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Guest Editorial: Non-IID Outlier Detection in Complex Contexts

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utlier detection, also known as *anomaly detection*, aims at identifying data instances that are rare or significantly different from the majority of instances. Due to its significance in many critical domains like cybersecurity, fintech, healthcare, public security, and AI safety, outlier detection has been one of the most active research areas in various communities, such as machine learning, data mining, computer vision, and statistics. Traditional outlier-detection techniques generally assume that data are independent and identically distributed (IID), which are significantly challenged in complex contexts where data are actually non-IID. These contexts are ubiquitous in not only graph data, sequence data, spatial data, temporal data, and streaming data,^{1–3} but also traditional multidimensional, textual, and image data.^{4–6} This demands for advanced outlier-detection approaches to address those explicit or implicit non-IID data characteristics. Motivated by this demand, we organized a Special Issue in IEEE Intelligent Systems to solicit the latest advancements in this topic in October 2019. In total, we received eight valid submissions from diverse countries, including China (2), Belgium (2), United States (1), Australia (1), India (1), and New Zealand (1). Each submission was reviewed by at least three reviewers. In the following, we provide a brief introduction to the five accepted articles.

In “Anomalous event sequence detection,”⁷ Dong *et al.* study the problem of detecting abnormal event sequences in complex systems such as cyberphysical systems, aiming at identifying a sequential combination of event entities that are abnormal as a whole, but not for specific individual events. A graph diffusion-based method is introduced to tackle the problem and extensively evaluated on a large real-world system

monitoring dataset containing 10 different types of intrusion attacks. This work showcases an interesting non-IID outlier-detection problem in sequential data.

In “Anomaly detection aided budget online classification for imbalanced data streams,”⁸ Liang *et al.* study the problem of classification on imbalanced streaming data in the presence of outliers. The key challenge is to accurately classify the known majority and minority classes, while differentiating the outliers from the minority classes. A feedforward network with incrementally updated weights and an embedded distance-based outlier detector are jointly optimized to address this challenge. The method also incorporates a memory budget-aware module to efficiently maintain a set of active instances for classification and outlier detection in the current time windows. We believe this work provides an example of joint classification and outlier detection on imbalanced streaming data with potential concept drift.

In “How to optimize an academic team when the outlier member is leaving?,”⁹ Yu *et al.* explore the problem of identifying “outlier” members in an academic team, in which the “outlier” members are defined as those whose collaboration network and skill sets are not or only weakly tied to those of the team. Both pairwise and high-order relations between the academic members are considered to identify the outliers. Extensive experiments are performed using large datasets from CiteSeerX and the Microsoft Academic Graph. This work provides a good real-world application of leveraging complex data dependence for outlier detection.

In “Isolation forest based anomaly detection framework on non-IID data,”¹⁰ Xiang *et al.* study the problem of extending a widely used outlier detector, called isolation forest (iForest), to handle data drawn from a nonmetric space. The authors combine the underlying mechanism of isolation forest and extend distance-based hashing techniques to tackle this problem. The proposed method is evaluated on five non-IID datasets with trajectory anomalies, text anomalies, and discrete sequence

anomalies, in addition to a number of traditional commonly used IID datasets. This article demonstrates the issues of applying traditional outlier-detection methods to non-IID data, and presents a hashing-based solution for addressing these issues.

In “Outlier detection for foot complaint diagnosis: Modeling confounding factors using metric learning,”¹¹ Booth *et al.* explore an interesting application of outlier detection in computer-aided diagnosis of foot complaints using plantar pressure data. The work is motivated by the fact that the abnormality of the plantar pressure of a patient is dependent differently on individual demographic features, when comparing to healthy control samples. The authors further introduce a contextual metric-learning method to take into account this type of dependence in outlier detection, providing an example of re-inventing distance-based outlier detection for non-IID contexts.

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