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Neural network and multiple linear regression to predict school children dimensions for ergonomic school furniture design

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ABSTRACT

The current study investigates the possibility of obtaining the anthropometric dimensions, critical to school furniture design, without measuring all of them. The study first selects some anthropometric dimensions that are easy to measure. Two methods are then used to check if these easy-to-measure dimensions can predict the dimensions critical to the furniture design. These methods are multiple linear regression and neural networks. Each dimension that is deemed necessary to ergonomically design school furniture is expressed as a function of some other measured anthropometric dimensions. Results show that out of the five dimensions needed for chair design, four can be related to other dimensions that can be measured while children are standing. Therefore, the method suggested here would definitely save time and effort and avoid the difficulty of dealing with students while measuring these dimensions. In general, it was found that neural networks perform better than multiple linear regression in the current study.

1. Introduction

Primary school students spend much of their time sitting on chairs daily. Bad design of furniture may lead to health and learning problems. Therefore, design of furniture with proper dimensions is critical to encourage appropriate postures (Straker et al., 2010). So many studies were conducted to ergonomically design the school furniture using anthropometric measurements which vary according to many factors. Most of these studies showed school children frequently use furniture that is not suited to their anthropometry (Straker et al., 2010). Anthropometric measurements are not easy to perform and they need a large sample size and a lot of dimensions. Some of these dimensions are necessary to ergonomically design the chair and yet they are not easy to measure. This study attempts to find some easy-to-measure dimensions that are capable of predicting the difficult-to-measure ones used in designing school furniture for primary school students.

2. Literature review

Although measuring all the necessary body dimensions is very expensive and time consuming, little was published on how to predict difficult-to-measure dimensions from easy-to-measure ones. It is necessary to know the interrelationships between dimensions to predict additional ones (Haslegrave, 1980). The existing studies can be classified into studies that used a single variable (predictor) and others that used multiple variables. Jeong and Park (1990) used stature alone to predict the dimensions needed to design school furniture. The results show that different regression equations are needed for males and females. Another study by Lewin (1969) studied the relationship between some anthropometric measures and found that some differences exist in the regression equation between males and females. It is noted that the study still used a single variable. Al haboubi (1992) also used a single variable regression model to obtain some anthropometric dimensions using weight and stature for Easterners population. Chao and Wang (2010) used Constant Body Ratio (CBR) benchmarks to convert old anthropometric data into new data. In other words, these CBRs are used to predict new data from old data. 197 estimation formulae using 19 easily measured dimensions were built using a total of 483 CBR benchmarks. Ma et al. (2011) studied the body characteristics of adult Koreans aging between 18 and 59 using a three-dimensional scan. The body of each adult was divided into 16 segments and the mass inertial parameters were estimated by assuming that the density of each segment is uniform. At least one circumference of each segment and the length were determined for scanned data. Body segment parameters were then estimated using nonlinear regression equations as a function of length and circumference. A study by Kaya et al. (2003) used

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adaptive neuro-fuzzy inference system to estimate anthropometric measurements. However, the study used 18 body dimensions to predict six dimensions. To measure all these 18 dimensions is still not an easy task. This study uses only four anthropometric dimensions to predict five essential ones needed for ergonomic design of primary school furniture using multiple linear regression and neural networks.

2.1. Ergonomic furniture design

Workplace furniture design and user anthropometry have become an important consideration in designing ergonomically appropriate furniture (Van Wely, 1970; Harris et al., 2005). School children are at risk of suffering negative effects from ill-fitting furniture (Parcells et al., 1999). The use of proper furniture design reduces fatigue and discomfort in the sitting posture. According to Cranz (2000), correct standing and sitting postures would help in the prevention of musculoskeletal symptoms. The anthropometric dimensions needed to determine school furniture dimensions that promote a correct sitting posture include popliteal height, knee height, buttock popliteal length and elbow height (Knight and Noyes, 1999; Parcells et al., 1999; Panagiotopoulou et al., 2004; Gouvali and Boudolos, 2006; Chung and Wong, 2007; Agha, 2010; Straker et al., 2010).

2.2. Predictive models

A large number of different predictive models have been proposed over the years. Despite the number of research activities, there is still a doubt to advise practitioners as to what prediction models they should select, because studies have not converged to similar answers. There are a number of factors that should be considered in the selection of a prediction technique, and it is likely that trade-offs will need to be made in the process. Technique selection is driven by both organizational needs and capability. In terms of need, the most common aim is to maximize the accuracy in prediction; however, other issues may also need to be considered. For instance, a technique that produces slightly less accurate but generally more robust models might be preferred, especially in cases where the organizations do not have access to locally calibrated, well-behaved data sets. While it is very positive that more sophisticated (and potentially more useful) techniques are being employed to build predictive models, genuine benefits will be achieved if the techniques are appropriately used (Tronto et al., 2007).

2.2.1. Multiple linear regression

Many problems in engineering and science involve exploring the relationships between two or more variables. Regression analysis is a statistical technique that is very useful for these types of problems. Many applications of regression analysis involve situations in which there are more than one regressor variable. A regression model that contains more than one regressor variable is called a multiple regression model (Montgomery and Runger, 2007). Multiple linear regression analysis is usually used to summarize data as well as study relations between variables (Norusis, 1990). The multiple regression model can be formulated as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon \qquad (1)$$

where: Y is the dependant variable or response, k is the number of independent or regressor variables, x_j is the independent or regressor variable, $j = 0, 1, \ldots, k$, β_j is the regression coefficient, $j = 0, 1, \ldots, k$, and $\mathcal{E}$ is a term that includes the effects of un-modelled sources of variability that affect the dependant variable.

Traditionally, multiple regression analysis has been used to model the functional relationships between anthropometric measurements. Meanwhile, in recent years, various methods based on artificial intelligence techniques are proposed as alternatives to statistical methods, especially to model highly nonlinear functional relationships (Kaya et al., 2003).

2.2.2. Neural network technique

In the last years, a great interest on the use of Artificial Neural Networks (ANNs) has grown. ANNs have been successfully applied to several problem domains, in areas such as medicine, engineering, geology, and physics, to design solutions for estimation problems, classification, control, etc. They can be used as predictive models because they are capable of modelling complex functions (Tronto et al., 2007).

A neural network represents a highly parallelized dynamic system with a directed graph topology that can receive the output information by means of a reaction of its state on the input actions (Galushkin, 2007). To achieve a good performance, neural networks employ a massive interconnection of simple computing cells referred to as “neurons” or “processing units” (Haykin, 1999).

A neuron is an information-processing unit that is fundamental to the operation of a neural network. Sigmoid function, whose graph is S-shaped, is normally used as activation function. The sigmoid function is by far the most common form of activation function used in the construction of ANN. It is defined as a strictly increasing function that exhibits a graceful balance between linear and nonlinear behaviour (Haykin, 1999).

“Behaviour” of a neural network has two aspects: processing tasks and learning or self-organization. A neural network reacts to signals, presented by the environment, by processing the presented input information in a manner meaningful to the network or network users. The network changes itself to process information meaningfully. The change in processing is mostly realized by the change in weight values (Hirose, 2006).

Learning is the change of the neural network, made by the network itself, in such a way that the resultant processing behaviour becomes in accordance with the wishes of network users. Typically, models of neural networks are divided into two categories in terms of signal transmission manner: feed forward neural networks and recurrent neural networks. They are built up using different frameworks, which give rise to different fields of applications (Hirose, 2006).

Multilayer Feed forward Neural Networks (FNNs), or equivalently referred to as multilayer Perceptrons (MLP), have a layered structure and process information flow in feed forward manner: an input layer consisting of sensory nodes, one or more hidden layers of computational nodes, and an output layer that calculates the outputs of the network (Tang, et al., 2007). FNN features a supervised training with a highly popular algorithm known as the error back-propagation algorithm (Hirose, 2006).

3. Materials and methods

A sample of 600 students voluntarily participated in this study. Students aged between 6 and 11 years old were randomly selected from five UNRWA-UNESCO primary male schools. 120 students were randomly selected from each school. Since a primary school consists of six classes, twenty students were selected from each class. The measurements were performed by two teams, each consisting of two people. Two Lafayette anthropometers along with a tape and adjustable sitting chairs were used to measure some of the anthropometric dimensions of these students. Specific details