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NEURAL NETWORK APPLICATION FOR AIR EXCHANGE

J.Z. Piotrowski

Department of Civil Engineering, Technical University of Kielce, POLAND

ABSTRACT

The process of air exchange can be described through both planar and spatial network system. It depends on a few random variables (those related to climate) and also on controlled variables (i.e. those like arrangement, etc.). Consequently, the air exchange problems are solved only approximately. In order to avoid that, a neural model was applied as well as estimation in the so-called learning process with simultaneous weight correction. On the basis of comparison with experimental data it can be claimed that solutions presented in the paper demonstrate high result congruence.

Neural network applications in air exchange offer quick diagnosis and can be adapted to all climatic and environmental (controlled) conditions.

KEYWORDS

Air exchange efficiency
Modelling
Natural ventilation
Neural network

INTRODUCTION

Air exchange, being a component of building microclimate and energy considerations, should be estimated as accurately as possible. It is, however, impossible in practice, where the accuracy is measured according to the probability rate of given experimental conditions, under which thorough examinations were carried out before. The accuracy can be also expressed by approximate calculation formulas. The fact that perfect accuracy cannot be obtained results from the building air exchange complexity. The process of air exchange is dependent on both a large number of controlled characteristics (height, floor location, room arrangement, tightness, etc.) as well as on random characteristics (climatic conditions) (Piotrowski 1996). Investigations carried out by means of holomorphic kind methods offer only generalisations and estimations resulting from comparisons with experiments of similar characteristics.

Recent years have brought the popularity of methods in which neutral networks are applied. They seem of particular importance while dealing with diagnosing, predicting and estimating. Those methods rely on collected data base, simulation and interpolation in the so-called learning process. There are attempts at neural network application in building engineering (Lefik and Gawin 1996). The paper sums up the initial phase of research on neural applications in the air exchange estimation. Due to substantial experimental data base, one is able to make all the calculations whichever might be necessary, for whatever prevailing conditions, both controlled or random.

METHODS

Network analysis of air exchange

Air exchange, as well as air flux directly connected with it, can be described by a general expression form:

$$f(I_{ij}) = a_{ij} \cdot X^b \qquad (1)$$

where I_{ij} = air exchange or flow between nodes i - j

a_{ij}, b = controlled conditions characteristics (tightness, building height, floor location, flat spatial arrangement) which affect the flow between nodes $i - j$

X = function argument which specifies variation of random conditions, also in inter-node action

In a particular case, the formula (1) assumes the following form:

$$I_{ij} = a_{ij} \cdot L_{ij} \cdot \Delta P_{ij}^{n} \quad (2)$$

where a_{ij} = air infiltration coefficient in $m^3/(m \cdot h \cdot daPa^{0.7})$

L_{ij} = slit length in m

ΔP = pressure difference between both sides of the element in $daPa$

n = exponent, assumed to equal 0.7 on average

In a general case the expression (1) is a set of a few function dependencies, controlled conditions and random factors which affect air flow between nodes $i - j$. The nodes $i - j$ provide representation of two different neighbouring environments (network edge) or two different rooms (internal nodes). The final solution could be obtained on the basis of mass balance of flowing air.

In the network construction inter - node dependence was determined by the formula (2), where other influence factors (controlled conditions) were described by the system of function dependencies which account for the network dynamics. Such a construction allowed neuron as well as neural network dependence characteristics modelling. Below there was presented an example of equation system for controlled conditions:

- 5 - storeyed building, flat on the 3rd floor: $y = 1.21 \cdot x^{-0.6}$

- unilateral room arrangement: $y=0.23 \cdot x^{0.81}$

- tight woodwork fixed, sealed well at fixtures, of $a=0.6\ m^3/(m \cdot h \cdot daPa^{0.7})$: $y=0.36 \cdot x^{0.65}$

Neural network construction

The presented neural network was constructed as programme structure. For the sake of analysis of air flow in buildings the non - linear one - layered, recurrent neural network model was assumed (Osowski 1996). The network diagram was presented in Figure 1. The network components were nodes representing floors, flats or rooms in the form of neurons. The links between network nodes stood for air flow between floors, flats or rooms. The input signal setting in recurrent networks is a dynamic process due to the occurrence of delay unitary operators (z^{-1}).

The construction of neuron, i.e. of an elementary cell in the neural network, was described at the assumption that there was certain capacity for air infiltration ($a \cdot L$) revealed at the impulse provided by the external environment, which was pressure change (ΔP) (2). At the same time the range of change in output conditions was specified. They could be obtained by means of diversifying:

- room arrangement,
- floor number,
- ventilating ducts location,
- staircase location.

The mutual interaction of nodes being the network components was determined. The nodes centred volumes of individual rooms. Due to that it was possible to construct both planar (within one level) and spatial (often referred to as multi - zone) models.

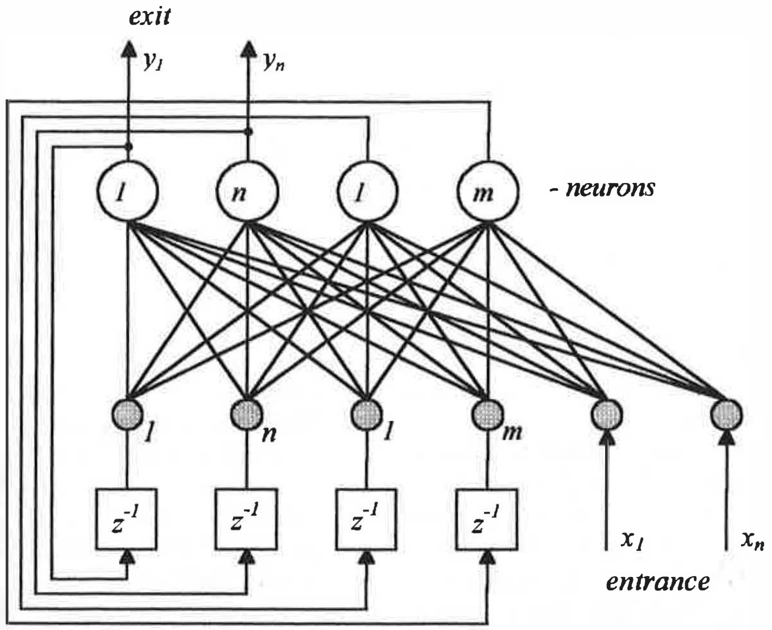

Figure 1 Neural network construction

The output model was described on the basis of thorough investigation results (Piotrowski 1996). Therefore, it was possible to determine the velocity of the impulse motion between the nodes, dependencies holding among controlled conditions, the amount of air exchange, tightness, etc. Quite independently, under real conditions, there were verified the functions which determine weights when both controlled and random conditions change. The neuron cell was thus adapted to accommodate change in:

- object height,
- floor,
- tightness of partitions (air infiltration coefficient change),
- room arrangement and location,
- ventilation system,
- flow conditions in the staircase,
- character of building development,
- internal and external temperatures,
- wind velocity and direction.

The neural network worked out in such a manner can, among others, diagnose changes in air flow, determine the volume of air flowing into a room at a given moment. It is also possible to specify under which external conditions the optimum flow is expected for a given configuration, and vice versa, for what change in controlled conditions the optimum flow will be obtained for average climatic parameters.

Weight identification

The value of each neuron input signal is controlled by means of weight vector (***W***). The general diagram of neuron was presented in Figure 2. The neuron level activation was given in the form of the function $f(u_i)$, following the formula (1). Individual values of coefficients a_{ij}, b and also variable X were determined experimentally.

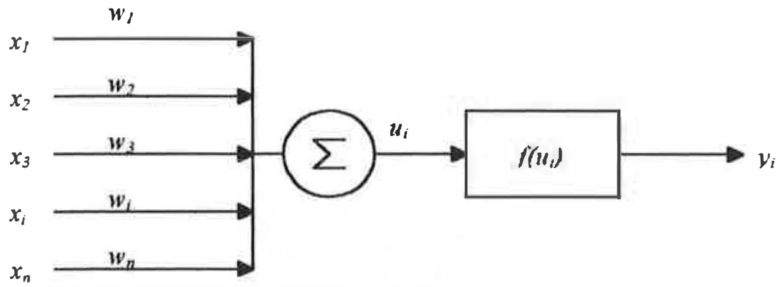

Figure 2 The general diagram of neuron

Investigations under real conditions were also employed to specify attributes, taking into account of which resulted in weight correction. The ultimate impulse, loaded with weight proceeded to the next node - neuron. Attribute variation ranged *(-20 ÷ +20)*, whereas the variation of weight *(0 ÷ 1)*. Attributes were ascribed to each feature, both controlled and random. Weights were determined on the basis of attribute quantity, according to the dependence:

$$\boldsymbol{W} = |\boldsymbol{A}| / 20 \qquad (3)$$

were $\boldsymbol{W}$ = input signal weight vector
$\boldsymbol{A}$ = attribute number matrix

Thus, the impulse loaded with the lowest weight was decisive and modelled flow conditions in a given node. The impulse passage through a successive node was accompanied by repeated specification of attributes and weight characteristic of a given place and random (climatic) conditions. Loading with weights occurred also in case of random change. In this way, air exchange sometimes originated in wind preference, another time in temperature preference. With successive repetition and change, attributes and weights were again generated on the basis of previous values. In this way the process of network learning was initiated.

RESULTS

Air exchange analysis was carried out for a 5 - storeyed in a flat located on the 3rd floor, equipped with window joinery of $a=0.6 \; m/(m \cdot h \cdot daPa^{0.7})$, with rooms arranged in north - south (bilateral) configuration. Table 1 presents the results for the hall, kitchen (north) and room (south) at varied external conditions (and the temperature inside $+20^oC$). Results of measurements taken in a real object are to be found in parentheses.

Table 1 Results of air exchange analysis

Climatic conditions	Air exchange in a flat (1/h)		
	kitchen	hall	room
t_e=-5 °C v=1.2 m/s, north - - east direction	**0.72** (0.76)	**0.41** (0.45)	**0.32** (0.32)
t_e=0 °C v=2.5 m/s, north direction	**0.85** (0.84)	**0.49** (0.52)	**0.37** (0.33)
t_e=-10 °C v=0 m/s	**0.66** (0.66)	**0.39** (0.35)	**0.28** (0.31)

DISCUSSION

Investigations into air flow and air exchange in microclimatic research constitute another area in which neural networks could be applied.

The analysis of neural network provides exhaustive information on air flow and exchange dependent on controlled and random conditions.

The network with neuron determining air exchange offers diagnosing, simulation analysis and is capable of learning at varied attributes and weights.

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