A Neuroevolution Strategy Using Multi-Agent Incorporated Hierarchical Ensemble Model

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ABSTRACT

In this study, a neuroevolution strategy using Multi-Agent Incorporated Hierarchical Ensemble Model (MAIHEM) inspired by human incorporated company structure is proposed. It utilizes the hierarchical structure to ensemble modules of entities into firms to preserve complex structure at lower level, and at higher level incorporates firms into departments to facilitate multiple objectives. The corporate level structure from the top guides and reviews their overall performance. The ensemble structure not only compete within their own ranks, but also cooperate and swap/merger underlying units for fast adaptation without compromising their existing structures. The preliminary result with multi-constrained music melody generation shows this strategy can not only solve complex multi-objective tasks steadily but also preserve diversity in the population.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics • **Networks** → Network reliability

KEYWORDS

Multi-agent Systems, Hierarchical Structure, Neural Networks, Genetic Algorithm, Neuroevolution, Multi-objective

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1 INTRODUCTION

In recent years, with increasing computational capability and parallel computation through cluster computing or GPUs, many previously unfeasible schemes from decades ago start to gain attractions. One of them is using neuroevolution strategies to solve reinforcement learning tasks[1], but it was considered too computational expensive or impractical for complex tasks in real world applications until recently. On the other hands, deep learning models utilizing gradient-based training methods are on the rise, and already show impressive results in solving complex real world tasks. However most of these accomplishments involve clearly defined goals and reward functions that can be easily quantified into singular objective function in order for gradient-based training approaches to work. And the convergence of loss function to the target objective is difficult to achieve especially for tricky tasks, since not only do they have deceptive or sparse reward functions but also multi-objectives need to be met simultaneously. Although evolutionary based training has its advantages and disadvantages. The advantages for the neuroevolution scheme are it can explore solutions without gradient guidance, hence can tackle with wider range of tasks and it is easier to scale up with parallelism. Also its structure can evolve coincide with its parameters and variables, thus is more flexible and producing compact final models. However, its disadvantages lie in the exploration and convergence of neuroevolution models which are hard to balance, with extra overheads, such as translating latent representation of genes into working models, sorting top performers, or extra meta-data to facilitate mating, etc.

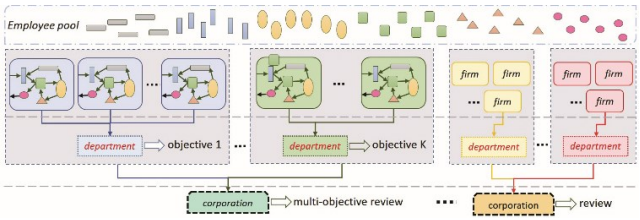

Figure 1: Multi-Agent Incorporated Hierarchical Ensemble Model (MAIHAM) structure diagram

Therefore, in this study we propose a neuroevolution strategy using Multi-Agent Incorporated Hierarchical Ensemble Model (MAIHEM) shown in Fig. 1. Inspired by modern multi-national corporations' abilities to adapt and thrive in complex and multi-orientations demands across different regions, yet still function like a living entity and maintaining their internal structures with local branches conform to different goals. MAIHEM scheme

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utilizes its hierarchical structure similar to human corporations and ensembles many learning agent entities into a corporate entity. It preserves the complex structure for recent deep neural network models, and also conforms multi-objective in difficult tasks. Flexible agents called *Employees* act as modules or layers in deep network structures form *Firms* representing a functional network. Then a group of *Firms* ensemble into heterogeneous *Departments* divisions, each being evaluated with different objective functions. Finally at the top level, *Corporations* tasked with multi-objectives review their *Departments'* performances and restructure themselves periodically. Each level of entities compete within their own ranks and corporations can be disbanded or go bankrupt when not meeting target performances, where new entities rise up and replace them to explore new combinations and novel solutions with variations.

2 EXPERIMENTS AND RESULTS

2.1 Definitions and Setup

In order for MAIHEM to work on time-sequence generation, such as music notations, we pick Gated Recurrent Unit (GRU) model as the framework basis and divided its function blocks into *Employee* blocks and treat each *Firm* as an aggregation of *Employees* where each *Employee's* job is solely to produce signals input and output to its coworkers, treated like segregated subnetworks within the GRU network[2]. Each *Firm* hires *Employees* from the *Employee Pool* and releases them back to the pool, and copies from higher performance *Firms* within the same *Corporation*. A *Department* is an aggregation of many *Firms* assigns objectives across its *Firms*, collects and reevaluates the overall performance of them, determines either to sells off or disbands underperforming *Firms*, and purchasing copies of *Firms* from other *Corporations* with better performance with certain objective. The *Corporation* level keeps records of all its *Departments* and review them not just with each individual targeting objective, but also other objectives with frequencies depending on the importance of different objective criteria, and base on each *Department's* requirement finds replacement *Employees*, *Firms*, or *Departments* from competitors or from the *World Achieve*. *Customers* with all the objectives as demands evaluate the overall performance of each *Corporation* and based on the importance of criteria make *Corporations* with worst performing objectives go bankrupt each run and their liquidated assets return to the *World Achieve* and can be picked up by newly formed startup *Corporations*. One crucial difference at the *Employee* level evaluation is that it's not easy to sub-divide each objective to fit each *Employee*, hence a more generalized structure is deployed. Instead of using the objective function to evaluate the successfulness of each *Employee*, Novelty Search Algorithm[3] is used to reward higher novelty performance and explore unseen problem search space. Finally, each *Employee* can reinvent itself with mutation mechanic to introduce variations. Currently, crossover mechanism is not deployed to *Employees*. The lifecycle flowchart of MAIHEM is shown in Fig. 2.

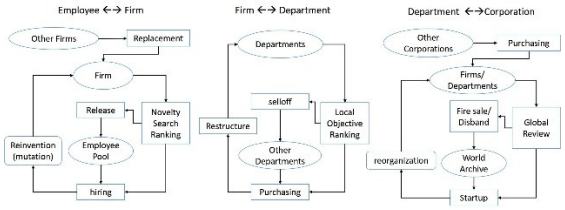

Figure 2: MAIHEM lifecycle flowchart on each level

2.2 Multi-Constrained Melody Generation

In generating music melody, there are constrains with varying degree of importance and varied drastically with different genres[4]. Basic tempos and beats, usually highly regulated, need to be relatively precise across the whole melody. Tonal and harmonic structures within and across different segments are more relaxed but generally still need to follow certain contains. Steps of notes and how rapidly music pitches rise and fall in rhythm, almost entirely subjective, only have very few constrains. Finally, the construction of genre music based on all the above is constrained by the culture preferences. Also variations of the same melody don't affect the perception of melodies but their music scores representation would look completely different on the surface. Hence the music melody generation task is both difficult as multi-objective task but also can be evaluated from nearly completely objectively like tempo and tonal, to human-centric fuzzy definitions of genres that are arbitrarily and subjectively. The generated result by MAIHEM with different level of constrains can be heard in [5]

3 CONCLUSIONS AND FUTURE WORKS

As a new framework for neuroevolution strategy, MAIHEM can be adapted to fulfill multi-objective task such as melody generation. Although its parameters still need to be assigned empirically. Drawing inspiration from past neuroevolution strategies, its framework can also be adapted to real time evolutionary algorithm instead of epoch based, and more local refinement methods similar to crossover can be added.

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REFERENCES

[1] F. P. Such, V. Madhavan, E. Conti, J. Lehman, K. O. Stanley, J. Clune. 2017. Deep Neuroevolution: Genetic Algorithms Are a Competitive Alternative for Training Deep Neural Networks for Reinforcement Learning. arXiv preprint arXiv:1712.06567.

[2] M. Lin, Q. Chen, S. Yan. 2013. Network in network. arXiv preprint arXiv:1312.4400.

[3] K.-W. Su. 2012. Study on Retrieving Subjective Knowledge from Music Using Adaptive Cloud-Based Structure. Master's thesis. National Taiwan University of Science and Technology (NTUST), Taipei, Taiwan.

[4] J. Lehman, K. O. Stanley. 2011. Abandoning objectives: Evolution through the search for novelty alone. Evolutionary computation, 19(2), 189-223.

[5] MAIHEM melody generation samples. 2018. https://goo.gl/GmGVLq Accessed: 2018- 02- 06.