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A Brief Insight into Interaction Between the Brain and the World

Susumu ITO[1]* and Katsuhiko Hata[1,2,3]

[1]*High-Tech Research Centre, Kokushikan University, Tokyo, Japan*

[2]*Department of Neuroscience, Research Centre for Mathematical Medicine, Tokyo, Japan*

[3]*Department of Applied Physics, Faculty of Science Division I, Tokyo University of Science, Tokyo, Japan*

***Corresponding Author:** Susumu ITO, High-Tech Research Centre, Kokushikan University, Tokyo, Japan.

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Abstract

Brain can be regarded as an automaton represented by 5 tuple $\langle I, Z, B, \delta, \lambda \rangle$, where the internal state B of the brain is shifted with input I from afferent peripheral neurons by the differential equation $\frac{d}{dt}B(t) = \delta(B(t), I(t))$ and gives output Z through efferent neurons expressed as $Z(t) = \lambda(B(t), I(t))$. If the free-will is included, B becomes B_ω depended on chosen free will $\omega \in \Omega$. State of the world can be conversely expressed by the 5-tuple $\langle Z, I, W, \delta_2, \lambda_2 \rangle$ and change of the state of world is also expressed as $\frac{d}{dt}W(t) = \delta_2(W(t), Z(t))$.

The brain can be divided into two sub-automata, the consciously active field B_{cons} and the unconsciously active field B_{uncons} and the world can be divided into two sub-automata, the body of the self W_{body} and the external environment W_{env}. these sub-automata constitute a network through their respective inputs and outputs. The brain creates an image of the world based on sensory input and memory, predicts how its actions will change the world and acts in such a way as to maximise his assessment of the value of the world, particularly the state of the body, in other words the quality of life (QoL).

Although various methods of modelling the brain and the world are possible, here we have attempted to break down brain functions into their essential elements as much as possible. This time we have only presented an abstract sketch, while next time we will use more specific models to help clarify the actual brain functions.

Keywords: *Automaton; Free Will; Quality of Life; Homeostasis*

Introduction

Organisms maintain Claude Bernard's "milieu intérieur" (internal environment) by homeostasis through feedback control [1]. This requires frequent intake of free energy, or more generally the so-called Schrödinger negentropy [2], against the constant influx of entropy from the environment and the internal entropy production that inevitably accompanies their activities, and this highly sophisticated mechanism is believed to be the result of Darwinian and Walrasian natural selection.

Plants have mainly chosen a sedentary lifestyle, as they take in free energy from the sun directly through photosynthesis, thereby reducing the need for movement, whereas animals obtain free energy by foraging for food consisted of organic compounds initially derived from plants. This has forced the animals to engage in locomotion and predatory behaviour, and in higher animals the nervous system is thought to have developed as a means of achieving individual consistency and rationality in this behaviour.

Animals have evolved their behaviour not only to eat and mate, but also to fight and cooperate with others and to move in search of a better environment to maintain their low entropy state, thus increasing the probability of long-term survival.

Lower animals can prey directly on food if they find it, avoid enemies if they see them, or move towards a more comfortable environment, but it is difficult for them to predict anything beyond their immediate surroundings and the phenomena that will immediately occur as a result of their actions. On the other hand, higher animals have the ability to estimate distant situations from information about their surroundings, and to predict possible near-future situations that may result from their actions, and to choose an optimal action.

In humans, with highly-developed brains, the ability to use words and letters as a means of exchanging information with each other has made it possible to obtain a wide range of information from afar and from the past and to modify behavioural patterns more quickly by sharing judgments.

In this paper, we considered information exchange between the human brain and the internal and external environment (the real world) in a model simple but as generalised as possible.

Brain model

The brain and the world

The brain is here denoted not as an object but as the mechanism of its information processing function and the totality of the information it possesses, and is denoted B. The whole world other than B is denoted W. W includes both the body and the external environment, and in particular the brain itself as a physical object is also included as part of the body. For convenience, B and W together are referred to as the universe U, to mean that it contains everything.

The brain as automaton

The idea of automata was developed mainly by mathematicians around the middle of the 20th century [3], and it seems quite natural to regard the brain as an automaton [4].

An automaton can be described by the 5-tuple $<I, Z, Q, \delta, \lambda>$ where I is a set of input messages, Z a set of output messages, Q a set of internal states, δ a mapping $Q \times I \rightarrow Q$, and λ a mapping $Q \times I \rightarrow Z$.

To apply this to the relationship between the brain and the world, with a slight modification, the brain internal state B (instead of Q) represents the active state of the brain, the input I is all information obtained from the sensory organs via the afferent peripheral nerves, and the output Z is all commands given by the efferent peripheral nerves to the effector organs such as muscles. Because time is a continuous variable, changes in state are given in the form of differential equations, and time t is explicitly indicated.

Therefore, the internal states of the brain can be expressed as $\frac{d}{dt}B(t) = \delta(B(t), I(t))$ and output Z at time t is expressed as $Z(t) = \lambda(B(t), I(t))$ (or rather simply $Z(t) = \lambda(B(t))$).

On the other hand, world also changes with time and with the choice of output from the brain and can be expressed by the 5-tuple $<Z, I, W, \delta_2, \lambda_2>$, with $\frac{d}{dt}W(t) = \delta_2(W(t), Z(t))$ and $I(t) = \lambda_2(W(t), Z(t))$ (Figure 1).

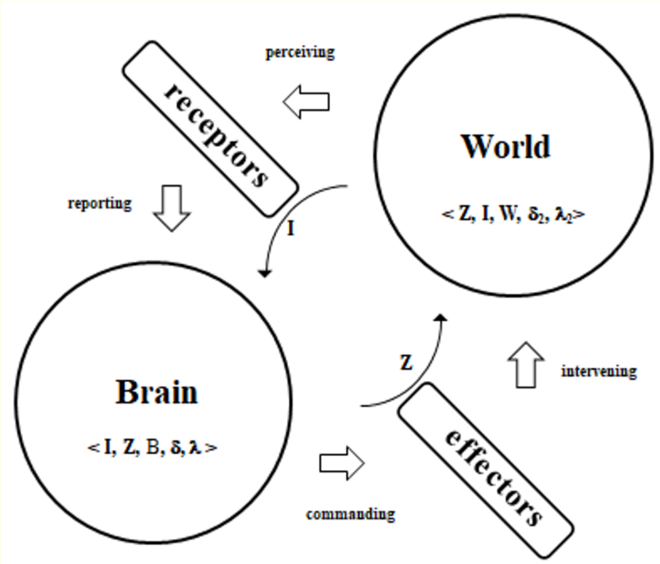

Figure 1: *The brain and the world as two interacting automata.*

The brain B can be regarded as an automaton, represented <I, Z, B, δ, λ>, which receives information I from the world via the body's sensory receptors and influences the world by sending commands Z to muscles or other effectors. On the other hand, the world W can also be regarded as an automaton represented <Z, I, W, δ_2, λ_2> > that exchanges information with the brain.

Conscious and unconscious fields

The field of brain activity can be divided into conscious B_{cons} and unconscious fields B_{uncons}. The activities of the unconscious field include simple reflexes, negative feedback for homeostasis and automatic control of habitual behaviours such as breathing and walking, while the activities of the conscious mind are assigned the function of extracting information from the image of the world projected in the brain to memorise, to verbalise, to think logically, and finally, to make decisions. This conscious mind is particularly necessary for communicating with others, and if consciousness was created during evolution, this is perhaps one of the major factors.

Body and the external world

The body and the external environment can be distinguished as subsystems of the world (W_{body} and W_{env}, respectively). The internal environment of the body is maintained in a quasi-steady state by homeostasis and is separated from the external environment by a boundary such as the skin. The information about the state of the body and the external world enters the brain through afferent peripheral neurons from the sensory organs that are part of the body. In terms of brain output, the body can be directly controlled by the brain output, while the external world is the part that can be indirectly interfered with through the body activity.

Input and output

Information from the world is received by the sensory organs and transmitted to the brain through afferent neurons. Output is transmitted by efferent neurons to effectors such as muscles and glands, which in turn influence the external world. In both cases, information is transmitted as impulse sequences (action potentials). Thus, the information exchanged between the world and the brain is (for the most part) information on the impulse series, the amount of which is responsible for the brain's informational negentropy.

World image in the brain

Information about the world, including visual and auditory information, is delivered to the brain as a series of impulses through the sensory organs and their associated afferent neurons, to construct a picture of the world in the brain. If there are inconsistencies between the world image and sensory information, or inconsistencies between the brain's predicted image in the past and the actual image at the present time, the world image in the brain gradually corrected unconsciously (trained) or consciously (learnt), so that inconsistencies do not arise. If a large discrepancy occurs, the brain is alerted.

Predicting the future

The brain makes predictions about the future based on its image of the world. As the future is split according to one's behavioural choices, there can be many possible futures as a function of one's behavioural choices. Even if the behavioural choices are determined, the brain must take into account the fact that the actual future will deviate from the predicted future due to the uncertainties inherent in the prediction.

Evaluation function

If humans, as living organisms, have evolved by competing for survival, the criterion for behavioural decisions is to choose behaviour that will ultimately increase the survival rate of self and one's own kind, as well as leaving more offspring. Indeed, humans behave in ways that seek comfort, which is usually in line with the homeostatic maintenance of their own internal environment and with the goals of self-preservation and procreation, such as appetite and sexual desire. However, humans are not only able to evaluate the short-term situation at a given time, but also to make overall value judgments about the long-term future based on future predictions. If the evaluation function is expressed as QoL borrowing the term Quality of Life commonly used in public health, then the overall evaluation value of the entire future TQoL as a functional of QoL ($t > t_{now}$) changes by the behaviour chosen to take, and the actual behaviour is chosen to maximise the TQoL.

Emotions

Emotions including joy, anger, sorrow and pleasure can be regarded as types of evaluation function for a situation. In additions, the evaluation functions of expectation and anxiety, which are used to evaluate the future, are also considered important. The above mentioned QoL can be regarded as a summary of these emotion assessment functions.

Free will

Free will is considered unpredictable and governed by a random variable $\omega \in \Omega$. The internal state of the brain B will therefore also depend on ω, in addition to I and the previous internal state B, turning B into a non-deterministic automaton. It is precisely this unpredictability that makes free will useful, allowing it to gain an advantage by making it difficult for competitors to predict its behaviour.

Brain and communication

Humans are social animals and a significant part of their brain function is thought to have developed in relation to others. Communication through language is particularly important, and this requires the ability to organise information in the brain in order to code it into language, as well as the ability to correctly decode the received language into the original information. This is thought to have been one of the main driving forces behind the human brain's ability to think logically.

Sub-automaton network

As mentioned above, the brain and the world each have complex internal structures that can be regarded as sub-automata, and the brain, the world and thus the whole universe can be seen as a network of sub-automata. How sub-automata are combined is not defined exactly here, but roughly the space of internal states is the direct product of the space of their respective internal states, and only those of the inputs and outputs that are connected to the outside remain as inputs and outputs of the combination (Figure 2).

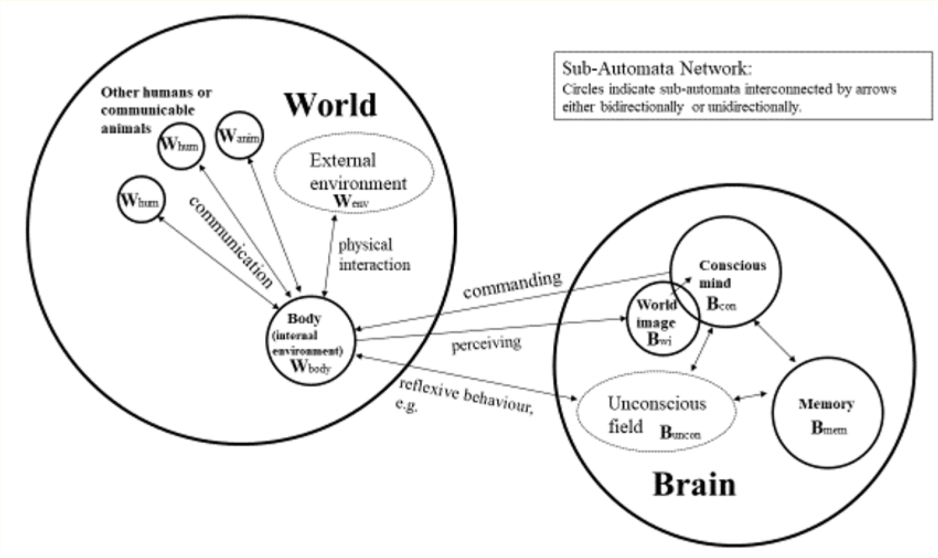

***Figure 1:** The universe as sub-automata network.*

The brain and the world can be divided into sub-automata. The figure shows an example of this: the brain is divided into sub-automata such as the conscious field B_{cons}, and the memory field B_{mem}. Here, the unconscious field B_{uncons} and the external environment W_{env} refer to the field of the brain excluding B_{cons} and other sub-automata, and the field of the world excluding sub-automata such as the body W_{body} and other humans W_{hum}s, respectively. The world image B_{wi} is shown here as a slightly overlapping sub-automaton to indicate the ambiguity of merging or separating with the conscious mind.

Discussion

Research into the function of the brain, its mathematical analysis and engineering applications, has progressed remarkably from the end of the 19th century to the 20th century [5-8], and in the 21st century, computers with artificial intelligence can pass the so-called Turing test [9], and in some areas, far surpass human intellectual capacity [10]. The current digital computer system is of the von Neumann type, and its operation is identical in principle to that of a Turing machine, and moreover, it is possible to simulate it completely, i.e. to make it behave indistinguishably as an automaton, using a universal Turing machine that operates on a very simple operating principle.

Significant advances have been also started in linguistics and information theory since the past century or so with regard to the study of human communicative competence [11-13].

In relation to homeostasis, significant progress has also been made in the last century in the field of non-equilibrium thermodynamics, including Prigogine's famous principle of minimum entropy production [14], and Friston., *et al*. have begun to apply them to the study of brain function and appear to be making promising progress [15].

The current study was to build the simplest possible model of the brain structure, but the model will be fleshed out in subsequent years to reflect these recent neuroscience-related advances.

Conclusion

The brain and the world can each be regarded as an automaton that exchange input-output information through the body. Furthermore, it is possible to interpret the entire universe as a network of sub-automata by regarding the brain and the world each as a collection of even finer sub-automatons.

As a result of evolutionary competition for survival, it can be assumed that the internal state of the brain automaton has an evaluation function, provisionally called QoL, whose value is used as a reference to select behaviours that are more likely to result in the survival of the self and the prosperity of its own species.

Conflicts of Interest

We have no conflicts of interest to declare.

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