

Figure 2. Brain Inspired Computing System

### 2.3 Our Objective and Approach

Brain function and its mechanism has become to be investigated precisely, so we believe that we can realize a new computer system which solves the previously mentioned three challenges by focusing on the cutting-edge results of these studies, extracting and organizing the elements available for engineering purposes. By this approach, we try to realize three technologies, new computer architecture, calculation mechanism and programming model. In addition, these technologies can be flexibly implemented by several kinds of methods (semiconductor chip, IoT, supercomputer, etc.) The application of these results will cover various fields such as society, workstyle and livelihood.

## 3. Brain Inspired Computing (BIC)

### 3.1 3 Layer Structure of Brain Science Research

We categorize the brain science research into the three-layer structure. The first layer is the investigation of the nerve circuits and the physical structure of brain. The second layer is the investigation of the behavior of nerve cells and the mechanism of basic functions of intelligence produced by neural network, such as recognition, determination, motion, memorization and learning. The third layer is the investigation of the high-order brain function that leads to creativity such as concept generation and verbal communication, etc. At present, these three layer studies are independent from each other respectively, and are concentrated in the "investigation of the brain" in each layer. We recognize these brain science researches in the three-layer structure from the viewpoint of computer, and associate these three layers vertically and integrate them as a computer technology.

### 3.2 Reflection of Brain Science to Computer Science

We rethink the three layers of brain science research from the perspective of computer engineering (Figure 2). Study of the first layer is the investigation of physical circuit structure integrated and interconnected with component levels of synapses and neurons, and can be applied to the structural design of architecture in computer system. Study of the second layer is the investigation of neural circuit signal processing model, and can be applied to the design of the calculation algorithm. Study of the third layer is the investigation of the high-order function mechanism such as concept generation and verbal communication, etc. caused by integration and operation of the second layer functions, can be applied to the design of programmability. Of course, each layer of the above-described computer system study is related mutually and it is necessary to cooperatively designed.

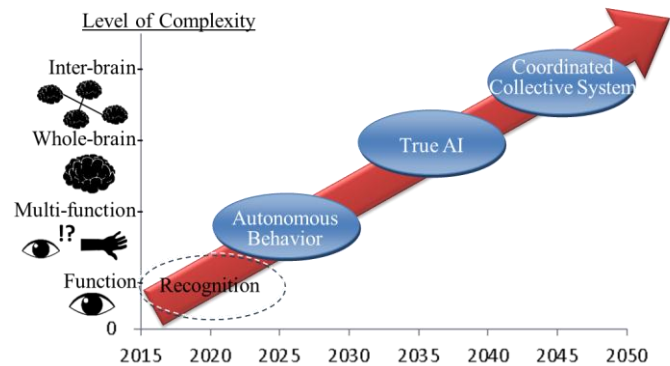


Figure 3. Progress of Brain Inspired Computing

By the way previously proposed, BIC System aims to solve Ultra-large scale, Ultra-high autonomy and Ultra-low power subjects in the future BigData solutions.

### 3.3 Progress of Brain Inspired Computing

It is said that the human brain is consisted of 100 billion neurons [5]. The brain realizes the functions of recognition, determination, motion, memorization and learning.

The evolution of BIC system depends not only on the number of neurons or circuits, but also on the complexity of functions (Figure 3). As the first step, by our research we realize the autonomous behavior BIC that can recognize, determine and control motions automatically and adaptively. The autonomous behavior BIC can become the platform for "True AI" system research, and in the future these "True AI"s collaborate each other as the "Coordinated Collective System".

## 4. Conclusion

In this paper, we considered the cooperation between brain science and computer science and discussed realization of a new computer system based on these. We believe the new paradigm brought by Brain Inspired Computing (BIC) is able to solve subjects of Ultra-large scale, Ultra-high autonomy, and Ultra-low power.

Our goal is to solve social problems by the realization of the BIC and to cause a technological singularity. In this case, the singularity is not a threat of humanity. It will become a desirable starting point to challenge many social difficulties.

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## 6. REFERENCES

- [1] "The SINGULARITY IS NEAR" web site, <http://www.singularity.com/>
- [2] The Singularity Is Near: When Humans Transcend Biology, Ray Kurzweil(2005)
- [3] NICT CiNet web site, <https://cinet.jp/>
- [4] RIKEN BSI web site, <http://www.brain.riken.jp/>
- [5] Suzana Herculano-Houzel, "The Human Brain in Numbers: A Linearly Scaled-up Primate Brain," Front Hum Neurosci, 2009, PMC2776