Analog Neural Circuit by AC Operation and the Design of Deep Learning Model

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Abstract. In the neural network field, many application models have been proposed. Previous analog neural network models were composed of the operational amplifier and fixed resistance. It is difficult to change the connecting weight of network. In this study, we used analog electronic AC circuits. The connecting weights describe the voltage and input signal describe the frequency. It is easy to change the connection coefficient. This model works only on analog electronic circuits. It can finish the learning process in a very short time and this model will enable more flexible learning. However, the structure of this model is only one input and one output network. We improved the number of unit and network layer. Moreover, we suggest the possibility of realization about the hardware implementation of the deep learning model.

Introduction

We propose the dynamic learning of the neural network by AC operation analog electronic circuits. This model will develop a new signal device with the analog neural electronic circuit. One of the targets of this research is the modelling of biomedical neural function. In the field of neural network, many application models have been proposed. And there are many hardware models that have been realized. These analog neural network models were composed of the operational amplifier and fixed resistance. It is difficult to change the connection coefficient.

Analog Neural Network

The analog neural network expresses the voltage, current or charge by a continuous quantity. The main merit is it can construct a continuous time system as well as a discrete time system by the clock operation. Obviously, the operation of the actual neuron cell utilizes analog. It is suitable to use an analog method for imitating the operation of an actual neuron cell. Many Artificial neural networks LSI were designed by the analog method. Many processing units can be installed on a single-chip, because each unit can be achieved with a small number of elements, addition, multiplication, and the nonlinear transformation. And it is possible to operate using the super parallel calculation. As a result, the high-speed offers an advantage compared to the digital neural network method [1][2].

Overview

The results of the neural network research provide feedback to the neuro science fields. These research fields have been widely developed. The learning ability of a neural network is similar to the human mechanism. As a result, it is possible to make a better information processing system, matching both advantages of the computer model and biomedical brain model. The structure of the neural network usually consists of three layers, the input layer, intermediate layer and output layer.
Each layer is composed of the connecting weight and unit. A neural network is composed of those three layers by combining the neuron structures.

In the field of neural network, many application methods and hardware models have been proposed. A neuro chip and an artificial retina chip are developed to comprise the neural network model and simulate the biomedical vision system. In this research, we are adding the circuit of the operational amplifier. The connecting weight shows the input voltage of adding circuits. In the previous hardware models of neural net-work, changing connected weights was difficult, because these models used the resistance elements as the connecting weights.

Moreover, the model which used the capacitor as the connecting weights was proposed. However, it is difficult to adjust the connecting weights. In the present study, we proposed a neural network using analog multiple circuits. The connecting weights are shown as a voltage of multiple circuits. The connecting weights can be changed easily. The learning process will be quicker. At first we made a neural network by computer program and neural circuit by SPICE simulation. SPICE means the Electric circuit simulator as shown in the next chapter. Next we measured the behavior confirmation of the computer calculation and SPICE simulation. We compared both output results and confirmed some extent of EX-OR behavior.

**SPICE**

In this research, we used the electric circuit simulator SPICE. Electric circuit simulator (SPICE) is the abbreviation of Simulation Program with Integrated Circle Emphasis. It can reproduce the analog operation of an electrical circuit and the electric circuit. After this, the circuit drawn by CAD, set the input voltage. SPICE has the function of AC, DC and transient analysis. At first, we made the differential amplifier circuits and Gilbert multipliers circuits. And we confirmed the range of voltage operated excellently. The neuron structure was composed of multiple circuits by an operational amplifier for multiplication function achievement, current mirror circuits to achieve nonlinear function and differential amplifier circuits.

In the previous hardware model of neural network, we used the resistance element as a connecting weight. However, it is difficult to change the resistance value. In the neural connection, it calculates the product the input value and connecting weight. We used the multiple circuit as the connecting weight. Each two inputs of multiple circuits means an input value and connecting weight. The connecting weight shows the voltage value. It is easy to change the value in the learning stage of neural network.

Figure 1 is the neural circuit of two inputs and one output which reproduces the characteristic of one neuron, using current addition by current mirror circuits, the product of the input signal and connecting weights. In the neural circuit, we have to use adder and subtraction circuit as input part of each synapse. In our previous research, we used adder and subtraction circuit by opamp.
AC Operation Neural Circuit

We proposed analog neural network in the previous research [3]. However, the working range is very small because of the semiconductor characteristics. We tried to use the alternative current in the analog neural network in Figure 2. The alternative current has two elements, voltage and frequency. In the previous model, we use the multiple circuit to calculate the input signal and connecting weight. However, this AC circuits can calculate the products voltage and frequency by CR circuits. Figure 3 is the output of AC operation neural circuit. It operates satisfactorily in the frequency range from 3kHz to 30kHz.
Dynamical Learning Model

We propose the dynamical learning model using a pure analog electronic circuit. We used analog neural network, explained in a previous chapter. In the learning stage, we used analog feedback circuits. We use a separate neural network of each teaching signal. Real time learning is possible. We used the sample hold circuit in the working stage. It can hold the connection weights. In the working stage, this neural network is working. This circuit can perform periodical work, learning mode and working mode.

On the other hand, the pulsed neural Network has an advantage. Particularly, this network can also keep the connecting weights after the learning process. However, it takes a long time for the learning process when many pulses are required. As the typical pulsed neuron model, about 1000 pulses were required for the learning process. However, our proposed model is constructed with a cheap electrical device. If we use the high quality analog electrical device, the learning speed will be improved more than pulsed neuron model. In the result of this experiment the performance is low because of using general-purpose, inexpensive parts. The operating speed will be improved by using a high-performance element which has a good slew rate. However, this system is a simple circuit. The number of parts is few. The cost will not rise much even if good performance parts are used.

Deep Learning Model

Recently, a deep learning model has been proposed. Deep learning is a kind of algorithms in learning model. It attempts the high-level categorizing of data using multiple non-linear transformations and one method of machine learning. In the field of image recognition and speech recognition, the deep learning method has attracted the attention [4].

The Stacked Auto Encoder

The stacked auto-encoder is one method of deep learning. This is the pre-learning method of large number layer network. How to construct the deep layer network is as follows.

After the learning process of stacked auto-encoder is completed, remove the decoding part (output layer) of stacked auto-encoder and keep the coded portion (from the input layer to the intermediate layer) shown in Figure 4. Thus we obtain the network which converts from input signal to compressed information representation shown in Figure 5.

Moreover, we obtain more compressed internal representation, as the compressed representation input signal to apply the auto-encoder learning. Thus, we obtain a multi-layered hierarchical network, recursively repeated auto-encoder learning, and stacked the encoding part of the network. This constructed multilayer network is called stacked auto-encoder. In this way, after building a multi-layer network, to add the identified network using the output of the final layer, a new supervised learning method is proposed.

![Figure 4. Learning the Auto-encoder and Removing the Decoding Part of Stacked Auto-encoder.](image-url)
Stacked auto-encoder has been applied to the various subject as well as the DNN which is stacked the RBM. Recently, it became famous the learning experiment of feature extractor from a large amount of image.

In the previous research, we described the dynamical neural network learning model. However, this model has only one input unit and one output unit. To realize the hardware deep learning model, we have to increase the number of units in each layer. Next, we constructed a 2 input, 1 output and 2 patterns neural model.

**Conclusion**

We constructed a three-layer neural network, two-input layers, two-middle layers and one output layer. We confirmed the operation of the three layer analog neural network with the multiplying circuit by SPICE simulation. The connection weight can be changed by controlling the input voltage. This model has extremely high flexibility characteristics. When the analog neural network is operated, the synapse weight is especially important. It is how to give the synapse weight to this neural network. To solve this problem, it is necessary to apply the method of the back propagation rule that is a general learning rule for the neural networks. This neural circuit model is possible the learning. The learning speed will be rapid. And dynamic learning will be realized. The method is calculating the difference between the output voltage and the teaching signal of the different circuits and the feedback of the difference value for changing connecting weights. The learning speed of this model is very high in spite of a very simple circuit using low cost elements.

The learning time of this model is very short and the working time of this model is almost real-time. The pulsed neuron model represents the output value by the probability of neuron fires. To represent the analog quantity using the Pulsed Neuron Model, enough time for at least a few dozen pulses is needed. The output value of this model is the output voltage of this circuit. We don’t need to convert the data; we can use the raw data from this model. This model allows for switching the working mode and learning mode. It is always necessary to input the teaching signal. However, the connecting weight changes according to the changing of the teaching signal. This model can also easily accommodate changes in the environment. In each scene, optimal learning is possible. It will improve the artificial intelligence element with self-dynamical learning. The realization of an integration device will enable the number of elements to be reduced. The proposed model is robust with respect to fault tolerance. Future tasks include system construction and mounting a large-scale integration.

Moreover, deep learning method is proposed recently. If this system improved toward the deep learning model, many applications will be realized. It is a kind of algorithms in learning model. It attempts to high-level categorizing data using multiple non-linear transformations and one method of machine learning. In the field of image recognition and speech recognition, the deep learning method has attracted the attention. We suggested the possibility of realization about the hardware implementation of the deep learning model. It will improve the artificial intelligence element with self-dynamical learning. The realization of an integration device will enable the learning time to be reduced. The proposed model is robust with respect to fault tolerance. Future tasks include system construction and mounting a large-scale integration.
References


