Brain Inspired Cognitive Computing System

Kosuke NISHIHARA   Norihiko TAYA   Toshiyuki KANOH

Osaka University NEC Brain Inspired Computing Research Alliance Laboratories
1-5 Yamadaoka, Suita-city, Osaka, 585-0871, Japan
Email: k-nishihara@ist.osaka-u.ac.jp   n-taya@ist.osaka-u.ac.jp   t-kanoh@ist.osaka-u.ac.jp

Abstract– Neural network based artificial intelligence like deep learning research makes remarkable progress by using huge and high performance computing resource. On the other hand, brain science research clarifies that human brain realize a multimodal, flexible and efficient cognitive function by only 20 watts power consumption and about 2kg weight body. This paper introduces our challenge realizes the artificial cognitive system by following the result of brain function and structure analysis.

Keyword– Artificial Intelligence, Brain Science, Brain Inspired Computing

1. Introduction

Human brain is a system with about 2kg and 20 watts power consumption, and the compact body has sophisticated cognitive ability. In recent year, brain science research is showing significant progress in elucidation of brain functions and brain structures. We have been studying to realize a new artificial intelligence system by following brain research results and its knowledge [1]. This paper introduces our challenge to aim for realization of a brain inspired artificial intelligence system with a different approach from Deep Learning.

2. Approach following Cognitive Function

This paper focuses on efficiency and flexibility of human cognitive functions and applies these research results to realize “Brain Inspired Cognitive Computing System”. Recent researches are making it revealing that brains effectively use the limited resources to realize flexible and high-performance computing.

For example, the presence of two cognitive pathways in processing such as facial recognition [2], bio-logical motion recognition [3] and others, has become apparent. Thus, mechanisms for selecting efficient resources and pathways in response to situations, are being elucidated. In addition, in the process of acquiring a representation of motion, the possibility that the representation is being reconstruct using discretized data rather than original continuous input is shown [4]. In the process to acquire new functions by extending the body , it is pointed out that the brain can re-allocate the other already used resources to this extension processing [5]. These findings show that the brain has taken a strategy to make the best use of limited resources.

We follow the cutting-edge results of human cognitive functions to establish computationally executable models which by reassembling human cognitive abilities as Brain Inspired Cognitive Computing System.

3. Brain Inspired Cognitive Computing System

3.1. Brain Inspired Cognitive Computing System Features

We defined a system as Brain Inspired Cognitive Computing System that meets the following requirements.

- Optimization of resource usage
- Multimodality for diversified perspective
- Autonomy to behave on goal-oriented
- Visibility of internal processing

One of the important points to optimize usage of limited resource is knowledge that human brains use properly two cognitive pathway. One is a quickly and roughly processed pathway, another is a slowly and finely processed pathway. For example the former is used for avoidance of danger or defense against attack while saving resource with low load. On the other hand the latter is used to recognize face expression in detail with sufficient resource. We believe the proper usage of resource is one of the reason that human brains can effectively perform with much lower power compared to a today’s computer. The mechanism could be helpful to establish an overwhelmingly effective system which respond in real time depending on the purpose of use.

Brains handle different kind of sensory input in the same manner. The process by neuron firing does not depend on sensory perceptions. The common handling across multi-modalities of sensory input makes it possible to compliment damaged information of a modality by using information from the others. The diversified perspective in the basis of multimodal information could be beneficial to build a robust system from ambiguous input.

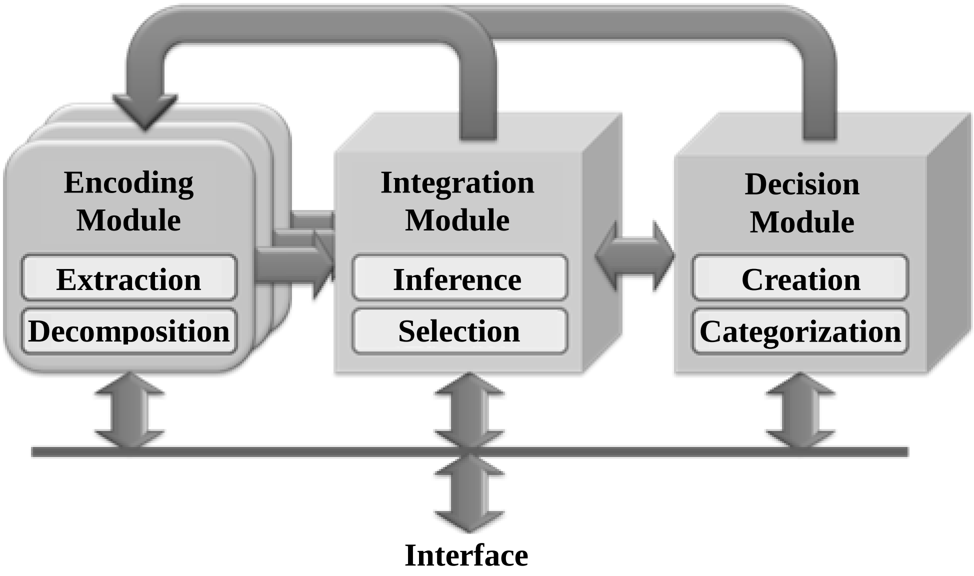

Fig. 1 Conceptual Diagram

People analyze environmental stimuli while decomposing the input into primitive elements. Then the representations are constructed through the combination of the primitive elements depending on respective goals so that we understand the environment. It is believed that even a new representation can be constructed with the combination. The adaptable attribute to novel environment could be used to realize an autonomously adaptive system.

Although current AI technologies like Deep Learning are gaining popularity, it is pointed out that the process is a black box. Features for internal representation are automatically optimized by using large amount of learning data. Eventually visibility in the internal process degrades because human-friendly features are not always extracted. An externally controllable and transparent system is preferable in practical use.

3.2. Conceptual Design of Brain Inspired Cognitive Computing System

The conceptual diagram of Brain Inspired Computing System was designed (Fig. 1). It consists of 3 parts, encoding module which inputs environmental stimuli as internal information, integration module which integrates features extracted with respect to each modality and decision module which handles manipulation on categories. Each module is composed of sub modules.

The encoding module translates system inputs into feature vectors following a common format. First, the module decomposes its inputs into primitive elements. Then it extracts features from respective elements. The format of the vector does not depend on the difference of modality.

The integration module integrates selected element representation. The module infers the element representation from feature vectors while complementing the damaged information. It selects appropriate representations across multi-modalities according the system purpose.

The decision module outputs a category suited for the system inputs. The module makes a novel category if necessary, when the input is confusing and cannot be categorized.

In recent years, brain science research is showing significant progress in the development of observation technology such as fMRI, NIRS and others. We instantaneously utilize the cutting-edge results toward realization of Brain Inspired Cognitive System.

4. Architecture Design

We designed a system architecture in the basis of the previously described conceptual diagram. Above all, we place emphasis on a manner to easily implement the research result into the system. Brain function’s research is progressing day by day. It is important that researchers can try their models in a moment of inspiration on a feasible platform. We show our proposed platform in Fig. 2.

4.1. Features of Platform Architecture

The features of our proposed architecture are as follows.

- Event-driven module execution optimized across the whole system
- Data handling structure sharing any data via Brain Information Database
- Graphical user interface (GUI) with internal information monitors and query-based commands for Brain Information Data

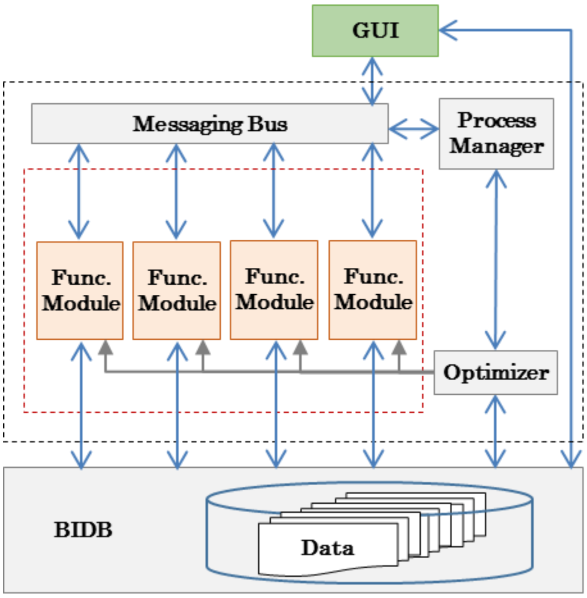

Fig. 2 Platform Architecture

Human brains feature modularity that separated regions work cooperating with each other. Multiple sensory inputs can be processed in parallel modules. In spite of the independent and parallel behavior of modules without central control, gathering of the modules look to be appropriately optimized as a whole. If the optimization manner can be applied, we believe the total system can perform more than summation of functional modules although even each module is independently designed.

A functional modules is driven by specific events and shares data with other modules via “Brain Information Database (BIDB)”. A functional module is a process that implements the aforementioned modules of Fig. 1. Event messages such as completion of a specific module are communicated between modules through “Messaging Bus”. The chain of events forms the processing flow. An event message can be received in multiple modules. Modules do not share data directly. Data stream optimized as a whole system is communicated between functional modules via DB we named as BIDB. Any data is stored into BIDB with history and can be loaded from any modules. Indirect communication between modules keeps the independence of the module and facilitates the addition and recombination of modules.

Data communicated between modules can be visualized by GUI. Any data such as extracted features, inferred element representation, category classification history and others from the past to the present are stored into BIDB according to the published specifications. The data for any moment can be accessed, so that queries can be issued to observe the internal state and to analyze the processes leading to cognition.

The platform makes it easy to implement models of various status and to connect each model. We believe the easy-to-implement manner boosts the cycle of brain function’s research and its model implementation.

5. Conclusion

We considered the cooperation between brain science and information science and discussed realization of a new computing system based on the research results of human cognitive functions. The previous computing system has evolved with the evolution of semiconductor technology increasing the amount of computational resources. The realization of computing systems that follow the brain would change the perspective of improvement from "Quantity" to "Quality". In the future, the interaction between two science regions will accelerate the development of both sides. We hope that our proposed platform can contribute to research beyond the fields of information science and brain science. We believe the new paradigm brought by Brain Inspired Cognitive Computing is able to solve hard problems we will face in near future.

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