THE GLARE EVALUATION METHOD FOR CIVIL AIRPLANE FLIGHT DECK

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Abstract

Glare is a key factor influencing the visual performance in light conditions of flight deck, and glare sources in flight deck are extraordinarily complex. It is difficult to apply existing glare equations in evaluation of intricate glare sources, such as non-uniform glare, irregular shape glare and indirect glare. To evaluate glare of flight deck, this paper proposed a novel method by carrying out secondary development on SPEOS/CATIA platform. Thus, the glare sources could be detected, the key parameters of quantifiable evaluation were calculated, including source luminance, background luminance, position index, solid angle of source, and etc., and the desired glare index can be computed automatically and rapidly. Finally, Unified Glare Rating (UGR) and Daylight Glare Probability (DGP) equations are utilized as examples in evaluation of the glare in flight deck. The results indicated that the proposed method is convenient for safety design of flight deck.

1 Introduce

Van Nakagawara[1,2] investigates the relationship between visual impairment from natural sunlight and aviation accidents. They queried The National Transportation Safety Board Aviation Accident and Incident Database for the period January 1, 1988 to December 31.1998, and found there were 130 accidents in which glare was found to be a contributing factor. More and more visual information has to be displayed in a civil airplane flight deck. For safety reasons, and in order to avoid tiredness this information must be seen as clearly as possible by the aircraft pilot in any light conditions. On the other hand, visual comfort has been a factor what need be taken into account in the flight deck design. Glare is a strong factor to influence visual performance in light conditions of the flight deck, and it is important to predict glare in flight deck design.

According to the different visual influence, glare can be generally divided into two types, discomfort glare and disability glare. In general illumination engineering, relative to the disability, the discomfort is more universal phenomenon. The method to control the discomfort glare can solve the disability glare problem. So, the glare we discussed is the discomfort glare in this paper. The glare source of flight deck is very complex, including non-uniform glare source, irregular shape glare source and indirect glare source, etc. Current glare indices cannot reliably evaluate the level of discomfort glare from daylight in flight deck with complex non-uniform glare sources and irregular shape glare source. This is because that many of the existing glare equations were developed for the evaluation of discomfort glare from small artificial light sources. Furthermore, as it is very difficult to compute luminance of reflective glare source, these indices cannot evaluate indirect glare, such as reflective glare source.

Nowadays, the computer accurate simulation is an effectual method to solve this problem. Wienold[3] proposed a new index, called “daylight glare probability (DGP)”, what can evaluate glare from a venetian blind system. They developed new evaluation tool *evalglare* based on RADIANCE enables assessments of possible glare problems with simulated

RADIANCE pictures. Mendoza's study[2] presents a comparative study between a physical daylight glare monitoring evaluation with that from a computer based tool (Ecotect/Radiance).

So, we developed a new evaluation method based on SPEOS/CATIA software to evaluate glare of non-uniform source, irregular shape source and indirect glare, especially in flight deck environment, as shown in Fig. 1. The method needs three stages. Firstly, simulation of glare scene is carried out using SPEOS/CATIA software. Secondly, glare source is detected using secondary development. The last stage computes source luminance, background luminance and position index and solid angle of source, and computes whatever glare index is desired.

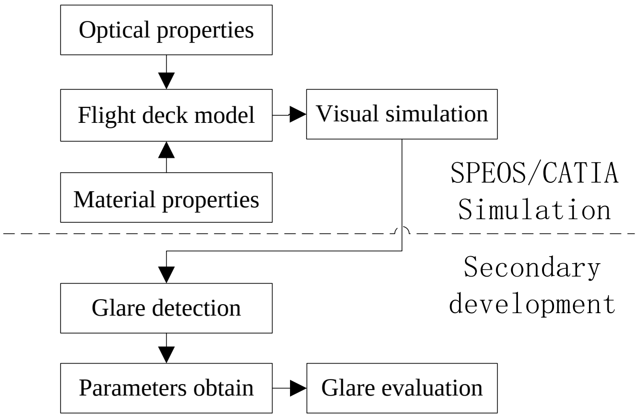

Fig.1. Glare evaluation method based on SPEOS/CATIA

2 Simulation of glare scene

2.1 Modeling of scene

With SPEOS any kind of light source can be modeled by entering geometry and defining its emission properties, such as the intensity distribution and the spectrum of the luminaire. Daylight glare can be simulated using CIE standard general sky by SPEOS software. The simulation result of scene model is shown in Fig. 2. The light conditions include daylight and reflective light.

2.2 Photometric simulation

Through photometric simulation, we can have information about the result we are studying, such as luminance, color, etc. Fig. 3 is the result of luminance levels.

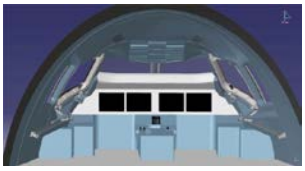

Fig.2. The model of flight deck

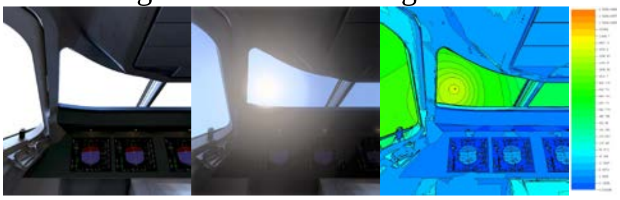

Fig.3. The optics simulation results of flight deck

3 Secondary development based on SPEOS/CATIA

In this paper, we choose SPEOS software to carry out computer simulations. The software has the advantage what Radiance has, and also has been available inside CATIA V5. It includes real light emission, exact instrument geometry and 3D environment. Due to its physics based approach to light, a real life measured library of materials is used to calculate the level of reflection of light anywhere in the scene.

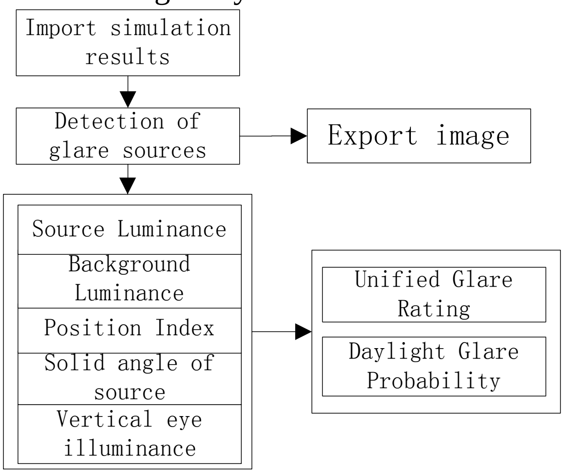

Fig.4.Secondary development model of SPEOS/CATIA

3.1 Detection of glare sources

Three principal methods were used for automatic detection of glare sources[3]:

1).Calculate the average luminance of the entire picture and count every section as a glare source that is x-times higher than the average luminance;

2).Take a fixed value and count every section as a glare source that is higher than the fixed value;

3).Calculate the average luminance of a given zone (task area) and count every section as a glare source that is x-times higher than the average luminance of this zone.

The first method was implemented in the RADIANCE findglare tool. For very bright scenes only few parts or nothing could be detected, although the facade was obviously a glare source. Reducing the x-factor can increase the sensitivity to detect glare sources in a scene, but might lead to "over-detecting" potential glare sources in darker scenes.

The second method, which applied a fixed luminance value as threshold does not take into account eye adaptation. This method was therefore not considered to be a reliable method for lighting scenes with substantial luminance variations.

The last method was used in Wienold's new evaluation method for daylight environment[3]. Each pixel with a luminance value four times higher than the average task-zone luminance was treated as a glare source. This detection sensitivity factor can be changed.

In this paper, we use the first method to detect glare sources as same as RADIANCE. The detected result is shown in Fig.5. When the threshold is different, the detected result of glare is different. Reducing the threshold can increase the range to glare sources.

Fig.5. Glare detected result of the flight deck.

3.2 Calculating the key parameters of glare evaluation

In general, the glare evaluation draws upon the four physical parameters:

- The luminance of the glare source: the brighter the source, the higher the index;
- The background luminance: the general field of luminance controlling the adaptation levels of the observer's eye. The brighter the room, the lower the index;
- The position index: the angular displacement of source from the observer's line of sight. The further from the centre of vision, the lower the index;
- The solid angle: the larger the area, the higher the index.

Especially, the vertical eye illuminance is also considered as a primary factor influencing glare index in the DGP[3] .

3.2.1 *Source Luminance (L)*

The source luminance is the average luminance of all pixel of source. Through photometric simulation in SPEOS software, luminance levels can be obtained, see Fig.2. The luminance value of each pixel is obtained by the function "GetValueRectangle()". The average luminance of glare source can be calculated through traversing all pixels of glare source.

3.2.2 *Background Luminance (L_b)*

The background luminance is luminance of the field of view, not including source luminance, and called adaption luminance in some study. It can be calculated by

$$L_b = total\ luminance - L_s \quad (1)$$

3.2.3 *Position Index (p)*

The position index of a source, P, is an inverse measure of the relative sensitivity to a glare source at different position throughout the field of view. There are two methods to calculate position index.

The first method is Guth position index, where is given by [4]

$$P = \exp[(35.2 - 0.31889\alpha - 1.22e^{-2\alpha/9})10^{-3}\beta + (21 + 0.26667\alpha - 0.002936\alpha^2)10^{-5}\beta^2] \quad (2)$$

Where

α=angle from vertical of the plane containing the source and the line of sight, in degrees,

β=angle between the line of sight and the line from the observer to the source.

Through the new study, Iwata[5]found that sensitivity to glare caused by a source located below the line of vision is greater than sensitivity to glare caused by a source located above the line of vision. Then, a new method to calculate the position index was developed; it could be expressed by this equation[3,5]:

$$P=1+0.8\times R/D\ (R<0.6D)$$

$$P=1+0.6\times R/D\ (R>=0.6D) \qquad (3)$$

$$R^2=H^2+Y^2$$

Where

R=distance between source and fixation point (m),

D=distance from eye to vertical plane on which a source is located (m),

H=vertical distance between source and fixation point (m),

Y=horizontal distance between source and fixation point (m).

In this paper, Guth position index is used above the line of vision, and the new position index of Iwata is used below the line of vision. The position index of each pixel is obtained by the function "GetPositionIndex()". The mapping of position index is shown in Fig.6. The map is obtained by secondary development.

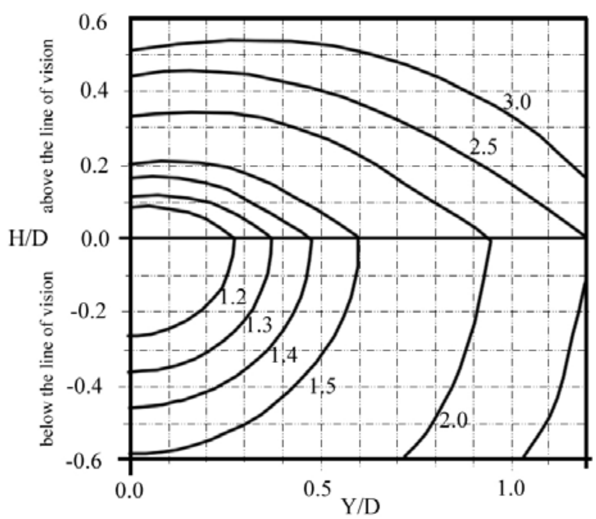

Fig.6. The mapping of position index[5]

3.2.4 Solid angle of source (ω)

Solid angle (ω) is a measure of that portion of space about a point bounded by a conic surface whose vertex is at the point. It is defined as the ratio of intercepted surface area of a sphere centered on that point to the square of the sphere's radius. It is expressed in steradians[4]. Solid angle is given by the following equation:

$$Solid\ angle=A\cos\theta/l^2 \qquad (4)$$

Where

A= area of source,

l= distance between eye and source,

θ=angle from source to vertical plane on which a source is located.

Because the area of each pixel is very small, so (4) can be simplified:

$$\omega=A/l^2 \qquad (4a)$$

Where, A is the area of a pixel, l is the distance between eye and source.

The solid angle of each pixel is obtained by the function "GetSolidAngle()".

3.2.5 Vertical eye illuminance (Ev)

The Ev can be obtained in the result of simulation in SPEOS.

3.3 The Glare Evaluation

Several discomfort glare indices have been developed to assess glare from artificial light sources. These include British Glare Index (BGI)[3,5] , CIE Glare Index (CGI)[6], Unified Glare Rating (UGR)[4] . And, there are several glare indices developed to evaluate the glare caused by daylight. These include Daylight Glare Index (DGI)[7], New Daylight Glare Index (DGI_N)[8] , Daylight Glare Probability (DGP)[3] .

In this paper, Unified Glare Rating (UGR) equation[4] commended by CIE is utilized to evaluate the glare form interior light sources of flight deck. Daylight Glare Probability (DGP) [3] is utilized to evaluate the glare form exterior daylight of flight deck.

The UGR equation [9] is

$$UGR = 8\log_{10}(\frac{0.25}{L_b})\sum_{i=1}^{n}\frac{(L_i^2\omega_i)}{p_i} \qquad (5)$$

Where

UGR=Unified Glare Rating,

L_b= the background luminance (cd/m^2),

L_i= the luminance of the *i*th part of the source (cd/m^2),

ω_i=the solid angle of the *i*th part of the source (sr),

p_i= the position index of the *i*th part of the source.

The DGP equation [3] is

$$DGP = 5.87\times10^{-5}E_V + 9.18\times10^{-2}\log_{10}(1+\sum_i\frac{L_{S,i}^2\omega_{S,i}}{E_V^{1.87}P_i^2}) + 0.16 \qquad (6)$$

Where

DGP= Daylight Glare Probability,

Ev= the vertical eye illuminance (lux),

L_s= the luminance of the source (cd/m^2),

ω_S=the solid angle of the source (sr),

p= the position index of the source.

The function “GetUGR()” and “GetDGP()” are used to express the above two equation respectively in secondary development of SPEOS/CATIA

4 The example of the glare evaluation for flight deck

4.1 Use UGR to evaluate the glare in nighttime

Using UGR is to evaluate the glare in nighttime for the reading light above the display being on and off. The observe position is the design eye position of pilot, and observe direction is the direction to look on the display. In nighttime, the glare sources include light and reflected light. The detection threshold luminance of the glare source which is 30.8 cd/m^2 is four times higher than the average luminance which is 7.7 cd/m^2. The glare of light and reflected light which can be detected effectively is shown in Fig.7. The left figure is the detection result with reading light on. The right figure is the mapping of the luminance.

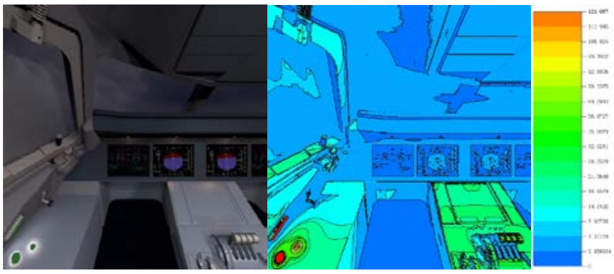

Fig.7. The detection result of the glare source and the mapping of luminance in nighttime

The most luminance of the reading light that is opened on is the 25380cd/m^2, and the angle between the center of reading light and the center of the vision line is only 3.1°. In this condition, the calculation result of UGR is 23.25, and people are discomfortable. When the reading light is shut off, the UGR is only 9.84. So, the light exposed in the visual field will impact the discomfort f for person.

4.2 Use DGP to evaluate the glare in daytime

Using DGP is to evaluate the glare in daytime. The observe position is the design eye position of pilot, and observe direction is the horizontal direction. In the example, the fight deck scene in forward, up, down, left and right direction are simulated for simulating the 180° visual field. The detection threshold luminance of the glare source which is 501.88 cd/m^2 is four times higher than the average luminance which is 125.47 cd/m^2. The detection result of the glare source is shown in Fig.8. In daytime, the glare sources include windshield and interior light.

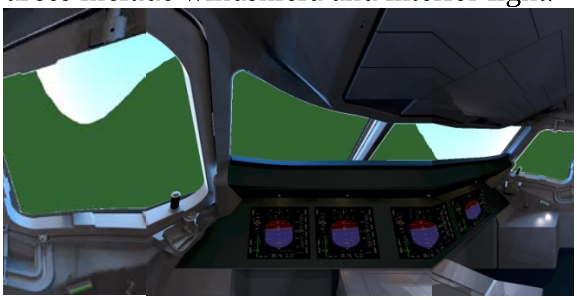

Fig.8. The mapping of luminance in nighttime

The calculation result of DGP is 0.241, which express that only 24.1% people feel fidget and discomfort. So, in this condition, the most people are comfort.

5 Conclusions

Several glare indices based on current glare equations cannot utilized to evaluate non-uniform glare, irregular shape glare and indirect glare correctly. Thus, we developed a novel method based on SPEOS/CATIA software to predict several types of glare. SPEOS/CATIA software is chosen to simulate the glare scene. Based on secondary development on SPEOS, /CATIA glare sources can be detected automatically. After calculating source luminance, background luminance, position index, solid angle of source, the desired glare index can be computed. The results indicate that the method can compute glare index automatically and quickly, and has the advantage of short cycle and low cost for the evaluation of illumination design of flight deck, and has good engineering application value.

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