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Modelling learning systems
A DSL for cognitive neuroscientist

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1 Introduction

In the past years machine learning has surpassed humans in some recognition tasks, and the development shows no signs of slowing down. These developments are however based on relatively old research on neural networks (Nilsson 2009; Russell and Norvig 2002). Newer investigation into rehabilitation and learning indicates that such networks alone cannot account for the same amount of learning that happens in the brain (Mogensen 2011; Block 2007; Russell and Norvig 2002; Moravec 1998; Dennett 2017). For that reason the breakthroughs in machine learning are hard to transfer to the domain of cognitive neuroscience.

As an attempt to remedy this, this project sets out to define a domain-specific language (DSL) that is capable of representing the concepts of learning systems within the domain of neuroscience. The latter part of the paper validates this DSL through the modelling of a small learning task. The benchmark will be written in Futhark and compiled to the OpenCL standard, but the DSL abstraction allows it to be executed on any machine architecture.

The goal is for the DSL to lay the foundation for a more accurate scientific representation of learning and learning concepts, serving as a more approachable simulation tool for cognitive neuroscience.

1.1 Problem statement

Building on theories and concepts of the domain of cognitive neuroscience this paper examines the hypothesis that *the DSL presented in this paper can model meaningful machine learning tasks for the cognitive neurosciences, agnostic of the learning system implementation*. The paper will approach this in two steps:

1. Defining a DSL abstraction for the expression of learning tasks, based on the REF model from (Mogensen 2011).

2. Testing the DSL by expressing a learning task in a Krechevsky T-maze (Krechevsky 1932), backed by a traditional machine learning implementation in Futhark.

2 Theory

This section accounts for the theoretical foundation of paper and is divided into three parts. The first part concerns the broad topic of computation and learning in neural systems as seen from the perspective of computational neuroscience. By focusing on cognition, plasticity, learning and rehabilitation, it derives the necessary and sufficient language abstractions to capture the complexity of the domain. The second part introduces traditional machine learning from the perspective of computer science. These concepts will be applied in the validation phase of learning model abstractions in section 4. In the final part the theoretical background for linguistic abstractions and the construction of domain specific languages will be treated.

2.1 Computation and learning in neural systems

> Activity-dependent synaptic plasticity is widely believed to be the basic phenomenon underlying learning and memory (Dayan and Abbot 2001).

Commonly referred to as *what fires together, wires together*, Hebbian learning suggests that synaptic connections from neuron A to neuron B are strengthened or weakened when neuron A excites or inhibits the chance of firing neuron B respectively (Dayan and Abbot 2001). Hebbian learning is believed to play a large part in the plastic nature of the brain, especially within learning and memory formation (Dayan and Abbot 2001; Johnston 2009; Robertson and Murre 1999).

(Robertson and Murre 1999) studied patients during rehabilitation of brain damage and conjectured that learning — whether when the brain acquires new information or recovers from lost information — occurs based on the structural changes induced by the Hebbian principle (Robertson and Murre 1999).

(Mogensen 2011)

Reorganisation of elementary functions

2.2 Machine learning

2.3 Language abstractions

3 Volr: A DSL for learning systems

4 Case study: applying Volr in a Krechevsky maze

Glossary

Futhark A programming language geared towards performance in parallel environment such as graphics processors (GPUs). Futhark is a purely functional array language and is developed by HIPERFIT research center under the Department of Computer Science at the University of Copenhagen (DIKU).. 2

OpenCL An open standard for cross-platform parallel programming, which allows software to be executed on CPUs, GPUs or other processors or hardware accelerators. See `https://www.khronos.org/opencl/`. 2

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