UNIVERSITI TEKNOLOGI MARA

HYPERPARAMETER TUNING IN DEEP LEARNING USING NSGA-III: A MULTI-OBJECTIVE PERSPECTIVE

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ABSTRACT

The rapid advancement of Deep Learning (DL) has introduced critical challenges in optimizing model performance while managing computational constraints. Traditional hyperparameter tuning methods such as manual search, grid search, and random search are inefficient and computationally expensive, failing to address real-world trade-offs among conflicting objectives. This thesis proposes and implements a novel framework: the Multi-Objective NSGA-III-DL model, wherein the Non-Dominated Sorting Genetic Algorithm III (NSGA-III) is directly infused into the deep learning optimization process. This integration enables simultaneous optimization of three pivotal objectives: model accuracy, F1-score, and model size—constituting a multi-objective optimization problem that remains underexplored in contemporary DL research. The proposed Multi-Objective NSGAIII-DL framework is benchmarked against six baseline optimization strategies—manual search, grid search, random search, Bayesian optimization, particle swarm optimization, and standard genetic algorithms using MNIST and CIFAR-10 datasets. Experimental results demonstrate that Multi-Objective NSGAIII-DL consistently dominates in composite performance metrics across various model architectures. For the MNIST dataset, Multi- Objective NSGAIII-DL achieves superior scores in MLP (2.9669), LeNet (2.9884), and CNN (2.9882) architectures; for CIFAR-10, it leads in MLP (2.0439), LeNet (2.2835), and CNN (2.4348) configurations. These findings underscore its adaptability across architectures of varying complexity and dataset difficulty. Multi-Objective NSGAIII-DL effectively navigates high-dimensional hyperparameter spaces, yielding Pareto-optimal solutions that strike an effective balance between accuracy and F1-score while minimizing model size. The framework reduces dependence on manual expertise and mitigates the biases inherent in conventional tuning methods. Detailed convergence analysis further reveals Multi-Objective NSGAIII-DL's superior optimization trajectory, characterized by more rapid and stable convergence towards optimal trade-offs. This research provides a robust methodological advancement for deploying efficient, scalable DL models in resource-constrained environments such as edge computing and embedded systems. The findings establish Multi-Objective NSGAIII-DL as a powerful, automated approach to multi-objective hyperparameter optimization, significantly enhancing the efficiency, adaptability, and practicality of deep learning systems.

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CHAPTER 1
INTRODUCTION

This chapter begins with the discussion about background of study, problem statements, research objectives, scope of research, and significant of research of the Hyperparameter Tuning via Multi-Objective Evolutionary Algorithm in the Deep Learning.

1.1 Introduction

Artificial Intelligence (AI) and Deep Learning (DL) advancements have had and continue to have a significant impact on scientific research and industry. The implementation of DL to real-life problems has been studied by researchers in many domains of areas including medicine (Agarwal & Godavarthi, 2023; Awan et al., 2023; Kumar & Kumar, 2023), stock market prediction (Wu et al., 2023), agriculture (Li et al., 2024; Mehta et al., 2023), and many others. The acceleration of advancement in DL has been contributed by a few factors such as access to massive data, hardware capability in the computation, and novel algorithms (Azfar et al., 2022; Taye, 2023). Even though the adaptation of DL to the advancement of technology is becoming more relevant, there are many fields of research that are ongoing to fill the gap in DL. As previously mentioned, the implementation of DL algorithm required high computing power to solve classification, clustering, regression, and generation tasks in various fields.

The computational power required to implement DL models varies depending on the specific domain and scenario. In some cases, DL models need to be implemented on low computing device as in (Akhter et al., 2024; Heo et al., 2024), while other situations may require different types of hardware. In many cases, the process of training DL models require high computing complexity Yang, 2024; Yu et al., 2024). Thus, the gap between the technical capabilities of low computing power devices, and the performance of DL algorithms still exist. To narrow down the gap between the technical capabilities and the performance of DL algorithm, optimizing of DL algorithm is required.