# Neurochip using stochastic logic

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A neural-network utilizing stochastic logic, which has been proposed by Kondo et al. [1], is one of the pulse neural networks. One can convert analog quantity to pulse firing rate by stochastic logic, and various complex operations can be done with basic logic gates. For example, multiplication is done with a single AND gate. Also, non-monotonic functions are realized by choosing suitable random number used for stochastic operation. Therefore, the number of transistors in a chip can be reduced greatly while the reliability is high.

Stochastic logic realizes pseudo analog operations using stochastically coded pulse sequence [2]. A coding circuit, which is a simple digital comparator, encodes a digital input value in a stochastic pulse sequence as shown in Fig.1, where $X$ is a digital value to be coded, $X_{\max}$ is the maximum value of $X$, and $R$ is a random number which ranges [0 : $X_{\max}$] uniformly. The comparator outputs "1" if $X < R$, or "0" else, and the decoding circuit, which is an up/down counter, counts pulses. Then the expectation and the variance of a decoded value $\tilde{X}$ are given as,

$$E[\tilde{X}] = X_{\max} N_a P_f / N_a = X, \quad (1)$$

$$V[\tilde{X}] = X_{\max}^2 N_a P_f \left(1 - P_f\right) / N_a^2 = X\left(X_{\max} - X\right) / N_a, \quad (2)$$

where $N_a$ and $P_f$ are accumulation time and firing probability, respectively. Eq. (2) implies that the quantity of the coding noise can be controlled by $N_a$. The stochastic property disappears as $N_a$ becomes large.

We have designed and fabricated stochastic neurochips [3], [4] in which non-monotonic neurons are introduced in order to improve association property as shown in Fig.2. Also, a network with higher order synaptic connections shown in Fig.3 has been implemented. We can realize a complex function with less transistors by stochastic logic, and such an extra functionality added to a neuron is useful for performance enhancement.

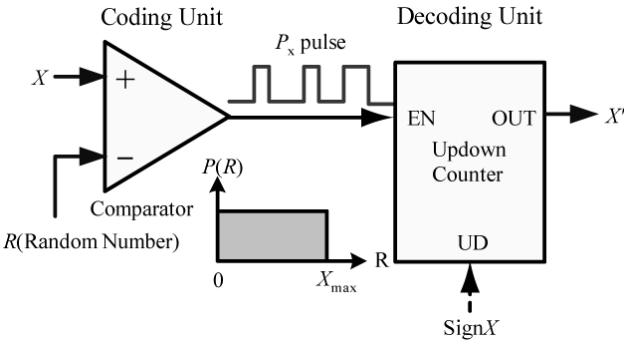


Fig.1 Coding and decoding units of stochastic logic.

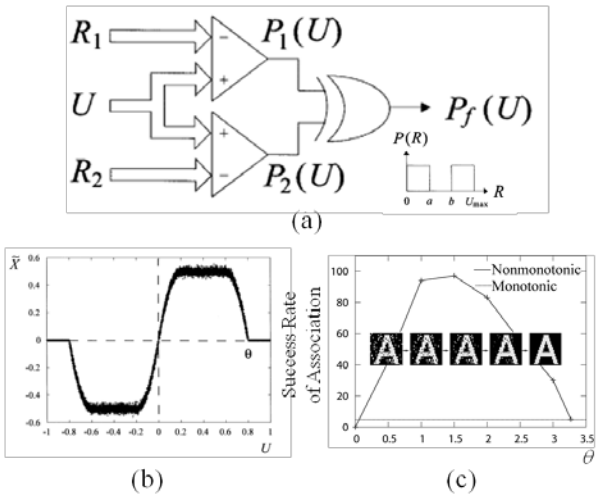


Fig.2 (a) Non-monotonic neuron circuit using stochastic logic, (b) Non-monotonic function, (c) Success rate of association as a function of the 2nd threshold θ.

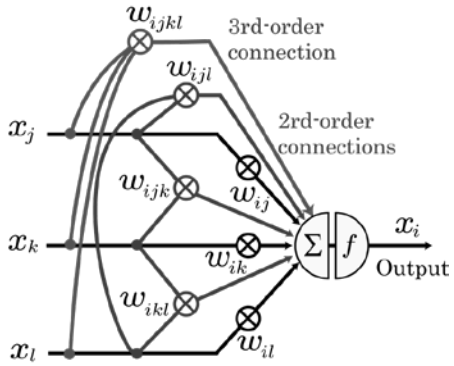


Fig.3 A neural network with higher order connections for solving optimization problems.

## REFERENCES

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