Special Session: Applied Mathematics in Artificial Intelligence and Green Computing

This special session on **Applied Mathematics in Artificial Intelligence** aims to open the blackboxes in AI and to bring together contributions that advance the **mathematical foundations, theoretical analysis, and computational methodologies** underlying modern machine learning and artificial intelligence systems.

The session welcomes articles that explore both **fundamental mathematical principles** and **innovative algorithmic techniques**, as well as their **practical deployment in real-world applications**.

A particular emphasis will be placed on **Green and sustainable AI and computationally efficient learning**, addressing the urgent need to design AI systems that are not only accurate and robust but also **energy-efficient, scalable, facilitate the AI interpretation, saving water in cooling, and environmentally sustainable**. Contributions are encouraged to investigate how mathematical modeling can reduce computational cost, memory footprint, carbon emissions, and training time without sacrificing performance.

Topics of interest include, but are not limited to, optimization, feature extraction and selection, statistical learning theory, deep and reinforcement learning, game theory, graph-based models, cybersecurity, and advanced data visualization. Submissions may also address **current limitations of state-of-the-art machine learning**, proposing novel mathematical frameworks that overcome challenges related to scalability, interpretability, robustness, and efficiency.

The session is particularly interested in **new mathematical models inspired by unresolved conjectures, natural phenomena, or physical principles**, with the objective of addressing complex problems in artificial intelligence and computer science in a principled and sustainable manner.

Introduction

Machine learning has fundamentally transformed decision-making processes by extracting relevant knowledge and structure from data. The fields of **Machine Learning and Deep Learning** encompass a wide spectrum of mathematical theories, algorithmic strategies, and computational architectures designed to achieve this objective efficiently.

This special session provides a forum to explore **emerging directions in AI driven by applied mathematics**, with a strong focus on **data preprocessing, feature extraction, feature selection, pattern recognition**, and **computational efficiency**. As modern AI models grow increasingly large, mathematical tools play a critical role in controlling model complexity, improving generalization, and reducing computational overhead.

The exponential growth of data—originating from social media, connected devices, medical imaging, energy systems, oil and gas, finance, and healthcare—has ushered in the era of **Big Data**. Extracting the most informative features from these massive datasets is essential not only for improving predictive performance but also for **reducing model size, training time, and energy consumption**, which are central goals of **Green AI**.

Big data analytics has become a transformative force across education, healthcare, science, industry, and environmental studies. Mathematical data-driven techniques enable the discovery of hidden patterns and actionable insights, leading to improved decision-making, optimized resource usage, risk mitigation, and cost reduction. This session highlights how **mathematical rigor can directly contribute to sustainable and responsible AI systems**.

We invite original research contributions presenting **new theories, mathematical frameworks, algorithmic innovations, and impactful applications** that advance artificial intelligence with an emphasis on **efficiency, scalability, and sustainability**. Particular attention is given to work on feature engineering, model compression, efficient training, data preprocessing, and mathematically grounded pattern recognition.

Recommended Topics (Non-Exhaustive)

- **Statistical Learning Theory**: Generalization bounds, bias-variance trade-off, regularization, and robustness.
- **Optimization Methods for Machine Learning**: Convex and non-convex optimization, stochastic methods, adaptive and large-scale optimization.
- **Green AI and Efficient Learning**: Energy-aware algorithms, model compression, pruning, low-rank methods, and sustainable AI.
- **Linear Algebra for Machine Learning**: PCA, SVD, matrix factorizations, and spectral methods.
- **Time series processes in visualization, forcasting, diagnotics, and interpreation along with extension theory of path signature**
- **Probability and Statistics**: Bayesian inference, uncertainty quantification, hypothesis testing.
- **Information Theory**: Entropy, mutual information, KL divergence, and representation learning.
- **Numerical Methods**: Solving large-scale linear and nonlinear systems for ML models.
- **Graph Theory and Graphical Models**: Graph neural networks, Bayesian networks, and network analysis.
- **Calculus and Differential Equations**: Gradient-based learning, continuous-time models, and dynamical systems.
- **Functional Analysis and Kernel Methods**: RKHS, operator-theoretic approaches.
- **Computational Complexity and Scalability**: Algorithmic efficiency, parallelism, and large-scale deployment.
- **Information Geometry**: Geometric analysis of probability distributions and learning dynamics.

- **Nature-Inspired Mathematical Models**: Evolutionary computation, swarm intelligence, biologically inspired learning.
- **Ethics, Fairness, and Transparency**: Mathematical approaches to bias mitigation and explainability.
- **Real-World Applications and Case Studies**: Healthcare, finance, energy, computer vision, NLP, robotics.
- **Open Problems and Future Directions**: Mathematical challenges for next-generation AI.

Submission Information: We invite researchers and practitioners to submit their original contributions to this special session. Please send your submissions to Dr. Samir Bellhaouari sbelhaouari@hbku.edu.qa.