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ILLUMINANCE CONTROL OF A LED LIGHTING NETWORK USING BACK PROPAGATED NEURAL NETWORK

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***Abstract* -Need for energy increases every day with rapid development of industries, widespread urbanization, extensive lighting, increased usage of electronic equipment etc. Avoiding wastage of energy in any situation helps to resolve the problem of energy hunger to an extent. Saving light energy in buildings in different conditions plays an important role in overall energy saving process. In the proposed approach illumination at the working tables are controlled based on a neural network trained LED network. Brightness of the luminairesis adjusted effectively to provide the required luminance at the table. Back propagation algorithm is used to train the neural network which establishes a relationship between the dimming level of luminaires and illuminance at the table. Dimming level control of the luminaires based on the occupancy status and illuminance level required at the table, results in achievement of efficient power usage. Moreover the sensor less control loop approach provides ease of installation and proves cost efficient. In addition to these, back propagated neural network control of the LED network provides fast response and high accuracy.**

Index Terms –Backpropagation, luminaire, illuminance, neurons, training, dimming level, neuron layers.

I.INTRODUCTION

Energy utilization has been increasing with increase in development of electronics and electrical equipments in all the fields replacing human power. Considering the overall energy consumption, energy used for lighting purpose occupies a considerable part. Effective and smart lighting system implementation can optimize the power utilization and hence save energy. Some smart luminance systems areavailable which control the brightness of the luminaires based on the luminance requirement and user comfort [2]-[7].

In the effort of trying to achieve energy reduction and human lighting preferences at same time, conventional approaches face the problem of decision making in choosing luminaire among a luminaire network to light up an area. Zoning approach was considered to solve this problem but it had the disadvantages that interaction between the zones exists and also manual presetting of the zone was required. Energy saving efficiency is lost as these interactions are not considered during design phase.

In lighting applications with multiple LED luminaires, illumination control problem can be given as providing sufficient illuminance at the working table by adjusting the dimming level of the luminaires at minimal power consumption. For solving thisit is required to get the information on occupancy status at the working tables and the information of illuminance at the table which is an optional requirement as it can be modeled and also the illuminance sensors fixed at working table may prove as a hindrance to the workers and the users may accidently affect the functionality of these sensors. Hence many systems have been developed, avoiding the illuminance sensors and using simulation software to establish relationship between luminaires and illuminance. Major drawback of these systems is that for different building the light setting has to be manually changed and the simulation software cannot accurately work for real time environment.

To overcome the drawbacks of the above mentioned system, neural network based approach is proposed, where the neural network is used to establish a relationship between the illuminance at the user table and dimming level of luminaires at the corresponding area.

II.CONVENTIONAL ILLUMINATION CONTROL APPROACHES

Open loop control is the most traditional illumination control approach which does not include any light sensor feedback. It involves manual adjustment of the dimming levels luminaire.Without the luminance feedback the dimming level calculations become inaccurate. Inaccuracy in the dimming level calculations results in decrease in the level of saving power. Also when the number of luminaires used increases it becomes a tedious job to manually control the dimming level of individual luminaires according to the interest of the user.

Another technique to achieve lighting automation is using lux sensor feedback to control the dimming levels. This method overcomes the inaccuracy in the open loop control approach. Light Sensor is used to measure the illuminance level at the user table and is fed back to the corresponding luminaire where it is compared with its reference to find the error value which is used to adjust the dimming level of that particular luminaire [5]. This approach overcomes the inaccuracy in the open loop type but this system is useful only if the luminaires are present apart from each other or portioned from each other such that their luminance does not affect each other. This is because the existence of correlation between the luminaires results in difficulty in relating the sensor and controller of the luminaires as the illuminance at a place is contributed by the correlated luminaires. This control system as an improvement can be implemented using grouping approach where the luminaires providing luminance to a particular zone are preset or predefined. The disadvantage of using this system for implementing networked luminaires is that it takes considerable amount of time to settle in its stable state. Lighting at a zone influence the nearby zone and they adjust each other to provide the desired lighting levels but to achieve the stable state the system takes some time.

There exists a correlation between the light output of the luminaire and its input power which is a linear relationship [2]. With this assumption we can approximate that the relationship between the dimming levels of the luminaires and the illuminance at working table is also linear. Consider the control of networked luminaires as a linear MIMO model. An illuminance model is built up using simulation software [6] and no light sensors areused, because of which this approach becomes very easy to install. But still there exists large inaccuracy in this approach because of the use simulation software build up illuminance model.

III.INVALIDATION OF LINEAR MIMO MODEL

Illumination model is built up as a linear MIMO model considering d as M x 1 vector of dimming levels of the LED luminaires where M is the number of LED luminaires in the test bed.t is the N x 1 vector of illuminance at working tables where N is the number of tables in the test bed considered

As assumed that there exists a linear relationship between the dimming levels of the luminaires and the illuminance at the working table, we have

$$A \times d = t$$

Where A is the coefficient matrix.

However this linearity does not hold in all cases and provides efficient output. DALI controller which isused for discretization of signaldoesn't follow this linearity and results in non-constant efficiency performance. Hence the relation becomes nonlinear one.

IV.NEURAL NETWORK CONTROLLED LED NETWORK

A. Proposed Approach Using Back Propagated Neural Network

In the proposed approach of controlling the luminance of the network of LEDs using neural network, a two layer back propagated neural network is used. Neural network acts as a black box relating the inputs and outputs. The neural network models the relationship between the luminance required at a working place and the dimming level of the corresponding luminaires at the place [1]. This helps to attain a non linear multiple input multiple output model of the networked LED lighting system.Fig.1 shows the framework of the proposed approach.

Compared with other sensor based methods, the proposed neural network based system uses light sensors to update the illumination details only at initial set up time and they are used again only when the work place configuration is changed. This avoids the inaccuracies that occur in the simulation software based approach. As the sensors are used only once it avoids the maintenance problems of the sensors, corresponding battery problems etc. Moreover the proposed approach has the advantage of low cost and ease of installation compared to the complete sensor based approaches.

Initial configuration of the led network, working place configuration and the luminance level required at each location are studied initially. Also the dimming level of corresponding LEDs in the network required to provide the desired luminance at a workplace are analysed and determined.Based on the determination, sample input and target data sets are generated. These samples are then fed to the neural network to train the network to relate the input andoutput. The trained network predict the dimming level output of the luminaires required to illuminate an area based on the presence of users at the working tables

B. Neural network configuration

A neural network can be viewed as a network of internal layers which consists of neurons involving which the network is trained initially using sample data sets to establish a relationship between the input and output. In our proposed system neural network acts as a black box relating the dimming levels of the luminaire with the luminance at the tables based on the occupancy of users at the table.

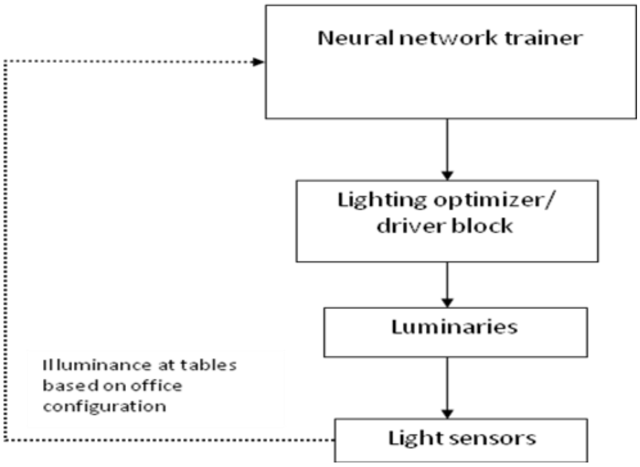


Fig.1. Framework of the proposed system

We use back propagation algorithm to build up the neural network. It is a gradient descent technique to minimize the total squared error of the output which is computed by the network. Process of training in back propagation involves feed forward of the input vector, calculation and back propagation of the error to adjust the weight.

Consider the two layer neural network with M inputs L hidden neurons and N outputs as shown in the Fig.3, the vector of hidden neurons is given as

$$h = [h1, h2, \dots, h_L]^T$$

Weight matrix W^hin the hidden layer is given below where $w^h_{j,k}$is the weight that connects hidden neuron *j* with input neuron *k*.

$$W^h = \begin{bmatrix} w^h_{1,1} & w^h_{1,2} \cdots & w^h_{1,M} \\ w^h_{2,1} & w^h_{2,2} \cdots & w^h_{2,M} \\ \vdots & \vdots \ddots & \vdots \\ w^h_{L,1} & w^h_{L,2} \cdots & w^h_{L,M} \end{bmatrix}$$

Similarly $w^o_{i,j}$is the weight connecting hidden neuron *j* with output neuron *i*. The weight matrix in output layer is given as

$$W^o = \begin{bmatrix} w^o_{1,1} & w^o_{1,2} \cdots & w^o_{1,L} \\ w^o_{2,1} & w^o_{2,2} \cdots & w^o_{2,L} \\ \vdots & \vdots \ddots & \vdots \\ w^o_{N,1} & w^o_{N,2} \cdots & w^o_{N,L} \end{bmatrix}$$

b^h and b^o are the bias vectors in the hidden layer and output layer respectively

$$b^h = [b^h_1, b^h_2, \dots, b^h_L]^T$$

$$b^o = [b^0_1, b^o_2, \dots, b^o_N]^T$$

We use transfer function tansig in the hidden layer and linear transfer function or purlin function in the output layer. The output vector t can be given as

$$h = tansig(W^h d + b^h) = \frac{2}{1 + \exp\left[-2(W^h d + b^h)\right]} - I$$

$$t = (W^o h + b^o) = \frac{2W^o}{1 + \exp\left[-2(W^h d + b^h)\right]} - W^o + b^o$$

C. Neural Network Implementation

A working room scenario is considered for the implementing the proposed approach as shown in the Fig.2 .Considering the LED luminaires network configuration and the working table configuration, sample datasets *d* (user occupancy) and *t* (dimming level) are generated.

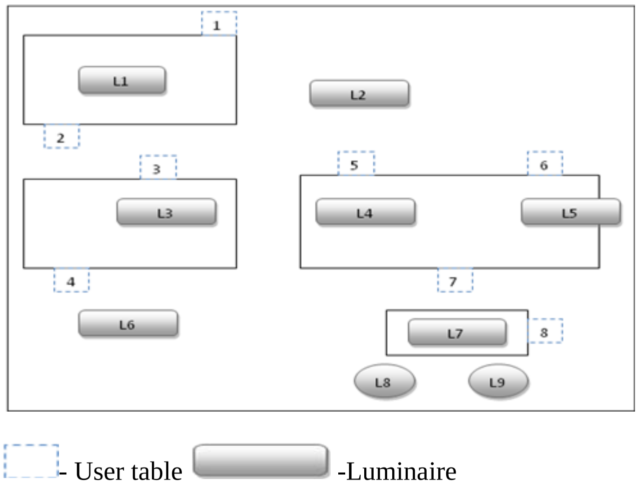


Fig.2.Working room scenario considered for the proposed approach

These vectors are used to train the neural network to relate the occupancy with the dimming level of luminaires hence governing the illuminance required at a work place based on the presence of user at the table. The sample datasets are divided into three groups of training (70%), validation (15%) and testing (15%).The training data groups are used to adjust the coefficients in the network. Validation data group is used to measure network generalization and indicate the time of stop of training. Testing data group is used to independently analyze the network performance after training. Analysis shows that network accuracy is high with selection of L=M.

MATLAB tool is used here to setup and train the neural network. The network is trained to considerable number of iterations or epochs to reach the goal of the training. Training, validation and testing performance for different epochs is shown in the fig.4.

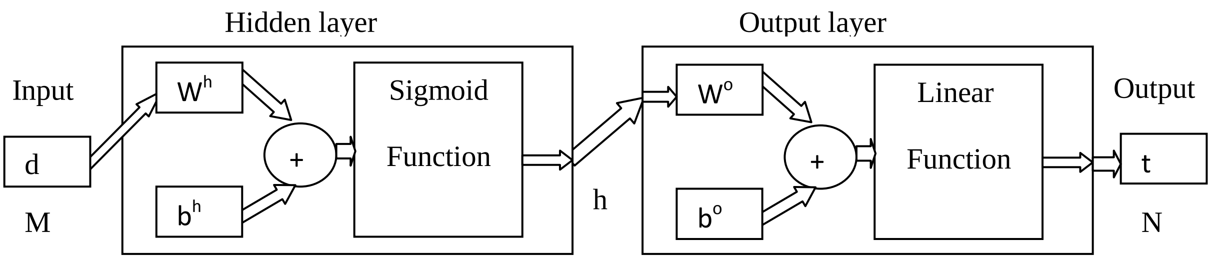


Fig.3.Two-layer neural network

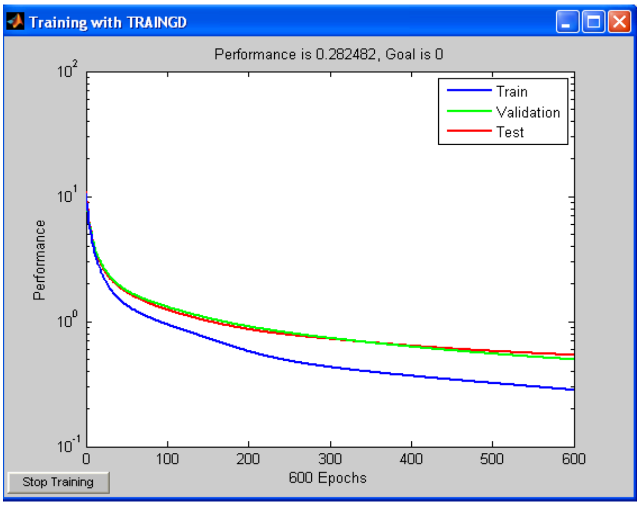


Fig.4 Performance vs epochs

Simulink model for the neural network is build up as in Fig.5.The functional fitting neural network block contains the actual neural network part including two layers of neurons.Fig.6 shows the internal subsystems of each block. Block x represent the input block and the neural network outputs are viewed across the output block.

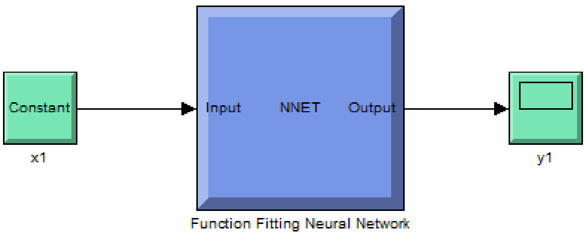
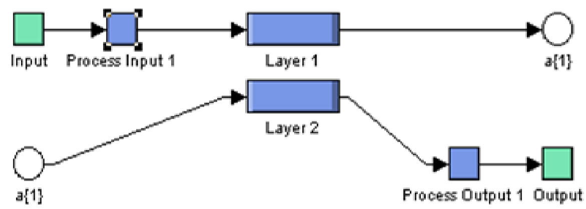


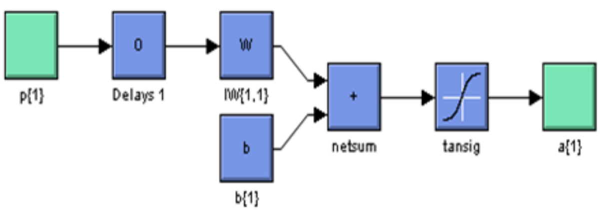
Fig.5 Simulink block set of the control system

V. OPTIMIZATION RESULTS AND ENERGY SAVING

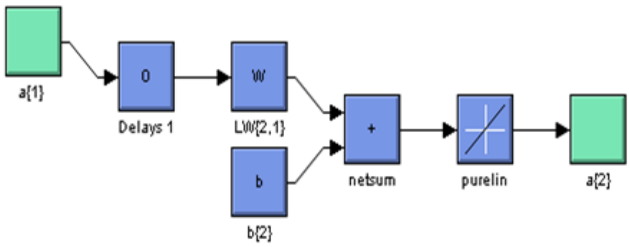
The LED lighting system is designed to illuminate the whole area of the room (scenario considered as in fig.3).When all luminaires are operating at full brightness there exists high luminance at most of the places inside the room. But there exists different situations where only a particular part of the room is to be illuminated or only few users are available at their tables etc.On all these situations not all the tables need sufficient illuminance of more than 350lx. Concentrating only on the tables and not on the whole space, the proposed neural network based illumination control approach can obtain about 28% energy saving. For scenario where only two users are available at the table power saving of about 66% can be achieved.



(a)



(b)



(c)

Fig.6.Internal blocks: (a) Functional fitting neural network; (b) Layer 1; (c) Layer 2

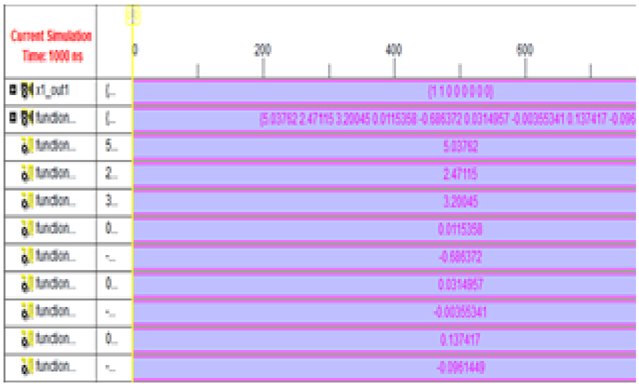


Fig.7.Xilinx simulation output

VI.IMPLMENTATION

The internal subsystems of the functionalfitting neural network block are analysed and VHDL code is developed for the intended purpose of each block. Functional fitting neural network block contains two neuron layers. The input layer uses sigmoid transfer function and output layer uses linear function. Subsystem codes are integrated to obtain the overall functionality. Integrated codes are compiled to check for presence of error if any and simulated to obtain the output waves. Xilinx tool was used to simulate the code and check for output. Fig.7 shows the simulation output obtained using the developed VHDL code for the neural network based dimming level controller for the LED lighting network.

Merits of the neural network based illumination control system are the fully automated operation, minimum use of the illumination sensors, low installation and maintenance cost. The lighting sensors are used at the time of initial setup and again used only when the room lighting configuration is changed. At real time operation the lighting sensors are not used as the model of the lighting system trained and stored in the neural network is used to adjust the dimming levels of the luminaires to provide sufficient illuminance based on the requirements

VII. CONCLUSION

In this paper, a neural network controlled illuminance approach of a LED network has been presented .The effectiveness of this approach in handling the non linearity characteristics of networked LED system has been shown. The proposed approach has the advantages of low cost, ease of installation, accurate and fast response. Hence this approach proves to be a promising one in future for achieving energy efficient lighting system. Experimental results have been shown supporting the configuration of the neural network and its efficient functionality.

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