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Architecture on the Device for Information Processing controlled by Consciousness
－A bottom-up approach for engineering on the mechanism of brain－

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Abstract

Activities on the multiple areas of the new cortex are controlled by thalamus. There is neural circuit that reciprocates between the thalamus and primary visual cortex (V1). In this paper, the function of this circuit is explained as follows. Data retention time on the circulation is controlled by thalamus. A nerve cell outputs an impulse as recognition of one set of pixels that occur at the same time. Priority of activity is controlled by the hypothalamus at each instant. Since voice is varied along the time axis, the serial inputs are converted to parallel outputs by hippocampus. Each impulse from a neuron is the representative of a group of impulses through the segmentation. If neural network was formed a hierarchical structure, the activities of each layer is overlapping. Each representative possesses individual retention time. It can be realized in the form of a network of subroutines.

Keywords consciousness, vision, language use, brain, thalamus, nerve cells, impulse, subroutine

1. Introduction

This report describes the brain mechanism that is processing by transferring impulses. It is a time-sharing system by a synchronous control. It would be helpful to the design of the device to handle the various data that entered in large quantity.

The mechanism of brain circuits has become clear fairly [1-2]. However, there are differences in detail among those descriptions. In order to fully understand the neural circuit, it is necessary to understand the signal processing by impulse. The impulse is an activity that represents the achievement of the rule. Neural network must deal with the impulsive response. The problem is how to maintain activity in the impulse transfer circuit.

In 2000, the authors reported the mechanism of nerve circuit to perform the information processing by transference of the impulses [3]. He also reported the memory of serial data by the granule cells in 2007 [4], and he reported the mechanism of automatic sensitivity control of retina in 2009 [5]. After that, he recognized that the control of visual data on V1 is carried out by the thalamus through looped circuit.

The author understands the mechanism of consciousness as follows. The human being thinks by using words. But the other animal has intelligence without language use. So, the mechanism of vision by consciousness has been acquired before language use.

Therefore, the architecture of information processing apparatus having a mechanism of consciousness is discussed after the description of the brain mechanism of vision under the control of consciousness.

2. The mechanism of human vision

2.1. Control of the neural network by thalamus

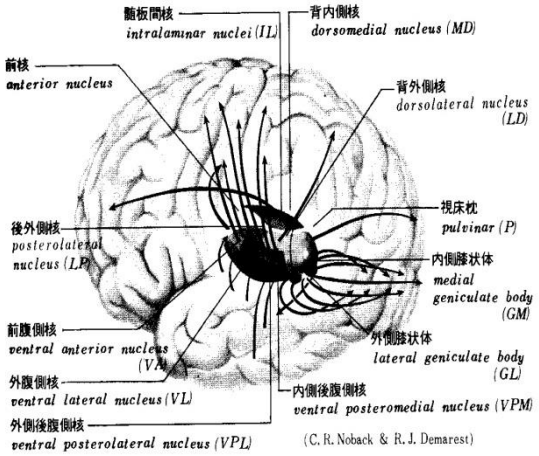

Fig.1. Nerve circuit between the thalamus and cerebral cortex (by C.R. Noback & R. J. Demarest, copied from the reference [4] p. 16)

As shown in Fig.1, the impulses are projected to the specific part of neocortex through the thalamus. The activated portions in the nerve circuits in the brain are changed by the circumstances at each moment.

The thalamus is a gathering of nuclei in the top of the brain stem, and it has nerve tracts to various areas of the neocortex in the cerebrum. The nerve cell is only transfer

the impulse. However, it is possible to control the transferring at the passing through the thalamus.

The propagation due to neurons is one-way traffic. It is necessary another neural circuit in order to propagate in the opposite direction. The action potential from nerve cell is very short time, and it occurs respectively.

2.2. The nerve circuit between V1 and thalamus

There are two routes from retina to the brain. One route is connected to primary visual cortex (V1). The other route is connected to the superior colliculus for eye movement.

As shown in Fig.2, V1 receives impulse from thalamus and it sends the impulse to thalamus. If the connections between V1 and thalamus are formed loop circuits, the circulating impulse is retained as a short-term memory.

A sub-cortical structure (later area) receives impulse from V1 and it sends impulse to V1. Then, a particular group of impulse sent from sensory input area is recognized by certain neuron in the later area.

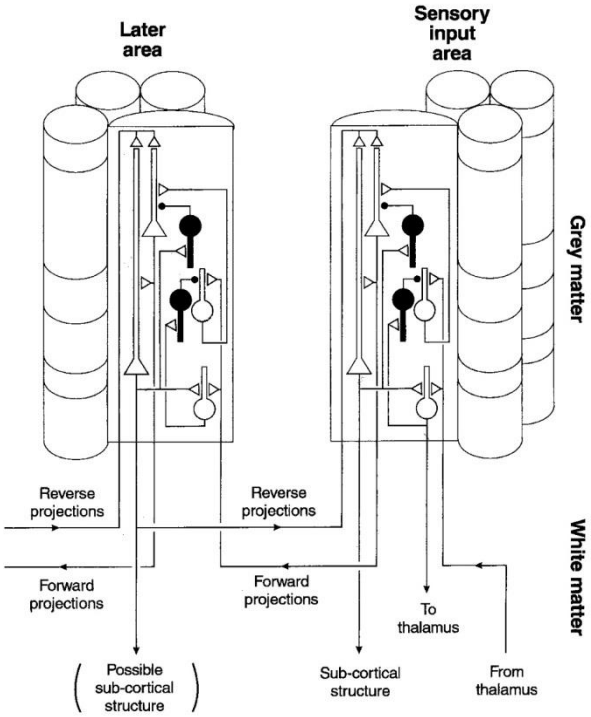

Fig.2. The nerve circuit on the visual area of cat, the work of C.D. Gilbert and T. N. Wiesel [5], (copied from Fig 7.8 in reference [6] p.205,).

The thalamus receives impulses from the primary sensory area. Moreover, the thalamus receives impulse from the superior colliculus for eye movement. There, the temporal activation on V1 is changed by the signal on movement of the viewpoint.

As shown in Fig.3, there is also a disinhibition pathway from the cerebral cortex to the excitatory nerve pathways.

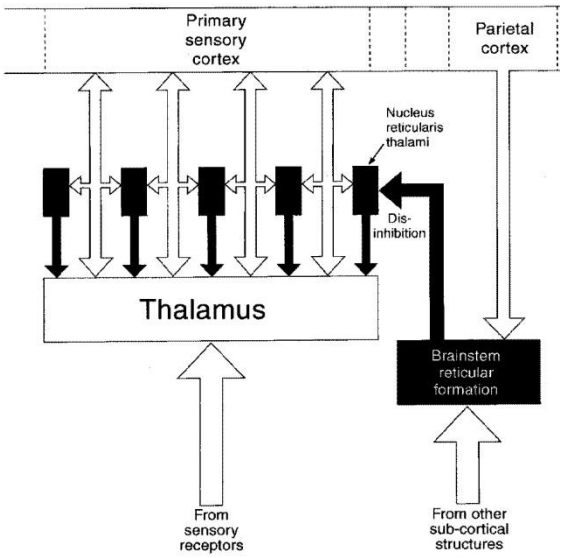

Fig.3. Excitatory nerve pathways from the hypothalamus, there are routes of disinhibition from the other cortex. (This figure was copied from Fig 7.11 in the reference [6], p.225)

2.3. Neural circuits surrounding the brainstem

The brain stem communicates with sensors, actuators and cerebrum. Those linkages are shown in Fig.4.

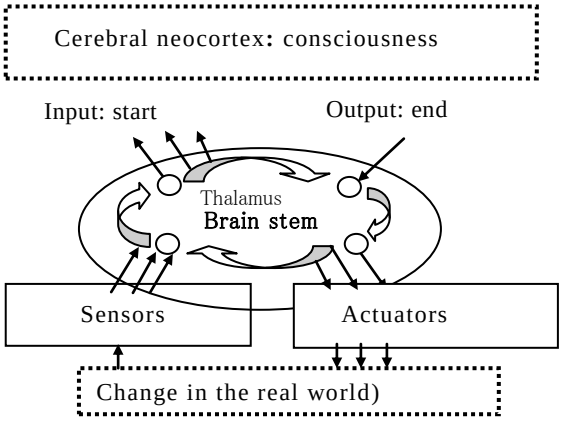

Fig.4. The brainstem that relays the information to sensory organs, cerebrum and actuator

2.4. Time-sharing processing for vision.

The movie consists of 24 frames of images per second. Each frame is a still image. But we perceive the movie similarly to the natural phenomena. We do not recognize the intermittent change of the frame. This fact indicates that our vision is time-sharing system.

Zeno of Elea（he was active in the 460s BC） produced

the paradoxes “Arrow is stopped even if flying”([9]p.115). The shape of the object may recognize from still images. The motion may recognize by comparing still images in continuous intermittent images.

The “present” is a reality, and “think” is of information processing in the brain. There are differences. H. Bergson (1859-1941) wrote “When we think this present as going to be, it exists not yet, and when we think it as existing, it is already past”([10] p.214).

2.5. The meaning that is included in nerve circuit

Reaction of a neuron is not continuous, and it is not linear phenomenon. It stands up in a short period of time and disappears immediately, i.e. it is the impulse. The output indicates fulfillment of the conditions to be fire the impulse from nerve cell. The conditions are memorized by connections of the nerve cell.

A nerve cell will be connected to the axons of neurons those are activated at the same time. The neuron outputs an impulse to the subsequent neurons, if the integral value of inputs exceeds the threshold.

There is the refractory period that is needed to return to the previous state. So, every reaction in the nerve system proceeds in one-way traffic.

Fig.5 shows relationship between impulse function δ(t) and step function of U(t).

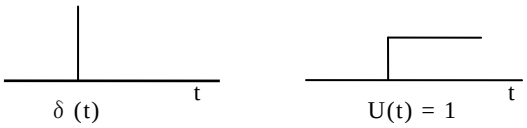

Fig.5 An impulse response δ (t) and unit step function U(t)

$$\int \delta(t)dt = U(t) = 1 \qquad (1)$$

As expressed in equation (1), U(t) is integration of δ(t). An impulse causes a change, it corresponds the force in the case of Newtonian mechanics. The impulsive force brings step up of the speed. The length of distance will change linearly by the impulsive force. The situation changes by the impulsive reaction. Sensor in a living body detects the results immediately and the input is updated. That constitutes a cycle of feedback in a nerve system.

An impulse of neural network has a positive charge. It may react with surrounding molecules by the ionization that deprives electrons. So, the transmission of impulse can form the circuit to replay its activities.

It is considered that the information processing by positive impulses had begun from the transference of proton. The hydrogen ions (H^+: proton) does not possess electron, it is easy to move. And the proton is responsible for hydrogen bond. So, the organization of the molecules in the living body is deformed by transference of the proton. The control of organization can is carried out by transference of protons.

2.6. Reaction of neuron and its recognition

Since the reaction of a neuron corresponds to accomplishment of the rule, a digital event of impulse is recognized as the achievement of analog rule.

When transference of an object from point A to point B at the next processing, it is recognized as if the object has moved in a straight line from A to B in an analog manner.

Enormous amount of neurons are involved in human vision. A large amount of rules (nerve cells) are active at the same time. It is understood that all of them is the analog.

2.7. Activities of view field and point of view

The human performs visual recognition of the localization (Where is it?) and recognition of identification of each image (What is it?). The former is included in the signal processing of view field, and the latter is included in the system of point of view.

The nerve system of visual field is formed first. After that, the nerve system of viewpoint was formed. For, the signal processing on the point of view relates to neocortex of brain. The neocortex has been developed in human brain. Association area occupies 2/3 of the neocortex [12].

When a new ability is added, the traditional reaction and newly added activities are activated concurrently. Although the overlapped activations take place at the same time, the higher priority is given to newly added activities.

The thalamus gives priority to the command from the neocortex by suppressing the command from instinctive area. On the other hand, the thalamus receives the information from the superior colliculus. The activities in the visual area of neocortex are controlled by the signal on movement of eyes.

Two regions are required for the operation of control. One is control area and the other is the area to be controlled. If it is a time-sharing system, it does not matter to interchange the control region to the area to be controlled.

In macular at center region in human retina, cones are present only. The cones are responsible for color vision

with bright vision. The thalamus relays the image in the macular area to the neocortex and it is compared with the image stored. The reaction is selected by the information that has been stored.

As for the region of the visual field, rods are present. The rod is sensitive to faint light, and it reacts by brightness finely. The information from visual field is sent to the superior colliculus where information processing for the unconsciousness activities is carried out.

3. Information processing of serial data

3.1. Structure and function of hippocampus

Neural pathways of the hippocampus are shown in Fig.6 and Fig.7.

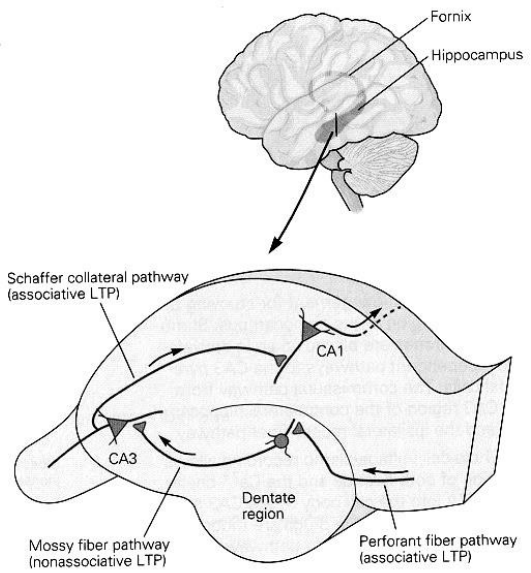

Fig.6 Cross section hippocampus (from reference [1] p.1257 Fig.63-7)

Three-dimensional structure of hippocampus is shown in Fig.6. The hippocampus has a structure like a banana. It consists of dentate gyrus (DG) and hippocampus. The nerve cell in DG is the granule cell. The nerve cell in hippocampus is the pyramidal cell. The granule cell of which axon is mossy fiber connects with plural of pyramidal cells.

Principal signal transmission of the hippocampus is shown in Fig.6. The information enters through perforating fiber (pp), and it transferred to hippocampus (CA3 → CA2 → CA1) via the dentate gyrus(DG). At last, it sent to the entorhinal cortex (EC) in the cerebrum.

Entorhinal cortex (EC) is an old area in the course of evolution, it has been widely linked to the entire cerebrum.

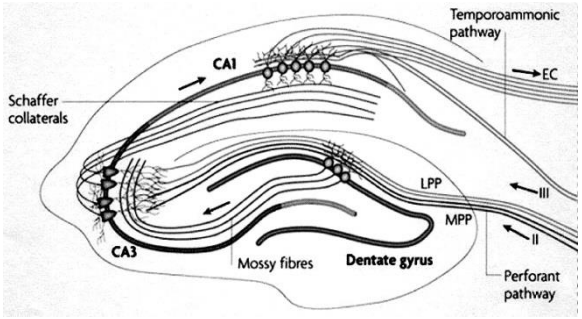

Fig.7 Principal nerve circuits in hippocampus (from http://www.nature.com/nrn/journal/v11/n5/images/nrn2822-f1.jpg)

When the refractory period of granule cells is short, the serial impulses those enter one after another are inputted to parallel fiber. The parallel fiber in which exists impulse will be connected by means of the excitation due to the impulse that comes from the cerebrum.

The model is shown in Fig.7.

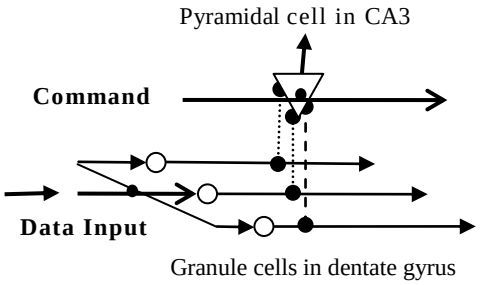

Fig.8 The timing of serial impulses sent from sensor is recorded in the nerve circuit under the following assumptions. That is, the transmission velocity of the axon of granule cell is slow, and the refractory period of granule cell is short.

A model of the neural circuit for storing the impulse train is shown in Fig.8. Here, it is assumed that the refractory period of granule cell is short and the propagation velocity of axons of the granule cells is slow.

Serial impulses can be placed in the fiber, if the refractory period of granule cell is shorter than the distance between the impulses. The length of serial data depends on propagation velocity and length of the fiber.

The propagation velocity of the impulse is dependent on the channel density of axons. it is assumed that the propagation speed of parallel fibers is slow. So, the delay time of parallel fibers differs by length of propagation. So, serial impulse train is placed in the fiber. Since the axon of granule cell is mossy fiber, it is able to connect to pyramidal cell in the various positions.

A pyramidal cell will be connected to a set of fibers at the time when the impulse of writing instruction is arrived from cerebrum. Therefore, the serial pulses can be memorized as the connecting points between pyramidal cell and the set of parallel fibers.

The direction of transference of activated area is shown in Fig.6 and Fig.7. There are reported that activated area progress spirally in the hippocampus ([12] p.18-23). It shows that the active region of the hippocampus is moved.

3.2. Refractory period of neuron

The nerve cell receives neurotransmitter molecules in a narrow synaptic gap and it changes synaptic potential. The action potential that is a spike of +30 mV～+50mV, occurs in the neuron when the resting potential of about -80mV becomes over -40mV by the change of synaptic potential.

The action potential usually finishes within 1 millisecond. The refractory period occurs more than a few milliseconds after the generation of an impulse. Therefore, the delay time longer than refractory period is required for one circulation in the loop for short-term memory.

Serial impulses are possible to enter in a parallel fiber in case of short refractory period of granule cell. A refractory period of serial input will be used as the signal for segmentation of the serial-parallel conversion.

3.2. How memorize serial data in cerebellum

Main neural circuits of the cerebellum are shown in Fig.9. There are granule cells of intermediate-mediated cells. It is considered that these granule cells generate serial impulses similarly to hippocampus.

The cerebellum is received inputs from sensory organs of the body via spinocerebellum and precerebellar nuclei. Moreover, It receives input through pontine nuclei in the brain stem, and it also receives the input that has passed through the inferior olivary nucleus and red nucleus in relation to voluntary movement from the cerebral cortex area (Ref. [2], Chap.15, Fig.8).

Purkinje cell received only one climbing cell. The signal from climbing specifies the timing of connection. At the moment of the impulse for connection, the parallel fiber, in which there is an impulse of serial data will be connected to the Purkinje cell. The Purkinje cell with the many delay lines converts a serial data into paralleling connections.

It is known that input from the parallel fiber and climbing fiber to the Purkinje cell is excitatory. But Purkinje cells outputs the inhibitory impulse to deep cerebellar neurons (DCN). The inhibitory impulse controls the other activities by suppression.

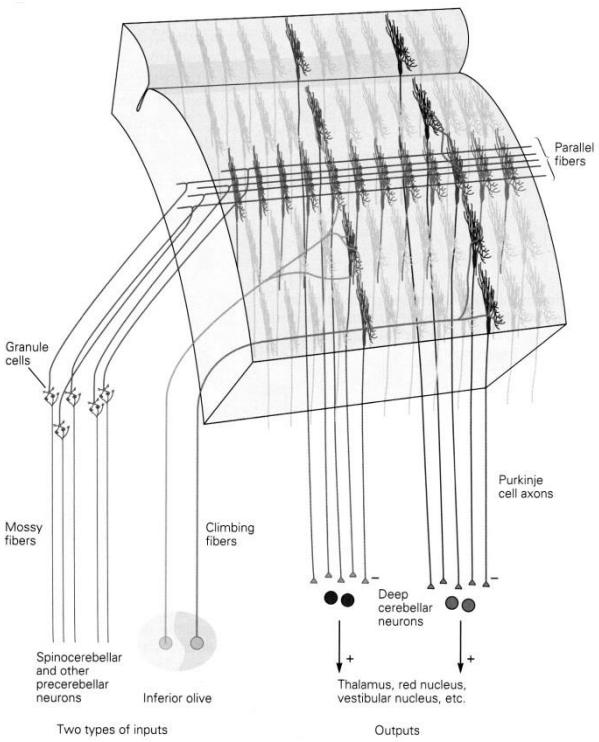

Fig.9 Nerve circuits in cerebellum （from reference [1] p.838 Fig.42-7）

If it is assumed that Purkinje cell generates inhibitory impulse when the impulse of the excitatory does not come, it is possible to reproduce the serial data at the timing of reproduction instruction sent from climbing fiber.

But the operation of pyramidal cell in hippocampus is not the same to Purkinje cell. A buffer cell for a loop circuit and a control circuit for stopping the circulation are needed in order to keep the written signal data in pyramidal cells.

3.3. Analysis of the data sheet by nerve cells

A impulse train propagates in a parallel fiber in the case that the refractory period of granule cell is short and the propagation velocity of the axons of the granule cells is slow.

When a sensor generates serial impulses of a component along time progress, the data of total components become two-dimensional. Data sheet is given to the neocortex in units of separated. It can be analyzed by the method of pattern matching data for this pattern. That is, the recognition of two-dimensional data is recognized in the same way as vision.

4. Information processing for behavior control

4.1. Mechanism of control by impulses

We remember an action by means of pose by frame by frame, and the smooth operation is possible by pose control of frame advance. The reason is that, the timing control is memorized in synchronization with the actual operation. The data required for the behavior of the robot are the angle of each joint at before and after, and the transition time [13]. The data on unit action of the robot is shown in Fig.10.

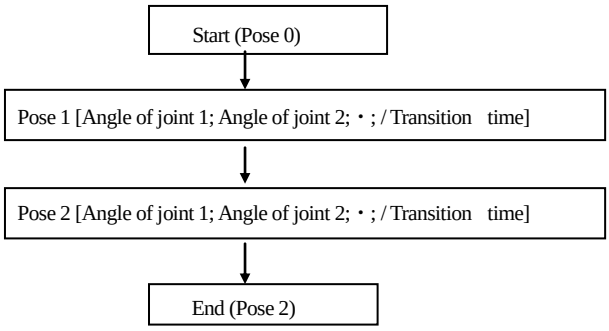

Fig.10 The implementation of an action is carried out by using data on angles of joint and transition time.

4.2. Description of behavior by hierarchical structure of representatives

The hierarchical structure of representatives is shown in Fig.11.

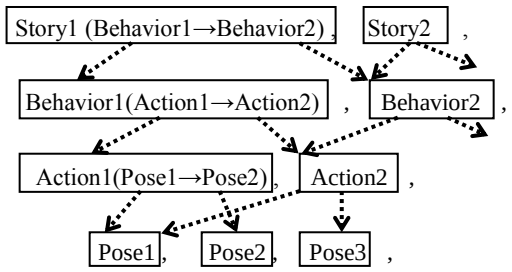

Fig.11 A connection of neurons for control of behavior (arrow indicates direction of flow at the replay)

A nerve cell in a network of neurons generates an impulse by the set of concurrently activated impulses. In order to form the circuit of upper layer, the impulse train that includes all of the impulse train of the lower layer is necessary. At the implementation, activation of the constituent that arrives ahead must be held until at the time that the last of the serial data arrives.

The implementation is carried out by calling the subroutines. In case of replay by the top down method, the activity of representative in higher layer must be continued until the end of the series of representatives in the lower layer. Such control of activation is carried out by the thalamus.

Program of behavior are formed by the bottom-up and executed from the top down. The program of behavior control is described by the connection of the hierarchical structure of the operation of the robot series (subsumption architecture [14]).

5. Mechanism of thinking

5.1. Is language use most important intelligence?

The intelligence is carried out by transference of the impulse in the neural network where each impulse is a representative of the reaction. The information is the representation that indicates things and affairs in the real world.

The human beings use language to express their knowledge. The language use is the function that was newly added to existing intelligence. The newly added knowledge has the higher priority than existing knowledge.

Human has the tendency that the priority of operation is given to the theory. But, the experience of language use is important than knowledge of grammar.

5.2. Attempts to build a world of “Logos”

The human has attempted to understand the world through the reason from 6^{th} century BC. It is possible to glimpse from the sentence written by Heraclitus (his peak is early 6^{th} century BC). “The upward and downward paths are the same ([10] p.14)”. Universal concept can be extracted by removing or by extracting the same. It is the beginning of science.

The activity of mind is extrapolation of the trends and events that were experienced individually. Even the knowledge obtained in the information is extrapolation of the trends and events that mankind has experienced.

In order to correspond to the real world, activity suitable for the present moment is required.

6. Conclusions

This report described the brain mechanism including consciousness by the mechanism of the impulse circuit.

There is a limit to guess the mechanism of thought by

thought. To infer the unconscious processing is difficult. To persist in the mechanisms is necessary, even if it deals with mind.

The consciousness is an activity that controls the other nerve cells. The activity of consciousness is controlled in the same manner as action. The thalamus includes the mechanism that controls the activity of the neocortex of the cerebrum.

The mechanism of intelligence by transference of impulses is carried out by time-sharing system by a synchronous control. It can be realized in digital technology.

The intelligent apparatus having a mechanism of consciousness is realized calling subroutines as similar manner to the CPU. Layered structure of intelligence can be realized by assigning the activity of subroutine hierarchically. Furthermore, the semiconductor device that stores the charge as a representative of impulse can be manufactured.

The author hopes that this report will contribute for development of "Engineering of Mind [15]".

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