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Robust Statistical Methods for Estimation, Detection and Application in Skewed Distribution: A Comprehensive Systematic Review

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ABSTRACT

This systematic review paper provides an overview of robust statistical methods under skewed distributions and their applications across various fields. A comprehensive search strategy was implemented via Scopus and Web of Science databases based on advanced keyword searching, i.e., mean, robust and skewed distribution. This study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. There are 33 article journals were identified and categorized into three thematic sections: (i) estimation and detection methods, (ii) statistical methods, and (iii) its application, for skewed distributions across various fields. An extensive review of the article highlights the effectiveness of various robust statistical methods in handling skewed distribution across different scenarios, thus improve results and data analysis. Moreover, the findings emphasize the significance of the robust statistical methods in estimation and outlier detection when facing skewed distributions. This paper provides insights and recommendations for researchers and practitioners, fostering the advancement of statistical methodologies in mitigating the problem of skewed distributions.

Keywords:
Skewed distribution; robust methods; detection; robust estimation; systematic review

1. Introduction

In applied science and technology, as in many other domains, data analysis is the cornerstone of informed decision-making [1-3]. Researchers, engineers, and professionals in these fields routinely encounter complex datasets that often defy the assumption of normality, where the data is symmetrically distributed around a central point [1-3]. Instead, they grapple with skewed data distributions characterized by pronounced asymmetry, where one tail of the distribution extends further than the other. This skewness, a ubiquitous feature of real-world data, introduces unique challenges, particularly when estimating central tendencies [4,5]. The use of the arithmetic mean is a popular [6-8] and conventional estimator [9-11]. The mean estimator are used it can be severely

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compromised when applied to skewed datasets [12,13] and leading to potentially flawed conclusions [14-17].

This systematic review embarks on exploring a diverse array of robust statistical methods that cater to the complexities of skewed data. From estimation methods to detection approaches, these methods have been developed to tackle the unique challenges presented by skewed distributions.

Skewed data distributions are pervasive, including in the applied science and technology areas. Consider, for instance, the field of environmental science, where measurements of environmental pollutants often exhibit skewed distributions due to the presence of rare, high-concentration events [18,19]. In medical research, the distribution of patient recovery times or hospitalization costs may display pronounced skewness [20-22]. The list encompasses fields such as materials science, engineering, biology, and more.

The consequences of misinterpreting skewed data in these domains can be profound. Inadequate central tendency estimations can lead to flawed risk assessments, suboptimal resource allocation, and ineffective decision-making. In the design of engineering systems, the failure to correctly estimate central tendencies in skewed datasets can result in costly over-designs or, conversely, catastrophic under-designs [23,24]. Furthermore, in healthcare, improper estimations may affect resource allocation, leading to inefficiencies and disparities in patient care [25,26].

This systematic review bridges the gap between theoretical advancements in alternative estimators for skewed data and their practical applications in applied science and technology. By presenting various methods for estimating central tendencies in skewed data, it helps academics and professionals produce accurate research outcomes and reduce errors. The paper begins by exploring the challenges of using the mean in skewed distributions, then examines various alternative estimators and their applicability in applied science and technology. Finally, it summarizes key findings and offers suggestions for future research, aiming to equip professionals with the knowledge and tools to handle skewed data effectively, resulting in more robust and reliable outcomes in applied science and technology.

2. Literature Review

The robust statistical methods for estimation, detection, and application in skewed distributions, a plethora of innovative methodologies has emerged to address the inherent challenges in dealing with non-normal data. These methodologies have been meticulously designed to enhance the accuracy, reliability, and robustness of statistical estimators when confronted with skewed data distributions, aligning closely with the overarching theme of our comprehensive systematic review. In the domain of statistical estimation concerning skewed distributions, many pioneering methodologies have materialized, each intricately devised to confront the challenges inherent in non-normal data. Zarinkolah *et al.*, [27] introduce a cost-effective estimator for the population mean in asymmetric populations. Their method employs median ranked-set sampling, effectively dividing the population into equal-sized subsets based on the ranking order in accordance with a prominent auxiliary variable. This technique is further extended with extreme ranked-set sampling, focusing on the extreme values with respect to the auxiliary variable. Simulations and real-world applications reveal that the estimator outperforms traditional methods, consistently reducing the mean square error (MSE).

On a related note, other studies have explored innovative approaches to estimation and control for skewed distributions. Liu *et a*l., [28] propose the IM-c-means clustering algorithm, specifically designed to handle clusters with skewed distributions and imbalanced data. Meanwhile, Schmoch [29] recommends replacing standard mean values with adjusted mean values, especially in bibliometric contexts where the citation distribution is skewed. These adaptations lead to a more accurate assessment, aligning more closely with the Hirsch-Index concept. Moreover, researchers have investigated various confidence intervals, bootstrap methods, and control charting techniques to enhance the accuracy and reliability of estimators for positively skewed data [30-34]. The common thread among these studies is the exploration of methodologies and approaches that better suit skewed distributions and significantly improve the reliability of estimators in various applications.

The estimator's effectiveness was showcased through simulation studies utilizing the lognormal distribution as well as real data from a chromium concentration dataset sourced from an EPA toxic waste site. The findings notably highlighted the superior performance of the proposed estimator. This suggests its potential as a valuable improvement over the upper confidence limit (UCL) estimator currently utilized by the EPA to tackle the issue of underestimation. Furthermore, Rivest [35] delves into analysing the sampling characteristics of estimators used for the mean of positive random variables. Specifically, the study investigates the application of Winsorization techniques on the highest observations within the sample. The research presents approximate as well as exact formulations for MSEs, outlines the optimal Winsorization strategies tailored to different skewed distributions, and conducts effective contrasts between Winsorized samples and means. Additionally, the study introduces an almost unbiased estimator for the MSE of the Winsorized mean, thereby expanding to the toolkit of methods designed to enhance the estimation of means in skewed data scenarios. These research endeavours collectively contribute to the development of robust and accurate techniques for handling skewed distributions, benefiting a wide range of applications and fields.

Recent research has seen a surge in innovative statistical methods designed to handle skewed data distributions effectively. For instance, Meeden [36] introduced a modified 'Polya posterior' Bayesian approach utilizing the weighted Polya distribution. This enhances coverage properties for finite population sampling with skewed populations as well as small sample sizes while simultaneously bolstering hypothesis testing concerning the mean in skewed distributions. Furthermore, studies by Mahmood *et al*., [37] have employed repetitive sampling (RS) alongside CUSUM-type statistics and the Shewhart chart (RS-SEC-TCC) to swiftly detect mean shifts ranging from small to large, addressing the challenge of average run length (ARL) bias and exhibiting robustness in the face of skewed process distributions. Their proposed RS-SEC-TCC method serves as a valuable benchmark chart for quality and industrial engineers.

Additionally, Mahmood *et al*., [38] have unveiled a combined triple exponentially weighted moving average (TEWMA) chart together with a Tukey control chart (TCC), demonstrating robustness for skewed distributions and effective detection of mean shifts in both directions. These charts outperform existing alternatives, including Tukey and Shewhart charts, particularly under repetitive schemes, making them highly suitable for applications in aerospace manufacturing. Notably, Abu-Shawiesh *et al*., [39] introduced a robust modified confidence interval that adjusts the Student's t-confidence interval relying on the decile mean as well as standard deviation, facilitating accurate estimation of the population mean in skewed distributions. Finally, Abbas *et al*., [40] proposed an NP progressive mean control chart relying on the Wilcoxon signed-rank statistic (NPPM-SR), offering robust and efficient means of detecting deviations in process locations, especially in the context of heavy-tailed and skewed distributions. Comparative evaluations with existing NP charts highlighted its efficiency under zero-state conditions, positioning it as a valuable tool for process monitoring in a variety of industrial scenarios. These advancements collectively contribute to a burgeoning array of statistical methods established to enhance the robustness as well as accuracy of mean shift detection and process control, even in the presence of challenging skewed data distributions.

The reviewed methodologies collectively contribute to the development of robust and accurate techniques for handling skewed distributions, benefitting a wide range of applications and fields. This literature review provides a foundation for our systematic review, where we will further explore these methods, their efficacy, and their implications in the context of skewed data.

3. Methodology

3.1 Identification

The systematic review for this report was conducted in three main phases. The initial phase comprised several steps. First, keywords and related terms were identified by consulting various resources such as dictionaries, thesauruses, encyclopaedias, as well as past studies. Moreover, once the relevant keywords were finalized, specific search strings were formed for the WoS as well as Scopus databases, which are outlined in Table 1. This process yielded a total of 116 papers from both databases, marking the completion of the first stage of the systematic review.

Table 1
The search string

Scopus	TITLE-ABS-KEY (“mean” AND “skew* distribution” AND robust) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (PUBSTAGE, “final”)) AND (EXCLUDE (SUBJAREA, “PSYC”) OR EXCLUDE (SUBJAREA, “BUSI”) OR EXCLUDE (SUBJAREA, “ARTS”) OR EXCLUDE (SUBJAREA, “ECON”) OR EXCLUDE (SUBJAREA, “SOCI”) OR EXCLUDE (SUBJAREA, “MULT”)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”))
WOS	Results for “mean” AND “skew* distribution” AND “robust” (Topic) and Social Sciences Other Topics or Business Economics or Psychology (Exclude – Research Areas) and English (Languages) and Article (Document Types) and 2021 or 2020 or 2019 or 2017 or 2016 or 2014 (Publication Years)

3.2 Screening

In the initial screening phase, redundant papers were excluded. Moreover, the study’s first phase dismissed eight papers, while the second phase scrutinized 50 papers based on scholars’ diverse inclusion as well as exclusion criteria. The primary criterion utilized was literature, primarily research articles. This encompassed meta synthesis, systematic reviews, meta-analysis, reviews, book series, chapters, books, as well as conference proceedings that were not the most recent research. In addition, the review specifically focused on publications in English. It is crucial to emphasize that the plan targeted the past two years (2013-2023), excluding the field of social sciences. Overall, 66 publications were excluded based on specific criteria.

3.3 Eligibility

There are 42 articles produced for the eligibility phase, which is the third step. Here, the titles as well as the substantial content of every article were meticulously evaluated in ensuring that the inclusion criteria were satisfied and the papers fit within the current study and its goals. As a result, nine papers were removed as they were impure and applied science publications relying on actual data, were out of the area, or had titles that did not significantly connect to the study’s purpose. Lastly, Table 2 indicates that 33 articles are accessible for examination.

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2013 – 2023	< 2013
Literature type	Journal (Article)	Review, Book, Conference
Publication Stage	Final	In Press
Subject Area	Science and Technology	Besides Social Sciences, Psychology, Business, Accounting. Economic, Finance / Others

3.4 Data Abstraction and Analysis

This study employed an integrative analysis as a key assessment strategy to thoroughly assess as well as synthesize various research designs, including qualitative, quantitative, and mixed methods. The primary objective was to identify pertinent topics as well as subtopics. The initial phase involved collecting data to form the foundation for thematic development. As illustrated in Figure 1, following [40], the scholars systematically analysed compiled publications to extract assertions or materials pertinent to the study’s topics. Subsequently, robust statistical methods were employed in the second stage to identify and establish significant groupings. The evolution of key topics, such as robust estimation and skewed distribution detection, stemmed from the methodology employed. Subsequently, the researchers delved deeper into each established subject, exploring associated notions, themes, as well as ideas. Collaborating with other co-researchers, themes were developed based on contextual evidence within the studies. A log was meticulously maintained throughout the data analysis process, capturing analyses, puzzles, perspectives, as well as pertinent thoughts for data interpretation. Finally, the researchers conducted a comparative analysis of the results to identify any inconsistencies within the theme development process. The researchers actively address any discrepancies in concepts by engaging in discussions among themselves. The resulting themes undergo adjustments to ensure their coherence. Expert analysis, with one specialist in public health and another in medical science, validates the identified issues. This process ensures domain validity, affirming the clarity, significance, and relevance of each sub-theme. The researcher incorporates feedback and professional assessments to refine their judgments.

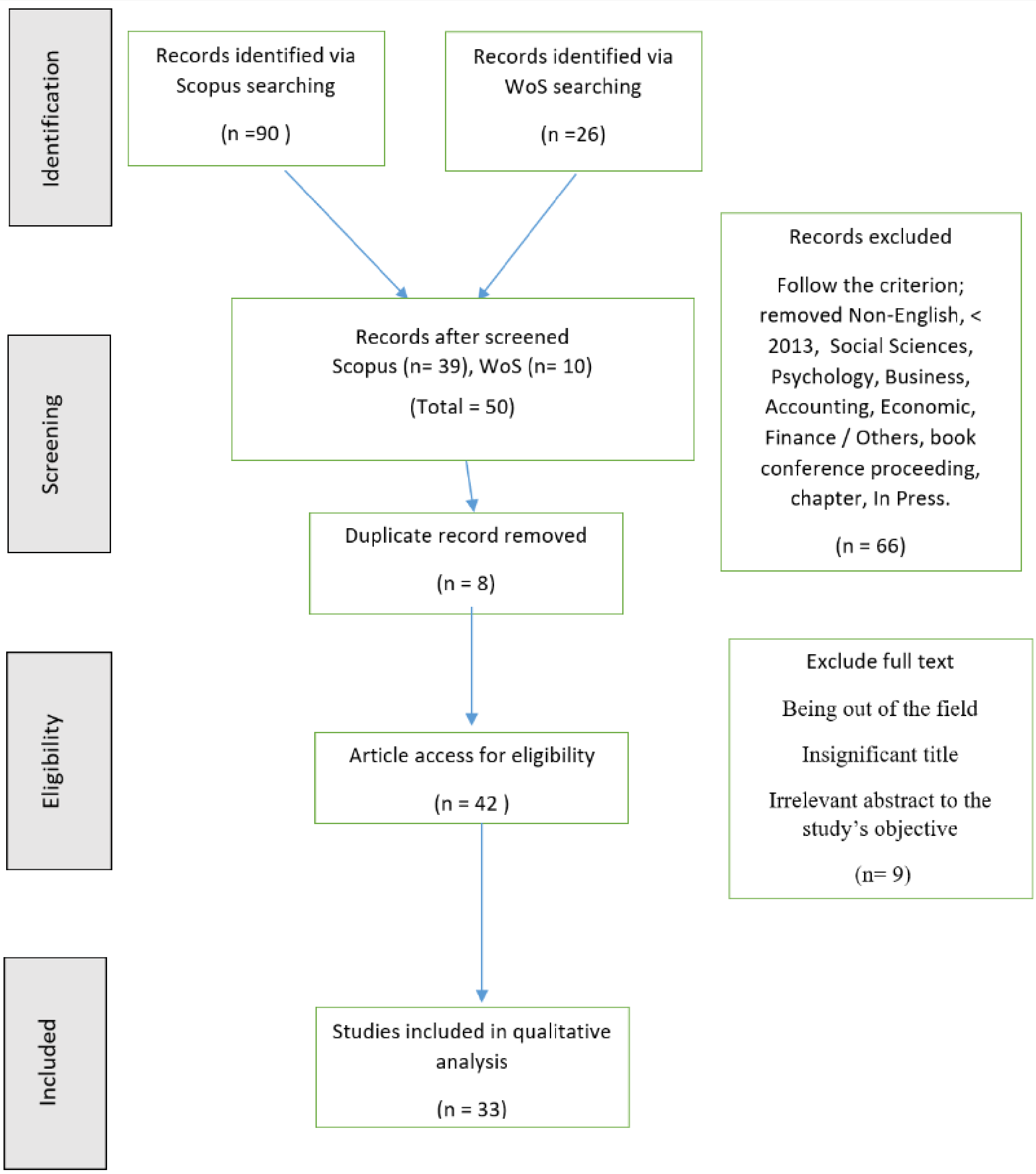

Fig. 1. Flow diagram of the suggested searching study

4. Theme

This comprehensive systematic review is dedicated to exploring three central themes, as shown in Table 3.

4.1 Theme 1: Estimation and Detection Methods for Skewed Distributions

We begin by addressing the fundamental challenges posed by skewed data. Traditional methods, such as the arithmetic mean, are often ill-suited for skewed distributions. We delve into alternative estimation techniques and detection methods designed to navigate the intricacies of skewed data, offering insights into their applicability in diverse fields.

4.2 Theme 2: Statistical Methods for Skewed Data

Next, we delve into the landscape of statistical methods tailored specifically for skewed datasets. These methods go beyond conventional approaches, seeking to improve the robustness as well as the accuracy of central tendency estimation. We evaluate the effectiveness of these statistical tools and discuss their implications in the skewed data analysis context.

4.3 Theme 3: Application of Statistical Methods in Various Fields

Skewed data distributions are pervasive, finding relevance in a multitude of fields, including environmental science, medical research, engineering, biology, and more. Misinterpreting skewed data can have far-reaching consequences, affecting risk assessments, resource allocation, and decision-making in these domains. We shed light on the real-world applications of the statistical methods discussed, emphasizing the importance of sound statistical principles in making informed decisions.

Table 3
The research article's findings based on the proposed searching criterion (*Theme 1: Estimation and Detection Methods for Skewed Distribution)*

Authors	Title	Year	Source Title	Method	Advantage and finding
Kirschstein T.; Liebscher S.; Porzio G.C.; Ragozini G. [41]	Minimum volume peeling: A robust nonparametric estimator of the multivariate mode	2016	Computational Statistics and Data Analysis	Minimum volume peeling is a reliable procedure for direct multivariate mode estimation. This method culminates in the determination of the mode by computing the mean of all points within the ultimate set.	The method's robustness is evaluated by employing finite sample breakdown point analysis as well as minimum volume set algorithms, confirming efficient mode estimates in both uncontaminated and contaminated situations.
Harris T.; Li B.; Tucker J.D. [42]	Scalable multiple changepoint detection for functional data sequences	2022	Environmetrics	The method of multiple changepoint isolation (MCI) is utilized to identify alterations in both the mean as well as covariance of a functional process.	The method demonstrates its effectiveness on large time-series water vapor mixing ratio profiles by outperforming multiple functional changepoint detectors, showcasing robustness, as well as scaling linearly with sample size.
Jayathavaj V.; Pongpullponsak A. [43]	A simulation study on the performance of the sign test, Mann-Whitney test, Hodges-Lehmann estimator and control charts for Normal and Weibull data	2014	International Journal of Industrial Engineering Computations	A proposal has been made for a new approach to create Hodges-Lehmann (HL) estimator control chart.	The study reveals that ST and MW perform well, with HL outperforming Wilcoxon signed rank statistics. The robust outlier properties are suggested by the HL estimator control chart.
Favre-Martinoz C.; Haziza D.; Beaumont J.-F. [44]	Efficient nonparametric estimation for skewed distributions	2021	Canadian Journal of Statistics	The study proposes an efficient estimator of the population mean based on unit conditional bias.	Empirical investigation shows the estimators perform well for various distributions.
Hubert M.; Gijbels I.; Vanpaemel D. [45]	Reducing the mean squared error of quantile-based estimators by smoothing	2013	Test	Enhancing the empirical distribution function by applying a suitable kernel and bandwidth to derive robust estimators for scale, location, as well as skewness.	Utilizing the smoothing method enhances the performance of the medcouple, a robust skewness measure, leading to reduced MSEs. This is particularly beneficial for detecting outliers within skewed distributions.

Mahmood Y.; Khoo M.B.C.; Teh S.Y.; Lee M.H. [37]	Robust Shewhart-CUSUM design for monitoring process means using repetitive sampling	2023	Computers and Industrial Engineering	Integrate CUSUM type statistics with the Shewhart chart, forming the RS-SEC-TCC (RS for CUSUM Type Statistics and Shewhart Chart).	The RS-SEC-TCC serves as a process monitoring tool designed to identify subtle or significant mean shifts within both symmetric as well as skewed distributions, effectively rectifying the issue of ARL bias.
Rudovic O.; Pavlovic V.; Pantic M. [46]	Context-sensitive dynamic ordinal regression for intensity estimation of facial action units	2015	IEEE Transactions on Pattern Analysis and Machine Intelligence	Modelling context-sensitive facial action unit intensity with the Conditional Ordinal Random Field (CORF).	The proposed model surpasses current methods and provides enhanced parameter estimation from imbalanced intensity data in contrast to conventional learning approaches, demonstrating superior performance.
Hossain A.; Beyene J. [47]	Application of skew-normal distribution for detecting differential expression to microRNA data	2015	Journal of Applied Statistics	Examining miRNA studies involves various stages, including the analysis of skewness in normal distribution, the formulation of a test statistic to compare means, juxtaposing it with alternative Wald-type statistics, as well as the examination of two authentic miRNA datasets.	The research reveals that utilizing SN distribution enhances the detection of variously expressed miRNAs, particularly in skewed and asymmetric data, akin to the behaviour of other Wald-type statistics.
Yusof Z.; Abdullah S.; Yahaya S.S.S. [48]	Comparing the performance of modified Ft statistic with ANOVA and Kruskal Wallis Test	2013	Applied Mathematics and Information Sciences	Ft statistics with a prominent robust scale estimator, including LMSn, Tn, as well as MADn was integrated into former Ft method.	The modified Ft statistic method improves Type I error rate control, particularly for skewed data, as demonstrated in real education data.
Webster R.; Lark R.M. [49]	Analysis of variance in soil research: Examining the assumptions	2019	European Journal of Soil Science	ANOVA to ensure reliability in soil data analysis, based on normality of residuals, homogeneity of variances, as well as additivity of treatment and block effects. Data transformation is used to meet these assumptions, with non-parametric tests considered when necessary.	The study emphasizes the significance of addressing deviations from ANOVA assumptions in soil data analysis, particularly with skewed distributions, and suggests logarithmic transformations as effective tools.

Abu-Shawiesh M.O.A.; Sinsomboonthong J.; Kibria B.M.G. [39]	A modified robust confidence interval for the population means of distribution based on deciles	2022	Statistics in Transition New Series	Student's t-confidence was modified using decile mean as well as decile standard deviation. The efficiency of estimator was assess using Monte Carlo simulation study.	The simulation results affirm the efficacy of the suggested interval estimator, advocating for its application in estimating the population mean, particularly in scenarios where data is derived from either a normal or skewed distribution.
AbuShawiesh M.O.A.; Akyüz H.E.; Migdadi H.S.A.; Golam Kibria B.M. [50]	Robust alternatives to Tukey's control chart for the monitoring of the statistical process mean	2019	International Journal for Quality Research	Median Absolute Deviation (MAD) and quantiles was introduced as estimators to replace the traditional standard deviation. It proposes alternative control charts to the TCC relying on these robust estimators.	Simulation findings demonstrate that suggested control charts are more efficient in detecting process mean than Tukey's, but their out-of-control ARL values worsen when probability distribution is non-normal.
Lim W.K.; Lim A.W. [13]	A comparison of Usual t-Test Statistics and Modified t-Test Statistics on Skewed Distribution Functions	2016	Journal of Modern Applied Statistical Methods	The t-test robustness when applied to non-normally distributed population data.	The t-test's robustness is influenced by population distribution skewness, which can compromise its ability to accurately identify differences between groups and affect confidence interval width and coverage, emphasizing the need for careful data distribution.
Qureshi M.N.; Kadilar C.; Noor Ul Amin M.; Hanif M. [51]	Rare and clustered population estimation using adaptive cluster sampling with some robust measures	2018	Journal of Statistical Computation and Simulation	Generalized ratio estimator within the framework of adaptive cluster sampling (ACS). This estimator incorporates robust measures, particularly HL, mid-range (MR), tri-mean (TM), as well as conventional measures.	The simulation study's findings reveal that the proposed estimators outperform competing estimators in accurately estimating both real as well as artificial populations.

Table 4
The research article's findings based on the proposed searching criterion *(Theme 2: Statistical Methods for Skewed Data)*

Authors	Title	Year	Source Title	Method	Advantage and finding
Amro L.; Pauly M. [52]	Permuting incomplete paired data: a novel exact and asymptotic correct randomization test	2017	Journal of Statistical Computation and Simulation	Implementing a Randomized Methodology for Addressing Missing Data.	The test procedure demonstrates asymptotic correctness and finite exactness while maintaining an invariant data distribution. Its performance with small sample sizes has been analysed through simulations and compared against current methods.
Webster R.; Lark R.M. [49]	Analysis of variance in soil research: Examining the assumptions	2019	European Journal of Soil Science	Data transformation through logarithmic or Box-Cox transformations	The study emphasizes the significance of addressing deviations from ANOVA assumptions in soil data analysis, particularly with skewed distributions, and suggests logarithmic transformations as effective tools.
Abu-Shawiesh M.O.A.; Sinsomboonthong J.; Kibria B.M.G. [39]	A modified robust confidence interval for the population means of distribution based on deciles	2022	Statistics in Transition New Series	The Robust Modified Confidence Interval is a statistically adjusted version of the student's t-confidence interval. It relies on the decile mean as well as the decile standard deviation to estimate the population mean, specifically tailored for skewed distributions.	The simulation results affirm the efficacy of the suggested interval estimator, endorsing its applicability in estimating the population mean when data is derived from either a normal or skewed distribution.
Mahmood Y.; Khoo M.B.C.; Teh S.Y.; Saha S. [38]	On designing TEWMA-Tukey control charts for normal and non-normal processes using single and repetitive sampling schemes	2022	Computers and Industrial Engineering	Triple EWMA and TCC for non-normal as well as normal data.	The proposed charts, including TEWMA-TCC, outperform Tukey and Shewhart charts in repetitive schemes, providing better steady-state findings for aerospace manufacturing surveillance and process monitoring.
Galarza C.E.; Zhang P.; Lachos V.H. [53]	Logistic Quantile Regression for Bounded Outcomes Using a Family of Heavy-Tailed Distributions	2021	Sankhya B	Develop a resilient logistic quantile regression model employing a logit link function in conjunction with an EM-based algorithm to estimate the maximum likelihood of the p^{th} quantile regression parameters.	The restructuring involves comprehensive estimation and inference for the parameters, automatic identification of the optimal model, and the generation of envelope plots. These plots serve as valuable tools for evaluating the goodness-of-fit.

Junsawang P.; Promwongsa M.; Srisodaphol W. [54]	Robust outliers' detection method for skewed distribution	2021	Thailand Statistician	A robust method for detecting outliers in skewed distributions, known as the MH boxplot, is introduced in this study. This method is an adaptation of Hubert's boxplot, incorporating the Bowley coefficient, which is the ratio of the lower split interquartile range (IQR) to the upper split IQR, into the boxplot's fences. To assess the performance of the MH boxplot, we examine its ability to detect outliers by calculating the mean percentage of outliers in three scenarios: simulated data (uncontaminated, truncated, as well as contaminated) and real data.	The MH boxplot effectively detects outliers and is robust to data skewness, demonstrating its ability to accurately represent the shape of real data.
Ahmad S.; Riaz M.; Abbasi S.A.; Lin Z. [55]	On median control charting under a double sampling scheme	2014	European Journal of Industrial Engineering	A series of Shewhart charts rely on auxiliary information following normal, t, and gamma distribution was developed. These charts are designed to determine the median type control limits.	The study evaluates the charts' performance based on run length characteristics, examines the impact of contaminated environments and provides examples to explain their workings.
Abbas Z.; Nazir H.Z.; Akhtar N.; Abid M.; Riaz M. [40]	Non-parametric progressive signed-rank control chart for monitoring the process location	2022	Journal of Statistical Computation and Simulation	NPPM-SR.	The study presents the findings of the performance evaluation and comparative analysis, highlighting the efficiency of the suggested NPPM-SR chart, particularly in the zero-state scenario, when contrasted to steady-state as well as existing control charts.
Oh, S; Heo, K; Jufri, FH; Choi, M; Jung, J [56]	Storm-Induced Power Grid Damage Forecasting Method for Solving Low Probability Event Data	2021	IEEE ACCESS	Method for forecasting power grid damage caused by storm events using machine learning. It uses G-mean values to identify key explanatory variables and combines weighted ELM and LSTM.	The superiority of the proposed method lies in its enhanced robustness as well as accuracy compared to the conventional forecasting method.

Mehmood R.; Lee M.H.; Iqbal M.R.; Hassan S. [57]	New robust location control charts for unknown process distribution with practical significance	2022	Soft Computing	Location control charts used to monitor the process characteristics with unknown probability distribution based on skewness correction. These charts encompass median, mean, as well as HL methods.	The study reveals control charts effectively maintain false alarm rates, with median and HL being optimal for leptokurtic distributions, while IQR as well as Gini mean difference play crucial roles.
Qureshi M.N.; Kadilar C.; Noor Ul Amin M.; Hanif M. [51]	Rare and clustered population estimation using adaptive cluster sampling with some robust measures	2018	Journal of Statistical Computation and Simulation	The proposal introduces a Generalized Ratio Estimator within the ACS design, utilizing robust measures in conjunction with a single auxiliary variable. This approach integrates robust measures such as MR, TM, as well as HL of the auxiliary variable alongside traditional measures.	The simulation study's findings indicate that the proposed estimators outperform the competing estimators in estimating both real as well as artificial populations.
Galarza Morales C.; Lachos Davila V.; Barbosa Cabral C.; Castro Cepero L. [58]	Robust quantile regression using a generalized class of skewed distributions	2017	Stat	A likelihood-based approach for estimating regression quantiles uses a new family of skewed distributions, which include Student-t, normal, contaminated normal, Laplace, as well as slash distributions, with zero quantile property and novel stochastic representation.	The R package IQR has integrated the algorithm, offering comprehensive parameter estimation, inference, as well as simulation envelope plots that are valuable for evaluating the goodness of fit.
Subzar M.; Al-Omari A.I.; Alanzi A.A.A. [59]	The robust regression methods for estimating of finite population mean based on SRSWOR in case of outliers	2020	Computers, Materials and Continua	Utilizing simple random sampling without replacement (SRSWOR), new estimators for the finite population mean ratios are recommended. These estimators leverage supplementary information from Bowley's coefficient of skewness in conjunction with quartiles. To estimate the population parameters, various methods, including Huber-M, OLS, Schweppe GM-estimate, Mallows GM-estimate, as well as SIS GM-estimate, are employed for the proposed estimators.	The MSE equations of different estimators are derived and juxtaposed against the OLS method. The findings are validated through simulations using skewed distributions like the Gamma distribution. Furthermore, an illustrative application using a real dataset containing outliers is explored to support these results.

Arachchige C.N.P.G.; Prendergast L.A.; Staudte R.G. [12]	Robust analogues to the coefficient of variation	2022	Journal of Applied Statistics	Explored were quantile-based measures of relative dispersion, considered as alternatives to the CV. Specifically, focus was placed on the robust estimators of relative dispersion, such as the IQR divided by the median and the MAD divided by the median.	Estimators' influence functions, asymptotic biases, and variances are compared by employing simulation studies to evaluate coverage.

Table 5
The research article's findings based on the proposed searching criterion *(Theme 3: Application of Statistical Methods in Various Fields)*

Authors	Title	Year	Source Title	Method	Advantage and finding
Amro L.; Pauly M. [52]	Permuting incomplete paired data: a novel exact and asymptotic correct randomization test	2017	Journal of Statistical Computation and Simulation	Implementing a randomization strategy for managing missing data.	The test procedure is asymptotically correct and finitely exact, with invariant data distribution. The performance of its small sample is examined through simulation and then contrasted with established methods.
Prietzel J.; Christophel D. [60]	Organic carbon stocks in forest soils of the German Alps	2014	Geoderma	Gaussian simulation	The study reveals a skewed distribution of Soil Organic Carbon (SOC) stocks in German Alps forest soils, with higher-elevation sites having larger SOC stocks, indicating climate change sensitivity and potential SOC losses.
Anagnostou E.; Dimopoulou P.; Sklavos S.; Zouvelou V.; Zambelis T. [61]	Identifying jitter outliers in single fibre electromyography: Comparison of four methods	2021	Muscle and Nerve	The 18th Jitter Value (18thJV) method was compared to three outlier detection methods for the whole distribution: the log-normal method, the IQR method, as well as the Z-score method.	The 18th JV method demonstrates superior robustness in comparison to whole-distribution-based methods, justifying its application in clinical practice. In a clinical setting where the ultimate electrodiagnosis relies on outlier count, a meaningful tolerance zone of approximately 2 µs is pertinent, aligning closely with the variance observed across various methods.

Arachchige C.N.P.G.; Prendergast L.A.; Staudte R.G. [12]	Robust analogues to the coefficient of variation	2022	Journal of Applied Statistics	Investigated alternative measures of relative dispersion by exploring quantile-based methods, such as the division of the IQR and the median, as well as the MAD divided by the median. These approaches serve as robust estimators of relative dispersion, offering alternatives to the CV.	Through simulation studies, we aim to evaluate the coverage of interval estimators by comparing the influence functions, asymptotic biases, as well as variances of competing estimators.
Oh, S; Heo, K; Jufri, FH; Choi, M; Jung, J [56]	Storm-Induced Power Grid Damage Forecasting Method for Solving Low Probability Event Data	2021	IEEE ACCESS	Developing a storm event responsive power grid damage forecasting method using machine learning. It uses G-mean values to identify key explanatory variables and combines weighted ELM and LSTM. The method's efficacy is verified utilizing actual storm event data.	The demonstrated findings highlight the superior robustness and accuracy of the suggested method compared to the conventional forecasting approach.

5. Discussion and Conclusion

In conclusion, this comprehensive systematic review illuminates three interconnected themes that together highlight the robustness and versatility of statistical methods. Theme 1 addresses estimation and detection methods for skewed distributions, revealing the effectiveness of various techniques in confronting challenges presented by non-normal data. Theme 2 focuses on statistical methods for skewed data, illustrating the development and application of innovative approaches that enhance the accuracy and reliability of estimators in different domains. Finally, Theme 3 explores the application of statistical methods in various fields, showcasing how these methods find utility in addressing real-world challenges and advancing domains such as climate science, clinical practice, and industrial monitoring.

The first theme underscores the importance of addressing skewness in data, highlighting the successful assessment of robust statistical methods capable of providing efficient mode estimates even in the presence of contamination. Furthermore, the findings show that these methods surpass traditional changepoint detectors and provide robust and scalable solutions for time series data analysis, such as water vapor mixing ratio profiles. The study also emphasizes the significance of the HL estimator control chart in addressing outlier properties.

Theme 2 delves into the development of statistical methods specifically tailored for skewed data. It demonstrates the feasibility of utilizing various estimation techniques and interval estimators that outperform existing alternatives, especially in the context of skewed distributions. The proposed models and innovative approaches, such as the SN distribution and modified Ft statistic, provide valuable tools for addressing challenges posed by skewed data and offer significant advantages in both theoretical and practical settings.

Lastly, Theme 3 presents the real-world applications of these statistical methods in various fields. The study showcases their utility in fields as diverse as climate science, clinical practice, and industrial monitoring, where they improve the accuracy of intensity estimation, differential expression identification, and process monitoring. The results demonstrate the robustness and accuracy of the methods, positioning them as valuable tools in addressing the complex issues encountered in practical applications.

In conclusion, this systematic review underscores the versatility and robustness of statistical methods, emphasizing their significance in addressing skewed distributions and enhancing the accuracy and reliability of estimators across diverse fields. The findings highlight the practical utility of these methods in real-world scenarios and signify their potential to contribute significantly to advancements in climate science, clinical practice, and industrial monitoring.

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