Sequential High-Dimensional Data Analysis for Anomaly Detection and System Monitoring

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The rapid development of the sensing technology has enabled the real-time data analytics of complex systems, such as manufacturing, healthcare, and social systems. Multiple sensors that monitor these systems generate massive high-dimensional (HD) streaming/cloud data with complex spatio-temporal structure at a fast rate. This provides distinctive opportunities for data analytics and decision making. This presentation includes two main topics in this area: the first topic focuses on anomaly detection in HD streaming data for the purpose of system monitoring. In addition to high-dimensionality, other challenges include the spatio-temporal structure of data, and high rate of data collection, which requires real-time analysis of data streams. To address these challenges, a novel decomposition methodology named spatio-temporal Smooth Sparse Decomposition (ST-SSD) that separates the sparse anomaly from the smooth spatio-temporal functional mean and random noises. Efficient optimization algorithm based on the iterative thresholding algorithm is proposed and the convergence properties and the error bound are studied. Furthermore, to enable the real-time implementation of ST-SSD, we present a recursive estimation and updating framework. Various case studies and simulation results will be presented to show the effectiveness of the proposed ST-SSD in analyzing single images, multi-channel signal streams, as well as video data. The main focus of the second topic is to develop an adaptive sampling and estimation methodology for recovery of sparse anomalies from noisy data. The proposed method, named Adaptive Kernelized Maximum Minimum Distance, can balance the sampling efforts between the space filling sampling (exploration) and focused sampling near the anomalous region (exploitation). Furthermore, the properties of this methodology are also discussed. The proposed methodology is validated by conducting simulations and a case study of anomaly detection in composite parts using a guided wave test.

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