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Outliers' detection for non-Gaussian distributions

by Olivier Cheffert and Jean Dessain

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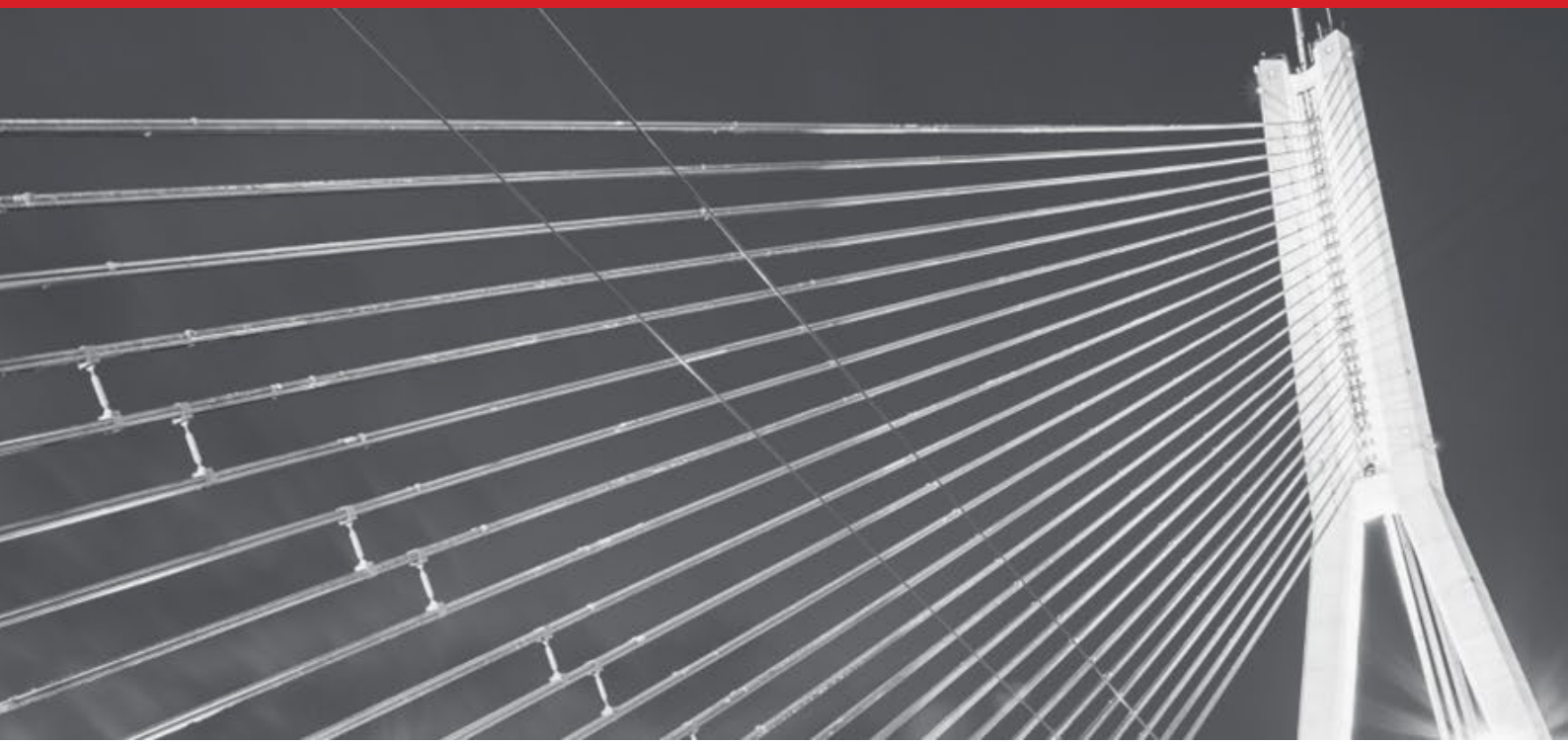


ABSTRACT

Detecting outliers in financial or insurance datasets is critical for accurate risk assessment and decision-making, particularly in the context of non-Gaussian distributions characterized by skewness and heavy tails (e.g. financial returns series). Traditional outlier detection methods often rely on assumptions of normality, which can lead to misleading results in the presence of such data anomalies. A robust outlier detection system does more than just identify anomalies; it provides significant business advantages. By enhancing data quality, this approach optimizes the performance of predictive models that depend on this data, leading to better-informed strategic decisions and more accurate risk management. Indeed, poor input data quality will impact the accuracy of the model and prevent it from considering the real underlying dynamics in the dataset. Thus, while impacting its accuracy, it will also impact its interpretability since the model will try to fit to outliers.

In this paper, we show a framework for outlier detection able to deal with skewed and heavy-tailed distributions. The goal is to effectively identify outliers while maintaining sensitivity to the underlying distributional characteristics. Through practical use cases, we will illustrate its applicability as part of the preprocessing task.

Reacfin

TVA: BE 0862.986.729
BNP Paribas 001-4174957-56
RPM Nivelles

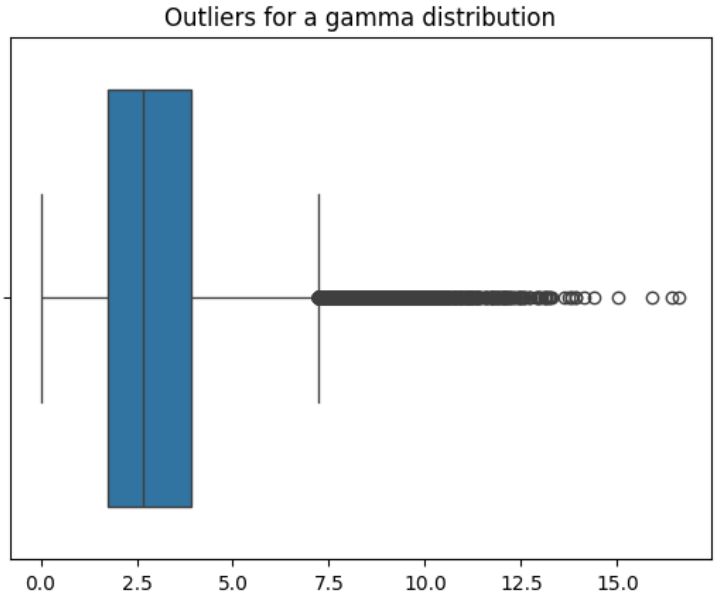
Tel: +32 (0)10 68 86 07
info@reacfin.com
www.reacfin.com

Reacfin s.a./n.v.
Place de l'Université 25
B-1348 Louvain-la-Neuve
Belgium

1. CLASSICAL TECHNIQUE: THE INTERQUARTILE RANGE

The interquartile range technique (IQR) is designed to exclude 0.7% of the normal distribution. If Q_i is the i^{th} quartile of given samples, then the interquartile is defined as IQR = Q_3 -Q_1 and each sample outside of [Q_1 – 1.5 IQR; Q3 + 1.5 IQR] is labelled as an outlier.

While this technique is easy to understand and to implement, the assumption of normality is strong, and this technique may not work in practice. For example, if a given variable is sampled 100 000 times from a gamma distribution, the skewness and tail heaviness of this variable will lead the IQR method to label true data as outliers:



Applied on this gamma (α=3, β=1) distribution, 2.6% of the samples are labelled as outliers. In a non-life insurance context, the variable can be skewed, heavy tailed (severity) and even discrete (frequency). In finance, these non-normal characteristics can also appear, for example, in the study of Loss Given default in credit risk, stock returns, ….

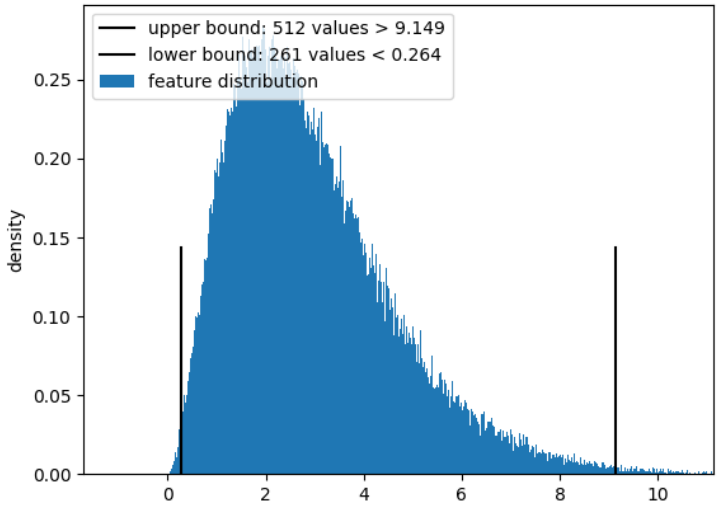
Fortunately, some new techniques allow to deal with specificities of a given sample but most of them focus only on a particular characteristic like tail heaviness. Therefore, a collection of different tools is required to detect outliers in practice which may increase the operational risk.

2. STAR OUTLIERS

STAR outliers, standing for Skew and Tail-heaviness Adjusted Removal of outliers, is a univariate outliers detection method developed by Gregg and Moore (Gregg & Moore, 2023). Through transformation functions, this technique deals with tail heaviness, skewness, multimodality, monotonicity and discrete distributions.

STAR outliers use a generalized method based on IQR, as proposed by Verardi and Vermandele (Verardi & Vermandele, 2018) which defines the concept of asymmetrical outlying (ASO). Initially, a ratio is calculated by subtracting each data point from the median and then dividing by the interquartile range. Subsequently, this ratio is scaled to fit within the unit interval and subjected to a probit transformation. If these ASO values are uniformly distributed on the unit interval before the probit transform, the final values are normally distributed. However, if it's not the case, this gives a transformed normal distribution with skew and tail heaviness. Such a distribution is called a Tukey g and h distribution which adds a skewness and a kurtosis parameter. Furthermore, multimodality is detected using the Hartigan's dip test (Hartigan & Hartigan, 1985) and a Tukey mixture will be fit to the data. Highly skewed variables are passed into mirror transforms before using the ASO technique. Finally, the outlier threshold is computed from the fitted Tukey distribution.

Using the same sampled gamma distribution as before, 0.77% of the sample is considered outliers:



This case study shows that STAR can deal with highly skewed and heavy tailed distributions like this gamma distribution.

On discrete (frequency) laws such as Poisson, this method can also be used and will label 1.1% of data as outliers for a Poisson(λ=3). When using STAR on a standard normal distribution, it detects 0.8% or outliers with a slightly narrower interval than IQR which detects 0.73% of outliers. Thus, for normally distributed data, the Interquartile Range (IQR) method, due to its simplicity, may be sufficient.

3. TAKEAWAYS

Preprocessing is essential when working with financial and insurance datasets, as inaccuracies in input data can compromise the performance of machine learning models. A critical step in preprocessing is outlier detection, which helps prevent bias in the model. Indeed, poor input data quality can severely impact the accuracy of predictive models, preventing them from capturing the true underlying dynamics of the dataset. This degradation in accuracy not only undermines the model's performance but also affects its interpretability, as the model may erroneously try to fit to outliers rather than the relevant trends.

This paper demonstrates that the classical interquartile range (IQR) method can significantly misestimate the target of 0.7% outliers, incorrectly labeling valid data as outliers on non-Gaussian data. In the case of real Loss Given Default data, even higher proportions of outliers were observed, highlighting the limitations of this method (Cheffert, 2024). For instance, some financial ratios of defaulted companies exhibited outlier rates as high as 25% according to the IQR approach. Thus, critical applications such as risk management for a bond portfolio can fail to accurately reflect the true risk due to poor data quality. Therefore, practitioners must recognize the presence of non-Gaussian data in business applications; an incorrect preprocessing step can lead to misguided predictions, regardless of the model used thereafter.

More generally, when datasets exhibit non-normal characteristics—such as excess kurtosis, skewness, multimodality, or integer distributions—the IQR method fails to address these issues, which can lead to accuracy problems in subsequent modeling. The STAR outlier detection method offers an advantage by accommodating non-Gaussian distributions and identifying a more accurate number of outliers. Additionally, it can handle missing data, making it a crucial preliminary step before imputation. Imputing data before detecting outliers or relying on ineffective outlier detection methods can result in erroneous and biased imputed values. However, the analysis made on normally distributed data has shown that IQR can still be used when working with a Gaussian distribution. Thus, a first step may be to use a normality test, such as the Jarque-Bera test, to decide whether IQR or STAR should be used.

4. REFERENCES

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Xavier Maréchal
Managing Partner
xavier.marechal@reacfin.com

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+ 32 (0)10 68 86 07

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