Quantum-Enhanced Negative Selection Algorithm (NSA)

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Abstract

This document outlines the implementation of a Quantum-Enhanced Negative Selection Algorithm (NSA), which combines quantum computing techniques with classical artificial immune system (AIS) algorithms for advanced anomaly detection. Using the Qiskit framework, the project enhances anomaly detection by leveraging quantum circuits for efficient similarity comparisons between antigens and quantum-encoded detectors.

1 Introduction

The Quantum-Enhanced Negative Selection Algorithm (NSA) utilizes quantum principles to enhance classical anomaly detection techniques. This project applies the NSA using quantum circuits simulated on Qiskit's Aer simulator, with a focus on detecting non-self patterns in datasets. The approach combines classical Artificial Immune System (AIS) methods and quantum computing for anomaly detection.

2 Features

- **Quantum-enhanced Negative Selection Algorithm (NSA)**: Uses quantum circuits to improve the detection of non-self patterns.
- **Classical Artificial Immune System (AIS) Algorithms**: Includes traditional algorithms such as Negative Selection, Artificial Immune Network (AIN), Clonal Selection, Danger Theory, and Dendritic Cell Algorithm.
- **Quantum Circuit Simulation**: Executes quantum circuits and measurements using Qiskit and its Aer simulator.
- **Anomaly Detection**: Identifies outliers by comparing antigen-like data to quantum-encoded detectors.

3 Requirements

This project requires Python 3.6 or later, along with the following Python packages:

- Qiskit:
  - `qiskit`
  - `qiskit-aer`
  - `qiskit-algorithms`
  - `qiskit-ibm-runtime`
  - `scipy`

To install the required dependencies, run the following command in your terminal:

```
pip install Qiskit qiskit-aer qiskit-algorithms
    qiskit-ibm-runtime scipy
```

4 Project Structure

This repository contains both classical and quantum algorithms for anomaly detection.

4.1 Classical Algorithms

- **NegativeSelection**: A classical implementation of the Negative Selection Algorithm for distinguishing self from non-self patterns.
- **ArtificialImmuneNetwork (AIN)**: A model based on immune system behavior for detecting anomalies.
- **ClonalSelection**: Simulates antibody selection based on affinity to antigens.
- **DangerTheory**: Detects danger signals and triggers immune response.
- **DendriticCell**: Simulates the behavior of dendritic cells in processing antigens.

4.2 Quantum Algorithms

- **encode_antigen()**: Encodes antigen data into a quantum circuit representation.
- **quantum_similarity()**: Measures the quantum similarity between an antigen and a detector.
- **quantum_negative_selection()**: Performs Negative Selection using quantum principles, comparing antigens to quantum-encoded detectors.

5 Example Usage

To run the Quantum-Enhanced Negative Selection Algorithm, execute the script as follows:

```
python quantum_nsa.py
```

This will output the number of non-self patterns detected in the dataset, along with the indices of these patterns.

5.1 Example Output

```
Number of non-self patterns detected: 45
Indices of non-self patterns: [3, 8, 12, 29, ...]
```

6 License

7 Contributions

Contributions are welcome! Feel free to fork this repository, report issues, or submit pull requests. For questions or suggestions, please contact the project maintainers via GitHub issues.

8 Acknowledgments

- Qiskit for providing the quantum computing framework used in this project.
- Resources on Artificial Immune Systems and anomaly detection techniques.