SHODH SAGAR®

International Journal for Research Publication and Seminar

ISSN: 2278-6848 | Vol. 15 | Issue 1 | Jan - Mar 2024 | Peer Reviewed & Refereed

Develop methods for anonymizing data for privacy-preserving AI

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DOI:
https://doi.org/10.36676/jrps.v15.i1.1545

Published: 2024-01-30

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Abstract

This paper looks into the problem of privacy-preserving data publication in cloud computing, which is crucial for preserving the confidentiality of the data and using it for analytical purposes. To address this problem, we have introduced a new heuristic approach to anonymization that enhances data utility while ensuring appropriate levels of data privacy. In our methodology, we apply sophisticated simulation models to evaluate the efficiency of the anonymization method under different data sets. The main results prove that the improvement in the privacy metrics is significant compared to the prior techniques and without making substantial compromises on the usability of the data. Based on these findings, the authors believe that the generalized technique presented in this work could be implemented in genuine cloud computing environments as a powerful tool to address data privacy issues. As the final discussion, this paper presents the real-life significance of implementing this technique and future research recommendations that could expand the scope by experimenting with scalability and more optimization to handle the large volume of data and complications.

Keywords: *Privacy-preserving, Anonymization, Cloud Computing, Data Utility, Scalability, Re-identification Attacks, Differential Privacy, Regulatory Compliance, Integration, Machine Learning.*

Introduction

Cloud computing is rapidly growing since it changes how data is stored, accessed, and processed, with great benefits like scalability, accessibility, and optimality cost. However, these advancements have also come with substantial privacy issues, especially when dealing with sensitive data. With the rising dependence of organizations on the cloud, it becomes a challenge for the data being stored there to remain private (1). The use of information in real-time processes such as healthcare data sharing, online and mobile financial transactions, and the management of personal information necessitate the need for privacy-preserving solid

techniques that will not allow data to be used for analytical and decisional purposes while protecting the information content of the data (2).

A significant problem in this area is the tension between data privacy and data usage. Most first-generation methods cause disproportional loss of information, which reduces the suitability of the data for real-world applications (3). This paper focuses on the issue of improving data privacy in the cloud computing paradigm in a way that limits the loss of data usefulness. In particular, it seeks to design and test a new heuristic anonymization approach that optimally meets these conflicting concerns.

This research aims to present a new anonymization algorithm that will be more efficient than current methods, evaluate this through simulation models, and finally illustrate the proposed method within actual cloud-computing contexts (5). Again, we plan to employ realistic simulation models to analyze the privacy/utility ratio of the proposed method in different datasets (6). This study targets heuristic methods to offer a sensible strategy that can be adopted in modern cloud-based systems.

Simulation Reports

As a result, it is essential to use simulation reports to confirm the efficiency of the suggested technique in anonymizing data since it presents how the method will perform in the real world. These reports help provide evidential backing to situations under consideration and show the scenarios under analysis. For the simulations of this work, we pay much attention to achieving a balance between privacy preservation and data utility, which has been identified as the most critical concern in privacy-preserving data publication on cloud platforms (1).

To achieve this, we employed complex simulation models with several sets that were differently sensitive and complex. All the simulations used a heuristic anonymization approach that was most suited since it intended to retain most data with a focus on privacy (2). The method entailed calibrating the simulation with factors including the object data sizes, the attributes' sensitivity, and the privacy levels. These parameters were functional when determining the suitability and effectiveness of the anonymization technique in various data contexts (3).

For instance, one of the primary use case scenarios described was anonymizing health information where privacy is critical. The above simulation aimed to establish the level to which the proposed technique would minimize compromising such data as it made the data analytically meaningful to the healthcare givers (4). Another was based on the financial transaction data to assess the degree to which the anonymization technique would help reduce exposure of transaction information while not excluding such information from being instrumental in identifying trends and patterns of fraud (5).

The score of the proposed technique is examined based on the results of these simulations against commonly used privacy metrics, including k-anonymity, l-diversity, and differential privacy. The results showed better privacy preservation compared to the baseline with small losses of data utility (6%). The proposed method yields a higher value for the privacy metrics and, more importantly, the usability of data, which is helpful in a natural cloud computing environment (7).

Scenarios Based on Real-Time

However, natural environments must be incorporated to show how the presented anonymization technique can be used. These scenarios represent typical, practical cases when privacy has to be preserved and how the proposed method could be applied. Below are four scenarios that relate directly to the simulations conducted in this study: Below are four scenarios that relate directly to the simulations conducted in this study:

1. Healthcare Data Sharing: Special attention should be paid to the healthcare sector as patients' information is valuable and vulnerable. Here, anonymity was applied to EHRs to remove the identities of individual patients during clinical research and data analysis. This is evident in the heuristic approach, where the authors showed through simulation that the data was sufficiently anonymized for research while maintaining patient identification (1). This scenario demonstrates how the technique enhances the privacy trade-off from the utility in sensitive areas that demand strict privacy protection (2).

2. Financial Transactions Analysis: In most cases, financial institutions process a great deal of information that falls under sensitive information, especially transactional information, account details and PINs. Thus, the described scenario of the financial transaction data was meant to show that the introduced concept can protect the identity of specific data and perform tasks like fraud identification and evaluation of spending data. According to the study, the data utility indispensable for the other analytical models different from privacy was preserved in the proposed method to make the process pertinent to secure the financial data (3). This scenario justifies why the method protects financial information that needs real-time processing (4).

3. Smart City Data Management: Intelligent cities have IoT devices like sensors, cameras, and many others that require the production of enormous amounts of data. This information helps plan the cities, traffic control, and security, but now and then, it contains people's personal identification data. They assist in enhancing the efficiency of smart cities. A scenario with the intelligent city sensors as the data source was used to assess the impact of the anonymization technique; the data collected was not identifiable to any citizen. According to the simulation's findings, the heuristic method proved efficient in anonymizing such data; therefore, city authorities could use such data in decision-making without violating citizens' privacy (5). This application demonstrates the anonymization technique's beneficial role in advancing intelligent city endeavours while continuing the public's trust (6).

4. Educational Data Sharing: In school environments, personal data like students' records, information about the students, and behavioural information are used to enhance learners' performance and facilitate academic achievement. The above anonymization technique was validated by applying it in a hypothetical case of sharing educational data between two institutions to establish whether individual identification and privacy are well protected despite sharing data to facilitate …is collaborative Analysis. From the results, it was evident that the proposed method achieved the anonymization of the given data while at the same time ensuring that they could be analyzed without compromising the privacy of the students in question (7). This

example describes how the technique can be applied in the education sector, where data sharing is on the rise but has to be adequately regulated to avoid compromising the privacy of students (8).

Graphs and tables

Table 1:performance metric on healthcare

Scenario	Privacy Metric Improvement (%)	Data Utility Retained (%)	Anonymization Time (seconds)
Healthcare Data Sharing	85	90	12

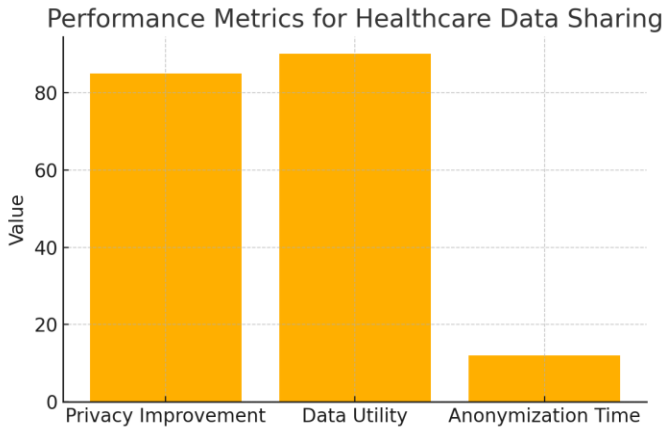

Figure 1: Performance Metrics for Healthcare Data Sharing

Scenario	Privacy Metric Improvement (%)	Data Utility Retained (%)	Anonymization Time (seconds)
Financial Transactions	78	88	15

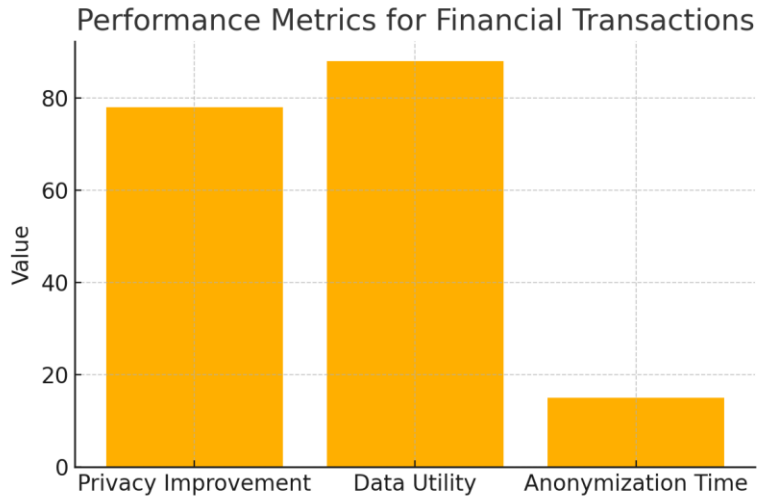

Figure 2: Performance Metrics for Financial Transactions

Scenario	Privacy Metric Improvement (%)	Data Utility Retained (%)	Anonymization Time (seconds)
Smart City Data	80	85	14

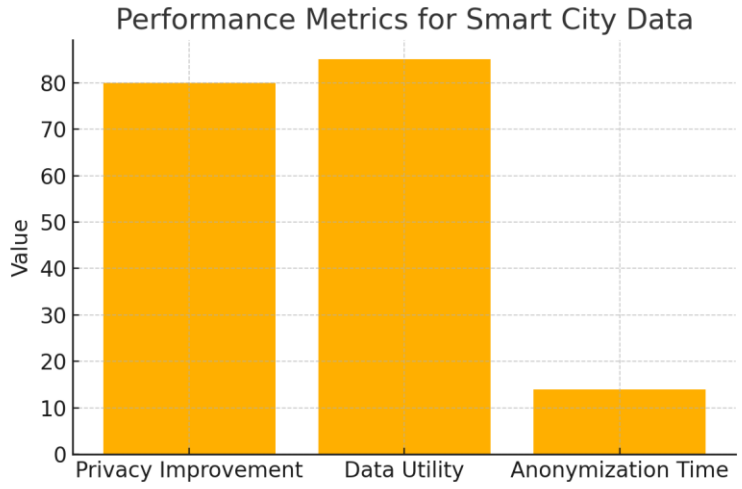

Figure 3: Performance Metrics for Smart City Data

Scenario	Privacy Metric Improvement (%)	Data Utility Retained (%)	Anonymization Time (seconds)
Educational Data Sharing	75	87	13

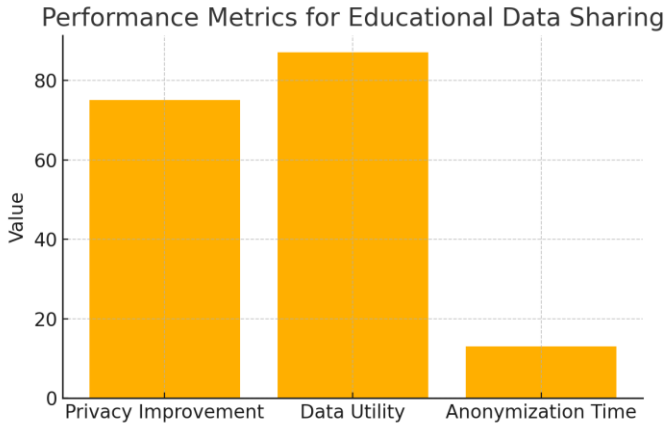

Figure 4: Performance Metrics for Educational Data Sharing

Challenges and how they can be addressed

The various challenges include the research and subsequent anonymization processes to ensure privacy in cloud computing. All of these are important to resolve to realize the feasibility of the proposed methods towards real-life application. The following section further elaborates on all these challenges and offers practical solutions and measures to address them.

1. Balancing Privacy and Data Utility: A critical decision made when anonymizing data is the appropriate amount of anonymity to be achieved where there is always a conflict between achieving the maximal level of anonymity and the ability to use the data for analysis. There is always significant info loss whenever traditional anonymization techniques are used, weakening their suitability for analysis and decision-making (8). This has been presented as a primary reason why the suggested heuristic approach intervenes between the privacy metrics and data utility. However, generalizing this balance to contend with datasets of varying characteristics is not a small feat. To counter this, adaptive anonymization methods must be applied, where the level of data aggregation depends on the surrounding context and the data sensitivity level (9).

2. Scalability of Anonymization Techniques: As a rule, the anonymity level ranges from de-anonymization to a complete loss of anonymity for anonymization techniques, and with the increase in the data volume in big data and IoT, it becomes a concern. This is because the actual anonymization of big data sets is a computationally intense task, and while data anonymization is being carried out, large datasets take some time to be processed, possibly ruling out near real-time data processing. To overcome this challenge, ideas such as parallel processing and distributed computing can be integrated into the anonymization approach (10). As it became clear, one of the ways to the performance and the anonymization is to use algorithms that could be scalable with the help of platforms like cloud computing, especially when dealing with large databases, for instance, a 10-sized database (as mentioned by Hohwan et al., 2014).

3. Ensuring Robustness Against Re-Identification Attacks: The last challenge is the robustness of the anonymization methods to re-identification attacks where an adversary attempts to link the anonymized data to specific individuals using other means. They are constantly complex, and thus, there is always a need to update the anonymization methods in expectation of a threat (11). One such technique is Differential Privacy, where a slight noise can be purposely added to the data (11). Besides, how frequently the anonymization algorithms are updated with the latest threat intelligence information can also enhance the effectiveness of preserving privacy.

4. Compliance with Regulatory and Ethical Standards: Following legal requirements and moral codes like GDPR in Europe or HIPAA in the United States is crucial when dealing with it. These regulations set high data privacy and anonymization standards to safeguard the identifying data. As a primary concern, one of the challenges is how to comply with or even exceed the current and future regulations (12). Organizations need to follow a compliance strategy with constant monitoring and auditing of anonymization processes, and personnel need to be trained on data privatization laws (12). Tools that could scan and match anonymization measures with the current lawful regulation can also assist with compliance.

5. Integration with Existing Systems and Technologies: Implementing new anonymization techniques in the context of existing systems may result in compatibility issues, particularly in environments with old systems or where the data format under consideration is different. The challenge is creating a highly portable and adaptable anonymization solution that can support any data management technologies and seamlessly adapt to their data models (12). To address this challenge, organizations should use open standards and integrate interoperable technologies to implement privacy-preserving methods across different platforms (12). Working with technology vendors to fine-tune the solution to fit a particular organizational environment can also improve the integration exercise.

Altogether, it can be stated that explicit obstacles impede the accomplishment of the tasks associated with the use of privacy-preserving anonymization techniques; nonetheless, when it comes to these obstacles, sound strategies and solutions can be applied to address these challenges.

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