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Article

Revisiting Gradient Boosting-Based Approaches for Learning Imbalanced Data: A Case of Anomaly Detection on Power Grids

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Abstract: Gradient boosting ensembles have been used in the cyber-security area for many years; nonetheless, their efficacy and accuracy for intrusion detection systems (IDSs) remain questionable, particularly when dealing with problems involving imbalanced data. This article fills the void in the existing body of knowledge by evaluating the performance of gradient boosting-based ensembles, including gradient boosting machine (GBM), extreme gradient boosting (XGBoost), LightGBM, and CatBoost. This paper assesses the performance of various imbalanced data sets using the Matthew correlation coefficient (MCC), area under the receiver operating characteristic curve (AUC), and F1 metrics. The article discusses an example of anomaly detection in an industrial control network and, more specifically, threat detection in a cyber-physical smart power grid. The tests' results indicate that CatBoost surpassed its competitors, regardless of the imbalance ratio of the data sets. Moreover, LightGBM showed a much lower performance value and had more variability across the data sets.

Keywords: imbalance learning; oversampling; anomaly detection; gradient boosting ensembles; power grid; MWMOTE

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1. Introduction

Power grid infrastructure has a significant positive impact on economic growth. It is an effective tool for stimulating regional economies [1]. In its current form, a smart power grid (SP) regulates both the supply of power and information across its intricate cyber-physical network. Hence, SP is a critical infrastructure with a significant socio-economic benefit. An SP is a sophisticated cyber-physical system that integrates the physical power system with computing, sensor, and advanced communication technologies so that an efficient and reliable process of transmission, distribution, monitoring, and control of electricity can be considerably maintained [2]. The majority of countries consider SP to be a vital infrastructure and have developed security procedures and policies to protect it [3,4]. As the design and implementation of SP become increasingly complex in nature, phasor measurement units (PMUs) have been adopted to increase system performance. One of the advantages of this approach is the process of making quick decisions based on the gathered data. Nonetheless, attackers can launch attacks to wreak havoc on power grid networks and induce blackouts [5].

Previous works have proposed IDSs to secure SP [6–9]. One of the IDSs domain research issues is choosing a seamlessly and computationally efficient classifier in the wild. It is not that straightforward since every intrusion data set has its own characteristics, differing from network architecture and attack scenario distributions. Knowing that those aforementioned problems are critical, this paper aims to establish a comparative analysis of several ensemble learners, providing researchers in this field with a better insight into finding the best-performing classifier ensembles. This study focuses on gradient boosting ensembles for IDSs in power grids, an area of research that has received scant attention in the current literature. In addition, those ensemble algorithms are deemed to be the most effective approaches for classification tasks involving imbalanced data problem [10,11]. Four implementations of gradient boosting ensembles are taken into account in our experiment, namely GBM [12], XGBoost [13], LightGBM [14], and CatBoost [15]. To sum up, this article has the following contributions:

- We benchmark several implementations of state-of-the-art gradient boosting ensembles for anomaly detection on power grids;
- We assess the performance of each gradient boosting ensemble under different imbalanced ratios (I_r);
- We apply an oversampling strategy, namely the majority weighted minority oversampling technique (MWMOTE) [16], to overcome the imbalanced data issue.

We structure the rest of this article as follows. Section 2 describes pertinent existing works in the realm of machine learning-based IDSs in power grids, followed by Section 3, which presents an overview of the oversampling method and gradient boosting ensembles. The experimental settings and results are specified in Section 4, while, finally, we conclude with some remarks in Section 5.

2. Related Work

This section presents the state-of-the-art machine learning techniques for IDSs in power grids. We present the existing studies in chronological order. Hink et al. [17] investigated the potential of several machine learning algorithms as an approach for discerning kinds of power system disruptions, with an emphasis on identifying cyber-attacks. Pan et al. [6] utilized a sequential pattern mining to identify patterns associated with power systems outages and cyber-attacks effectively. In addition, the work also introduces the term "common path", which is a sequence of critical system states in the temporal order that corresponds to distinct sorts of disruptions and cyber-attacks. Similarly, Pan et al. [7] built a hybrid IDS that can learn the temporal states of power system circumstances such as disruptions, regular control operations, and cyber-attacks. The proposed model is built based on a data mining method called "common path mining" to discover patterns using a power system audit log and other measurement data.

A new privacy-preserving IDS based on the correlation coefficient and expectation-maximization clustering algorithm is introduced in [18]. The proposed model is tested on the multi-class attacks of the power system data sets. Next, Keshk et al. [8] proposed another privacy-preserving technique for anomaly-based IDS. The proposed framework is comprised of two modules, namely a data preprocessing module and an anomaly detection module. The power system and the UNSW-NB15 data set are considered to evaluate the performance of the proposed technique. A gradient boosting-based feature selection technique for an IDS in smart grids is presented in [19]. The proposed model does not only reduce execution time but also enhances the detection rate. Several machine learning algorithms are applied to the selected feature subset.

Upadhyay et al. [9] combined a recursive feature elimination-XGBoost-based feature selection and majority voting-based classifier ensemble models for IDS in power grids. The ensemble framework blends nine heterogeneous individual learners to obtain an accurate solution to the IDS task. It improves the performance accuracy while reducing the false rate compared to other similar existing techniques. Lastly, this current work is similar to Louk and Tama [20], and they compared and analyzed classifier ensembles that are specifically designed for handling imbalanced data sets. The experiment results show that EasyEnsemble outperforms other classifier ensemble models considered in the study. Moreover, undersampling and oversampling techniques effectively improve the performance of boosting but not of bagging. This work, however, differs significantly from that presented in Louk and Tama [20] in terms of the classifier ensembles considered and the oversampling strategy utilized.

3. Methods

In this section, we first present an overview of the oversampling method considered in this study, followed by the four classifiers in the gradient boosting family.

3.1. Oversampling Technique

The aim of oversampling methods is to generate a set of synthetic positive examples based on the training ones. Note that the term 'examples' refers to "samples" or "instances" of a data set. Let $\zeta = \{(x_1, y_1), ..., (x_m, y_m)\}$ be the training data set, where $y_i \in \{-1, 1\}$ is the data labels; let $\zeta^+ = \{(x, y) \in \zeta : y = 1\}$ be the positive or minority examples; and let $\zeta^- = \{(x, y) \in \zeta : y = -1\}$ be the negative or majority examples. If $|\zeta^+| > |\zeta^-|$, the performance of classification algorithms is significantly hampered, particularly when it comes to the minority examples. Hence, it is necessary to have a method to improve such performance. In this work, we utilize MWMOTE [16] to generate new examples by filling up blank spaces among the minority examples. MWMOTE has a benefit over the classical method, e.g., SMOTE, as it is able to detect noisy examples by assigning higher weights to borderline examples. The following (Algorithm 1) is the procedure for generating synthetic examples using MWMOTE.

Algorithm 1: General procedure of majority weighted minority oversampling technique

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Preparation:
Training samples, ζ; number of examples to generate, $numEx$; threshold, T_{clust};
Procedure:
1. Calculate a set of filtered positive examples, ζ_f^+
2. Calculate positive boundary of ζ_f^+, U and negative boundary, V.
3. $\forall x \in V$, determine the likelihood of picking x by assigning: $P(x) = \sum_{y \in U} I_{\alpha,C}(x, y)$ and normalize those likelihoods.
4. Estimate $L_1, ..., L_M$ clusters of ζ^+ using agglomerative clustering algorithm and threshold, T_{clust}
5. Generate $numEx$ by iteratively picking $x \in V$ w.r.t. the likelihood $P(x)$, and update ζ iteratively by performing $E := E \cup \{x + r(y - x)\}$, where $y \in L_k$ is uniformly picked and L_k is the cluster containing x.

3.2. Gradient Boosting Ensembles

Gradient boosting tree (GBT) is an ensemble learning that combines several weak classifiers into a strong one. It is typically an additive model (e.g., linear addition of weak classifiers) and uses the CART regression tree algorithm as the base weak model. Let $D = \{(x_i, y_i) | i \in \{1, ..., l\}, x_i \in \mathbb{R}^k, y_i \in \mathbb{R}\}$ be the power system data set with k features and l examples. It is a binary classification problem, where label y corresponds to each example x. Hence, the aim of a classification algorithm is to identify a classifier that maps the examples to either of the two classes (e.g., attack or normal).

Given an ensemble of T trees, the prediction output $y(\hat{x})^T$ for an input x is the sum of predictions from each tree, $y(\hat{x})^T = \sum_{i=1}^{T} f_i(x)$, where f_i is the output of the i-th regression tree of the $T-$tree ensemble. To construct the $(T + 1)$-th tree, GBT minimizes a regularized objective function $Obj^t = \Omega^t + \Theta^t$, where Ω^t is loss function and Θ^t is a regularization function to control the over-fitting. In this study, we employ four different GBT implementations, namely GBM [12], XGBoost [13], LightGBM [14], and CatBoost [15].

4. Experiment Settings and Results

4.1. Power Grid Data Set

To evaluate the classifier ensemble models, we utilize a benchmark data set that is developed by the Oak Ridge National Laboratories [7]. The data set was generated by setting up a power grid testbed that includes measurements related to the normal, disturbance, control, and cyber attack behaviors of the electric transmission system. The data set is composed of 128 features that were recorded by PMUs, relay snort alarms, and other control panel logs. A power system binary-class classification data set is considered since we aim to perform an anomaly-based intrusion detection task, where a machine learning algorithm usually classifies whether the traffic is natural or attack. The data set contains 15 sets with different instance distributions of each class. The class distribution in each set is measured by the imbalanced ratio (I_r), which is a proportion of #minority examples to #majority examples. Therefore, a non-skewed data set has a value of 1, and conversely, a skewed data set has a value less than 1. In summary, the characteristics of each data set used in this study is provided in Table 1. In addition, the table provides information concerning the total examples (ζ_T), number of examples labeled natural (ζ^-), and number of examples labeled attack (ζ^+).

Table 1. The characteristics of power system data sets. Imbalance ratio (I_r) less than 0.4 indicates highly imbalanced data sets.

Data Set	ζ_T	ζ^-	ζ^+	I_r
Data 1	4966	3866	1100	0.285
Data 2	5069	3525	1544	0.438
Data 3	5415	3811	1604	0.421
Data 4	5202	3402	1800	0.529
Data 5	5161	3680	1481	0.402
Data 6	4967	3490	1477	0.423
Data 7	5236	3910	1326	0.339
Data 8	5315	3771	1544	0.409
Data 9	5340	3570	1770	0.496
Data 10	5569	3921	1648	0.420
Data 11	5251	3969	1282	0.323
Data 12	5224	3453	1771	0.513
Data 13	5271	4118	1153	0.280
Data 14	5115	3762	1353	0.360
Data 15	5276	3415	1861	0.545

4.2. Evaluation Metrics

In this experiment, we adopt 10-fold cross validation, where the final result is the mean value of 10 elements. The performance of classifiers on the test set is measured under three different metrics, i.e., Matthew correlation coefficient (MCC), area under the receiver operating characteristic curve (AUC), and $F1$ scores. A performance value is usually derived from a confusion matrix, $H = \begin{pmatrix} TP & FN \\ FP & TN \end{pmatrix}$, which summarizes the outcome of a binary classification [21,22]. Supposing that $FN + TP = \zeta^+$ and $FP + TN = \zeta^-$, a classification algorithm has perfect score if $H = \begin{pmatrix} \zeta^+ & 0 \\ 0 & \zeta^- \end{pmatrix}$, where TP is true positive, FN is false negative, FP is false positive, and TN is true negative.

MCC provides more realistic estimates of the model performance and is calculated as the Pearson product moment correlation coefficient between actual and predicted scores. More specifically, it is obtained from the following formula:

$$MCC = \frac{TP \cdot TN - FP \cdot FN}{\sqrt{(TP + FP) \cdot \zeta^- \cdot (TN + FN) \cdot \zeta^+}} \tag{1}$$

where it ranges in the interval $\{-1, +1\}$, with -1 and +1 achieved in the case of perfect misclassification and perfect classification, respectively.

AUC is a popular metric to summarize the receiver operating characteristic curve, which is a probability curve that plots the true positive rate (TPR) against false positive rate (FPR) at various threshold values. Formally, it is calculated as follows:

$$AUC = \int_0^1 TPR(FPR)dFPR = \int_0^1 TPR(FPR^{-1}(x))dx \quad (2)$$

where it ranges in the interval $\{0, 1\}$. The higher its value, the more accurate the performance of the algorithm is at differentiating between positive and negative classes.

$F1$ is defined as the harmonic mean of precision and recall metrics. It has the following form:

$$F1 = \frac{2 \cdot TP}{2 \cdot TP + FP + FN} \quad (3)$$

where it ranges in the interval $\{0, 1\}$, with $TP = 0$ and $FN = FP = 0$ gained in case of perfect misclassification and perfect classification, respectively.

4.3. Hyperparameters Search

Hyperparameters for each implementation were searched using random search [23]. For GBM implementation [12], the hyperparameters were used specify include tree size, interaction depth, and shrinkage. XGBoost [13] has several hyperparameters to tune such as maximum depth, η, subsample, column sample by tree, and tree size. There are several hyperparameters to train LightGBM [14] such as maximum bin, maximum depth, minimum data in leaf, learning rate, lambda $l1$, lambda $l2$, tree size, feature fraction, bagging fraction, path smoothing, and minimum gain to split. Lastly, the hyperparameters of CatBoost [15] for tuning include tree size, depth, learning rate, $l2$ leaf regularization, border count, and boosting type.

For all implementations, we searched the number of trees from four possible values, i.e., 100, 200, 500, and 1000 trees. We determined the search space of other hyperparameters as follows. GBM: interaction depth = $\{3, 4, ..., 12\}$ and shrinkage = $\{0.005, 0.01, 0.05, 0.1, 0.3\}$. XGBoost: maximum depth = $\{1, 2, ..., 12\}$, $\eta = \{0, 0.1, 0.2, ..., 1\}$, subsample = $\{0.1, 0.5, 0.8\}$, and column sample by tree = $\{0.5, 0.6, ..., 0.9\}$. LightGBM: maximum depth = $\{1, 2, ..., 15\}$, maximum bin = $\{100, 255\}$, minimum data in leaf = {100,200,...,1000}, learning rate = $\{0.01, 0.02, ..., 0.3\}$, lambda $l1$ and $l2 = \{0, 10, 20, ..., 100\}$, feature fraction and bagging fraction = $\{0.5, 0.9\}$, path smoothing = $\{1E-8, 1E-3\}$, and minimum gain to split = $\{0, 1, 2, ..., 15\}$. CatBoost: depth = $\{1, 2, ..., 10\}$, learning rate = $\{0.03, 0.001, 0.01, 0.1, 0.2, 0.3\}$, $l2$ leaf regularization = $\{1, 3, 5, 10, 100\}$, border count = $\{5, 10, 20, 30, 50, 100, 200\}$, and boosting type = {'ordered','plain'}.

4.4. Result Discussion

All experiments were run on a machine with a Linux operating system, an Intel Xeon processor, and 32GB of memory. All data sets used in this study are publicly available (https://sites.google.com/a/uah.edu/tommy-morris-uah/ics-data-sets, accessed on 8 March 2022), while the code was implemented in R using the $mlr3$ package [24]. This section aims to provide a performance validation of the gradient boosting ensembles (i.e., GBM, XGBoost, LightGBM, and CatBoost) in two different scenarios. First, the performance behavior of all benchmarked algorithms is assessed on the original (e.g., imbalanced) power system data sets. Second, we analyze the algorithms' performance on the synthetically oversampled data sets (e.g., balanced). Here, the MWMOTE technique is used to oversample the minority class of each data set instances.

Figure 1 depicts the average performance of all algorithms across two distinct scenarios and data sets with respect to MCC, AUC, and F1 metrics. While LightGBM performs worse on average than the other three algorithms, all algorithms have appeared to be outstanding (score > 0.8) and maintain a constant AUC and F1 metric regardless of the I_r of the data set. More precisely, two metrics, AUC and F1, produce over-optimistic and elevated results; thus, they do not notify us of ongoing prediction problems. However, a somewhat different picture emerges when MCC is considered as a performance metric. There is a slight difference in the algorithms' performance, particularly when dealing with an imbalanced data problem. For instance, LightGBM reports relatively low MCC scores for the data set #1, #11, and #13, despite the fact that those data sets are highly imbalanced ($I_r < 0.4$). However, an outlier pattern was discovered in our analysis, in which data set #6 has a lower MCC score despite having $I_r > 0.4$. Additionally, unlike AUC and F1, we can argue that MCC is a consistent and effective statistical metric in any data set without producing misleading results [21].

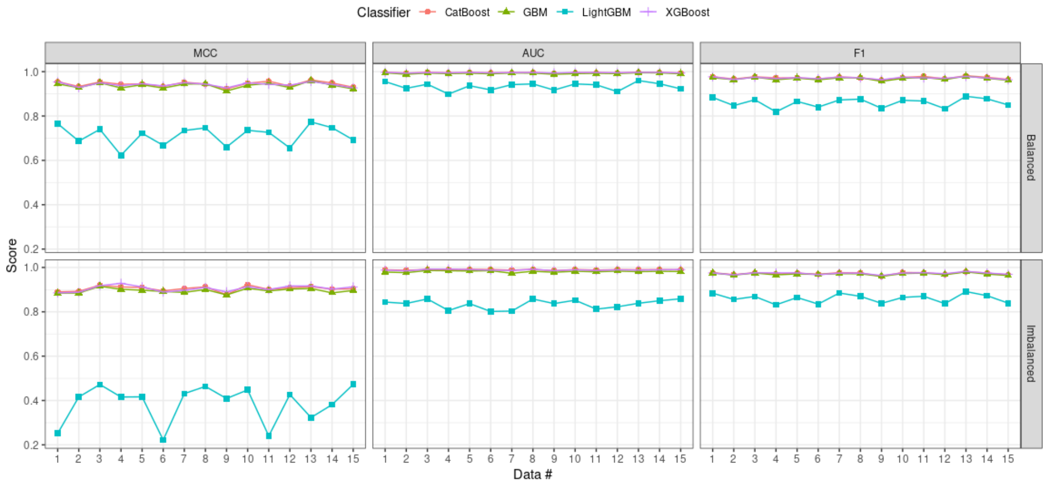

Figure 1. Average performance of all algorithms across various power system data sets.

It can also be noted that the performance of CatBoost, XGBoost, and GBM is much more consistent than the performance of LightGBM, which varies slightly across the data sets (see Figure 2). There are striking similarities and differences between the four performance distributions. In particular, the performance distributions of CatBoost, XGBoost, and GBM have roughly the same median, whereas LightGBM has a much lower median over all performance metrics. The performance values of LightGBM have much larger variability than the performance values of the other three algorithms.

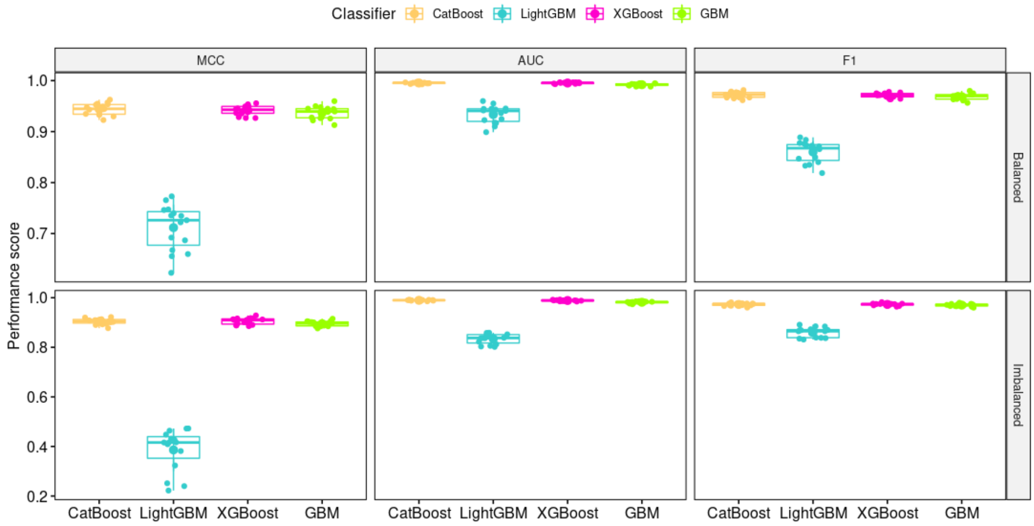

Figure 2. The skewness and spread of algorithms' performance over two distinct scenarios.

Moreover, we apply hierarchical clustering to group the algorithms and data sets using the Ward.D dissimilarities measure [25]. We chose $k = 3$ as the number of clusters to be built. Figures 3 and 4 show the hierarchical clusters of vertical observations (e.g., classification algorithms) and horizontal observations (e.g., data sets) in imbalanced and balanced data sets, respectively. The clustering method categorizes the classification algorithms into two main groups, where LightGBM has a considerable dissimilarity with GBM, CatBoost, and XGBoost, irrespective of the performance metrics and data set issues. In imbalanced data sets (see Figure 3), considering the MCC metric as an example, there are clearly two distinct groups: The red color group seems to consist of three more distinct groups, whereas the majority of blue and green color observations (i.e., data set #13, #1, #6, and #11) are clustered together at approximately the same height. This result confirms that the observations in blue and green are highly imbalanced data sets ($I_r < 0.4$), similarly to what we obtained in the previous section. In contrast, regarding balanced data sets (see Figure 4), there are obviously two unique groups in which three separate groups seem to be part of each group.

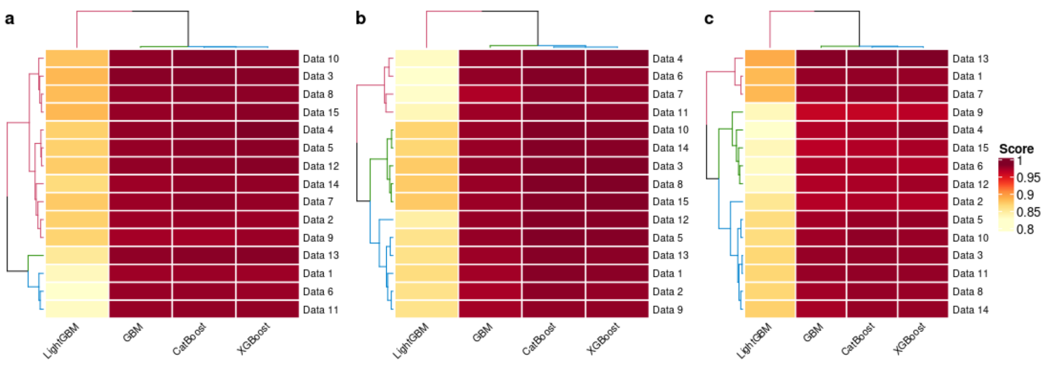

Figure 3. Hierarchical clusters (shown in three distinct colors) of algorithms and imbalanced data sets in terms of (**a**) MCC, (**b**) AUC, and (**c**) F1 metrics. The color in each cell represents the corresponding performance value (light yellow: low; dark red: high).

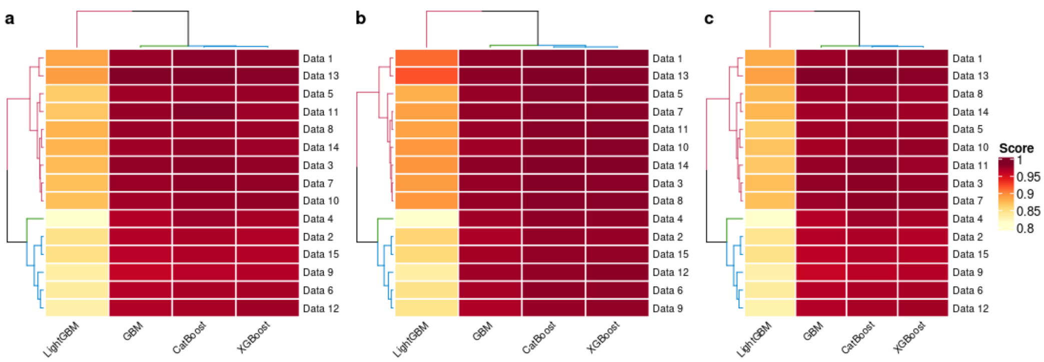

Figure 4. Hierarchical clusters (shown in three distinct colors) of algorithms and balanced data sets in terms of (**a**) MCC, (**b**) AUC, and (**c**) F1 metrics. The color in each cell represents the corresponding performance value (light yellow: low; dark red: high).

Lastly, we further benchmarked the algorithms' performance based on the Friedman rank test [26,27]. Each algorithm was scored independently for each data set, ascending from the best-performing algorithm to the worst-performing one based on the performance metrics [28,29]. Using MCC as an example, the performance of LightGBM is consistent across two different settings, while CatBoost and GBM performed significantly better in the balanced data set setting than in the imbalanced data set setting. On the contrary, XGBoost performs worse when the data sets are balanced than when they are imbalanced (see Table 2).

Table 2. Average Friedman rank of all algorithms across different performance metrics.

Scenario	Performance Metric	CatBoost	GBM	LightGBM	XGBoost
Imbalanced	MCC	1.47	2.93	4.00	1.60
	AUC	1.27	3.00	4.00	1.73
	F1	1.40	2.87	4.00	1.73
Balanced	MCC	1.40	2.67	4.00	1.93
	AUC	1.53	3.00	4.00	1.47
	F1	1.40	2.67	4.00	1.93

5. Conclusions

This paper benchmarked four implementations of gradient boosting ensembles, namely GBM, XGBoost, LightGBM, and CatBoost, on various imbalanced data sets. We considered anomaly detection in power grids as a case study, whereas the performance of ensembles was examined under three performance measures, namely MCC, AUC, and F1 scores. Our study revealed that CatBoost was the best-performing algorithm in two different experimental settings, while LightGBM had a substantially lower performance value and a lot more variation in how it worked with different data sets. CatBoost slightly outperformed XGBoost with respect to all performance metrics when the Friedman rank test was used. The limitation of this study lies in the evaluation, which was only restricted to the fifteen power grid data sets. Future work should incorporate more diverse and relevant IDSs data sets to produce more generalizable findings. Finally, it is critical to introduce a novel public benchmark data set that can significantly impact the evaluation bechmark of machine learning algorithms.

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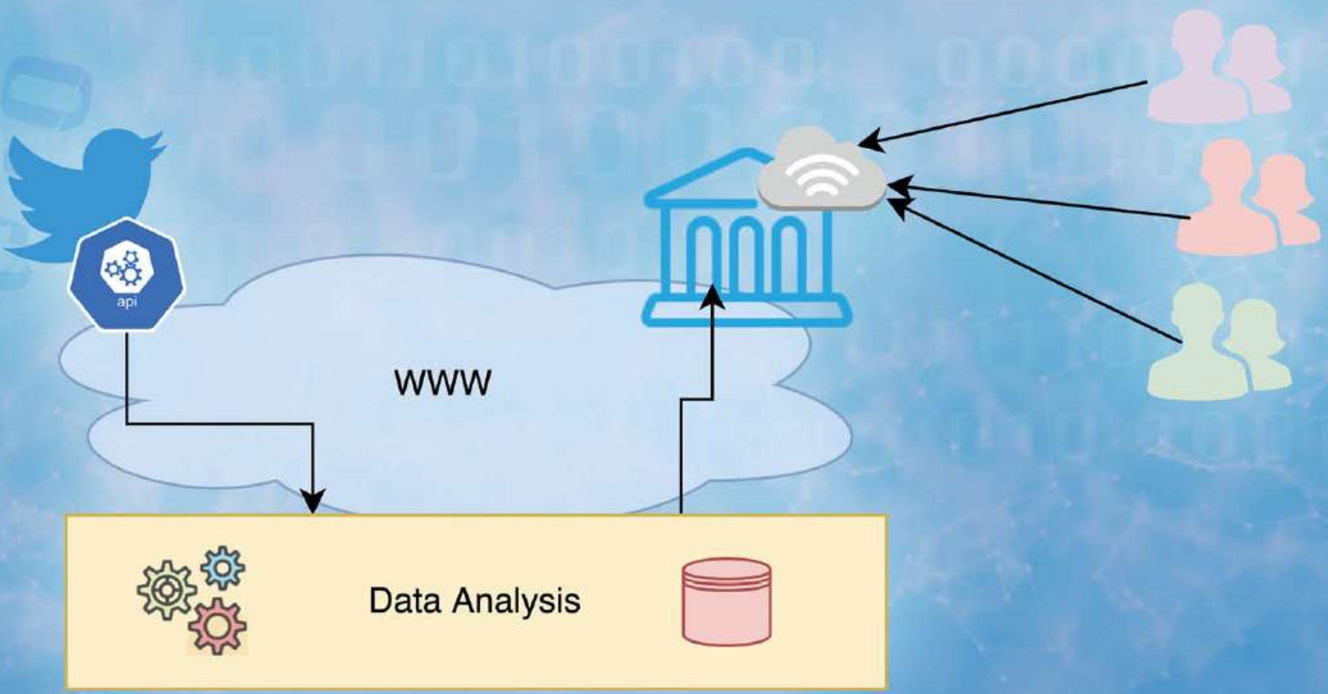

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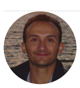

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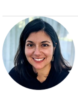

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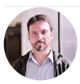

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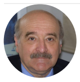

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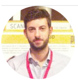

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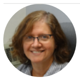

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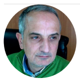

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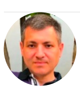

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Big Data Cogn. Comput., Volume 6, Issue 2 (June 2022) – 36 articles

Cover Story (**view full-size image (/files/uploaded/covers/BDCC/big_cover-BDCC-v6-i2.png)**): People nowadays tend to use the Internet, especially social media, more frequently and for a wider variety of purposes. Even though cultural spaces are using the Internet, participating, growing their audience, or locating an appropriate group of people to share their information with remain tedious tasks. The investment is mainly financial —usually large—and directed to advertisements. Still, there is space for research and investment in analytics, which can provide evidence that considers the spreading of information or finding groups of people interested in specific trending topics and influencers. The Internet demands participation and not just presence. In this work, we describe a procedure through which cultural institutions can benefit from the data analysis of Twitter's trending topics. **View this paper (https://www.mdpi.com/2504-2289/6/2/63)**

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Áika: A Distributed Edge System for AI Inference (/2504-2289/6/2/68)

by **Joakim Aalstad Alslie (https://sciprofiles.com/profile/author/bStkRnY5ZFdkcDF4dm5aZm5jdjZJdW93TUM4ellyMWdhSVlyeERyMWVXTT0=)**, **Aril Bernhard Ovesen (https://sciprofiles.com/profile/1815243)**, **Tor-Arne Schmidt Nordmo (https://sciprofiles.com/profile/1841659)**, **Håvard Dagenborg Johansen (https://sciprofiles.com/profile/1861542)**, **Pål Halvorsen (https://sciprofiles.com/profile/1330812)**, **Michael Alexander Riegler (https://sciprofiles.com/profile/1330811)** and **Dag Johansen (https://sciprofiles.com/profile/author/V2NyRENqa3AxNWJKYzZFblF4NmlxLzdyUS9ZVVpVcWxzMy8yL0JzNUI2UT0=)**

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Abstract Video monitoring and surveillance of commercial fisheries in world oceans has been proposed by the governing bodies of several nations as a response to crimes such as overfishing. Traditional video monitoring systems may not be suitable due to limitations in the offshore fishing **[...] Read more.**

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Iris Liveness Detection Using Multiple Deep Convolution Networks (/2504-2289/6/2/67)

by **Smita Khade (https://sciprofiles.com/profile/1886790)**, **Shilpa Gite (https://sciprofiles.com/profile/1520062)** and **Biswajeet Pradhan (https://sciprofiles.com/profile/49990)**

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Abstract In the recent decade, comprehensive research has been carried out in terms of promising biometrics modalities regarding humans' physical features for person recognition. This work focuses on iris characteristics and traits for person identification and iris liveness detection. This study used five pre-trained **[...] Read more.**

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CompositeView: A Network-Based Visualization Tool (/2504-2289/6/2/66)

by Stephen A. Allegri (https://sciprofiles.com/profile/author/a0l1TDExVHhzOEtOVUY3UnZEOTZNNjV3azk1Tys1dWZHZWlkajhxMUl0az0=), Kevin McCoy (https://sciprofiles.com/profile/1650012) and Cassie S. Mitchell (https://sciprofiles.com/profile/764515)

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Abstract Large networks are quintessential to bioinformatics, knowledge graphs, social network analysis, and graph-based learning. CompositeView is a Python-based open-source application that improves interactive complex network visualization and extraction of actionable insight. CompositeView utilizes specifically formatted input data to calculate composite scores and display [...] Read more.

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Abstract Policymakers, practitioners, and researchers around the globe have been acting in a coordinated manner, yet remaining independent, to achieve the seventeen Sustainable Development Goals (SDGs) defined by the United Nations. Remarkably, SDG-centric activities have manifested a huge information silo known as big data. [...] Read more.

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Social Media Analytics as a Tool for Cultural Spaces—The Case of Twitter Trending Topics (/2504-2289/6/2/63)

by Vassilis Poulopoulos (https://sciprofiles.com/profile/502804) and Manolis Wallace (https://sciprofiles.com/profile/500718)

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Synthesizing a Talking Child Avatar to Train Interviewers Working with Maltreated Children (/2504-2289/6/2/62)

by Pegah Salehi (https://sciprofiles.com/profile/2198246), Syed Zohaib Hassan (https://sciprofiles.com/profile/1971340), Myrthe Lammerse (https://sciprofiles.com/profile/author/UlJSS3FnNFVGYlg0QlBDZGs2WmZGTjZUMEFuWVBqaGVnaFdFVWtXeVNncz0=), Saeed Shafiee Sabet (https://sciprofiles.com/profile/2198321), Ingvild Riiser (https://sciprofiles.com/profile/author/bkF6SzFTZkQ4TUprWk4vWU9xYXpPZ2t6dUdidFpJVWcwLzZPaXJKZ2h2bz0=), Ragnhild Klingenberg Røed (https://sciprofiles.com/profile/author/TiswRlRUMnhNR1g1V0JsT0tGOTVydz09), Miriam S. Johnson (https://sciprofiles.com/profile/author/NDF4S09YVHBZaW5UcngvUVI5SHFVZzNDdkVwbUttTm5kbVJxejdRd1dybz0=), Vajira Thambawita (https://sciprofiles.com/profile/1867086), Steven A. Hicks (https://sciprofiles.com/profile/1849591), Martine Powell (https://sciprofiles.com/profile/author/Y0dzcWREaVVPUGRZWWg3M2xZRjBpN1VoZzNJMm9hRmJGVVFOekhpenBxOD0=), Michael E. Lamb (https://sciprofiles.com/profile/author/eHB4TFo3MG1UWWNVSlJpV0ZvYUVCdz09), Gunn Astrid Baugerud (https://sciprofiles.com/profile/2242997), Pål Halvorsen (https://sciprofiles.com/profile/1330812) and Michael A. Riegler (https://sciprofiles.com/profile/1330811)

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Abstract When responding to allegations of child sexual, physical, and psychological abuse, Child Protection Service (CPS) workers and police personnel need to elicit detailed and accurate accounts of the abuse to assist in decision-making and prosecution. Current research emphasizes the importance of the interviewer's [...] Read more.

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A Novel Method of Exploring the Uncanny Valley in Avatar Gender(Sex) and Realism Using Electromyography (/2504-2289/6/2/61)

by Jacqueline D. Bailey (https://sciprofiles.com/profile/2040931) and Karen L. Blackmore (https://sciprofiles.com/profile/2210261)

Big Data Cogn. Comput. **2022**, *6*(2), 61; https://doi.org/10.3390/bdcc6020061 (https://doi.org/10.3390/bdcc6020061) - 30 May 2022

Abstract Despite the variety of applications that use avatars (virtual humans), how end-users perceive avatars are not fully understood, and accurately measuring these perceptions remains a challenge. To measure end-user responses more accurately to avatars, this pilot study uses a novel methodology which aims [...] Read more.

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Earthquake Insurance in California, USA: What Does Community-Generated Big Data Reveal to Us? (/2504-2289/6/2/60)

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by Fabrizio Terenzio Gizzi (https://sciprofiles.com/profile/288589) and Maria Rosaria Potenza (https://sciprofiles.com/profile/author/ZTRrS0xXMElaYnNlZk9CWThCMU10QkR1a2Z5Qi84K0w1NmRuei9lSldZZz0=)

Big Data Cogn. Comput. **2022**, *6*(2), 60; https://doi.org/10.3390/bdcc6020060 (https://doi.org/10.3390/bdcc6020060) - 20 May 2022

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Abstract California has a high seismic hazard, as many historical and recent earthquakes remind us. To deal with potential future damaging earthquakes, a voluntary insurance system for residential properties is in force in the state. However, the insurance penetration rate is quite low. Bearing [...] Read more.

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The Predictive Power of a Twitter User's Profile on Cryptocurrency Popularity (/2504-2289/6/2/59)

by Maria Trigka (https://sciprofiles.com/profile/1497326), Andreas Kanavos (https://sciprofiles.com/profile/227248), Elias Dritsas (https://sciprofiles.com/profile/550367), Gerasimos Vonitsanos (https://sciprofiles.com/profile/1232868) and Phivos Mylonas (https://sciprofiles.com/profile/219876)

Big Data Cogn. Comput. **2022**, *6*(2), 59; https://doi.org/10.3390/bdcc6020059 (https://doi.org/10.3390/bdcc6020059) - 20 May 2022

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Abstract Microblogging has become an extremely popular communication tool among Internet users worldwide. Millions of users daily share a huge amount of information related to various aspects of their lives, which makes the respective sites a very important source of data for analysis. Bitcoin [...] Read more.

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COVID-19 Tweets Classification Based on a Hybrid Word Embedding Method (/2504-2289/6/2/58)

by Yosra Didi (https://sciprofiles.com/profile/2149997), Ahlam Walha (https://sciprofiles.com/profile/2178617) and Ali Wali (https://sciprofiles.com/profile/2175475)

Big Data Cogn. Comput. **2022**, *6*(2), 58; https://doi.org/10.3390/bdcc6020058 (https://doi.org/10.3390/bdcc6020058) - 18 May 2022

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Abstract In March 2020, the World Health Organisation declared that COVID-19 was a new pandemic. This deadly virus spread and affected many countries in the world. During the outbreak, social media platforms such as Twitter contributed valuable and massive amounts of data to better [...] Read more.

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Sentiment Analysis of Emirati Dialect (/2504-2289/6/2/57)

by Arwa A. Al Shamsi (https://sciprofiles.com/profile/2166093) and Sherief Abdallah (https://sciprofiles.com/profile/author/YkVqQUFqYVNENURvVlNDN1dvNWlpR0dwdEs4MktGQWtOVDBjN2xJYmdxVT0=)

Big Data Cogn. Comput. **2022**, *6*(2), 57; https://doi.org/10.3390/bdcc6020057 (https://doi.org/10.3390/bdcc6020057) - 17 May 2022

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Abstract Recently, extensive studies and research in the Arabic Natural Language Processing (ANLP) field have been conducted for text classification and sentiment analysis. Moreover, the number of studies that target Arabic dialects has also increased. In this research paper, we constructed the first manually [...] Read more.

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A Better Mechanistic Understanding of Big Data through an Order Search Using Causal Bayesian Networks (/2504-2289/6/2/56)

by Changwon Yoo (https://sciprofiles.com/profile/78765), Efrain Gonzalez (https://sciprofiles.com/profile/2158978), Zhenghua Gong (https://sciprofiles.com/profile/2158812) and Deodutta Roy (https://sciprofiles.com/profile/130604)

Big Data Cogn. Comput. **2022**, *6*(2), 56; https://doi.org/10.3390/bdcc6020056 (https://doi.org/10.3390/bdcc6020056) - 17 May 2022

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Abstract Every year, biomedical data is increasing at an alarming rate and is being collected from many different sources, such as hospitals (clinical Big Data), laboratories (genomic and proteomic Big Data), and the internet (online Big Data). This article presents and evaluates a practical [...] Read more.

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Virtual Reality Adaptation Using Electrodermal Activity to Support the User Experience (/2504-2289/6/2/55)

by Francesco Chiossi (https://sciprofiles.com/profile/2139783), Robin Welsch (https://sciprofiles.com/profile/author/N3RpTHFZNlFoeEhEeWg3U0NkK3k2M3czN20xbDloS2dXWVl0YzFLcFo0WT0=), Steeven Villa (https://sciprofiles.com/profile/author/Zk1MRWdvWkRTQU0wQWRvdkdtbGZ4WVRoaDJJV1ViRm1BK3NGbVhUYXNrdz0=), Lewis Chuang (https://sciprofiles.com/profile/author/Y2gyZTlkYVFjZk9pNCswOU8vdFJDZXQ2Y1RkcnZpWVlDNVpZcHg1M3l4az0=) and Sven Mayer (https://sciprofiles.com/profile/author/MlV2cGFQREJXN1Ewc3Z3V05BSjJmbzc5OW1JYzZzeGJXODJsV0hTZlB3ST0=)

Big Data Cogn. Comput. **2022**, *6*(2), 55; https://doi.org/10.3390/bdcc6020055 (https://doi.org/10.3390/bdcc6020055) - 13 May 2022

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Abstract Virtual reality is increasingly used for tasks such as work and education. Thus, rendering scenarios that do not interfere with such goals and deplete user experience are becoming progressively more relevant. We present a physiologically adaptive system that optimizes the virtual environment based [...] Read more.

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A New Comparative Study of Dimensionality Reduction Methods in Large-Scale Image Retrieval (/2504-2289/6/2/54)

by Mohammed Amin Belarbi (https://sciprofiles.com/profile/2177736), Saïd Mahmoudi (https://sciprofiles.com/profile/1169134), Ghalem Belalem (https://sciprofiles.com/profile/2204241), Sidi Ahmed Mahmoudi (https://sciprofiles.com/profile/697316) and Aurélie Cools (https://sciprofiles.com/profile/2168042)

Big Data Cogn. Comput. **2022**, *6*(2), 54; https://doi.org/10.3390/bdcc6020054 (https://doi.org/10.3390/bdcc6020054) - 13 May 2022

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Abstract Indexing images by content is one of the most used computer vision methods, where various techniques are used to extract visual characteristics from images. The deluge of data surrounding us, due the high use of social and diverse media acquisition systems, has created [...] Read more.

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Knowledge Modelling and Learning through Cognitive Networks (/2504-2289/6/2/53)

by Massimo Stella (https://sciprofiles.com/profile/397752) and Yoed N. Kenett (https://sciprofiles.com/profile/763621)

Big Data Cogn. Comput. **2022**, *6*(2), 53; https://doi.org/10.3390/bdcc6020053 (https://doi.org/10.3390/bdcc6020053) - 13 May 2022

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Abstract Knowledge modelling is a growing field at the fringe of computer science, psychology and network science [...] Full article (/2504-2289/6/2/53)

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Cognitive Networks Extract Insights on COVID-19 Vaccines from English and Italian Popular Tweets: Anticipation, Logistics, Conspiracy and Loss of Trust

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by Massimo Stella (https://sciprofiles.com/profile/397752), Michael S. Vitevitch (https://sciprofiles.com/profile/452669) and Federico Botta (https://sciprofiles.com/profile/2205385)

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Big Data Cogn. Comput. **2022**, *6*(2), 52; https://doi.org/10.3390/bdcc6020052 (https://doi.org/10.3390/bdcc6020052) - 12 May 2022

Abstract Monitoring social discourse about COVID-19 vaccines is key to understanding how large populations perceive vaccination campaigns. This work reconstructs how popular and trending posts framed semantically and emotionally COVID-19 vaccines on Twitter. We achieve this by merging natural language processing, cognitive network science [...] Read more.

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Robust Multi-Mode Synchronization of Chaotic Fractional Order Systems in the Presence of Disturbance, Time Delay and Uncertainty with Application in Secure Communications (/2504-2289/6/2/51)

by Ali Akbar Kekha Javan (https://sciprofiles.com/profile/1411285), Assef Zare (https://sciprofiles.com/profile/1355101), Roohallah Alizadehsani (https://sciprofiles.com/profile/1656937) and Saeed Balochian (https://sciprofiles.com/profile/author/SGI4L3FpTUx4a1YzQ3JUSDJtV2xpVVkvTXF5OEVFbzJLbGFCQXNlcmRqND0=)

Big Data Cogn. Comput. **2022**, *6*(2), 51; https://doi.org/10.3390/bdcc6020051 (https://doi.org/10.3390/bdcc6020051) - 08 May 2022

Abstract This paper investigates the robust adaptive synchronization of multi-mode fractional-order chaotic systems (MMFOCS). To that end, synchronization was performed with unknown parameters, unknown time delays, the presence of disturbance, and uncertainty with the unknown boundary. The convergence of the synchronization error to zero [...] Read more.

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Gender Stereotypes in Hollywood Movies and Their Evolution over Time: Insights from Network Analysis (/2504-2289/6/2/50)

by Arjun M. Kumar (https://sciprofiles.com/profile/author/SDBENWZrSDI3b1lheGlFazZGcHJaK1VZZnNHL3NUNHVOQVFoQWVEMCtMcz0=), Jasmine Y. Q. Goh (https://sciprofiles.com/profile/author/R0c5T0Z4V3lSQW5EZHI3bmRBSmQwankxekZ4dTdRb0RTckhQNy92cXBSRT0=), Tiffany H. H. Tan (https://sciprofiles.com/profile/2170693) and Cynthia S. Q. Siew (https://sciprofiles.com/profile/969968)

Big Data Cogn. Comput. **2022**, *6*(2), 50; https://doi.org/10.3390/bdcc6020050 (https://doi.org/10.3390/bdcc6020050) - 06 May 2022

Abstract The present analysis of more than 180,000 sentences from movie plots across the period from 1940 to 2019 emphasizes how gender stereotypes are expressed through the cultural products of society. By applying a network analysis to the word co-occurrence networks of movie plots [...] Read more.

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A Comparative Study of MongoDB and Document-Based MySQL for Big Data Application Data Management (/2504-2289/6/2/49)

by Cornelia A. Győrödi (https://sciprofiles.com/profile/1331159), Diana V. Dumșe-Burescu (https://sciprofiles.com/profile/1360147), Doina R. Zmaranda (https://sciprofiles.com/profile/1362168) and Robert Ș. Győrödi (https://sciprofiles.com/profile/1363333)

Big Data Cogn. Comput. **2022**, *6*(2), 49; **https://doi.org/10.3390/bdcc6020049 (https://doi.org/10.3390/bdcc6020049)** - 05 May 2022

Abstract In the context of the heavy demands of Big Data, software developers have also begun to consider NoSQL data storage solutions. One of the important criteria when choosing a NoSQL database for an application is its performance in terms of speed of data **[...] Read more.**
(This article belongs to the Topic **Complex Data Analytics and Computing with Real-World Applications (/topics/Data_Analytics)**)

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Open Access Article **(/2504-2289/6/2/48/pdf?version=1651243573)**

A New Ontology-Based Method for Arabic Sentiment Analysis (/2504-2289/6/2/48)

by **Safaa M. Khabour (https://sciprofiles.com/profile/author/YjM1MWc2M2w1S3hpZDZCM1lUZEE5ZjR3eW9ueFByZzRMenRsd1ZlQXlTZz0=)**, **Qasem A. Al-Radaideh (https://sciprofiles.com/profile/360693)** and **Dheya Mustafa (https://sciprofiles.com/profile/2145225)**
Big Data Cogn. Comput. **2022**, *6*(2), 48; **https://doi.org/10.3390/bdcc6020048 (https://doi.org/10.3390/bdcc6020048)** - 29 Apr 2022

Abstract Arabic sentiment analysis is a process that aims to extract the subjective opinions of different users about different subjects since these opinions and sentiments are used to recognize their perspectives and judgments in a particular domain. Few research studies addressed semantic-oriented approaches for **[...] Read more.**
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Open Access Article **(/2504-2289/6/2/47/pdf?version=1651067196)**

Incentive Mechanisms for Smart Grid: State of the Art, Challenges, Open Issues, Future Directions (/2504-2289/6/2/47)

by **Sweta Bhattacharya (https://sciprofiles.com/profile/2475604)**, **Rajeswari Chengoden (https://sciprofiles.com/profile/2451558)**, **Gautam Srivastava (https://sciprofiles.com/profile/568375)**, **Mamoun Alazab (https://sciprofiles.com/profile/684608)**, **Abdul Rehman Javed (https://sciprofiles.com/profile/1209878)**, **Nancy Victor (https://sciprofiles.com/profile/1909393)**, **Praveen Kumar Reddy Maddikunta (https://sciprofiles.com/profile/919112)** and **Thippa Reddy Gadekallu (https://sciprofiles.com/profile/927289)**
Big Data Cogn. Comput. **2022**, *6*(2), 47; **https://doi.org/10.3390/bdcc6020047 (https://doi.org/10.3390/bdcc6020047)** - 27 Apr 2022

Abstract Smart grids (SG) are electricity grids that communicate with each other, provide reliable information, and enable administrators to operate energy supplies across the country, ensuring optimized reliability and efficiency. The smart grid contains sensors that measure and transmit data to adjust the flow **[...] Read more.**
(This article belongs to the Special Issue **Energy-Efficient IoT (Internet of Things) and Big Data Challenges for Connected Intelligence (/journal/BDCC/special_issues/iot_data)**)

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Open Access Article **(/2504-2289/6/2/46/pdf?version=1650772072)**

A Non-Uniform Continuous Cellular Automata for Analyzing and Predicting the Spreading Patterns of COVID-19 (/2504-2289/6/2/46)

by **Puspa Eosina (https://sciprofiles.com/profile/2142247)**, **Aniati Murni Arymurthy (https://sciprofiles.com/profile/author/RzVaY3JBR2s1ZThhM3JHZS9mSThSd2c4elR1UE9aRlFjUHRTVjh1c0dBVT0=)** and **Adila Alfa Krisnadhi (https://sciprofiles.com/profile/1625303)**
Big Data Cogn. Comput. **2022**, *6*(2), 46; **https://doi.org/10.3390/bdcc6020046 (https://doi.org/10.3390/bdcc6020046)** - 24 Apr 2022

Abstract During the COVID-19 outbreak, modeling the spread of infectious diseases became a challenging research topic due to its rapid spread and high mortality rate. The main objective of a standard epidemiological model is to estimate the number of infected, suspected, and recovered from **[...] Read more.**
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Open Access Article (/2504-2289/6/2/45/pdf?version=1650456236)

Virtual Reality-Based Stimuli for Immersive Car Clinics: A Performance Evaluation Model (/2504-2289/6/2/45)

by Alexandre Costa Henriques (https://sciprofiles.com/profile/2105930), Thiago Barros Murari (https://sciprofiles.com/profile/721549), Jennifer Callans (https://sciprofiles.com/profile/2104000), Alexandre Maguino Pinheiro Silva (https://sciprofiles.com/profile/author/TzRzNm9jQjNyNkl5a1R6bURPQTROWEZOd0VqQ1NDOS95VE9jcW1iYTV0cz0=), Antonio Lopes Apolinario, Jr. (https://sciprofiles.com/profile/2147104) and Ingrid Winkler (https://sciprofiles.com/profile/1717686)

Big Data Cogn. Comput. **2022**, *6*(2), 45; https://doi.org/10.3390/bdcc6020045 (https://doi.org/10.3390/bdcc6020045) - 20 Apr 2022

Abstract This study proposes a model to evaluate the performance of virtual reality-based stimuli for immersive car clinics. The model considered Attribute Importance, Stimuli Efficacy and Stimuli Cost factors and the method was divided into three stages: we defined the importance of fourteen attributes [...] Read more.

(This article belongs to the Special Issue Virtual Reality, Augmented Reality, and Human-Computer Interaction (/journal/BDCC/special_issues/Virt_Reality))

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Deep Learning Approaches for Video Compression: A Bibliometric Analysis (/2504-2289/6/2/44)

by Ranjeet Vasant Bidwe (https://sciprofiles.com/profile/2051812), Sashikala Mishra (https://sciprofiles.com/profile/2053511), Shruti Patil (https://sciprofiles.com/profile/1664942), Kailash Shaw (https://sciprofiles.com/profile/1884746), Deepali Rahul Vora (https://sciprofiles.com/profile/1955391), Ketan Kotecha (https://sciprofiles.com/profile/1259205) and Bhushan Zope (https://sciprofiles.com/profile/2167306)

Big Data Cogn. Comput. **2022**, *6*(2), 44; https://doi.org/10.3390/bdcc6020044 (https://doi.org/10.3390/bdcc6020044) - 19 Apr 2022

Abstract Every data and kind of data need a physical drive to store it. There has been an explosion in the volume of images, video, and other similar data types circulated over the internet. Users using the internet expect intelligible data, even under the [...] Read more.

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New Efficient Approach to Solve Big Data Systems Using Parallel Gauss–Seidel Algorithms (/2504-2289/6/2/43)

by Shih Yu Chang (https://sciprofiles.com/profile/2099453), Hsiao-Chun Wu (https://sciprofiles.com/profile/1988862) and Yifan Wang (https://sciprofiles.com/profile/author/YlFnbERqUm1waE9lbHU1WFJqUnZWbnE1V1FGeFBUK3JHRHlMS2NJeURTVT0=)

Big Data Cogn. Comput. **2022**, *6*(2), 43; https://doi.org/10.3390/bdcc6020043 (https://doi.org/10.3390/bdcc6020043) - 19 Apr 2022

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Abstract In order to perform big-data analytics, regression involving large matrices is often necessary. In particular, large scale regression problems are encountered when one wishes to extract semantic patterns for knowledge discovery and data mining. When a large matrix can be processed in its [...] Read more.

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An Emergency Event Detection Ensemble Model Based on Big Data (/2504-2289/6/2/42)

by Khalid Alfalqi (https://sciprofiles.com/profile/2056716) and Martine Bellaiche (https://sciprofiles.com/profile/250754)

Big Data Cogn. Comput. **2022**, *6*(2), 42; https://doi.org/10.3390/bdcc6020042 (https://doi.org/10.3390/bdcc6020042) - 16 Apr 2022

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Abstract Emergency events arise when a serious, unexpected, and often dangerous threat affects normal life. Hence, knowing what is occurring during and after emergency events is critical to mitigate the effect of the incident on humans' life, on the environment and our infrastructures, as [...] Read more.

(This article belongs to the Topic Big Data and Artificial Intelligence (/topics/Big_Data_Artificial_Intelligence))

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Revisiting Gradient Boosting-Based Approaches for Learning Imbalanced Data: A Case of Anomaly Detection on Power Grids (/2504-2289/6/2/41)

by Maya Hilda Lestari Louk (https://sciprofiles.com/profile/1948671) and Bayu Adhi Tama (https://sciprofiles.com/profile/828102)

Big Data Cogn. Comput. **2022**, *6*(2), 41; https://doi.org/10.3390/bdcc6020041 (https://doi.org/10.3390/bdcc6020041) - 16 Apr 2022

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Abstract Gradient boosting ensembles have been used in the cyber-security area for many years; nonetheless, their efficacy and accuracy for intrusion detection systems (IDSs) remain questionable, particularly when dealing with problems involving imbalanced data. This article fills the void in the existing body of [...] Read more.

(This article belongs to the Special Issue Cyber Security in Big Data Era (/journal/BDCC/special_issues/cyb_bd))

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Breast and Lung Anticancer Peptides Classification Using N-Grams and Ensemble Learning Techniques (/2504-2289/6/2/40)

by Ayad Rodhan Abbas (https://sciprofiles.com/profile/1864261), Bashar Saadoon Mahdi (https://sciprofiles.com/profile/2164894) and Osamah Younus Fadhil (https://sciprofiles.com/profile/2169838)

Big Data Cogn. Comput. **2022**, *6*(2), 40; https://doi.org/10.3390/bdcc6020040 (https://doi.org/10.3390/bdcc6020040) - 12 Apr 2022

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Abstract Anticancer peptides (ACPs) are short protein sequences; they perform functions like some hormones and enzymes inside the body. The role of any protein or peptide is related to its structure and the sequence of amino acids that make up it. There are 20 [...] Read more.

(This article belongs to the Topic Machine and Deep Learning (/topics/Machine_Deep_Learning))

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PCB Component Detection Using Computer Vision for Hardware Assurance (/2504-2289/6/2/39)

by Wenwei Zhao (https://sciprofiles.com/profile/1973685), Suprith Reddy Gurudu (https://sciprofiles.com/profile/2147923), Shayan Taheri (https://sciprofiles.com/profile/1444955), Shajib Ghosh (https://sciprofiles.com/profile/author/MmhBSm1HODZOR1ZVMXpzTUJQWTkxYUI5Q3F4S09sQlhQbUxQNXlyY3FpTT0=), Mukhil Azhagan Mallaiyan Sathiaseelan (https://sciprofiles.com/profile/1443910) and Navid Asadizanjani (https://sciprofiles.com/profile/1212165)
Big Data Cogn. Comput. **2022**, *6*(2), 39; https://doi.org/10.3390/bdcc6020039 (https://doi.org/10.3390/bdcc6020039) - 08 Apr 2022

Abstract Printed circuit board (PCB) assurance in the optical domain is a crucial field of study. Though there are many existing PCB assurance methods using image processing, computer vision (CV), and machine learning (ML), the PCB field is complex and increasingly evolving, so new [...] Read more.
(This article belongs to the Topic Applied Computer Vision and Pattern Recognition (/topics/Computer_Vision_Pattern_Recognition))

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Big Data Cogn. Comput. **2022**, *6*(2), 38; https://doi.org/10.3390/bdcc6020038 (https://doi.org/10.3390/bdcc6020038) - 07 Apr 2022

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Big Data Cogn. Comput. **2022**, *6*(2), 37; https://doi.org/10.3390/bdcc6020037 (https://doi.org/10.3390/bdcc6020037) - 01 Apr 2022

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Big Data Cogn. Comput. **2022**, *6*(2), 36; https://doi.org/10.3390/bdcc6020036 (https://doi.org/10.3390/bdcc6020036) - 01 Apr 2022 (/toggle_desktop_layout_cookie)

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Big Data Cogn. Comput. **2022**, *6*(2), 35; https://doi.org/10.3390/bdcc6020035 (https://doi.org/10.3390/bdcc6020035) - 25 Mar 2022

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Big Data Cogn. Comput. **2022**, *6*(2), 34; https://doi.org/10.3390/bdcc6020034 (https://doi.org/10.3390/bdcc6020034) - 25 Mar 2022

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Big Data Cogn. Comput. **2022**, *6*(2), 33; https://doi.org/10.3390/bdcc6020033 (https://doi.org/10.3390/bdcc6020033) - 22 Mar 2022

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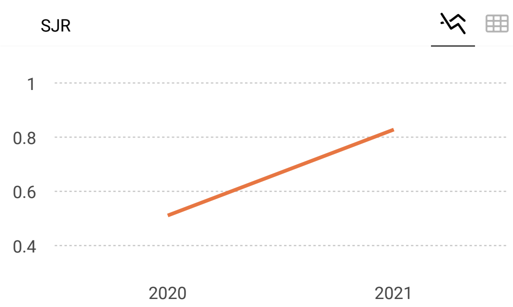

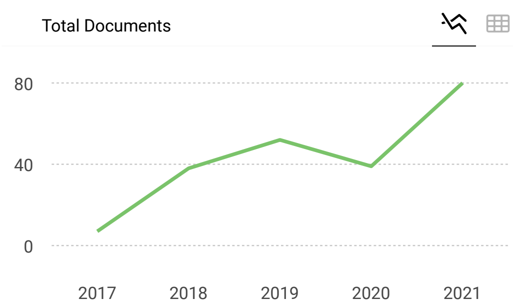

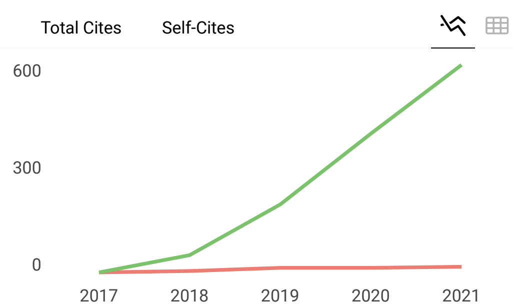

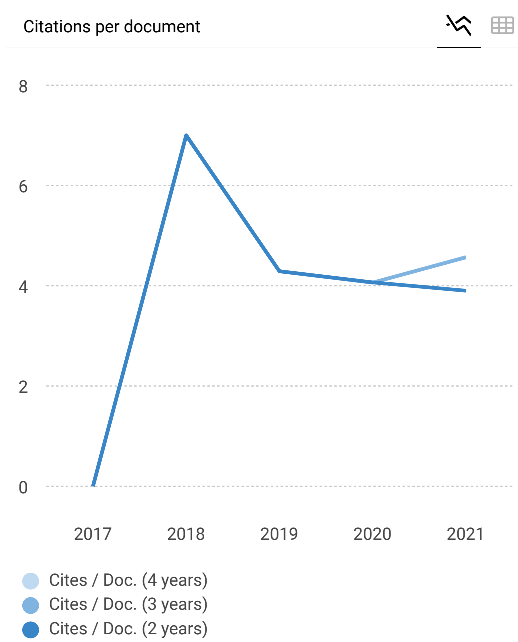

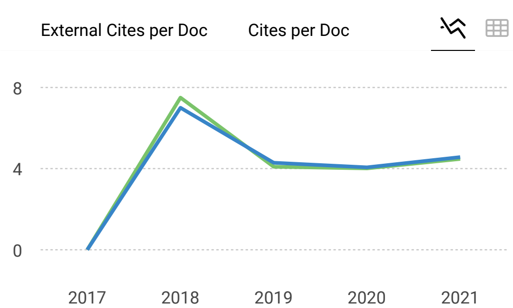

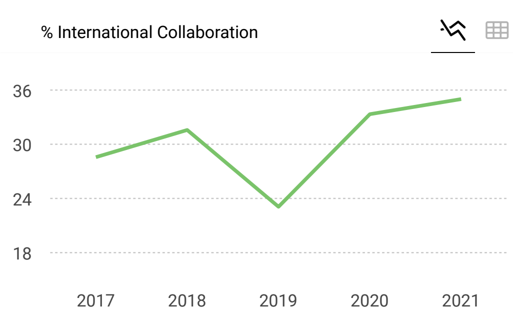

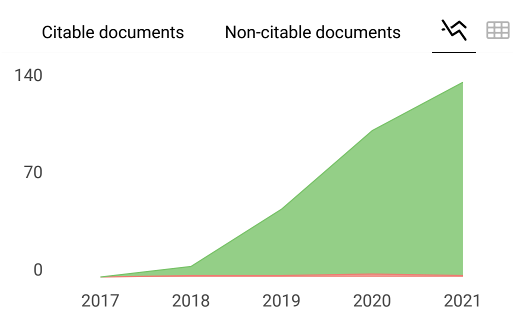

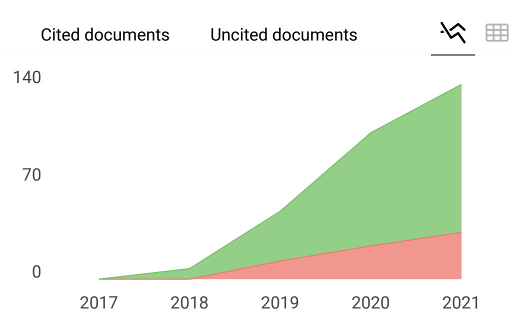

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