Study some applications of fractional derivative in machine learning

Dang Thu Hien

Abstract: This thesis investigates several applications of fractional-order derivatives in machine learning, aiming to enhance model performance and generalization. Unlike classical integer-order derivatives, fractional derivatives possess a memory effect and non-local properties, making them suitable for capturing complex dynamics in data. The study first introduces the theoretical foundations of fractional calculus, focusing on the Caputo and Riemann-Liouville definitions. It then proposes novel fractional gradient descent algorithms for training neural networks, demonstrating improved convergence and avoidance of local minima compared to standard methods. Furthermore, the research explores fractional-order regularization techniques to prevent overfitting and applies fractional derivatives to feature extraction in signal and image processing tasks. Experimental results on benchmark datasets show that the proposed fractional approaches achieve higher accuracy and robustness, particularly in scenarios with noisy or non-stationary data. This work contributes a new mathematical framework to machine learning, offering a powerful tool for modeling intricate patterns and optimizing learning processes.

Keywords: Fractional calculus, machine learning, fractional derivatives, applications