APPLICATION OF ARTIFICIAL NEURAL NETWORKS ON VERTICAL TRAFFIC SIMULATION

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ABSTRACT

Artificial neural networks (ANN) are a powerful tool for parallel processing of information, based on the behavior of the human brain. They are able of learning and generalizing from instances and their ability as universal function aproximators is widely known. They are especially useful in those problems without a mathematical model or in those with a complex or very specific model.

In vertical traffic problems [1], there are a lot of outstanding variables as the hour capacity, the number of floors of the building, the number of inhabitants, the kind of building, the technical characteristics of the elevators (nominal speed, load capacity,...), the kind of operation (universal, duplex, ...). All those inputs result in a very wide range of solutions that difficult the analysis of the problem.

In this paper, an approach to the simulation of vertical traffic using a backpropagation neural network is described. We try to estimate the mean time a user has to wait depending on the values of some of these variables. The required data are obtained from a simulation program developed in the University of Zaragoza [2] that also acts as a tester for the network performance.

1. INTRODUCTION

When designing a group of elevators in a building, it is very important to know in advance, the type of service that is required as a function of number of elevators, its capacity, the nominal velocity, type of operation, etc. Also is needed to know the number of floors, number of basements, population of the building, and the type of building that we are analyzing. In order to evaluate the level of service given by the group of elevators, a magnitude as the mean time that a user has to wait from calling to arriving can be used.

The calculation of this magnitude it is very complex due to the number of required variables and in addition, this magnitude, it is not clearly dependent of some of these variables, that is the reason that traditional formulation gives poor results.

Another way to solve the problem is by means the use of simulation programs, which show better results but require more developing time as well as a good knowledge of the problem if we want to simulate accurately the real problem.

The proposed method in this paper to estimate the mean waiting time uses artificial neural networks (ANN). This calculation tool has the property to learn by means using examples and obtain a general procedure for new cases. Moreover, this technique does not require a prior knowledge of the functional dependence of the variables.

2. ESTABLISHMENT OF THE PROBLEM

The problem which is intended to solve is the estimation of the mean time waiting for users of a group of elevators from the calling to arriving of the elevator for a given type of building, the group of elevators and the demand of them.

The entry variables can be grouped depending to if they are referred to the type of building, type of elevator or simulation parameters. The grouping considered in this study is the following:

- Referring to type of building:
  - Traffic between floors (flats, offices, hospitals...).
  - Number of floors upper to hall
  - Number of floors under the hall (basements)
  - Total population in the building.
- Referring to type of elevator:
  - Type of operation used (universal, duplex, selective up/down...).
  - Capacity of elevator.
  - Nominal velocity of elevator.
- Referring to the usage:
  - Percentage of the population in the building that requires the service in a temporary interval considered.

Using the program Tráfico Vertical [3], developed in the University of Zaragoza, examples will be created to train the neural network in order to generate the correct output when a combination of entry variables is introduced (see figure 1), and also to verify the obtained solutions.

Figure 1. Program for vertical traffic simulation.

3. NEURAL NETWORK DESCRIPTION

The ANN we use in this application is the multilayer perceptron that learns with Backpropagation algorithm [4]. The ANN consists of a layer of input neurons, another layer of output neurons and, optionally, one or more layers of hidden neurons (figure 2).

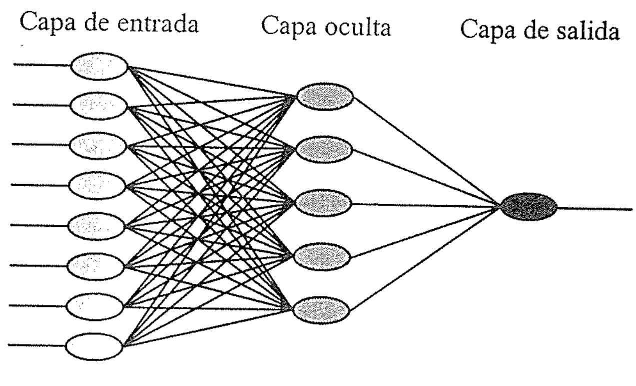
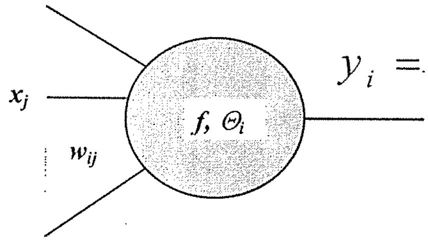


Figure 2. Example of a Backpropagation network with 8 input neurons, 5 neurons in a hidden layer and 1 output neuron.

The number of neurons to be used in the input and output layers is determined for the application for which the ANN is designed. The number of hidden layers and hidden neurons do not depend on the application itself, and several combinations must be tested in order to get the best generalization ability.

Each neuron of the network (excepting the input ones) produces an output when an activation function is applied (Ec.1.) to the weighted sum of the inputs and the synaptic weights (figure 3). Each neuron gets the information of a layer closer to the input of the system and sends the output to a layer closer to the output. This is usually referred as *feedforward* ANN.



$$y_i = f(\sum w_{ij} x_j - \Theta_i) \qquad (1)$$

Figure 3. *Task carried out by an artificial neuron i, characterized by an activation function f and an internal threshold Θ.*

The operation mode of the ANN consists of a learning stage and a recall stage. The learning stage is an iterative process in which representative instances and its expected outputs are shown to the system, settling the synaptic weights by means of an algorithm, and storing the knowledge in the final values of the weights. After that, in the recall mode, instances never seen by the system can be introduced, obtaining satisfactory results.

4. APPLICATION OF THE ANN

The input variables of the problem must be codified before introducing them to the ANN. In order to do this, 15 neurons are arranged as inputs in the following manner:

2 neurons will codify the traffic between floors: the first one will be on (state value 1) when a significant traffic between floors can be considered, and off (state value 0) in the other case. Conversely occurs for the second neuron.

1 neuron for the number of floors: buildings from 4 to 12 floors are considered.

1 neuron for the number of basements: from 0 to 2 basements.

1 neuron for the building population: from 75 to 300 inhabitants are considered.

7 neurons for the type of operation: one of them is activated and the rest deactivated depending to the type of operation: Universal (PB), two elevators with Universal operation (2 PB), Universal Duplex (2C-PB), Selective Down (1BC), Selective Down Duplex (2C-1BC), Selective Up an Down (2BC), and Selective Up and Down Duplex (2C-2BC).

1 neuron for the elevator capacity: capacities of 4, 8 y 16 people are considered.

1 neuron for the nominal velocity: allowed values are 1, 1.6 y 2 m/s.

1 neuron for the demand: the cases considered are those in which the 10, 20 ó 30% of the population requests for the elevator system services during the simulation.

Those input values are scaled in the interval [0,1] in order to be correctly processed by the ANN.

A set of 200 patterns was obtained with Vertical Traffic software to train the network with different values of these inputs. Another 50 patterns were produced as a test set. All the chosen examples, due to the high dimensionality of the input space, were sought to be representative of real situations, so constraints were imposed about the number of inhabitants depending on the number of floors, about the velocity and capacity of the elevators, etc. The simulation interval was fixed in five minutes, and other parameters of the software were also fixed (opening doors time, distance between floors, acceleration...).

Table 1*. Results for several topologies.*

Topology	Training error	Test error
3-0	0.074082	0.059
5-0	0.071084	0.06028
7-0	0.080741	0.05801
9-0	0.073895	0.05601
10-0	0.063868	0.05497
3-2	0.064162	0.05214
5-3	0.064393	0.05261
7-3	0.063207	0.05251
5-3	0.037161	0.05202
9-3	0.052205	0.05195
11-5	0.042216	0.04262
11-7	**0.034772**	**0.0404**
11-9	0.036253	0.04193

Once the training and test sets were obtained, several topologies were tested for the neural network to get the one that fits best the test patterns. The scaled root mean squared error reached with some topologies is shown in table 1.

As can be seen, the best configuration is a network with 15 input neurons, 11 neurons in the first hidden layer, 7 neurons in the second hidden layer and 1 output neuron (figure 4).

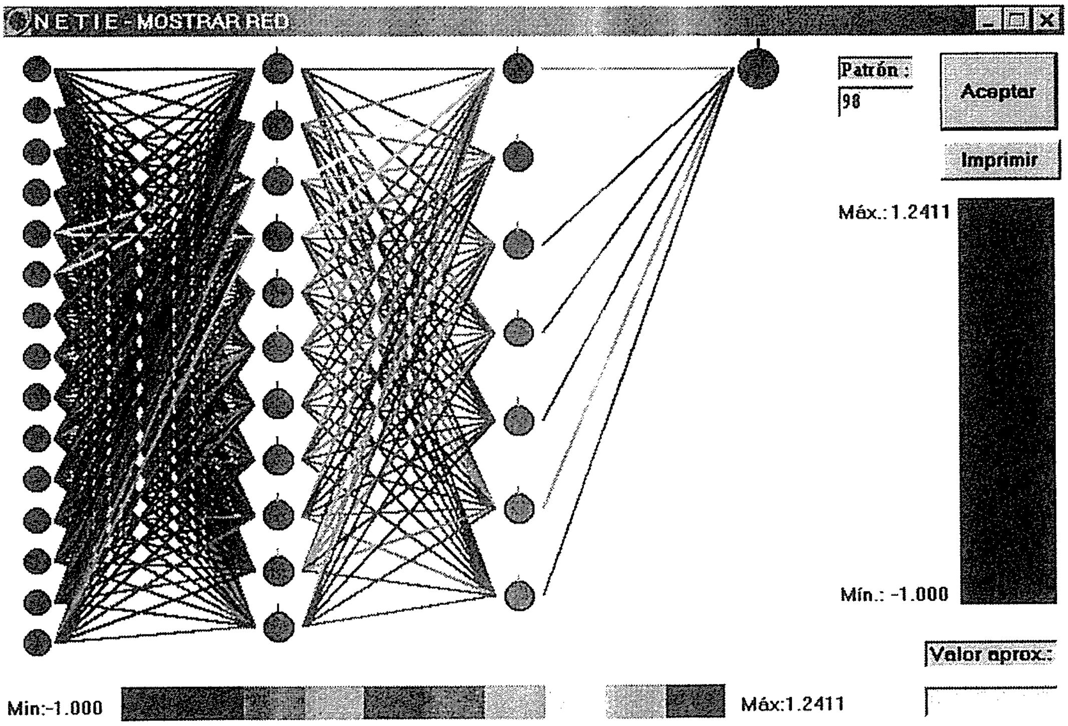


Figure 4. Best topology for the ANN.

It is important to realize that, once the network has been trained, it is ready to use as a system in which the output is produced immediately given an input pattern.

5. RESULTS AND CONCLUSIONS

The final results obtained after applying the techniques in the previous point are shown in figure 5. The ANN predictions for some combinations of input variables not seen in training stage are represented. Test patterns have been clustered according to elevator operation in order to make the analysis easier.

First of all, it must be noticed that the average waiting time obtained with the simulation program is not fixed. This is due to the random processes involved in simulating the behavior of the inhabitants requesting the elevator services. However, the average waiting time strongly depends on the operation mode of the elevator, and this can be easily seen in the figure. Prediction errors are sometimes due to the poor knowledge of the ANN on that zones of the input space (not enough training patterns in that region), and sometimes due to the atypical feature of a test pattern, being the average value of more simulations on that pattern better fitted by the neural network.

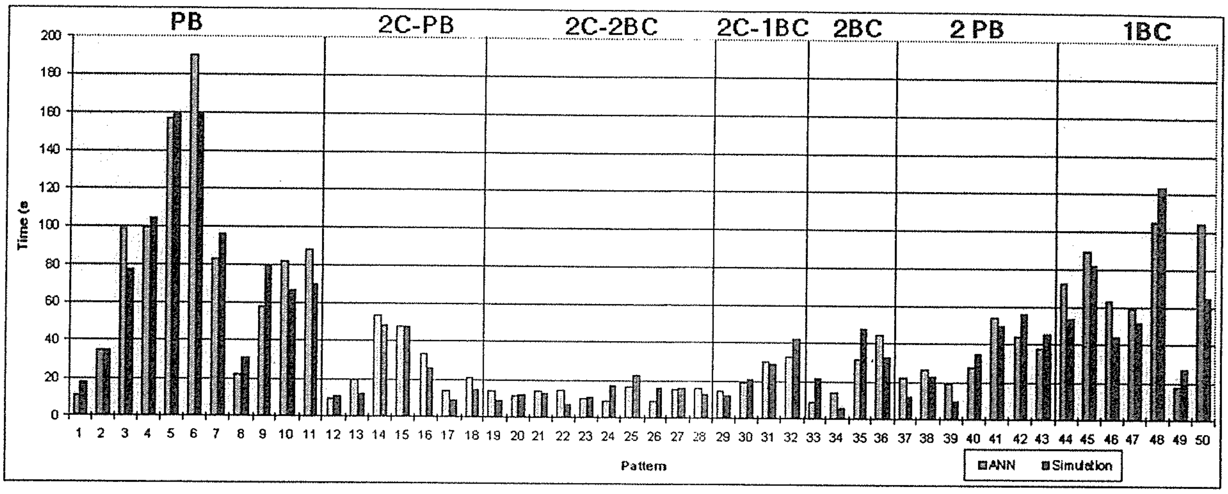


Figure 5. Results obtained with ANN.

As some conclusions, a new tool in studying vertical traffic problems has been introduced that does not require a complete knowledge of all variables and performs a simulation in an easy and immediate way once it has been trained. Also, the neural network produces as output the expected average value, while several simulations are required with the software to reach the same average value.

6. REFERENCES

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