




# nonconform: Conformal Anomaly Detection (Python)

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## Software

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## Summary

Quantifying uncertainty is fundamental for AI systems in safety-critical, high-cost-of-error domains, as reliable decision-making depends on it. The Python package nonconform offers statistically principled uncertainty quantification for semi-supervised anomaly detection based on one-class classification (Petsche & Gluck, 1994). It implements methods from conformal anomaly detection (Bates et al., 2023; Jin & Candès, 2023; Laxhammar & Falkman, 2010), grounded in conformal inference (Lei & Wasserman, 2013; Papadopoulos et al., 2002; Vovk et al., 2005).

The package nonconform calibrates anomaly detection models to produce statistically valid  $p$ -values from raw anomaly scores. Conformal calibration uses a hold-out set  $\mathcal{D}_{\text{calib}}$  of size  $n$  containing normal instances, while the model is trained on a separate normal dataset. For a new observation  $X_{n+1}$  with anomaly score  $\hat{s}(X_{n+1})$ , the  $p$ -value is computed by comparing this score to the empirical distribution of calibration scores  $\hat{s}(X_i)$  for  $i \in \mathcal{D}_{\text{calib}}$ . The conformal  $p$ -value  $\hat{u}(X_{n+1})$  is defined as the normalized rank of  $\hat{s}(X_{n+1})$  among the calibration scores (Liang et al., 2024):

$$\hat{u}(X_{n+1}) = \frac{|\{i \in \mathcal{D}_{\text{calib}} : \hat{s}(X_i) \leq \hat{s}(X_{n+1})\}|}{n}.$$

By framing anomaly detection as a sequence of statistical hypothesis tests, these  $p$ -values enable systematic control of the *marginal* (average) false discovery rate (FDR) (Bates et al., 2023; Benjamini & Hochberg, 1995) at a predefined significance level via appropriate statistical procedures. The library integrates seamlessly with the widely used pyod library (Chen et al., 2024; Zhao et al., 2019), extending conformal techniques to a broad range of anomaly detection models.

## Statement of Need

A major challenge in anomaly detection lies in setting an appropriate anomaly threshold, as it directly influences the false positive rate. In high-stakes domains such as fraud detection, medical diagnostics, and industrial quality control, excessive false alarms can lead to *alert fatigue* and render systems impractical.

The package nonconform mitigates this issue by replacing raw anomaly scores with  $p$ -values, enabling formal control of the FDR. Consequently, conformal methods become effectively *threshold-free*, since anomaly thresholds are implicitly determined by underlying statistical procedures.

$$FDR = \frac{\text{Efforts Wasted on False Alarms}}{\text{Total Efforts}}$$

(Benjamini et al., 2009)

35 Conformal methods are *nonparametric* and *model-agnostic*, applying to any model that  
36 produces consistent anomaly scores on arbitrarily distributed data. Their key requirement is  
37 the assumption of *exchangeability* between calibration and test data, ensuring the validity of  
38 resulting conformal  $p$ -values.

39 Exchangeability only requires that the joint data distribution is invariant under permutations,  
40 making it more general—and less restrictive—than the independent and identically distributed  
41 (*i.i.d.*) assumption common in classical machine learning.

42 To operationalize this assumption, nonconform constructs calibration sets from training data  
43 using several strategies, including approaches for low-data regimes (Hennhofer & Preisach,  
44 2024) that do not require a dedicated hold-out set. Based on these calibration sets, the  
45 package computes *standard* or *weighted* conformal  $p$ -values (Jin & Candès, 2023), which are  
46 particularly useful under covariate shift, when exchangeability is only approximate.

47 These tools enable practitioners to build anomaly detectors whose outputs are statistically  
48 controlled to maintain the FDR at a chosen nominal level.

49 Overall, reliance on exchangeability makes these methods well-suited to cross-sectional data  
50 but less appropriate for time series applications, where temporal ordering conveys essential  
51 information.

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