Adaptive Tensor Decomposition for Real-Time Anomaly Detection in High-Dimensional Data Streams

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Abstract. In the burgeoning domain of computational science, the detection and interpretation of anomalies in high-dimensional data streams pose significant challenges. This study introduces an adaptive tensor decomposition framework designed to dynamically adjust to evolving data structures, ensuring real-time anomaly identification. Employing state-of-the-art machine learning algorithms, our method enhances detection accuracy while minimizing computational overhead. The results demonstrate significant advancements over existing models, offering novel insights into anomaly characterization necessary for critical decision-making processes.

Keywords: Tensor Decomposition, Anomaly Detection, High-Dimensional Data, Real-Time Analysis, Adaptive Algorithms, Machine Learning, Data Streams, Computational Efficiency

Introduction

The exponential growth of data across numerous sectors necessitates advanced methods for identifying and interpreting anomalies, particularly in high-dimensional data streams. Anomalies, often indicative of crucial system faults or novel phenomena, require real-time detection to mitigate potential risks. Traditional techniques, though effective under static conditions, falter amidst the dynamic, ever-evolving nature of today's data. This paper addresses the pressing need for a robust, adaptive solution capable of maintaining performance integrity in such environments. Leveraging tensor decomposition—a mathematical framework that excels in unraveling complex, multi-dimensional data—we propose a novel methodology that adapts in real-time to shifts in data distribution. By integrating cutting-edge machine learning algorithms, our approach not only improves detection accuracy but also significantly reduces the computational burden associated with high-frequency data analysis. We conduct a series of experiments across varied datasets to validate the efficacy of our model, demonstrating its superiority in adjusting to novel patterns without compromising speed or reliability. Our findings have profound implications for sectors reliant on timely anomaly detection, including finance, healthcare, and cybersecurity. Concluding the introduction, this paper outlines its structure as follows: Section 2 delves into related works, providing a comparative analysis of existing solutions. Section 3 details the proposed methodology, followed by Section 4, which presents the experimental setup and results. Section 5 discusses the implications of our findings, and Section 6 concludes with potential future directions.

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