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Fake Papers in Science: Paper Mills, Characteristics and Detection Strategies

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Fake scientific articles, or **fake papers**, are a significant issue and a threat to research integrity. They spread misinformation, which might have a severe impact on research and ultimately also undermine the public's trust in science. This research aims to raise **awareness** among the research community about fake papers and highlight strategies to detect them. Fake papers contain various issues, including fabricated data, plagiarized content, manipulated images, and AI-generated content. Often, such papers are produced by professionals, i.e., so-called "**paper mills**" that sell authorship or manuscripts for a profit. Those fabricated papers pollute the scientific record and increase the burden on reviewers and other scientists. The rise of **Large Language Models** (LLMs) like ChatGPT and Gemini, as well as the increase in publication volume over the years, additionally contributes to the issue. Therefore, the need for **detection tools** to **ensure scientific integrity** is becoming more critical. Specific tools exist for publishers to detect fake papers, including Integrity Hub from STM, Snapshot, and Gepetto. However, these tools are not publicly accessible, thus hindering researchers to evaluate their impact. We present preliminary results from our ongoing research using text mining techniques and metadata features. Our initial findings suggest that there are indicators to flag papers for closer scrutiny and that further research is promising.

What are Papermills?

- Papermills are organizations that produce academic manuscripts for researchers for money [1]. They have **professional writers** for different domains in science and charge hefty fees from researchers to appear as an author on their paper, as shown in Fig. 1.
- For researchers whose promotion or PhD requires them to publish frequently, this is an easy way out for them.

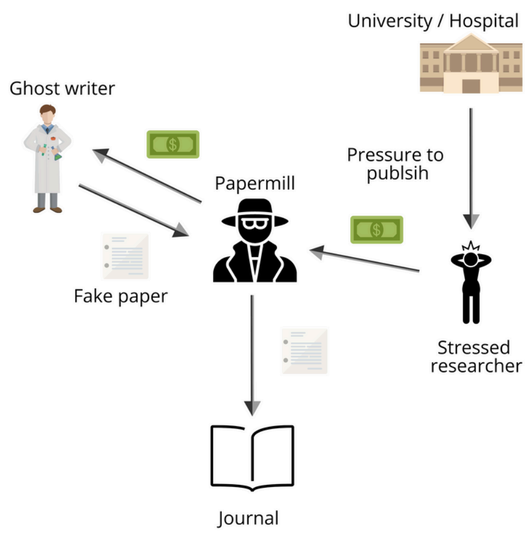


Fig 1: An illustration on how papermills work

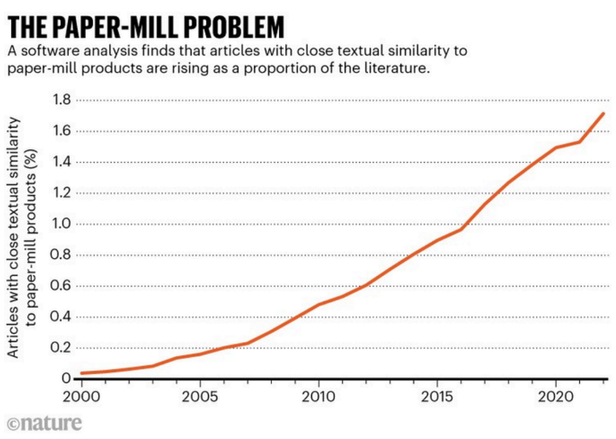


Fig 2: The increase in papermill activity over the years[2]

- Papermill-produced research has been increasing steadily since the beginning of the year 2000, as shown in an article by Nature [2] in Fig. 2.
- The abundance of papermill products in the scientific literature undermines the hard work of authentic researchers and poses a threat to scientific integrity.

Characteristics of Fake Papers

Fake papers could contain one or multiple different reasons that make them inauthentic. The following list states some reasons as to why a paper could be flagged as being fake.

- Fabricated data
- Manipulated images
- AI-generated text
- Non-institutional email address
- Plagiarized content

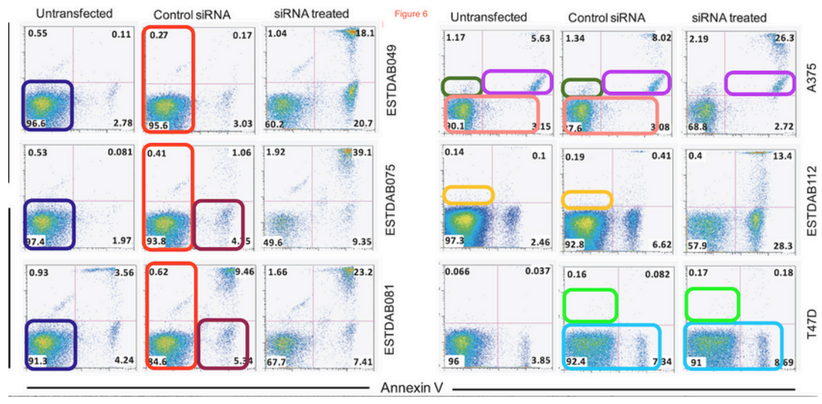


Fig 3: Image duplications in a research article [3]

Figure 3 shows an example of duplication in different parts of an image in an actual research paper [3], where the similar colors represent duplications.

How to Detect Faked Papers

The detection of fake papers is a challenging task because fraud in publications can be in different forms; therefore, multiple detection methods are required to verify the authenticity of the research carried out. Secondly, due to the emergence of **LLMs** like ChatGPT and Gemini, detection of AI-generated texts is becoming more difficult.

- Commercial tools exist for publishers such as **Integrity Hub, Problematic Paper Screener, Snapshot and Gepetto** to weed out papers with integrity issues, however, these tools are not available for the public to use.
- There are different research papers that propose detection techniques using machine learning (Decision Trees) [4], BERT models [5], image manipulation detection [6], and LSTM models [7]. However, each method has its limitations and shortcomings related to a high false positive rate and manual detection methods etc.

Preliminary Results

In order to develop a detection method, we collected a dataset of publications from the biomedicine domain containing fake and authentic papers. Different types of features and machine learning algorithms to detect fraudulent papers. The features used for the machine learning model were a combination of **metadata** and **TF-IDF based features** from the abstracts of the papers. The recall score was used as an evaluation metric, and the **Gradient boosting classifier** achieved a score of **83%**.

- The word cloud in Fig. 4 presents the most common terms found in fake papers, including **'cell', 'protein'** and **'mir'** (referring to DNA), especially in the ones from papermills.
- The papermill products have a common writing style as well as image format. Another observation was that most of the fake papers in biomedicine are in the field of **molecular biology**.

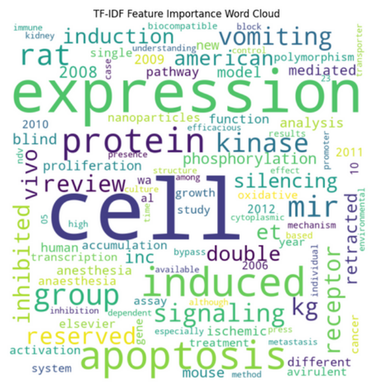
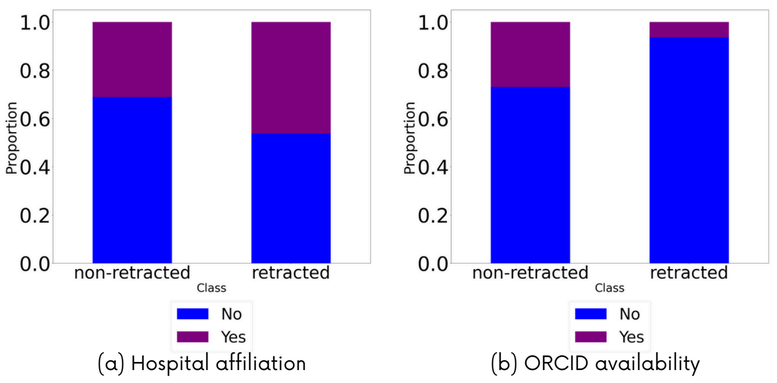


Fig 4: A word cloud of common terms in fake papers



(a) Hospital affiliation (b) ORCID availability

Fig 5: : Stacked bar plots of proportion of important binary features across classes

There are also significant differences in metadata features of fake papers, including **ORCID availability** and **hospital affiliation**, as can be seen in Fig. 5.

Impact on Scientific Community

- The mass production of fake papers could make the public question the validity of scientific papers and ultimately loose trust in science. Especially in the field of **medicine** and **biology**, where authentic knowledge and research is directly related to human health and well-being, fake papers would have a huge adverse effect.
- Research by Nature [2] shows the distribution of likely papermill products across different domains, with medicine and biology having the highest number (around **3%** of all papers), followed by c**hemistry** and c**omputer science**. Similarly, Sabel et al. [1] recently reported the rate of red-flagged potential fake papers at **11%.**

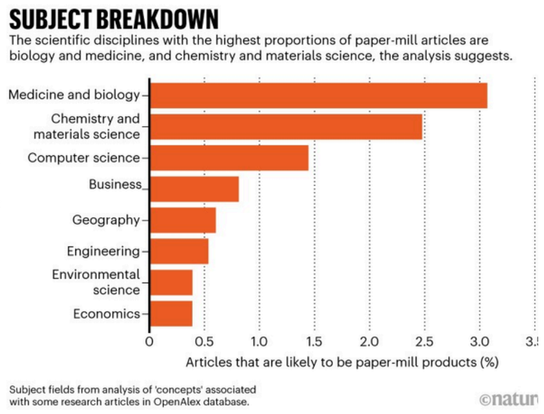


Fig 6: Distribution of papermill activity across domains [2]

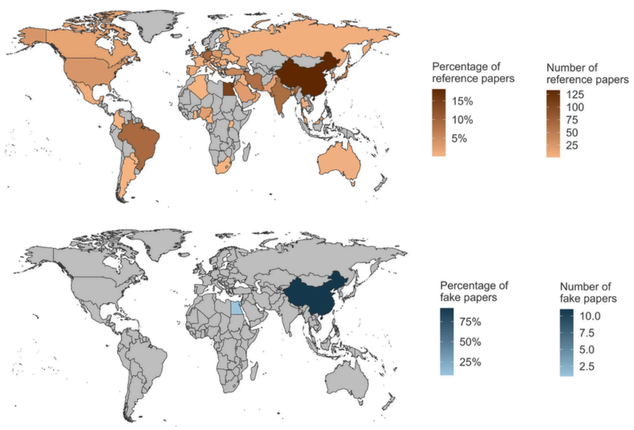


Fig 7: Distribution of fake papers across countries [8]

- Fig. 7 shows the distribution of fake papers by country based on a pool of fake papers selected and analyzed by [8]. The bottom figure is a distribution of 12 proven fakes, whereas the top one is a reference group consisting of 733 papers.
- Another huge impact of this phenomenon includes the **wastage of time and resources** spent on funding to produce fradulent research.
- Producing fake research by a researcher can also be harmful to the **reputation of the research group** and the university producing it.

Conclusion

The aim of this research is to spread awareness in the scientific community about the presence of fradulent research and present preliminary results of our contribution to detect them. Our findings suggest that there exists certain metadata and domain-related features that separate fakes from non-fakes. The future direction of the research will include refinement of the detection methods by adding further relevant features from the full text of papers and organization of workshops to raise awareness among researchers about the presence of fake papers in science.

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