Holonicity and Homoiconicity in the context of Multi-Agent Learning

Michéle Cullinan & Prof. Duncan Coulter
University of Johannesburg
Academy of Computer Science and Software Engineering
920306285@student.uj.ac.za

Introduction

Artificial Intelligence (AI) is a field of science and engineering that attempts to build intelligent entities with the purpose of solving complex problems [9]. The Machine Learning (ML), pattern recognition and data mining sub-disciplines of AI involve the development of intelligent algorithmic models from data sets [10]. The research proposed will study the application of holonicity and homoiconicity to various learning algorithms for which a set of models will be developed. Holons are systems forming a multi-levelled hierarchy of semi-autonomous sub-wholes where the whole becomes more than the sum of its parts due to its emerging properties [5]. Homoiconicity is the property of a computer programming language. The code in a homoiconic language can be transformed into its own data structures, i.e. code is its own data [3]. There has been some recent work, for example by [6], applying holonicity to multi-agent systems, but none have simultaneously focussed on homoiconicity, which is what this thesis will explore.

Main Objectives

This research proposes the application of holonicity and homoiconicity to distributed algorithms applied to various machine learning tasks, such as Decision Trees and clustering algorithms, and also to efficient data storage and retrieval tasks, such as Patricia Merkle Tries. The system architecture will be inspired by an ensemble method approach achieved as a cluster of mapping and reducing components. The models that are built will also exploit the novel benefits arising from the intersection of holonic self-similarity in multi-agent systems by leveraging the homoiconic properties of the lisp language family. Homoiconicity gives a program the ability to manipulate its own internal structures [3].

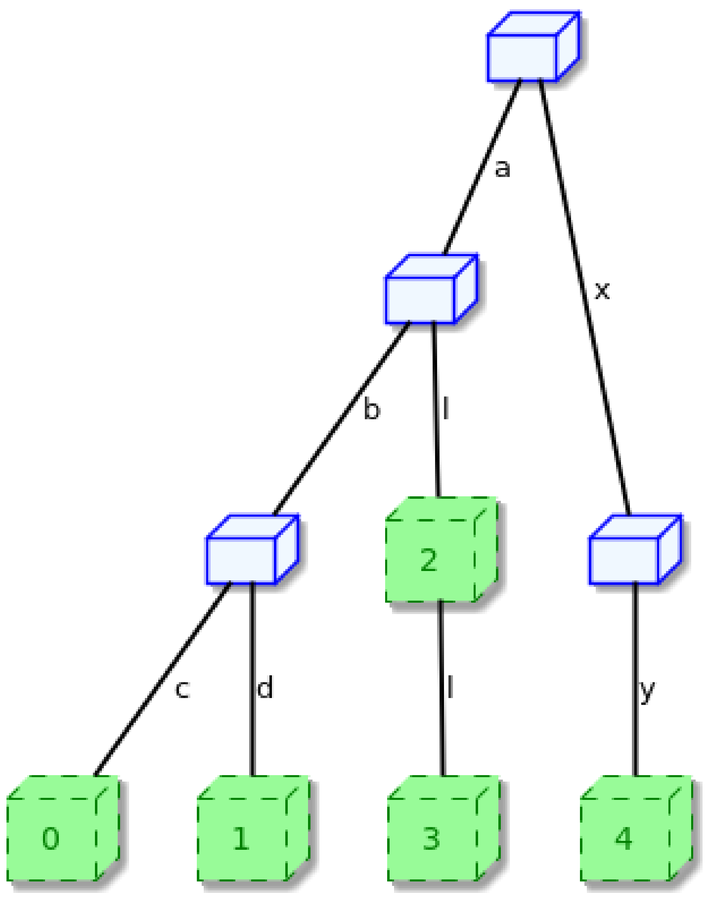

Figure 1: A Patricia Trie Example adapted from [7]

Common data structures in the lisp language are s-expressions, which are lists containing lists, or nested lists, which can represent trees. In contrary, holonicity is something that can be implemented in a given language and is not a property of the language itself. Of the major agent-oriented programming platforms, such as JADE, Agent Speak (Jason), GOAL, JACK, and SARL Language, none are written in programming languages that support homoiconicity. Multi-agent systems can also be implemented using the actor model [4]. Of the 23 most popular Actor programming languages, none have the property of homoiconicity. This research aims to expose homoiconicity by using a lisp family programming language, such as clojure, for expressing agent concepts. Aspects of this thesis will also focus on functional programming and reasons for why it is appropriate to model holonic multi-agent systems will be explored.

Materials and Methods

This research will follow a quantitative design with a positivism philosophy that attempts to test the hypothesis that holonicity and homoiconicity can be exploited in the realisation of suitably self-similar multi-agent learning systems, which can be used for recursive modelling. The methods include literature review, model, prototype and experimentation.

A new model will be developed for solving classification and optimisation problems using intelligent agents with holonic and homoiconic properties. A set of classification and optimisation problems in the domain of machine learning will be chosen to evaluate the model. All previous work including books, journal articles, publications and scientific blogs of the current literature will be reviewed and existing solutions to the problem will be implemented and understood [8].

Problem Statement

It is computationally complex to design agents with abilities to automatically form societies resulting in coherent emergent groups that coordinate their behaviour and learn form their actions taken. These systems are called self-organised multi-agent systems in which self-organisation, based on different mechanisms, is used to solve complex problems [2]. Improved computing power from multi-core processors, cheap computer networks and the availability of data on the internet allow for larger and more complex models to be built. The result is that technology systems are becoming more and more complex which requires new control approaches where decentralisation is playing an important role in AI paradigms such as MAS and Holonic Systems (HS) [1].

Results Expected

This thesis aims to show that multi-agent systems with holonic and homoiconic properties can be successfully applied in modern learning algorithms in the field of AI. The results will be a set of models and prototypes. The goal is to discover how the use of homoiconicity and holonicity can capture the self-similar properties of certain learning systems. For example, a hierarchical multi-agent based ensemble learning community is recursively composed of smaller sub-communities yet the aggregate must perform as a single entity with emergent properties. This can be mapped onto a holarchy. The resulting design can be expressed as a formal model-architecture using a suitable notation. The model-architecture will then be expressed in a homoiconic domain specific language, implemented as a prototype system and applied to a suitable test problem. The process will be repeated for a variety of learning approaches which can be mapped onto multi-agent implementations and that display suitable self-similar properties as identified during the literature survey.

References

[1] José Barbosa, Paulo Leitão, Emmanuel Adam, and Damien Trentesaux. Structural self-organized holonic multi-agent manufacturing systems. In *Proceedings of the 6th International Conference on Industrial Applications of Holonic and Multi-Agent Systems - Volume 8062*, HoloMAS 2013, pages 59–70, New York, NY, USA, 2013. Springer-Verlag New York, Inc.

[2] Carole Bernon, Vincent Chevrier, Vincent Hilaire, and Paul Marrow. Applications of self-organising multi-agent systems: An initial framework for comparison. *Informatica*, 30, 01 2006.

[3] Drew Colthorp. Understanding homoiconicity in clojure, 2013.

[4] Michéle N. Cullinan and Duncan A. Coulter. Revisiting the Society of Mind: Convolutional Neural Networks via Multi-Agent Systems. In *Twelfth International Symposium on Tools and Methods of Competitive Engineering*, pages 121–132. 2018.

[5] Michael Fischer, Klausand Schillo and Jörg Siekmann. Holonic multiagent systems: A foundation for the organisation of multiagent systems. In Vladimír Mařík, Duncan McFarlane, and Paul Valckenaers, editors, *Holonic and Multi-Agent Systems for Manufacturing*, pages 71–80, Berlin, Heidelberg, 2003. Springer Berlin Heidelberg.

[6] Gerard Gouws and Elizabeth Marie Ehlers. Holonic superposition intelligence of multi-agent systems. In *Twelfth International Symposium on Tools and Methods of Competitive Engineering*, pages 171–182. 2018.

[7] M. Odersky, L. Spoon, and B. Venners. *Programming in Scala, 3rd Edition*. Artima Press, 2016.

[8] M.S. Olivier. *Information Technology Research: A Practical Guide for Computer Science and Informatics*. Van Schaik, 2004.

[9] Stuart Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach*. Prentice Hall Press, Upper Saddle River, NJ, USA, 3rd edition, 2009.

[10] Zhi-Hua Zhou. *Ensemble Methods: Foundations and Algorithms*. Chapman & Hall/CRC, 1st edition, 2012.