"2nd" Year PhD Seminar Presentation

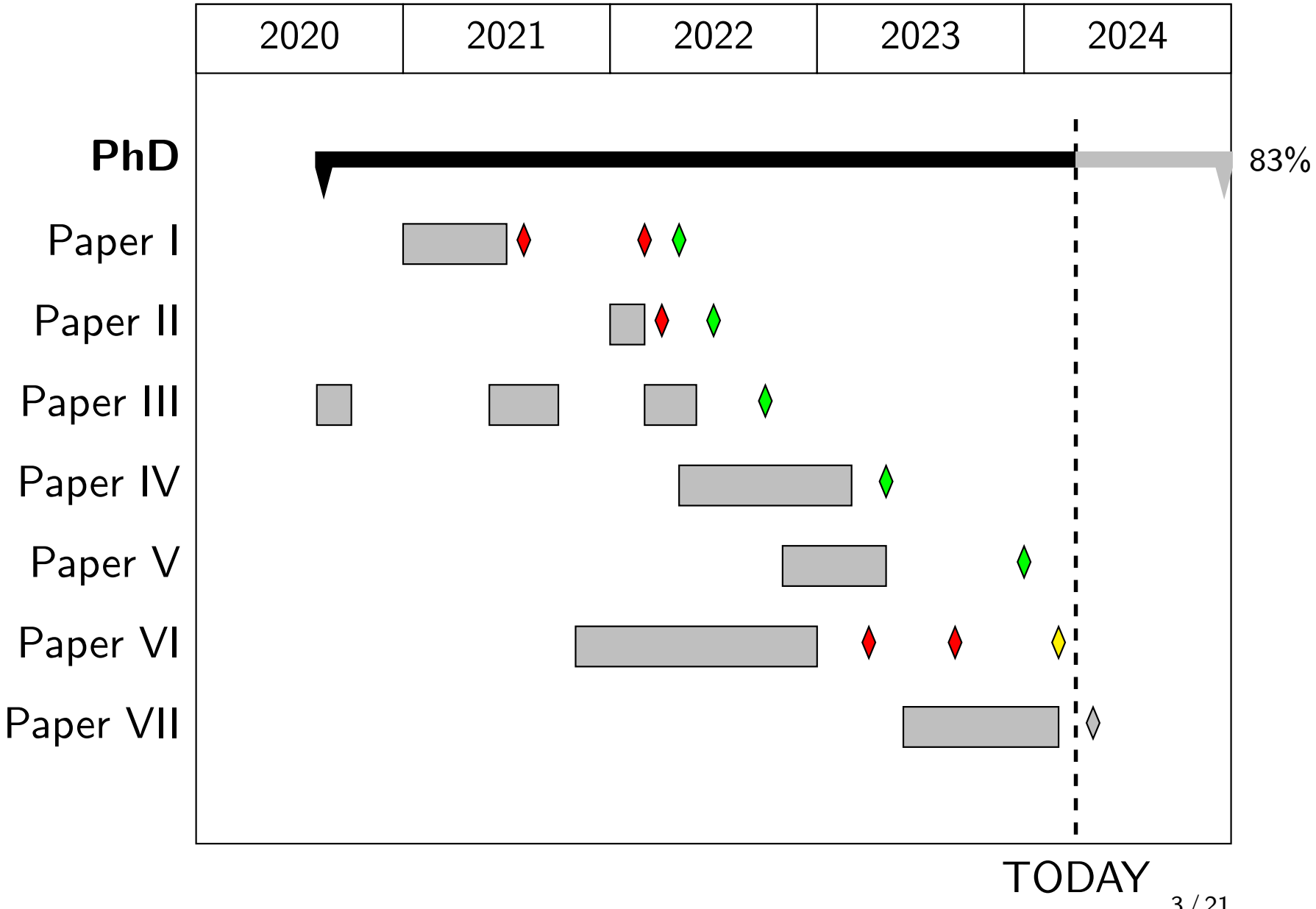
Ananth Mahadevan

February 29, 2024

Quick Recap

- **Masters:** Aalto University
- **Started:** Aug 2020 (contract) and Jan 2021 (study right)
- **Supervisor:** Michael Mathioudakis
- **Research Group:** Algorithmic Data Science (ADS)

PhD Progress



Papers

Number	One Word Title	Venue	Include in Thesis?
I	Unlearning	MAKE 2022	✅
II	JANE	Entropy 2022	✅
III	Sketching	CIKM 2022	🤷
IV	ReceptionReader	JOHD 2023	🤷
V	Mandeville	DES 2023	🤷
VI	Retraining	KBS 2024	✅
VII	TextReuse	VLDB 2024	✅

Research Projects

Multiple Projects:

1. Maintaining ML models
   - Paper I: Unlearning
   - Paper VI: Retraining
2. Analyzing Historical Documents
   - Paper IV: ReceptionReader
   - Paper V: Mandeville
   - Paper VII: TextReuse
3. Scaling and Evaluating Algorithms
   - Paper II: JANE
   - Paper III: Sketching
   - Paper VIII ?: Diverse Sampling

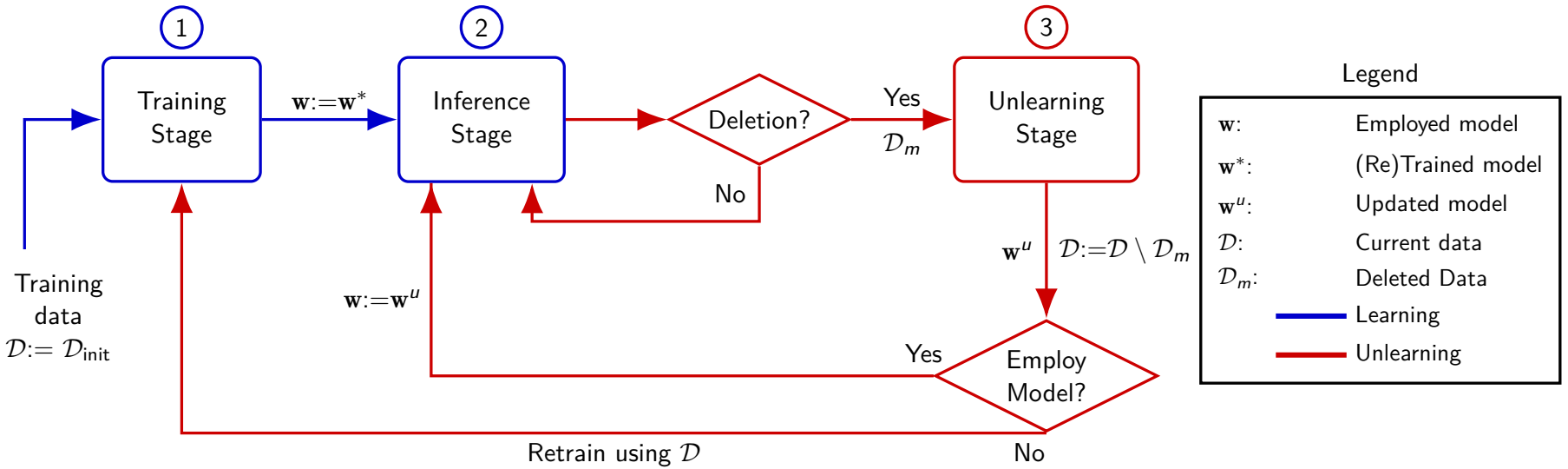
Maintaining ML models

Research Question

How to update a trained ML model when the data changes?

1. Machine Unlearning
   - Training data is deleted/removed
   - Update model parameters to forget information
   - Mahadevan and Mathioudakis [2022]
2. Cost-Aware Retraining
   - Streams drift over time
   - Data and Queries are present
   - Retraining consumes resources
   - When is it worth retraining?
   - Mahadevan and Mathioudakis [2023]

Machine Unlearning



Unlearning

Task of updating a ML model after partial deletion of training data

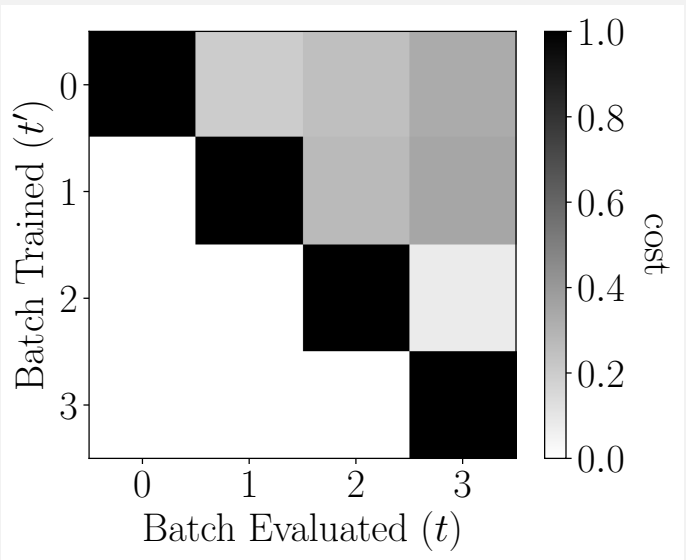
Qualities of an approximate unlearning method:

- **Certifiability**: How similar are $\mathbf{w}^u$ and $\mathbf{w}^*$?
- **Effectiveness**: How well does $\mathbf{w}^u$ perform?
- **Efficiency**: How much time to produce $\mathbf{w}^u$?

Cost-Aware Retraining Algorithms

Cost Matrix

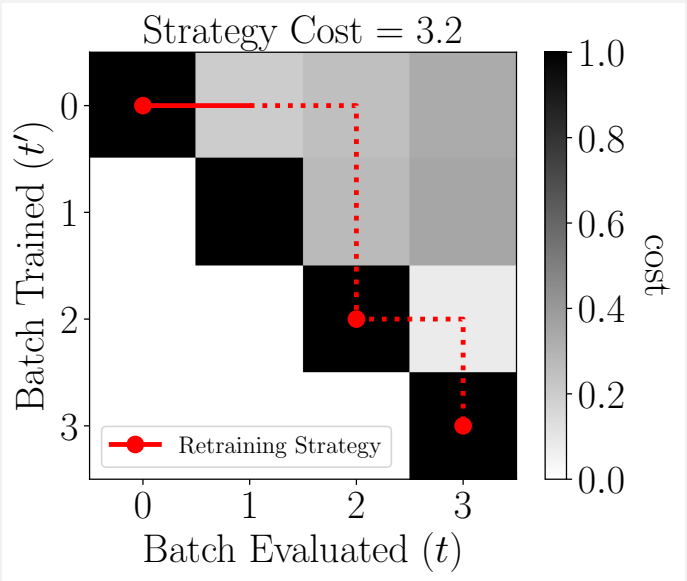
$$C[t', t] = \begin{cases} \text{Staleness Cost} & \text{if } t' < t \\ \text{Retraining Cost} & \text{if } t' = t \\ \infty & \text{otherwise} \end{cases}$$



Strategy

- Strategy is a set of decisions
- Cost of decisions is strategy cost
- Aim is to minimize strategy cost

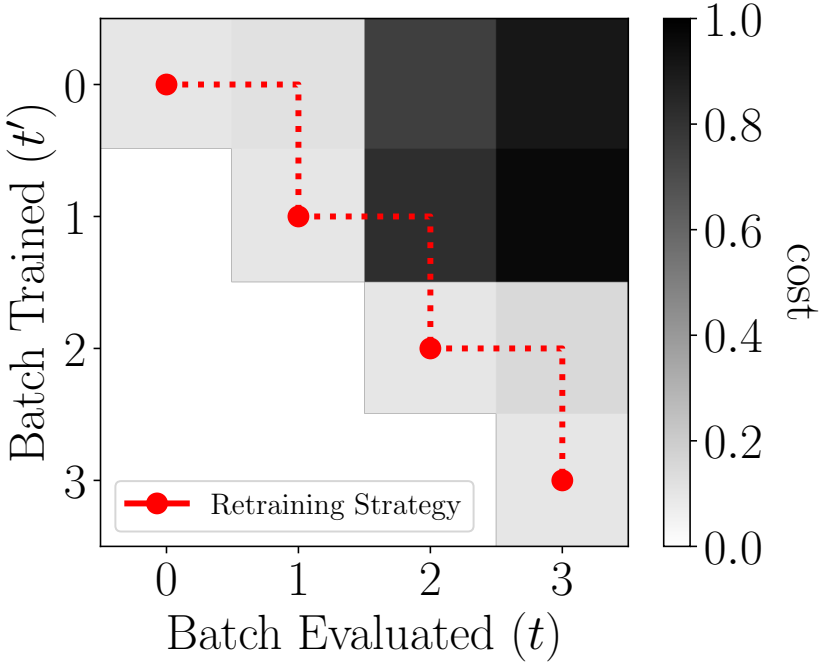
$S = \{\texttt{Keep}, \texttt{Keep}, \texttt{Retrain}, \texttt{Retrain}\}$



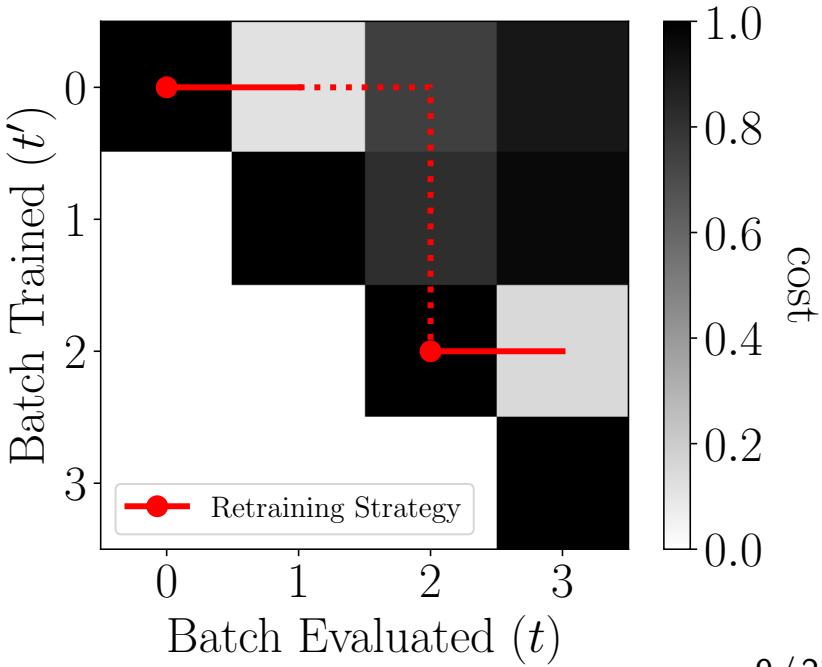
Retraining Cost κ

- Trade-off parameter between resources & performance
- Low κ
  - Performance is important
  - Frequent `Retrain` decisions to minimize staleness cost
- High κ
  - Resources are important
  - `Retrain` decisions when large enough drops in performance

Low κ

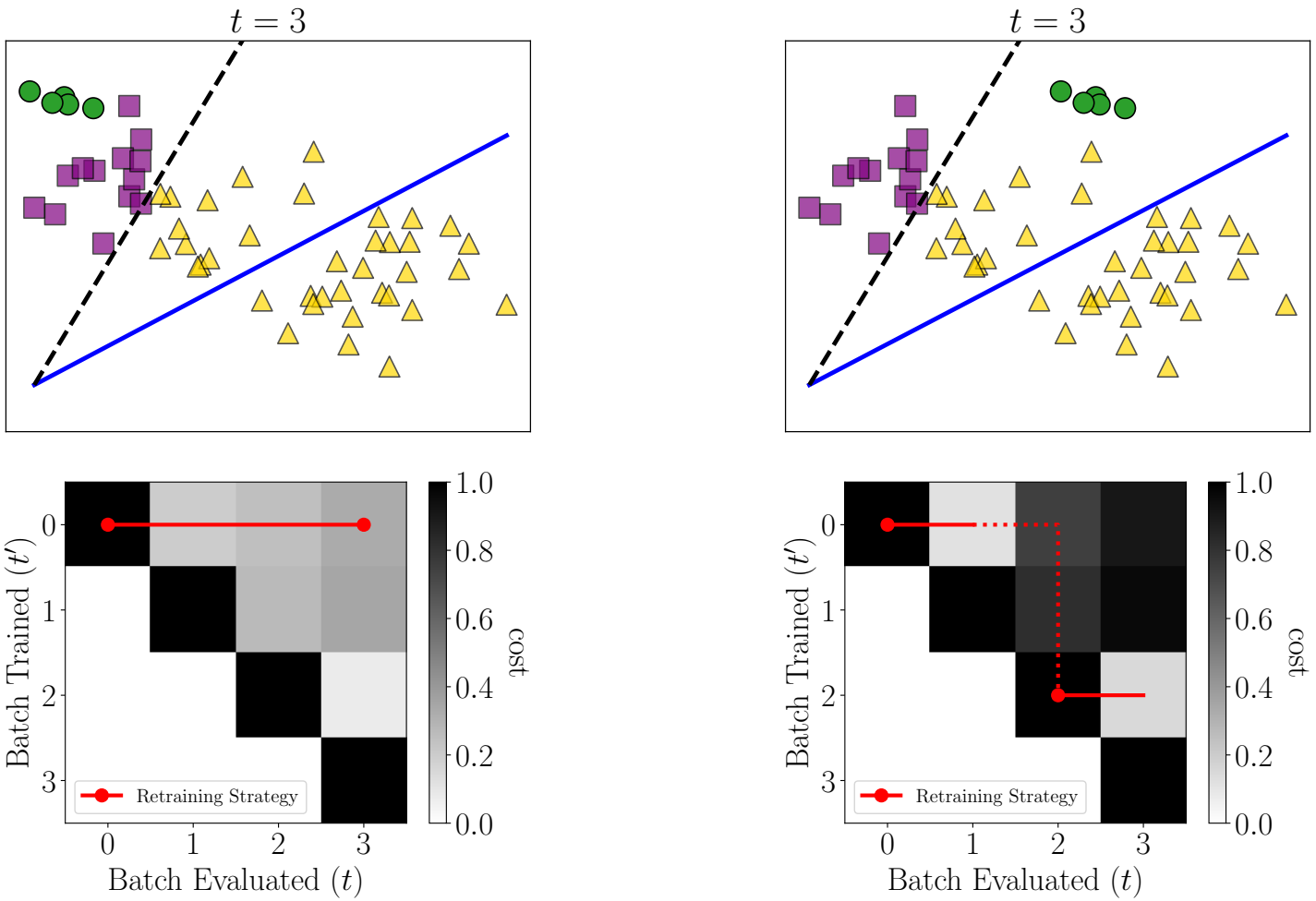


High κ



Staleness Cost

- Query-aware performance cost of old model $M_{t'}$ at batch t
- Scenario 1: Low staleness Scenario 2: High staleness



Analyzing Historical Documents

Data:

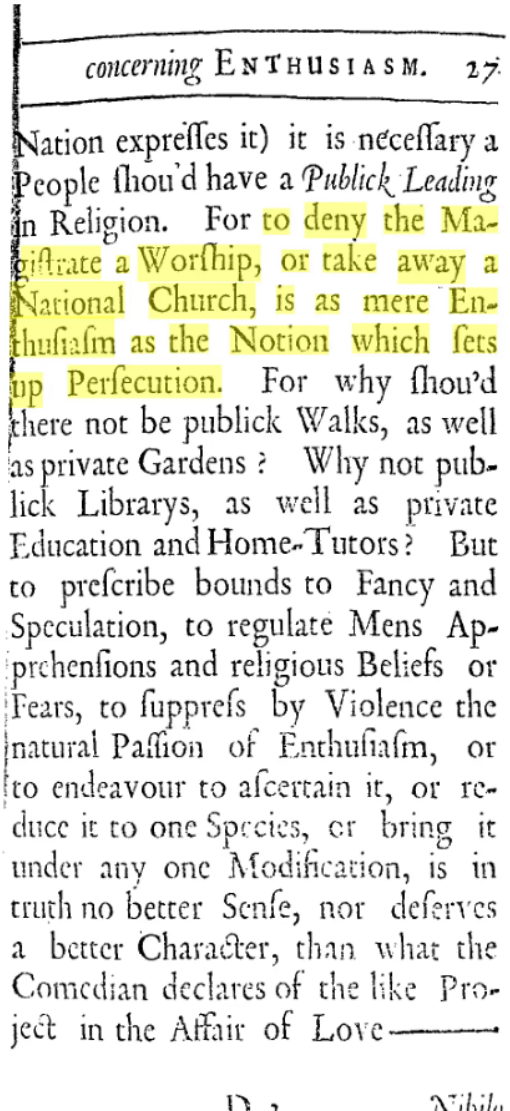
- 250k books and 1M newspapers from the 17th and 18th century
- Tons of heterogeneous metadata
  - Collections of books and articles
  - Publisher details
  - Author information
- Multi-modal data
  - Scanned page images
  - OCR text
  - XML style structured page layouts

Task:

- General exploration
- Reception studies with Text Reuses
- Top quotes of authors

Reception Studies with Text Reuse

Shaftesbury, Anthony Ashley Cooper (1671-1713)
1708 - A letter concerning enthusiasm

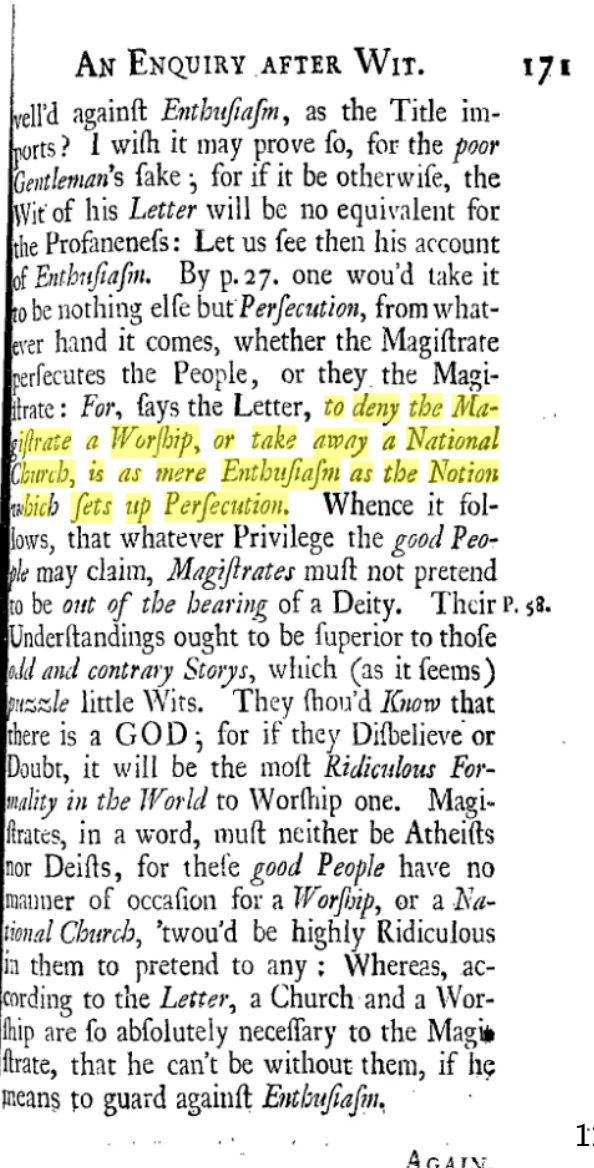


concerning ENTHUSIASM. 27

Nation expreſſes it) it is neceſſary a People ſhou'd have a *Publick Leading* in Religion. For to deny the Magiſtrate a Worſhip, or take away a National Church, is as mere Enthuſiaſm as the Notion which ſets up Perſecution. For why ſhou'd there not be publick Walks, as well as private Gardens? Why not publick Librarys, as well as private Education and Home-Tutors? But to preſcribe bounds to Fancy and Speculation, to regulate Mens Apprehenſions and religious Beliefs or Fears, to ſuppreſs by Violence the natural Paſſion of Enthuſiaſm, or to endeavour to aſcertain it, or reduce it to one Species, or bring it under any one Modification, is in truth no better Senſe, nor deſerves a better Character, than what the Comedian declares of the like Project in the Affair of Love ———

D 2 *Nihilo*

Astell, Mary (1668-1731)
1709 - Bart'lemy fair



AN ENQUIRY AFTER WIT. 171

vell'd againſt *Enthuſiaſm*, as the Title imports? I wiſh it may prove ſo, for the *poor Gentleman*'s ſake; for if it be otherwiſe, the Wit of his *Letter* will be no equivalent for the Profaneneſs: Let us ſee then his account of *Enthuſiaſm*. By p. 27. one wou'd take it to be nothing elſe but *Perſecution*, from whatever hand it comes, whether the Magiſtrate perſecutes the People, or they the Magiſtrate: *For*, ſays the Letter, *to deny the Magiſtrate a Worſhip, or take away a National Church, is as mere Enthuſiaſm as the Notion which ſets up Perſecution.* Whence it follows, that whatever Privilege the *good People* may claim, *Magiſtrates* muſt not pretend to be *out of the hearing* of a Deity. Their P. 58. Underſtandings ought to be ſuperior to thoſe *odd and contrary Storys*, which (as it ſeems) *puzzle* little Wits. They ſhou'd *Know* that there is a GOD; for if they Diſbelieve or Doubt, it will be the moſt *Ridiculous Formality in the World* to Worſhip one. Magiſtrates, in a word, muſt neither be Atheiſts nor Deiſts, for theſe *good People* have no manner of occaſion for a *Worſhip*, or a *National Church*, 'twou'd be highly Ridiculous in them to pretend to any: Whereas, according to the *Letter*, a Church and a Worſhip are ſo abſolutely neceſſary to the Magiſtrate, that he can't be without them, if he means to guard againſt *Enthuſiaſm*.

AGAIN

Identifying Text Reuse

However, OCR texts are very noisy

Document 1 string

```
to deny the Ma-
tifl:ate a Worflip, or take away a
hational Church, is as mere En-
Ihufiafin as the Notion which sets
uip Persecution
```

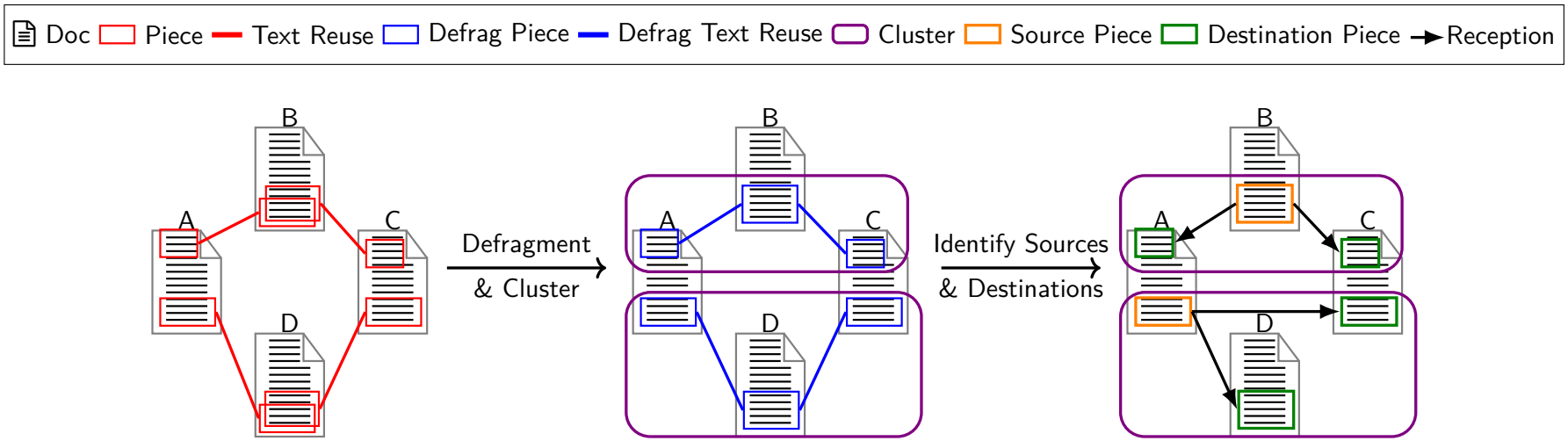
Document 2 string

```
, to deny the Ala-
inrate a ITorftip, or take awvay a National
'uircb, is as mere Entnztfiafm as the Notion
.bic fJets tup Persecution. W
```

How to identify text reuses?

- Use BLAST to do fuzzy alignment

Pre-Processing Pipeline



- Clean up BLAST hits for downstream tasks
- Implemented in Apache Spark
- Uses Dagster for asset management
- Scales up to **6.31 billion** pairs of reuses

Related Publications

1. Paper IV: Rosson et al. [2023]
   - *Reception reader: Exploring text reuse in early modern british publications*
   - Front-end user interface for browsing reuses
2. Paper V: Ryan et al. [2023]
   - *A Comparative text similarity analysis of the works of Bernard Mandeville*
   - Study using the data and interfaces from Paper IV
3. Paper VI: Mahadevan et al. [2024]
   - *Optimizing a Data Science System for Text Reuse Analysis*
   - Studies design choices to optimize performance of the system
   - Plans to scale interface from Paper IV based on insights

Scalability and Robustness

- Paper II: Merchant et al. [2022]
  Scaled up GNN alternative from Merchant and Mathioudakis [2022] to run effectively on graphs with millions of nodes
- Paper III: Mahadevan et al. [2022]
  Explored the robustness of Sketched Linear Networks from Tai et al. [2018] to adversarial attacks
- Paper VIII?: Scalable Diverse Sampling
  - Original algorithm from Wang et al. [2023]
  - Re-implemented for edge-case requirement in Historical Project
  - Nearly $200\times$ speed-up compared to original code
  - Plans to develop theory and code for distributed algorithm

Next Steps

1. Complete a few more transferrable skill credits
2. Start Writing Thesis
3. Work on Paper VIII in tandem

References I

Ananth Mahadevan and Michael Mathioudakis. Certifiable unlearning pipelines for logistic regression: An experimental study. *Machine Learning and Knowledge Extraction*, 4(3): 591–620, 2022. ISSN 2504-4990. doi: 10.3390/make4030028. URL https://www.mdpi.com/2504-4990/4/3/28.

Ananth Mahadevan and Michael Mathioudakis. Cost-effective retraining of machine learning models, 2023.

Ananth Mahadevan, Arpit Merchant, Yanhao Wang, and Michael Mathioudakis. Robustness of sketched linear classifiers to adversarial attacks. In *Proceedings of the 31st ACM International Conference on Information & Knowledge Management*, CIKM '22, pages 4319–4323, New York, NY, USA, 2022. Association for Computing Machinery. ISBN 9781450392365. doi: 10.1145/3511808.3557687. URL https://doi.org/10.1145/3511808.3557687.

References II

Ananth Mahadevan, Michael Mathioudakis, Eetu Mäkelä, and Mikko Tolonen. Optimizing a data science system for text reuse analysis, 2024.

Arpit Merchant and Michael Mathioudakis. Joint use of node attributes and proximity for node classification. In Rosa Maria Benito, Chantal Cherifi, Hocine Cherifi, Esteban Moro, Luis M. Rocha, and Marta Sales-Pardo, editors, *Complex Networks & Their Applications X*, pages 511–522, Cham, 2022. Springer International Publishing.

Arpit Merchant, Ananth Mahadevan, and Michael Mathioudakis. Scalably using node attributes and graph structure for node classification. *Entropy*, 24(7), 2022. ISSN 1099-4300. doi: 10.3390/e24070906. URL `https://www.mdpi.com/1099-4300/24/7/906`.

References III

David Rosson, Eetu Mäkelä, Ville Vaara, Ananth Mahadevan, Yann Ryan, and Mikko Tolonen. Reception reader: Exploring text reuse in early modern british publications. *Journal of Open Humanities Data*, Apr 2023. doi: 10.5334/johd.101.

Yann Ryan, Ananth Mahadevan, and Mikko Tolonen. A comparative text similarity analysis of the works of bernard mandeville. *Digital Enlightenment Studies*, 1:28–58, 12 2023. ISSN 3029-0953. doi: 10.61147/des.6. URL `https://digitalenlightenmentstudies.org/article/id/6/`.

References IV

Kai Sheng Tai, Vatsal Sharan, Peter Bailis, and Gregory Valiant. Sketching linear classifiers over data streams. In *Proceedings of the 2018 International Conference on Management of Data*, SIGMOD '18, page 757–772, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450347037. doi: 10.1145/3183713.3196930. URL https://doi.org/10.1145/3183713.3196930.

Yanhao Wang, Michael Mathioudakis, Jia Li, and Francesco Fabbri. *Max-Min Diversification with Fairness Constraints: Exact and Approximation Algorithms*, pages 91–99. 2023. doi: 10.1137/1.9781611977653.ch11. URL https://epubs.siam.org/doi/abs/10.1137/1.9781611977653.ch11.