Research on Illumination Estimation Based on Data Fitting

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Abstract. In order to solve the illuminance sensor placed on the work surface, it is easily shielded by office objects, human activities, cannot get an accurate work surface illumination an in the indoor lighting control system. In turn, will make dimming system inaccurate and the illumination of the work surface cannot meet the needs of the human eye. Based on the theory of radio energy transmission, Discussed the distribution of sunlight in indoor space, A prediction method for replacing the illuminance sensor of the work surface with an illuminance sensor provided on the wall and the ceiling is proposed. The influence of the orientation relationship between the daylight and the sensor on the illumination of the desk was investigated by simulation.

Keywords: Illumination estimation · Data fitting · Energy saving

1 Introduction

According to the survey, indoor closed-loop control of dimming system metrics usually uses a single point calibration. This single point calibration will work as long as the operating conditions are not different from the conditions at the time of calibration. However, only certain parts of the building can meet these conditions. Most of the space that is significantly affected by sunlight is due to direct sunlight, and reflections from blind corners or the height of the window create variable solar reflection conditions. This change does not apply to single point calibration techniques. Although placing the photosensor on the work surface is an ideal location to monitor the illumination of the internal working plane, the work plane sensor is susceptible to interference from passengers or accidentally covered by paper.

Therefore, light sensors for closed loop lighting control are typically mounted on the ceiling to reduce the likelihood of being disturbed. This paper presents an effective strategy for estimating the illumination of the working plane.

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2 Illumination Collection

Building address: Dalian (longitude: 121.62° latitude: 28.92°).

Volume: 5.4 m*3.6 m*2.8 m.

Building type: one floor. Orientation: South. The height of the lighting window is 0.8 m, the area is 1 m*1 m, and the wall-to-window ratio is 25.5%.

External Illumination Sensor 1- (2.0, 3.6, 1.8) Ceiling Near Window Sensor 2- (2.7, 2.4, 2.8) Ceiling Far Window Sensor 3- (2.7, 1.2, 2.8) Level Illumination Sensor 4- (1.3, 1.7, 0.85) (Figs. 1 and 2).

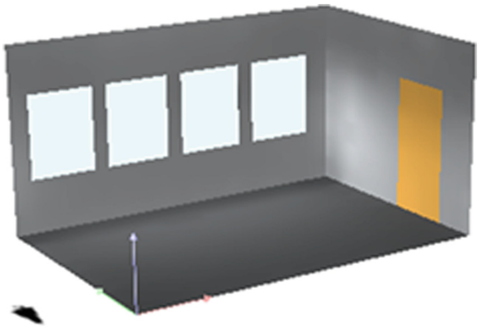

Fig. 1. Dialux model diagram

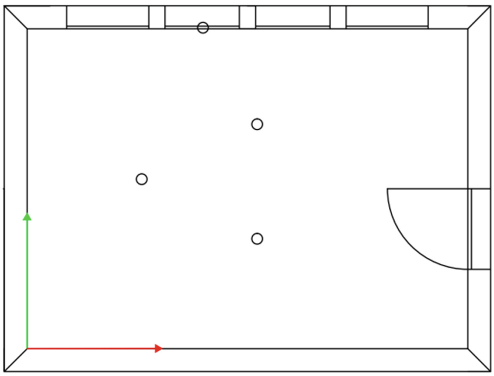

Fig. 2. Sensor position diagram

In this paper, the illuminance values of 2018.3.21-3.22 were collected as the benchmark, and the illuminance is shown in the following table.:

Table 1. illuminance value collection Table (2018.3.21)

Sensor type	Illuminance value					
Sensor 1	1896	2690	3472	4026	4667	5230
Sensor 2	48	69	91	108	128	144
Sensor 3	59	78	112	140	158	182
Sensor 4	101	143	184	213	247	277
Sensor type	Illuminance value					
Sensor 1	5705	6063	6363	6063	6595	6063
Senso 2	156	169	174	177	181	178
Sensor 3	193	209	216	220	224	220
Sensor 4	303	322	337	332	350	322
Sensor type	Illuminance value					
Sensor 1	6386	6089	5622	5284	4730	4096
Sensor 2	175	166	157	140	129	118
Sensor 3	216	206	195	170	160	143
Sensor 4	339	328	305	280	251	217

Table 2. illuminance value collection Table (2018.3.22)

Sensor type	Illuminance value					
Sensor 1	6420	6152	5781	5314	4759	4125
Sensor 2	176	168	158	143	130	114
Sensor 3	218	210	196	178	161	144
Sensor 4	340	326	307	282	252	219
Sensor type	Illuminance value					
Sensor 1	1796	2599	3361	4069	4709	5271
Sensor 2	49	79	92	108	129	144
Sensor 3	61	89	114	139	160	177
Sensor 4	95	138	178	216	250	280
Sensor type	Illuminance value					
Sensor 1	5746	6102	6363	6402	6631	6102
Sensor 2	157	169	176	178	182	179
Sensor 3	195	209	218	223	225	221
Sensor 4	305	324	337	327	352	324

3 Work Surface Illumination Estimation

Based on the theory of light energy, the working plane illuminance can be described as a linear combination of other internal sensor illuminances. Therefore, the working surface illumination can be described as:

$$I_{task} = I_S^T f(n) \tag{1}$$

Where I_{task} is the estimated working plane illuminance, I_S is the illuminance vector measured by the ceiling mounted sensor, and f(n) is the coefficient vector of condition n.

The work plane is estimated to have two steps. The first step is to classify the training data into different categories based on blind height, plate angle or external illumination. The second step is to optimally estimate the coefficient f(n) of each group by minimizing the mean square error between the measured and estimated working plane illuminance. For each clustering condition, use the corresponding estimated coefficient to estimate the work plane illumination.

3.1 Cluster Analysis

There are many factors influencing the factor f, for example: the geometry of the room is different, and the change of the weather will produce different distributions of daylight flux through the window from the external environment. Therefore, the coefficient f should be estimated for different situations. The system may consider collecting blind blind heights, slit angles, dimming levels of lights, external illumination measured by window mounted sensors, and internal illumination of ceiling mounted sensors.

In this paper, the factors affecting the external illuminance are considered and clustered. According to the measured outdoor illuminance, considering that there is no other light source in the room, the indoor illuminance is very poor according to the lighting conditions, the lighting conditions are general, and the lighting conditions are well divided into three categories. Therefore, using K-means clustering algorithm, take K = 3 (Fig. 3).

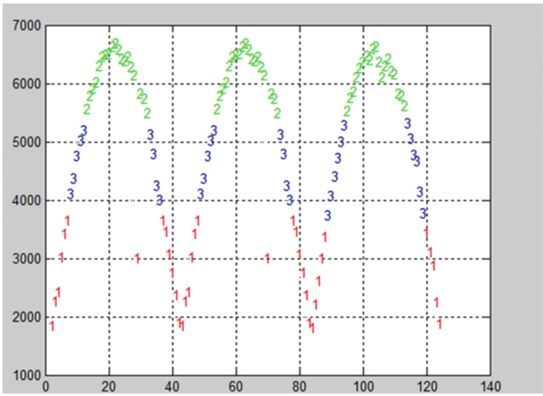

Fig. 3. Clustering result diagram

The resulting external illumination is classified as follows: the first type of boundary ans = (1796,3640); The second type of boundary ans = (3723,5314); The third type of boundary ans = (5483, 6667).

3.2 Coefficient Estimation

After data clustering, we now focus on the data fit of any condition n, i.e. the coefficient f(n) of each cluster, which represents the coefficients of a particular environmental condition. In data measurements, the illuminance of the light sensor and the illumination of the working plane are usually expressed as discrete time series.

$$I_{task} = \begin{bmatrix} I_1[1] & I_2[1] & \cdots & I_Q[1] \\ I_1[2] & I_1[2] & \cdots & I_Q[2] \\ \vdots & \vdots & \ddots & \vdots \\ I_1[M] & I_2[M] & \cdots & I_Q[M] \end{bmatrix} \begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_Q \end{bmatrix} = \mathbf{H}\boldsymbol{f}, \tag{2}$$

Where H is the discrete time measurement data of the Q internal sensor. By the least squares method, the sum of the squares of the estimation errors between the Itask of the measured value and its estimate is minimized, thereby providing a closed form solution of the optimal coefficient f. The best factor is:

$$\hat{f} = \left(H^T H\right)^{-1} H^T I_{task} \tag{3}$$

Since the system is aggregated into different conditions, the same linear estimation structure is used for different conditions, and the estimated coefficient f is a discrete function under different conditions. Therefore, the general expression of the illuminance estimation is:

$$\hat{I}_{task}[n] = H[n]\hat{f}[n] \tag{4}$$

4 Simulation and Experiment

Based on the three sets of data measured in Tables 1 and 2, the estimated coefficients are constructed, and the illuminance of the working surface is estimated for the ceiling illuminance measured by the model of 2018.4.1-2018.4.2, and the normalized root mean square error value is used to represent Estimate the error between illuminance and measured illuminance (Table 3).

$$NRMSE = \frac{\sqrt{E\left[\left(\widehat{\boldsymbol{I}}_{task} - \boldsymbol{I}_{task}\right)^2\right]}}{\max(\boldsymbol{I}_{task}) - \min(\boldsymbol{I}_{task})}. \tag{5}$$

Table 3. Partial illuminance value (2018.4.1-2018.4.2)

Sensor type	Illuminance value					
Sensor 1	15	61	104	140	168	185
Sensor 2	19	76	128	173	208	229
Actual value	37	146	247	337	400	442
Estimated value	35	112	221	294	362	405
Sensor type	Illuminance value					
Sensor 1	191	157	138	101	55	28
Sensor 2	236	195	171	125	69	37
Actual value	445	375	329	245	133	68
Estimated value	412	336	289	210	115	52
Sensor type	Illuminance value					
Sensor 1	17	62	105	169	186	192
Sensor 2	21	77	130	209	230	237
Actual value	40	149	250	403	444	457
Estimated value	26	123	219	365	410	421
Sensor type	Illuminance value					
Sensor 1	185	167	139	102	52	33
Sensor 2	229	207	172	126	69	47
Actual value	442	399	331	243	120	82
Estimated value	423	356	303	216	92	59

NRMSE = 0.1432

5 Conclusion

This paper presents a strategy to estimate the working plane illumination from other internal sensors (usually mounted on the ceiling). The system first classifies the data into various categories and calculates the estimated coefficients for each category. These estimated coefficients are later used to estimate the working plane illuminance by combining the illuminance levels measured by other photosensors, The algorithm proposed in this paper performs well in the experiment.

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