Report of Session 1 talk Discussion

Session Theme: Deep Learning and Reinforcement Learning

Chair: Jun Morimoto (ATR Brain Information Communication Research Laboratory Group)

Discussant: Shun-ichi Amari (RIKEN Center for Brain Science)

Session 1 Speakers:

Yann LeCun (FAIR & New York University)

Yutaka Matsuo (The University of Tokyo)

Doina Precup (McGill University)

David Silver (DeepMind)

Masashi Sugiyama (RIKEN AIP/ The University of Tokyo IRCN)

Reporter: Tadashi Kozuno

Report

A discussion was on diverse but highly connected topics, which are the following:

1. A unified theory for deep learning and the mind;
2. The role of attention;
3. Components necessary for one-shot learning;
4. How to realize the higher cognitive functions, such as the reasoning and understanding of commonsense;
5. The involvement of language processing in higher cognitive functions.

In this report, I will explain each of them. Then, I conclude the report with my thoughts about these topics.

A Unified Theory of Deep Learning and the Mind

Prof. Amari raised a question on whether it is possible to establish a unified theory for deep learning. There are several theories of deep learning, but they are isolated and can capture only a small aspect of deep learning wherein they are specialized.

Dr. Silver argued that besides a unified theory for deep learning, we need a unified theory for the mind: what is an overall objective of the mind? For example, we divide a task into small subgoals and solve them one by one. When we look at a person trying to complete a subgoal, we can identify what they want to do. Nonetheless, we cannot understand what the person is trying to archive in the end by solving subgoals. Therefore, to fully understand intelligence, we need to understand the overall objective of the mind, which he thinks is possible.

He also pointed out the importance of keeping in mind the overall objective instead of identifying and understanding each subgoal of a brain part. Each part of the brain is specialized in its task, but it exists to archive the overall objective.

On the contrary, attributing the success of AlphaGo to a combination of two distinct learning systems, Prof. Sejnowski argued that a unified theory for learning would be impossible since the brain is dozens of learning systems running parallelly and interacting with each other.

The Role of Attention

Prof. Wang asked why the brain can pay attention to only one thing and has a limited working memory capacity. Seemingly, such limitations are unnecessary.

A hypothesis by Prof. LeCun was the following: we need multiple world models specialized in different situations, but the size of the brain is limited; as a result, the brain has only one configurable world model. Since such a world model needs to be configured for a task at hand, we can pay attention or focus on only one thing at a time.

Components Necessary for One-shot Learning

Prof. Wang also asked what components are necessary for one-shot learning, besides a differentiable neural network.

Prof. LeCun answered as follows: in deep learning, we have neural network architectures similar to the hippocampus, such as memory networks, with which one-shot learning is possible. The next step for AI is to enable AI to reason by combining hippocampus-like and cortex-like neural networks.

How to Realize the Higher Cognitive Functions

Everyone agreed that it is important to understand the higher cognitive functions and implement them in (and with) deep learning models.

In particular, Prof. LeCun and Prof. Tenenbaum emphasized the importance of learning to reason with neural networks and gradient descent. As witnessed in the deep learning community, gradient descent is a scalable and powerful tool. However, a question is how to *approximate* the symbolic reasoning by neural networks; the symbolic reasoning is inherently discrete, whereas neural networks can output only continuous values.

The Involvement of Language Processing in Higher Cognitive Functions

Prof. Sejnowski referred to the following fact as a paradox: previously, symbolic AI was a dominant paradigm, but it was superseded by neural networks or deep learning; nonetheless, neural networks, like GPT-3, are very good at language processing.

Prof. Tenenbaum said that it is not a paradox, citing a paper by Martin Schrimpf and colleagues. The paper examined whether neural networks for language processing, particularly GPT-2, can explain activities of a brain region that selectively responds to linguistic inputs. It tuned out that neural networks do almost perfectly. This result is consistent with the hypothesis in psycholinguistics that the brain's language system is optimized for predictive processing and has no deep understanding like common sense. In other words, symbolic manipulation and language processing seem to be different.

Both Prof. LeCun and Prof. Tenenbaum, therefore, argued that there is a system bridging the perception, language, and actions. It is the basis of the reasoning and higher cognitive functions that not only humans but also other animals possess.

My Thought

While I might be missing or misunderstanding some critical parts of the discussion, I learned a lot and found the discussion inspiring.

In particular, I like Dr. Silver's suggestion to seek the objective of the mind and his reward-is-enough hypothesis, although my hypothesis is slightly different. In my opinion, the mind's objective is to maximize the reproduction probability of an agent and its descendants, from which (extrinsic and intrinsic) rewards emerge.

Indeed, animal behaviors occasionally deviate from the pure reward maximization principle. For example, human parents sometimes commit a suicidal action to save their children. One might say that it is caused by the mind perceiving the loss of children as a negative reward. Then, why does the mind perceive it as a negative reward? I think it is because the loss decreases the reproduction probability, and the mind obtained the ability to understand it through evolution.

That being said, my hypothesis and Dr. Silver's are almost the same. Mine is that intelligent behaviors arise from the reward maximization principle, but the mind determines rewards for reproduction probability maximization. Conversely, I would say that every creature that tries to reproduce has a mind, regardless of whether it has a central nervous system; many parts of the brain are just tools for the mind to archive its goal.

However, as the number of "tools" increases, it becomes necessary for the mind to have a system dedicated to bridging different brain parts and sending appropriate commands to them, something Prof. LeCun and Prof. Tenenbaum mentioned.

Because of its purpose, the number of such a dedicated system must be no more than one, which might explain why we can pay attention to only one task at a time. This view is different from that of Prof. LeCun's as there can be multiple world models in this view, but only one manager can listen to them and determine what to do next.

I agree with everyone that the future step of AI and brain science is identifying the neural substrate of the "tool" manager and how it operates.