

UC Merced

Proceedings of the Annual Meeting of the Cognitive Science Society

Title

Learning to Learn by Modular Neural Networks

Permalink

<https://escholarship.org/uc/item/4pt9c0vf>

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 22(22)

Authors

Sashima, Akio
Hiraki, Kazuo

Publication Date

2000

Peer reviewed

Learning to Learn by Modular Neural Networks

Akio Sashima (sashima@etl.go.jp)

Electrotechnical Laboratory
1-1-4 Umezono, Tsukuba, Ibaraki, 305-8568, JAPAN

Kazuo Hiraki (hiraki@idea.c.u-tokyo.ac.jp)

Department of Systems Science, The University of Tokyo
3-8-1 Komaba, Meguroku, Tokyo, 153-8902, JAPAN

Introduction

Encountering a stream of learning tasks, humans learn not only knowledge of current task but also biases of learning future tasks. Thrun (1998) insists that modeling this human ability is one of the promising new approaches in the area of machine learning research and call this approach “Learning to Learn”(LTL).

Although some LTL algorithms have been proposed by machine learning researchers, little is known about the relation between LTL and representation of mind.

In this paper, we discuss LTL in the context of modular representation of cognitive system. We hypothesize that modules of a cognitive system are building blocks for learning new tasks (Hiraki, 1998). If each module learns a reusable basic function at the initial task, mixture of modules can learn various complex functions at future tasks. That is, generality and reusability of each module enables the ability of LTL. We implement this hypothesis using modular neural networks and examine it with a function approximation task.

Function Approximation Task

Functions The networks are trained to approximate the following functions:

Function A

$$f(x, y) = \begin{cases} \cos(x) & \text{for } y = 1.0 \\ -\cos(x) & \text{for } y = -1.0 \end{cases}$$

Function B

$$f(x, y) = \begin{cases} |\cos(x)| & \text{for } y = 1.0 \\ -|\cos(x)| & \text{for } y = -1.0 \end{cases}$$

Where $|x|$ represents function that computes absolute value.

Training procedure The training procedure is divided into two consecutive stages to examine the effects of learning function A at initial stage. We compare the approximations to function B in the following two tasks:

- **AB task** The networks learn function A first, and then learn function B.
- **BB task** The networks learn function B twice.

Training times of each stage at two tasks are the same.

Modular Network Architecture We implement our model using multiple forward models that are part of the architecture recently proposed by Wolpert & Kawato (1998). The networks have 2 expert modules and 1 gating module.

Result and Discussion

By all trials (20 times), the networks at AB task can correctly approximate function B, but the networks at BB task cannot approximate it. As an analysis of output of each module, we find that the training procedure makes difference in module formation of function B.

For the BB task, one expert module captures $|\cos(x)|$, another captures $-|\cos(x)|$ and the gating module switches between the output of these two modules based on y . A single module network cannot correctly approximate the absolute value function, so the networks fail to approximate function B. Alternatively, for the AB task, one expert module captures $\cos(x)$, another captures $-\cos(x)$ and the gating module switches between these modules based on x and y . These expert modules were already formed during the initial stage to approximate function A. So the networks have only to learn a mixture of these modules to approximate function B.

This result shows that learning a stream of tasks with modular representation is strongly affected by task order. We consider that modular representation is one of the key factors for LTL.

We believe our model of LTL can help us to understand relation between developmental process and module formation. Karmiloff-Smith (1992) argues that humans show the developmental stages that correspond to module reformation. Humans may need each developmental stage to learn simple skills that enable more complex one for later stages. We will test for these effects in developmental tasks, such as learning arm control and eye movement.

References

- Hiraki, K., Sashima, A., & Phillips, S. A. (1998). Maturational Biases and Encapsulation in Spatial Development, *Proceedings of the 20th Annual Conference of the Cognitive Science Society* (pp. 1226). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Karmiloff-Smith, A. (1992). *Beyond Modularity: A Developmental Perspective on Cognitive Science*. Cambridge, MA: MIT Press/Bradford Books.
- Thrun, S., & Pratt, L. (Eds.) (1998). *Learning to Learn*. Kluwer Academic Publishers.
- Wolpert, D.M., & Kawato, M. (1998). Multiple paired forward and inverse models for motor control. *Neural Networks*, 11, 1317-1329.