

Qrlew: automatic differential privacy for SQL queries

Anonymous submission

Abstract

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Last year papers: <https://aaai-ppai23.github.io/#sp2> This year program: <https://ppai-workshop.github.io/>

Comparable open-source projects

- Paszke et al. 2017 - Automatic differentiation in PyTorch <https://openreview.net/pdf?id=BJJsrmfCZ>
- Frostig et al. 2018 - Compiling machine learning programs via high-level tracing <https://mlsys.org/Conferences/2019/doc/2018/146.pdf>

Comparable DP SQL papers

- Lessons Learned: Surveying the Practicality of Differential Privacy in the Industry (Garrido et al. 2022)
- Tumult Analytics: a robust, easy-to-use, scalable, and expressive framework for differential privacy (Berghel et al. 2022)
- Differentially Private SQL with Bounded User Contribution (Wilson et al. 2019)
- CHORUS: a Programming Framework for Building Scalable Differential Privacy Mechanisms (Johnson et al. 2020)
- Towards Practical Differential Privacy for SQL Queries (Johnson, Near, and Song 2018)

Introduction

In recent years, the importance of safeguarding privacy when dealing with personal data has continuously increased. Traditional anonymization techniques have proven vulnerable to re-identification, as demonstrated by numerous works (Archie et al. 2018; Dwork et al. 2017; Narayanan and Shmatikov 2008; Sweeney, Abu, and Winn 2013). The total cost of data breaches has also significantly increased (IBM

2023). And governments have introduced stricter data protection laws. Yet, the collection, sharing, and utilization of data hold the potential to generate significant value across various industries, including healthcare, finance, transportation, and energy distribution.

To realize these benefits while managing privacy risks, researchers have turned to *differential privacy (DP)* (Wood et al. 2018; Dwork, Roth et al. 2014), which has become the gold standard in academia since its introduction by Dwork et al. in 2006 (Dwork et al. 2006) due to its provable and automatic privacy guarantees.

Despite the availability of open-source tools, DP adoption remains limited. One of the reasons for this lack of adoption is the relative complexity of the existing tools considered the utility of the results. *Qrlew* has been designed to solve this problem, by providing the following features:

Leverages existing infrastructure *Qrlew* rewrites a SQL query into a *differentially private* equivalent.

Is fully automated *Qrlew* can rewrite a large class of queries into *differentially private* ones.

Leverages synthetic data using jointly *differentially private* mechanisms and *differentially private* Synthetic Data

This In summary, our main contributions are as follows:

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```
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```

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Tables should be presented in 10 point roman type. If necessary, they may be altered to 9 point type. You may not use any commands that further reduce point size below nine points. Tables that do not fit in a single column must be placed across double columns. If your table won't fit within the margins even when spanning both columns, you must split it. Do not use minipage to group tables.

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Algorithm 1: Example algorithm

Input: Your algorithm's input

Parameter: Optional list of parameters

Output: Your algorithm's output

```

1: Let  $t = 0$ .
2: while condition do
3:   Do some action.
4:   if conditional then
5:     Perform task A.
6:   else
7:     Perform task B.
8:   end if
9: end while
10: return solution

```

tinguishing colors. Your paper must be decipherable without using color for distinction.

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Algorithms. Algorithms and/or programs are a special kind of figures. Like all illustrations, they should appear floated to the top (preferably) or bottom of the page. However, their caption should appear in the header, left-justified and enclosed between horizontal lines, as shown in Algorithm 1. The algorithm body should be terminated with another horizontal line. It is up to the authors to decide whether to show line numbers or not, how to format comments, etc.

In L^AT_EX algorithms may be typeset using the `algorithm` and `algorithmic` packages, but you can also use one of the many other packages for the task.

Listings. Listings are much like algorithms and programs. They should also appear floated to the top (preferably) or

Listing 1: Example listing quicksort.hs

```
1 quicksort :: Ord a => [a] -> [a]
2 quicksort [] = []
3 quicksort (p:xs) = (quicksort lesser) ++
  [p] ++ (quicksort greater)
4 where
5   lesser = filter (< p) xs
6   greater = filter (>= p) xs
```

bottom of the page. Listing captions should appear in the header, left-justified and enclosed between horizontal lines as shown in Listing 1. Terminate the body with another horizontal line and avoid any background color. Line numbers, if included, must appear within the text column.

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```
\bibliography{bibfile1,bibfile2,...}
```

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```
\fontsize{9.8pt}{10.8pt} \selectfont
```

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The following commands are available for your use in citing references:

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`\shortcite`: Cites the given reference(s) with just the year. This appears as “(Year)” for one reference, or “(Year; Year)” for multiple references.

`\citeauthor`: Cites the given reference(s) with just the author name(s) and no parentheses.

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L^AT_EX is a difficult program to master. If you’ve used that software, and this document didn’t help or some items were not explained clearly, we recommend you read Michael Shell’s excellent document (testflow doc.txt V1.0a 2002/08/13) about obtaining correct PS/PDF output on L^AT_EX systems. (It was written for another purpose, but it has

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Reference Examples

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Acknowledgments

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The preparation of the L^AT_EX and BibTeX files that implement these instructions was supported by Schlumberger Palo Alto Research, AT&T Bell Laboratories, Morgan Kaufmann Publishers, The Live Oak Press, LLC, and AAAI Press. Bibliography style changes were added by Sunil Issar. \pubnote was added by J. Scott Penberthy. George Ferguson added support for printing the AAAI copyright slug. Additional changes to `aaai24.sty` and `aaai24.bst` have been made by Francisco Cruz and Marc Pujol-Gonzalez.

Thank you for reading these instructions carefully. We look forward to receiving your electronic files!

References

Archie, M.; Gershon, S.; Katcoff, A.; and Zeng, A. 2018. Who’s watching? de-anonymization of netflix reviews using amazon reviews.

Berghel, S.; Bohannon, P.; Desfontaines, D.; Estes, C.; Haney, S.; Hartman, L.; Hay, M.; Machanavajjhala, A.; Magerlein, T.; Miklau, G.; et al. 2022. Tumult Analytics: a robust, easy-to-use, scalable, and expressive framework for differential privacy. *arXiv preprint arXiv:2212.04133*.

Dwork, C.; McSherry, F.; Nissim, K.; and Smith, A. 2006. Calibrating noise to sensitivity in private data analysis. In *Theory of Cryptography: Third Theory of Cryptography Conference, TCC 2006, New York, NY, USA, March 4-7, 2006. Proceedings 3*, 265–284. Springer.

Dwork, C.; Roth, A.; et al. 2014. The algorithmic foundations of differential privacy. *Foundations and Trends® in Theoretical Computer Science*, 9(3–4): 211–407.

Dwork, C.; Smith, A.; Steinke, T.; and Ullman, J. 2017. Exposed! a survey of attacks on private data. *Annual Review of Statistics and Its Application*, 4: 61–84.

Garrido, G. M.; Liu, X.; Matthes, F.; and Song, D. 2022. Lessons learned: Surveying the practicality of differential privacy in the industry. *arXiv preprint arXiv:2211.03898*.

IBM. 2023. Cost of a Data Breach Report 2023.

Johnson, N.; Near, J. P.; Hellerstein, J. M.; and Song, D. 2020. Chorus: a programming framework for building scalable differential privacy mechanisms. In *2020 IEEE European Symposium on Security and Privacy (EuroS&P)*, 535–551. IEEE.

Johnson, N.; Near, J. P.; and Song, D. 2018. Towards Practical Differential Privacy for SQL Queries. *Proc. VLDB Endow.*, 11(5): 526–539.

Narayanan, A.; and Shmatikov, V. 2008. Robust de-anonymization of large sparse datasets. In *2008 IEEE Symposium on Security and Privacy (sp 2008)*, 111–125. IEEE.

Sweeney, L.; Abu, A.; and Winn, J. 2013. Identifying participants in the personal genome project by name (a re-identification experiment). *arXiv preprint arXiv:1304.7605*.

Wilson, R. J.; Zhang, C. Y.; Lam, W.; Desfontaines, D.; Simmons-Marengo, D.; and Gipson, B. 2019. Differentially private SQL with bounded user contribution. *arXiv preprint arXiv:1909.01917*.

Wood, A.; Altman, M.; Bembenek, A.; Bun, M.; Gaboardi, M.; Honaker, J.; Nissim, K.; O’Brien, D. R.; Steinke, T.; and Vadhan, S. 2018. Differential privacy: A primer for a non-technical audience. *Vand. J. Ent. & Tech. L.*, 21: 209.