

Determining the Influence of Papyrus Characteristics and Data Augmentation on Fragments Retrieval with Deep Metric Learning

Master's Thesis in Computer Science

submitted
by

Gunzenhause Bohnstedt
born 17.02.1992 in Erlangen

Written at

Lehrstuhl für Mustererkennung (Informatik 5)
Department Informatik
Friedrich-Alexander-Universität Erlangen-Nürnberg.

Advisor: Dr.-Ing. V. Christlein, Prof. Dr.-Ing. habil. A. Maier, Mathias Seuret M. Sc.

Started: Start

Finished: Ende

Ich versichere, dass ich die Arbeit ohne fremde Hilfe und ohne Benutzung anderer als der angegebenen Quellen angefertigt habe und dass die Arbeit in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegen hat und von dieser als Teil einer Prüfungsleistung angenommen wurde. Alle Ausführungen, die wörtlich oder sinngemäß übernommen wurden, sind als solche gekennzeichnet.

Die Richtlinien des Lehrstuhls für Studien- und Diplomarbeiten habe ich gelesen und anerkannt, insbesondere die Regelung des Nutzungsrechts.

Erlangen, den 21. November 2021

Zusammenfassung

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu.

Abstract

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu.

Contents

Zusammenfassung	v
Abstract	vii
List of Figures	xi
List of Tables	xiii
1 Introduction	1
1.1 Structure	2
1.2 Contribution	2
1.3 Outline	3
2 State of the Art	5
2.1 Deep Metric Learning	6
3 Algorithms as Puzzle Helper	7
3.1 Goals and Questions	7
3.2 Methods	8
3.3 Results	8
3.4 Evaluation	8
4 Separating Text and Papyrus Fibers	11
4.1 Goals and Questions	11
4.2 Methods	12
4.3 Results	12
4.4 Evaluation	12

5	Generating Historical Documents	15
5.1	Goals and Questions	15
5.2	Methods	16
5.3	Results	16
5.4	Evaluation	16
6	Exploding Papyrus Fibers	19
6.1	Goals and Questions	19
6.2	Methods	20
6.3	Results	20
6.4	Evaluation	20
7	Discussion	23
7.1	Impact of Text and Fiber Separation	23
7.2	Impact of Generating Artificial Data	24
7.3	Impact of Exploiting the Fibers	25
8	Conclusion	27
8.1	Learnings and Findings	27
8.2	Future Work	28
	Bibliography	29
A	Appendix	31

List of Figures

List of Tables

Chapter 1

Introduction

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged.

1.1 Structure

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged.

It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book.

It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu.

1.2 Contribution

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged.

It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book.

It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with

the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu.

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged.s

1.3 Outline

It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsu.

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged.s

Chapter 2

State of the Art

In this chapter is an overview of the state-of-the art for this thesis. The common research field is computer vision. State-of-the-art presents the results of recent publications but since numbers alone are not meaningful, the methods and the exact context are also discussed. This includes approaches based on deep unsupervised metric learning , graph theory and data argumentation.

Puzzling and information retrieval from historical documents is becoming increasingly popular in the computer vision community. The applications, challenges and projects focus on different areas. The diagram in Figure X is a chronological overview of research areas and state-of-the art publications. The areas are not defined in a general way. The publications were choosen subjectivly by us. The are just a subset of all the work and include just the state-of-the art.

Task	Publication	Year	Method	Dataset	Public	Train Data	Val Data	Test Data	Metric	Result
Fragment Retrieval	Self-supervised deep metric learning for ancient papyrus fragments retrieval	2021	Self-supervised deep metric learning	Michigan	yes	800 papyri	100 papyri	100 papyri	Top-1 Accuracy	0.73
Fragment Retrieval	Self-supervised deep metric learning for ancient papyrus fragments retrieval	2021	Self-supervised deep metric learning	Hisfrag	yes	9000 papyri	1000 papyri	100 papyri	Top-1 Accuracy	0.87
Fragment Retrieval	Papy-S-Net: A Siamese Network to match papyrus fragments	2019	Siamese Network	B500	no	8500 patches	2000 patches	1000 patches (50 fragments)	True Pos. / Accuracy	0.79
Position Estimation	Using Graph Neural Networks to Reconstruct Ancient Documents	2021	Graph Neural Networks	B500 (subset)	no	3394 imgs	500 images	200 images	Accuracy	0.85
Data Argumentation	Data Augmentation Generative Adversarial Networks	2018	Generative Advesarial Networks	EMNIST	yes	-	-	-	Accuracy	+0.13

2.1 Deep Metric Learning

As indicated in the introduction, DML is a comparison-based algorithm and is therefore well suited for a field in which there is little ground truth. Pirone and his colleagues were the first who used DML in domain of papyri fragment retrieval. In their 2019 paper Papy-S-Net : A Siamese Network to match papyrus fragments“, they presented a so-called Siamese network that was able to correctly match 79% of the papyri fragments. In 2021, they further improved their approach. A dataset under a public domain was generated to better evaluate their results. Through certain experiments with different models and preprocessing steps, a top-1 accuracy of 0.73% was achieved. Because the authors communicated clearly what data was used, how it was prepared, and what metrics were used, the results from 2021 are much more reliable.

Chapter 3

Algorithms as Puzzle Helper

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

3.1 Goals and Questions

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

3.2 Methods

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

3.3 Results

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

3.4 Evaluation

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat.

Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Chapter 4

Separating Text and Papyrus Fibers

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

4.1 Goals and Questions

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

4.2 Methods

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

4.3 Results

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

4.4 Evaluation

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat.

Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Chapter 5

Generating Historical Documents

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

5.1 Goals and Questions

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

5.2 Methods

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

5.3 Results

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

5.4 Evaluation

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat.

Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Chapter 6

Exploding Papyrus Fibers

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

6.1 Goals and Questions

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

6.2 Methods

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

6.3 Results

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

6.4 Evaluation

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat.

Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Chapter 7

Discussion

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

7.1 Impact of Text and Fiber Separation

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

7.2 Impact of Generating Artificial Data

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

7.3 Impact of Exploiting the Fibers

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Chapter 8

Conclusion

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

8.1 Learnings and Findings

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

8.2 Future Work

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Bibliography

Appendix A

Appendix

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam volutpat gravida nulla eu suscipit. Nulla hendrerit erat lectus, ac finibus ligula ornare nec. Donec mattis ultricies varius. Sed maximus fermentum ipsum, vitae vulputate urna molestie ac. Duis hendrerit accumsan mattis. Donec condimentum, velit quis ultrices mattis, quam nulla tincidunt risus, a iaculis est nulla quis urna. Morbi vel ligula fringilla, pharetra metus vitae, posuere sem. Vestibulum rutrum auctor nibh eget tincidunt. Sed molestie sollicitudin erat et venenatis. Morbi sollicitudin id nisl non feugiat. Nunc ipsum metus, semper nec varius sit amet, vulputate tincidunt nisl. Praesent eget arcu lacus. Fusce nec libero in elit pretium posuere. In cursus vel purus in congue. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Praesent ultricies et turpis vitae pharetra.

Integer porta, libero laoreet tristique vehicula, nisi nisl eleifend metus, suscipit laoreet nibh sapien nec nulla. Mauris facilisis sodales massa, eu fermentum leo suscipit sit amet. Vestibulum vel massa dolor. Integer scelerisque dictum tortor ac sollicitudin. Duis sem orci, vehicula vitae ex sed, porttitor mattis nisl. Proin rhoncus libero quis pharetra congue. Donec leo neque, pulvinar non ultricies sit amet, consequat vitae magna. Morbi eu turpis vel purus luctus porta. Suspendisse non congue felis. Nulla et orci eros. Praesent elementum tellus turpis, at ultricies quam porta faucibus. Suspendisse potenti. Suspendisse id viverra dolor. Sed tristique massa vitae urna ornare aliquam. Mauris malesuada, mi nec fringilla sodales, libero justo porta enim, a posuere diam nunc in elit.

Duis risus diam, dapibus id neque ut, ultricies fermentum orci. Aenean porta semper eros, id porttitor risus efficitur at. Praesent ut dolor ante. Curabitur nec sem nibh. Phasellus a ligula suscipit, ornare sapien a, pharetra sem. Duis euismod, massa ut vulputate finibus, justo orci egestas urna, eget mattis odio sapien vel tellus. Sed ac augue cursus, vulputate orci vitae, porttitor

risus. Sed vitae nunc in justo bibendum malesuada ac nec libero. Sed ac dolor elit. Praesent blandit nisl ut velit varius, vitae posuere elit lobortis. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia curae; Morbi non finibus sem. Maecenas sit amet est ut enim blandit facilisis at non purus. Maecenas dapibus orci eu felis posuere, nec fermentum dui porttitor.

Vivamus eget accumsan quam. Quisque vehicula est et ornare lacinia. Suspendisse mollis eros a malesuada aliquet. Vestibulum porta, lacus eget varius tempor, enim nunc accumsan nulla, sed viverra quam elit sed risus. Etiam commodo rutrum arcu, vitae semper enim interdum et. In aliquet venenatis erat. Vivamus nisl sem, gravida a ante et, interdum elementum ex. In tellus sem, cursus ut massa nec, luctus pellentesque nunc. Donec nunc nisi, porta a pulvinar sit amet, auctor ac orci. Mauris tincidunt erat a lectus aliquet elementum. Suspendisse vitae lorem eros. Nulla dapibus ex in malesuada porta.

Praesent ac enim massa. Aenean dignissim consequat dolor egestas dapibus. Pellentesque et magna ullamcorper, malesuada lectus a, ultricies ante. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Curabitur euismod id velit ac mattis. Mauris nec ipsum sed nisl iaculis consectetur. Nam ipsum lacus, luctus id ullamcorper non, maximus nec erat. Nunc tempor eu dui vitae suscipit. Maecenas facilisis libero ac malesuada sodales. Morbi ac neque nisl. Vestibulum vehicula tortor lorem, a vestibulum justo porttitor pulvinar. Ut ligula dolor, ullamcorper eget dui nec, tincidunt interdum leo. Aliquam tincidunt laoreet lectus non convallis. Proin lacinia, mauris ut imperdiet ullamcorper, lorem libero ornare lectus, in dictum purus justo in nulla.