ArXiv Preprints Version Analysis

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Abstract

Many scientific papers change over time in order to correct mistakes, address peer review comments, or to modify metadata. The aim of this project is to identify such papers on arXiv, analyse changes between their versions, find the most common ones and see how they may differ based on the subject of the paper.

1 Introduction

Traditionally, after a scientific paper was submitted and accepted by an academic journal, there was little an author could do to change any aspect of the paper. Their work would be frozen in time. However, with the advent of services such as arXiv, there was a paradigm shift in how articles are published.

ArXiv is an online, open-source repository of scientific papers hosting more than 2 million scholarly articles. One feature arXiv provides is the possibility of hosting multiple versions of the same paper. Using this, authors may upload a preliminary version of their work and then, as they receive feedback from peers, update the paper accordingly. A byproduct of this process is that a paper's history can be accurately traced out.

By analysing this history and comparing different versions of the same paper, information about the most common modifications may emerge. In addition, by sampling papers from three distinct fields (Physics, Computer Science and Mathematics), potential underlying trends in scientific literature can be analysed based on subject.

In this report, we were able to identify and analyse such trends, both in terms of the evolution of scientific articles, as well as based on subject.

2 Data

By using data available on the Kaggle website[1], we selected and analysed a subset of 12000 papers, consisting of 28724 distinct versions. Only papers with between 2 and 4 versions were taken into account as they make up the majority of the data set.

At the time of writing, ArXiv classifies papers into 8 fields (Computer Science, Economics, Electrical Engineering and Systems Science, Mathematics, Physics, Quantitative Biology, Quantitative Finance, Statistics) which are further subdivided (e.g. Quantum Physics, Computational Geometry, Subcellular Processes). In this report we considered Physics, Computer Science and Mathematics, as they make up 93% of the papers hosted on arXiv (see Figure 1).

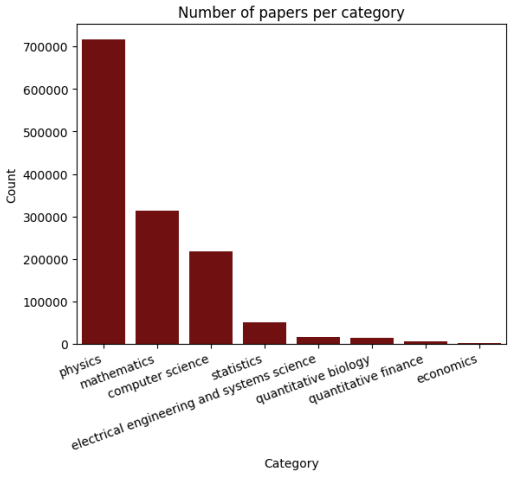

Figure 1: Number of papers per category

Some papers appear in more than one category, but

[1]Kaggle arXiv data set: https://www.kaggle.com/datasets/Cornell-University/arxiv

this is not a significant segment of the corpus (around 10%).

After randomly choosing 4000 papers from each of the three aforementioned categories, we downloaded and processed each version of these papers using Grobid[2], a machine learning library that extracts data from PDFs and structures it into XML/TEI[3] files with a particular focus on technical and scientific publications. In the end, 24758 versions were successfully downloaded and processed.

3 Analysis

We computed a number of features which were then used to examine differences between consecutive versions of the same paper. The ones we present in this report are:

- time interval between the publication of consecutive versions
- number of references
- number of authors
- number of figures
- number of pages
- number of words
- number of tokens

3.1 Time differences

The date when a version was uploaded to arXiv is available in the Kaggle data set, so finding the time interval between versions is straightforward.

The shortest time interval between the publication of consecutive versions is the one between the first and the second version, regardless of field.

On the other hand, Mathematics is the slowest field to update papers, with an average of 245 days between consecutive versions, as opposed to 157 days for Computer Science and 139 days for Physics. This difference becomes clear in Figure 2.

[2]Grobid: https://grobid.readthedocs.io/en/latest/
[3]Text Encoding Initiative: https://tei-c.org/

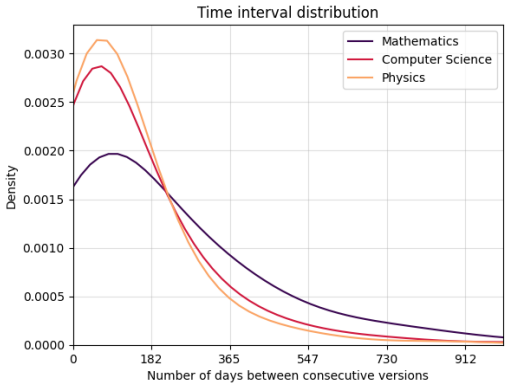

Figure 2: Kernel Density Estimation (KDE) of time interval between versions

Figure 2 also shows that there is a consistently higher probability for mathematicians to update a paper after one year compared to Computer Science and Physics.

These findings may indicate a slower review process for Mathematics, as well as an overall tendency to work on a paper or a problem for a longer time.

3.2 Paper size & contents

Before anything can be said about the contents of the papers, in this report we make the distinction between *words* and *tokens*. From now on, *tokens* will be referring to all of the words that constitute a paper, while *words* will indicate the unique tokens that appear in a paper (e.g. "he is tall and he is short" consists of 7 tokens and 5 words). In practice, we extracted tokens using a basic lexer consisting of the following regex `/\p{L}{2,}` (two or more Unicode codes classified as letters). Due to the specific type of language used in scientific publications, usually a formal register, much of the variation of natural language is lost, so no stemming was performed as it was not considered necessary.

A rough estimate for the size of a paper is the number of pages. For Computer Science and Physics, this averages at around 18 to 19 pages, whereas mathematical papers are longer, with an average of 25.9 pages, leading to a relative difference of 39%.

On the other hand, Computer Science and Physics are, on average, denser, with 435 tokens per page and 389, respectively, while mathematical papers only have 271 tokens per page.

Overall, the previous two variations even out, leading to papers of about the same size in tokens, with Computer Science being, on average, the longest, with 6930 tokens per paper (see Figure 3).

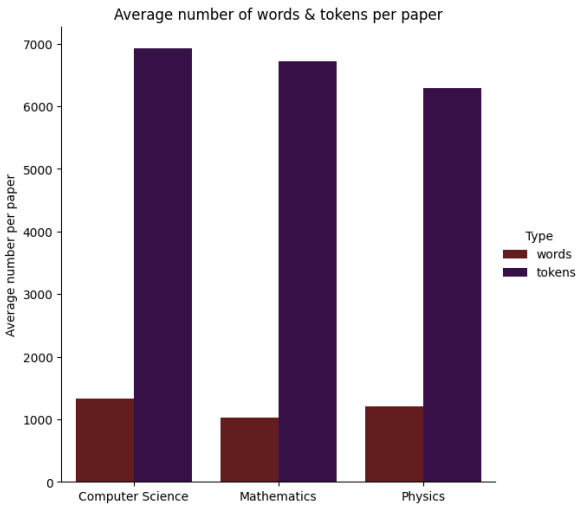

Figure 3: Average number of words & tokens per paper

Between consecutive versions, papers from all fields add and remove a similar number of words. In general, 6.6% of the words are removed from one version to the next, while 10% of them are new.

However, the average ratio between added and removed words is not constant (see Table 1). This may indicate that computer scientists are more inclined to rephrase, while physicists add new words.

	CS	Math	Phys
$\frac{\#\text{ of added words}}{\#\text{ of removed words}}$	2.81	3.88	4.55

Table 1: Average ratio between added words and removed words

3.3 References

Grobid is able to extract references from a paper. Using this feature, we looked at changes in bibliographic references between consecutive paper versions.

Out of all the versions, 6% remove references from one to the next, 28% add at least one reference, while 10% add more than 6.

As such, there is an overall tendency to add references (see Figure 4, the areas under the graphs on the positive x-axis are greater than on the negative side):

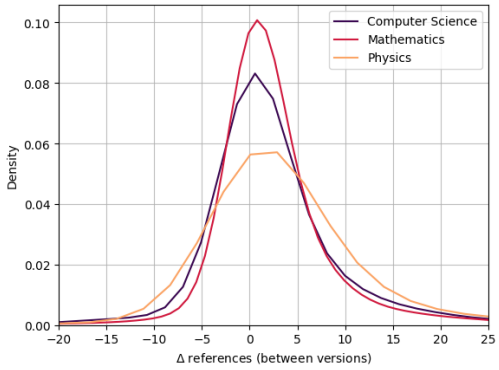

Figure 4: KDE of difference in number of references between versions

Figure 4 also indicates that physicists are the likeliest to add or remove greater amounts of references. It is also Physics papers that have, in general, the highest number of references, with an average of 49 per paper (29 for Mathematics and 38 for Computer Science).

3.4 Other metrics

	CS	Math	Phys
# of authors	4	2.2	11.6
# of figures	11.3	10.3	9.0
# of figures per page	0.72	0.4	0.55

Table 2: Table with other metrics (all values are averages over all versions)

Some of the other features we computed are summarised in Table 2.

Mathematics papers have, on average, the fewest authors, while Physics papers have by far the most, 5 times the amount. This may be due to the huge collaborative efforts that take place at international particle accelerators (see [1]).

Computer Science papers have the highest number of figures per article, as well as the highest concentration of figures per page.

4 Outliers

Interesting extremes in some of the categories:

- Most versions: 187 [2]
- Most authors: 2832 [3]
- Most references: 690 [4]
- Longest paper: 485 pages [5]
- Shortest time between consecutive versions: 3 minutes and 13 seconds [6]
- Longest time between consecutive versions: 11 years, 188 days, 22 hours, 31 minutes and 3 second [7]

5 Conclusions

By analysing the evolution of papers on arXiv it becomes clear that field-specific trends do exist.

Mathematical papers are more of an individual effort spread out over many years, whereas Physics papers imply more collaboration, both in terms of authors and references. Computer Science papers are, on the other hand, denser, containing more words and figures. In general, more information is added to a paper rather than subtracted (number of words, length, number of references and figures).

Scientists pride themselves on objectivity and logical reasoning, yet there are many implicit traditions and customs specific to every field that may no longer have any objective basis, including the type of content and formatting of an article. These customs are not necessarily detrimental to the scientific community, but it is paramount to be aware of them so as to not overlook any discovery that does not fit in with the status quo.

The work conducted in this area of research, up to this point, is by no means exhaustive. The possibilities presented by the open access of arXiv are countless, including inquires into topics such as networks of authors, detecting multi-disciplinary and interdisciplinary works, etc.

Acknowledgments

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Thank you to arXiv for use of its open access interoperability.

Thank you to Grobid for its open source software.

References

The code used in this analysis is available on GitHub: https://github.com/andcov/arXiv_preprints_version_analysis

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