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Fuzzy Neural Networks with Interval Set for Emotional Color Reasoning

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Abstract: The interest of emotional lighting with the LED is increasing. To control the emotional lighting a fuzzy neural network for emotional colors reasoning is designed. This studty proposes a fuzzy neural network with interval sets for emotional color reasoning. The mono image scale and the adjective image scale are used to extract the emotional colors in accordance with emotional languages. The uncertainty of emotional languages is expressed by membership functions and the fuzzy lookup table is made by matching the emotional colors. The consequence of fuzzy neural network is expressed by polynomial with interval set whose the parameters are learned by BP algorithm. The designed fuzzy neural network is evaluated with the data. The experiment result showed that emotional lighting system through the proposed fuzzy neural network can be controlled and adjusted in some situations through learning process with interval sets to handle emotional uncertainty. The proposed fuzzy neural network with interval sets can be applied to various fields with uncertainty.

Key words: Human emotion, emotional language, emotional reasoning, fuzzy neural network with interval sets, learning, membership functions

INTRODUCTION

Light Emitting Diode (LED) as environmentally-friendly energy sources has been developed and is being used in diverse fields of human society. LED emotional lighting relates to the lighting technology which can change the space atmosphere. Especially, the color and brightness suitable for person's psychological state or biorhythms are applied to emotional control. The space representation by LED lighting is an important factor affecting the human psychology. The emotional lighting has been used to increase the sales revenue by stimulating human emotions as it targets for special goals such as sales facilities, exhibition and so on (Shin *et al*., 2013; Lee and Suk, 2012). Many studies are also carrying out to identify external environmental factors so, that, they allow the emotional lighting control in diverse situations rather than the simple conventional emotional lighting (No, 2005; Baek *et al*., 2011).

Since, fuzzy set is introduced by Zadeh, many researchers have been studied and applied to fuzzy inference systems or fuzzy expert system (Jang *et al*., 1997). The study (Santhanam and Ephzibah, 2015) takes into account the Genetic Algorithm (GA) for feature selection and fuzzy logic for classification to diagnose heart disease. This research (Kaur *et al*., 2016) has discussed about customer's defaulter risk as well as credit risk using a fuzzy expert system which can categorized customer as defaulter and non-defaulter. Hybrid technologies in the area of Fuzzy Neural Networks (FNNs) have also been studied and applied (Jang *et al*., 1997; Park *et al*., 2013). The concept of a type-2 fuzzy set as an extension of fuzzy sets of type-1 is introduced by Zadeh (Mendel, 2001). Mendel (Zadeh, 1975) studied the theory of type-2 fuzzy logic systems. This fuzzy systems are also described in the form of fuzzy if-then rules but their premises and/or consequents are type-2 fuzzy sets and/or interval fuzzy sets. An interval type-2 fuzzy neural network comes as a result of interaction of interval fuzzy set and neural networks. Fuzzy sets to deal with uncertain information are key elements of the fuzzy model and the premise part as well as the consequence part can be applied to implement a wider range of fuzzy model. To establish emotional lighting control, it should handle the uncertainties inherent in emotional language.

In this study, we propose a fuzzy neural network with interval sets for reasoning emotional colors which change a color according to a situation. The emotional languages according to the situation with the temperature and concentration are selected through IRI adjective image

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scale. And emotional colors are chosen by contrasting to the IRI mono color image scale. The uncertainty of emotional languages is expressed by membership functions and the fuzzy lookup table representing the fuzzy rule is made by matching the emotional colors. The consequence of fuzzy neural network is expressed by polynomial with interval set. The parameters of the polynomials are learned by back-propagation algorithm. The designed fuzzy neural network is illustrated through the experiments.

MATERIALS AND METHODS

Emotional lighting: The emotional lighting is to provide a lighting environment similar to natural light according to the human emotion and refers to a lighting which can change the atmosphere by using the temperature and intensity of the color coming from the lighting device and applying it properly for the psychological state and biorhythms of people (No, 2005).

As the emotional language is to express linguistically the emotions that human feels, it means love, joy, hatred, fear, etc. Human can feel different emotions depending on the color and the efficiency improvement with respect to action in a particular color can be made. The emotional colors are classified into IRI mono color image scale as shown in Fig. 1 and IRI adjective image scale in Fig. 2 in which Lee Bok-Sin extracted the emotional elements through the color emotional study taking into consideration of the emotional structure of Korean in 1997 (Lee, 1997). Emotional lighting is displayed by extracting the emotional color according to the situation and comparing the extracted color with CIE color coordinate.

Fuzzy neural network with interval sets: Fuzzy neural networks 5 come from the hybrid techniques between fuzzy inference systems and neural networks. Fuzzy neural networks are represented by fuzzy “If-Then” rules while the parameters of the network are adjusted by Back Propagation (BP). Fuzzy neural networks have the ability of learning from the data sets from some environments. The overall topology of the fuzzy neural network with interval sets is illustrated in Fig. 3.

The structure of a fuzzy neural network with interval sets consists of fuzzy inference system represented by the mutual relationship between input variables in the premise part. In this, sense, the fuzzy rule of fuzzy neural network can be expressed as the following format:

$$R^j: \text{If } x_1 \text{ is } A_{1j} \text{ and } x_2 \text{ is } A_{2j} \text{ Then } y_j = W_j \quad (1)$$

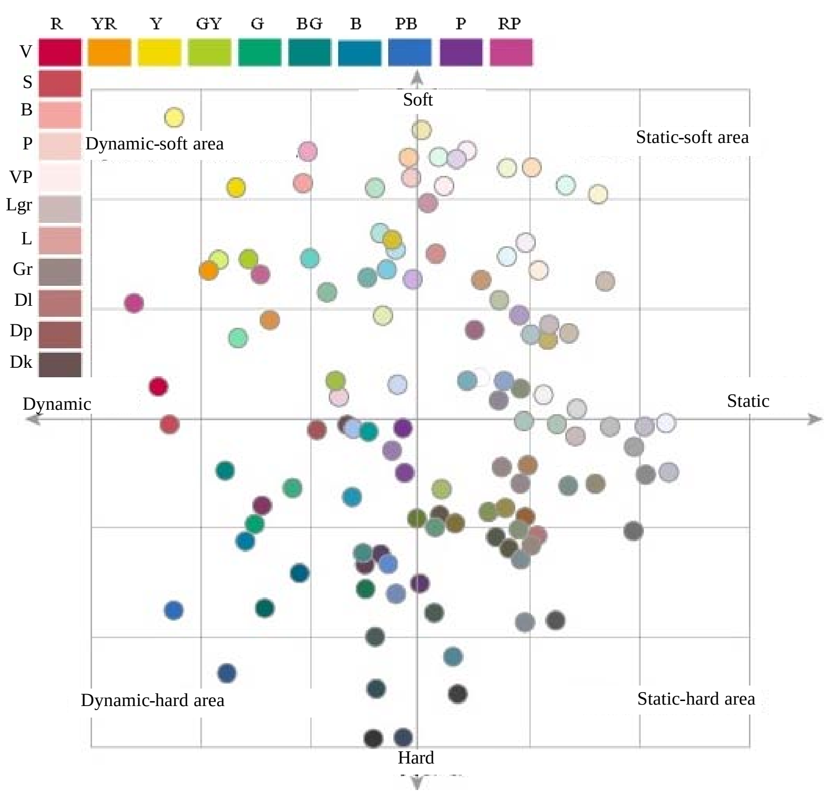

Fig. 1: Mono color image scale

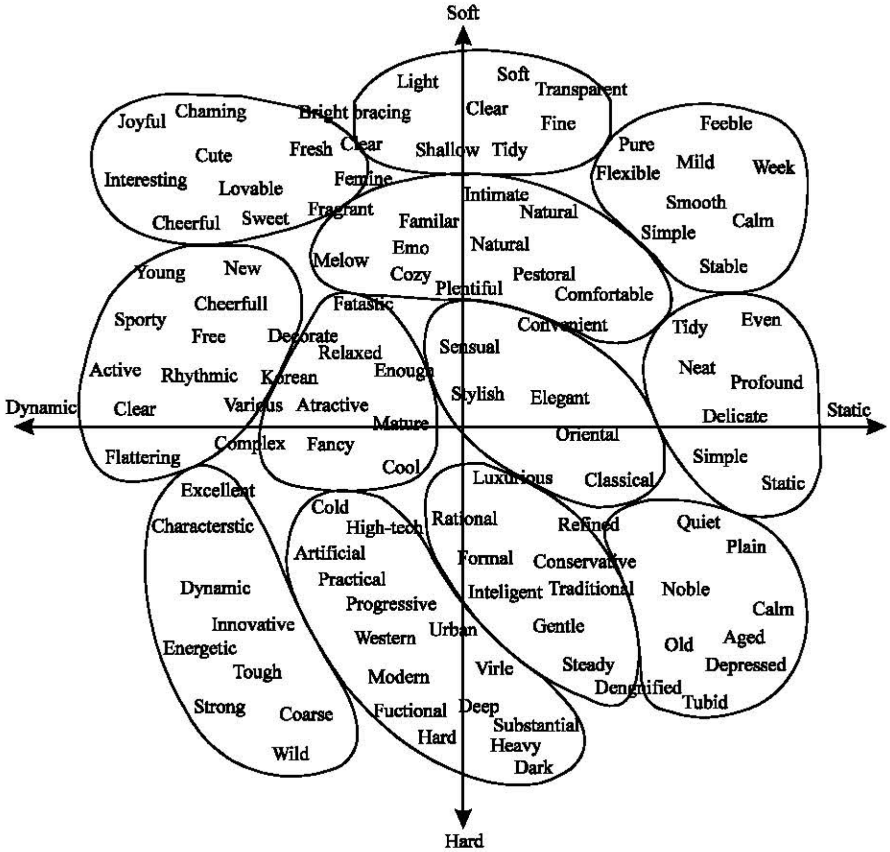

Fig. 2: Adjective image scale

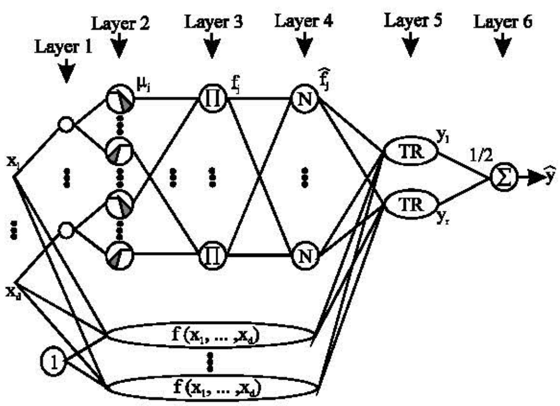

Fig. 3: The structure of a fuzzy neural network with interval sets

To be more specific, R_j is the j-th fuzzy rule, while A_{kj} denotes k, j-th membership function. $W_j = [W_j\text{-}S_{jl}, W_j\text{+}S_{jr}]$ is consequent parameters as the connecting weights. W_j and S_j are the center and the spread of W_j, respectively.

Mapping from input to inference output is determined by the fuzzy inferences. The output has the interval value due to the interval set. This leads to need a type-reduction scheme to obtain the final output. And final output is obtained by using Karnik-Mendel (KM) algorithm (Zadeh, 1975). The functionality of each layer is described as follows.

Layer 1: The nodes in this layer transfer the inputs to the individual inputs.

Layer 2: The nodes here are used to calculate the membership degrees of triangular membership function:

$$\mu_j = \text{triMF}(x;\ a,\ b,\ c) = \begin{cases} 0, & x < a \\ \dfrac{x\text{-}a}{b\text{-}a} & a \le x < b \\ \dfrac{c\text{-}x}{c\text{-}b} & b \le x < c \\ 0 & x \ge c \end{cases} \qquad (2)$$

Layer 3: The nodes in this layer compute the firing strength of each rule:

$$f_j = \mu_{1c}(x_1)\times,\cdots,\times\mu_{kc}(x_k) \qquad (3)$$

Layer 4: The nodes in this layer normalize the membership degrees for each input:

$$\hat{f}_j = \frac{f_j}{f_1+,\cdots,+f_n} \quad (4)$$

Layer 5: The nodes in this layer are used to conduct type-reduction. Note that left-most point y_l and right-most point y_r depend upon the values of f_j^r. Hence, using Karnik-Mendel (KM) algorithm (Zadeh, 1975) y_l and y_r can be expressed as follows:

$$y_l = \frac{\sum_{j=1}^{n}\hat{f}_j y_j^l}{\sum_{j=1}^{n}\hat{f}_j}, \; y_r = \frac{\sum_{j=1}^{n}\hat{f}_j y_j^r}{\sum_{j=1}^{n}\hat{f}_j} \quad (5)$$

Here, y_j^l and y_j^r are the left point and right point that affected by firing strength of each rule, respectively.

Layer 6: The nodes compute the outputs by taking the average of y_l and y_r:

$$\hat{y} = \frac{y_l+y_r}{2} \quad (6)$$

The parametric learning of fuzzy neural network with interval sets is realized by adjusting connections of the network and carrying out a back-propagation algorithm. The change amount of the connection weight can be obtained using the gradient descent method for minimizing the error:

$$E_p = \frac{1}{2}\left(y_p - \hat{y}_p\right)^2 \quad (7)$$

Where:

E_p = An Error reported for the p-th data
y_p = The p-th target output data
$\hat{y}_p$ = Stands for the p-th actual output of the model

As far as learning is concerned, the connections are changed (adjusted) in a standard fashion:

$$w_j(p+1) = w_j(p)+\Delta w_j \quad (8)$$

$$s_{jl}(p+1) = s_{jl}(p)+\Delta s_{jl} \quad (9)$$

$$s_{jr}(p+1) = s_{jr}(p)+\Delta s_{jr} \quad (10)$$

where, this update formula follows the gradient descent method, namely:

$$\Delta w_j = \eta\left(-\frac{\partial E_p}{\partial w_j}\right) \quad (11)$$

$$\Delta s_{jl} = \eta\left(-\frac{\partial E_p}{\partial s_{jl}}\right) \quad (12)$$

$$\Delta s_{jr} = \eta\left(-\frac{\partial E_p}{\partial s_{jr}}\right) \quad (13)$$

with η being a positive learning rate. Quite commonly to accelerate convergence, a momentum coefficient α is being added to the learning expression. Then, the complete update formula reads as follows:

$$\Delta w_j = 0.5\eta\left(y_p - \hat{y}_p\right)\hat{f}_j + \alpha\left(w_j(p) - w_j(p-1)\right) \quad (14)$$

$$\Delta s_{jl} = 0.5\eta\left(y_p - \hat{y}_p\right)\left(-\hat{f}_j\right) + \alpha\left(s_{jl}(p) - s_{jl}(p-1)\right) \quad (15)$$

$$\Delta s_{jr} = 0.5\eta\left(y_p - \hat{y}_p\right)\hat{f}_j + \alpha\left(s_{jr}(p) - s_{jr}(p-1)\right) \quad (16)$$

RESULTS AND DISCUSSION

Experimental studies: We first design the fuzzy rules of the fuzzy neural network according to the temperature and concentration for emotional lighting. And then the connections of the network are adjusted by BP algorithm. Regarding the membership function for temperature, the range of temperature is set to 17~25°C and the temperature interval is set to 4°C. The linguistic definition of concentration situation is divided into art/music section, language section, mathematics section and computer section. The initial color for each section was set by matching the mono color image scale and the adjective image scale. In the art/music section, orange colors were set when the temperature was low and yellow colors were set when the temperature was high. In the language section, the colors were set to yellow colors. In the mathematics and computer section were initially set by white colors when the temperature was low and cyan colors when the temperature was high. The IF-THEN rules of twenty are set through the membership function of Temperature (Tem.) and Concentration (Con.) as follows:

- R^1: if temp is very cold and con is art/music section then color is orange
- R^2: if temp is cold and con is art/music section then color is orange
- R^3: if temp is warm and con is art/music section then color is orange
- R^4: if temp is hot and con is art/music section then color is yellow
- R^5: if temp is very hot and con is art/music section then color is yellow

Table 1: Fuzzy lookup table

Tem/Con*	Art/Music	Langauge	Mathematics	Computer
Very cold	Orange†	Yellow$^{\nabla}$	White	White
Cold	Orange†	Yellow$^{\nabla}$	White	White
Warm	Orange†	Yellow$^{\nabla}$	Cyan‡	White
Hot	Yellow$^{\nabla}$	Yellow$^{\nabla}$	Cyan‡	Cyan‡
Very hot	Yellow$^{\nabla}$	Yellow$^{\nabla}$	Cyan‡	Cyan‡

*Tem/Con: Temperature/Concentration; % colors at initial state: †Orange, $^{\nabla}$Yellow, ‡Cyan, white

Table 2: Fuzzy lookup table after learning

Tem/Con*	Art/Music	Language	Mathematics	Computer
Very cold	Orange†	Yellow‡	Lovry$^{4)}$	White
Cold	SB Orange$^{1)\dagger}$	Yellow‡	D Cyan$^{5)\circ}$	lvory$^{4)}$
Warm	SB Orange$^{1)\dagger}$	Yellow‡	Cyan$^{\bullet}$	B Cyan$^{6)\bullet}$
Hot	O-Yellow$^{2)\nabla}$	Yellow‡	Cyan$^{\bullet}$	Br Cyan$^{7)\bullet}$
Very hot	D-Yellow$^{2)\nabla}$	Yellow‡	Cyan$^{\bullet}$	Cyan$^{\bullet}$

*Tem/Con: Temperature/Concentration; % change colors at final state: $^{1)\ \dagger}$ SB Orange: Slightly Brighter Orange; $^{2)}$ $^{\nabla}$O-yellow: Orange-yellow; $^{3)}$ ‡D-yellow: Dark yellow; $^{4)}$ Ivory; $^{5)}$ $^{\circ}$D Cyan: Dark Cyan; $^{6)}$ $^{\bullet}$B Cyan: Bright Cyan; $^{7)}$ $^{\bullet}$Br Cyan: Brighter Cyan

- R^{6}: if temp is very cold and con is language section then color is yellow
- R^{7}: if temp is cold and con is language section then color is yellow
- R^{8}: If temp is warm and con is language section then color is yellow
- R^{9}: If temp is hot and con is language section then color is yellow
- R^{10}: If temp is very hot and con is language section then color is yellow
- R^{11}: If temp is very cold and con is mathematics section then color is white
- R^{12}: If temp is cold and con is mathematics section then color is white
- R^{13}: If temp is warm and con is mathematics section then color is cyan
- R^{14} : If temp is hot and con is mathematics section then color is cyan
- R^{15}: If temp is very hot and con is mathematics section then color is cyan
- R^{16}: If temp is very cold and con is computer section then color is white
- R^{17} : if temp is cold and con is computer section then color is white
- R^{18}: If temp is warm and con is computer section then color is white
- R^{19}: If temp is hot and con is computer section then color is cyan
- R^{20}: If temp is very hot and con is computer section then color is cyan

Table 1 shows the fuzzy lookup table of the fuzzy neural network is generated through the IF-THEN rules for temperature and concentration. The distinction of colors by hard regions is distributed by four colors such as orange, yellow white cyan color through color-matching according to the temperature and concentration situations. In order to estimate and adjust the colors from the situation, we used a total of 100 data set from temperature and concentration situations. The fuzzy neural network with interval sets is trained and adjusted using the data. Table 2 shows the results of the colors after learning process for situation. Form the Table 2, we note that the colors obtained are changed and adjusted more smoothly according to the situation. In the arts and music section, as the temperature increased, the colors gradually changed from orange to yellow. In the language section there is little change after learning. In the mathematical and computer section, the colors changed from white to blue as the temperature increased, respectively. In particular, it can be seen that the colors at the boundaries of the different colors are changed to the surrounding colors in each situation.

CONCLUSION

In this study, we have designed fuzzy neural network with interval sets for emotional color reasoning on temperature and concentration situations. The colors for the emotional languages were selected and coordinated with the fuzzy rules of the fuzzy neural network using IRI adjective image scale and IRI mono color image scale. The fuzzy lookup table were designed and adjusted by learning the fuzzy rules of fuzzy neural network. The experiment result showed that emotional lighting system through the proposed fuzzy neural network can be controlled and adjusted in some situations through learning process with interval sets to handle emotional uncertainty. Therefore, the emotional reasoning using fuzzy neural network could have a significant emotional effect on human behavior.

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REFERENCES

Baek, C.H., S.O. Park and H.S. Kim, 2011. The analysis of emotion adjective for LED light colors by using kobayashi scale and IRI scale. J. Korean Inst. Illum. Electr. Installation Eng., 25: 1-13.

Jang, J.S.R., C.T. Sun and E. Mizutani, 1997. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. 1st Edn., Prentice Hall, Upper Saddle River, NJ., USA., ISBN: 0132610663.

Kaur, A., V. Madaan, P. Agrawal, R. Kaur and S.K. Singh, 2016. Fuzzy rule based expert system for evaluating defaulter risk in banking sector. Indian J. Sci. Technol., 9: 1-6.

Lee, B.S., 1997. The development of color image scale by using adjectives. J. Korean Soc. Des. Sci., 19: 17-18.

Lee, E. and H. Suk, 2012. The emotional response to lighting hue focusing on relaxation and attention. J. Korean Soc. Des. Sci., 25: 27-39.

Mendel, J.M., 2001. Uncertain Rule-Based Fuzzy Logic Systems: Introduction and New Directions. Prentice Hall, Upper Saddle River, New Jersey, USA., pp: 265-272.

No, S.C., 2005. Emotional lighting system. Korean Soc. Des. Sci., 3: 86-87.

Park, K.J., Y.K. Kim, B.G. Kim and G.C. Hoang, 2013. Design of optimized pattern recognizer by means of fuzzy neural networks based on individual input space. J. Inst. Internet Broadcast. Commun., 13: 181-189.

Santhanam, T. and E.P. Ephzibah, 2015. Heart disease prediction using hybrid genetic fuzzy model. Indian J. Sci. Technol., 8: 797-803.

Shin, J.Y., S. Y. Chun and C.S. Lee, 2013. Analysis of the effect on attention and relaxation level by correlated color temperature and illuminance of LED lighting using EEG signal. J. Korean Inst. Illum. Electr. Installation Eng., 27: 9-17.

Zadeh, L.A., 1975. The concept of a linguistic variable and its application to approximate reasoning-I. Inform. Sci., 8: 199-249.