COMP4082 Autonomous Robotic System

University of Nottingham Malaysia

Reinforcement Learning using Gymnasium Environments

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Redefining Activation Dynamics: An Empirical Comparison of Oscillating, Mixture, and Adaptive Activation Functions in Deep Reinforcement Learning

Research Paper:

1. [Biologically Inspired Oscillating Activation Functions can Bridge the Performance Gap between Biological and Artificial Neurons]
2. [A survey on recently proposed activation functions for Deep Learning]
3. [Adaptive activation functions in convolutional neural networks]

Background Studies

1. **Biologically Inspired Oscillating Activation Functions can Bridge the Performance Gap between Biological and Artificial Neurons**

   Context:
   - This paper explores the potential of oscillating activation functions, which are inspired by the oscillatory nature of biological neurons. The rationale is that biological neurons do not simply fire in an on/off manner but exhibit complex dynamics that may be critical to the processing capabilities of biological neural networks.

   Contributions:
   - Proposes a novel oscillating activation function that mimics biological neuron behaviour.
   - Propose 4 new oscillating activation functions.
   - Conducts empirical evaluations to compare the performance of these functions against traditional activation functions in neural networks which can be a reference for research experimental design.
   - Demonstrates potential performance improvements in certain tasks, suggesting that these biologically inspired functions can bring artificial neurons closer to the complexity of their biological counterparts.

   Significance:
   - The work challenges the status quo of activation functions in artificial neural networks and opens up new avenues for research into more complex and potentially more powerful neural network architectures.

2. **A Survey on Recently Proposed Activation Functions for Deep Learning**

   Context:
   - Given the rapid evolution of deep learning, there has been a surge in proposing novel activation functions aimed at improving various aspects of neural network training and performance. This survey aims to compile and synthesize these recent advancements.

   Contributions:
   - Provides a comprehensive overview of the latest activation functions proposed in the literature.
   - Analyzes the theoretical motivations behind these functions and the contexts in which they are beneficial.
   - Facilitates a better understanding of the landscape of activation functions, aiding practitioners in choosing appropriate functions for their specific applications.

   Significance:
   - The survey is a valuable resource for researchers and practitioners in the field, highlighting the strengths and weaknesses of a wide range of activation functions and potentially guiding future research directions.

3. **Adaptive Activation Functions in Convolutional Neural Networks**

   Context:
   - This research focuses on adaptive activation functions within the context of convolutional neural networks (CNNs), which are a cornerstone of modern deep learning, particularly in vision-related tasks. Adaptive functions have the potential to dynamically adjust during the learning process, offering the possibility of more flexible and powerful models.

   Contributions:
   - Investigate the implementation and impact of adaptive activation functions in CNNs with different strategies such as mixed activation, gated activation and hierarchical activation.
   - Examines how these combination functions can change their behaviour based on the data and learning stage to potentially improve learning efficiency and model accuracy.
   - Offers insights into the application of such functions in practice and their effect on the training and performance of CNNs.

   Significance:
   - This work could significantly impact the development of CNNs, particularly in how neural networks can be made more efficient and possibly achieve better performance with less manual tuning by leveraging the adaptability of the activation functions.

Overall Gaps that have been found:

1. Performance Evaluation of Oscillating Activation Functions: There is a scarcity of empirical data on the utility of oscillating activation functions in DQNs by comparing their performance with that of conventional activation functions in standardized control environments.
2. Mixture Activation Functions' Efficacy: While mixture activation functions have been proposed, their comparative analysis, especially using the traditional and oscillating counterparts in the context of DQNs, remains under-explored.
3. Adaptive Activation Functions in DQNs: The application and impact of adaptive activation functions, which dynamically adjust their behaviour during learning, have not been thoroughly investigated in DQNs, particularly in combination with both traditional and oscillating functions.

Research question:

1. How do oscillating activation functions compare to traditional activation functions in terms of enhancing Deep Q-Network (DQN) performance in standardized control tasks?
2. What performance differences, if any, are observable when employing mixed activation functions in DQN architectures?
3. In the context of DQN, do adaptive activation functions with different mechanisms like gated activation and hierarchical demonstrate significant performance enhancements over static activation functions, particularly when utilizing gating mechanisms and hierarchical structures?

Justification:

The exploration of oscillating activation functions could provide a critical link in advancing artificial neural networks towards the complexity of biological neural computation. If such functions can indeed mirror or surpass the capabilities of traditional activation functions, they could significantly contribute to the development of more biologically plausible models. This is particularly relevant for DQNs, which stand as a robust empirical framework for evaluating activation function performance due to their success in various control tasks provided by OpenAI Gym benchmarks.

This research will also aim to explore whether mixture activation functions will provide better performance in an artificial neural network.

Additionally, this research will explore whether the integration of adaptive Gated mechanisms and Hierarchical structure can render DQN architectures more flexible and efficient in learning. Through comprehensive experiments involving environments such as the Cart Pole, we will assess whether these innovative activation functions can lead to performance improvements, thereby guiding future neural network design strategies.

Classic control:

Classic control to be used is the **Cart Pole environment** for creating a DQN algorithm for the minesweeper. Both environments have been used to train DQN agents. DQN agents have been successfully trained to solve both the Cart Pole environment and the Acrobat environment.