USE OF NEURONAL NETWORKS AND FUZZY LOGIC TO MODELLING THE FOOT SIZES

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ABSTRACT

The world is driven by technology, companies is now seeking to automate the majority of their tasks. In particular, the footwear market has changed, the industry had to adapt the new customer demands: the number of products on the market has increased, the requirements of comfort are becoming stronger, the life of products becoming shorter.

We have a set of measures produced from a 3D scan of the foot of a diverse population (women, men,) and we try to analyze this data to define a model of the foot to the Tunisian footwear design. In this paper, we present different methods of data analysis by classifying them into two categories: conventional methods such as statistical methods and unconventional methods based on fuzzy logic and neural networks. So we offer six models of Tunisian foot sizes: two statistical models, two models based on neural networks in unsupervised learning (a model sizes and a model and half sizes) and two others that integrate neural networks and fuzzy logic : it exploits the properties of learning neural networks with fuzzy learning functions to improve footwear models. A comparison of six approaches is then performed to evaluate their performance.AIRCC Journals.

KEYWORDS

Morphology of foot, foot size, half foot size, neural network, Kohonen network, fuzzy logic, model of foot size.

1. INTRODUCTION

The foot have many functions: they absorb shock, they help us stay balanced, and they provide the flexibility to walk, jump and run. To define new models that provide more comfortable shoes, it was necessary to study the morphological characteristics of the foot.

2. MORPHOLOGICAL CHARACTERISTICS OF THE FOOT

The dimensions of the foot are the lengths, widths, boundaries, heights and angles of the foot. There are 14 foot lengths. These lengths are necessary to design a shoe.

The number of perimeters is 7: two on the leg, five foot [1]. It has 10 heights. The height at the entrance is among the measures necessary for the design of shoes [1].The foot consists of three main widths: at the forefoot joint, at the heel and the width of the ankle. The Angles are five in number. They determine the overall shape of the foot. There are three angles and contour angles to the two joint.

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For modelling these dimensional parameters, we proposed six approaches to define a new model of foot.

3. PROPOSED APPROACHES

Neural networks represent a very unconventional approach used for data analysis, due to their ability to model very different issues and their robustness to noisy data. This section presents the implementation of different approaches, based on the self-organizing map Kohonen, to find a model of Tunisian foot sizes to design comfortable shoes. The first approach proposes a Model of Sizes using Kohonen networks (MSK). This approach is improved by another one which Modeling the Half Sizes by Kohonen network (MHSK). The use of the Kohonen network for data analysis gave interesting results. On another level fuzzy logic is another unconventional approach to model the data and identify information closest to reality. This has identified the main idea on which the third proposed a new approach called MSFK (Modeling Sizes by Fuzzy Kohonen) where we exploit the properties of learning of neural networks with fuzzy learning functions. The MSFK approach is then improved by introducing the concept of half sizes. This approach has issued MHSFK (Modeling of Half Sizes by Fuzzy Kohonen network).

3.1. Description of MSK approach

From much architecture of neural networks were selected self-organizing maps of Kohonen to implement our first proposed approach: modeling sizes by Kohonen (MSK). The Kohonen networks are competitive and dynamic model of which is a process of self-organization which will project the initial data on a discrete space of small dimension (typically 1, 2 or 3D). We chose to use the linear architecture (one dimension) of the Kohonen network: In each node of the grid, consisting of 15 neurons that represent the sizes (29, 45, and 46), is a neuron. Each neuron is connected to a reference vector, responsible for an area in the data space which is also called input space and representing the various dimensional parameters of the feet. The output represents the model of the fit for each size.

The principle of competitive learning is generally promoted a winner neuron and the closer the input vector. We follow the algorithm bellow:

After a random initialization values of each neuron of the grid, starting a learning cycle which consists of the following steps:

- ✓ Present an input vector, $X = \{x1, x2, xn\}$, associated with a stimulus to the grid.
- ✓ Find the winner node k; this is the closest neuron from the input vector
- ✓ Modify the weights of the winning neuron K and its neighbors by applying the Kohonen learning rule follows:

$$W\_i (t+1) = W\_i (t) + \alpha (t) * V (i, k, t) * [X\_i (t)-W\_i (t)] \quad (1)$$

With: $[xi (t) - wi (t)]$ represents the Euclidian distance between the input vectors X and W at the instant t, α (t) is the coefficient learning and V (i, k, t) represents the neighborhood function.

The Figure Fig1 shows schematically the process of MSK learning.

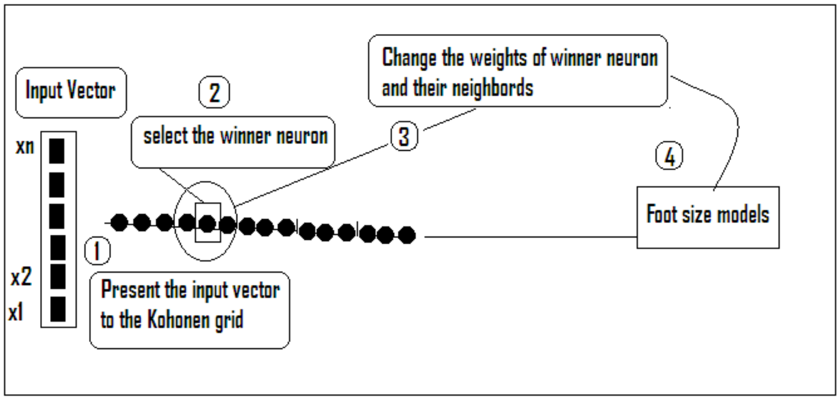

Fig1: The learning process of MSK

3.2. Description of MHSK approach

To improve more comfort of foot, and to design models of footwear more accurate and closer to the actual dimensions of the Tunisian population, we introduce the concept of half size that describes the difference in length between two successive sizes. We define a new approach to model the half-sizes by the Kohonen network (MHSK). The principals operating and implementation of MHSK are the same as the MSK approach. What is different is the network architecture: this architecture is no longer linear but triangular switch to change the neighborhood of neurons as described in Figure fig2.

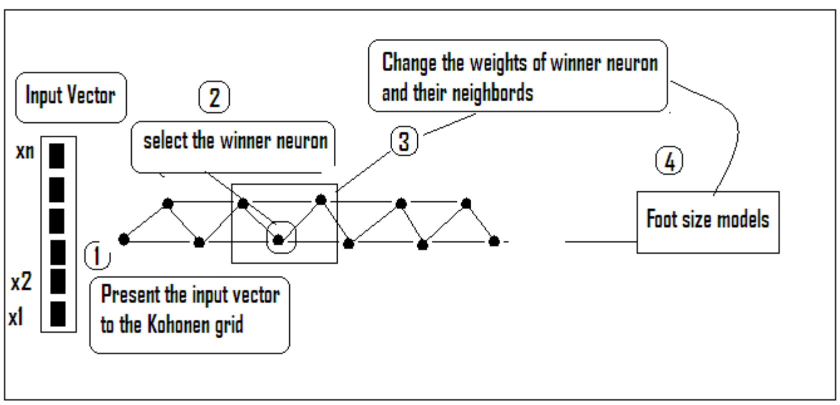

Fig2: The learning process of MHSK

3.3. Description of MSFK approach

To further refine the model of shoes, and since the sizes are not always fixed (a person may hunt from 40 to a certain type of shoes and 39 others), it is interested to introduce the concept of fuzzy networks.

To implement the approach MSFK, we must, first, implement the fuzzy inference system (FIS), test the input stimuli, build the Kohonen network, call the FIS, start learning and define the fuzzy neuronal final model. This is the subject of the next section. We start by construct the Fuzzy Logic System in our case, the Kohonen network consists of 15 neurons (sizes 29, 30, 46), the inputs are the dimensions of the foot and the outputs represent models of different sizes. The intervention of fuzzy logic is at learning: instead of considering only one winner neuron and change its weight and weight according to their neighborhood, the Fuzzy Logic System decide that such a neuron is the winner but with a certain degree of membership "µ" and when we change the learning neurons winners (each with its degree of membership) and the weight of its neighbors according to the entrance. To define our FIS, the variables are, first, treated as linguistic variables. In our case, we have only one input which is the distance that represents the Euclidean distance between the input stimulus and the neural network. We equate this distance to a single linguistic variable "minimal". Then this variable in the inference mechanism for finding a vector V that contains the decisions of the FIS came about. Specifically, for each input, we define all the winner neurons each with its degree of membership "µ". For example, a woman given X (input stimulus), shoe size 35 (neuron 7) is the winner (the nearest) with µ = 0.2, size 36 (neuron 8) winner (the nearest) with µ = 0.6, the size 37 (neuron 9) is the winner (the nearest) with µ = 0.2 ...

Figure fig3 describes the operating of the FIS.

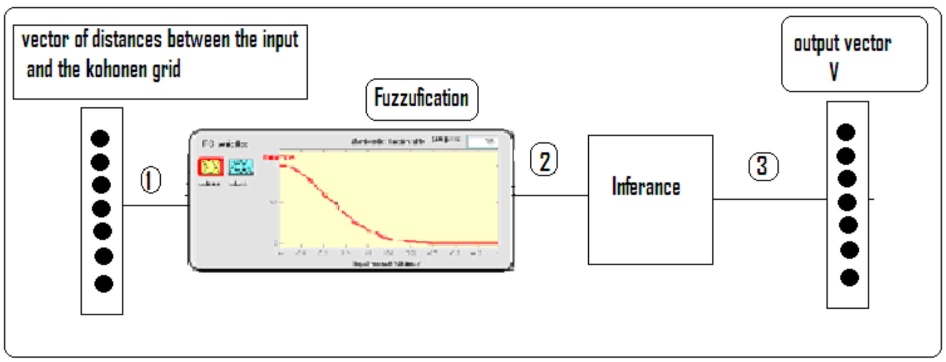

Fig3: the principal operating of the FIS

Now we applicant de fuzzy Kohonen algorithm

The architecture of fuzzy Kohonen is similar to Kohonen usual, but the weights are modeled by fuzzy sets. Activations, outputs, and functions of propagation will be changed. Also the intent of this model is that it is interpretable by linguistic rules and can use knowledge bases of rules a priori.

After defining the FIS, called the fuzzy Kohonen algorithm is described by the following part:

- Present an input vector to the grid.
- Find nodes winners, each with its degree of belonging, by calling the FIS.
- Stoker's responses FIS in a vector T.
- Modify the weights Wi nodes winners, and those of its neighborhoods. The modification of the weights of neurons winners and its neighbors is done by modifying the Kohonen learning rule as follows:

$$W_i (t+1) = W_i (t) + T_i (t)\, \alpha * (t) * V (i, k, t) * [X_i (t) - W_i (t)] \quad (2)$$

- Stop learning if the learning coefficient is zero; otherwise, introduce another stimulus to the grid.

The Figure fig4 explains schematically the learning process of the MSFK approach.

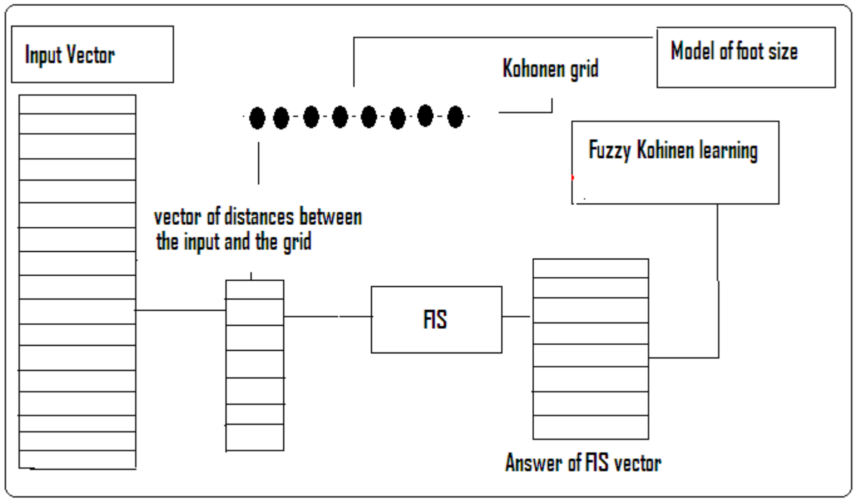

Fig4: The learning process of the MSFK approach

3.4. Description of Static Method (SM)

Several statistical studies have detailed a new Tunisian model of foot sizes. Statistical methods (SM) are based on applying statistical equations.

The same studies have detailed statistical another statistical method, using the same rules of calculation which the concept of half-size statistics (SHM).The Figure fig describes the process of operation of the SM (or SHM).

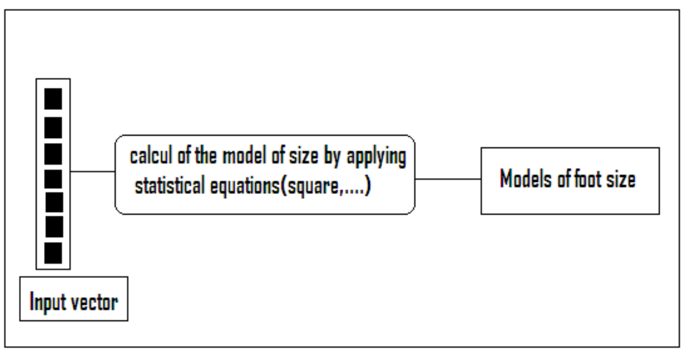

Fig5: Process operation of the SM and SHM

4. Results and Performance Evaluation

To compare different approaches, we calculated the mean square error between our six models and we found the training set, for all sizes and half sizes of the population.

In order to obtain clearer results, we chose to represent two histograms: the first describes the evolution of the MSE for the female Tunisian population (Fig 6).

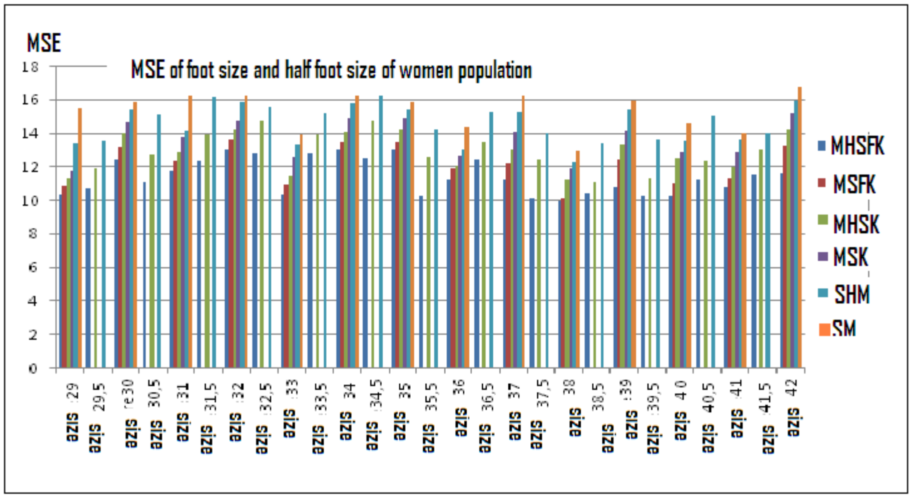

Fig6: comparison of approaches

From the comparison of the MSE of approaches according to the sizes and half sizes of Tunisian women, we can observe that the mean square error between the methods MHSK, MSK, and MSFK MHSFK is less than those of the statistical method (SM, and SHM). So we can see that the unconventional methods based on neural networks and fuzzy logic, improve models of footwear and give results closer to the actual values recorded in the training set. Thus, we can see that the MSE of the MHSFK and that of the MSFK are generally lower than those of MHSK, the MSK, the SM and SHM, for all sizes. So we can conclude that the self-organizing maps, combined with fuzzy inference rules, can improve the modeling of sizes compared to methods based on neural networks only or other conventional methods such as statistical modeling, in defining models closer to reality then we combine the learning ability and generalization of neural networks, with the formalization of rules that are unclear, uncertain information corresponding to an approximate human. Concerning the notion of half size, compare now the approaches that introduce the notion of half size with other approaches. The histogram shows before, a first hand that the mean square error of MHSFK is less than the MSFK, a second part, the mean square error of MHSK is less than the MSK and on the other hand, the mean square error of the SHM is lower than that of SM. So we can conclude that the concept of half size improves the style of footwear. It has been shown, through this histogram, the notion of half size improves the model of foot.

5. CONCLUSIONS

The results provide interesting findings emerged stronger following:

- The notion of half-size models improves shoes.
- The combination of two intelligent techniques: fuzzy logic and neuronal networks improves the models of footwear.
- The use of intelligent techniques combined with the concept of halves sizes can provide more accurate models of sizes and adaptable to the target population.
- The learning mechanism (conventional or fuzzy), combined with the notion of half-size, improves the models of sizes giving the dimensions of the feet very close to those of the population concerned.

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