

**RAINFALL-RUNOFF MODELLING IN BATANG LAYAR AND OYA
SUB-CATCHMENTS USING PRE-DEVELOPED ANN MODEL FOR
TINJAR CATCHMENT**

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*This project report is dedicated to
my beloved mother and father,
my dearest brother and sister
for their love and support*

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ABSTRACT

Artificial Neural Network (ANN) has been widely used to forecast Rainfall-Runoff relationships. Many ANN has been developed by experts in order to forecast Rainfall-Runoff relationships in certain catchment. However, there are uncertainties whether the developed ANN can be used to forecast Rainfall-Runoff relationships in other catchments dominantly, just like how it can forecast Rainfall-Runoff relationships for its purposed catchments. Therefore, the purpose of this study is to check whether a developed ANN for forecasting Rainfall-Runoff relationships in Sungai Tinjar catchment can be used in two other catchments which are Batang Layar and Hulu Batang Oya. The network was trained using Back Propagation Algorithm. The Back Propagation Algorithm consists two phases; forward phase and backward phase. The variant used is Resilient Backpropagation (trainrp). To do the training, Matlab 7 computer software was used. This study had successfully proven that a developed ANN for forecasting Rain-Runoff relationships in Sungai Tinjar Catchment is achievable for Batang Layar and Hulu Batang Oya Catchment; however deeper understanding and further improvement of the network are necessary.

ABSTRAK

Rangkaian Neural Buatan (ANN) telah digunakan secara meluas untuk meramal kaitan antara jumlah hujan pada sesuatu masa dan saliran. Banyak ANN telah dibina oleh pakar bagi mendapatkan ramalan kaitan antara jumlah hujan pada sesuatu masa dan saliran untuk kawasan tadahan tertentu. Namun, terdapat beberapa ketidakpastian samada ANN yang telah dibina untuk meramal kaitan antara hujan dan saliran untuk satu kawasan tadahan boleh digunakan (untuk tujuan yang sama) di kawasan tadahan lain. Oleh itu, tujuan kajian ini adalah untuk memastikan samada ANN yang telah dibina bagi meramal kaitan antara hujan dan saliran di kawasan tadahan Sungai Tinjar dapat digunakan di dua kawasan tadahan lain iaitu Batang Layar dan Hulu Batang Oya. Rangkaian ini telah dilatih menggunakan *Back Propagation Algorithm*. *Back Propagation Algorithm* ini mengandungi dua fasa iaitu fasa hadapan dan fasa belakang. Perbezaan yang digunakan dalam rangkaian ini ialah *Resilient Bacpropagation (trainrp)*. Untuk membuat latihan ini, perisian Matlab 7 digunakan. Kajian ini telah berjaya menunjukkan bahawa ANN yang telah dibina untuk meramal kaitan antara hujan dan saliran di kawasan tadahan Sungai Tinjar dapat digunakan untuk kawasan tadahan Batang Layar dan Hulu Batang Oya, walaubagaimanapun pemahaman yang lebih mendalam dan pembaikan lanjutan adalah perlu.

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CHAPTER 1

INTRODUCTION

1.1 Rainfall-Runoff Relationship

Runoff, or in other words, discharge can be define as the draining away of rainfall or other liquid from the surface of an area. This can explain the fact that runoff is generated by precipitation. The flow which was caused by the rainfall will flow out through a river, from upstream to downstream. Although, there are other ways that the water can be abstracted from water surface, it has become a major concern that most of the water will discharge through stream flows and ended at the seas.

Runoff occurrence and quantity are dependent on the characteristics of rainfall event, such as intensity, duration and distribution. For example, the higher the intensity of rainfall, the higher runoff will occur in that catchment's area.

Rainfall-runoff is a hydrological model which determines runoff signal which leaves the watershed basin from the rainfall signal received by this basin. The relation between rainfall and direct runoff may be considered to have three aspects (Singh V. P., 1998):

- The relation between the volume of rainfall in a given storm and the resulting volume of direct runoff.
- The relation between the time distribution or hydrograph of direct runoff and the time distribution or hyetograph of the effective rainfall.
- The relation between rainfall frequency and discharge frequency.

1.1.2 Importance of Rainfall-Runoff Modelling

Modelling rainfall-runoff is very important as it has many purposes for doing it. The main purpose of modelling the rainfall-runoff is because of the limitation of hydrological data's measurement techniques (Baven K. J., 2001). In fact, there is limited range of measurement techniques especially when it comes to ungauged catchments (where measurements are unavailable) and to the future (where measurement is impossible).

1.3 What is Artificial Neural Network?

An artificial neural network (ANN) is a mathematical model or computational model based on how the information is being processed by a biological nervous system. Like mammalian nervous system, ANN consists of an interconnected group of neurons (which are artificially made in a computer system) and processes information using internal connecting operators which are doing all the computations. ANN is a non-linear statistical data modelling tool. And because of this, it has the ability of processing almost all of the complex computations or even for the purpose of modelling. In most cases, ANN is very adaptive as it can change its structures based on the external or internal information that flows in the network during the training phase.

1.4 Problem Statements

Rainfall-Runoff modelling conventionally has always been a very difficult job. It involves a lot of data which need to be analysed. However rainfall-runoff modelling is very essential in order to forecast the patterns of future runoff by observing and analysing previous patterns of runoff, based on the rainfall parameters.

But there is an efficient way to do the rainfall-runoff modelling which is by using Artificial Neural Network. By learning the patterns of the given input data of the rainfall-runoff relationship, ANN can forecast rainfall-runoff relationship. The accuracies of the predictions critically depend on how much it learns about the patterns.

Usually, experts will develop a neural network in propose of doing the rainfall-runoff modelling for one or more basin. But the question arrived from this mechanism is will the developed neural networks model the rainfall-runoff relationships for other basins, as good and dominant as it can do for it purposed basin?

1.5 Objective of the Study

The objective of this study is to check whether a developed Artificial Neural Network for Rainfall-Runoff relationship can be used dominantly in other catchments. For this study, the Artificial Neural Network which was recommended best by Hafiz F. A. (2004) to model Rainfall-Runoff relationship for Baram Basin will be checked whether it can be used in two other catchment areas. The parameters which will be used in this study are daily rainfall and runoff data at both sub-catchments. The two sub-catchments which will be chose are in Batang Layar Catchment and Batang Oya Catchment.

1.6 Outline of Chapters

Chapter 2 will discuss about the topics which are mainly related to the project such as Artificial Neural Network (ANN), the application of ANN in Rainfall-Runoff modelling and the application of ANN in other hydrological fields.

Meanwhile in Chapter 3, the topic which will be discussed is mainly about the methodology of the project. It will elaborate how the project is carried, problems occurred during the implementation of the project, and how the problems are solved.

In Chapter 4, results and analysis of the study will be discussed. The outcome of this study will be shown and analysis or discussions will be stated based on the outcomes.

The final chapter, Chapter 5 will discuss about the conclusion of this study. Recommendation may be stated if there are possible further studies which are related to this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The topics that will be discussed in this chapter is about Artificial Neural Network (ANN), the application of ANN in Rainfall-Runoff relationship, the developed ANN by Hafiz F. A. (2004) for Rainfall-Runoff relationship at Baram Basin and the application of ANN in other hydrological fields.

2.2 Artificial Neural Network

An Artificial Neural Network (ANN) is an information-processing system based on the operation of biological neural networks, in other words, it is an emulation of biological neural system which is densely interconnected and having a non-linear structure (parallel structure).

The idea of biological model of Artificial Neural Network is introduced in the form of simplified neurons by McCulloch and Pitts in 1943. McCulloch and Pitts (1943) stated that neurons are the basic signalling units of the nervous system and each neuron is a discrete cell whose several processes arise from its cell body (Michael M., 2006). The idea is to explain that the biological neuron system as conceptual components for circuits of our body that could perform computational task.

A neuron cell consists of four main components which are the dendrites, cell body (or soma), axon and synapses. The dendrites functioned as the input terminals where all the information (considered as the input) accepted. The information then will be processed by the cell body or in biological terms, can be call soma which contains the nucleus to maintain the protein synthesis. After being processed, the axon will conduct electric signals called action potentials to the synapses which will be connected with other dendrites of neuron cells. Each identical signal may be conducted to different neuron cells and finally will end up being processed by the brain. Then, the brain will analyze the patterns of signals being sent and interpret the type of information being received based on the path of the signal took (patterns). These processes occur in extremely high speed. Information can be processed in a very instant duration. Figure 2.1 shows the structures of a single normal neuron cell.

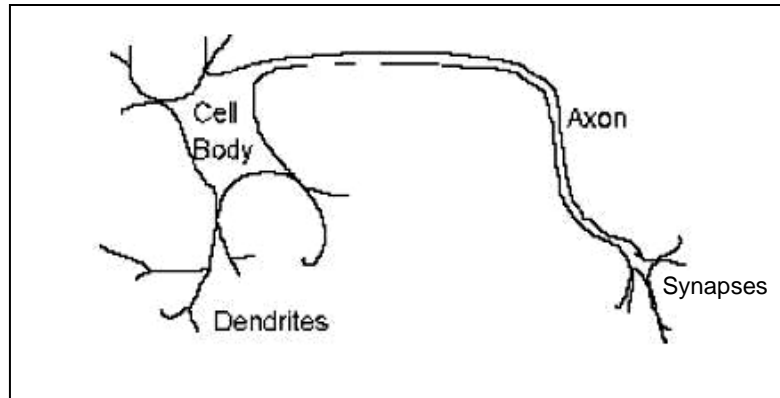


Figure 2.1: Parts of a Normal Neuron Cell

It is true that there are advanced computing systems nowadays. Unfortunately, these systems are not very reliable because there are certain assignments that are not executable by a program made for a regular microprocessor. Artificial Neural Network is a very efficient computation system which has many advantages such as;

- can perform tasks that a linear computer generated programs cannot.
- can continue even though an element of the network fails by its parallel (nonlinear) nature.
- can learn and there is no need to reprogram the network.
- can be implemented in any application without any problem.

Although, a system will typically has weaknesses and this includes the Artificial Neural Network (ANN) itself. ANN has some disadvantages such as;

- needs training to operate.
- the complexity of the ANN's structures is different from the structure of microprocessors therefore it needs to be emulated.
- time for processing a network is long.

Computation of an Artificial Neural Network is adaptive, nonlinear system which learns to perform a function (an input/output map) from data. The terms adaptive in the context of Artificial Neural Network (ANN) can be defined as ANN's system parameters which are changed during operation, called the training phase.

As been discussed before, the structure of an Artificial Neural Network is quite similar with the biological model of a nerve cell. In fact, its architecture is based on the biological nervous system. In ANN, the synapses of the neuron are modelled as the weights. Then, the actual activities within the soma of a neuron cell are modelled as the summing junction and the activation function. During the summing junction, an adder sums up all the inputs (linear combination) modified by their respective weights. Meanwhile the activation function controls the output of the neuron's amplitudes to an acceptable range, usually between 0 to 1, or -1 to 1.

2.2.1 Neuron Model and Network Architecture

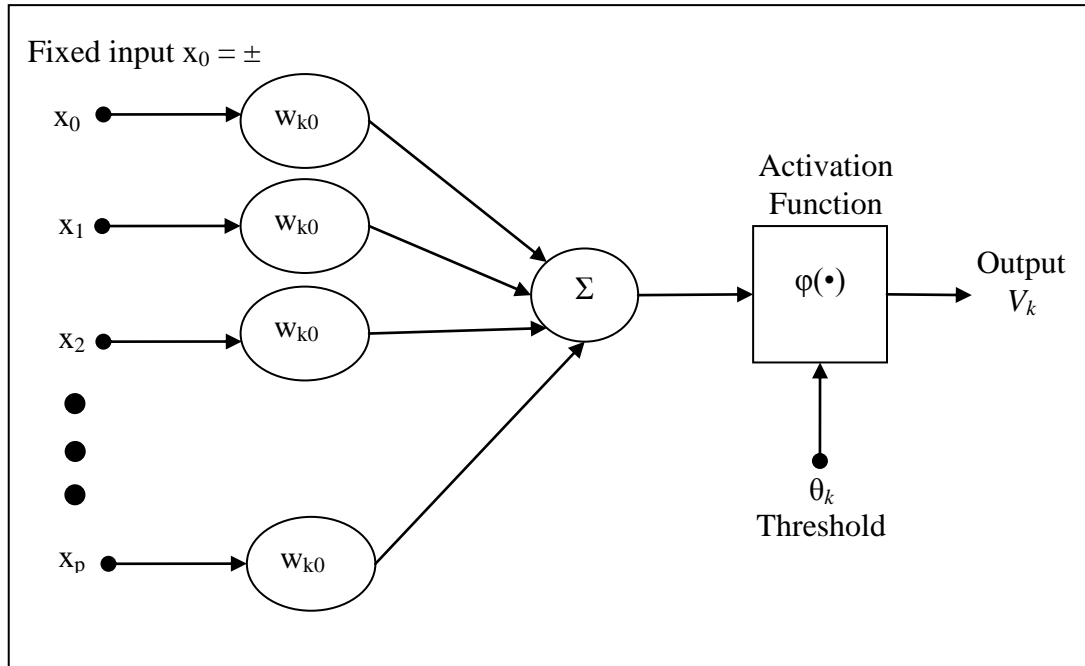


Figure 2.2: Mathematical Model of an ANN

From the mathematical model shown in Figure 2.2, the interval activity of the neuron can be expressed in Equation 2.1 as:

... Equation 2.1

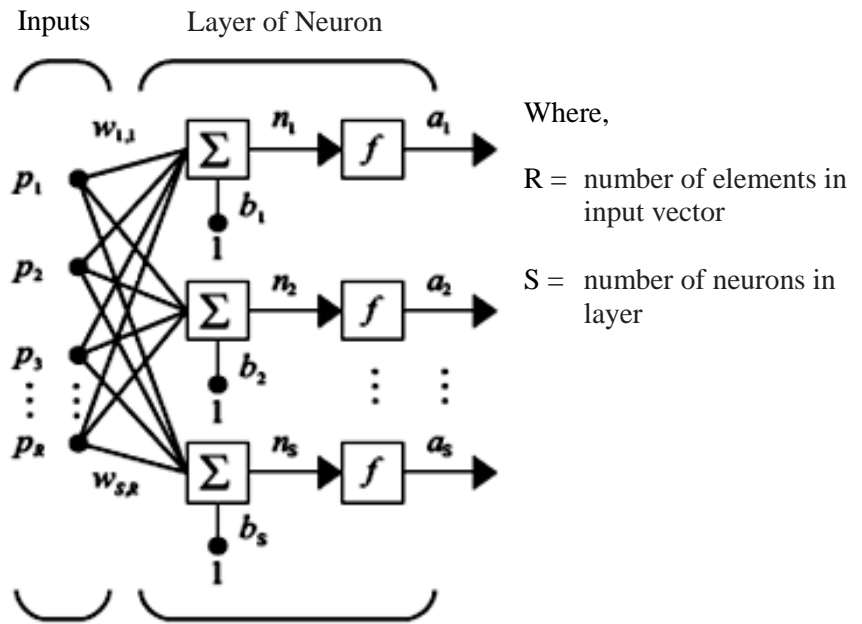


Figure 2.3: Network Architecture for Single Layer Network

Figure 2.3 shows the network architecture for a single layer network. In this network, weight matrix W is connecting each element of the input vector p to each neuron input. The i th neuron has a summer (noted as Σ) which will gathers its weighted inputs, (product of W matrix and p vector) and bias (noted as b in Figure 2.3) to form its own scalar output n_i . The various n_i taken together form an S -element net input vector n . Finally, the neuron layer outputs form a column vector a . Vector a can be expressed as:

$$a = f(Wp + b) \quad \dots \text{Equation 2.2}$$