Building Simulation

*Seventh International IBPSA Conference*
**Rio de Janeiro, Brazil**
**August 13-15, 2001**

# Knowledge Management for comfortableness and the energy saving of building management

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## ABSTRACT

This paper proposed two simulation methods of the "Cooperation control ".
The Cooperation control is defined the optimize connecting control in the HVAC, artificial lighting and day-lighting combined with venetian blind control.
The first method is RBFN(Radial Basis Function Networks)[1] that is a kind of Neural Networks. The method is adopted for learning the data of the "Expert" contorol value. The method makes the modl.
The second is SOM (Self-organizing Maps) [2] that is another Neural Networks, too. SOM is one method of the Data Mining. The method is adopted for classification data that is made by RBFN. The rules of Cooperation control are made by classifying result. There is the IF-THEN rule as an example of the rule.
Both methods could provide the Cooperation control.

## INTRODUCTION

Building management systems is generally operated for the purpose of making building management system realize the optimize comfortableness and energy saving, it is necessary to control each subsystem in cooperation with others.
This study describes the cooperatiive control utilizing Knowledge Management. The target systems of controls are HVAC, artificial lighting and day-lighting combined with venetian blind control. Comfortableness of the occupied area in perimeter zone is not attained only by the conventional room temperature control because of the radiation from window surface. The loss of energy often takes place among zones due to mixing when cooling mode operation and heating mode operation interfaces as it happens between the interior zone and perimeter zone in winter. The view environment is sacrificed when venetian venetian blind is always closed in order to protect the perimeter space from direct solar inoslation. This proposal could hardly find out useful information, standards or design manual for optimize operation of the Cooperation control. The present paper refers to the classification phase of the knowledge data before completing rule base thereafter in order to make use of it for cooperation control.

## PROPOSED METHODOLOGY

(1) The Cooperation control

The details of the Cooperation control are as follows.
-To optimize control in the VAV (Variable Air Volume), artificial lighting and day lighting combined with venetian blind control.
-To control in consideration of energy saving
-To control in consideration of the optimize comfortableness in the view environmen and heat environment.

The following controls are realized by the above restriction.
- To decide condition of the venetian blind (Up-Down, the angle of the slat) based on the information related to day-lighting.
-To control dimmer for artificial lighting for making the account point, the desk of value.
-To control the opening value of VAV damper in consideration of artificial lighting, day lighting and the number of residents.

(2) The “Expert“

The “Expert“ is defined the person who has the experience knowledge how to control HVAC, artificial lighting and day lighting combined with venetian blind control. The aim of authers is to establish control rules the expert‘s judgement.

(3) Neural Networks

Neural Networks is an information processing method imitated the human brain and nerve system. The characteristic is as follows.

*The pattern recognition*
-To extract the meaningful information from the pattern information including noises.

*The parallel distributed processing*
-To process a great deal of information in real-time.
-To refer to the memory information at high speed.

*The adaptation/The learning/The generalization*
-To adapt to the condition that have been given.
-To learn the condition that have been given for improving reappear-ability.
To copes with the strange situation.

(4) Knowledge Management and Data Mining

The component of the Knowledge Management includes followings.
-To develop the knowledge property.
-To share the knowledge property.
-To create the knowledge.
The Data Mining is kind of the Knowledge Management. The Data Mining resembles a statistical method but differs in the purpose. The statistical method applies from data pre-processed such as excluding an extraordinary data on the hypothesise. On the other hand, the Data Mining deals with all data, finds a concealed law in the data.
The Data Mining is generally applied to mail-order business such as customer segmentation and customer purchase pattern analysis; retail trace such as shopping & basket analysis, merchandising effect measurement and laying-out change; maker & wholesale businesses such as optimizing of a delivery route, development of a new product and patent analysis; Finance such as portfolio management; Insurance such as detection a fraud; and Industry such as quality control. In this study the Data Mining method has been applied to construct the rule base for cooperation control including HVAC, artificial lighting and day-lighting that means venetian venetian blind control. It should be kept in mind that this Cooperation co could not be solved with usual statistical classification method. When calculation the statistical method, it takes enormous time compared with the Data Mining.

(5) RBFN

The RBFN(Radial Basis Function Networks)[1] simulate model. RBFN is a kind of the algorithms of the neural network.

*The characteristic of RBFN*
A reason to adopt RBF network for this modeling is as follows.
-The model is non-liner configuration . So it can be built easily to apply RBF network.
-The plan of authers is to learn by the bit data at first, then learn additionally with data collected at different opportunity. The RBF network can handle addtional learning more effectively in high precision.

*The structure of RBFN*
Radial Basis Function is a special class of functions. This characteristic feature is that their response decreases (or increases) monotonically with the distance from the central point. The central point, the distance, and the precise shape of the Radial Basis Function on are parameters of the model, all fixed if it is linear.
A typical Radial Basis Function is described the Gaussian Formula (1).

$$h(x)=\exp\left(-\frac{(x-c)^2}{r^2}\right) \qquad (1)$$

C is the center c and r is radius, Fig. 01 illustrates the Gaussian. RBF with center c=0 and radius r=1.

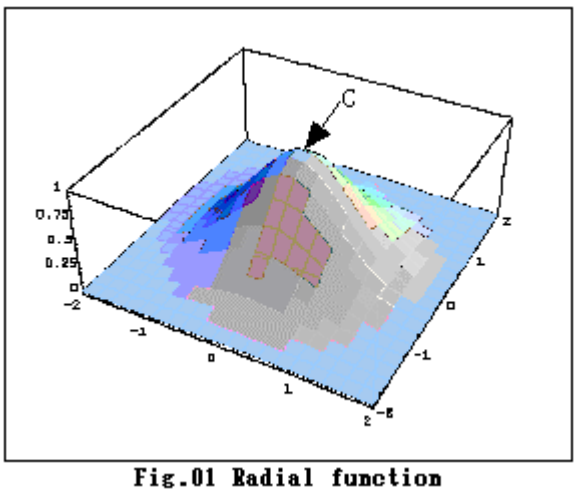

Fig.01 Radial function

The Gaussian monotonically decreases with distance from the center. In contract, a multiquadric RBF in the case of scalar input described Formula (2).

$$h(x)=\frac{\sqrt{r^2+(x-c)^2}}{r} \quad (2)$$

The value is monotonically increases with distance from the center (see Fig. 01). Gaussian type RBF are local (give a significant response only in a neighborhood near the center) and are more commonly used than multiquadric type RBF that have a global response. They are also more biologically plausible because their response is finite.

In principle, they could be employed in any sort of model, linear or nonlinear, and any sort of network single-layer or multi-layer. However, RBFN have traditionally been associated with the Radial Basis Function with a single-layer network such as shown in Fig. 02.

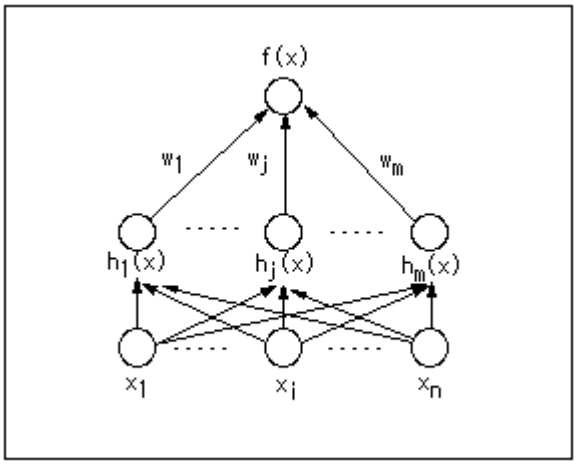


**Fig.02 Radial basis function network**

Fig. 02. is the traditional RBFN. Each of n components of the input vector x feeds forward on m basis functions whose output are linearly combined with weights {wj}m into the network output f(x).

An RBFN is nonlinear if the basis function can move or change size or if there is more than one hidden layer. Here it focuses on single-layer networks with functions, which are fixed in position and size. It uses nonlinear optimization but only for the regularization parameters in ridge regression and the optimize subset of basis functions in forward selection. It also avoids the kind of expensive nonlinear gradient descent algorithms (such as the conjugate gradient and variable metric methods) that are employed in explicitly nonlinear networks. Keeping one foot firmly planted in the world of linear algebra makes analysis easier and computations quicker.

*The learning of RBFN*

A way of learning RBFN is explained. The purpose of the learning is to get the optimize output value in the output layer of Fig. 02. An output value is decided at the amount of the product between the output value and the weight with the Gaussian function. An output value with Gaussian function is decided by the input data and the input parameter. The remainder is to decide weight. RBFN decides weight with the method of Minimum Square. The method of Minimum Square is to find weight in case to minimum the square of the teacher data and the error of the actual output. The input data sets multidimensional data.

-$w_j$; The combination coefficient between the middle layer and the output layer
-$x_j$; Input data
-$h_j$; The output of the middle layer
-$f(x_i)$; The output of the output layer
-$t_i$; The teacher data
-i; The number of the data
-j; The number of the middle layers
i=1,….,p. j=1,….,m.
The capital shows a vector.

The output of the middle layer and the output layer is as follows.

$$h_j(x_j)=\exp\left(-\frac{(x_j-c_j)^2}{r^2}\right) \quad (3)$$

$$f(x)=\sum_{j=1}^{m} w_j h_j(x_j) \quad (4)$$

The *SSE(sum-squared-error)* of $f(x_i)$ to the teacher data is as follows.

To minimize *SSE*, is a purpose of the learning. The square error, COST is used to keep balance of the

$$SSE=\sum_{j=1}^{p} (t_i-f(x_i))^2 \quad (5)$$

leaning weight.

λ;parameter

$$Cost=\sum_{i=1}^{p} (t_i-f(x_i))^2+\sum_{j=1}^{m} \lambda_j w_j^2 \quad (6)$$

The weight when Formula (6) minimized searches.

*The algorithm of RBFN*

Step0
The initial setting of the network.
Step1
Inputs a central point with Gaussian function.

Step2
Calculate h(x)
Step3
Find weight.
Step4
Calculate f(x) output.
Step5
Calculate *SSE Cost*.
If the result is bad, returns to Step 0.

(6) SOM

SOM (Self-organizing Maps) [2] is classification method. SOM is a kind of the Data Mining. The algorithm of SOM is modeling of self-organization imitated brain mapping is formed. SOM and a tool of visualization that permits to follow
The times on that kind of classification give us a way to control it. According to it, the way of the brain information processing is simple formula (7).

$$m_i(t+1)=m_i(t)+h_{ci}(t)[x(t)-m_i(t)] \quad (7)$$

This formula means following thing.
When the information processing ability is $m_i(t)$ in time t, the cell learns the input signal. The cell has the information processing ability mi (t+1), which is close to the input signal in the next time. This t (=0,1,2,…) is an integer(Separation time coordinate), $h_{ci}(t)$ is a neighborhood function including the learning rate coefficient. It is understood that SOM is the network of 2 layers from Formula (7) and Fig. 03.

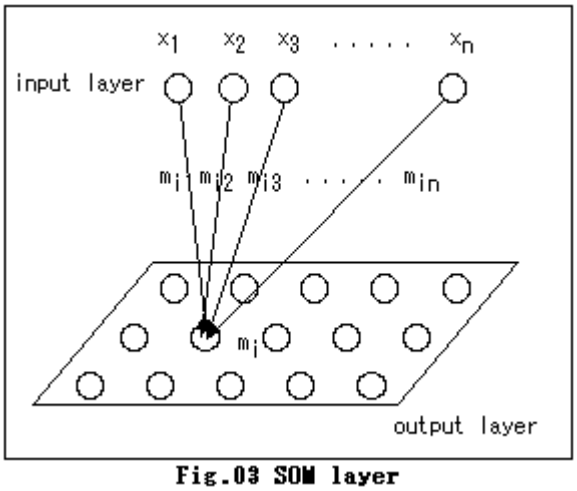

**Fig.03 SOM layer**

The first layer is the input layer x(t) of the n dimension. The second layer is arranged in two dimensions to catch the output visually. The vector that they compete with each other in the second layer is shown in the reference vector $m_i(t)$. It has the element of the n individual in accordance with the dimension of the input layer.

Learning is done like followings. The input vector x(t) searches the node i which is smallest Euclidean distance $|x-m_i|$. The reference vector is decided by this a winner unit.

## AREA of APPLICATION

In order to realize a comfortable environmental condition near the perimeter zone, it is necessary to be able to look out over outside. However, when releasing all venetian blind, the brightness of the window surface is too
high and causes the cooling load .
During the daytime direct insolation through the window is too strong that it is necessary to control day-lighting and artificial lighting in harmonious mode in order to keep comfortable visual environment. The basic principle for comfortable environment is to keep balance of illuminance between perimeter zone and interior zone.

An example of situation where the rule-based compound control is requested is thermal and visual environment of the perimeter zone near the window, that is, compound HVAC and lighting control using the venetian venetian blind control. Details are as follows and refer Fig. 04 and Fig. 05.

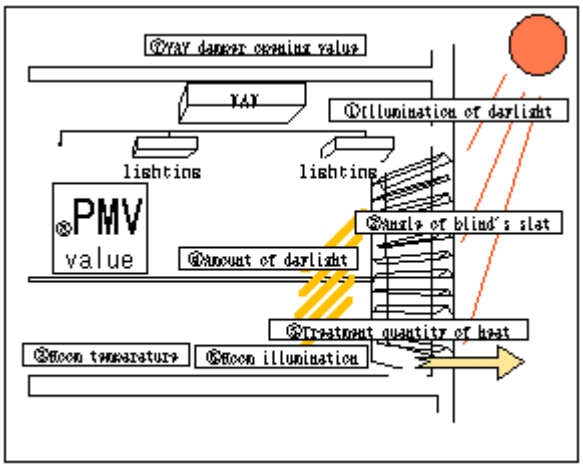

**Fig.04 Perimeter Zone Function**

1:I*lluminance of daylight*
The value of the measurement is adopted.
The unit is (lx).

2:*Angle of venetian blind's slat*
The unit is ( ° ).

3:*Room illuminance*
The value of the measurement is adopted.
The average data with 14 pieces of illumination at the room (about 800m2) is adopted(see Fig. 05).
The unit is (lx).

4:*Amount of daylight*
Adopted the following as the way of calculation.
Amount of daylight =
Illuminance of daylight[kJ/m2h]*
The sunlight shelter coefficient*
The window area[m2].
The unit is (kj/m2h).

5:*Treatment quantity of heat*
Adopted the following as the way of calculation.
Treatment quantity of heat=
Exhaust wind quantity *
(Exhaust air temperature - the room temperature)
The unit is (kj/m2h).

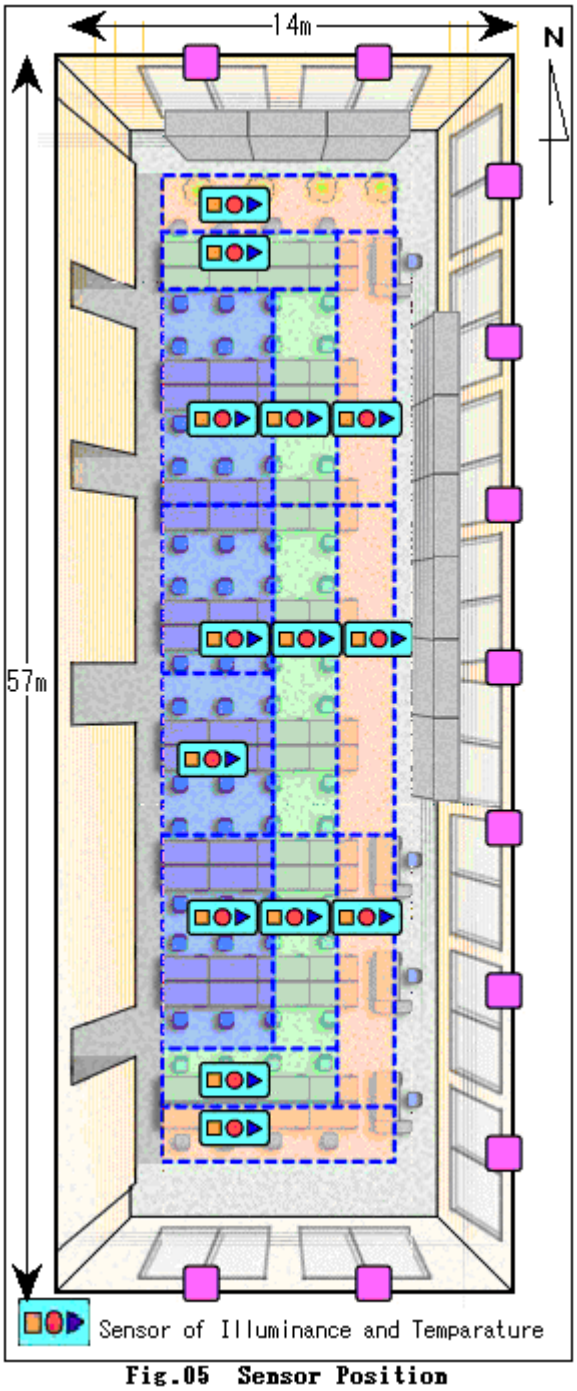


**Fig.05 Sensor Position**

6:*Room temparature*
The value of the measurement is adopted.
The average data with 14 pieces of temparature at the room (about 800m2) is adopted(see Fig. 05).
The unit is ( ).

7:*VAV Damper openong value*
The value of the measurement is adopted.
The unit is (%).

8:*The output is PMV value*
The PMV (Predicted Mean Vote) value is calculated by Fanger formula[3].

## SIMULATION

The RBFN described in the former chapter is used as the tool of simulation. The teach data is the PMV (Predicted Mean Vote) value which Fanger is proposing. The PMV is calculated with formula [3]. Input data is values, that is illuminance of daylight, slat angle of the venetian blind, room illuminance The output is PMV value (see. Table1 Fig. 04 and Fig. 05 and Fig. 06).

**Table.01 Simulation Data**

| | |
|---|---|
| learn data | ①Illumination of daylight (lx) |
| | ②Angle of blind's slat (° ) |
| | ③Room illumination (lx) |
| | ④Amount of daylight (J) |
| | ⑤Treatment quantity of heat(J) |
| | ⑥Room temparature (℃) |
| | ⑦VAV Damper opening value (%) |
| teach data | ⑧PMV value |

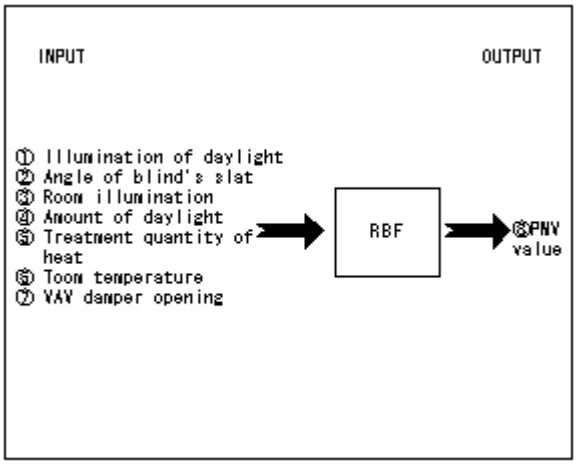


Fig.06 Simulation item

The network structure is 3 layers. It is composed by the input layer, the hide layer, the output layer. The input value includes loss value in this learning time. Even the above data could be learned with RBFN in the high precision.
PMV value and the relations of 7 variables could be modeled in the high precision. The RMS error of the input data (PMV value) is 0.0027 by the simulation model.
The reason to make a model PMV value and 7 variable is the following.
-It is unacceptable to obtain all actual data because PMV value and the combination of 7 variable are enormous.
-PMV value and the relation of 7 variable are acquired, and it becomes possible that it guesses 7 variable PMV value which data don't have mutually.

## CLASSIFICATION

It is applied SOM for classification rule. The data is made by the simulation is mapped in the two-dimensional space. It is Fig. 07.

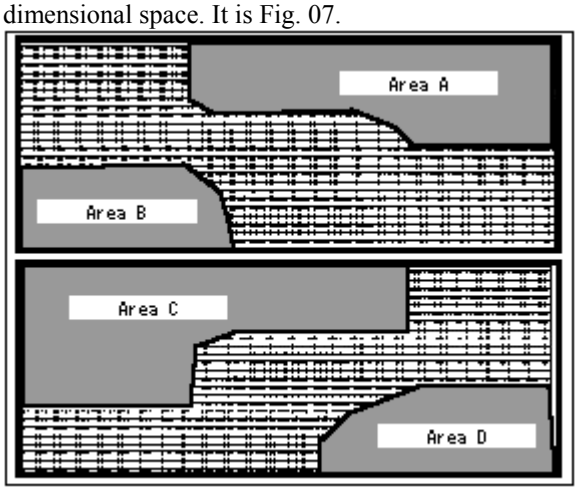


Fig.07 SOM visualization tool output

It knows the thing that the PMV value plus and the minus are divided well.
The climates are as follows (see Fig. 07).
Area A: Amount of daylights > Treatment quantity of heats, PMV value is plus.
Area B: Amount of daylights = Treatment quantity of heats, PMV value is plus.
Area C: Amount of daylights < Treatment quantity of heats, PMV value is minus.
Area D: Amount of daylights = Treatment quantity of heats, PMV value is minus.
This proposal method can recognize unknown pattern in the data to apply SOM.

## CONCLUSIONS

This paper proposed two simulation methods of the "Cooperation control " as the optimize connecting control in the HVAC, artificial lighting and day-lighting combined with venetian blind control.
The possibility is found about the classification before making the rule base.
The model learns additional data as the next phase. Then This proposal method must classify it again.
Authors must examine the way of untying the reverse problem. The reverse problem is searching for 7 values from PMV value. Authors must realize the most optimize cooperation control as the next phase.
This proposal method must adopt not only the PMV value but also the evaluation value of visual, energy as a standard for the judgment at the time.

This research is a part of the national project managed by NEDO (New Energy and Industrial Technology Development Organization).
We appreciate the organization of NEDO.

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