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# DEVELOPMENT AND APPLICATIONS OF ARTIFICIAL NEURAL NETWORK FOR PREDICTION OF ULTIMATE BEARING CAPACITY OF SOIL AND COMPRESSIVE STRENGTH OF CONCRETE

**By**

**SEYED JAMALALDIN SEYED HAKIM**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science**

**December 2006**

## DEDICATION

**I wish to dedicate this work especially, to my dear late father who passed away during the duration of my study.**

**I dedicate this work to my mother for her continuous prayer, encouragement and patience.**

**I dedicate this work to my wife, Sarah for her sacrifices of her health and time to provide me with a suitable environment. Her patience and encouragement was the drive for me.**

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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**December 2006**

**Chairman : Associate Professor Jamaloddin Noorzaei, PhD**

**Faculty : Engineering**

Artificial Neural Networks (ANNs) have recently been widely used to model some of the human activities in many areas of science and engineering. One of the distinct characteristics of the ANNs is its ability to learn from experience and examples and then to adapt with changing situations. ANNs does not need a specific equation form that differs from traditional prediction models. Instead of that, it needs enough input-output data. Also, it can continuously re-train the new data, so that it can conveniently adapt to new data. This research work focuses on development and application of artificial neural networks in some specific civil engineering problems such as prediction of ultimate bearing capacity of soil and compressive strength of concrete after 28 days.

One of the main objectives of this study was the development and application of an ANN for predicting of the ultimate bearing capacity of soil. Hence, a large training set of actual ultimate bearing capacity of soil cases was used to train the network.

A neural network model was developed using 1660 data set of nine inputs including the width of foundation, friction angle in three layer, cohesion of three layers and depth of first and second layer are selected as inputs for predicting of ultimate bearing capacity in soil. The model contained a training data set of 1180 cases, a verification data set of 240 cases and a testing data set of 240 cases. The training was terminated when the average training error reached 0.002.

Many combinations of layers, number of neurons, activation functions, different values for learning rate and momentum were considered and the results were validated using an independent validation data set. Finally 9-15-1 is chosen as the architecture of neural network in this study. That means 9 inputs with a set of 15 neurons in hidden layer has the most reasonable agreement architecture. This architecture gave high accuracy and reasonable Mean Square Error (MSE).

The network computes the mean squared error between the actual and predicted values for output over all patterns. Calculation of mean percentage relative error for training set data, show that artificial neural network predicted ultimate bearing capacity with error of 14.83%. The results prove that the artificial neural network can work sufficiently for predicting of ultimate bearing capacity as an expert system. It was observed that overall construction-related parameters played a role in affecting ultimate bearing capacity, but especially the parameter “friction angle” play a most important role. An important observation is that influencing of the parameter “cohesion” is too less than another parameters for calculating of ultimate bearing capacity of soil.

Also in this thesis is aimed at demonstrating the possibilities of adapting artificial neural networks (ANN) to predict the compressive strength of concrete. To predict the compressive strength of concrete the six input parameters, such as, cement, water, silica fume, superplasticizer, fine aggregate and coarse aggregate identified. Total of 639 different data sets of concrete were collected from the technical literature. Training data sets comprises 400 data entries, and the remaining data entries (239) are divided between the validation and testing sets. The training was stopped when the average training error reached 0.007. A detailed study was carried out, considering two hidden layers for the architecture of neural network. The performance of the 6-12-6-1 architecture was the best possible architecture.

The MSE for the training set was 5.33% for the 400 training data points, 6.13% for the 100 verification data points and 6.02 % for the 139 testing data points. It can recognize the concrete in term of 'strength' with a confidence level of about 95%, which is considered as satisfactory from an engineering point of view. It was found from sensitivity analyses performed on a neural network model that the cement has the maximum impact on the compressive strength of concrete.

Finally, the results of the present investigation were very encouraging and indicate that ANNs have strong potential as a feasible tool for predicting the ultimate bearing capacity of soil and compressive strength of concrete.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMBANGUNAN DAN PENGGUNAAN JARINGAN NEURAL ARTIFISIAL (JNA) UNTUK MERAMAL KEUPAYAAN GALAS TANAH DAN KEKUATAN MAMPATAN KONKRIT**

Oleh

**SEYED JAMALALDIN SEYED HAKIM**

**Disimber 2006**

**Pengerusi : Profesor Madya Jamaloddin Noorzaei, PhD**

**Fakulti : Kejuruteraan**

Sejak kebelakangan ini, Jaringan Neural Artifisial (JNA) digunakan secara meluas untuk memodelkan sesetengah aktiviti manusia dalam kebanyakan bidang sains dan kejuruteraan awam. Salah satu ciri-ciri yang nyata kelihatan adalah keupayaan JNA mempelajari daripada pengalaman, contoh-contoh dan seterusnya menyesuaikan dengan perubahan keadaan. JNA tidak memerlukan persamaan formula yang spesifik,tetapi tidak bagi petilikan model tradisional. Selain daripada itu, ia juga memerlukan data input-output yang secukupnya. Ia juga boleh merujuk data yang baru secara berterusan adaptasi kepada data baru lebih menyenangkan.Kajian ini memfokuskan pembangunan dan aplikasi Jaringan Neural Artifisial (JNA) dalam sesetengah masalah kejuruteraan awam yang spesifik seperti penganggaran kapasiti muatan mutlak tanah dan kekuatan mampatan konkrit selepas 28 hari.Salah satu objektif kajian ini adalah membangunkan dan mengaplikasikan JNA untuk penganggaran kapasiti muatan mutlak tanah.Oleh itu, satu set rujukan yang besar daripada kes kapasiti muatan mutlak tanah yang sebenar telah digunakan sebagai rujukan kepada JNA.

Satu model JNA telah dibangunkan dengan menggunakan 1660 set data daripada 9 input termasuk keluasan tapak, sudut cengkaman/geseran 3 lapisan, kohesi 3 lapisan dan kedalaman lapisan pertama dan kedua telah dipilih sebagai input untuk menggangarkan kapasiti muatan mutlak tanah. Model tersebut mengandungi satu set data rujukan sebanyak 1180 kes, satu pengesahan set data yang terdiri daripada 240 kes dan juga satu set data ujian yang terdiri daripada 240 kes. Rujukan terhadap data diberhentikan apabila purata kesilapan mencapai 0.002.

Banyak kombinasi lapisan-lapisan, bilangan neuron, fungsi pengaktifan, nilai yang berbeza untuk kadar sandaran dan momentum telah diambil kira dan keputusan telah disahkan dengan menggunakan set data pengesahan yang tiada hubungan. Akhirnya 9-15-1 telah diputuskan sebagai kerangka JNA. Ini menunjukkan satu lapisan tersembunyi dengan satu set sejumlah 15 neuron mempunyai keserasian yang paling wajar. Kerangka ini memberikan kejituan yang tinggi dan MSE yang sewajarnya.

JNA mengira "mean squared error" antara nilai output sebenar dengan nilai output anggaran dalam pelbagai bentuk. Pengiraan relatif purata peratusan dalam rujukan set data menunjukkan JNA dianggarkan akan memperolehi kejituan kapasiti muatan mutlak sebanyak 85 %. Keputusan telah menunjukkan bahawa JNA mampu bekerja secara cekap untuk penganggaran kapasiti muatan mutlak. Melalui pemerhatian, keseluruhan parameter yang berkaitan dengan pembinaan memainkan peranan yang akan menjejaskan kapasiti muatan mutlak terutamanya parameter sudut cengkaman/geseran.

Satu pemerhatian telah menunjukkan bahawa parameter kohesi adalah sangat rendah berbanding parameter lain yang digunakan untuk mengira kapasiti muatan mutlak tanah.Tesis ini juga bertujuan untuk menunjukkan kemungkinan menggunakan JNA untuk menganggarkan kekuatan mampatan konkrit. Enam input parameter seperti simen, air, debu silika, superplasticiser, pasir kasar dan pasir halus telah ditentukan untuk menganggarkan kekuatan mampatan konkrit. Sejumlah 639 set data berlainan daripada konkrit telah diambil daripada sorotan literatur. Set data rujukan terdiri daripada 400 masukan data dan masukan data yang selainnya (239) dibahagikan kepada set pengesahan dan set ujian. Rujukan diberhentikan apabila purata kesilapan rujukan mencapai 0.007. Satu kajian yang mendalam telah dijalankan dengan mengambil kira dua lapisan tersembunyi dalam kerangka JNA. Prestasi kerangka JNA 6-12-6-1adalah kerangka JNA yang paling baik.

MSE untuk set data rujukan adalah 5.33% untuk 400 mata data rujukan, 6.13% untuk 100 mata data pengesahan dan 6.02% untuk 139 mata data ujian. Ia dapat mengenalpasti konkrit dalam terma “kekuatan” dengan tahap keyakinan sebanyak 95% di mana ia telah dianggap sebagai memuaskan dari pandangan kejuruteraan. Daripada analisis sensitiviti yang telah dijalankan menggunakan model JNA, didapati simen mempunyai impak yang paling maksimum dalam mampatan konkrit. Sebagai kesimpulan, keputusan daripada kajian yang dijalankan adalah sangat menggalakkan dan menunjukkan JNA mempunyai potensi yang tinggi untuk dijadikan peralatan yang baik untuk menganggarkan kapasiti muatan mutlak tanah dan kekuatan kuasa mampatan konkrit.

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I certify that an Examination Committee has met on 20th December 2006 to conduct the final examination of Seyed Jamalaldin Seyed Hakim on his Master of Science thesis entitled "Development and Applications of Artificial Neural Network for Prediction of Ultimate Bearing Capacity of Soil and Compressive Strength of Concrete" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981.The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are follows:

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Date: 12 APRIL 2007

## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

**SEYED JAMALALDIN SEYD HAKIM**

Date:

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