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ENHANCING ARITHMETIC OPTIMIZATION ALGORITHM FOR ROBOT
PATH PLANNING IN DYNAMIC ENVIRONMENTS

G H C Madushani

228843V

MSc in Artificial Intelligence

Department of Computational Mathematics

Faculty of Information Technology

University of Moratuwa

Sri Lanka

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
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DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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Date: 21/06/2025

The above candidate has carried out research for the PhD/MPhil/Master's thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. Thilini Piyatilake

Signature of the Supervisor:

Date: 21/06/2025

DEDICATION

This thesis is dedicated to my family, whose unwavering support and encouragement have been a source of strength throughout my academic journey. Their love and belief in me have made this achievement possible.

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I would like to thank my supervisor, Dr. Thilini Piyatilake, wholeheartedly for her encouragement, guidance, and support throughout this research. Dr. Piyatilake's encouragement and guidance were most crucial in overcoming and accomplishing this study, and her helpful comments and support actually helped improve my methodology and perception in its conduct.

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ABSTRACT

Autonomous robot path planning in dynamic environments poses significant challenges for many industries: military, industrial automation, and security, to name a few. The goal is to fairly and safely navigate both unpredictable and complex spaces as efficiently as possible, however, traditional planning algorithms lack the speed and versatility needed to react to a dynamic landscape. For this reason, there is a need for new solutions which enhance efficiency of the algorithm in complex environment with aid of AI techniques.

This thesis contributes to minimizing the above challenges by presenting the Hybrid Arithmetic Optimization Algorithm (HAOA) which integrates adaptive arithmetic-operator updates, online reinforcement learning, and spline-based path refinement. HAOA works by creating far and near candidate trajectories and subjecting them to multiplicative and additive arithmetic transformations before assessing progress. This initial updating process allows the algorithm to transition from a global exploration state back to a local exploitation state. A Q-learning agent observes the incremental changes along the candidate trajectories to begin to update key parameters, which allows the algorithm to adapt to the dynamic environment. Finally, the algorithm performs a final refinement of its solution by executing self-intersection removal, waypoints pruning, and B-spline smoothing so it can deliver continuous and collision free paths for a real robot to follow its path with minimal acceleration discontinuities. Extensive experiments on four classical benchmark functions (Sphere, Rosenbrock, Rastrigin, Ackley) and five grid-based scenarios featuring both static and dynamic obstacles demonstrate HAOA's superior performance. Compared to standard AOA and a Genetic Algorithm baseline, HAOA converges 15–25 % faster, attains lower final objective values, and yields paths that are on average 10–12 % shorter and substantially smoother. Although embedding reinforcement learning introduces moderate per-iteration overhead, the overall wall-clock time to reach target performance is reduced due to accelerated convergence. These results underscore HAOA's promise as a robust, adaptable framework for real-time autonomous navigation in complex and unpredictable settings.

Keywords: Robot, Path, Dynamic, Arithmetic Optimization, Reinforcement Learning

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LIST OF ABBREVIATIONS

Abbreviation	Description
ACO	Ant Colony Optimization
AI	Artificial Intelligence
AOA	Arithmetic Optimization Algorithm
MSOA	Multi Strategy Enhanced Arithmetic Optimization Algorithm
BELS	Boundary Enclosing Local Search
CNN	Convolutional Neural Network
CPU	Central Processing Unit
DENPSO	Differential Evolution-based Particle Swarm Optimization
DSLS	Directional Strategy Local Search
DWA	Dynamic Window Approach
DQN	Deep Q-Network
GA	Genetic Algorithm
GPS	Good Point Set
GPU	Graphics Processing Unit
IDE	Integrated Development Environment
LiDAR	Light Detection and Ranging
HAOA	Hybrid Arithmetic Optimization Algorithm
PPO	Proximal Policy Optimization
PRM	Probabilistic Roadmap
PSO	Particle Swarm Optimization
RAM	Random Access Memory
RL	Reinforcement Learning

RRT	Rapidly Exploring Random Tree
SAC	Soft Actor-Critic
UAV	Unmanned Aerial Vehicle
USV	Unmanned Surface Vehicle
VFH	Vector Field Histogram

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