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Review

Application of genetic algorithm for optimization on projects of public illumination

Rômulo Alves de Oliveira[a,*], Manoel Firmino de Medeiros Júnior[b], Roberto Felipe Andrade Menezes[c]

[a] Federal Institute of Sergipe, Engenheiro Gentil Tavares Av., 1166, Aracaju, SE 49055-260, Brazil
[b] Department of Computer Engineering and Automation, Federal University of Rio Grande do Norte, Senador Salgado Filho Av., 3000, Natal, RN 59078-900, Brazil
[c] Department of Electrical Engineering, Federal University of Sergipe, Rosa Elze, São Cristóvão, SE 49100-000, Brazil

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ABSTRACT

This paper presents a proposal for minimizing costs of public illumination projects (PI), using the optimization technique of genetic algorithm (GA). The solution is found from the characteristics of public roads (input parameters) and existing norms and standards, which sets the parameters for evaluating each project, ensuring the minimum requirements for safety and comfort efficiently. In order to evaluate the results of the proposed algorithm, tests were performed, based on the characteristics of several existing roads in the state of Sergipe, Brazil, with the distribution of masts in accordance with the following standards: Unilateral, Bilateral Opposite and Central. The implemented GA provides as solution the height of the mast to be used, in addition to the distance between the masts, the number of petals and their orientation, arm size, luminaries model and power of the bulbs used. The photometric features of the set formed by the luminaries and lamp are presented in a file of type IES, like those created from tests conducted by the manufacturers of the models. The results show a good performance of the proposed methodology.

Contents

1. Introduction

The PI is essential for security in cities, preventing accidents, being directly related to the individual's attention in roads that have vehicle traffic. Likewise, it is of fundamental importance to search for optimization of PI projects, seeking to decrease spending in this sector. Given these factors, it is necessary to develop new technologies to enhance the lighting systems of public roads, seeking greater benefit for both the user as to the funder of the project.

Over the years, studies related to illumination gained more importance due to the search for more economical solutions. In this scenario, the studies related to PI seek to minimize costs by reducing the number of masts and the use of more efficient luminaries, combined with the quality of service. Currently, the Brazilian standard NBR 5101 which regulates the PI is used to establish the lighting requirements needed to provide the minimum level of security to roads.

* Corresponding author. Tel.: +55 7988800002.
E-mail addresses: ralvesuol@uol.com.br, romulo.oliveir@uol.com.br (R.A. de Oliveira), firmino@dca.ufrn.br (M.F. de Medeiros Júnior), roberto.menezess@ymail.com (R.F.A. Menezes).

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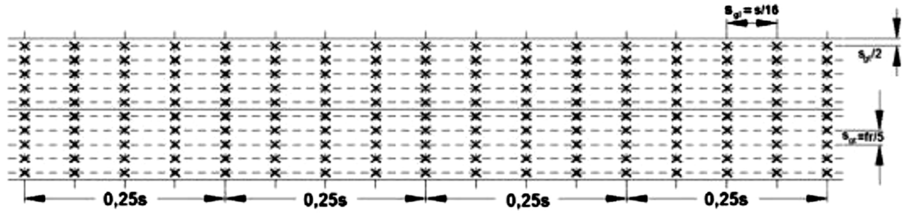

Fig. 1. Checking mesh.

The parameters adopted by NBR 5101 to adjust the light engineering standards in motorized traffic routes are the levels of uniformity of illuminance and luminance, as well as their average and minimum values established in accordance with the classification of route and type of traffic volume [1]. This appropriateness is promoted through the choice of lamps, luminaries, mounting height and positioning of the masts for light distribution and the calculations needed to design optimization.

The use of computational intelligence by means of nature inspired techniques is important to obtain good results in problems encountered in engineering. Genetic algorithms (GA) are robust methods, used primarily to solve numerical optimization problems of functions and machine learning, among other applications areas [2]. The GA technique provides a mechanism for adaptive search that is based on the Darwinian principle of reproduction and survival of the fittest individuals [3].

In this context, this paper aims to present a method to assist the PI projects, from the achievement of lighting calculations to check the requirements of the standard, and the theory of GA, in order to choose the best configurations for the benefit of lower cost.

The existing computational tools on the market do not have satisfactory processing time and require some user experience in the area of lighting. Moreover, lack practicality of these programs, where each project must be entered separately for resolution of the calculation and verification of standards. That is, they are just tools of calculus. The proposed program provides, from input parameters, a higher number of projects analyzed, generating a set of low-cost solutions and within the norm.

The research is justified by the need to stimulate discussions about optimization processes that can culminate in a better use of available technologies in the area of public illumination, and who can collaborate, in general, on minimizing the cost of engineering projects.

The first objective of the research is to provide options beyond existing commercial programs. During the research will be tested other methods than AG and used different standards beyond the NBR 5101.

This work may be used as a tool or as a reference for professionals working in the area and who long for a higher quality of projects that perform and manage.

2. Public illumination

The specific conditions described by NBR5101 (2012) involve the parameters of illuminance: minimal average illuminance ($E_{med,min}$), minimal uniformity of illuminance (U), minimal illuminance (E_{min}); and luminance parameters: average luminance (L_{med}), overall uniformity (U_0), and longitudinal uniformity (U_L). These parameters are used as restrictions in the work.

The calculation and adequacy of these parameters are performed with the aid of a *checking mesh*, consisting of points defined by the intersection of the transverse and longitudinal rows on each track. Fig. 1 shows the verification mesh described in the standard, where S_{gl} is the longitudinal spacing ($\leq$5 m), S_{gt} the transverse spacing ($\leq$1 m), s the space between masts, fr the track width.

Table 1
Illuminance parameters for different types of roads and traffic.

Type of road and traffic	$E_{med,min}$ (lx)	U
Rapid transit, arterials, highways and roads to heavy traffic	30	0.4
Rapid transit, arterials, highways and roads to medium traffic	20	0.3
Collector roads to heavy traffic	20	0.3
Collector roads to medium traffic	15	0.2
Collector roads for light traffic	10	0.2
Local routes for medium traffic	10	0.2
Local routes for light traffic	5	0.2

The parameter $E_{med,min}$ assumes a value obtained by calculating the arithmetic average of the readings taken on the horizontal plane, on the level of the floor according the *checking mesh* shown in Fig. 1. The variable U is the ratio between the minimum illuminance and average illuminance on a specific plan. Table 1 describes what should be the parameters of illuminance for each type of road according to traffic.

The value of E_{min} must be ever higher than 1.0 lx.

The variable U_0 is the ratio between the minimal luminance and the average luminance in a specific plan. The variable U_L is described in the standard as the ratio between the minimum and maximum luminances along the lines parallel to longitudinal axis of the track, at a specific plane. Table 2 describes what should be the parameters of luminance for each type of road, according to the traffic.

The illuminance at the crossing points of the *checking mesh* described in NBR 5101 (2012) is calculated by definition from (1) [4].

$$Ep = \frac{I(\theta) \cdot \cos(\theta)}{D^2} \tag{1}$$

where E_p is the illuminance at point P, due to the luminous flux from the light source (lx), I the light intensity of the source in direction of the angle θ (cd), θ the angle between the light direction and the normal to the horizontal plane through the point P (°), D the distance between the light source and the point P (m)

Once the illuminance is known, the luminance in a surface is calculated from (2) [4].

$$L = \frac{E_p \cdot \rho}{\pi} \tag{2}$$

Table 2
Luminance parameters for different types of roads and traffic.

Type of road and traffic	L_{med} (cd/m^2)	$U_0 \geq$	$U_L \leq$
Rapid transit, arterials, highways and roads to heavy traffic	2	0.4	0.7
Rapid transit, arterials, highways and roads to medium traffic	1.5	0.4	0.7
Collector roads to heavy traffic	1.5	0.4	0.7
Collector roads to medium traffic	1.0	0.4	0.7
Collector roads for light traffic	0.75	0.4	0.6
Local routes for medium traffic	0.75	0.4	0.6
Local routes for light traffic	0.5	0.4	0.6