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Multimedia Classroom Natural Lighting Glare Research and Lighting Optimization Design

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Abstract: *At present, multimedia teaching has become the main teaching method, but most multimedia classrooms due to natural lighting caused by the glare problem, resulting in classroom lighting effect is not ideal. In order to understand the relationship between glare and natural lighting and provide reference for the improvement of the light environment of multimedia classrooms, this article selects a typical classroom in a university in Henan as the research object. Based on the natural lighting glare index (DGI), the paper studies the influence degree of natural lighting glare of multimedia classrooms, and uses DALI software simulation to dynamically simulate and analyze the improvement of the light environment of multimedia classrooms from the perspective of shading from the side windows of buildings, then obtains the lighting design scheme with the least affected by glare, which provides reference for the lighting design of multimedia classrooms and teaching buildings.*

Keywords: *Natural lighting glare, DGI, Multimedia classroom, Side window shading*

1. Introduction

As an important part of green building design and assessment, natural lighting in buildings not only reduces energy consumption of building lighting, but also has a significant impact on the comfort of the internal light environment of the building. With the increase in the demand for natural lighting, building lighting design has been adopted in favor of natural lighting whenever possible, but the increase in indoor illumination has also brought about possible uncomfortable problems with glare [1]. Therefore, how to create a classroom light environment that meets both the learning needs and the energy-saving needs has become an urgent issue for many schools.

Nowadays, various research methods have been developed for classroom glare, among which Quan Ren [2] used a combination of subjective and objective methods to investigate the glare problem of natural lighting in multimedia classrooms, and proposed measures to improve classroom glare in terms of classroom window design forms. Miaomiao Cui [3] and Jingyu Yuan [4] applied two quantitative evaluation indexes, the percentage of attained area and the percentage of attained time, to evaluate the natural light glare in multimedia classrooms. Wenrui Duan [5] discussed the measurement method of uncomfortable glare of windows from the definition of DGI, and put forward some suggestions for architectural lighting design with the measurement results. Zhen Lu [6] conducted software simulation on the current situation of natural lighting glare in a classroom of a college in Guangxi, and proposed optimization strategies from the perspectives of improving the form of side windows and window orientation. Xibing Hu et al [7-9] studied the influencing factors of classroom glare under artificial lighting conditions and proposed some measures to improve the glare problem.

In the previous studies, not many studies have reviewed the natural lighting glare in college multimedia classrooms and studied it from the perspective of side window shading. Therefore, this article aims to evaluate and optimize the design of classroom light environment in a university in Henan from the perspective of glare problems caused by natural lighting, using the natural lighting glare index (DGI) as the evaluation index and software simulation analysis, and to provide reference for solving such problems.

2. Research Methodology

The article adopts the model of natural light glare commonly used at present as the evaluation index of classroom glare effect, and carries out the research on the influence degree of multimedia classroom by natural light glare through the analysis of actual research data and simulation of DALI light environment analysis software, hoping to obtain the evaluation result of natural light glare with reference value.

2.1. Natural Lighting Glare Indicators

In order to quantify the impact of glare on people, many scholars have proposed several indexes for evaluating glare through a large number of experimental and theoretical studies [10]. Among them, Hopkinson proposed the Daylight Glare Index (DGI) for natural lighting glare in 1972, and the calculation process is shown in Equation (1) (2). This index is applicable to a large area of natural lighting glare source of window class. A large number of studies and experiments have proved that DGI has the ideal evaluation accuracy of glare prediction [11] (Figure 1). According to GB 50033-2013 "Design Standards for Lighting in Buildings" [12], the DGI limits are shown in Table 1, where the lighting level of multimedia classrooms is III.

$$DGI = 10\log 0.478\sum \frac{L_s^{1.6}\left(\int \frac{\omega}{p^2}\right)^{0.8}}{L_b + 0.07\omega^{0.5} L_s} \quad (1)$$

$$p = \exp\left[\left(35.2 - 0.31889\alpha - 1.22e^{-2\alpha/9}\right)10^{-3}\beta + \left(21 + 0.26667\alpha - 0.002963\alpha^2\right)10^{-5}\beta^2\right] \quad (2)$$

In the above equation.

L_s - window brightness, the weighted average brightness of the sky, shade and ground seen through the window (cd/m^2).

L_b - background brightness, the average brightness of each surface in the observer's field of view (cd/m^2).

ω - the stereo angle formed by the glare source to the eye (sr).

p - Guth Position Index.

α - window diagonal and the angle of the vertical direction of the window.

β - the angle between the line of the observer's eye and the center point of the window and the direction of the line of sight.

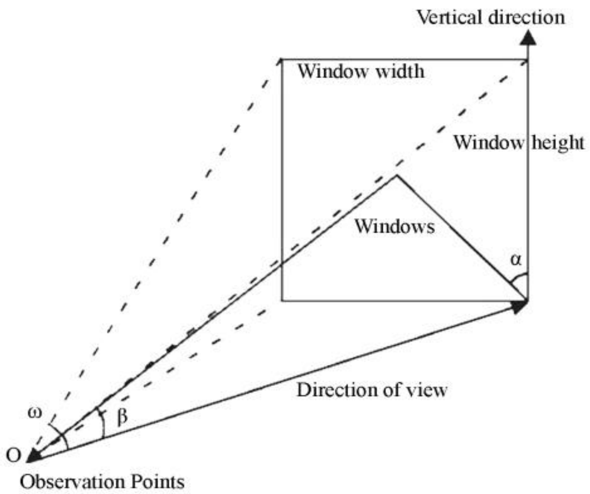

Figure 1: Schematic diagram of each angle of natural lighting glare calculation.

Table 1: DGI limit of glare index for natural lighting.

Lighting level	Glare Index DGI
I	20
II	23
III	25
IV	27
V	28

According to the natural lighting glare model, time and measurement points are the boundary conditions that should be considered, and a reasonable boundary condition should be the most unfavorable condition. In other words, if DGI can meet the requirements under the most unfavorable conditions, then the lighting condition of the classroom can also meet the glare requirements in general.

2.2. DALI Light Environment Analysis Software

The article uses Green Building Swell Light Analysis Software DALI, which is the first software in China to support the national standard "Building Light Design Standard" GB50033-2013, and supports the light index requirements of "Green Building Evaluation Standard" GB/T50378-2014. The software takes Radiance as the calculation core. Radiance is currently the internationally recognized optical simulation software that can simulate indoor natural lighting more accurately [13]. Radiance is able to calculate the luminance and illuminance values in the scene space by ray tracing, taking into account the scene geometry, materials, artificial and natural light sources, and return the results to DALI for processing and analysis. In addition, DALI provides a quick analysis of glare index, attainment rate, etc.

3. Data Analysis

3.1. Experimental data measurement and analysis

The natural lighting glare experiment selected the classroom 2501 of the second teaching building of the North Campus of Henan Polytechnic University as the object of study, using a luminance meter (model XYL-III) and a steel tape to measure. The experiment was conducted under sunny conditions and the influence of artificial lighting has been excluded during the experiments, and the measurement personnel were dressed in dark colors and did not block the light receiver.

The whole classroom was divided into 12 measurement points, as in Figure 2. In order to focus on the influence of different times of the day on the degree of natural lighting glare in the multimedia classroom, the measurement point 1 near the window in the classroom was selected for a day (9:00-18:00) of data tracking measurements and recorded at 1 h intervals. Place the luminance meter on the observation point and adjust the height to the position of the human eye, 1.2 m above the ground. Experimental measurement data and DGI numerical variation curves are shown in Table 2 and Figure 3 respectively.

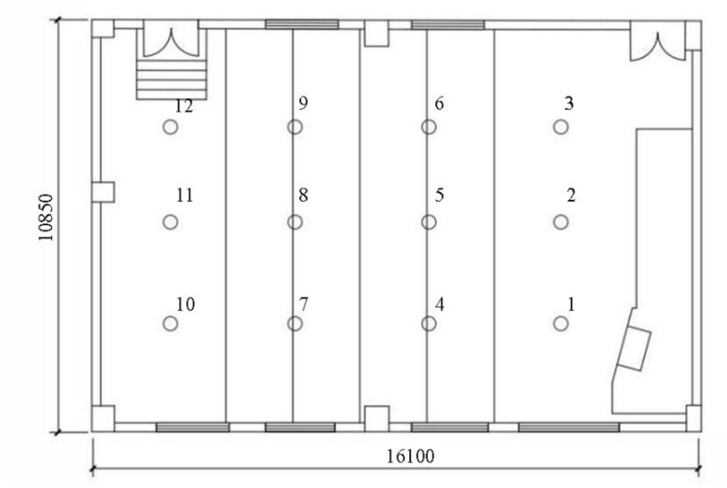

Figure 2: Planar measurement point distribution map.

Table 2: Actual measurement of DGI values at different moments.

Time	DGI value	Time	DGI value
9:00	22.6	14:00	23.7
10:00	22.9	15:00	23.6
11:00	23.6	16:00	22.9
12:00	23.9	17:00	22.5
13:00	23.9	18:00	22.0

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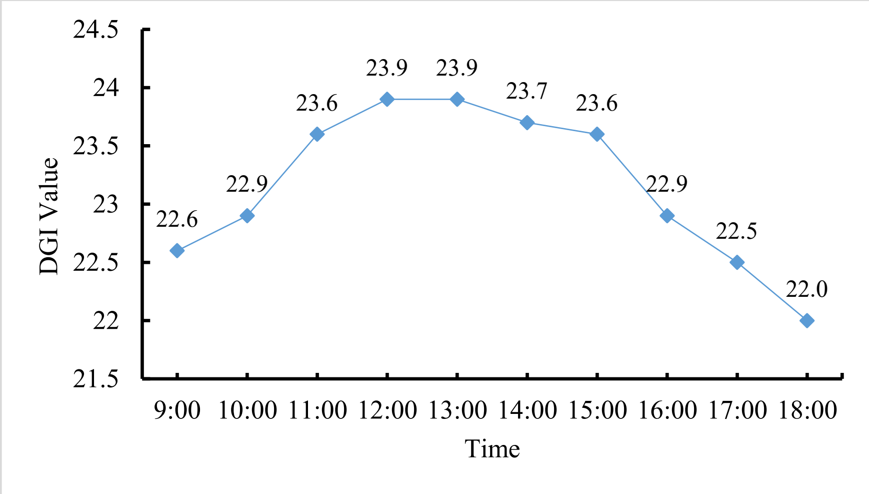

Figure 3: Measured DGI values over time.

As can be seen from Figure 3, although the natural lighting glare value of the classroom does not exceed the limit, the natural lighting glare value from 11:00-15:00 is high, with DGI values above 23.0, which can be considered as slight glare. And the glare value before 11:00 am and after 15:00 pm is low. Overall, the multimedia classroom has a slight glare problem, and measures need to be taken to improve the overall light environment of the classroom.

3.2. Software Simulation Analysis

In order to accurately analyze the current situation of natural lighting glare in this multimedia classroom, the article conducted a simulation of DALI software based on the information available in the classroom. The feasibility of the DALI software simulation can be confirmed by comparing the software simulation glare data with the measured glare data and the overall trend of glare changes between the two.

Before conducting the simulation, the light reflection ratio and light transmission ratio were measured for various materials in the multimedia classroom (see Table 3 and Table 4 for experimental data), and the materials were given to the walls, desktops and floors in the DALI software to make them more consistent with the actual classroom parameters. The current situation of this multimedia classroom was simulated and analyzed, and the values of natural lighting glare at different moments of the day were recorded as shown in Table 5 and Figure 4.

Table 3: Various material light reflection ratio values.

Material	Color	Average light reflection ratio
Plastered roof	White	0.8
Terrazzo flooring	Black, white and grey	0.3
Plastered wall	White	0.6
Blackboard	Black	0.1
Wooden desktop	Yellow	0.2
Wooden door	Red	0.2

Table 4: The value of light transmission ratio of glass material.

Material	Color	Average light transmission ratio
Glass Window	Transparent	0.9

Table 5: Software simulation of DGI values at different moments.

Time	DGI value	Time	DGI value
9:00	22.5	14:00	23.6
10:00	22.9	15:00	23.5
11:00	23.5	16:00	22.9
12:00	23.6	17:00	22.4
13:00	23.7	18:00	21.9

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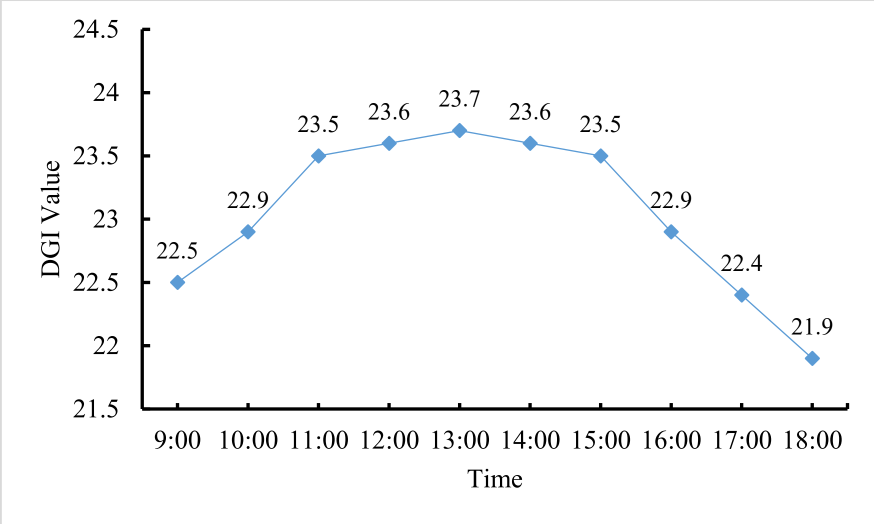

Figure 4: Software simulation of DGI values over time.

From the comparison of Figure 3 and Figure 4, we can see that the natural lighting glare values simulated by DALI software are similar to the actual measured natural lighting glare values, and the overall change pattern is the same. Therefore, DALI light environment analysis software can be used to simulate the optimization strategy of natural lighting glare in this multimedia classroom.

4. Simulation of Optimization Strategy based on DALI Software

4.1. Side Window Sunshade Design Scheme

Based on the theory of natural lighting shading and the current situation of multimedia classroom glare, six forms of side window shading are proposed and simulated for analysis and research. As shown in Figure 5-10, Program 1 sets vertical sunshades on the basis of the existing window form, with a pick-out size of 600 mm. Program 2 sets horizontal sunshades on the upper edge of the window, with a pick-out size of 600 mm. Program 3 adopts the form of comprehensive sunshade, setting not only horizontal sunshades on the upper edge of the window, but also vertical sunshades on both sides of the window, with a pick-out size of 600 mm. Program 4 is based on the original window form set horizontal sunshade, pick out the size of 600 mm, while the front side of the window set vertical sunshade, down the pick out size of 1200 mm. Program 5 is louvered window type sunshade, along the window horizontal horizontal horizontal set louvers, louver pick out size and louver spacing are 200 mm. Program 6 along the window vertical vertical set louvers, louver pick out size and louver spacing are also 200 mm.

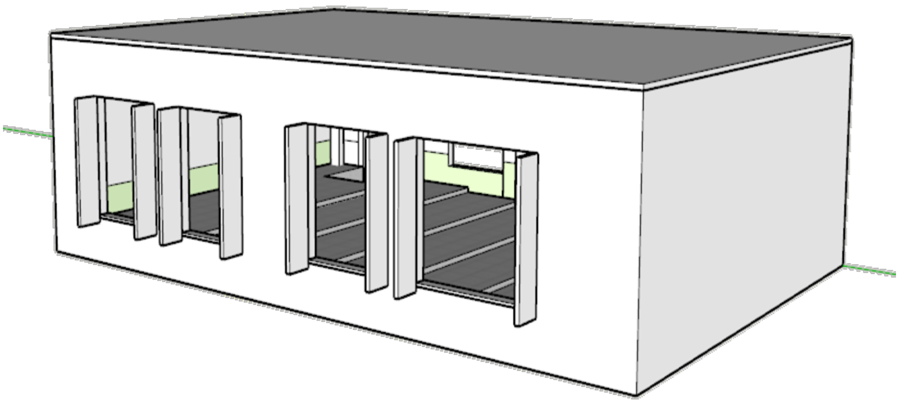

Figure 5: Diagram of vertical shading form.

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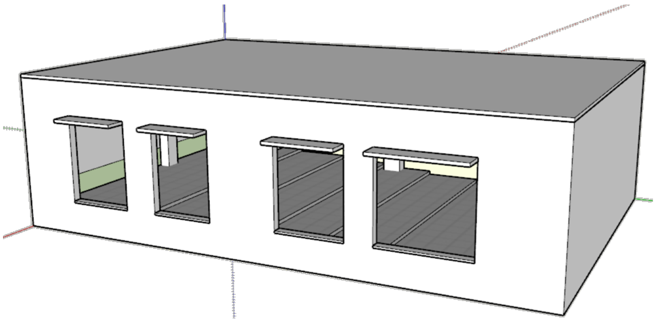

Figure 6: Schematic diagram of horizontal shading form.

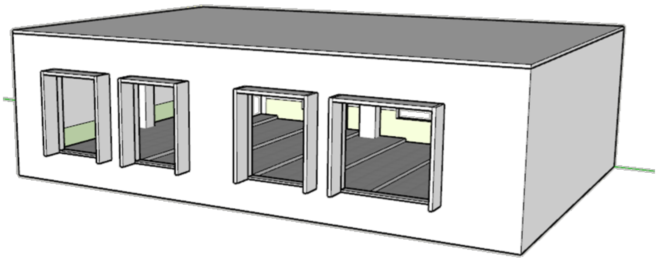

Figure 7: Schematic diagram of integrated shading form I.

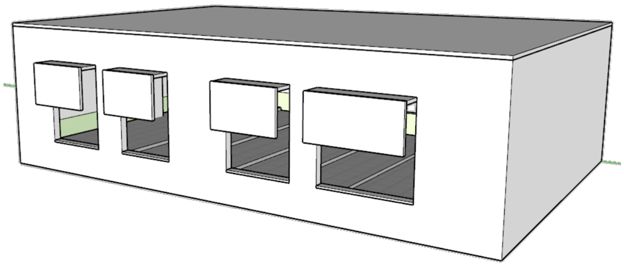

Figure 8: Schematic diagram of integrated shading form II.

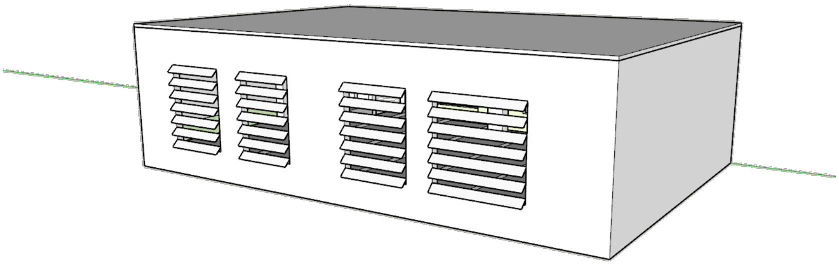

Figure 9: Schematic diagram of horizontal louver type shading.

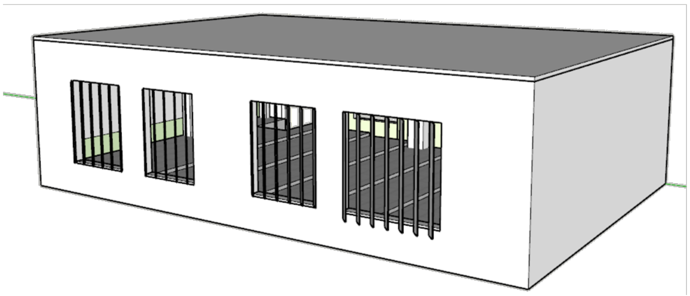

Figure 10: Schematic diagram of vertical louver type shading.

4.2. Side Window Sunshade Software Simulation

Simulations were performed for the different shading forms of the above six scenarios, and the

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graphs of the variation of DGI values with time for each shading form on four typical days (vernal equinox, summer solstice, autumn equinox, and winter solstice) were also plotted, as shown in Figures 11-14.

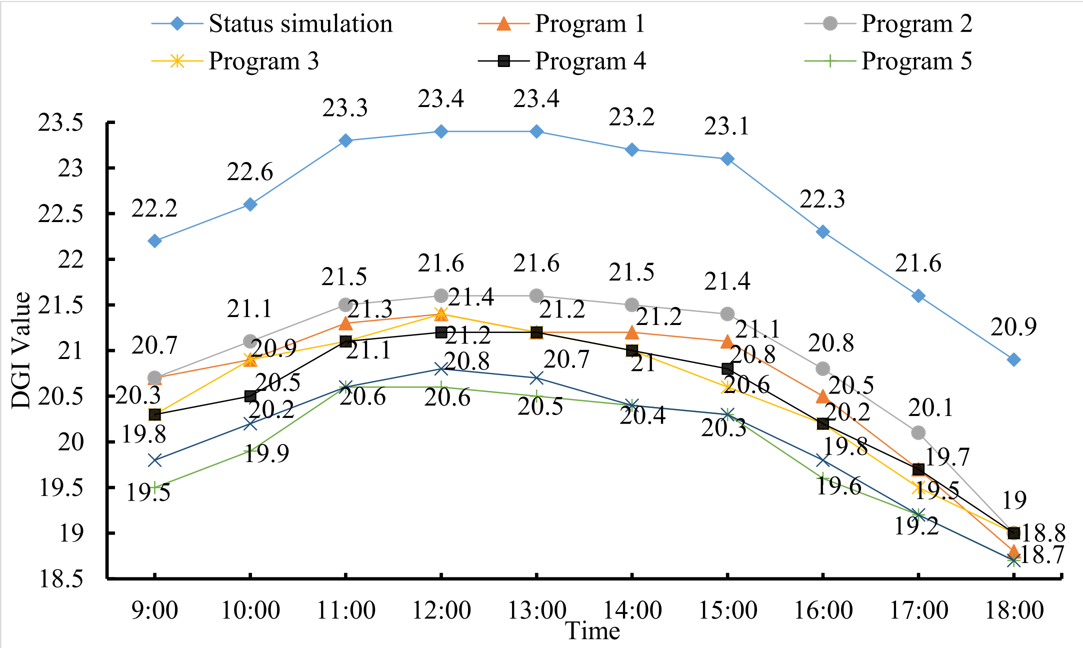

Figure 11: Variation of DGI values on vernal equinox day.

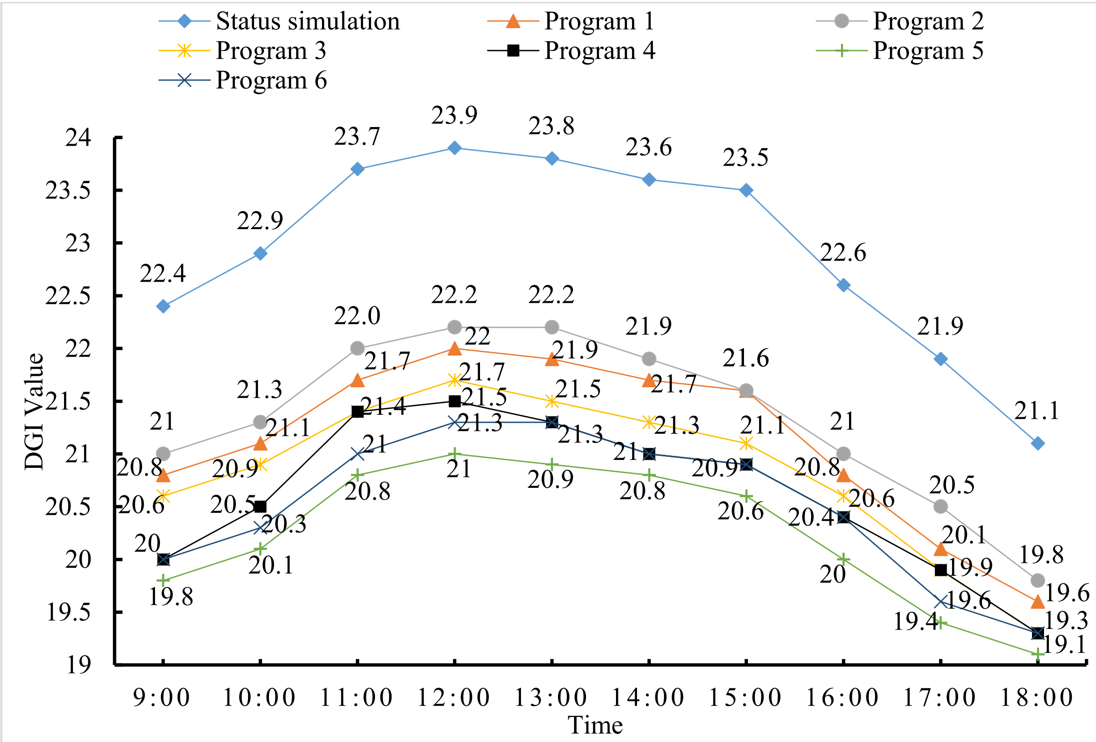

Figure 12: Variation of DGI values on summer solstice.

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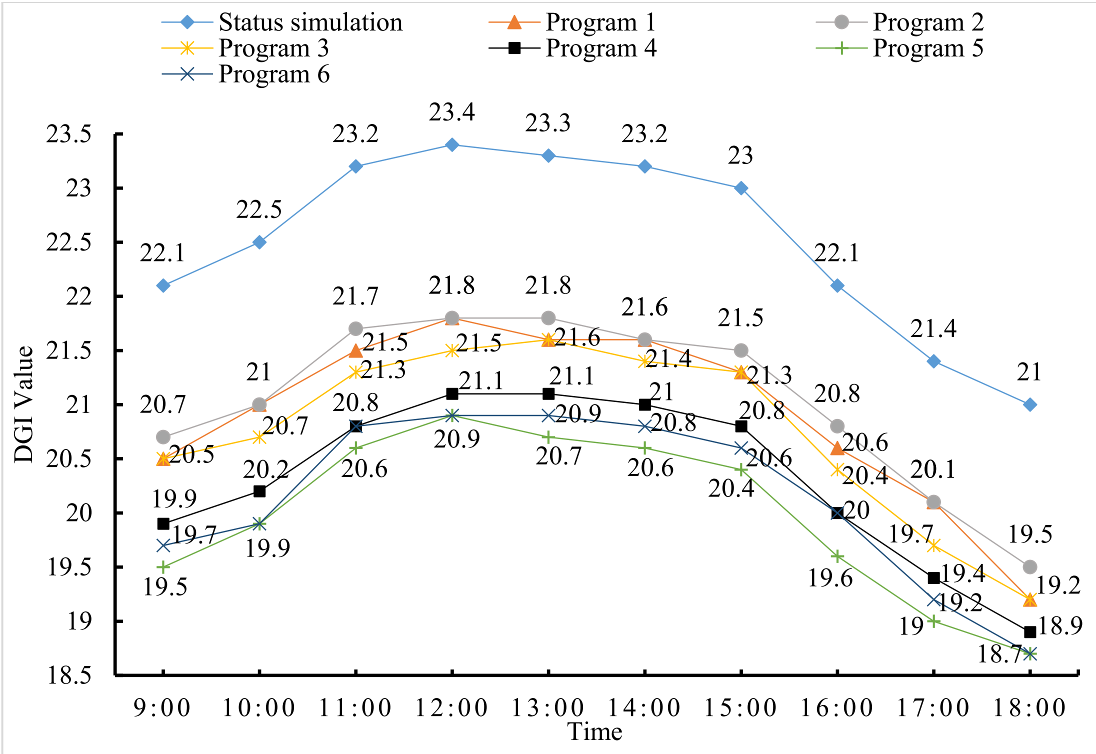

Figure 13: Variation of DGI values on autumn equinox day.

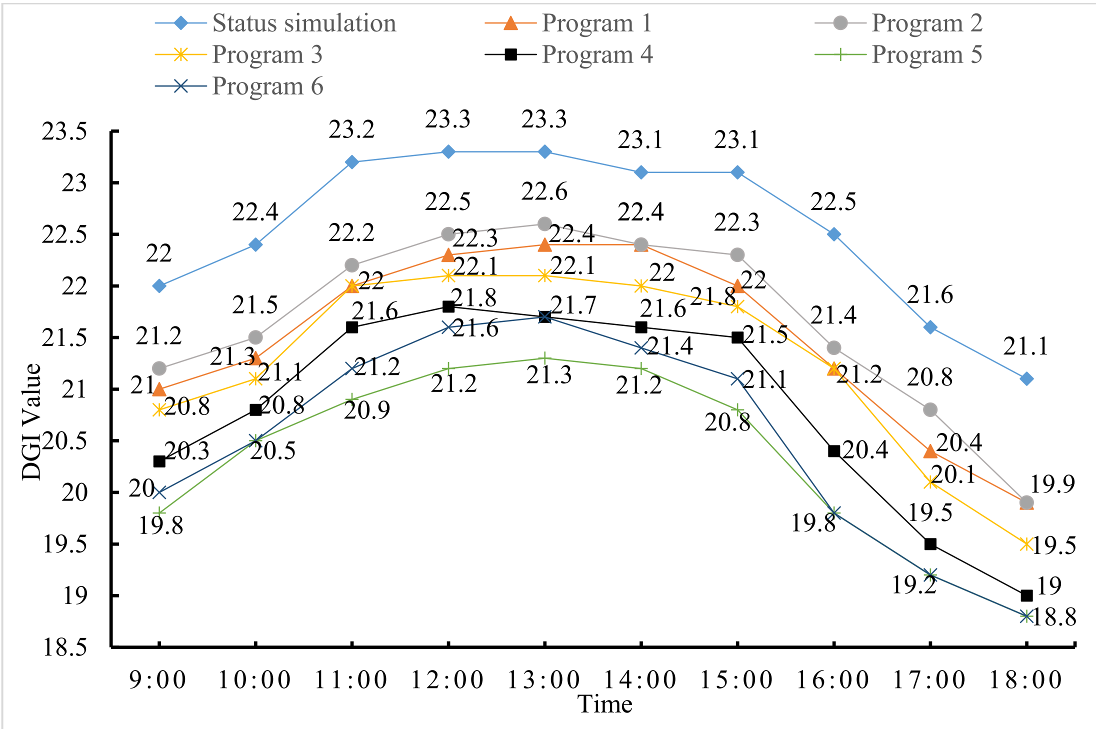

Figure 14: Variation of DGI values on winter solstice.

By comparing the DGI value change curves of each scheme, it is found that each shading method reduces the DGI value to some extent at the same moment. The ability of each shading method to reduce the glare index in descending order is scheme 5 > scheme 6 > scheme 4 > scheme 3 > scheme 1 > scheme 2 > actual situation (no baffle), in which the two louver shading methods have the best ability to reduce the glare index and the horizontal baffle shading has the worst ability to reduce the glare index.

Although the use of side window shading can reduce the effect of natural lighting glare, it will also

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affect the indoor lighting effect to a certain extent, so it is necessary to consider the natural lighting glare and indoor lighting. Six different shading schemes were analyzed for light simulation (Figure 15-20) and the results were compared (as in Table 6).

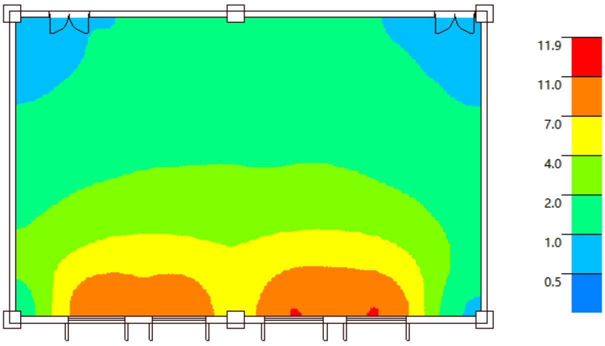

Figure 15: Color picture of multimedia classroom lighting effect of program 1.

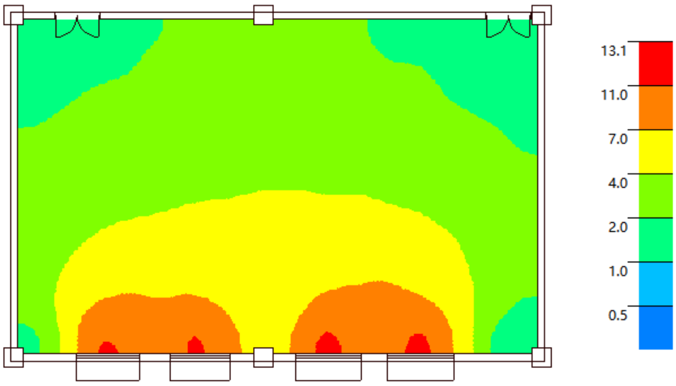

Figure 16: Color picture of multimedia classroom lighting effect of program 2.

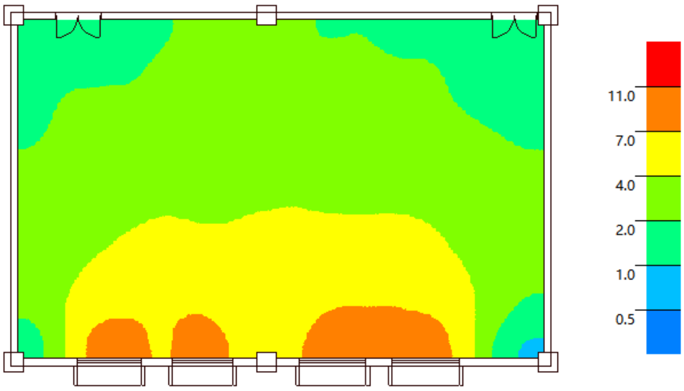

Figure 17: Color picture of multimedia classroom lighting effect of program 3.

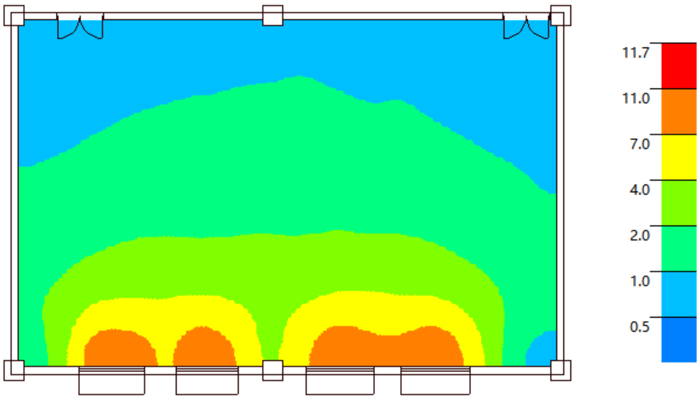

Figure 18: Color picture of multimedia classroom lighting effect of program 4.

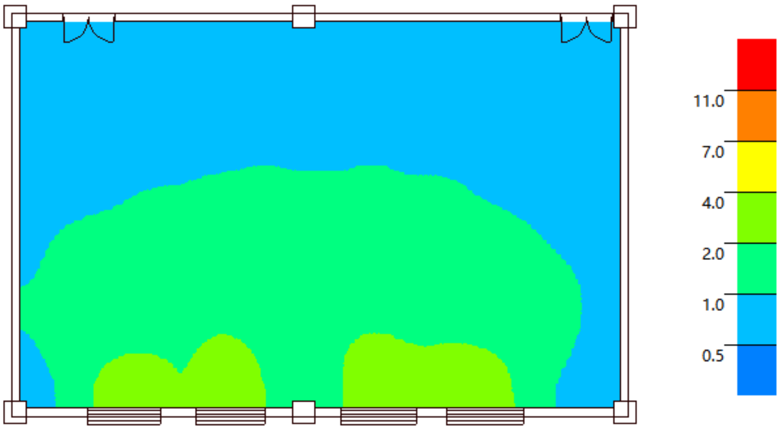

Figure 19: Color picture of multimedia classroom lighting effect of program 5.

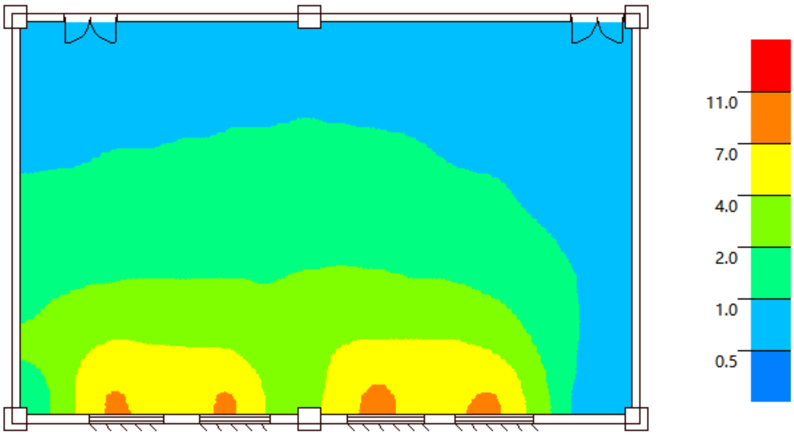

Figure 20: Color picture of multimedia classroom lighting effect of program 6.

Table 6: Comparison of the lighting situation of each scheme.

Program	Daylighting factor C (%)	Standard value of lighting coefficient (%)	Whether to meet the lighting requirements
program 1 (Vertical baffle shading)	2.69	3.00	Unsatisfied
program 2 (Horizontal baffle shading)	3.75	3.00	Satisfied
program 3 (Integrated shading form I)	3.44	3.00	Satisfied
program 4 (Integrated shading form II)	2.13	3.00	Unsatisfied
program 5 (Horizontal louvered shading)	1.16	3.00	Unsatisfied
program 6 (Vertical louvered shading)	1.80	3.00	Unsatisfied

From Table 6, we can see that programs 1, 4, 5 and 6 do not meet the indoor lighting requirements, so they are discarded. Combined with the ability of each program to reduce the glare index size (program 5 > program 6 > program 4 > program 3 > program 1 > program 2), a comprehensive analysis shows that program 2 and program 3 are more reasonable shading methods in reducing glare in multimedia classrooms and meeting multimedia classroom lighting, where program 3 is better than program 2 in reducing the impact of indoor glare, and program 2 is better than program 3 in meeting indoor lighting.

5. Conclusion

The following conclusions are drawn from the field measurements and DGI numerical simulations of natural lighting glare values in multimedia classrooms, and the simulation and evaluation of indoor light environment optimization measures combined with the current situation of classrooms.

(1) The DGI value of multimedia classroom is higher in the range of 11:00-16:00, indicating that the classroom is most seriously affected by natural lighting glare during this period.

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(2) According to the degree of improvement of natural light glare in multimedia classroom by six shading methods calculated from four typical day simulations, it can be seen that horizontal louver type shading has the best ability to improve natural light glare and horizontal baffle shading has the worst ability to improve natural light glare.

(3) While improving the natural lighting glare, the external shading of the building will also affect the indoor lighting effect, of which only the horizontal baffle shading method and comprehensive baffle shading method a meet the multimedia classroom lighting requirements, the remaining four shading methods are not met.

(4) The comprehensive analysis of various shading methods shows that the integrated shading form one is better than the horizontal baffle shading in reducing the degree of natural lighting glare; in meeting the requirements of indoor natural lighting, the horizontal baffle shading is better than the integrated baffle shading method one.

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