ESTIMATING INTERMEDIATE VALUES OF POLAR CURVE USING ARTIFICIAL NEURAL NETWORKS AND COMPARISON WITH OTHER METHODS

Nesrin ÇOLAK, Önder GÜLER, Sermin ONAYGIL

Abstract:
The luminous intensity curves are given with luminous intensity values measured in some directions. The unmeasured values can be obtained using various interpolation methods. In this study, the intermediate values not presented on the polar curve are obtained using Artificial Neural Networks and compared with values obtained from Linear and Lagrange Interpolation Methods. From the results it is shown that Artificial Neural Networks can be used for estimating intermediate luminous intensity values.

1. INTRODUCTION

A good quality illumination is only possible by following the criteria given in standards and recommendations. These criteria are significantly affected by the type of luminaire and the lamp used. That is why, the luminaire has to be selected according to the purpose. The selection of the luminaire has to be done by taking into consideration the economy, esthetic features and especially its luminous intensity distribution. The selection of a luminaire with a proper luminous intensity distribution is only possible by knowing the luminous intensity distribution surface. However, in practice instead of luminous intensity distribution surface, polar curves on selected planes such as C0, C30, C60,...C330 are presented. The luminous intensity curves are given with luminous intensity values measured in some directions. The unmeasured values can be obtained using various interpolation methods. In this study, the intermediate values not presented on the polar curve are obtained using Artificial Neural Networks and are compared with values obtained from Linear and Lagrange Interpolation Methods.

2. LUMINOUS INTENSITY DISTRIBUTION SURFACE AND CURVE

The surface of luminous intensity distribution is the surface formed by the extremities of all the radius vectors drawn from a common origin, the length of each radius vector being proportional to the luminous intensity of the source in the corresponding direction. In practice, luminous intensity curves are used instead of luminous intensity distribution surface. The luminous intensity curve is the curve, generally polar, which represents the luminous intensity in a plane passing through the source as a function of the angle measured from some given direction. There are three systems of planes for measurement of luminous intensity distributions. These are A-Planes, B-Planes and C-planes. C-Planes that are generally used are shown in Figure 1.

In this study, the luminous intensity distribution curves of tested luminaires are also given in C-planes.

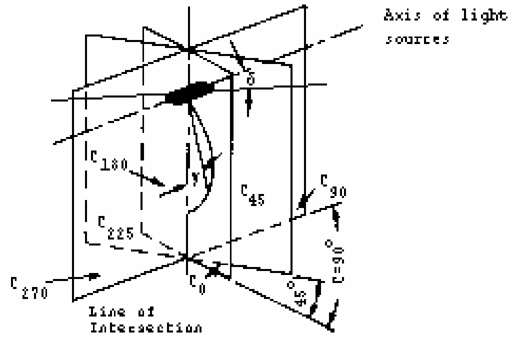

Figure 1 C-planes

Luminous intensities can be measured by a measurement of the illuminance and calculated using the photometric distance law. In this study, the luminous intensity curves of every tested luminaire are obtained in C0, C90, C180, and C270 planes. For this reason, the illuminance values in 5 degree increments (γ) are measured in our photometric laboratory. According to the photometric distance law, the luminous intensity values are calculated using [1].

$$I=E.r^2/\cos\varepsilon\ \Omega \qquad (1)$$

where,
I: Luminous intensity in the direction of the acceptance area (cd)
E: Illuminance on the acceptance area (lx)
r: Distance between light source and the acceptance area (m)
ε: Angle of incidence, measured relative to the normal of the acceptance area (°)
Ω: Unit solid angle (sr)

3. METHODS FOR ESTIMATING INTERMEDIATE VALUES

To estimate the intermediate values of luminous intensity, various interpolation methods (Linear, Lagrange, Cubic, Quadratic) can be used. In this study Linear, Lagrange Interpolation Methods and Artificial Neural Network approach are used to estimate the unknown intermediate values of luminous intensity distribution curves.

3.1 Linear Interpolation Method

The equation of the straight line through the two points (x_{i-1},y_{i-1}) and (x_{i+1},y_{i+1}), as given by the two-point formula from analytic geometry, is

$$y_i(x_i)-y_{i-1}=\frac{y_{i+1}-y_{i-1}}{x_{i+1}-x_{i-1}}(x_i-x_{i-1}) \qquad (2)$$

Solving for $y_i(x_i)$ and combining terms,

$$y_i(x_i)=\frac{y_{i-1}(x_{i+1}-x_i)-y_{i+1}(x_{i-1}-x_i)}{x_{i+1}-x_{i-1}} \qquad (3)$$

is obtained [2].

3.2 Lagrange Interpolation Method

By Lagrange Interpolation Method, an n^{th} degree polynomial is created to connect (n+1) points on a plane, and the data are interpolated according to the polynomial [3].
For (n+1) points the interpolating polynomial is given by

$$Q_n(x)= L_0(x)y_0+ L_1(x)y_1+ \dots + L_ny_n \qquad (4)$$

Lagrangians polynomials $L_i(x)$ are defined as

$$L_i(x)=\frac{(x-x_0)(x-x_1)\dots(x-x_{i-1})(x-x_{i+1})\dots(x-x_{n-1})(x-x_n)}{(x_i-x_0)(x_i-x_1)\dots(x_i-x_{i-1})(x_i-x_{i+1})\dots(x_i-x_{n-1})(x_i-x_n)} \qquad (5)$$

Here, the unknown values of the luminous intensity curves are estimated by the 2nd degree polynomial that connects 3 points.

3.3 Artificial Neural Networks

Artificial Neural Networks consist of a great number of processing elements (neurons) which are connected to each other (fully connected networks). The strength of connections is called weight. External data enter the network through the input neurons. As a result of the non-linear transformations, output data are generated by output neurons. In layered networks, there are a layer of input neurons, a layer of output neurons and one or more hidden layers. There are no connections between the neurons in the same layer. The information is transferred from one layer to the following layer. A typical example of a four-layered architecture is shown in Figure 2.

The knowledge lies in the interconnection weights between neurons, which have to be adjusted in order to allow the network to perform the required task. The Back-Propagation method is the most popular algorithm for performing supervised learning. During the training phase, the weights w_{ij} are successively modified based on a set of input patterns and the corresponding set of desired output targets to minimize the square error over the overall training set. During the presentation process, the training phase is repeated a numerous times and the learning process continues until the desired degree of accuracy is achieved [4].

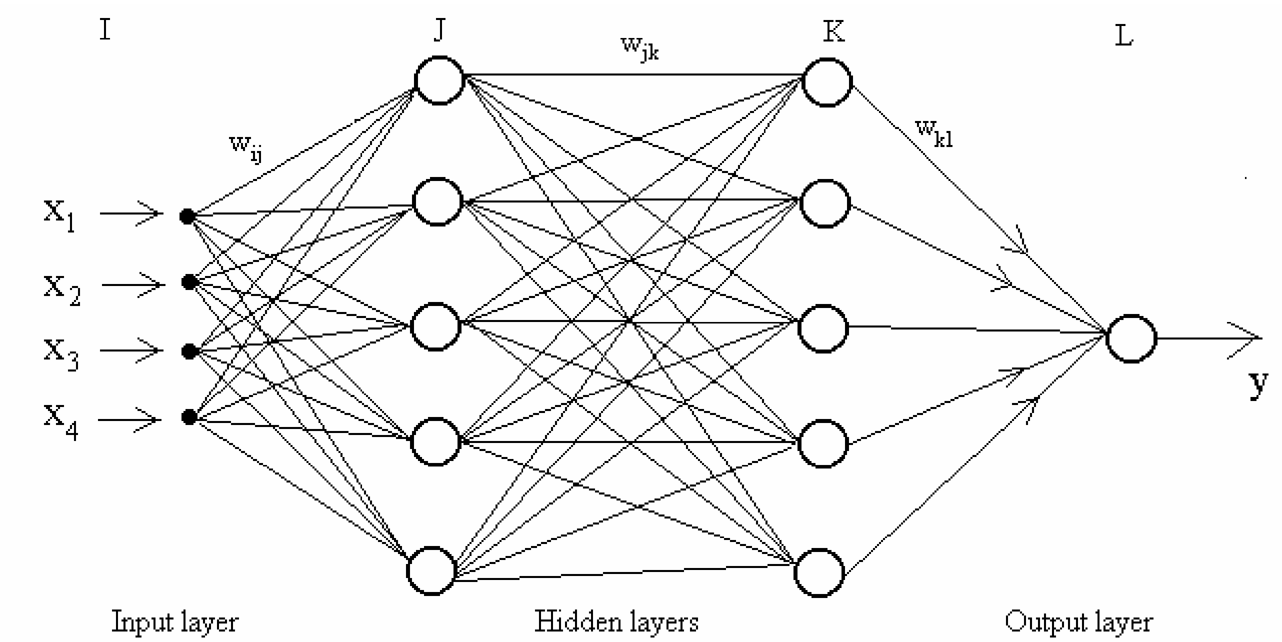

Figure 2 Typical architecture of a four-layered neural network with two hidden layers

For estimating intermediate values of the luminous intensity curves, a four-layered feed-forward back-propagation Neural Network with adaptive learning rate is used. Number of neurons on each hidden layer is five. The architecture of this Neural Network is the same as the one given in Figure 2. The input values used in this Artificial Neural Network are the "γ" angles and the output values are the luminous intensities.

The specific values of the ANN used here is,
learning rate=0.0001
momentum constant=0.95
error-ratio=1.04
number of iteration=50.000

The luminous intensity values for C0, C90, C180, C270-planes measured in 5 degree increments (γ angles) are divided into two groups. The first group data are used for the teaching phase. The data in the second group are used to test the system [5].

4. APPLICATION OF METHODS

Four different types of luminaries with 1x18W compact fluorescent lamp, 1x10W compact fluorescent lamp, 4x18W fluorescent lamps and 2X36W fluorescent lamps are tested in the Lighting Technology Laboratories of Istanbul Technical University for this study. The luminous curves for C0, C90, C180 and C270 planes for each luminaire are shown in Figures 3,4,5,6, respectively.

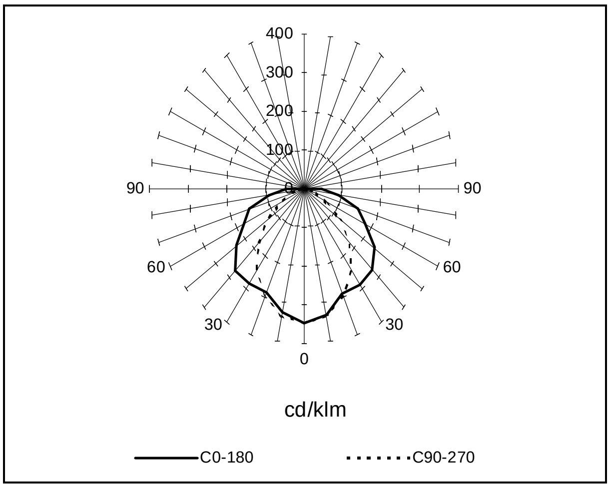

Figure 3 Luminous intensity curves of a luminaire with 1x18W compact fluorescent lamp

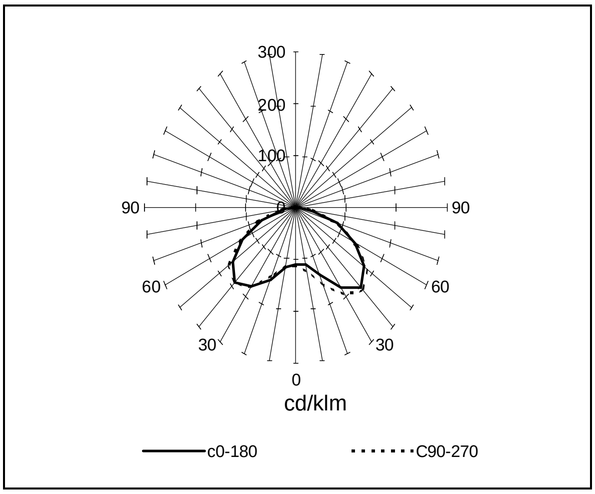

Figure 4 Luminous intensity curves of a luminaire with 1x10W compact fluorescent lamp

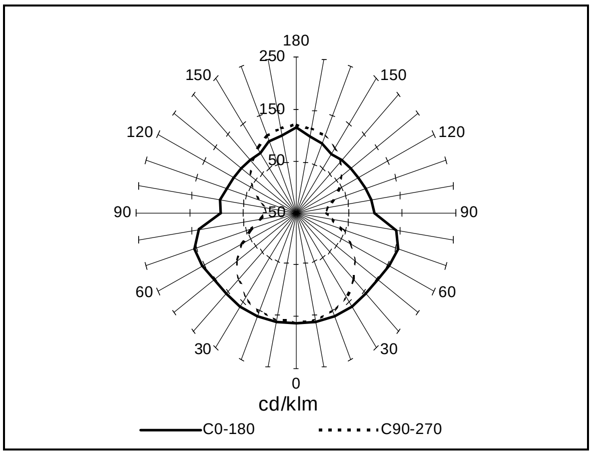

Figure 5 Luminous intensity curves of a luminaire with 4x18W fluorescent lamps

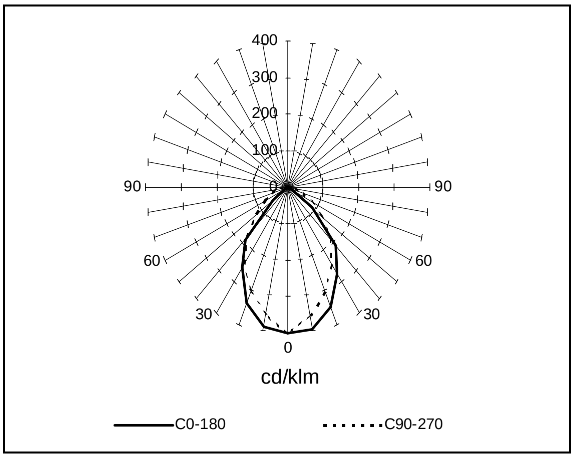

Figure 6 Luminous intensity curves of a luminaire with 2x36W fluorescent lamps

For estimating unknown values, Linear Interpolation Method, Lagrange Interpolation Method and Artificial Neural Networks are used. First, it is assumed that the luminous intensity values on each C plane at 10 degree intervals are known. Using these three methods the unknown values for

5^0,15^0,25^0.... are estimated. In the second step, it is assumed that the luminous intensity values on each C plane at 15 degree intervals are known. Also using these three methods, the unknown values for 5^0,10^0,20^0,25^0.... are estimated. As explained before, the estimation has been done by the 2^{nd} degree polynomial that connects any 3 points by the Lagrange Method. Depending on the selection of the points one or two of these 3 points may be the same for different interpolations. However, the estimated values vary with the selection of the points.
The average error between measured and estimated values for each type of luminaire are found. The results are given at 10^0 intervals in Table 1 and at 15^0 intervals in Table 2. The different results in the Lagrange Method are also represented in Tables as Lagrange1 and Lagrange2.

Table 1 The average error between measured and estimated values at 10^0 intervals

Luminaire type	Average luminous Intensity Error (cd)			
	Linear	Lagrange1	Lagrange2	ANNs
1x18W Compact fluorescent lamp	3.03	2.36	2.97	2.53
1x10W Compact fluorescent lamp	2.50	2.00	1.90	1.60
4x18W Fluorescent lamps	3.33	3.25	3.81	3.11
2x36W Fluorescent lamps	1.06	0.85	0.93	0.92

Table 2 The average error between measured and estimated values at 15^0 intervals

Luminaire type	Average luminous Intensity Error (cd)			
	Linear	Lagrange1	Lagrange2	ANNs
1x18W Compact fluorescent lamp	5.13	4.60	5.46	4.09
1x10W Compact fluorescent lamp	5.38	3.79	4.00	3.33
4x18W Fluorescent lamps	5.91	4.50	6.50	5.78
2x36W Fluorescent lamps	1.39	1.39	1.14	1.34

CONCLUSIONS

This study deals with the estimation of unknown values of luminous intensity distribution curves. For this purpose the Artificial Neural Network approach is employed and compared with other methods. For four different types of luminaires the average error between measured and estimated values are found and it is observed that smaller error is obtained by using the Artificial Neural Network Method. It is also shown that smaller error can be sometimes found by Lagrange Interpolation Method. Yet, the estimation is made only with three selected points and without considering the shape of a curve. Therefore, it is not always possible to minimize errors. On the other hand, if a suitable structure can be determined, the unknown intermediate values can be estimated by Artificial Neural Network Method considering the overall shape of the curve.
The results of this study support that Artificial Neural Networks can be used successfully for estimating unknown intermediate luminous intensity values.

REFERENCES

[1] "The Measurement of Absolute Luminous Intensity Distributions", Publication CIE No:70, 1987.

[2] Macon N., "Numerical Analysis", New York: Wiley, USA, 1963.

[3] Griffiths D.V., Smith J.M., "Numerical Methods for Engineers", Great Britain, 1991.

[4] Haykin S., "Neural Networks", A Comprehensive Foundation, Macmillan College Puplishing Company, Canada, 1994.

[5] Çolak N., Güler Ö., "Estimating Intermediate values of Polar Curve Using Artificial Neural Networks", (in Turkish), Elmeksen 97,Turkey, 1997.

Dr. Nesrin Çolak   Assis. Önder Güler   Assoc. Prof. Dr. Sermin Onaygil

Istanbul Technical University
Faculty of Electrical and Electronics Engineering
Maslak, 80626 Istanbul, TURKEY
Tel:+90.212.285.60.20
Fax:+90.212.285.67.00
e-mail:nesrin@elk.itu.edu.tr