一般社団法人 電子情報通信学会
THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
IEICE Technical Report

The mechanism of brainstem that constructs a model on external world through detection of movement on visual field

Shinji KARASAWA

Miyagi National College of Technology (Professor emeritus). 1-3-6, Oyama, Natori-shi, Miyagi-ken, 981-1233 Japan
E-mail: shinji-karasawa@kbh.biglobe.ne.jp

Abstract The mechanism that manipulates unconscious recognition of a view field is presented by referring to structure of vision. Nerve circuits in the brain crossing at brain stem. The output of intermediate neuron can be a representative of the impulsive signals those arrive concurrently at the neighboring region. The intermediate neuron can be available for the pattern recognition. A neuron is available to control the data flow in the brain. The neural network can respond to the outside world. Since understanding of image will be added through experiences, the multiple neural circuits will be activated. The multiple activations are adjusted at the brainstem as needed. That will be the formation of the corresponding model of the outside world.

Keyword Vision, Retina, Optic chiasm, Brainstem, Midbrain, Unconscious intelligence, Long-term potentiation.

1. 1. Introduction.

The technology of the data processing by using computer has been developed. Today, implementation of the device with a function of human vision is desired. On the other hand, the animal has a mechanism to recognize the outer world via the image that is reflected on the retina in real time. Many engineering researchers in this field are interested in the research on brain science [1], [2].

In 2007, the author reported the architecture of vision in which each element on image is manipulated through transference of impulses [3]. In 2009, basing on the knowledge on the structure and on the neurotransmitters [4] [5], data processing in a retina was reported [6].

Those mechanisms are very cleverly combined with biochemical reactions that antagonize. The function of interneuron that forms the unit for visual data processing is also described. The unconscious activity in the nerve system processes multiple activities at the same time.

Here, a conversion of paradigm is required in order to investigate the mechanism of such unconscious activities.

That is, the reaction of a neuron is not continuous, and it is not linear. An interneuron is connected to the axons those are operated at the same time, and it outputs an impulse to the connected regions by the integral value of the inputs. Then, the refractory period that returns to the state of before follows immediately after the reaction.

Since the representation of a real world is updated immediately, the brain system does not require a feedback circuit [7].

The connections of a neuron represents of the situation that is affected by the outer world. It also represents the experience as a rule. Then, the rule is available to extrapolate to the other situation. The illusion is the evidence that the empirical rules are involved in the vision.

The neural network will be the formation of the corresponding model of the outside world. The vision is the model of the real world in the brain, and it is updated in real time progression. The system does not require a feedback circuit will be immediately updated [7]. It is supported by the many unconscious activities of neurons.

The author attempted to elucidate the mechanisms that the brain unconsciously controls the vision. He proposes the concept that the neural system that reacts to the outside world corresponds to the formation of a model of the outer world. This concept is an extension of the ecological approach to visual perception proposed by J.J. Gibson [8].

2. Formation of the neural network for vision

2.1 Formation of the central nervous system through crossover of neural circuits

First nervous system of a multicellular is a diffuse nervous system. The function to react to outer world is distributed on the surface of a body.

The body causes changes after the evolution. In order to move well, the sensors are distributed to the front, and actuators are distributed to the back. When the neural network twists, the nerve pathways are gathered at the

cross point.

The crossing of pathways promotes the information processing for various reactions with keeping topographical organization. Formation of nerve circuits for information processing at the crossing formed the brain system. The model of the concentrated nervous system is shown in Fig.1.

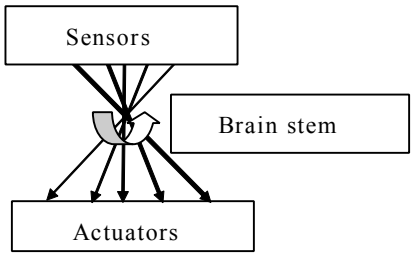

Fig.1. The concentrated nervous system that was formed by crossing of nerve

—The reason why the brain was formed—

A creature is the organization that must choose an operation suitable for each situation at each moment. A neuron that reacts for one job connects a group of simultaneously activated pathways in the crossover region.

If there are multiple outputs in the narrow area, the outputs will be unified into a single output by the operation of "winner-take- all [9]". Here, the function of "winner-take- all" can be carried out by operation of lateral inhibition on the outputs. The nerve pathway intermittently forms a topographical organization.

2.2 Formation of the neural circuits to recognize location of things

Photoreceptors in a diffuse nervous system are distributed on the surface of the body, and the light from the outer world is projected to the surface.

Since the image of outer world is transferred to the nervous system, there is a topographical organization in a diffuse nervous system.

The eye was formed through a process of evolution. It can be interpreted from the viewpoint of the neural network that the photoreceptors were gathered at the eye. The nerve circuits intermittently connect between photoreceptors and actuators by neurotransmitters. The neural system will be able to control the actuator even when photoreceptors are gathered in the eye.

A fish lives in the water. The vision of fish is coordinated with relative to its body by using two images those are projected in both eyes. A large portion of the image is different between left eye and right eye.

The optic nerve of a fish is complete intersection. If there is the image that is common to the left eye and right eye, the left and right visual fields can be combined at the crossing region.

2.3 Unconscious vision in the brain stem and conscious vision in the neocortex

The human believes that the visible world is the real world itself. However, the video data in the brain is intermittent. The information is transferred intermittently by discharge of neurotransmitters. The stimuli from the outside world are recognized based on the rules stored through the experience. The recognition is an application of the rule obtained in experience.

Although all thought is conscious activity, all activity of the nervous system is not necessarily conscious activity. There are unconscious activities in human vision.

Although the activity of neocortex is able to control the activities of brain stem, the brain stem is the center of information processing to control the whole body. That is, the brain stem controls the neocortex and the neocortex controls the brain stem.

Animals are alive by capturing representations of the outside world intermittently through the sensors. The activity of neuron is corresponded with the outside world. The neural network carries out the topographical organization on the vision. Fig.2 shows the intermittent correspondence between outer world and the brain stem.

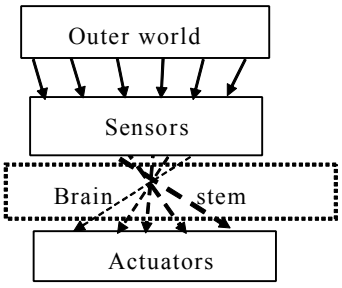

Fig.2. The topographical organization between outer world and the nerve network

2.4 The intelligence that is acquired by interneuron

Although the neocortex of frog is undeveloped, it preys on insects by the stereoscopic vision in binocular.

This fact shows that the space arrangement of the outer

world can be recognized even if the cerebral neocortex is undeveloped.

The thalamus and midbrain are in the brainstem, and those are involved in vision. The brain stem controls the body and the visual information. This area in the brain recognizes the real world dynamically.

-Existence of unconscious intelligence in the vision-

Image data cause the activity of a specific region in the brain by the circuit that has been formed by experiences. Many of movements of body are handled by conditioned reflex that is acquired through exercises.

The conditioned reflex is a relay function. The vision is supported by the relay functions. The neural circuit for the relay function is able to form through the experiences. We can regard as the intelligence even if it is unconscious activities. The unconscious intelligence is exists in the vision.

The neocortex is the organ for memory, and mammals have evolved the neocortex. The neocortex is the most newly added function in the brain, and it is part of the brain system to control the behavior.

3. Visual information processing by neurons in retina

3.1 Photo-response in ON area and OFF area

ON and OFF regions in retina of which reaction is antagonized are arranged as a checkered pattern region as shown in Fig.3.

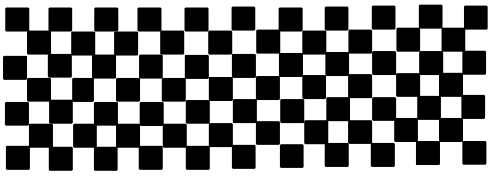

Fig.3. ON-areas and OFF-areas in retina are located in a checkerboard pattern.

At the OFF-region, hyperpolarization takes place if the light is turned on, and depolarization takes place if the light is turned off. On the other hand, at ON-region, depolarization takes place if the light is turned on, and hyperpolarization takes place if the light is turned off.

-The reason to antagonize reaction is distributed in a checkerboard pattern –

Reason of the opposite reaction that takes place at the adjacent region is derived from the relation of demand and supply in the biochemical reaction. The opposite reaction in a checkerboard pattern, the return to initial state is easier and it can be quickly. In addition, the optimum state can be provided easily by adjusting the combination of an antagonistic reaction.

3.2 Role of horizontal cell in the outer plexiform layer

As shown in Fig.4, there exist some kinds of interneuron in human retina. Those are horizontal cells, bipolar cells, and amacrine cells, and ganglion cells.

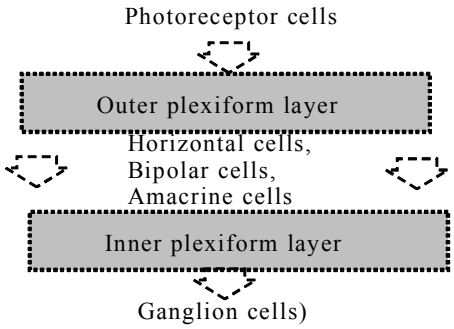

Fig.4. The inter-neurons in human retina

Photoreceptor cell and horizontal cells are connected in the outer plexiform layer.

The horizontal cell connects with many photoreceptor cells. It makes a reaction by the integrated value of the input. Since horizontal cell has the same sign conserved receptors, the output makes a positive feedback to the inputs.

-The role of horizontal cells-

The horizontal cell that connects to the photoreceptor cells in ON-region does not connect to the photoreceptor cell in OFF-region. The horizontal cell that connects to the photoreceptor cells in OFF-region does not connect to the photoreceptor cell in ON-region.

So, the horizontal cell enhances each reaction that is arranged in a checkered pattern by the positive feedback.

3.3 The sign inverting mechanism of ON-center bipolar cell

There are hyperpolarizing (H) “OFF”-center bipolar cells and depolarizing (D) “ON”-center bipolar cell. H cells respond with depolarization to light being turned “OFF”. D cells respond with depolarization to light being turned “ON”.

The photoreceptor cell causes hyperpolarization when light turns on, and it causes depolarization when light

turns off.

In the OFF receptive field of bipolar cell, the depolarization takes place when the light turns off. The operation of bipolar cell in OFF receptive field is sign-conserving type, because the photoreceptor cell is H-type cell. The horizontal cell in the OFF receptive field carries out the positive feedback for connected cells.

In the receptive field of ON center, the existence of APB abolishes the activity of photoreceptors and it depolarizes the membrane potential of ON dipole cell [10]. The abolishment of photoreceptor in ON center induces the antagonized change, i.e. the change of ON center is opposite to that of OFF center. The membrane potential of the horizontal cell in the ON center is depolarized at light.

On the other hand, D-type of bipolar cell in the ON area is surrounded by horizontal cell. It is a structure in which the horizontal cell interferes the transmission of neurotransmitters from photoreceptor cell. And it is the structure in which the horizontal cell can be depolarized by reaction of the bipolar cell. The horizontal cell in ON center reinforces the reaction of ON center.

3.4 Extraction of moving image by amacrine cell

The author proposes the mechanism how to extract a moving image in the retina as shown in Fig.5.

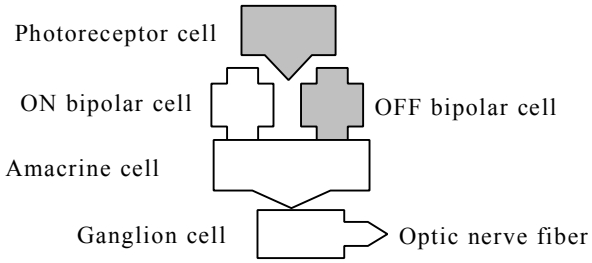

Fig.5. Extraction of moving-image is caused by depolarization of ON region after hyperpolarization of OFF region.

The data in the outer plexiform layer is transmitted to inner plexiform layer through the ON- and OFF- bipolar cells. An amacrine cell is connected to the ON- and OFF-bipolar cells in the inner plexiform layer.

In the inner plexiform layer, image of depolarization of ON-bipolar cells is delayed compared with that of hyperpolarization of OFF-bipolar cells, because the depolarization of the ON-bipolar cell is a result of hyperpolarization of OFF-center.

Accordingly, the depolarized image of the ON-area arrives later to the amacrine cell compared with the hyperpolarized image taken by OFF-area.

If the light turns off, the amacrine cell is received the depolarization from both bipolar cells at the same time. If an amacrine cell connects with ON-bipolar cells those are depolarized at the same time, it also connects with OFF-bipolar cells those are depolarized immediately after in same pattern. It will form the filter that emphasizes the image that is changed from bright to dark. It has been reported that amacrine cells have various types [11].

4. The neural circuit for timing control

4.1 How to manipulate the time variation in the nerve network

The intelligence is captured as changes of a state along time. The hippocampus belongs to the limbic system a part of cerebral cortex and plays important roles in the consolidation of information from short-term memory to lomg term memory.

The evidence that the brain memorizes information in the form of a representation of many-to-one is indicated by LTP (long-term potentiation) in the hippocampus [12].

Fig.6 is an illustration of the proposing model of LTP. The role of each granule cell in the model is a delay element. The mechanism to adjust the timing of operation in a nervous system is organized by the transmission time. Here, the velocity of impulse on axon is depended on the density of ionic channel.

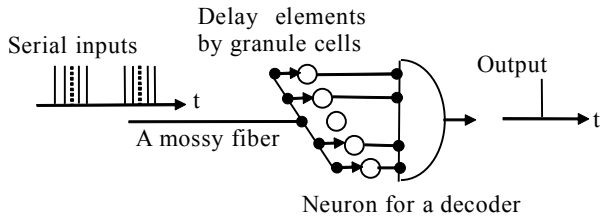

Fig.6. The mechanism of hippocampus that makes possible to recognize time variation of activities

The tetanus stimulation of input (10~100Hz for 1 second, repeated once after 5 seconds) for hippocampus produces an intense increase in the amplitude of excitatory synaptic potentials in the post-synaptic neuron that lasted for days or for weeks.

4.2 The cerebella circuit that outputs the data of habitual activity

The cerebellum outputs a set of serial data for a routine action. Purkinje cell outputs an inhibitory signal when the

excitatory input is absence, and the inhibitory potential suppresses excitatory impulses, and the system outputs the signal of time series [13]. Here, implementation of the Purkinje cell is achieved by simultaneous from parallel fibers and climbing fibers. The parallel fiber is the axons of granule cell that has received input from mossy fiber.

The proposing idea on the nerve configuration of cerebellum is shown in Fig. 7.

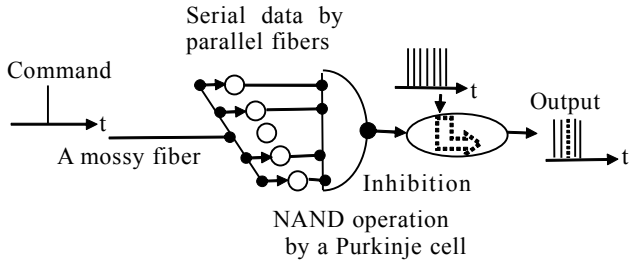

Fig.7. Model on the cerebellum that outputs the data of a habitual activity.

4.3 How to control the state where there are a lot of activities at the same time

The adjustment to unify the activities in a body is carried out primarily in the brain stem. The brain stem consists of neural networks, and the nuclei scattered. There are 3 kinds of processing to control the plural simultaneous activities. Those are the detection of the state to be controlled, the selection of the activities required, and the inhibition of the unnecessary activities.

Fig.8 shows the neural circuitry of the brainstem that communicates with sensory organs, brain and actuator. The basal ganglia have the caudate nucleus and the lens nucleus, which has an interesting structure, which is related to the movement. Those organs do not directly related to artificial vision.

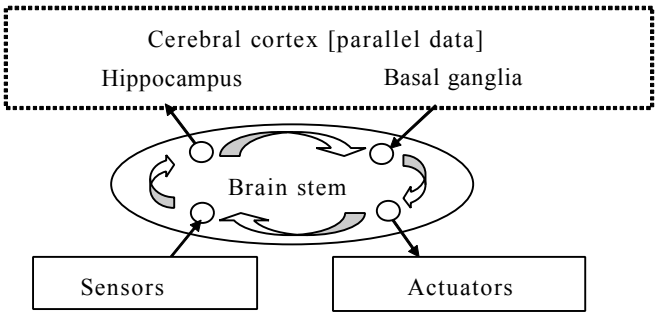

Fig.8. The nerve circuit on the brain stem that communicates with sensors, cerebrum and actuators

The brain stem is divided into thalamus, hypothalamus, midbrain, pons and medulla oblongata.

The thalamus receives the activities from sensors and the cerebral cortex and it relays those activities in order to be carried out properly.

The midbrain carries out the conditioned reflex on the eye movement and the vision. The optic nerve of fish and amphibian ends in the midbrain. The midbrain has become central portion of visual processing in fish and amphibian.

There is a mechanism to build a transient model of the outer world in the area of the brainstem from visual data.

4.4 The focused attention in the vision

The recognition on viewpoint is newly added in the evolution of vision. Both visions coexist overlapping. The perception on viewpoint is closely related to the conscious activity of the cerebral neocortex.

In the human retina, only cones exist in the macular region. The rods exist at peripheral region in the retina. The density of photoreceptors at periphery is lower.

The image projected in the macula of the human retina is sent to thalamus. The information is relayed through the thalamus that is controlled by conscious activities. In the neocortex, the visual information is processed and stored. The information stored in neocortex is compared with the image that is projected in the macula.

There are two kinds of visual perception. M. C. Escher drew a visual paradox “ascending and descending”. We can notice a never-ending stairs, if we pay attention to climb the stairs. But we do not notice this visual paradox if we look at the whole building. This is the evidence that there are two kinds of visual perception.

The vision on fast-rotating subject indicates the uniformly flowing of rotation [14]. This indicates that the simultaneous decoding is carried out through paralleling neurons. In this parallel processing of data, it does not need to detect the segmentation to replace the data.

4.5 Activity of the cerebral neocortex

A neuron manipulates the representative of activity in the brain. The visual data from the same substance occur at the same time, and the organization of nerve cells that recognizes the image is formed intermittently at the region [15]. It creates a neuron for a subgroup and the linkages among neurons are formed through the experience. The partial representation of neuron is partly shared by the neuronal network.

An activation of upper-layered element must retain

during appropriate period. The excitation is retained by high frequency stimulation. A closed loop of delay elements is possible to generate the high frequency signals. The activity of closed loop is controlled by excitatory signal together with inhibitory signal.

The thinking is activity of neuron and it is the representative of a reaction. Each neuron reacts for the situation and the results become the situation of next reaction. Such transition of state continues dialectically [16]. The transition is able to inspire the other activities by using the network.

The behavior of human has tendency to accompanying with a motivation. The tendency comes from the nature of neocortex that is newly added and the newly added activity has the priority. But the reaction that is early established is the foundation.

Human speaks a sequence of words by thinking a sentence. That is, the upper representative is activated continuously during the utterance of a series of lower layered representatives. Here, the high frequency stimuli Therefore, there needs a mechanism to control the high frequency stimulation that is generated to maintain the activation of the upper representative.

5. Applications

5.1 Digital electronic circuits for vision

A transition of digital state is given by transferring a positive impulse via the active state (excited state) in the nervous system. The timing of a nerve system is adjusted automatically at the implementation.

The CCD system is a candidate for the circuit. But synchronous control circuits are necessary for CCD device. And many trial manufacturing will be necessary for the CCD circuits.

On the other hand, the state of digital circuit is changed by the edge of pulse. Then, the existing digital technology is available for manufacturing the electronic device.

The use efficiency of circuit can be improved by sharing element. The system for sharing element forms a hierarchical structure. The similar image can be recognized as the same thing through data-matching process on the combination of elements. The recognition system will be implemented by the elements that specifically characterize the target.

5.2 Semiconductor device for pattern matching

Since the digital computer has segmentation for the data processing, it is not easy to recognize the pattern of a large amount of various images. A parallel processing is desirable for the pattern recognition.

In the parallel system, various decoders are connected parallel with bus lines, and the tasks of pattern matching are performed concurrently. The data of image patterns to be referred are compared with a transmitting image. The pulse train of one-dimensional parallel is transmitted on the two-dimensionally arrayed transfer elements. The array of transfer elements can be manufactured by the semiconductor technology that is used in digital camera.

By using a “flowing gate MOS-FET” as a pass gate, the non-volatile memory technology can be realized the programmable semiconductor electronic circuit [17].

6. Conclusions

In this report, the author proposes that the activation of multiple nerve circuits those correspond to the image projected on the retina corresponds to formation of model of the outer world, and he also presents following descriptions.

1) The concentrated nervous system is formed at the crossing of neural circuits.
2) The reason why OFF- and ON-regions exist in the retina.
3) Role of interneuron in plexiform layer of the retina.
4) Mechanism of retinal neural network to extract the moving picture.
5) Mechanism of long-term potentiation (LTP) in the hippocampus that is involved in memory.
6) The evolution in which the vision of viewpoint was superimposed to the vision of the visual field.
7) Formation of the hierarchical structure that elements of underlying representation are shared.
8) The method to control the activation of nerve cells in the upper layer.
9) The method to control the state where there are multiple activities at the same time.

Since understanding of image will be added through experiences, the multiple neural circuits will be activated. The vision depends on the activity of the nervous system of the unconscious, and it also involves awareness.

The basis of vision is the conditioned reflex, and it is also involved in long-term memory. The vision is involved with the entire nervous system.

The multiple activations are adjusted at the brainstem as needed. That will be the formation of the corresponding model of the outside world.

The author expects the development of dedicated semiconductor devices for vision system.

References

[1] E.R. Kandel, J.H. Schwartz, T.M. Jessell, Principles of Neural Science, 4th edition, McGraw Hill, 2000.

[2] J.G. Nicholls, A.R. Martin, B.G. Wallace, From neuron to brain, 3rd ed., Sinauer Associates, Inc., 1992.

[3] S. Karasawa, M. Iwamoto, “The architecture of device that manipulates image in which each set of activities is ignited through transference of impulses”, the 2nd Korea-Japan Joint Workshop on Pattern Recognition and Media Understanding, pp.201-206, Matsushima, Japan, Oct.25-26, 2007.

[4] D.H. Hubel, “David Hubel ’s Eye, Brain, and vision” http://hubel.med.harvard.edu/book/bcontex.htm, 1995.

[5] H. Kolb, R. Nelson, E. Fernandez, B. Jones “Webvision -The organization of the retina and visual system-”, http://webvision.umh.es/webvision/index.html new edition 2012.

[6] S. Karasawa," Functions of the interneuron that forms the data processing unit of vision ", 8th Forum on Information Technology ; G-011, Vol.2, pp.591-591, Tohoku Institute of Technology, Sendai, Japan, Sept. 2, 2009.

[7] S. Karasawa, “Forming of intelligence that is intermittently opened to the real world: How a newborn baby acquires primitive intelligence”, Seeing and Perceiving Vol.25, Supplement, 57, 13th Inter. Multisensory Research Forum, Univ. of Oxford, UK. 2012.

[8] J.J. Gibson, “The ecological approach to visual perception”, Houghton Mifflin Company, 1979.

[9] Winder SA J, “A model for biological winner–take-all neural competition employing inhibitory modulation of NMDA-mediated excitatory gain” Neurocomputing, 26-27, 587-592, 1999.

[10] M. M. Slaughter, R. F Miller,. (1981). 2-amino-4-phosphonobutyric acid: a new pharmacological tool for retina research. Science, 211, 182-5, 1981.

[11] H. Wassel, B.B. Boycott, “Functional architecture of the mammalian retina”, Physiol. Rev. 71, 447-480,1991.

[12] T.V.P. Bliss, T. Lomo, “Long-lasting potentiation of synaptic transmission in the dentate area of the anaesthetized rabbit following stimulation of the perforant path” J. Physiol, 232, 331-374, 1973.

[13] S. Karasawa, J. Oomori, “Impulse circuits for a distributed control inspired by the neuro anatomical structure of a cerebellum” Intelligent Engineering Systems through Artificial Neural Networks, Vol.10, (ASME Press) pp.185-190, 2000.

[14] S. Karasawa, “ Inspections of human vision by using the photographs on a rotating propeller", IEICE Technical Report, MBE2010-106, pp.19-24, ISSN 0913-5685, Vol.110, No.460, March 7, 2011.

[15] S. Karasawa, “The visual system where a subset of impulse is used as the processing unit of pattern recognition”, IEICE Technical Report, PRMU2003-39, pp. 7－12, June, 2003.

[16] S. Karasawa, "The dialectical architecture of visual intelligence where every activity is available as a tool for the next activity", website presentation for European Conference on Visual Perception, A Coruna-Spain, Aug 22-26, 2005.

[17] S. Karasawa, "Self-organization of network on activities for intelligent behaviors", 9th International Conference on Cognitive and Neural System, pp.101, Boston Univ., May 21, 2005.