Decoder-for-neuron translation models for brain mechanisms

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This paper presents the decoder-for-neuron translation models for brain mechanisms, in which the decoder functions when the pre-conditions are satisfied. The information is represened by the existence of impulses. The impulse is always on the move. The pattern of transmitting impulses can be memorized in the form of synaptic connections and the pattern of connections is able to represeut the activity.

The model of a column in the cerebral cortex is considered as the working memory which is comprised of the impulse recurrent loops and an [AND] circuit where the loop functions as a register and the AND circuit functions as a decoder. The brain mechanism is explained by the columnar organization by the synaptic connections which make possible to link the other columns not only in the same layer but also in the upper layer and in the lower layer. The organized module is able to carry out the function of a cerebrum.

The functional models for a hippocampus and a cerebellar cortex are also obtained by applying the proposing method to the neuroanatomical diagrams.

Key Words : Brain mechanism, Columnar organization, Cerebral cortex, Cerebellar cortex, Hippocampus.

1 Introduction

Many researchers investigate how to manufacture the equivalent machine that works in the same way of a human brain[1]. There are similarities in the faculty between human brain and digital computer, but there are differences in the way of executions.

The neural system is a distributed autonomous system. The reaction of a neuron is an impulse owing to the biochemical characteristics. The pattern of the firing neurons represents the circumstances. The brain mechanism needs automatic implementation of a great number of such decoders. But the computer can not implement the programs during the operation.

It can be said from the biological view point that today's neural network made of programs such as 'back propagation method' or 'Hopfield networks[2]' may develop the computerization but these approaches can not be the straight strategy to understand the brain mechanism.

An impulse is the key to understand the mechanism. Registers are necessary for intelligent activities and a looped circuit is able to hold the impulse in it. The neuron carries out individual role specialized by synaptic connections and the impulse in a nerve fiber causes the next reactions.

In 1994, we manufactured the autonomous robot in which the decoder is used as the universal element[3]. The system can be classified as a behavior-based robot. R.A.Brooks proposed the subsumption architecture for behavior-based robot in 1986[4]. But the hardware of our robot indicates that decoders and pathways of the robot looks like the feature of neurons and pathways in the brain. That is, the area of decoders corresponds to the gray matter and the area of pathways coresponds to the white matter.

The neuroanatomical investigations directly make clear the neural structures of the brain. But, not all the neuroanatomical constitutions are clear. There are uncertainties. Then, the proposing decoder-for-neuron translation diagram is not always obtained by the automatic translation.

The proposing circuits are thought out in order to achieve the function under the conditions of electronic circuits. The circuits include assumed structures which may differ from original existences slightly, but investigations about assumed circuits have the meaning to find out new architectures for the intelligent system.

The top-down approache makes clear the role of the part, but the bottom-up approaches is also the tool of this study, for the elements are easy to understand.

2 The decoder-for-neuron translation model

2.1 The individualities of intelligence

The intelligence is inseparable from the behavior. Many loops of biochemical reactions makes possible to achieve the activities of a life. The rules of the behavior are implemented through it's experiences. Then, completely the same intelligence can not exist. There is no creature posessing with the same position or the same situation.

The individuality of experience makes individuality of the creature and the similarity of the experiences makes the similarity of the creature. It can be said that even if the artificial intelligence is given by the same way of ourselves, the intelligence in the machine can not be identical to our intelligence, for the machine can not raised up by the same treatments to the human being.

This paper does not mention about contents of the intelligence but discussses about how to realize the intelligence in the form of circuits.

2.2 The representative of a neuron

We can consider that a neuron functions as a decoder, for the decoder functions when pre-conditions are satisfied. The pre-conditions of the firing is depends on the connections. The meaning of an impulse is the satisfaction on the conditions of firing with a thresold logic[5].

Since a decoder transfers input into output, the function of the decoder can be considered as a memory. The memory in the form of the decoder is a working memory which is able to function without other circuits.

In the logical aspest, the function of decoder can be described by [AND] logic for the pre-conditions. So, we use the peculiar mark, which is similar to AND circuit, as the symbol of the impulse decoder in this paper.

As for the software, the decoder is described by a proposition of 'if-then rule'. The if-then-rule is termed as 'the production rule' by Simon,H.A.,[6] and the concept forms one of the field of artificial intelligence.

2.3 The looped neurons

The impulse propagates along one direction in a tract of linked neurons owing to the after-effect of the action potential. Moreover, the propagation has a delay time.

If the delay time for the propagation around a looped neurons is larger than the time of after-effect on a neuron, the impulse is able to round the loop. The loop generates consecutive impulses during its activity. The rounding activity can not stop by itself, but it may vanish by the synaptic inhibition controlled by the other pathway. If the rounding stimulus is vanished, the loop stays without an activity.

The recurrent loop is able to hold one stimulus temporarily and this loop is formed by synaptic connections. The synaptic connections correspond to the long-term memory[7].

2.4 The role of an inhibitory synapse

According to the De Morgan's theorem, [AND] circuit on inhibited inputs and the inhibited output act as the excitatory [OR] circuit. In other words, the multiple inputs of [OR] connections can be implemented by the [AND] connections where inverted signals for the inputs and an inverted signal for the output are used.

De Morgan's theorem;

$$\text{NOT}(\text{NOT}(A)^{*}\text{NOT}(B)) = A + B \cdots (1)$$

But, the De Morgan's theorem can not be applied in the neural system, for an excitatory receptor changes the cytoplasmic potential to positive direction whereas an inhibitory receptor changes to negative direction. There is a neutral state. The excitatory operation in an inhibitory system needs excitatory signals.

The actual neuron in a cerebellum such as Purkinje cell, basket cell, stellate cell, Golgi cell possess with excitatory inputs and the inhibitory output. By putting together the facts concerned, we can consider that inhibitory neurons generate negative impulses under the condition of the absence of excitatory inputs. For, the excitatory [OR] operation may carry out by an [AND] circuit with low threshold. The input stage of outgoing motor nerves need numbers of [OR] connections for the overlapping control. These proposing operations of the neuron may explain the function of cerebellum clearly as described in section 5.

3 The circuit for sampling

The operation of a serial control must accompany with the timing. We consider how to acheive the timing control in the hippocampus as an example. The neuroanatomical structure of a hippocampus is shown in the reference [8] pp.433.

The decoder for neuron translation model on a hippocampus is shown in Fig. 1. Here, the main neuroanatomical configuration is inspired by the reference [8], whereas the tetanic part of Fig.1 is inspired by the reference [9]. The symbol similar to AND circuit in the diagram represents to a neuron. The arrow sign in the diagram indicates the direction of transmission.

By the way, the sampling operation is carried out by AND circuit between the input and the timing impulse. The timing impulse is given by a propagating impulse which scans the array. The circuit for sampling looks like the neuroanatomical structure of hippocampus.

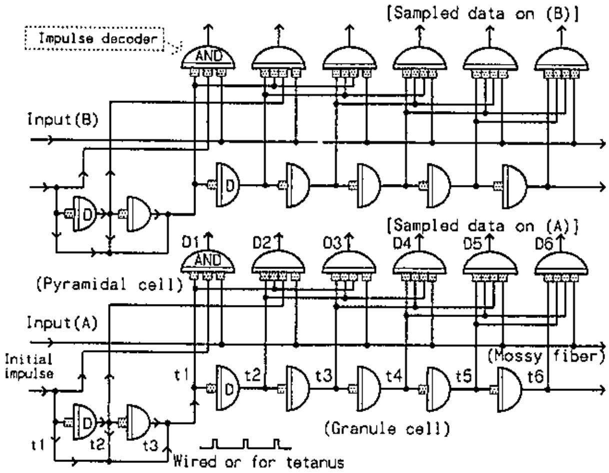

Fig. 1. The decoder for neuron translation model for a hippocampus

Moreover, Fig.1 shows overlapped connections which provide the tetanic stimulation. The timing of the sampling for the tetanic impulses are carried out AND circuits as shown in Fig. 1.

The tetanus operations achieves not only the robust control but also it provides the hold time which make the parallel operation possible. The successive impules caused by the overlapped connections are superior than that caused by recurrent loop, for the latter needs signal to stop the repetition.

4 The decoder-for-neuron translation model for the cerebral cortex

4.1 The structure of a building block

The most interesting item, that we want to know, is the brain mechanism. That is, how does it remember the information and how can we explain the mechanism of thought. The target of our reserch is focused on the cerebral cortex.

The function of a cerebral cortex is divided into various regions. Many areas of the cerebral cortex can be identified by the modern techniques, such as magnetic resonance imaging (MRI) and positoron emission tomography (PET). The observations reveal that each part of the brain links mutually and the excited parts contribute to the behavior. The pattern of the firing neurons represents the activity of the brain.

The cross-sectional appearance on the cerebral cortex are divided in six layers within the gray matter. We can get a building block on the brain mechanism from the cross-sectional features of the cerebral cortex.

The column structure in a cerebral cortex can be seen in the reference [10] pp.20 as an example. We can see a set of neuron forms one column in which a packed fibers runs up-and-down through the layers of the cortex. The columns correspond to the fundamental elements of the brain mechanism.

The 8 types of the principal neurons in a cat's visual cerebral cortex are shown in the reference [11] pp.608 after Gilbert and Wiesel (1981).

By considering functions and connections of neurons, shown in reference [11], we propose the circuit shown in Fig. 2 for a building block of cerebral cortex.

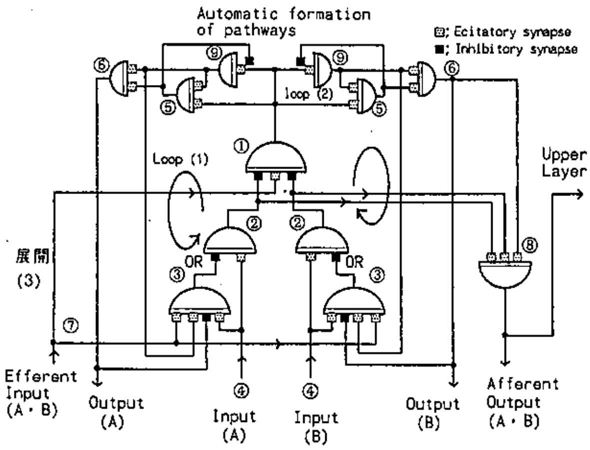

Fig. 2 The decoder for neuron translation diagram for a fundamental module in the cerebral cortex.

Here, the blackly painted rectangle indicates the inhibitory synapse which has control functions by suppressing the excitation. The dotted rectangle indicates the excitatory synapse.

4.2 The operations of a building block

The operations of the fundermental module shown in Fig.2 can be considered as follows;

[Step 1] The inputs are decoded by AND circuit① after passing through OR circuit②. In case of the output of the decoder① is connected to horizontal fibers, the recurrent loop (1) will be functioned and the impulse rounds the loop.

[Step 2] The looped circuit (1) for an impulse functions as a working memory. Another loop of neurons (2) is needed in order to reinforcse the primal horizontal connection. The loop functions in order to suppresse the synaptic connections around the neighboring area.

[Step 3] The route from one output of the decoder① to an input of upper layered module, acts an afferent route as shown in Fig. 3.

[Step 4] If an output of a module is connected to inputs of the lower layered module and the lower layered outputs are able to link the more lower layer, the route acts an efferent route as shown in Fig. 3.

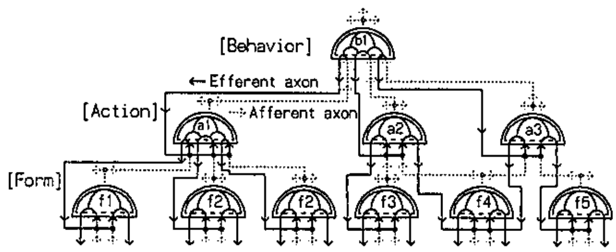

Fig. 3 The columnar organization in the cerebral cortex for a behavior control.

This module is able to explain the fundamental functions of the brain mechanisum where the stinuli come from afferent axons are transmited to the efferent axsons accompanying with the columnar organizations.

4.3 The columnar organizatin in the cerebral cortex

The information is abstructed from the transmitting stimuli by a decoder and the pattern of impulses can be hold in a column.

The building block of a cerebral cortex shown in Fig. 2 functions as a working memory which may carry out behavior control, speech recognition and visual recgnition.

For example, the module of loops connected by a decoder is able to memorize a firing pattern on an action. A set of loops for firing points corresponds to a column in a cerebrum.

One module is able to connect to the other modules and the connections organize an agent. The columnar organization for a behavior control is shown in Fig. 3. Here, the structure of each column is shown in Fig. 2.

The language faculty is achieved by the similar way of the behavior control. The columnar organization in the cerebral cortex may carry out the processes of speech production and speech comprehension where each elements of the language can be represented by the set of loops in the cerebral cortex.

As an example, the connections of elements on a sentence is shown in Fig. 4. The circuits for the language faculties are organized each other and those are linked to the circuits for behavior. This biological approach is one of the way to give the answer to the question, 'What is language'.

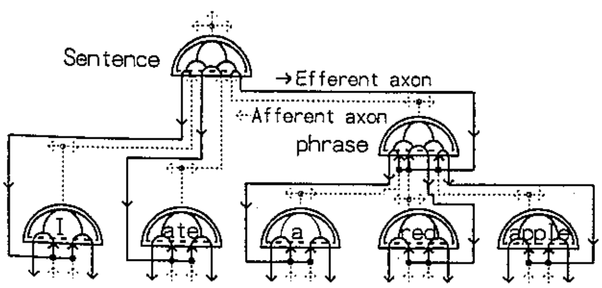

Fig. 4 The columnar organization in the cerebral cortex for a speeach productin 'I ate a red apple' as an example.

Hubel,D.H., and Wiesel,T.N., reported the existence of the columnar structure of fibers in the visual cortex.[13] They stressed that the column is the unit of the function in the visual cortex. Their views support our understanding of the visual recognition.

Assuming [NOT], [AND] and [OR] operations, the moving picture element is picked up by the exclusive OR circuit.

Exclusive OR for a moving ponit A ;

$$A = NOT(A(t-))A(t+) + A(t-)NOT(A(t+)) \quad \cdots\cdots\cdots(2)$$

The abstracted pattern is sent by parallel lines to the registers. Since there are many abstracted informations, the packed patterns will form the layered configuration. The layered structure of columns results in the organization of the decoders.

The joint-ownered system economizes the connections. Moreover, the organization of decoders makes possible to express huge number of matters, for the number of the combinations rapidly increases according to the increase of the constituents.

One agent can be carried out by the structure from afferent routes to the efferent routes. The looped neurons may solve the bi-directional aspects of the perceptive faculties.

5 The model for the cerebellar cortex

The neuroanatomical structure of the cerebellar cortex is relatively simple. We can see the entire appearance of the cerebellar cortex in the reference [8] pp.382.

The proposing decoder-for-neuron translation diagram for the cerebral cortex is shown in Fig. 5. Here, we refer the descriptions on the cerebellar cortex in the reference [14] pp.213.

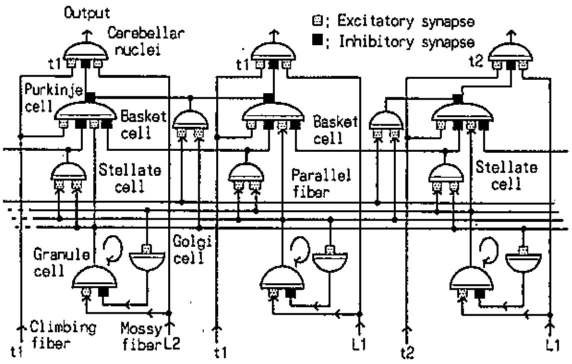

Fig. 5 The decoder-for-neuron translation model on the cerebellar cortex

The serial impulses for the overlapping motor control system are manipulated by a great number of shift registers. As a matter of fact, there are a very large number of granule cells (~500,000/mm^2), whose axons are parallel fibers, in a cerebellum. A great number of parallel fibers (~200,000) make excitatory synapses on a Purkinje cell. The great number of parallel fibers and the granule cell are considered as the registers for the propagating serial impulses.

Assuming the overlappimg motor controll system, the operation of the model shown in Fig. 5 is explained as follows;

The impulse on the mossy fibers is provided to a parallel fiber through the granule cells.

There are outgoing parallel lines from granule cells, Those fibers are able to link by the satellate cells and baskets cells. Satellate cells and basket cells are excited by the parallel fibers and those cells output the inhibitory impulses to Purkinje cells.

The Purkinje cell is excited directly by climbing fibers and granule cells. Excitatory inputs from the climbing fiber together with excitatory inputs from the granule cells, inhibitory inputs from the satellete cells and basket cells, the operation of excitatory [OR] is achieved on the Purkinje cell.

The impulse comes from a mossy fiber propagates along granule cells. The next coming impulse is distributed to neighboring granule cell owing to the after - effect of the neuron. The after - effect makes a tree featured route. The connections in the pathway yield steps in the route of granule cells where the feed back loop made of Golgi cell may control the excitation of the route.

This proposing model on the cerebellar cortex is different from traditional models, as proposed by Marr,D., (1969) or the model by Albus,J.S., (1971). Our proposing model for the operations of neurons reveals biological faculties i.e. the cerebellum assists the cerebrum by transferring the motor skills from the cerebrum to the cerebellum through its experiences.

6 Conclusions

By applying the decoder-for-neuron translation method to neuroanatomical structures, we can get impulse circuits for brain mechanisms.

The pattern of excited decoders represents the informations in the proposing models. The recurrent loop of decoders acts as a register and the rounding impulse is used for the automatic formation of the network. The module can be connected up and down or right and left. This structure is the model of the column in the cerebral cortex.

The building block in the cerebrum may solve the bi-directional aspects of the cognitive faculties such as the speech recognition and the visual recognition.

As for the timing control, the tetanic stimulation is given by the overlapped connections and it needs not to stop the repetition. The timing of the processings is carried out dynamically during the propagation of these impulses. By considering these circuits, the operation of a hippocampus is explained as a sampling circuit.

The parallel fibers from granule cells in a cerebellum functions as the registers for serial impulses.

This approach provides not only the knowledge on the brain mechanism but also gives the architecture of the intelligent circuits. The presenting circuits are operated by the impulses, but the digital technologies will be used in the realizations and the established hardware can be transfered to the software.

The proposing strategy is one of the promising way to achieve the visual recognition and the language processing. If our understanding reaches throughout the thalamus and the limbic system, our ability to devise ourselves will be much more capable.

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