Brain Science in Japan : Strategies and Golas

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1. Introduction

Understanding the principles of operation of the brain remains one of the greatest challenges of modern science. Often, brain science has been described as the last frontier of science. This description indicates the fact that in brain sciences we are confronted with more questions than answers, and that answering even the simplest questions like how we see, how we leam, and how we think remain mysterious. This, in part, is the reason why advanced countries like US(Decade of the Brain), European Union(European Decade of the Brain), and Japan (Frontiers Brain Science Program, Century of the Brain) are heavily engaged in establishing nationwide efforts for solving such questions.

One main difference between classical neurobiology(conducted aminly in medical schools) and modern brain science is the fact that while neurobiology mainly attempted to investigate the cellular and molecular structures of single neurons, the modern brain science tries to understand the structure and function of millions of neurons, and ultimately, that of entire brains. Tentatively, moden Brain Science can be divided into three principle components :

a) principles of Brain operation and development. In this, we ask the question, how a device like the human brain which is composed of 100 billion relatively simple switching elements(neurons) solves such computationally enormous tasks as seeing, understanding, speaking, thinking, and remembering. Until now, almost nothing is known about the biological and physiological foundations of such brain functions. Furthermore, it is essential for the operation of the brain, that the structural and algorithmic basis of its operations are not designed on the blue print, but rather, it emerges during postnatal life through self-organzed learning. Understanding both the language of the brain operation(i.e. understanding the programming code of brain operation), and the language of brain development(i.e. understanding its design principle) will provide us with essential knowledge about the biological basis of learning, social behavior, cognition, perception, and ultimately that of emotion and consciousness.

b) Healing Brain-related disorders. The research of brain operation and development provides the basis for understanding the cause and possible treatment of brain-related disorders such as Alzheimers disease, Parkinsons disease, stroke, and depression. With the steady increase of aging population in both developed and developing countries, brain-related disorders emerge as the biggest social and financial burden for all existing health care systems. In Japan alone, the medical expenditure for neurological and psychiatric diseases are estimated to be greater than 4 trillion Yen per year, which roughly accounts for 20 Percent of all medical expenditures. The current system of treatment of brain-related disorders, however, are mainly based on experience rather than on real understanding of the underlying problems. In analogy : as long as we dont understand how a normal computer works, all our efforts to repair an ill-operating computer must remain tentative

c) Development of neuromorphic(Brain-like) systems for real-world problems. Designingintelligent systems for real-world problems has been a dream of mankind for centuries. The latestapproach to tackle this problem, the symbolic AI(artificial intelligence), was based on an unrealistic hope that all human cognitive functions (such as object recognition, and understanding natural language) can be expressed in explicit algorithms.. This is a too optimistic notion that cannot be justified by what we know from human brains operations. A more promising approach is to learn how the brain solves certain classes of computational tasks, and apply its algorithms on artificial devices such as autonomous robots. The potential benefits of neuromorphic engineering are enormous: from caneras that can recognize faces and objects to computer systems that can understand natural languages. Next, we may be able to design artificial eyes and ears for humans and robots, and finally even entire computers and robots capable of learning, perception, and self-consciousness for human assistance in factories, military, and service areas.

2. Status of Japanese brain science in the past

In Japan, the importance of brain sciences was recoginzed early, and tentative programs were launched to initiate a nationwide effort, The Council for Science and Technology underlined the importance of brain sciences in a report titled Opinions on the Basic Policy for Promotion of Brain and Neurological Science and Technology as early as August 1987, Later, in June 1994, the Council for Aeronautics, Electronics and other Advanced Technologies announced in a report titled in the Ways of Promoting Comprehensive R&D for the Formation of Infrastructure for Promotion of Elucidation of Brain and Neural Functions the importance of modern brian research. A major step in promoting the brain sciences in Japan was the initition of Human Frontier Science Program(HFSP) - an extraordinary successful program in which leading international laboratories were encouraged to collaborate with Japanese institutes, For example: a leading US laboratory, when collaborating with a Japanese group, was almost certainly funded by the HFSP. The only condition was(and still is) that these foreign loboratories needed to submit a detailed progress report every year, Also, they were expected to present the results of their studies in Japan once a year. Within few years, Japanese brain science groups received on this way cutting-edge information about recent trends and results from leading laboratories in US and Europe.

Another major strategic success was the establishment of Frontiers Brain Science Program within the Institute of Physical and Chemical Research(RIKEN) mear Tokyo. As a dominant part of the Frontiers Research Program(which also consists of research in material sciences and photosynthesis), it introduced several new features revolutionary for Japan: the researchers were hired on limited contracts; laboratories were scheduled to be dissolved after 5-10 years; many foreign researchers including at principal investigator level were hired; and English was accepted as the official language for all seminars and internal meetings. While in most US laboratories researchers are forced to produce publishable results within 1-2 years to get federal or private funding, each laboratory in Frontiers Brain Science Program receives a stable and large size funding for many years. Today, the Frontiers

Brain Science Program is regarded - even in US and Europe - as one of the best places for conducting high-risk and long-term brain science projects. The most prominent members of the Frontiers Brain Science Program are: Professor Masao Ito(head of the Frontiers Program, working in learning mechanisms of cerebellum), Dr. Keiji Tanaka (working on face recognition system of monkeys), and Professor. Sun-Ichi Amari (theoretical neuroscience).

Brain Science in Japan is currently also conducted in many individual universities and laboratories. The most outstanding laboratories being located in Tokyo, Kyoto, and Osaka. Japanese Laboratories are extremely competent in molecular neuroscience, and recently gained substantial territories also in cognitive neuroscience. The Japan Neuroscience Society has about 3,000 members, and the total number of researchers participating in brain-related researches is estimated to be about 10,000 in Japan. The current budget for brain-related sciences, excluding the international HFSP, amounts to a total of 10 billion Japanese Yen per year.

3. Problems of current Japanese Brain Science

Despite the success of few outstanding laboratories(such as those in the Frontiers Brain Science Program), brain science in Japan as a whole, faces substantial problems (cited from The Age of Brain Science-Proposed Plan for Brain Science Research Advancement Program):

a) Brain science research in Japan has been conducted independently in various universities and laboratories with the support of research budget from several government ministeries and agencies. However, looking at the interdisciplinary and systematic development of brain science in recent years, cooperation on national scale is desired.

b) The budget for brain science research in Japan is smaller by an order of magnitude than that in the US, and at the same time the funding period is too short, The brain science related budget in the US is greater than 120 billion Yen from the National Institute of Health(NIH) alone. When compared with this figure, the research budget of 10 billion Yen(currently in Japan) is far too small.

c) The number of researchers in Japan is only a fraction of that of the US, a very small figure indeed(the Society for Neuroscience in US has 25,000 members, and the total number of researchers directly associated with brain science in US is over 100,000). It is desirable to call researchers together from many different disciplines and increase the total number of people working on this research.

d) Brain science research in Japan is being conducted in small research units in universities or in sections of laboratories, and the scale of research is very small. In any research, when the scale goes above a certain level, the degree of activity causes dramatic discoveries to be made. However, at present, the situation is that small groups of researchers are scattered over the country. It is therefore desirable to raise the efficiency of the activity by increasing the scale of research.

e) The recent development in brain science necessitates high-technology large-scale equipment and facilities. These are all very expensive, and it is extremly difficult for small research unit to procure enough for its needs.

f) The supply of research materials, including the development, maintenance and supply of animals for experiments is sadly lacking, so at present individual researchers are being forced to spend a great deal of time and effort simply on the development and procurement of test animals.

g) Generally, younger researchers tend to be immobile at national and public universites and laboratories(as in compare to US and Europe). Moreover, there is no system to provide them with opportunities and economic guarantees to help realize their potential in the period when their activity is in its prime.

h) Asistant researchers and highly qualified technicians are essential for researchers to deliver their full abilities by earning them effective time. Close mutual interaction is indispensable in a research team, but in Japan the total number of assistants is far too small to assure a sufficiently broad mass.

4. Strategic targets of Japans new brain science program

The recent declaration of Century of the Brain by the Japanese government, and the establishment of Brain Science Institute in October 1997 addresses the above problems, and tries to find innovative solutions. As a whole, three strategic targets were defined as goals of Japans brain science program:

a) Understanding the Brain. That is

ⅰ) Elucidation of the structure and function of brain regions that enable perception, emotion, and consciousness.

ⅱ) Elucidation of the brain functions for communication.

b) Protecting the Brain. That is

ⅰ) Control of the development and the aging process of the brain.

ⅱ) To restore and prevent neurological and psychiatric diseases.

c) Creating the Brain. That is

These strategic target are all extremely far-reaching and ambitious, each requiring a long period of intense research. While the entire period for achieving the above goals is projected to be 20 years, individual sub-goals will be defined in order to maintain maximum efficiency in research activities. The entire brain science program will be divided into two parts of ten years(sub-goals ⅰ and ⅱ), and each sub-goal again divided into two parts of five years targeting individual goals. From practical point of view, this means that individual laboratories will be supported for a period of maximum 2 times 5 years, in which they can target two individual research goals that should be framed within a larger sub-goal.

To implement the above goals, three measurements will be established;

1) The opening of a brand new central research institute dedicated sorely to modern brain sciences. This new Brain science Institute(BSI) is an independent research facility located within the campus of The Institute of Physical and Chemical Research (RIKEN) close to Tokyo. The former Frontiers Brain Science Program was completely dissolved, and the 20 brain science laboratories were incorporated into a 5-story building of the new Brain Science Institute. After completion of two more 7-story buildings in the next 2 years(construction begin: spring 1998), a total of more than 60 laboratories are scheduled to be located in the Brain Science Institute. Each laboratory is located in spacious and extremely will-equipped environment, A large and stable funding for at least 5 to 10 years guarantee efficient and productive research activities. Each laboratory consists of about 10 to 20 people(including students and foreigners), and is generously funded(50 million Yen per year for equipments and 36 million Yen per year for salaries). BSI is thought to be the central research institute of Japans Brain Sciences. This new central institute will be responsible for comprehensive studies of basic brain sciences, and it will also be responsible for the development of novel technologies and materials required for modern brain sciences. The idea behind this new institute is the assumption that the efficiency of research activities increases as the number of researchers and research projects goes above a certain level, and researchers from different specialized fields obtain the opportunity to work together. This is essential, as modern brain science absolutely requires interdisciplinary collaborations between researchers of such diverse backgrounds like Neurobiology, Computer Science, Psychology, Physics, Medicine, and Electrical Engineering. Therefore, the new BSI should be larger in scale than conventional ones, and have a greater number of researchers, both Japanese and foreign, from a wide spectrum of fields.

2) Establishment of Advanced Technology development Center(ATDC). It is recognized that for the strong promotion of brain sciences, technical support will be vital. Currently, the level of Japans supply of research equipments, materials, and animals is behind US and Europe. To address this problem, the ATDC will recruit researchers and engineers with high potentials of development of advanced key technologies for modern brain sciences, such as:

a) Development of advanced non-invasive recording techniques such as optical imaging, functional fMRI, MEG etc.

b) Development of advanced software for image analysis and data compression.

c) Development of large-size simulators for brain-circuitry modeling.

d) Development of next-generation microscopes, such as laser confocal microscopes or two-photon microscopes.

e) Development, maintenance, and supply of various kinds of experimental animals(for example rats, mice, cats, and monkeys), including those with specified genetic dysfunction for research purposes.

f) Development of an unified and object-oriented database for brain-related informations.

3) Establishment of Brain Science Promotion Office. To allow a efficient implementation of strategically important research subjects in brain sciences, a committee comprising representatives from related government agencies and leading researchers from various fields of brain science will be responsible for formulating the mid to long-term goals of brain science projects, and how to promote those goals. This committee will attempt to promote the personnel required for brain sciences, integrate brain-related research activities in Japan, and in general attempt to be a driving force for brain science in Japan both in terms of securing the necessary funding and strategic goals. Another important responsibility of this Brain Science Promotion Office will be to secure research promotion grants for strategic research for teams to be organized by talented leading researchers in universities and other research institutes.

During the first half of the 20 year brain science program in Japan, the total cost (direct and indirect costs) for implementation of the structures necessary for its strategic goals(establishment and operation of a central brain science, ATDC, and distribution of brain-related research grants under the Brain Science Promotion Program) is expected to be around 100 billion Yen per year(around 1 Billion Dollar per year). This extend is formulated to position Japans brain science program alongside the US and European one within the next years, and a stable funding was secured from the government at least for ten next ten years(i. e. about 1000 billion Yen for 10 years).

5. Potential problems of the current Japanese brain science program

Despite large funding and governmental support for Brain sciences, the current Japanese Brain Science program is not without serious-and potentially fatal-problems:

a) Most of the strategic goals for Japans Brain Sciences are too ambitious, too ambiguous and beyond the possibilities of todays assessments. Very similar to the current Brain sciences promotion program, Japan once announced the so called Fifth Generation Computer Program-an extremely ambitious program to construct a genuine artificial intelligence(AI). The Fifth Generation Computer Program failed almost completely because of the lack of concrete and measurable goals.

b) There are not enough Brain researchers in Japan qualified enough to use the available funding for world-class research. For example, the Brain Science Institute is scheduled to open 40 additional laboratories in the next few years, but there are not enough world-class brain researchers to fill those positions. One potential solution might be to hire high-quality researchers from USA and Europe, and indeed the Brain Science Institute tries to have at least 10 Percent of the Team Leaders (laboratory head) as foreigners. However, this is extremely difficult given the social and language problems a foreigner faces in Japan.

c) One of the most dangerous tendencies in current Brain Science Promotion Program in

Japan is the fact that a large amount of new funding and resources are being distributed among already established and old-style neuroscientists. This is in contradiction to the stategic goals of the Brain science program, since it claims to promote talented young researchers and to integrate interdisciplinary activities from various fields. For example, some of the most prestigious laboratory positions at BSI were given to several professors retired from leading Japanese Medical Universities. From logical point of view, it is difficult to imagine how a retired oldstyle university professor can lead a brain science laboratory aimed to promote emerging technologies and interdisciplinary researches.

d) Althoug the interdisciplinary character of brain science is recognized and facilitated, in reality, most of the new and well-funded laboratories are still dominated by research teams working in complete ignorance from each other. This is natural given the fact that the Japanese education still doesnt allow young students and researchers to be trained in different academic fields simultaneously. In US and European brain science laboratories, one find more and more people with university degrees in two or several disciplines, such as in computer science and psychology, or in medicine and physics. In Japan, researchers with such interdisciplinary background are almost not existent. This is a fatal weakness for a research program like the Brain Science, which in its core requires an interdisciplinary approach.

6. Summary, Conclusions, and lessons for emerging Brain science in Korea

In summary, all advanced countries (US, Europe, and Japan) now recognize that the Brain Sciences arethe last frontiers of science, and that the Brain sciences will generate the most amount of newknowledge and skills required for the technical and economic leadership of nations in 21th century. Thisis in analogy to the success of information technology and biotechnology in 20th century. The scientific, technical, and infrastructural foundations for them were prepared in advanced countries in the first half of this century, and those nations are still profiting most from their early investments. The strength of Japans Brain Science Program is its large and stable funding, its attempt to define stategic goal, and its willingness to invest in highly interdisciplinary and high-risk programs such as Brain-style computing devices. Its weakness, however, are its lack of sufficient high-quality man power, and the risk of the funding being distributed among low-quality researchers who just happens to be well-connected to funding institutions. The situation of Japans new Brain Science Promotion Program can be illustrated by a recent speech of Professor Arima, the head of The Institute of Physical and Chemical Research(RIKEN), in which the new Brain Science Institute is located: he wamed the members of the Brain Science Institute, that a research institute with poor equipments but good people can generate excellent results, but an institute with excellent equipments but low-quality researchers will never be a world-class laboratory.

In conclusion, Japans Brain Science Program now obtained a world-class hardware to conduct cutting-edge Brain sciences, but its software(the man-power) is still lacking far behind the more advanced nations, and it remains to see whether Japans Brain Science Program will be able to solve this software problem in coming years. Unfortunately, there are only a handful of laboratories in Korea which come even close to the definitions of the goals of modem Brain Sciences as described in the beginning of this article. Therefore, the lessons for Korea are obvious: if Korea doesnt want miss an unique opportunity to set foundations for the emerging technology and market leadership in next century, it needs to invest in modern brain Sciences now. Unlike in other next-generation high-technology disciplines, the gap between Korea and other advanced nations are not that huge in absolute term, since even they just started to switch their research efforts from more traditional neuroscience to advanced and interdisciplinary Brain Sciences. It is hoped that Korea can enter this new exciting and important field of science soon, and that young Korean researchers will be able to join and soon lead the world-class of Brain Sciences.

6. Notes and Acknowledgments

The author of this article was a senior researcher at the Brain Science Institute (former Frontiers Brain Sciences Program) in Japan from 1996 to 1997. After graduating in Cognitive Psychology and Computer science from the Technical University of Darmstadt in Germany, he obtained his PhD in Brain Sciences from the Max-Planck-Institute for Brain Research in Frankfurt, Germany(1994).

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