Neuroinformatics in vision: VISIOME Platform

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Abstract - The NRV project (Neuroinformatics Research in Vision) is the first project in Japan started in 1999 under the Science and Technology Agency of Japan, aimed at building the foundation of neuroinformatics research. Because of the wealth of data on the visual system, the NRV project will use vision research to promote experimental, theoretical and technical research as a pilot study on neuroinformatics. Details can be found at: http://www.neuroinformatics.gr.jp/.

I. BACKGROUND

Recalling the origins - in a recent report from the OECD Megascience Forum [1] the new field of neuroinformatics was defined as "the combination of neuroscience and information sciences to develop and apply advanced tools and approaches essential for a major advancement in understanding the structure and function of the brain". An emerging trend in modeling and understanding brain processes is that understanding brain at one level can be greatly enhanced by considering the process embedded in its context. Equally important is consideration of complexities of neuronal processes operating in much detailed sub-systems.

Significant goal is to explore how abstractions at different levels are related, e.g. the pathways from molecular to system levels. Another critical goal is to discuss the disposition of the computational approach to support effective modeling across abstractions and sub-systems.

II. BRAIN SCIENCE RESEARCH IN JAPAN

Figure 1 and 2 are the plan for a strategic target time table developed for the areas of "Understanding the Brain", "Protecting the Brain" and "Creating the Brain", by the Long-term Strategy for Research and Development of the brain (Brain Science Committee in Japan, May 1997, revised July 2000).

Along this plan, the NRV Project: Neuroinformatics Research in Vision (PI: Shiro Usui) has been started in 1999 under the grant for "Target Oriented Research and Development for Brain Science", the Special Coordination Funds for Promoting Science and Technology by the MEXT, JAPAN [2]. There is also a new national schemes related to Neuroinformatics, a new laboratory of Neuroinformatics at RIKEN BSI will be established in 2002.

![Figure 1. Strategic target time table for Brain Science Research in Japan](image-url)

(Brain Science Committee in Japan, May 1997, revised July 2000).
### III. NRV PROJECT

One of the frontiers of the 21st century is the elucidation of the complicated and elaborate functions of the brain, such as sensory perception, recognition, memory, emotion, etc. The specialization and segmentation of advanced research topics make it very difficult to integrate related evidence so as to understand the functions of the brain. The introduction of information science technology in the analysis, processing, transmission, storage, integration, and utilization of information is indispensable.

Neuroinformatics is the new research paradigm for the 21st century, which fuses the experimental techniques with the mathematical and information science techniques. In particular, mathematical models are used to describe and integrate data and results obtained from a number of research fields. These mathematical models can be regarded as the platform that supports the simulation experiment indispensable for studying and understanding the function and mechanism of the human brain.

In general, Neuroinformatics should construct the support environment that integrates the databases devoted to various research fields with the data analysis techniques. This should promote research relying on mathematical models, and advance the comprehension and knowledge of brain neuronal systems. If the research of each conventional field is a warp, neuroinformatics is the woof which links them.

The NRV project is the first project in Japan started in 1999 under the Science and Technology Agency of Japan, aimed at building the foundation of neuroinformatics research. Because of the wealth of data on the visual system, the NRV project will use vision research to promote experimental, theoretical and technical research in neuroinformatics.

The first goal of the project is to construct mathematical models for each level of visual system (single neuron, retinal neural circuit, visual function). The second goal is to build resources for neuroinformatics utilizing information science technologies and the research support environment which integrates them. The third goal is to realize a new vision device based on the brain-type information processing principle. The NRV Project has the following research groups and their sub-themes at this present fiscal year of 2001:

#### Table 2. Creating the Brain – Development of Brain-style Computer

(Brain Science Committee in Japan, May 1997, revised July 2000).

<table>
<thead>
<tr>
<th>Examples of brain-style computers to be developed</th>
<th>Information-processing technologies working in fluctuating, uncertain and fuzzy environments</th>
<th>Active information-processing technologies based on associative memory and flexible recall intuitive thinking</th>
<th>Basis for developing an information-oriented society with intelligence</th>
<th>System which understands and responds to human intentions and emotions</th>
</tr>
</thead>
<tbody>
<tr>
<td>To establish and elucidate the principles involved in information processing in the brain</td>
<td>• Determination of the calculation principle for cognitive and motion control</td>
<td>• Determination of the calculation principle for decisions, memory and information integration</td>
<td>• Establishment of neuroinformatics</td>
<td>• Development of human-friendly network-compatible neurocomputers that are symbiotic with human beings</td>
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<tr>
<td>To develop brain-style devices and neural architecture</td>
<td>• Development of memory neurochips with synapse modification (one million synapse scale)</td>
<td>• Development of a neural architecture for thinking mechanisms (100 million synapse scale)</td>
<td>• Development of computer systems equipped with intellectual, emotional and willing abilities</td>
<td>• Development of robot systems that support human intellectual life</td>
</tr>
<tr>
<td>To design brain-style systems for information generation and processing</td>
<td>• Development of brain-style dynamic memory systems</td>
<td>• Development of a self-organizing memory system with information integration</td>
<td>• Development of a system for the integration of intuitive thinking a logical reasoning</td>
<td>• Development of novel creative information systems</td>
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[Figure 2. Creating the Brain – Development of Brain-style Computer](https://doi.org/10.1109/9781557264213)
Group 1: Modeling a single neuron by mathematical reconstruction

Intracellular information processing mechanism between nerve cells are described by mathematical models. This group carries out the construction of "virtual nerve cell" by integrating knowledge obtained from molecular biology, biophysics, electrophysiology and anatomy, to produce models of single neurons. Such mathematical models can reproduce behavior of realistic neurons on a scale of molecular to simple neural circuit, spatially, and sub-millisecond to year, temporally. They are considered as the smallest functional units of a model family.

Study on the analysis and modeling of single cell signaling

Masahiro Sokabe (Nagoya University)

Creation and analysis of 3D biochemical reaction models for neuronal cells

Kazutoshi Ichikawa (Fuji Xerox Co., Ltd)

Synaptic integration in neuronal cells

Hiroyoshi Miyakawa (Tokyo University of Pharmacy and Life Science)

Research on dynamics of cultured neuronal networks

Akio Kawana (Takushoku University)

Mathematical model of insect brain neural network

Hidetoshi Ikeno (Himeji Institute of Technology)

Group 2: Realization of virtual retina based on cell physiology

The retina is an ideal preparation for studying brain structure and function as well as neural signal processing in the brain, partly because it is a very accessible and self-contained part of the brain. Consequently, there is a considerable amount of research results on all aspects of retinal visual information processing. A mathematical model of a retinal neural circuit will be constructed from neurophysiological experimental data and from the characteristics of single neurons obtained from G1. This retinal neural circuit will form the base for "virtual retina". Multiple cellular functions will be integrated into a mathematical model of the retinal-neural-circuit information processing mechanism that encompasses everything from the light energy conversion mechanism in a photoreceptor, which is the input, to the encoding mechanism of impulse sequence in a ganglion cell, which is the output cell of a retina.

Physiological studies on ion channels and synaptic mechanisms of retinal neurons

Akimichi Kaneko (Keio University)

Parallel information processing and neural coding in the visual system

Masao Tachibana (University of Tokyo)

A neuroinformatics study on the model of the vertebrate retina

Yoshimi Kamiyama (Aichi Prefectural University)
Group 3: Study on the visual function by computational and systems’ approach

Two kinds of information flow exist in the visual system: One part of the visual system processes information related to intrinsic object properties or discrimination of objects, such as color and shape. Another part is concerned with the discrimination of motion and position (spatial vision). This group evaluates the information processing mechanisms in both the object discrimination and motion perception, and constructs mathematical models for these visual functions.

A model study for self-organization of functional maps in visual cortex
Masanobu Miyashita (NEC)

Mathematical modeling of information integration for visual perception
Shigeru Tanaka (RIKEN)

A neurocomputational model for color perception
Shigeki Nakauchi (Toyoohashi University of Technology)

Brain dynamics of visual perception and cognition
Hidehiko Komatsu (NIPS)

Neural network model for spatial recognition based on motion parallax
Susumu Kawakami (Fujitsu Ltd.)

Cognitive and computational approaches to non-rigid 3D object recognition
Shigeru Akamatsu (ATR)

Derivation of qualia from spatiotemporal activity patterns in neural networks
Yoshihide Tamori (Kanazawa Institute of Technology)

Neural network model for the mechanism of visual pattern recognition
Kunihiko Fukushima (Tokyo University of Electrocommunications)

Binocular information processing mechanism in the visual cortex
Izumi Ohzawa (Osaka University)

Group 4: Realization of vision devices and utilization of silicon technology for recording and stimulation

Movement detection is based on the spatio-temporal information processing in vision. It is one of the most basic and important functions of human and other living creatures. This study carries out research on the realization of new devices, circuits, and networks which fuse the visual information processing mechanisms of movement detection with semiconductor devices or circuit functions. It aims at the development of the analog-digital hybrid vision device with the ability that exceeds human vision (for example, ultra-high speed). In order to record signals from nerve cells, or stimulate nerve cells, we utilize silicon growth technology and aim at developing multi-channel electrode array, which could be implanted on intact visual neural system.

Analog vision chip for early vision
Hiroo Yonezu (Toyoohashi University of Technology)

Hybrid vision chips for intelligent image processing
Yoshihito Amemiya (Hokkaido University)

Fabrication of micro 3D sensor array with ultra-small Si wire electrodes and applications to measurement of retina cell potentials
Makoto Ishida (Toyoohashi University of Technology)

Group 5: Fundamental neuroinformatics research and development

The total support environment for experimental data analysis, model parameter estimation, simulations, etc. will be developed. The results of this project will be made available on the internet in a database: VISIOME (= Vision + ome) Platform that integrates morphological and physiological knowledge, mathematical models, related studies, and references.

Study on the learning algorithms for neural data analysis
Andrej Cichocki (Riken, BSI)

Study on algorithms for analyzing brain and neuronal visual system
Yasunari Yokota (Gifu University)

Development of computer support environment for neuroinformatics
Keisuke Takebe (Nagaoka National College of Technology)

Construction of a neuroinformatics database for neuronal visual system
Isao Yamaguchi (Fuji Xerox Co., Ltd.)

Research and development on building the integrative support environment for modeling and simulation
Yasuo Fujii (DSP Technology Co., Ltd.)

IV. VISIOME PLATFORM: A Neuroinformatics Database and Environment for Vision Science.

Understanding the brain function requires integration of many and diverse information from the level of molecule to the level of neuronal networks. However, the huge amount of information is making it almost impossible for any individual researcher to make an integrated view of the brain. To solve this problem, it will be required to make useful neuroinformatics tools for information storing, maintenance and sharing. In the present study, we constructed a database system for neuronal visual system named "Visiome Platform" as a test bed for useful neuroinformatics environment.

The basic concept of the Visiome Platform is to make a website integrating mathematical models, experimental data and related information. The Visiome Platform has two major charac-
teristic features. First, it will allow researchers to reuse the models and experimental data in the database.

Researchers can see how the models work or compare their own results with other experimental data, improve or integrate models, and formulate their own hypothesis into a model. Second, it will provide novel index system (Visiome Index) of research field of the visual system specially oriented to the model studies. The Visiome Index is based on neuronal and cognitive functions that are important targets of modeling studies. The Visiome Index will help researchers to understand the visual system from the aspect of visual functions and to construct models formulating their own hypotheses.

The Visiome Platform will provide more than just a database of models and data. Powerful analysis libraries and simulation tools will be also available on the platform including the Personal Visiome. The Visiome Platform will realize a virtual environment for global electronic collaborations by making available to researchers useful tools for simulation and data analysis with reusable models and data.

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References