TELKOMNIKA, Vol.16, No.3, June 2018, pp. 1317~1323
ISSN: 1693-6930, accredited **A** by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v16i3.7437

Artificial Neural Network Model for Affective Environmental Control System in Food SMEs

Mirwan Ushada*[1], Tsuyoshi Okayama[2], Atris Suyantohadi[3]
[1,3]Universitas Gadjah Mada, Faculty of Agricultural Technology, Department of Agro-industrial Technology, Jl. Flora No.1 Bulaksumur, 55281 Yogyakarta Telp/Fax: +62-274-551219
[2]Ibaraki University, College of Agriculture, Department of Regional Environmental Sciences, 3-21-1, Chuuo, Inashiki, Ibaraki, 300-0393, Telp/Fax: +81-29-888-9592
*Corresponding Author e-mail: mirwan_ushada@ugm.ac.id

Abstract

This paper presents an affective environmental control system for Small and Medium-sized Enterprises (SMEs). The system is proposed as a technology innovation in appropriate information technology. It is defined that workplace environment set points could be controlled using worker workload. The research objectives are: 1) To design an affective environmental control model for SME; 2) To develop an Artificial Neural Network (ANN) model for predicting affective environment set points. The system consisted of 4 sub-systems as measurement, assessment, control and decision. An ANN model is developed for sub-systems of control. Training and validation data are acquired from 4 (four) samples of SME in Yogyakarta Special Region, Indonesia. The model has been developed successfully to predict temperature and light intensity set points using back-propagation supervised learning method. The research results indicated the satisfied performance of ANN with minimum error. ANN model indicated the closeness of R^2 value between training and validation data. The research results could be applied to support the worker productivity in food SMEs by providing a comfort workplace environment and optimum worker workload.

Keywords: *artificial neural network; heart rate; light intensity set points; profile of mood states; temperature set points*

1. Introduction

Sustainability of Indonesian industrial development is based on the economic activity of Small and Medium-sized Enterprises (SMEs). Most of Indonesian SME is focusing on food production system since food security and sovereignity is a challenging issue. Sustainability-oriented innovations is a critical aspect for the development of SMEs [1]. Costa et al [2] suggested that a collaborative information technology model and approach could be an important solution and applicable for developing a sustainable food production system in Indonesian SMEs.

The unique characteristic of Food SMEs is workplace environment in production system. The environment is specifically controlled for value-added process as freezing, doughing, boiling, baking, frying and steaming. However, SME workplace environment based on worker workload are left uncontrolled since the food production process required the specific environment which most of them was not fit to the worker's body. Worker workload could be defined as human body and limits to maximize production output without physically harming. Up to date, maintaining worker productivity in a limited comfort of workplace environment is a challenging problem for food production system. An appropriate information technology could be applied effectively to provide a comfort environment and optimum worker workload by workplace environment control [3]. The comfort environment is expected to optimize the worker workload.

Environmental control system could be a solution to provide a comfort workplace environment for worker in food SMEs. However, most of the systems were developed for the complex production systems and nor appropriate information technology. For example, an innovative environmental control was developed using speaking plant/fruit approach for greenhouses and plant factories [4]. They used plant responses to control the optimal

Received September 29, 2017; Revised February 13, 2018; Accepted March 2, 2018

environment [4]. Takahashi et al. [5] have developed a local temperature control model in a confined space. In this model, Takahashi et al. [5] did not incorporate the worker workload.

The term of affective design is required to characterize the worker workload in the environmental control system. The goal of affective design is extracting verbal and non-verbal parameters of human satisfaction [6]. Affective environment is defined as the workplace environmental effect to the worker responsiveness and/or workload in a production system. The worker workload are measurable using verbal and non-verbal parameters. In the previous research, Ushada and Murase [7] have used affective design to accomodate the human satisfaction in an intelligent quality control of bio-product. Artificial Neural Network (ANN) model was used due to its capability to define the complex affective design and human satisfaction [7]. ANN has been applied to model the human-related research as motion characteristics by classification of action characteristics [8], and human re-identifcation [9]

Some of the research over the past decades have defined that relationship between lighting and comfortable ambient temperature to human performance are essential for developing environmental control system (Lindsay [10], Luckiesh and Moss [11], and Josef et al. [12]). The others research have defined the relationship betweeen environment and affective states of worker. Kinnafick and ThØgersen-Ntoumani [13] have investigated the effects of urban-natural environment and level activity of walking and sitting. Gaspar et al. [14] have established relations between the user preference and acoustic engineering parameters in work system of car. Guenter et al. [15] have investigated information exchange delay from the perspective of affective events in workplace. However, these research does not link relationship between worker workload and affective environment in food SMEs.

This paper proposes an affective environmental control system a solution to provide a comfort workplace environment for worker in SMEs. The system is defined that temperature and light set points could be controlled using worker heart rate and mood. The research objectives are: 1) To design an affective environmental control model for small and medium-sized enterprises; 2) To develop an artificial neural network model for predicting affective environment set points. The research advantage is to increase human resource productivity by providing an affective environment-based production system.

2. Research Method

2.1. Affective environmental control systems

Figure 1 describes the design of affective environmental control system. The system consisted of 4 sub-systems as: 1) Measurement; 2) Assessment; 3) Control; 4) Decision. In sub-system 1, worker workload is measured using verbal and non verbal parameters. The verbal parameter is measurable using score of total mood disturbance and non verbal by heart rate. Heart rate is measured using wrist pulsemeter. Score of total mood disturbance is determined using questionnaire of Profile of Mood States/POMS [16]. The workplace environment is measured using data logger/sensor. Manager recordes the data and stored it in a simple data base. In sub-system 2, manager could use the data base in sub-systems 1 as input for a performance sensor [17]. If it generates the normal status, then the set point is decided. If it generate less and over status, then it gave feedback to the manager. In sub-system 3, an ANN model is developed. The inputs are from sub-systems 1. The outputs are the environment set points. Sub-system 4 is basically hardware to execute the output from other sub-systems. Air conditioner and lighting systems are utilized. The performance set points (Sub-systems 1) and environment set points (Sub-systems 3) are converted to signals. These signals could be used as inputs to a remote control to execute the affective environment for worker in SME. If it is dissatisfied, the signal give feedback to the sub-system 1 to repeat the process.

2.2. Artificial neural network model

An ANN model was developed to support sub-systems 3, as shown in Figure 2. The inputs of ANN were score of total mood disturbance, heart rate, workplace temperature after working, workplace relative humidity before and after working, and light intensity after working. The outputs were temperature and light intensity set points. Temperature was selected for the output since it is easy to control using air conditioner and fan in SME production system. Light intensity was selected for the output since it is controllable using commercial controller. ANN used feed-forward architecture and supervised backpropagation learning. The ANN software was developed using Macro-based Microsoft Visual Basic Application for Microsoft Excel [18]. Backpropagation ANN was commonly used in agricultural-based industry [19] and human perception-related research [20]. Training and validation data were acquired from 4 (four) samples of SME in Yogyakarta Special Region, Indonesia.

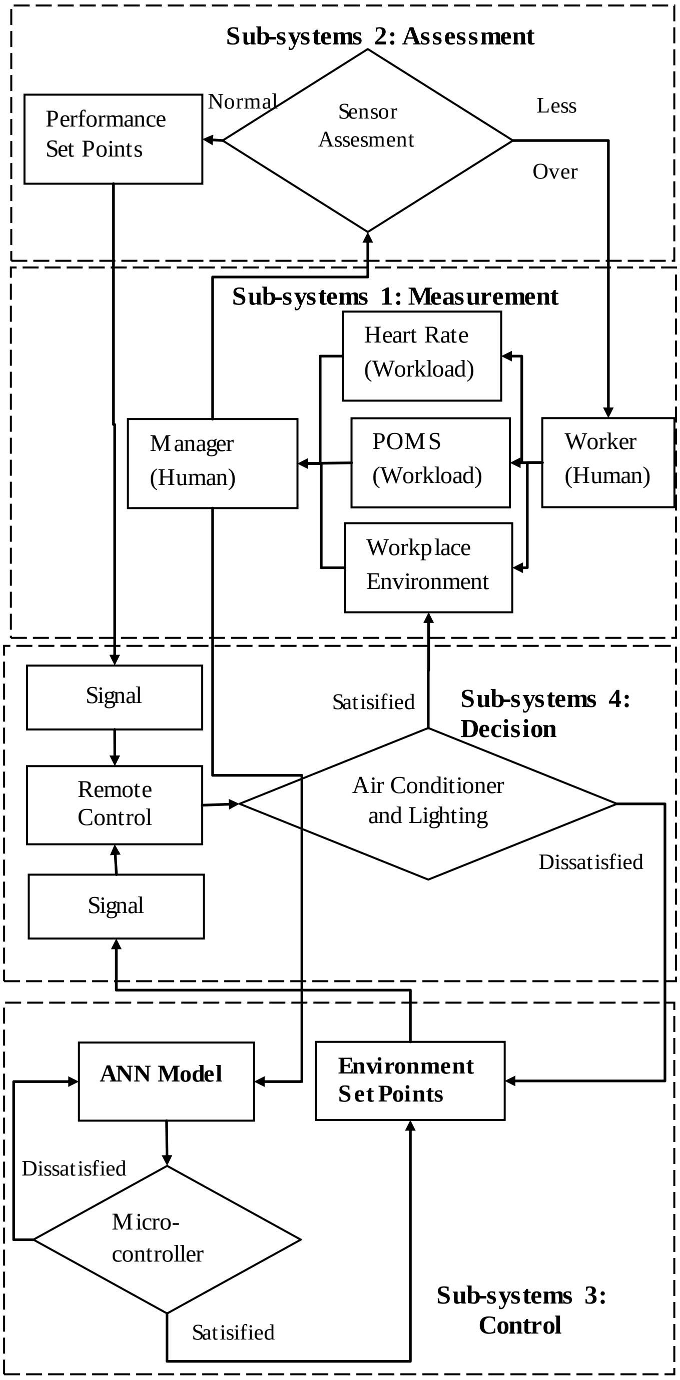


Figure 1. Design of affective environmental control system for SMEs

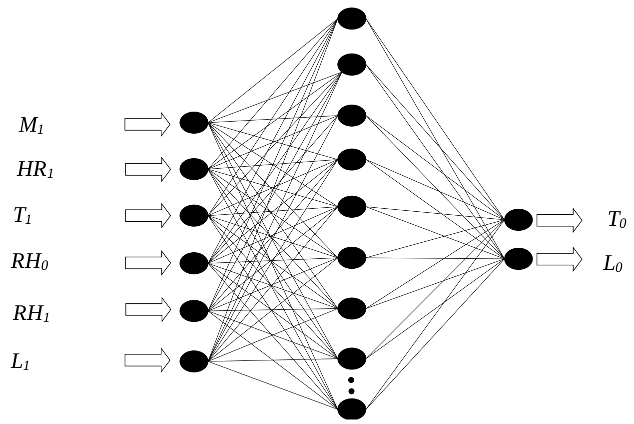


Figure 2. ANN model for prediciting environment set points

Notes:
M_1 = Score of total mood disturbance
HR_1 = Heart rate (Pulse per minutes)
T_1 = Workplace temperature after working (^{0}C)
RH_0 = Workplace relative humidity before working (%)
RH_1 = Workplace relative humidity after working (%)
L_1 = Workplace light intensity after working (Lux)
T_0 = Temperature set points (^{0}C)
L_0 = Light intensity set points (Lux)

3. Results and Discussion

The data of measurement sub-system were recapitulated in to 286 data set. The 272 data set were used in training ANN model. The remains were used in validation data. Table 1 described the sensitivity analysis of ANN model. It was based on output error by trial and error basis. Based on the minimum Root Mean Square Error (RMSE) of training and validation, twelve neurons in the hidden layer were selected. The architecture of ANN consisted of six neurons in the input layer, twelve neurons in the hidden layer and two neuron in the output layer (6-12-2).

Table 1. Sensitivity analysis of ANN model

No	Hidden Neuron	Iteration	RMSE Training	RMSE Validation
1.	6	10000	0.136	0.131
2.	8	10000	0.114	0.113
3.	10	10000	0.083	0.073
4.	10	20000	0.082	0.079
5.	12	10000	0.088	0.090
6.	12	20000	0.075*)	0.073*)

*)Minimum error

The training process converged approximately 20000 iterations. Learning coefficient of 0.1 and momentum of 0.9 were determined, as shown in Fig. 3. The RMSE of training and validation data were 0.075 and 0.073 respectively. These error are satisfied based on comparison to Sugiono et al. [19] using backpropagation neural network and genetic algorithm. The complexity data for affective environmental control system is less than the model of dairy cattle facilities [19].

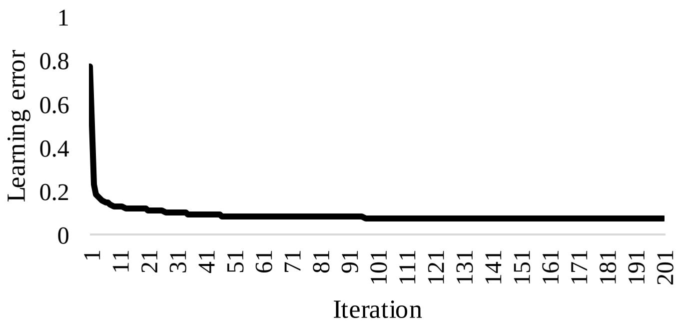
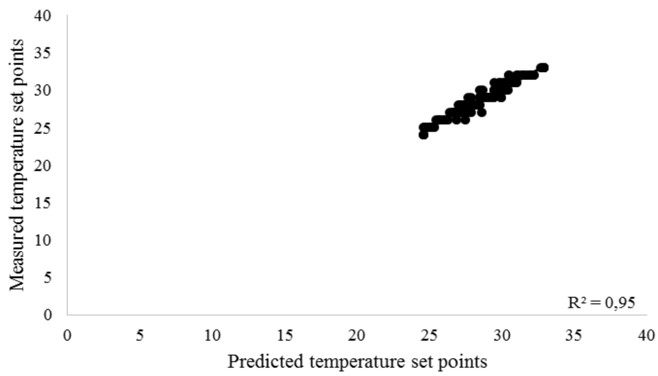
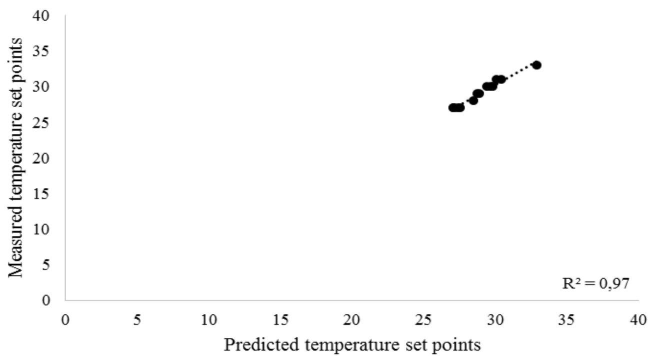


Figure 3. Learning iteration of ANN model

Ushada et al. [7] and [17] suggested that comparison for coefficient of determination (R^2) between predicted and measured parameters is essential to evaluate the performance of ANN model. Figures 4a and 4b indicate the comparison of R^2 value between predicted and measured temperature set points. R^2 value for training and validation data were 0.95 and 0.97, respectively. Figures 5a and 5b indicate the comparison of R^2 value between predicted and measured light intensity set points were 0.99, respectively. The validation results of the model confirmed Liping et al. [20] that predicting accuracy of ANN model is better than 90% according to the experiment. ANN model were tested successfully predicted temperature and light intensity set points using back-propagation supervised learning method. ANN model is ready to use to support affective environment control in food production systems of SMEs.



(a)



(b)

Figure 4. Comparison of R^2 value for temperature set points; (a) Training; (b) Validation data

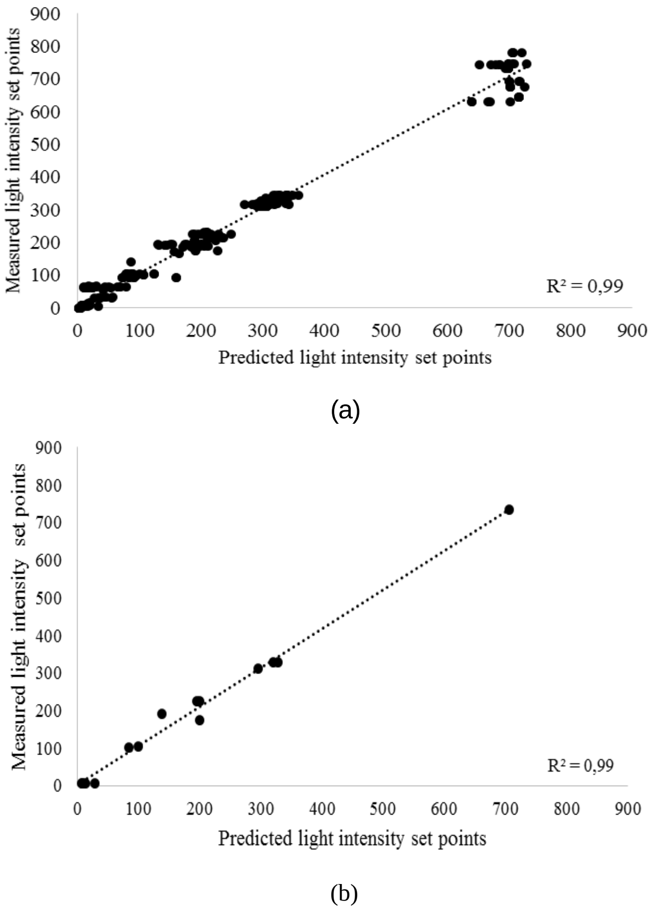


Figure 5. Comparison of R^2 value for light intensity set points; (a) Training; (b) Validation data

4. Conclusion

This paper proposed an affective environmental control system for food small and medium-sized enterprises. It consisted of 4 sub-systems: measurement, assessment, control and decision. An ANN model has been developed successfully to predict temperature and light intensity set points using back-propagation supervised learning method. The research results indicated the satisfied performance of ANN with the minimum error of 0.075 for training and 0.073 for validation data. ANN model indicated the closeness of R^2 value of 0.95 and 0.97 between training and validation for temperature set points data, respectively. Besides, ANN model indicated the closeness of R^2 value of 0.99 between training and validation for light intensity set points data, respectively. It can be concluded that temperature and light intensity set points in SMEs could be controlled using worker workload. The research results could be applied effectively to increase human resource productivity in food SMEs by providing a comfort workplace environment and optimum worker workload.

Acknowledgment

Authors wishing to acknowledge financial support from Ministry of Research, Technology and Higher Education of the Republic of Indonesia by 2016-2017 Research Grants of International Collaboration Competitive Research Grant for International Publication-Universitas Gadjah Mada ‘Penelitian Kerjasama Luar Negeri dan Publikasi Internasional Tahun 2016-2017”: 2016 (No: 015/SP2H/LT/DRPM/II/2016 and 1037/UN1-P.III/LT/DIT-LIT/2016); 2017 (No: SP DIPA-042.06.1.401516/2017 and No: 2273/UN1.P.III/DIT-LIT/LT/2017).

References

[1] Klewitz J, Hansen EG. Sustainability-oriented Innovation of SMEs: A Systematic Review. *J. Clean. Prod.* 2014; 65: 57-75.
[2] Costa E, Soares AL, De Sousa JP. Information, Knowledge and Collaboration Management in The Internationalisation of SMEs: A Systematic Literature Review. *Int. J. Inform. Manage.* 2016; 36: 557-569.
[3] Park J. Evaluating a Mobile Data-collection System for Production Information in SMEs. *Comp. Ind.* 2015; 68: 53-64.
[4] Morimoto T, Hashimoto Y. Speaking Plant/Fruit Approach for Greenhouses and Plant Factories. *Environ. Control Biol.* 2009; 47 (2): 55-72.
[5] Takahashi N, Murase H and Murakami K. Local Temperature Control within a Confined Space by using a Neural Network Model. *J. Soc. Hi. Tech. Agric.* 2002; 14(3): 131-135.
[6] Kwong CK, Huimin J. AI-based Methodology of Integrating Affective Design, Engineering, and Marketing for Defining Design Specification of New Products. *Eng. App. Artif. Intel.* 2016; 47: 49-60.
[7] Ushada M, Murase H. An Intelligent Watchdog Model for Quality Control of An Affective Bio-greening Material. *Environ. Control Biol.* 2009; 47(3): 145-156.
[8] Liang F, Zhang Z, Li X, Long Y and Tong Z. Action Recognition of Human's Lower Limbs Based on a Human Joint. *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*. 2016; 14(3): 1192-1202.
[9] Low KB, Sheikh UU. HumanRe-identification wuth Global and Local Siamese Convolution Neural Network. *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*. 2017; 15(2): 726-732.
[10] Lindsay DC. Manufactured Weather An Aid to Modern Industry, Health, and Efficiency, *Indust. Eng. Chem.* 1929; 21(5): 502–505
[11] Josef B, Ernst S, Ancel K. A Work Test for Quantitative Study of Visual Performance and Fatigue. *J. App. Psycho.* 1947; 31(5): 519-532.
[12] Luckiesh M, Moss FK. Light, Lighting and Seeing. *The Australasian J. Outometry*. 1939; 22(2): 57-68.
[13] Kinnafick FE, ThØgersen-Ntoumani C. The Effect of the Physical Environment and Levels of Activity on Affective States. *J. Environ. Psychol.* 2014; 38: 241-251.
[14] Gaspar J, Fontul M, Henriques E, Ribeiro A, Silva A and Valverde, N. Psychoacoustics of In-car Switch Buttons: From Feelings to Engineering Parameters. *App. Acoust.* 2016; 110: 280-296.
[15] Guenter H, Hetty van Emmerik IJ, Schreurs, B. The Negative Effects of Delays in Information Exchange: Looking at Workplace Relationships from an Affective Events Perspective. *J. Clean. Prod.* 2014; 65: 57-75.
[16] McNair DM, Lorr M, Droppleman LF. Manual for the profile of mood states (Rev. ed.). San Diego, CA: Educational and Industrial Testing Service, 1992
[17] Ushada M, Okayama T, Murase H. Development of Kansei Engineering-based Watchdog Model to Assess Worker Capacity in Indonesian Small-medium Food Industry. *Eng. Agric., Environ Food*, 2015; 8: 241-250.
[18] Okayama T. Neural Network Macro. Microsoft Visual Basic Application for Microsoft Excel. Microsoft Inc Japan, 2002
[19] Sugiono S, Soenoko R, Lukodono RP. A Designing Dairy Cattle Facilties Based On Statics/Dynamic Zoometry by Using Artificial Intelligence. *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*. 2017; 15(1): 399-406.
[20] Liping L, Zhigang L, Sunjisheng, Liangna. Prediction and Realization of DO in Sewage Treatment Based on Machine Vision and BP Neural Network. *TELKOMNIKA (Telecommunication, Computing, Electronics and Control*). 2014;12(4): 890-896.