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Semoga FT-UISU sukses dan maju.

Walbillahi Taufiq Walihidayah

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Wassalam

Redaksi
Artificial Neural Networks for Peak Static Strength Prediction

Nazaruddin¹, Zuarni², Adi Setiawan³

Abstract

Peramalan kekuatan statis sangatlah penting untuk menyelesaikan masalah-masalah ergonomik terutama dalam mengurangi terjadinya musculoskeletal disorders (MSD's) dan cumulative trauma disorder (CTD's) dalam melakukan pekerjaan secara manual. Pada penelitian ini digunakan suatu teknik baru untuk peramalan kekuatan statis manusia dalam kasis pengangkutan secara manual. Sebelumnya, pendekatan statistik seperti regresi linier berganda telah digunakan. Di samping mengusulkan suatu teknik baru, penelitian ini juga menguji kemampuan neural networks dalam peramalan kekuatan statis manusia dengan menggunakan ukuran-ukuran tubuh. Neural networks dilatih oleh weight yang dibentuk dari data yang diperoleh melalui suatu survei. Didapati bahwa neural networks dapat dengan akurat membaca data dan mampu dengan akurat meramalkan data tersebut. Dengan menggunakan pairwise t-test, didapati bahwa perbedaan antara data sebenarnya dan data hasil ramalan adalah tidak signifikan (p-value>0.05) dengan tingkat kepercayaan (CI) 95%.

Kata kunci : Kekutan Statis, Peramalan, Artificial Neural Network, Musculoskeletal Disorders (MSD's), Penanganan Manual

Keyword(s) : Static Strength, Prediction, Artificial Neural Network, Musculoskeletal Disorders (MSD's), Manual Handling

1. Introduction

Ergonomics today is growing and changing. Development stems from increasing and improving knowledge about the human, and is driven by new applications and new technological developments. The word of ergonomics was derived from the Greek terms ergon, indicating work and effort, and nomos, law or rules (Murrell, 1994). From basic sciences such as sociology, psychology, physiology, medicine, mathematics, etc., a group of more applied disciplines developed into the core of ergonomics such as anthropometry, biomechanics, industrial hygiene, etc. This paper is concerned about biomechanics especially in using artificial neural networks as new model to solve in predicting the workers static strengths. The strength prediction is an important consideration when solving ergonomic problems. Many of researches use regression method (Potvin et al., 1992 and K.M. Bolte et al., 1998) and others use polynomial method (McGill SM et al., 1996) for predicting the human strength. As we know, regression method does not give accurate prediction for non linear modeling or complex modeling. Previously, most of lifting strength values is calculated based on the NIOSH lifting equation. The NIOSH lifting equation is still being revised until today because it does not accurately calculate or predict human strength. Now days, artificial neural networks is very popular for predicting. This is mainly due to their successes in modeling complex domain tasks as opposed to techniques such as linear regression and Kalman filters. Besides, artificial neural network modeling technique are very flexible to apply, there are generally no needs to make presumptions about the characteristic of static
strength. The use of artificial neural network for strength prediction has not been used recently.

Artificial neural networks have been seen involve in various applications domain, such as motion analysis (Taha et al. 1996), the prediction of stock market trading volume (Weigend, A.S. and B. Lebaron, 1994), currency consumption (Refenes et al., 1993), energy consumption (MacKay, 1993). For ergonomics solution, an artificial neural network has been used in reach posture prediction (Jung and Park, 1994) and human motion analysis such as hand grasping, walking, running (Taha et al., 1995). Eksioglu, et al. (1996) used both artificial neural networks and statistical model for ergonomic solution about prediction of peak pinch strength from a variety of factors, such as elbow and shoulder flexion, age, weight, grip strength, and various arm and hand dimensions. They found that the ANN model better at predicting peak pinch strength than statistical model. In this paper we study a type of static strength which has different flavors from those in the above applications.

The data come from the direct measurement through the survey of industrial workers static strength. The data are set of anthropometric, age, and static strength which were collected from industrial workers. Static strength prediction is very useful in the design work task for the workers especially in manual material handling.

2. Back Propagation Technique

The artificial neural networks are typically organized in layers. Layers are made up of a number of interconnected 'nodes' which contain an 'activation function'. These data will be used to find a correlation between the inputs and outputs using a fully connected neural network.

The fully connected network used to simulate the data can be described by the following set of equations:

\[ s(\text{net}) = \frac{1}{1 + e^{-\text{net}}} \]  

(5)

In our study the number of inputs into the network are variable, we try to find the best combination of physical dimensions to fit the static strength. The output is standing lifting strength for position with two-handed pull 100 cm height level of the handle.

\[ E = \sum_{k=1}^{K} E(k) = \sum_{k=1}^{K} \sum_{i=1}^{n} (\frac{1}{2})(y_i - y_k)^2 \]  

(6)

\( K \) is the number of training sets. In this study the training sets are the inputs and outputs at the anthropometrics data and static strength data from measurements. \( Y_i \) are outputs of training sets corresponding to lifting strength and grasp.

3. Proposed Approach

The proposed approach is based on survey that measurements of human static strength for example using some of equipment for measure static strength do direct measurements of the workers static strength. Besides, the anthropometrics data also was collected to know whether any correlation between anthropometrics and static strengths. The anthropometrics data can be as input and the output is only static strength data for different size of anthropometrics data. Supposing the output parameters are defined by the static strength
predicted \( Y_i \) and the input as anthropometry and static strength \( X_i \) to find a function:
\[
Y_i = f(X_i)
\]  
(7)

The function \( f \) is mapping the outputs and the inputs. The outputs can be static strength from different position such as knee bend, knee straight, sit etc. In this case, we only take one output that is static strength of two-handed pull 100 cm level of handle on standing lifting posture (Figure 3). The inputs data \( X_i \) will consists of:
\[
X_i = \{ \text{stature, weight, arm reach, circumference, hand etc} \} 
\]  
(8)

The input components are not limited to those previously describe but can be extended to include other parameters such as age and other physical dimension data as need arises. The inputs parameter will be created for different number of inputs and different types of physical dimension. Even though these data can be predicted using linear regression method, but in the case of predicted problem are more reliably using artificial neural networks. The approach used here is illustrated in Figure 2.

4. Case Study

Data was taken from 146 industrial workers across Malaysia. The sample consists of 104 male (32 heavy industries and 72 light industries) and 42 female (light industries) workers. Subject was chosen randomly that was involved in manual material handling.

![Basic back-propagation](image)

Figure 2. Basic back-propagation

Age, weight, grasp strength and 9 different types of anthropometrics measurements from 52 types and 2 from 12 type’s measurements of static strength are taken.

Table 1. Physical dimensions measurement

<table>
<thead>
<tr>
<th>Stature</th>
<th>Knuckle height (NH)</th>
<th>Arm reach (ARF)</th>
<th>Knee height (KH)</th>
<th>Ankle (AC)</th>
<th>Wrist (WC)</th>
<th>Upper arm (UAC)</th>
<th>Crotch (CTC)</th>
<th>Lower Thigh (LTC)</th>
</tr>
</thead>
</table>

The anthropometry measurements are based on literature by Kroemer (1999) and White (1964), whilst the static strengths based on literature by Chaffin and Anderson (1991) and the guidelines by FAA (Section 14, 1996). There are 9 kinds of physical dimension measurement were taken, namely stature, knuckle height, arm reach, knee height, wrist circumference, upper arm circumference, crotch circumference, ankle circumference, and lower thigh circumference (see Table 1). The other hand the strength data were taken only standing strength for position with two-handed pull 100 cm height level of the handle.
Figure 3: Illustration of the power for 100 cm high level of the handle with two handed pull in standing posture.

5. Learning from Data and Simulating

The first step in this approach is retrieve physical dimension data to be simulated. Whichever methods are used, the output data of training value for ANN is in terms of static strength data for standing lifting with two-handed pull on 100 cm height level of the handle (Figure 3). Training is learning process by which inputs and output data are repeatedly presented to the network. This process is used to determine the best set of weights for the network, which allow the ANN to classify the input vectors with a satisfactory level of accuracy. In this study we want to see whether any correlation between types of physical dimensions and static strength for standing posture with two-handed pull on 100 cm height level of the handle.

From the result (Table 2) shows the static strength error of male workers (heavy industry) for different number of inputs of different physical dimension. It also show which part of the physical dimension have related to the static strength.

<table>
<thead>
<tr>
<th>Measured</th>
<th>Female (Light Industries)</th>
<th>Male (Light Industries)</th>
<th>Male (Heavy Industries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Weight</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Statute</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>KH</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LH</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ARF</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>UAC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>WC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CTC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LTC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>AC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Grasp</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>


* ✓: Selected Variables

Table 2. Root Mean Square Error (RMSE) for difference combination of parameters input.

The important result from this study is the artificial neural network can train the physical dimension data and human static strength data almost no significantly different compare to the output. Besides, ANN also can prove there are any relationship between physical dimension and human static strength.
The neural networks also able to produced model from human static strength in different position and different dimension of anthropometrics data. The model is stored as a set of neural network weights generating during the learning phase. In figure 3 above, shows that for male in heavy industries, the input parameters with the smallest RMSE (4.002) were age, weight, KH, UAC, CTC, and AC. With the pairwise t-test with 95% confident level was applied, there was no significant difference between predicted values and measurement values whereas \( p \)-value calculated was 0.456 \( (p<0.05) \). Figure 4 shows that results was approximately no difference compared to actual measurements. As a result that the ANNs model has capability with higher accuracy for predicting the standing strength with 100cm height level of male in light industries. Figure 5 shows that the number of passes also affects to the result. There is any certain number of passes that can make the smallest error. For the human static strength of two-handed pull 100 cm levels in standing posture for heavy industries workers have the smallest error when the number of passes is 20000.
exactly same with female in light industries such as Grasp. By using the pairwise t-test with 95% confident level, it was found that there was no significant difference between predicted values and measurement values whereas p-value calculated was 0.508 (p<0.05).

The Figure 6 shows that the accuracy of ANNs model for predicting was high, and slightly difference compared to actual measurements for male in light industries.

![Figure 6. Comparisons between measured and predicted for standing posture on 100cm height level of the handle (Male in Light Industries).](image)

The earlier numbers and types of parameters assumed for standing strength on 100cm height level was age, weight, stature, KH, NH, UAC, WC, AC, LTC, CTC, and Grasp, however, the combination of parameters were not exactly same. For female in light industries, the input parameters with the smallest error (RMSE = 2.108) were weight, stature, KH, NH, UAC, WC, CTC, AC, and Grasp.

The pairwise t-test with 95% confident level were applied, and found that there was significant difference between predicted values and measurement values whereas p-value calculated was 0.024 (p<0.05). Even though it was significant difference using pairwise t-test, but in the Figure 7 shows the predicted results approximately no difference compared to actual measurements.

![Figure 7. Comparison between Actual Measurement and Prediction for Standing Lifting on Height 100cm (Female in Light Industries).](image)
6. Discussions

The artificial neural network can be used to predict human static strength for different subject’s physical dimensions. These can be proved on the above graph and table that there are not significantly different between data measurement and ANN.

At the human static strength prediction for both male and female workers in light industries, age can affect the human static strength. The other hand the human static strength for male workers in heavy industries in the same position, age is affect to the human static strength.

From the results was shown that for the human static strength prediction of male workers in heavy industries need only 6 inputs parameter, but for male and female workers in light industries only 9 input to get the smallest error. Even between light and heavy industries had difference number of input, but there were no significant different especially in the shape of graph. However, there was still having any differences between data outputs from ANN and data measurement. These may caused there was not strong correlation between part of physical dimension and human static strength of two-handed pull 100 cm level.

Generally, the simulation results using ANN have at least two same values with the measurement data for each output parameter. All the inputs have been passed iteration 20000 times.

7. Conclusions

We conclude that artificial neural network can form the basis of physical dimension and weight for modeling human static strength and predict the human static strength for different physical dimension.

The strength predicting model that is developed will create into software, so that the users are easy to predict the strength. Next research, we will test the data and the result statistically and develop for predicting the other position of lifting strength and also dynamic strength model of workers.

References


