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Derived UGR methods for evaluation of glare by precising methods

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1 Work methods UGR for judging more lighting systems

In the year 2002 a new method for illuminating work areas is placed into effect in Europe. This method UGR which judges glare, was introduce in Technical paper CIE 117 in the year 1995. Today the UGR method is the most universal tool for judging glare in most kinds of lighting systems. Even though UGR is so versatile there are certain systems were it is not practical for judging glare.

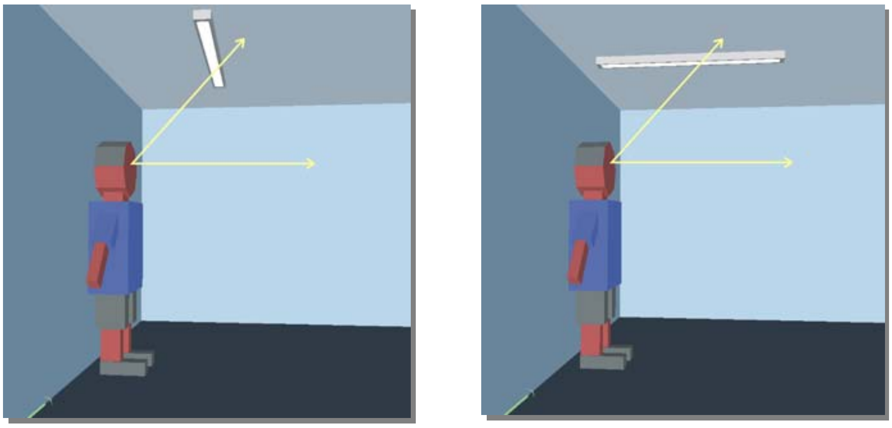
2 Design of integrated method superposition of light

One of the biggest limitations of UGR method is that it can only by used for lighting systems which do not exceed an area angle of 0,1 sr. The problem is that position index *p* is in UGR method related to center of light. This fact assists in the calculation for PC software, but on the other hand it causes a relatively large inaccuracy in the calculation in larger light fixtures. This error is caused because the position index doesn't represent the position of the sources glare. The inaccuracy with the index position occurs also with lights which are multiple times longer then wider even if the area angle doesn't exceed 0,1 sr. For example we can show light system which is created by fluorescent lamp. The glare index is derived by using the following UGR formula

$$UGR = 8 \cdot \log\left[\frac{0{,}25}{L_b} \cdot \sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{p_i^2}\right], \qquad (1)$$

for certain direction angle of the viewer fill in value of brightness of the light L *(cd.m^{-2})*, brightness of the background L_b *(cd.m^{-2})*, area angle of the light ω *(sr)* and the index position. If we don't take luminous intensity curve into consideration, the final glare index calculated by the UGR formula will be the same if the light will be directed in the direction view of the viewer and perpendicular to viewer view too. In case of the light will be in such a position like a cross the viewer will be out of view. There will be no glare.

If the light position is linearly in front of the viewer, will be part of light visible and if the light has high brightness, it can cause glare. (See diagram 1) Today the UGR method can not determine difference between amounts of glare when they are oriented perpendicular and linearly if front of the viewer. This is the main reason why the UGR method is not recommended for lights larger than 0,1 sr.



a) Perpendicularly oriented light b) Linearly oriented light

Diagram 1 Position and rotation of the light relative to viewer.

Solution: This problem can be solved by implementing *"Integrated methods super position of light".* The principal is in fictive replacement large light or long lights with smaller but similar shape luminous intensity curve and luminous intensity equally reduce to the changed dimensions of light. (See diagram 2)

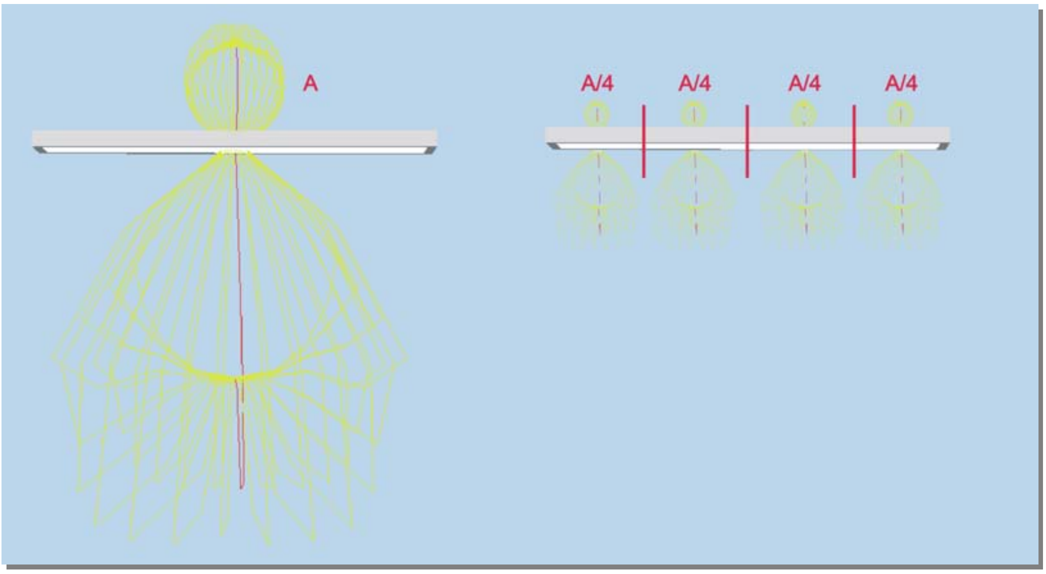


Diagram 2 Fictive dividing of large lights to smaller parts

The division can be done in halves, thirds, quarters and so on. So area angle does not exceed an angle 0,05 sr and so width and length of the light are almost the same. Each created divisions of the light will be calculated like light itself and index position will be recalculated for center of each section of light.

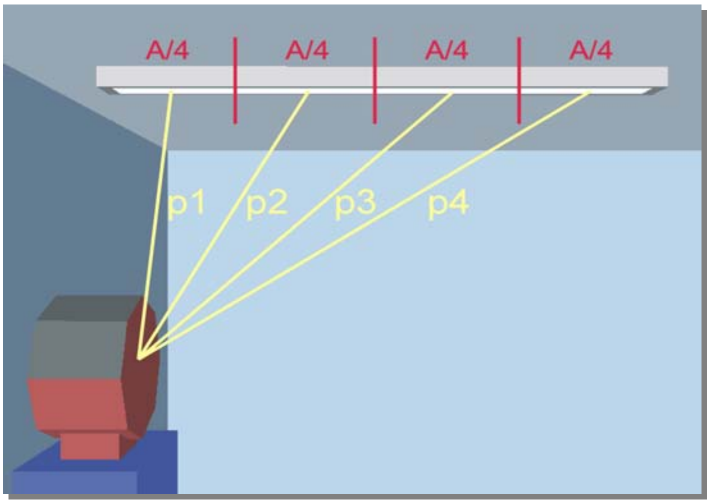


Diagram 3 Light divisions in smaller parts

The result is more accurate assessment of the glare index with large lights which also solves the problem with the orientation of the light and also increases upper limit of the UGR which was 0,1 sr till now. The maximum upper limit of area angle is to be determined experimentally. This is either because the oversize lights or ceiling lights will be affected by brightness of background on which is eye adapted.

By creating integral method super position of light will be the method UGR with lighting system including large lights reflecting glare caused more real. Index position determines a more accurate position of source of glare ant also the orientation of the light related to position of viewer.

3 Using UGR for different direction of view then horizontal

The UGR method comes from prediction that usual direction of the position of viewer is horizontal or slightly inclined. This prediction doesn't have to be usable in all typical situations. For example in the classroom is view from desk to blackboard is slightly inclined.

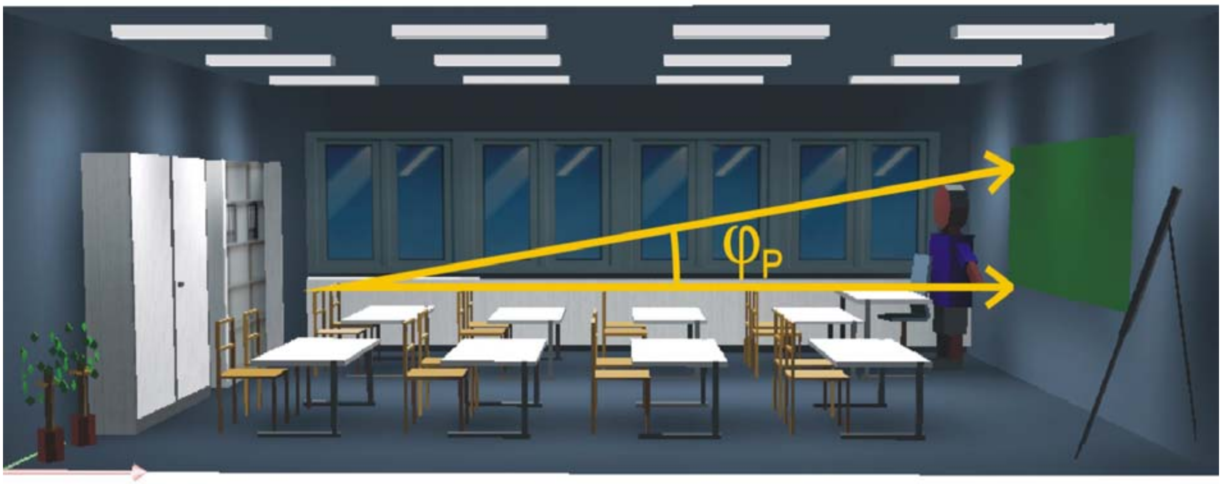


Diagram 4 Typical views in the classroom

Define the problem: The size of the index position *p* in the UGR method is dedicated from position of light to typical view of the viewer. There for T/R a H/R if R is distance from the desk to the light, T is the horizontal offset of direct view, H is the height above the eye of the viewer. All the coordinates are calculated to the center of the light. If you take the UGR method generally, think about the size of the glare calculation from the brightness of the source of the glare, the area angle, brightness of the background and offset from the typical direction of the view. This stands to be true also for not only the horizontal direction of the view. The problem is the definition of the mathematical expression of the UGR method doesn't lose its simplicity.

Solution: The index position in the vertical direction is determined for the angle φ_V, which is calculated from the difference between the two angles φ_S and φ_P. Angle φ_S is the angle from the horizontal view to the light. Angle φ_P is the angle from the horizontal view to where the subject is looking.

$$\varphi_V = \varphi_S - \varphi_P \qquad (2)$$

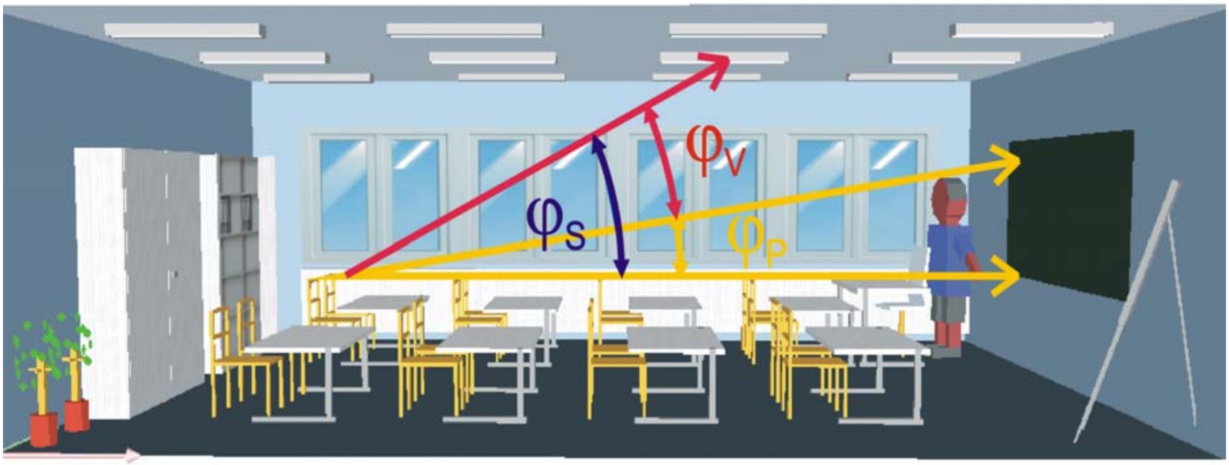


Diagram 5 Definition of the angle difference from the horizontal direction

The Angle φ_P is defined by the user of the software and the φ_S is calculated by formula number 3.

For φ_S

$$\varphi_S = arctg\left(\frac{H}{R}\right). \qquad (3)$$

Angle φ_V for finding the index position is possible to calculate with the following formula:

$$\varphi_V = arctg\left(\frac{H}{R}\right) - \varphi_P. \qquad (4)$$

The angle of deflection of source of glare from usual direction of view, which can be different then the horizontal, can be calculated by formula number 4. and in table index position H/R will be replaced by final value *(H/R)' = tg* φ_V.

The size of *(H/R)'* will be:

$$\left(\frac{H}{R}\right)' = tg\ \varphi_V = tg\ (\varphi_S - \varphi_P) = tg\left(arctg\frac{H}{R} - \varphi_P\right). \qquad (5)$$

With this way it is possible to use the UGR method also for all views not just the horizontal view.

4 Compatibility of the methods

4.1 The correlation between UGR a Jepanešnikovou method

UGR Method equation:

$$UGR = 8 \cdot \log\left[\frac{0,25}{L_b} \cdot \sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{p_i^2}\right], \qquad (6)$$

Jepanešnikov formula:

$$G = M = \sqrt{\sum_{i=1}^{n}\left[\frac{L_i\ .\ \omega_i^{0,5}}{L_b^{0,5}\ .\ p_i}\right]^2}, \qquad (7)$$

If L_b is the brightness of the background (cd.m^{-2}),

L_i brightness of source of glare in the direction of the eyes of the viewer(cd.m^{-2}),

ω_i Area angle under which you can see the glare source (sr),

p_i Guthov coefficient of the position of the source of the glare

K_i Netušilov coefficient of the position for the source of the

Adjustment equation UGR:

$$UGR = 8 \cdot \log_{10}\left[\frac{0,25}{L_b} \cdot \sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{p_i^2}\right] \Rightarrow \frac{UGR}{8} = \log_{10}\left[\frac{0,25}{L_b} \cdot \sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{p_i^2}\right] \Rightarrow$$

$$\Rightarrow 10^{\frac{UGR}{8}} = \left[\frac{0,25}{L_b} \cdot \sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{p_i^2}\right] \Rightarrow \frac{10^{\frac{UGR}{8}}}{0,25} = \left[\frac{1}{L_b} \cdot \sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{p_i^2}\right] \Rightarrow$$

$$\Rightarrow 4 * 10^{\frac{UGR}{8}} = \left[\sum_{i=1}^{n} \frac{L_i^2 \cdot \omega_i}{L_b \cdot p_i^2}\right] \qquad (8)$$

Adjustment Jepanešnikovej equation:

$$G = M = \sqrt{\sum_{i=1}^{n}\left[\frac{L_i \,.\, \omega_i^{0,5}}{L_b^{0,5} \,.\, p_i}\right]^2} \Rightarrow M^2 = \sum_{i=1}^{n}\left[\frac{L_i \,.\, \omega_i^{0,5}}{L_b^{0,5} \,.\, p_i}\right]^2 \Rightarrow M^2 = \left[\sum_{i=1}^{n}\frac{L_i^2 \,.\, \omega_i}{L_b \,.\, p_i^2}\right] \qquad (9)$$

With the help of the simple mathematical adjustments it is possible to derive the same results. That means that the both methods are compatible.

4.2 Derivation of conversion formula

The basic conclusion I realized that created a correlation between these two methods.

The correlation between Jepanešnikovej method to UGR:

$$UGR = 8 * \log\left(0,25 * G^2\right) \qquad (10)$$

The Correlation between UGR method to Jepanešnikovej method:

$$G = M = \sqrt{4 * 10^{\left(\frac{UGR}{8}\right)}} \qquad (11)$$

By using these formulas it is possible to calculate the glare coefficient and can be recalculated from Jepanešnikovou method to UGR method and back. There are no limits related to the precision. Therefore the recalculation is possible to do it to all light systems and it doesn't matter what light sources are used. The requirements for both methods have to be upheld.

Likewise in Netušilovej method, it is possible to create a table which can display all the results from the Jepanešnikovej method and the UGR method.

Table 1 Classification classes of factor discomfort M with UGR

Class and requirement for glare	factor discomfort M	UGR
Ak – high	≤ 25	≤ 17,6
Bk – increased	25 < M ≤ 40	17,6< UGR ≤ 20,8
Ck – normal	40 < M ≤ 60	20,8< UGR (23,6

References

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