TWO DIMENSIONAL DIRECT CURRENT RESISTIVITY MAPPING FOR SUBSURFACE INVESTIGATION USING COMPUTATIONAL INTELLIGENCE TECHNIQUES

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To my beloved parents, Othman Awang Ngah and Zarina Md Sharif, who have much faith in me.

To all my brothers and sisters who have stood by me.

To my respected supervisor, Dr Herman Wahid.

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ABSTRAK

Kajian ini dilakukan bertujuan mengkaji penggunaan rangkaian neural tiruan (ANN) dalam menyelesaikan pemetaan rintangan dua dimensi untuk kajian bawah permukaan bumi. Algoritma rangkaian neural yang dicadangkan adalah berdasarkan fungsi asas jejari (RBF) dan pelbagai lapisan perceptron (MLP) metamodel. Pendekatan konvensional seperti kaedah kuasa dua terkecil (LS) digunakan sebagai penanda aras dan perbandingan untuk menilai algorithma yang dicadangkan. Beberapa set data sintetik dihasilkan berdasarkan konfigurasi hibrid Wenner-Schlumberger dengan menggunakan perisian RES2DMOD. Data sintetik ini digunakan untuk menguji dan melatih cadangan algoritma. Kajian simulasi dilakukan untuk membandingkan antara cadangan algoritma dan kaedah kuasa dua terkecil berdasarkan faktor keberkesanan dan variasi ralat berbanding nilai sebenar. Berdasarkan kajian simulasi, cadangan algoritma menunjukkan prestasi yang lebih baik dalam keberkesanan dan perbezaan ralat yang lebih kecil berbanding kaedah kuasa dua terkecil. Hasil simulasi menunjukkan cadangan algoritma mampu menyelesaikan masalah songsang dan mampu digambarkan dalam bentuk grafik dengan berkesan.

ABSTRACT

The purpose of this study is to investigate the application of artificial neural network (ANN) in solving two dimensional Direct Current (DC) resistivity mapping for subsurface investigation. Neural network algorithms were proposed based on radial basis function (RBF) model and multi-layer perceptron (MLP) model. Conventional approach of least square (LS) method was used as the benchmark and comparison for the proposed algorithm. In order to train the proposed algorithm, several synthetic data were generated using RES2DMOD software based on hybrid Wenner-Schlumberger configurations. Results were compared between the proposed algorithm and least square method in term of its effectiveness and error variations to actual values. It was discovered that the proposed algorithms have better performance in term of effectiveness and have minimum error difference to actual model as compared to least square method. Simulations result demonstrated that proposed algorithm can solve the inverse problem and can be illustrated by graphical means.

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LIST OF ABBREVIATIONS

1D	-	One dimensional
2D	-	Two dimensional
3D	-	Three dimensional
MSE	-	Mean square error
RMSE	-	Root mean square error
MAE	-	Mean absolute error
R^2	-	Coefficient determination
d_2	-	Index of agreement
GUI	-	Graphical user interface
ANN	-	Artificial neural network
RBFNN	-	Radial basis function neural network
MLP	-	Multi layer perceptron
DC	-	Direct current
IP	-	Induced polarization
GPR	-	Ground penetrating radar
EM	-	Electromagnetic
AEM	-	Airborne electromagnetic
FDEM	-	Frequency domain electromagnetic
TDEM	-	Time domain electromagnetic
VES	-	Vertical electrical sounding
NN	-	Neural network
GA	-	Genetic algorithm
PSO	-	Particle swarm optimization

LIST OF SYMBOLS

Hz	-	Hertz
Ω	-	Ohm
Ωm	-	Ohm meter
f(x)	-	Function of x
∑	-	Summation
Q	-	Number of outputs
w_i	-	Weights in output layer
X	-	Input applied
X_i	-	Training data point
μ	-	Center
σ	-	Spread factor
exp	-	Exponential
min	-	Minutes

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CHAPTER 1

INTRODUCTION

1.1 General overview

Geophysics is an interdisciplinary study that relates the physical science with nature of the earth. Environmental behavior is characterized and interpreted through knowledge of physical science. In order to understand the structure and physical properties of the earth, geophysics combines knowledge and laws of physics, mathematics and chemistry. This study demands crucial information on the characterization properties that applies in geotechnical investigation, petroleum reservoir study, mining and environmental application.

Human needs geophysics in order to obtain conceptual model and visualization of the subsurface. Subsurface investigation requires multiple collections of data based on certain physical quantities. Geophysicist obtain conceptual model from analyzing and interpreting these data. Physical properties that are being concerned in this area of study are electrical resistivity, thermal conductivity, dielectric permittivity, magnetic susceptibility, acoustic velocity, natural radioactivity and density.

In general, geophysical measurement can be divided into two main categories which are active and passive. For active category, measurements are based on subsurface response to seismic energy, electrical and electromagnetic. Meanwhile, measurement based on earth's ambient magnetic, gravitational fields and electrical is known under passive category. With the help from proper tool, information from these two measurements is very helpful in mapping subsurface under investigation.

Geophysical methods can be subdivided into two main techniques which are surface and subsurface or bore hole method. In geophysical surface method, collection of data can be done quickly with less interference from other subjects. As for borehole method, drilling is required in order to insert wells or borings into the subsurface for measurement purpose. In the past, bore hole method is rarely being implemented due to high cost. However, in recent years, with new technologies, bore hole method is widely applied with cost effective. This study will only focus on subsurface investigation.

In subsurface investigation, difficulty to interpret measurement of data obtain from the equipment are risen. Data provided by the equipment did not indicate subsurface condition specifically and deviates from the expected standard due to numerous features. Thus, combination of other site information is suggested as an effective way to resolve ambiguities in geophysical survey.

Geophysical survey technologies have multiple approaches based on physical quantities and application as discussed earlier. The most popular approach is electrical method. Potential field and seismic approach also widely used depending on application. This study however will only concentrate on electrical method.

1.2 Problem Statement

In geophysical surveys, the most important aspect is to make inference about geophysical parameters obtained from the data measurement. Generally, the data that obtained from the laws of physics computation is known as forward problem. However, process of obtaining the data from sets of measurements and reconstruct the model is known as inverse problem. This model reconstruction based on data has becoming more challenging in geophysical surveys. Therefore, researchers have proposed multiple estimation technique to cater the inverse problem and provide estimation that close to actual model.

This work will only focus on two dimensional apparent resistivity inverse problem. The information on two-dimensional apparent resistivity will be used for inversion process in order to determine the actual resistivity of the subsurface. Therefore, this work will proposed a suitable method to solve the inversion process by using computational intelligence technique. Real data measurements are required to train the proposed method, however, factors such as hardware and time limitation will caused implementation problem. In order to cater this problem, synthetic data generation from software that are based on real measurement will be required.

1.3 Objectives of Study

This work requires three main objectives that need to be accomplished at the end of this work. The first objective is to solve the two dimensional apparent resistivity inverse problem using computational intelligence technique such as neural networks. The second objective is to train the proposed technique with synthetic data

samples obtained for different homogeneous mediums. The third objectives is to compare the proposed technique effectiveness with the conventional approach.

1.4 Scope of Study

The scope of this project is to simulate the proposed technique using MATLAB software. The proposed method will be trained with synthetic data that being generated from an open source software, RES2DMOD. Calculation of several statistical analysis such as Root Mean Square Error (RMSE), Mean Absolute Error (MAE), determination coefficient and index of agreement are part of the work scope and need to be compared with desired values. Finally, the significant findings must be compared with conventional approach by means of GUI programming in order to illustrates the results.

1.5 Outline of the Thesis

This project report consists of five main chapters. In first chapter, the main discussions are about the problem statement, objective and scope of work. General introduction about this work also included in this chapter in order to give readers an overview of this work.

Literature reviews are well discussed in the second chapter. In this chapter, the discussions are on geophysical measurements method, resistivity imaging techniques, inverse problem and also Artificial Neural Network (ANN) learning

method. This discussions are mostly based on information of previous researches findings.

In Chapter 3, the proposed methodology are discussed on how to generate synthetic data and implement Radial Basis Function Neural Network (RBFNN) and Multi Layer Perceptron (MLP) technique to solve the inverse resistivity problem. Development of reconstruction image and performance analysis is also discussed in this chapter.

Discussion on the work's findings is presented in Chapter 4. Appropriate and significant results and findings of each techniques will be well discussed in this chapter. Comparative analysis between each technique is also discussed in this chapter.

Last but not least, Chapter 5 discusses the conclusion of this work. Several limitations of this work are mentioned in this chapter and suggestion for future work also being included in this last chapter. This work's significant findings are proposed for future reference.

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