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An Optimal Visual Fatigue Relief Method for Workers Considering Rest Time Allocation

XIAOHUI REN[1], ZIQING GAO[1], AND QUAN SUI[2]
[1]The First Affiliated Hospital, Bengbu Medical College, Bengbu, Anhui 233000, China
[2]State Key Laboratory of Advanced Electromagnetic Engineering and Technology, Huazhong University of Science and Technology, Wuhan, Hubei 430074, China

Corresponding author: Ziqing Gao (gaozq70@126.com)

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ABSTRACT Working under the visual display terminal for several hours may lead to serious visual fatigue. Productivity will be reduced and the health of workers will be damaged. To address the problem, an optimal visual fatigue relief method for workers considering rest time allocation has been proposed in this paper. First, an analytic model is established to depict the relationship between the visual fatigue change and continuous work time. On this basis, according to optimization theory, aiming at minimizing the total visual fatigue level during work, an optimization model of hourly rest time allocation is developed considering working demands. This model is converted as a classic mixed-integer linear programming (MILP) problem and efficiently solved by Gurobi. Finally, a validation experiment with 20 participators is done to verify the effectiveness and superiority of the proposed strategy. The results show that the proposed analytic model could effectively evaluate the visual fatigue development, and the proposed rest time optimization strategy could significantly reduce the visual fatigue level and improve the visual health.

INDEX TERMS Visual fatigue, visual fatigue relief, rest time, optimization method.

I. INTRODUCTION

As an internal manifestation of the decline of human visual ability, visual fatigue could reduce productivity, impact comfort, and damage human health. Generally, proper rest could effectively reduce the level of visual fatigue. Therefore, it is of great significance to reasonably arrange rest time of workers while meeting the requirements of working hours.

More recently, many researchers have focused on the visual fatigue problem and achieved some results [1]. For example, [2] has shown that lighting conditions including lighting type, lighting level and related color temperature affects visual fatigue, where LED lighting inhibits visual fatigue more effectively compared with fluorescent lighting. [3] has noted that display luminance and ambient illuminance have an impact on subjective comfort evaluation and image quality evaluation, objective visual fatigue index, subjective comfort evaluation and so on. [4] has demonstrated that the lower the blue light ratio (the blue light ratio is 20%, 40%, 60%, 80%, 100%), the deeper the visual fatigue of users. On this basis, some researchers have carried out the study on numerous indicators to reflect the visual fatigue level. To be specific, [5] has studied the subjective visual fatigue indicators such as tired eyes, sore or burning eyes, double vision, slowness to focus, blurred vision, dizzy, headache and so on. [6]–[8] have proved that the significant decrease of the critical flicker frequency (CFF) means the increase of visual fatigue level and the deterioration of retinal function. [9], [10] have reported that tear film break-up time (BUT) could evaluate the visual fatigue level. [11], [12] discovered that the near-point accommodation (NPA) and near-point convergence (NPC) would be changed when workers got visual fatigue. [13], [14] has revealed that significantly shorter blink durations mean a higher workload level. [15] has shown that oxygen saturation (SpO2), and skin temperature (SKT), and galvanic skin response (GSR) are closely related with the visual fatigue or other symptoms. [16], [17] have reported that heart rate variability including heart rate, high and low frequency power could effectively reflect the worker's visual fatigue. Additionally, in [18], it was found that dry eye disease (DED) is associated with significantly lower on-the-job time and significantly affected worker's productivity. In [19], a written questionnaire was carried out

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to investigate the prevalence of ocular surface disease, and the results show that the severity of symptoms such as tired eyes is strongly related to the working time under the visual display terminal. In [20], [21], it was demonstrated that visual fatigue would become more serious with the increasing of working time under visual display terminal (VDT). In [22], a visual fatigue evaluation model under LED lights based on long-term visual display terminal work was established. Focusing on impact factors, numerous indicators, and time dependence trend of visual fatigue, the above literatures have not developed an explicit analytical model to depict the visual fatigue change, which may not provide a direct guidance on fatigue relief.

As a further study, several methods have been used to relieve visual fatigue level. For example, in folk practice, [23] has noted that eye scraping combined with eye point massage may be helpful in treating visual fatigue. [24] has reported that blink training to increase the blink rate during computer use could relieve dry eye symptoms. In clinical practice, [25] has shown that toric contact lenses, or a spectacle overcorrection could reduce the visual discomfort of individuals with spherical hyperopia and high myopia. [26] noticed that lubricating eye drops and special computer glasses may help improve visual comfort. [27] has demonstrated that acupuncture were able to improve eye symptoms including visual fatigue, visual acuity, dry eyes and so on. [28] has proved that the far-infrared rays could accelerate the relief of visual fatigue by expanding capillaries. [29] used based-thermal-eye-mask far-infrared (FIR) therapy to reduce the fatigue level and used the fixation frequency (FF) and saccade amplitude (SA) to track the treatment effect. [30], [31] have illustrated that different colloidal drug delivery systems and topical ophthalmic drug delivery systems could treat dry eye disease. However, the result evaluation of the folk practice is relatively subjective, and the effectiveness needs to be further explored. Additionally, the clinical method not only costs a lot of money, but also may increase patients' pain. Considering the defects, [32] proposed a rest time arrangement method to prevent serious visual fatigue, and demonstrated that a 3 min break each hour could enhance visual performances of individuals. However, the hourly optimal rest time has not been determined, especially considering the requirements of working hours.

With the aforementioned observations, this paper proposed an optimal visual fatigue relief method for workers considering the rest time allocation. First, according to the previous work in [20]–[22], a visual fatigue change model under visual display terminal was proposed. On this basis, a rest time optimization model integrating working demand constraints was developed to minimize the total visual fatigue level during the workday. Note that commercial solver Gurobi has a good ability to solve the optimization model, but it can only solve several specific optimization problems [33], [34]. Therefore, the proposed optimization model was first linearized as a classic mixed-integer linear programming (MILP) problem (Both the objective function and constraints are linear, and the optimization variables includes binary variables and continuous variables), and then solved by Gurobi efficiently. Finally, a validation experiment with 20 participators was done to verify the superiority of the proposed strategy.

II. PREVIOUS WORK

[22] carried out an experiment on 20 participators' visual fatigue levels under LED light sources. The levels of visual fatigue were evaluated from three aspects: subjective feeling, ophthalmological parameters, and physiological signals, and the detailed data were measured after 0, 2, 4, 6, and 8 hours of work. By analyzing this data, the visual fatigue prediction model was established.

A. THREE MANIFESTATIONS OF VISUAL FATIGUE

1) SUBJECTIVE FEELING

Since the subjective feeling of workers was able to directly reflect the visual fatigue level, the questionnaire survey was conducted to evaluate the visual fatigue level. The subjective feeling indicators mainly included tired eyes, sore or aching eyes, irritated eyes, dry eyes, hot or burning eyes, double vision, blurred vision, dizzy and headache. Each indicator was evaluated using a five point system (1=none, 2=slight, 3=moderate, 4=obvious, 5=severe). It was found that the general subjective fatigue state (SS) could be denoted by nine subjective feeling indicator score using a one-component model [22], as follows:

$$SS\left(t\right) = \sum W_i Z_{Si}\left(t\right) \tag{1}$$

where, $SS\left(t\right)$ denotes general subjective fatigue state at hour t, $Z_{Si}\left(t\right)$ was the normalized average relative score of subjective feeling indicator i at hour t, and W_i was the weight factor.

2) OPHTHALMOLOGICAL PARAMETERS

The ophthalmological parameters including the critical flicker frequency (CFF), the tear film break-up time (TFBUT), best corrected distance visual acuity (BCDVA), best corrected near visual acuity (BCNVA), positive relative accommodation (PRA), negative relative accommodation (NRA), near point accommodation (NPA) and near point convergence (NPC) were related with the visual fatigue level. A one component model was used to depict the relationship between the visual fatigue change and the ophthalmological parameters [22], as follows:

$$\begin{aligned} PCop\left(t\right) = &-0.200 \cdot Z_{NPA}\left(t\right) \\ &+0.214 \cdot Z_{CFF}\left(t\right) + 0.199 \cdot Z_{NRA}\left(t\right) \\ &+0.216 \cdot Z_{BCDVA}\left(t\right) + 0.215 \cdot Z_{BCNVA}\left(t\right) \end{aligned} \tag{2}$$

where, $PCop\left(t\right)$ stood for the correlation index of visual fatigue, $Z_{NPA}\left(t\right)$, $Z_{CFF}\left(t\right)$, $Z_{NRA}\left(t\right)$, $Z_{BCDVA}\left(t\right)$, and $Z_{BCNVA}\left(t\right)$ represented the normalized average relative NPA, CFF, NRA, BCDVA, and BCNVA values, respectively.

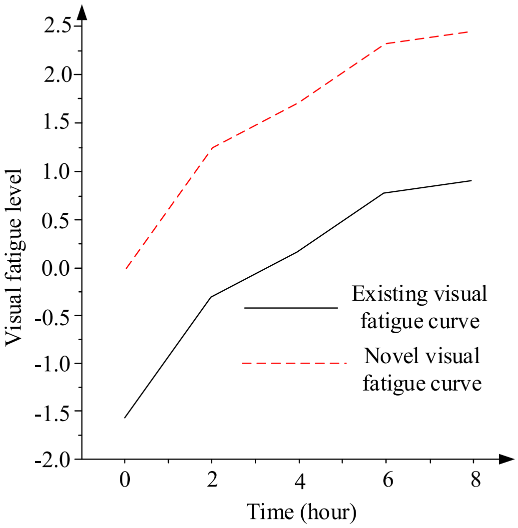

FIGURE 1. Relationship between the subjective level of visual fatigue and working time.

3) PHYSIOLOGICAL SIGNALS

The physiological signals including skin temperature (SKT), galvanic skin response (GSR), and eye blink could reflect the visual fatigue level [22], as follows:

$$PCps\,(t) = -0.376 \cdot Z_{SKT}\,(t) + 0.376 \cdot Z_{GSR}\,(t) + 0.347 \cdot Z_{Eyeblink}\,(t) \quad (3)$$

where, $PCps\,(t)$ expresses the correlation index of visual fatigue, $Z_{SKT}\,(t)$, $Z_{GSR}\,(t)$, and $Z_{Eyeblink}\,(t)$ are the normalized average relative SKT, GSR and eye blink values, respectively.

B. VISUAL FATIGUE PREDICITON MODEL

Through data analysis, it was found that the level of visual fatigue could be inferred according to $PCop\,(t)$ and $PCps\,(t)$. The prediction model was expressed as follows [22]:

$$ESS\,(t) = -0.588 \cdot PCop\,(t) + 0.426 \cdot PCps\,(t) \quad (4)$$

$$ESS\,(t) \approx SS\,(t) \quad (5)$$

where $ESS\,(t)$ means the inferred visual fatigue level.

The existing work shows that the visual fatigue could be acquired by measuring ophthalmological parameters and physiological signals, which lays a technical foundation for the evaluation of visual fatigue.

III. PROBLEM FORMULATION

According to company regulations and employment law, workers are allowed to take a rest during the shift. In order to guide the relief of visual fatigue, a visual fatigue change model and a rest time optimization model were developed in this paper.

A. VISUAL FATIGUE CHANGE MODEL

The black solid line in Figure 1 depicts the relationship between the visual fatigue level and working time in [22]. As observed from the figure, with the increasing of the working time, the visual fatigue level would rise simultaneously. However, the curve change rate was not monotonous. For example, the visual fatigue level would increase by 1.25 scores from 0 to 2 hours, 0.4531 score from 2 to 4 hours, and 0.6719 score from 4 to 6 hours. To directly depict the change trend of the curve, a visual fatigue mathematical model was established in this paper, as follows:

$$SS\,(t) = \begin{cases} k_{10}+k_{11}\times L\,(t)\,, & \textit{if } 0 \le L\,(t) \le 2 \textit{ is satisfied} \\ k_{20}+k_{21}\times L\,(t)\,, & \textit{if } 2 < L\,(t) \le 4 \textit{ is satisfied} \\ k_{30}+k_{31}\times L\,(t)\,, & \textit{if } 4 < L\,(t) \le 6 \textit{ is satisfied} \\ k_{40}+k_{41}\times L\,(t)\,, & \textit{if } 6 < L\,(t) \le 8 \textit{ is satisfied} \end{cases} \quad (6)$$

where k_{10}, k_{11}, k_{20}, k_{21}, k_{30}, k_{31}, k_{40}, and k_{41} are equation parameters, $L\,(t)$ represents the continuous working time of the worker at hour t. For example, when a worker works at hour 1 and hour 2, rests at hour 3, and then works again at hour 4, $L\,(t)$ could be represented as $L\,(1) = 1$, $L\,(2) = 2$, $L\,(3) = 0$, $L\,(4) = 1$.

On this basis, to facilitate analysis, the existing visual fatigue curve was moved upward to ensure all the possible fatigue levels were not less than 0, as depicted by the red dotted line in Figure 1. Therefore, a visual fatigue change model was established in this paper, as follows:

$$SS^*\,(t) = SS\,(t) + k_0 \quad (7)$$

where $SS^*\,(t)$ denotes the novel general subjective fatigue state of the worker at hour t, $SS^*\,(0) = 0$ is satisfied, and k_0 is a positive number.

Based on the visual fatigue change model, a rest time optimization method was proposed, as illustrated in details in following section.

B. OPTIMIZATION MODEL

Optimization theory is a theoretical method about the optimal design, optimal control and optimal management of systems [33]. It aims to maximize or minimize the objective function of the system while meeting the system operational constraints. This method has been used widely in energy management of power grid [34], operation control of machines [35], logistics distribution [36] and so on. Considering the working time constraint, optimization theory would be used in this paper to allocate the hourly rest time, in order to relieve the visual fatigue, as follows:

A lower level of visual fatigue means higher productivity and better health states. Therefore, the objective function was set to minimize the cumulative sum of fatigue level of the workers during the workday, as follows:

$$\min \sum_{t=1}^{T} SS^*\,(t) \quad (8)$$

where T stands for the length of working hours.

Also, the workers must satisfy working requirements such as working time. The detailed constraints were presented as follows:

1) HOURLY REST TIME CONSTRAINT

The rest time of workers at hour t shall be less than one hour. The corresponding constraint was denoted as follows:

$$U(t)\tau \le R(t) \le U(t) \tag{9}$$

where, $R(t)$ stands for the rest duration within hour t, τ means the minimum rest time, the binary variable $U(t)$ marks the rest behavior, where $U(t) = 1$ means workers take a rest at hour t, and $U(t) = 0$ indicates workers do not rest at hour t.

2) REST FREQUENCY CONSTRAINT

According to company regulations, the rest frequency shall not be more than the allowable value:

$$\sum_{t=1}^{T} U(t) \le N1 \tag{10}$$

where $N1$ expresses the number of the allowed break frequency.

3) TOTAL REST TIME CONSTRAINT

The total rest period for workers could not exceed the number of hours allowed during the workday, as follows:

$$\sum_{t=1}^{T} R(t) \le N2 \tag{11}$$

where $N2$ represents the allowed total rest time during the workday.

4) ASSOCIATIVE CONSTRAINT

There was associative constraint between the rest time and continuous working time, as follows:

$$L(t) = \begin{cases} 1 - R(t), & \textit{if } R(t) > 0 \textit{ is satisfied} \\ L(t-1) + 1, & \textit{if } R(t) = 0 \textit{ is satisfied} \end{cases} \tag{12}$$

Note that $R(t) > 0$ means that the worker takes a rest within hour t, and $R(t) = 0$ indicates that the worker does not rest at time t. Therefore, when $R(t) = 0$ is satisfied, the continuous working time at hour t is related with the continuous working time at hour t-1.

IV. SOLUTION ALGORITHM

A. MODEL SOLUTION

The optimization model included nonlinear constraints (i.e., (6) and (12)), which made it difficult to be solved. To address the problem, this model was first linearized, and solved by commercial solvers [34]. The detailed descriptions were presented as follows:

With regard to (6), first, define that binary variables $U_i(t)\,(i = 1, 2, 3, 4)$ denote four possible working time scenarios. For example, $U_1(t) = 1$ denotes that the continuous working time is satisfied by $0 \le L(t) \le 2$, and $U_1(t) = 0$ represents the continuous working time is satisfied by $L(t) > 2$. Considering that the worker has only one general subjective fatigue state at any hour t, the constraint could be denoted as follows:

$$U_1(t) + U_2(t) + U_3(t) + U_4(t) = 1 \tag{13}$$

On this basis, (6) was represented as follows:

$$\begin{aligned} SS(t) = {} & \left[k_{10}U_1(t) + k_{11}L_1^*(t)\right] \\ & + \left[k_{20}U_2(t) + k_{21}L_2^*(t)\right] \\ & + \left[k_{30}U_3(t) + k_{31}L_3^*(t)\right] \\ & + \left[k_{40}U_4(t) + k_{41}L_4^*(t)\right] \end{aligned} \tag{14}$$

where, the variable $L_i^*(t)\,(i = 1, 2, 3, 4)$ stands for $L(t) \times U_i(t)$, and it could be linearized as follows:

$$0 \le L_i^*(t) \le L(t) \tag{15}$$

$$-J + U_i(t) \times J + L(t) \le L_i^*(t) \le U_i(t) \times J \tag{16}$$

where, J means a large positive number.

With regard to (12), first, define that binary variable $U(t) = 1$ denotes $R(t) > 0$, and $U(t) = 0$ stands for $R(t) = 0$. The continuous variable $R^*(t)$ is used to replace $R(t) \times U(t)$, as follows:

$$0 \le R^*(t) \le U(t) \times J \tag{17}$$

$$-J + U(t) \times J + R(t) \le R^*(t) \le R(t) \tag{18}$$

where $R^*(t) = R(t)$ is satisfied with $U(t) = 1$, and $R^*(t) = 0$ is satisfied with $U(t) = 0$.

Similarly, the continuous variable $L^*(t-1)$ is used to replace $L(t-1) \times U(t)$, as follows:

$$0 \le L^*(t-1) \le U(t) \times J \tag{19}$$

$$-J + U(t) \times J + L(t-1) \le L^*(t-1) \le L(t-1) \tag{20}$$

where $L^*(t-1) = L(t-1)$ is satisfied with $U(t) = 1$, and $L^*(t-1) = 0$ is satisfied with $U(t) = 0$.

On this basis, (12) could be replaced by the following formulas:

$$L(t) = 1 + L(t-1) - R^*(t) - L^*(t-1) \tag{21}$$

where $L(t) = 1 - R(t)$ is satisfied with $U(t) = 1$, and $L(t) = 1 + L(t-1)$ is satisfied with $U(t) = 1$

Through the above process, the optimization model was converted as a classic MILP problem, as follows:

$$\min \mathbf{Ex} \tag{22}$$

$$\text{s.t. } \mathbf{Ax} = \mathbf{C} \tag{23}$$

$$\mathbf{Bx} \le \mathbf{D} \tag{24}$$

where $\mathbf{x}$ means the variable matrix in the optimization model, $\mathbf{E}$, $\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$, and $\mathbf{D}$ stand for the coefficient matrixes. (22) represents (8), (23) stands for (7), (13), (14), and (21), and (24) means (9)- (11), and (15)-(20).

TABLE 1. The inclusion criteria.

Item	Inclusion criteria
Age	20-30 years
Best visual acuity	≥1.0 for both monocular and binocular
Myopic refractive error	≤-6 dioptres for both monocular
Anisometropia	≤1 dioptre
Tear break-up time	≥10 seconds
Astigmatism	≤-1 dioptre
Severe cardiovascular and cerebrovascular diseases	No
Colour blindness	No
Colour feebleness	No
Severe dry eye	No
Amblyopia	No
Heterophoria	No

Based on a 4.3-GHz Windows-based PC with 16 GB of RAM, the optimization problem was coded in MATLAB and solved using Gurobi called by Yalmip.

B. STATISTICAL ANALYSES

We used SPSS V.25.0 (IBM Corp) to analyze the data. We calculated the average and SD of the variables and used t-test to evaluate the characteristics. Define the threshold for statistical significance as 0.05.

V. RESULTS

A. EXPERIMENT CONDITIONS

To verify the superiority of the proposed method, 20 individuals participated in the experiment. All of them came from Bengbu Medical College and satisfied the criteria in Table 1. Additionally, their eyesight was corrected to reach the best visual acuity.

Without loss of generality, the experiment time was from 9:00 to 17:00. The allowed rest time and frequency were 1.5 hours and 2 times, respectively. To evaluate the effect of proposed method, all the participators took part in the following two experiments on different days:

Case 1: The participators followed the optimization result to take a rest.

Case 2: Without loss of generality, the participators took a break at 12:00-12:45 and 15:00-15:45.

According to [22], the ophthalmological parameters and physiological signals of all the participators were measured to obtain the level of visual fatigue.

B. RESULT ANALYSIS

Table 2 shows the optimal rest time in theory in case 1. As observed from the table, workers shall rest for 30 min at 11:00-12:00 and 60 min at 14:00-15:00. In this case, the total level of visual fatigue of workers during the workday would be 5.6873. For comparison, according to the mathematical model in (8), the total level of visual fatigue in case 2 would be increased to 6.0095. The theoretical results show that the proposed strategy could significantly relieve the visual fatigue.

TABLE 2. Optimal rest time.

Time	Rest time
9:00-10:00	0
10:00-11:00	0
11:00-12:00	30 min
12:00-13:00	0
13:00-14:00	0
14:00-15:00	60 min
15:00-16:00	0
16:00-17:00	0

TABLE 3. Total visual fatigue states of participators during the workday.

	Visual fatigue state	
	Theoretical value	Actual value $(\bar{x}+s)$
Case 1	5.6873	5.6870±0.1098
Case 2	6.0095	6.0085±0.2683

All the participators carried out the rest decisions in case 1 and case 2 on different days. The actual values of total visual fatigue states of participators during the workday are illustrated in Table 3. As observed from the table, the actual values of the visual fatigue level in case 1 and case 2 were 5.6870±0.1098 and 6.0085±0.2683, respectively. Some laws have been found as follows:

1) According to the theoretical value and actual value in case 1, $p = 0.990$ was obtained using t-test. Meanwhile, $p = 0.987$ was obtained using t-test by analyzing theoretical value and actual average value in case 2. Therefore, there was a significant interaction between the theoretical and actual value.

2) By analyzing the actual values in case 1 and 2, $p = 0.01$ was obtained using t-test. Therefore, there was a significant difference between the actual values in case 1 and case 2.

C. IMPACT OF REST DURATION AND WORK TIME REQUIREMENTS

The rest duration and working time requirements may impact the visual fatigue state of the workers. To verify the advantages of the proposed strategy in various conditions, the corresponding experiments were carried out.

Assuming that the working time is 8 hours, Figure 2 shows the impact of break duration on the visual fatigue state. As observed from the figure, with the increase of rest time, the level of visual fatigue was reduced simultaneously, indicating that the longer the rest time, the better the visual health. Additionally, compared with that in case 2, the level of visual fatigue in case 1 was always lower.

Assuming that the break duration is 1.5 hours, Figure 3 depicts the impact of working time on the visual fatigue state. As observed from the figure, with the increase of working time, the level of visual fatigue gradually deepened,

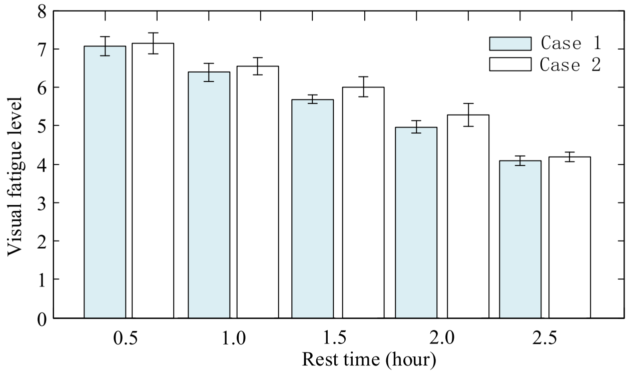

FIGURE 2. Impact of the rest time on visual fatigue states

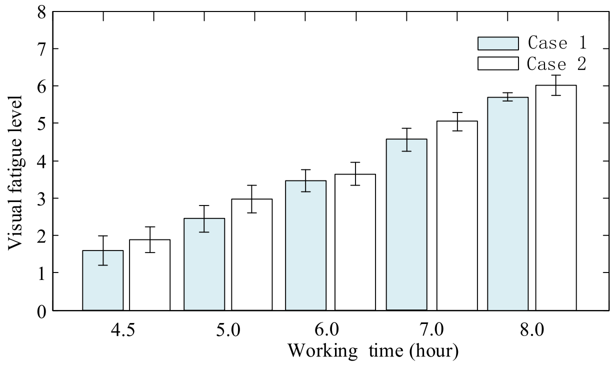

FIGURE 3. Impact of the working time on visual fatigue states.

TABLE 4. Algorithm comparison.

	Visual fatigue value	Solution time
Proposed algorithm	5.6873	11 seconds
PSO	5.6873	19 seconds

implying that the shorter the working time, the better the visual health. Additionally, unlike that in case 2, the visual fatigue in case 1 was more slight.

D. ALGORITHM COMPARISON

To verify the superiority of the proposed algorithm, particle swarm optimization (PSO) algorithm was used to solve the proposed optimization model.

Table 4 shows the algorithm comparison results. As observed from the table, the visual fatigue optimization results from two algorithms was exactly the same. However, compared with the PSO algorithm, the solution time using proposed algorithm could be reduced by 8 seconds (42.1%). The results verify the superiority of the proposed algorithm.

E. DISCUSSION

Benefiting from the convenience, nowadays the visual display terminal has been widely in offices. Meanwhile, Then, the problem of visual fatigue also occurs frequently, which not only reduces the productivity and comfort, but also endangers the health of workers. Therefore, it is necessary to relieve visual fatigue.

Previous studies have shown that the visual fatigue was related to the working time and the severity of symptoms depended on the length of work hours [19]–[22]. However, the analytical relationship between the level of visual fatigue and working time has not been given.

In our study, a visual fatigue change model based on the analytical method was established. By inputting the continuous working time into this model, the theoretical levels of visual fatigue of 20 participators could be calculated, and there was no significant difference between the actual and theoretical values ($p = 0.990$ in the rest-time optimization group and $p = 0.987$ in the routine group). On the one hand, our study demonstrated that the level of visual fatigue was positively correlated with working hours. On the other hand, the results showed that the actual level and development trend of visual fatigue could be accurately evaluated and predicted using the proposed visual fatigue change model.

Previous studies noted that eye scraping combined with eye point massage and blink training to increase the blink rate were helpful in the treatment of visual fatigue [23], [24]. In addition, toric contact lenses, a spectacle overcorrection, lubricating eye drops and special computer glasses, acupuncture, far-infrared rays, colloidal drug delivery systems and topical ophthalmic drug delivery systems were able to relieve symptoms of visual fatigue [25], [31]. However, these methods may not be able to balance the treatment effect, treatment cost, and comfort. Although a 3 min break each hour could improve visual performances, the working requirements in real scenes did not be considered [32].

In our study, a visual fatigue relief model for workers was developed considering working hour constraints, where optimization theory and linearization techniques were used to guide the rest time allocation. By inputting working requirements into this model, optimal rest time decisions were obtained. 20 participators were invited to take part in a validation experiment. The results showed that there was an obvious difference in visual fatigue levels before and after optimizing the rest time ($p = 0.01$). Therefore, the proposed rest time optimization model was able to effectively relieve the visual fatigue.

Previous studies have shown that the lighting conditions including lighting type, lighting level and related color temperature, display luminance, ambient illuminance, blue light ratio and so on could impact the visual fatigue [2]–[4]. However, once the office was decorated, these factors may hardly be changed.

In our study, the impact of company management regulations such as allowed rest duration and work time requirements was analyzed. The results showed that a longer rest time and shorter working time meant a lower visual fatigue level of workers. Additionally, by inputting different time management regulation into the proposed optimization model, an optimal hourly rest time decision could be obtained. The results showed that following the optimal rest time decision could always obtain a lower level of visual fatigue. Therefore, the proposed strategy could always effectively relieve the visual fatigue under different rest duration and working time.

VI. CONCLUSION

This paper mainly studied the visual fatigue relief method for workers considering the rest time allocation. An analytic model was proposed to infer the visual fatigue state and predict the visual fatigue development of workers. An optimization model was presented to relieve the visual fatigue by allocating the rest time.

The results show that the theoretical visual fatigue level obtained from the proposed analytic model was strongly related to actual visual states. Also, the visual fatigue level could be significantly reduced following the optimal rest time. Additionally, when the working time and rest time were changed, the proposed visual fatigue relief method for workers considering rest time allocation was always effective.

Note that in this paper, the visual fatigue problem was solved under ideal cases, and the survey conducted to validate the results were considered ideal candidates only. In fact, the actual problem may be more complex. Therefore, the future work includes the proposal of a more general and robust method suitable for more workers.

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XIAOHUI REN received the B.Sc. degree in electrical engineering from the Bengbu Medical College, in 2017. Her research interests include visual fatigue and glaucoma.

ZIQING GAO is currently the Director of Ophthalmology with The First Affiliated Hospital, Bengbu Medical College. His research interests include glaucoma, cataract, and other ophthalmic diseases.

QUAN SUI received the B.Sc. degree in electrical engineering from the Huazhong University of Science and Technology (HUST), in 2017. His research interests include microgrid planning and scheduling and optimal power systems.