Model Brain: Brain Information Hydrodynamics

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Abstract At present, there is no research method for viewing the brain from a broad perspective. We suggest that theories of complex systems like fluid are useful. We therefore propose Brain Information Hydrodynamics (BIH) as a theory that should serve as a basis for constructing a Model Brain, which is traditionally conceived as an electronically based neuronal network and / or chemically based hormone field. In BIH, the influx of information from the environment is filtered at the entrance of the brain to reduce the amount of information to a tractable number of chunks. The influx flows along the terrain, which was originally shaped by genes and then transformed through experience. Immediate behavior is generated when the influx reaches the cerebellum directly. Deliberate behavior, the outcome of the cerebrum, is generated when the influx is trapped midway to the cerebellum where a number of vortices are created to transform the values of attributes of the information that the influx is conveyed successively to the ones finally exerted. The real-time constraint of behavior is satisfied by creating emotional vortices that force the flow to reach the cerebellum in a timely manner.

Time axis is central to information flow

Time is the fourth dimension of our four-dimensional physical universe. However, unlike the X- Y- Z- dimensions, it is not symmetric, in other words, it is not reversible. The order of our universe is being shaped as the interactions between life and the surrounding environment and develops along the one-directional time dimension. The characteristic times of brain information processing ensure sustainability of those interactions.

The functioning brain is the result of the working of a huge network of 20 billion nerve cells and synapses. It basically converts input signals from the environment to information that is necessary for acting in real time. However, the phenomena that the flow of information in the brain causes are extraordinarily complex. We suggest that this is analogous to the complexity of the phenomena exhibited by a flow of fluid and that it is useful to apply the construct of the theory of hydrodynamics metaphorically to the phenomena of information flow in the brain.

Cerebrum formation process

In the very early days, the organisms first created cerebellum-like feed-forward networks. They were most suitable for generating prompt responses to the occurrence of libido, which is the free creative energy an individual has to apply to personal development. Those networks enabled the organisms to perform the required sequence of actions very smoothly: collecting information from the external environment, taking actions for satisfying the occurring libido, achieving it, and finally, returning to the resting state.

After developing the cerebellum-like feed-forward networks, organisms then developed the cerebrum. As opposed to cerebellum, the cerebrum is equipped with feedback networks for processing information. These networks enabled the organisms to perform complicated information processing that was impossible for cerebellum-like feed-forward networks.

How have the feedback-networks developed from the feed-forward networks? Here is our answer.

When libido occurs, information from the external environment is gathered via sensory organs, eyes for visual information, nose for olfactory information, and ears for auditory information. The set of information originating from the variety of sensors with different modalities constitutes a set of information flows in the brain network. They flow simultaneously and quasi-independently, and are ultimately transformed into the information for generating external actions.

However, the pattern of the flows is very complex because individual flows are not synchronous in time but the set of flows must converge at the time when an action associated with the input is taken. The timing of action is strictly determined by real time constraints.

Some flows may have spare time and have to wait until the other flows are ready to be integrated, or synchronized. While waiting, the flows of information may develop an order that is analogous to vortices in the stream of river. In the brain network, informational vortices may develop, drift, disappear, fission, and merge. A vortex can interact with the other vortices. These vortices can be conceived as manifestation of some functions that work as part of feedback control. See Figs. 1 and 2 for details.

Information flows in the brain

The brain consists of the three following non-linearly connected layers and functions by activating part of the structure.

- C-layer: Conscious state layer
- A^{2}BC-layer: Autonomous-automatic behavior control layer
- B-layer: Bodily state layer

Information flows in each layer with its specific purpose (Fig. 3). In the C-layer, information is for predicting the time course of events and for coordinating relationships between the self and others. In the A^{2}BC-layer, information is for autonomously and automatically controlling a variety of parts of the body. In the B-layer, information is for regulating the bodily state.

Vortices emerge in a river when the amount of flow exceeds some threshold. Similarly, when the amount of information flow in the brain exceeds a certain threshold, informational vortices emerge in the network. These vortices correspond to some conscious states.

In BIH, emotions are regarded as the phenomena by which the information flows in the three layers are interrupted in order to take timely actions, in other words, the real time constraints intervene in the information flows that may not converge and synchronize at the time an action must be taken. The vortices collapse immediately, i.e., conscious thinking terminates in favor of taking timely action.

In summary, consciousness and emotion function jointly for determining communication behavior.

Biorhythm of information flow

Information flow in the brain has a one-day cycle. While sleeping, the amount of the flow stays at a minimum level. In the daytime, the flow increases to the maximum level while working intensively. However, the actual amount of flow is determined by the relationships between the state of the external environment and the desire of the self. Metaphorically, the one-day cycle of information flow is similar to the daily changes of the ebb and flow in a narrow strait where the emergence of vortices depends on the amount of the one-directional tidal stream.

Role of language

The vortices emerge spontaneously when conditions are satisfied. However, as the skill of using language developed and matured, and began to be stably inherited among generations, it began to work as triggers to make vortices emerge, like pegs cause turbulent flows to make vortices emerge.

Multiple personality disorder

When making decisions, a number of candidate actions are evaluated for their suitability in the current situation. However, the actions that are actually taken are largely determined by the evaluation performed by the experience-based reward system located at the junction of the cerebrum and the cerebellum. This evaluation process is unconscious.

In the human brain, there coexist multiple personalities by nature. In the cerebrum, there are a number of small-scale networks that serve as elements for defining personality. The combination of the partial elements, which is the result of information flow in the cerebrum, is determined by the reward system, and therefore there is the possibility of emergence of one personality for some situation and another for a different situation. Which personality emerges depends solely on the external information that is fed to the brain, the contingency of selection of the route of information flow in the cerebrum, and the nature of the experience-based reward system.

Nonlinear Dynamic Human Behavior Model with Real-Time Constraints (NDHB-Model /RT)

Living organisms, including human beings, act autonomously. The living environment on the Earth is a field constructed through interactions among the living organisms in a variety of ways. The Earth's environment changes continuously in a one-year fundamental cycle. In order to attain stability in the ever-changing environment, which incorporates the Earth and the other living organisms, living organisms have developed their own autonomous control systems.

The whole universe of complexly interconnected living organisms thus constructed can be called "an organic self-consistent field." Figure A depicts such a field from the viewpoint of the information structure. The autonomous living organisms act by mapping the information structure shown in Fig. A onto their brains in their evolution. The nonlinear dynamic human behavior model with real-time constraints represents an organic self-consistent field as a model.

It consists of three fundamental nonlinear constructs that correspond to the information structure of Fig. A.

1. **Brain Information Hydrodynamics (BIH):** BIH deals with information flow in the brain and its characteristics in the time dimension. -- *This poster*
2. **Structured Meme Theory (SMT):** SMT deals with empirical effectiveness of information and its range. -- *A companion poster presented at CogSci2008*
3. **Maximum Satisfaction Architecture (MSA):** MSA deals with how autonomous systems achieve goals under constraints. -- *Poster presented at CogSci2007*

BIH, SMT, and MSA jointly define constraints for actions as follows. The phenomena that emerge in the human society are the results of the actions that each human's autonomous system takes in order to maximize satisfaction and happiness (MSA) under the constraints defined by BIH and SMT. Figure B depicts the brain mechanism according to the proposed model. The brain consists of memory that functions as an autonomous organ and bodily activity control that functions as a somatic organ.

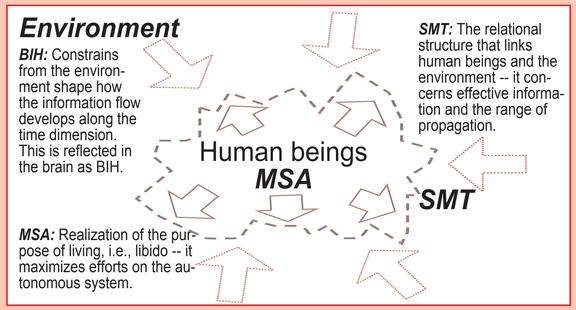

Figure A: Three fundamental constructs that define the nonlinear dynamic human behavior model with real-time constraints.

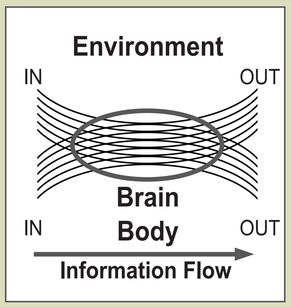

Figure 1: Interaction between brain and environment based on feed-forward control.

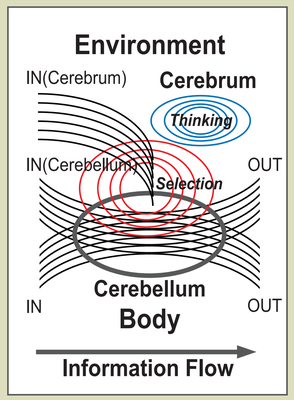

Figure 2: Formation of cerebrum.

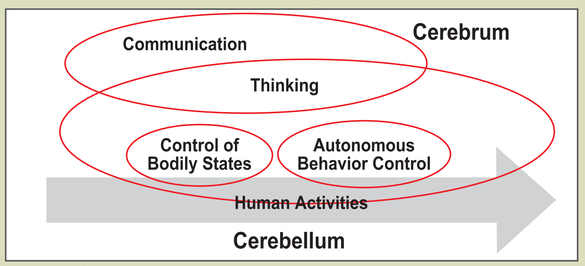

Figure 3: Information flows in the brain.

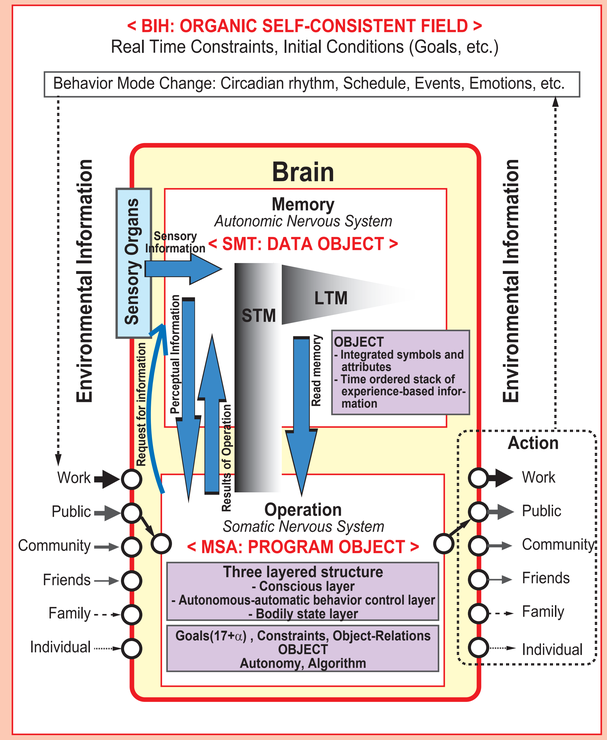

Figure B: Mechanism of the brain explained by the NDHB-Model/RT.