Fraud detection as an outlier detection problem

The idea of this project is to treat fraudulent claims as outliers and then to detect them using tools from the vast literature on outlier detection.

One possible approach to outlier detection consists in using a dimension reduction method to visually represent the observations and detect extreme data points. Dimension reduction techniques that preserve well the global structure of data, such as principal components analysis (PCA), are known to be efficient for outlier detection. TriMap (Amid and Warmuth, 2019) is another dimension reduction technique that typically performs well at preserving the global structure of the data but which, compared to PCA, has the advantage to also represent well the local structure of the observations.

Roughly speaking, in TriMap a loss function is used to assess the "quality" of a given low dimensional representation of the observations, where the loss increases when data points close to each other in the original space are far-away in the low dimensional space. Given an initial low dimensional embedding of the data, the loss function is numerically optimized to obtain the final low dimensional representation of the observations.

The main objective of this project is to assess if TriMap can be useful for outlier detection, and in particular if TriMap can improve upon PCA for carrying out this task. As mentioned above, PCA is particularity well-suited for outlier detection and it is therefore unlikely that a direct implementation of TriMap will outperform PCA to detect extreme data points.

Here are two possible questions that can be explored during this project:

1. We have various degrees of freedom when using TriMap, namely (i) the measure of similarity $s(\cdot)$ used to compare the data in the low dimensional space, (ii) the measure of distance $d(\cdot)$ used to compare the data in the original space, (iii) how these two functions are combined to define the loss function $l(\cdot)$ to be minimized and (iv) the initial low dimensional embedding of the data used to numerically minimize $l(\cdot)$.

   Question: Is it possible to exploit these degrees of freedom to propose a version of TriMap tailored to the fraud detection problem?

2. In TriMap, PCA is usually used as the initial low dimensional embedding of the data. Recently, it has been shown that this particular initialization is the key raison why TriMap preserves well the global structure of the observations (Wang et al., 2021). Hence, what TriMap actually does is to "adjust" the low dimensional embedding of the observations obtained with PCA in order to improve its representation of the local structure of the original data.

   Question: Instead of aiming at a good preservation of the local structure of the observations, can we instead "adjust" the low dimensional embedding obtained with PCA to facilitate the detection of outliers?

While the use of Trimap for fraudulent claims detection should be explored, you are encouraged to investigate the use of other outlier detection methods for performing this task. It is also worth keeping in mind that different types of outliers may be present in the data, and that different types of outliers may require different approaches to be detected.

Ideally, the proposed approach should be explainable, in the sense that factors that cause a particular observation to be classified as an outlier should be explainable.

Dataset: Bank Account Fraud (BAF) Tabular Dataset Suite[1]

[1] Available at https://www.kaggle.com/datasets/sgpjesus/bank-account-fraud-dataset-neurips-2022

References

Amid, E. and Warmuth, M. K. (2019). Trimap: Large-scale dimensionality reduction using triplets. *arXiv preprint arXiv:1910.00204*.

Wang, Y., Huang, H., Rudin, C., and Shaposhnik, Y. (2021). Understanding how dimension reduction tools work: an empirical approach to deciphering t-sne, umap, trimap, and pacmap for data visualization. *Journal of Machine Learning Research*, 22(201):1–73.