008; Ham 1987; Izenour 1996; John and Sheard 2000) suggest the sightline analysis method, which only examines whether the sightline from a seat is blocked by front-row seats through cross-sectional and plane view.

To overcome the limitation of the existing method, a 3D modeling tool has been widely used to check sightline being secured through a 3D BIM model. Although this method presents results visually, it is hard to check sightlines of every seat at the same time. Since a 3D BIM model has been modified frequently at an early design stage, sightline should be also analyzed whenever a 3D BIM model is modified.

This paper suggests new sightline analysis algorithm based on the 'sight area rate' index. The proposed algorithm utilizes coordinates of a seat and automatically calculates the visible screen area of every seat which derives sight area. This algorithm can be adapted at an early design stage when the 3D BIM model isn't fully developed.

This paper proposes the sight area rate analysis algorithm of the theater based on cross sectional and plane drawings. First, the limitations of existing sightline analysis methods will be briefly described and then a new analysis algorithm based on sight area will be proposed.

PREVIOUS METHODS

Since sightline affects the choice of stage type and the auditorium's width and depth (Burris-Meyer and Cole 1964), sightline should be analyzed when the theater is designed. Sightline is categorized into two types: vertical sightline and horizontal sightline. A vertical sightline is "the angular path of vision in the vertical plane over or under impediments, if any, between a sight point and the performance area" (Izenour 1996, p.4). When a vertical sightline is analyzed, spectators in the front-row of considered seat or building elements can be obstacles of sightline of considered seat. A vertical sightline is an important factor in deciding the slope of the auditorium since steep slopes ensure the vertical sightline. A horizontal sightline is "the angle of vision in the horizontal plane between or around intervening obstructions" (Izenour 1996, p.4), and is affected by width of the auditorium (Ham 1987; Izenour 1996).

There are two types of sightline analysis methods: sightline analysis through cross-sectional and plane drawings, and sightline analysis through 3D modeling tools. The former method only checks whether obstacles exist on the sightline path. The latter shows the visible area of considered seat using a camera view function based on 3D modeling. This method has limitations in that each visible area of considered seat should be checked manually and spends too much time analyzing every seat in the auditorium. This analysis method can easily be adapted to a fully developed 3D model which contains information on the type and angle of the seats. Since it is difficult to avoid modifying 3D models at the early design stages, there is a limit to the application of this method.

There is a commercial sight line analysis program called ‘Extreme Sightlines’ which analyzes sightline automatically based on existing analysis method (FDA). This program suggests theater design alternatives based on sightline analysis which shows the visible area of a considered seat using the camera view function of the 3D modeling tool. The limitation of this program is that it only can analyze sightline after the 3D model has been fully developed. To analyze sightline through this program, the 3D model should be fully developed.

This paper suggests a sight area rate analysis algorithm which can be conducted without a fully developed 3D model. The proposed algorithm calculates the sight area rate of considered seats after checking for the existence of obstacles in the sightline path through cross-sectional and plane drawings. It can be used when a 3D model isn’t fully developed and automatically draws the sight area of every seat in a short time.

Sight Area Definition

This paper proposes the notion that ‘sight area’ is the visible area of the screen from a considered seat. The existing methods analyze the view of audience in theater based on ‘sightline’ whereas the proposed analysis method focuses on sight area to secure the view of the audience rather than sightline. Figure 1 illustrates the notion of sight area with the gray area indicating the sight area of the considered seat. The figure expressed as a percentage in Figure 1 indicates the actual visible screen area rate of a considered seat compared to the total screen area.

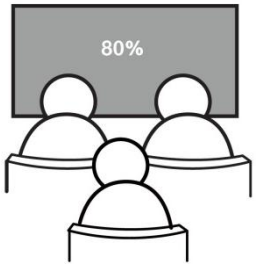

Figure 1 the notion of ‘sight area’

The sight area rate of a considered seat can be calculated by the following equation [1]. The sight area rate is the actual visible sight area (or screen area) divided by the total unblocked sight area (or screen area) from a seat.

$$\text{Sight Area Rate} = \frac{\text{Visible Screen Area}}{\text{Total Screen Area}} \times 100 \qquad [1]$$

Sight Area Rate Analysis using the Coordinates of a Seat

To analyze the sight area rate of a theater, the sightline analysis of every seat in the theater should be analyzed. After analyzing the sightline of every seat, the sight area of considered seat can be obtained from the proposed algorithm, which consists of two parts: obtaining the vertical distance from the vertical sightline analysis and obtaining horizontal distance from the horizontal sightline analysis. Since this paper applies the proposed algorithm to a 2D based theater design, X, Y, and Z coordinates extracted from plane and cross-sectional drawings are critical to calculating the sight area of every seat in a theater.

Obtaining the Vertical Distance from Vertical Sightline Analysis

To obtain the vertical distance of the visible area of a considered seat, Z coordinates from the eye point of the considered audience should be identified. First, obstacles in the vertical sightline path which connects the eye point of the considered seat and the viewpoint of the imaginary screen should be identified. If rows in front of a considered seat block the vertical sightline path, the critical line which connects the eye point of the considered seat and the highest head point of audience in front of that should be identified to obtain a vertical distance (shown in Figure 2). The vertical distance is defined as the vertical distance of the screen, which is unblocked from the considered seat. Figure 2 illustrates the vertical distance from the critical point to the highest point of the screen.

Obtaining the Horizontal Distance from Horizontal Sightline Analysis

The horizontal distance is defined as horizontal distance of the screen that is unblocked by the front-row audience from a considered seat. The definition of horizontal distance can be derived from that of the horizontal sightline. In a planar plan, horizontal sightlines are tangent lines of heads of front-row audiences of the considered seat which pass the eye point of the considered seat (shown in Figure 3). The horizontal distance of the considered seat is a distance between intersection points of a screen and horizontal sight lines.

Calculation of Sight Area Rate

Once the vertical distance and horizontal distance are obtained, the screen can be divided into several sections (shown in Figure 4) according to Figure 2 and Figure 3.

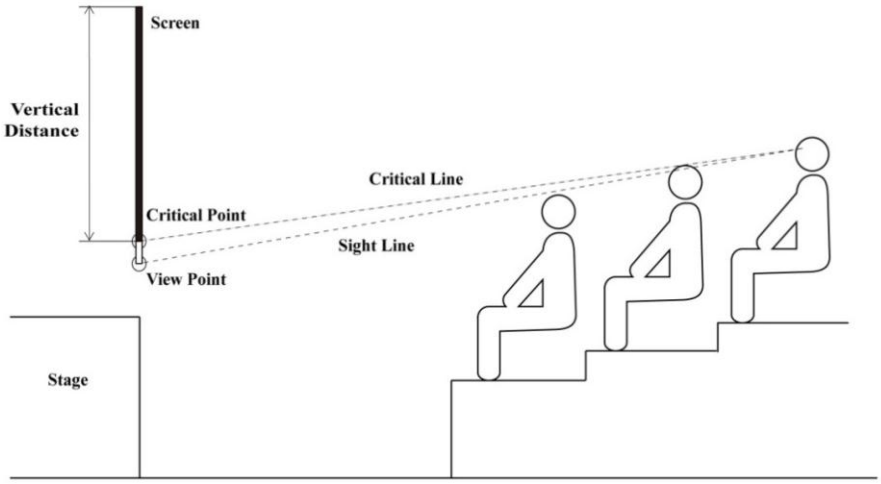

Figure 2 Definition of vertical distance and sightline and critical line

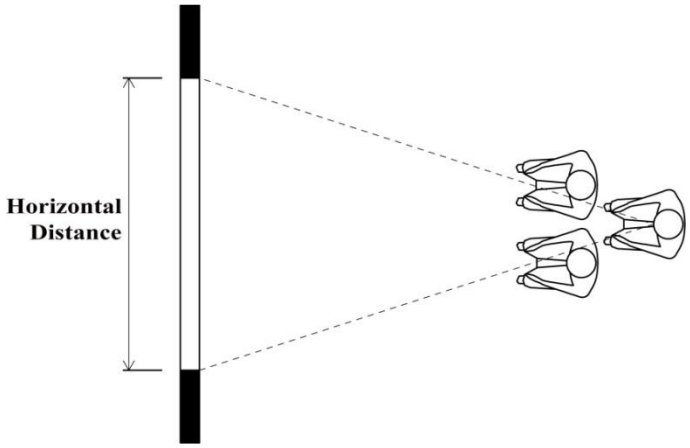

Figure 3 Definition of horizontal distance

Section 4, 5, and 6 are blocked screen area of a considered seat after analyzing vertical sight line. Section 1, 3, 4, and 6 are blocked screen area of a considered seat after analyzing horizontal sight line. The total unblocked screen area of a considered audience is intersections of unblocked screen area of vertical sightline analysis result and horizontal sightline analysis result. In this case, the intersections are section 4 and 6. The union sections of blocked screen area are the invisible area of the screen from the considered seat. Except for union sections of blocked area, sight area can be calculated by adding the area of the other sections. By applying equation [1], the sight area rate can be derived from the total sight area.

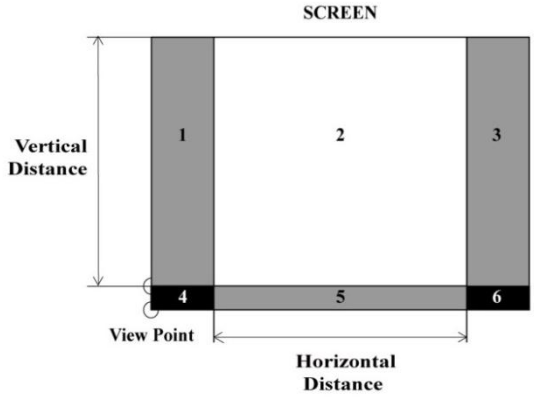

Figure 4 Concept of calculating sight area of screen

CONCLUSIONS

To secure the view of the audience in the theater, the existing methods analyze the view of audience based on ‘sightline,’ which is ‘line of sight’ between the viewpoint of the stage and the eye point of audience in the theater. The existing method can be categorized into two parts: visual identification of obstacles in the sightline based on 2D drawings, and identification of obstacles in a 3D model with a 3D modeling tool. However, these methods have the drawbacks of having to redo the 3D model whenever changes in the theater design plans are made and not having accurate analysis results. This paper proposes the analysis method focused on ‘sight area’ to secure the view of the audience rather than ‘sightline’. The newly proposed notion sight area in this paper is the visible area of a screen from the considered seat. The proposed analysis method can be applied to any theater stage design irrespective of developing a full 3D model. In the future, we will validate the sight area rate analysis method through a case study and compare the accuracy of the result with those of existing methods.

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