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A Generic Software Platform for Brain-Inspired Cognitive Computing

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Abstract

We have been developing BriCA (Brain-inspired Computing Architecture), the generic software platform that can combine an arbitrary number of machine learning modules to construct higher structures such as cognitive architectures inspired by the brain. We discuss requirements analysis and design principles of this cognitive computing platform, report its implementation, and describe plans for further development.

Keywords: software platform, cognitive architecture, machine learning, modularity, the whole brain architecture

1 Introduction

Inspired by the recent advance in neuroscience and machine learning (ML), we propose a hypothesis on reproducing the whole brain level functionality out of ML modules, to be tested with the software platform introduced below.

1.1 Background

There are trends in ML research such as the following: 1) ML research has been inspired by recent development of the cognitive neuroscience and often referring to neuro-scientific features of the brain. 2) Learning algorithms of heterogeneous paradigms have been combined to realize performance or functionality that could not be attained with a single paradigm (Vinyals et al. [1], Karpathy and Fei-fei [2], Minh et al. [3], and Gao et al. [4]). 3) The breakthrough in acquiring distributed representations with deep learning (Le et al. [5]) may have resolved the basic issues in AI such as the frame problem, the symbol grounding problem and knowledge acquisition bottleneck.

1.2 The Hypothesis

The following is the hypothesis on which the current article is based:

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> The brain combines modules, each of which can be modeled with a machine learning algorithm, to attain its functionalities, so that combining machine learning modules in the way the brain does enables us to construct a generally intelligent machine with human-level or super-human cognitive capabilities.

The hypothesis involves the three following sub-hypotheses:

1) Modularity of the Brain

We shall assume the hypothesis that the brain is constituted of computationally independent modules (the modularity hypothesis). The brain apparently is constituted of anatomically independent modules in various levels, such as organs like neo-cortices, hippocampi, and basal ganglia, cortical areas like the primary visual cortex and the primary motor cortex, and sub-organ loci like CA1 and CA3 in the hippocampus.

2) Brain Organs and Machine Learning

For the hypothesis above to hold, the brain modules must be modeled in a functionally encapsulated manner. In other words, they must be modeled in the functional level (or Marr's computational level). Here, we assume that the learning functionality of brain modules can be modeled with the functionalities of (known or to-be-invented) ML algorithms (the machine learning hypothesis).

3) Emergent Cognitive Functions

It is not evident that combining ML modules yields the whole brain cognitive functionality (the emergence hypothesis). The system should be carefully designed to attain desired functional emergence and put to the test. Meanwhile, we could follow suit with the effort in the ML discipline to combining algorithms as mentioned above.

2 Platform Requirement

Our aim here is to test the hypothesis above and to realize highly capable cognitive systems, hopefully at the human level. As the attainment of knowledge and techniques in neuroscience, machine learning, and cognitive architecture would require decades to come, the effort should be better done on a long-lasting platform. While a research organization could also be an important platform, the current paper focuses on the software platform for testing the hypothesis. The platform is called BriCA (Brain-inspired Computing Architecture) and is intended to support the build-and-test approach in an efficient way.

2.1 The Necessity of a Software Platform

To test the hypothesis above, models must be implemented (for the build-and-test approach). This requires an implementation mechanism that simultaneously runs heterogeneous ML modules and arbitrates them in an efficient manner.

The construction of the entire cognitive architecture also requires various processes such as brain architecture modeling, cognitive architecture design, research and development of ML algorithms, cognitive architecture fostering (by making them learn in a certain environment), and application to products. These processes would involve collaboration of numerous participants in the community and certainly be helped with a software platform that integrates them.