Quantum-Augmented Detection of Growth-Stunted Salmon: A Comparative Study of Quantum GANs and Quantum Vision Transformers with Classical Methods

Introduction

Growth-stunted or "loser" salmon are a major concern in aquaculture because they reduce productivity and affect fish welfare. The base research paper proposed classical computer vision models such as YOLOv5, YOLOv7, and transfer learning with ensemble classifiers to identify these fish. While these approaches achieved promising results, they also faced challenges such as limited data, annotation ambiguity, and reduced accuracy in varied environments.

Problem Statement

The main issue in the existing work is the small dataset size and the lack of robustness when fish images are captured under different conditions like turbidity, blur, or poor lighting. Current classical methods perform well but may not generalize effectively. This opens the question: can quantum-based models, especially Quantum GANs (QGANs) for data generation and Quantum Vision Transformers (QViTs) for classification, provide improvements in accuracy and robustness compared to traditional methods?

Objectives

- Reproduce classical baselines (YOLOv5, YOLOv7, ResNet + Ensemble).
- Apply Quantum GANs to generate synthetic salmon images to overcome data limitations.
- Develop Quantum Vision Transformer models for fish classification and detection.
- Compare quantum and classical methods in terms of accuracy, sample efficiency, and robustness.
- Provide a clear analysis of where quantum methods are practically useful in aquaculture monitoring.

Methodology

The research will first replicate classical pipelines from the base paper to establish a reference. Then, a hybrid Quantum GAN will be implemented to generate new fish images for data augmentation. These synthetic images will be validated for quality and diversity. Quantum Vision Transformers will be designed and tested as classifiers and compared against classical ViTs and CNNs. Experiments will measure accuracy, F1-score, robustness under noisy conditions, and performance with reduced training data.

Features

- Use of QGANs for realistic image generation in low-data environments.
- Deployment of Quantum Vision Transformers for efficient representation learning.
- Hybrid pipelines combining classical detection (YOLO) with quantum classifiers.
- Detailed evaluation of classical vs. quantum methods on the same dataset.

Expected Outcomes

It is expected that QGANs will enhance model performance in small-data settings by improving recall for minority classes. QViTs may achieve comparable or better accuracy than classical models with fewer parameters. The hybrid quantum-classical pipeline is likely to be more practical than fully quantum approaches on current hardware. Overall, even a modest improvement in accuracy and robustness could provide valuable benefits to the aquaculture industry.

Conclusion

This research explores how quantum machine learning can complement existing computer vision approaches for salmon welfare monitoring. By combining Quantum GANs for data augmentation and Quantum Vision Transformers for classification, the study aims to overcome key limitations of classical models. The findings will provide insights into the real potential and current limits of quantum methods, offering both scientific and industrial value.