The ROOTS search tool - motivations and implementation

Aleksandra Piktus
piktus@huggingface.co

The ROOTS corpus was developed during the BigScience project with the purpose of training the multilingual, large language model—BLOOM. The **ROOTS search tool**—a search engine giving access to all document in the ROOTS corpus is available on Hugging Face Spaces. In this document we describe the motivations and technical details of the ROOTS search tool implementation.

1. Motivations

The current NLP landscape is dominated by research showcasing a spectacular and ever increasing boost in the performance of language models (LMs), initiated by the introduction of the transformer architecture [15]. Modern language models such as GPT-3 [4] and BLOOM [3] perform impressively well on generation tasks, often producing text indistinguishable from that written by a person. However, the inner workings of such systems are notoriously obscure, with the lack of visibility into their training corpora emerging as a common culprit. This state of affairs was the main motivator behind the BigScience project[1]—a collaborative research endeavor initiated by Hugging Face, aiming to explore the area of large-scale language modelling through training an open-access, massively multilingual language model now known as BLOOM. We subscribe to this ethos and propose the ROOTS search tool—a search engine indexing all document in the ROOTS corpus [8]. We want to give researchers the ability to explore the documents forming ROOTS. We believe this is important due to reasons we outline below.

Data quality. The question of the quality of large scale textual datasets is a valid one in its own right, even before we start thinking about using them to train LMs. Papers often give only cursory descriptions of their data sources or how they were filtered to maintain a certain quality bar and curb undesired phenomena. A no-code tool allowing to browse through the corpus broadens the audience and can help us surface problematic instances and gain a better understanding of the overall text quality and potential corpus-level blindspots.

Model Interpretability. The ability to search through the training corpus of a language model helps explain and interpret its generations, e.g. it might allow us to uncover cases of generations directly memorized from the training data (BLOOM seems like a pretty good *Lorem ipsum* generator[2]) as well as cases of hallucinations where certain names or concepts don't appear in the training data at all.

[1] `https://bigscience.huggingface.co/`

[2] See the BLOOM demo at `https://huggingface.co/spaces/huggingface/bloom_demo`

ROOTS language tag	# documents	Data size in GB	# passages	Index size in GB	Analyzer
zh, zhs, zht	88,814,841	168	111,284,681	682	zh
indic	84,982,982	68	100,810,124	95	whitespace
en	77,010,827	449	695,521,432	731	en
es	67,005,817	165	267,542,136	253	es
fr	58,847,091	195	299,938,546	292	fr
vi	34,110,375	41	76,164,552	70	whitespace
pt	31,969,891	74	122,221,863	115	pt
code	26,176,998	166	365,424,222	198	whitespace
ar	15,234,080	71	68,509,441	90	ar
id	12,514,253	19	29,531,873	26	id
ca	6,142,390	17	26,844,600	29	es
eu	5,149,797	2	6,219,039	4	whitespace
nigercongo	1,162,568	1	1,462,238	1	whitespace
total	597,936,751	1,436	2,171,474,747	2,586	

Table 1: Each row represents a single index we've built. The Data size column represents the size of compressed data and may not match numbers presented in the ROOTS paper [8].

Knowledge. The task of extracting and using facts contained in large scale, textual knowledge sources is what knowledge-intensive NLP has been attempting to solve with retriever-reader architectures. In a relatively recent trend, researchers have been looking at large scale LMs as *autoregressive* search engines able to surface the *knowledge* they acquire in the training process [12, 10, 2]. Papers in this niche mostly concern themselves with modelling challenges, the question we find more pressing though pertains to the quality of knowledge present in the training corpora - which can be explored using our tool.

Better tooling. Large scale text corpora pose many challenges to people who would like to access and analyze them. First their sheer scale (1.6TB in case of ROOTS) introduces resource requirements that may be hard to acquire by individual researchers, it also constitutes a barrier of entry for people unfamiliar with programmatic ways of accessing large scale data. Next come legal challenges—text, especially that scraped from the internet may be subject to copyright and licences which makes people who collect the data reluctant to re-releasing it for fear of infringing on any laws. As a result, corpora used to train modern LMs are rarely shared with the public. One common pattern is to open-source tools enabling the reproduction of the corpus rather than the corpus itself, e.g. in [16]. BigScience's meticulous and principled approach to data governance [6] gives us a unique opportunity to work with actual data while following the guidelines of the responsible AI licence [5]. In this context, it is worth mentioning a related, although perhaps less principled effort which resulted in opening a C4 [13] search tool by AllenAI: `https://c4-search.apps.allenai.org/`.

2. Data

The ROOTS corpus [8] is a high-quality, heterogeneous and multilingual text corpus collected as part of the BigSceince project to train BLOOM. The full dataset is open to the members of the BigScience Data organization on the Hugging Face hub. To inquire about gaining access to the organisation, please consult this Google Form. The ROOTS corpus consists of 1.6TB of textual data in 46 natural languages and 13 programming languages. The data is organized in

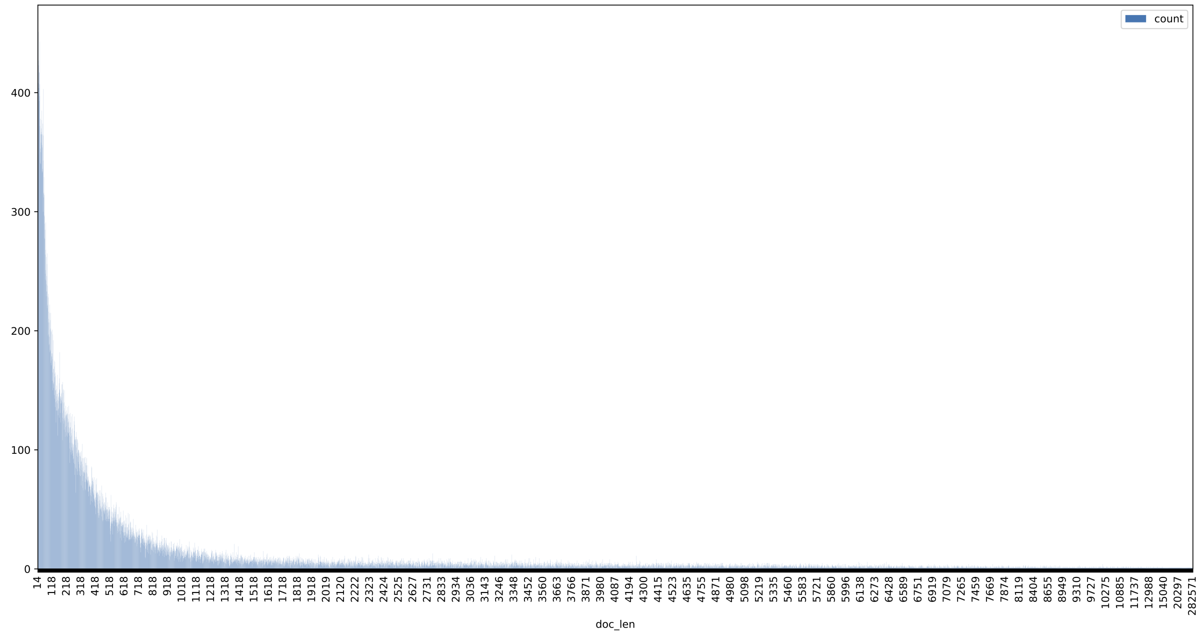


Figure 1: Document lengths distribution in a 100000-element random sample of the ROOTS corpus. The x-axis indicates the document length in characters. The y-axis indicates the number of documents of given length in the sample.

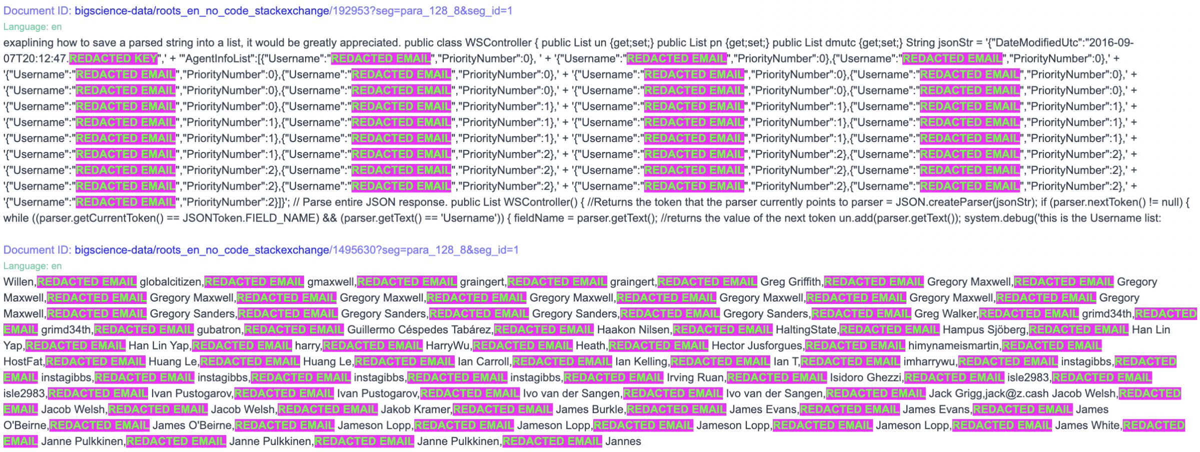
498 datasets, following a common naming pattern—the `bigscience-data` organization name followed by a slash, then the `roots` prefix, followed by the language tag and the data source identifier, delimited by underscores, e.g. `bigscience-data/roots_indic-mr_mkb`. There are two types of language identifiers—those indicating an individual language, e.g. `pt` for Portuguese, `vi` for Vietnamese, and those indicating a language belonging to a language group, e.g. `indic-mr` for Marathi, as part of the Indic language group. Additionally, all programming languages are collected under a common `code` language tag. In our experiments we build 13 indices—one for each individual language, with the exception of Chinese, where we collect 3 independent language tags available in ROOTS (`zh`, `zht`, `zhs`) into a single index; one for `code`, and one per language group (`indic` and `nigercongo`) In Table 1 we present basic information per index. The full list of indexed datasets is available in the appendix.

2.1. Data Governance

The notion of data governance was core to the development of ROOTS—we refer the reader to the FAccT paper summarizing core findings [6] and the preamble of our access form for a more thorough analysis of the guiding principles of the data governance workstream and how they were operationalized during the course of BigScience and after. Here, we briefly share the logic behind sharing the ROOTS search tool publicly. First and foremost, the tool gives no practical way to reconstruct the full corpus. We mitigate the risk of copyright infringements by only displaying 128-word snippets of indexed documents. Wherever possible, we link to source documents by displaying respective URLs (that said, metadata in ROOTS is inconsistent and we only have access to URLs in `pseudocrawl` datasets). Additionally, for each displayed result we provide a link to the ROOTS dataset it came from for further inspection.

2.2. Data preprocessing

Datapoint vs document. The ROOTS corpus was design with the language modeling task in mind. In such a setup, we're primarily concerned with text understood as stream of words



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Language: en

exaplining how to save a parsed string into a list, it would be greatly appreciated. public class WSController { public List un {get;set;} public List pn {get;set;} public List dmutc {get;set;} String jsonStr = '{"DateModifiedUtc":"2016-09-07T20:12:47.REDACTED KEY",' + '"AgentInfoList":[{"Username":"REDACTED EMAIL","PriorityNumber":0}, ' + '{"Username":"REDACTED EMAIL","PriorityNumber":0},{"Username":"REDACTED EMAIL","PriorityNumber":0},' + '{"Username":"REDACTED EMAIL","PriorityNumber":0},{"Username":"REDACTED EMAIL","PriorityNumber":0},' + '{"Username":"REDACTED EMAIL","PriorityNumber":0},{"Username":"REDACTED EMAIL","PriorityNumber":0},' + '{"Username":"REDACTED EMAIL","PriorityNumber":0},{"Username":"REDACTED EMAIL","PriorityNumber":0},' + '{"Username":"REDACTED EMAIL","PriorityNumber":0},{"Username":"REDACTED EMAIL","PriorityNumber":0},' + '{"Username":"REDACTED EMAIL","PriorityNumber":0},{"Username":"REDACTED EMAIL","PriorityNumber":1},' + '{"Username":"REDACTED EMAIL","PriorityNumber":1},{"Username":"REDACTED EMAIL","PriorityNumber":1},' + '{"Username":"REDACTED EMAIL","PriorityNumber":1},{"Username":"REDACTED EMAIL","PriorityNumber":1},' + '{"Username":"REDACTED EMAIL","PriorityNumber":1},{"Username":"REDACTED EMAIL","PriorityNumber":1},' + '{"Username":"REDACTED EMAIL","PriorityNumber":1},{"Username":"REDACTED EMAIL","PriorityNumber":1},' + '{"Username":"REDACTED EMAIL","PriorityNumber":1},{"Username":"REDACTED EMAIL","PriorityNumber":2},' + '{"Username":"REDACTED EMAIL","PriorityNumber":2},{"Username":"REDACTED EMAIL","PriorityNumber":2},' + '{"Username":"REDACTED EMAIL","PriorityNumber":2},{"Username":"REDACTED EMAIL","PriorityNumber":2},' + '{"Username":"REDACTED EMAIL","PriorityNumber":2},{"Username":"REDACTED EMAIL","PriorityNumber":2},' + '{"Username":"REDACTED EMAIL","PriorityNumber":2},{"Username":"REDACTED EMAIL","PriorityNumber":2},' + '{"Username":"REDACTED EMAIL","PriorityNumber":2}]}'; // Parse entire JSON response. public List WSController() { //Returns the token that the parser currently points to parser = JSON.createParser(jsonStr); if (parser.nextToken() != null) { while ((parser.getCurrentToken() == JSONToken.FIELD_NAME) && (parser.getText() == 'Username')) { fieldName = parser.getText(); //returns the value of the next token un.add(parser.getText()); system.debug('this is the Username list:

Document ID: bigscience-data/roots_en_no_code_stackexchange/1495630?seg=para_128_8&seg_id=1

Language: en

Willen,REDACTED EMAIL globalcitizen,REDACTED EMAIL gmaxwell,REDACTED EMAIL graingert,REDACTED EMAIL graingert,REDACTED EMAIL Greg Griffith,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Maxwell,REDACTED EMAIL Gregory Sanders,REDACTED EMAIL Gregory Sanders,REDACTED EMAIL Gregory Sanders,REDACTED EMAIL Gregory Sanders,REDACTED EMAIL Greg Walker,REDACTED EMAIL grimd34th,REDACTED EMAIL grimd34th,REDACTED EMAIL gubatron,REDACTED EMAIL Guillermo Céspedes Tabárez,REDACTED EMAIL Haakon Nilsen,REDACTED EMAIL HaltingState,REDACTED EMAIL Hampus Sjöberg,REDACTED EMAIL Han Lin Yap,REDACTED EMAIL Han Lin Yap,REDACTED EMAIL harry,REDACTED EMAIL HarryWu,REDACTED EMAIL Heath,REDACTED EMAIL Hector Jusforgues,REDACTED EMAIL himynameismartin,REDACTED EMAIL HostFat,REDACTED EMAIL Huang Le,REDACTED EMAIL Huang Le,REDACTED EMAIL Ian Carroll,REDACTED EMAIL Ian Kelling,REDACTED EMAIL Ian T,REDACTED EMAIL imharrywu,REDACTED EMAIL instagibbs,REDACTED EMAIL instagibbs,REDACTED EMAIL instagibbs,REDACTED EMAIL instagibbs,REDACTED EMAIL instagibbs,REDACTED EMAIL Irving Ruan,REDACTED EMAIL Isidoro Ghezzi,REDACTED EMAIL isle2983,REDACTED EMAIL isle2983,REDACTED EMAIL Ivan Pustogarov,REDACTED EMAIL Ivan Pustogarov,REDACTED EMAIL Ivo van der Sangen,REDACTED EMAIL Ivo van der Sangen,REDACTED EMAIL Jack Grigg,jack@z.cash Jacob Welsh,REDACTED EMAIL Jacob Welsh,REDACTED EMAIL Jacob Welsh,REDACTED EMAIL Jakob Kramer,REDACTED EMAIL James Burkle,REDACTED EMAIL James Evans,REDACTED EMAIL James Evans,REDACTED EMAIL James O'Beirne,REDACTED EMAIL James O'Beirne,REDACTED EMAIL Jameson Lopp,REDACTED EMAIL Jameson Lopp,REDACTED EMAIL Jameson Lopp,REDACTED EMAIL Jameson Lopp,REDACTED EMAIL James White,REDACTED EMAIL Janne Pulkkinen,REDACTED EMAIL Janne Pulkkinen,REDACTED EMAIL Janne Pulkkinen,REDACTED EMAIL Jannes

Figure 2: PII leakage - reuslts for the query `gmail.com`. We indicate the redacted PII with green and pink treatment.

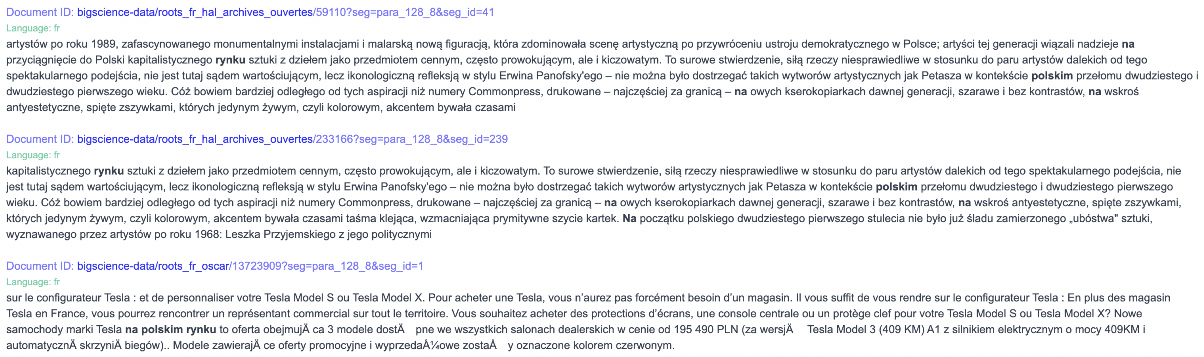
fed to the training process in equally sized batches (potentially with special tokens marking the end of a datapoint, like in the case of BLOOM). From the point of view of retrieval, however, each datapoint is considered a document—a discrete entity, associated with uniform metadata. It turns out the datapoints in ROOTS have vastly varying lengths - see Figure 1 for details. In order to be able to compare and rank documents, we make them more comparable by splitting them into roughly equally sized paragraphs and assign a unique ID to each paragraph.

Document Segmentation. We split documents into passages of 128 words each, with 8-word overlap between subsequent paragraphs. Overall, when talking about passages we mean the unit of text used during indexing. When referring to a document or a datapoint we mean a datapoint as it appears originally in one of the ROOTS datasets.

Unique Documents IDs. Each passage comes with an ID which uniquely identifies both the original datapoint and the passage within the datapoint. We adopt the following convention. First, we use the dataset name as defined on the Hugging Face hub, followed by a slash and an ID of the datapoint form which the given dataset came from. We follow this with a question mark introducing two parameters allowing us to uniquely identify the passage within the document. The `seg` parameter describes the segmentation strategy used, and the `seg_id` parameter indicates the index of the given passage under the specified segmentation strategy. E.g. `bigscience-data/roots_en_oscar/54676994?seg=para_128_8&seg_id=5` indicates the fifth passage obtained by splitting the document into 128-word passages with 8-word overlap. The document in question is the 54676994-th document in the `roots_en_oscar` dataset.

PII redaction During preliminary experiments on the ROOTS corpus, OSCAR [11] has been identified as a source of a large amount of documents containing personally identifiable information or PII. A regular-expression-based PII redaction script[3] has been applied to OSCAR prior to BLOOM training. However, the datasets themselves still contain unredacted text. In order to avoid leaking PII in our search engine, we apply an improved variant of the BigScience PII redaction script on the backend side and display results with PII redacted in a visible way - this way one can inspect the data and observe the problem, but personal information are predominantly removed.

[3] `https://github.com/bigscience-workshop/data-preparation/tree/main/preprocessing/training/02_pii`



Document ID: bigscience-data/roots_fr_hal_archives_ouvertes/59110?seg=para_128_8&seg_id=41

Language: fr

artystów po roku 1989, zafascynowanego monumentalnymi instalacjami i malarską nową figuracją, która zdominowała scenę artystyczną po przywróceniu ustroju demokratycznego w Polsce; artyści tej generacji wiązali nadzieje **na** przyciągnięcie do Polski kapitalistycznego **rynku** sztuki z dziełem jako przedmiotem cennym, często prowokującym, ale i kiczowatym. To surowe stwierdzenie, siłą rzeczy niesprawiedliwe w stosunku do paru artystów dalekich od tego spektakularnego podejścia, nie jest tutaj sądem wartościującym, lecz ikonologiczną refleksją w stylu Erwina Panofsky'ego – nie można było dostrzegać takich wytworów artystycznych jak Petasza w kontekście **polskim** przełomu dwudziestego i dwudziestego pierwszego wieku. Cóż bowiem bardziej odległego od tych aspiracji niż numery Commonpress, drukowane – najczęściej za granicą – **na** owych kserokopiarkach dawnej generacji, szarawe i bez kontrastów, **na** wskroś antyestetyczne, spięte zszywkami, których jedynym żywym, czyli kolorowym, akcentem bywała czasami

Document ID: bigscience-data/roots_fr_hal_archives_ouvertes/233166?seg=para_128_8&seg_id=239

Language: fr

kapitalistycznego **rynku** sztuki z dziełem jako przedmiotem cennym, często prowokującym, ale i kiczowatym. To surowe stwierdzenie, siłą rzeczy niesprawiedliwe w stosunku do paru artystów dalekich od tego spektakularnego podejścia, nie jest tutaj sądem wartościującym, lecz ikonologiczną refleksją w stylu Erwina Panofsky'ego – nie można było dostrzegać takich wytworów artystycznych jak Petasza w kontekście **polskim** przełomu dwudziestego i dwudziestego pierwszego wieku. Cóż bowiem bardziej odległego od tych aspiracji niż numery Commonpress, drukowane – najczęściej za granicą – **na** owych kserokopiarkach dawnej generacji, szarawe i bez kontrastów, **na** wskroś antyestetyczne, spięte zszywkami, których jedynym żywym, czyli kolorowym, akcentem bywała czasami taśma klejąca, wzmacniająca prymitywne szycie kartek. **Na** początku polskiego dwudziestego pierwszego stulecia nie było już śladu zamierzonego „ubóstwa" sztuki, wyznawanego przez artystów po roku 1968: Leszka Przyjemskiego z jego politycznymi

Document ID: bigscience-data/roots_fr_oscar/13723909?seg=para_128_8&seg_id=1

Language: fr

sur le configurateur Tesla : et de personnaliser votre Tesla Model S ou Tesla Model X. Pour acheter une Tesla, vous n'aurez pas forcément besoin d'un magasin. Il vous suffit de vous rendre sur le configurateur Tesla : En plus des magasin Tesla en France, vous pourrez rencontrer un représentant commercial sur tout le territoire. Vous souhaitez acheter des protections d'écrans, une console centrale ou un protège clef pour votre Tesla Model S ou Tesla Model X? Nowe samochody marki Tesla **na polskim rynku** to oferta obejmujÄ ca 3 modele dostÄ   pne we wszystkich salonach dealerskich w cenie od 195 490 PLN (za wersjÄ   Tesla Model 3 (409 KM) A1 z silnikiem elektrycznym o mocy 409KM i automatycznÄ skrzyniÄ biegów).. Modele zawierajÄ ce oferty promocyjne i wyprzedaÅ¼owe zostaÅ   y oznaczone kolorem czerwonym.

Figure 3: Language contamination - we issue a query against the French index, however, the results are predominantly in Polish.

3. Findings

As stated above, the main motivation for creating the ROOTS search engine is to allow researchers to gain insights into the datasets used to train BLOOM. Some findings pertaining to PII leakage and language contamination that we've observed when testing the tool can be examined in Figure 2 and figure 3. We have also observed evidence of low quality text, e.g. racist slurs, sexually explicit language or hate speech—interestingly, they often come from datasets containing movie subtitles. On one hand, the nature of the data source introduces an extra layer of parenthesis around the controversial content—as readers we understand movie subtitles are less reliable as a knowledge source and may be consciously breaking standards of respectable communication. At the same tame, a language model trained on this data isn't provided with any metadata which would allow it to classify such datapoints as coming from a specific context and therefore make any judgements on the quality of the source.

4. Implementation

We host 13 sparse, BM25 [14] indices, built for all main languages and groups of languages in the ROOTS corpus using Pyserini [9]. We host the index server on a GCP instance. We use native Lucene[4] analyzers available via Pyserini API to perform text tokenization. Table 1 contains information on data and analyzers used to tokenize the text. We index the data using the following sample command.

```
python -m pyserini.index.lucene
    --collection JsonCollection \
    --input bigscience-data-pyserini/en/ \
    --index bigscience-data-index/en/ \
    --generator DefaultLuceneDocumentGenerator \
    --threads 64 \
    --storePositions \
    --storeDocvectors \
    --storeRaw \
    --language en
```

The ROOTS search tool UI allows people to search in a specific language, in all languages (then results are surfaced separately for each language) and to detect the query language on the backend side and then serve results accordingly. The language identification logic uses a FastText-based classifier [7] available on the Hugging Face hub. The user can control how many results they want to see. We apply PII redaction to all datasets on the backend side. We surface links to external URLs whenever available, and links to respective ROOTS dataset on

[4] https://lucene.apache.org/

the Hugging Face hub for each result. We enable flagging of suspicious results—in such case, we store the reports in the backend and may use them to inform future data filtering efforts. We use Gradio [1] frontend served via Hugging Face Spaces to host the demo. The front end code can be accessed here, the Spaces demo is available here and the Community is open for discussions here.

5. Next steps

The current tool is heavily influenced by the UX of popular search engines. In the future we intend to review classic corpus analysis tools for ideas of different possible treatments. We would like to add more quantitative information, e.g. term frequency information, number of hits, co-occurrence statistics and others. We're also review a possibility of adding an exact search retrieval (potentially supported by different backend). We welcome the feedback and suggestions from discussions in the Community tab of the demo. We're also pursuing a spin-off collaboration with Pyserini to make large scale indexing and hosting of textual data even more seamless.

6. Acknowledgements

All throughout building the tool, the project was supported by the amazing folks at the BigScience Data Visualization Working Group, especially Christopher Akiki, Anna Rogers, Gerard Dupont and Yacine Jernite. The project wouldn't be the same without insights from the Pyserini team—Jimmy Lin, Odunayo Ogundepo and Xinyu (Crystina) Zhang. Big thanks to the Gradio team, especially Pete Allen for their support on the frontend side, and the Hugging Face infra team for answering my questions regarding hosting the tool.

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A. Appendix

A list of all datasets available on the Hugging Face hub, indexed and available in the ROOTS search tool.

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bigscience-data/roots_code_stackexchange
bigscience-data/roots_en_book_dash_books
bigscience-data/roots_en_multi_un_2
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bigscience-data/roots_indic-ta_open_subtitles
bigscience-data/roots_indic-ta_opus100
bigscience-data/roots_indic-ta_pib
bigscience-data/roots_indic-ta_samanantar
bigscience-data/roots_indic-ta_ted_talks_iwslt
bigscience-data/roots_indic-ta_wikibooks
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bigscience-data/roots_nigercongo-zu_aggregated
bigscience-data/roots_pt_brwac
bigscience-data/roots_pt_open_subtitles
bigscience-data/roots_pt_opus100
bigscience-data/roots_pt_oscar
bigscience-data/roots_pt_project_gutenberg
bigscience-data/roots_pt_pseudocrawl-filtered_672_pt_globalvoices_org
bigscience-data/roots_pt_qedcorpus
bigscience-data/roots_pt_scielo
bigscience-data/roots_pt_ted_talks_iwslt
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bigscience-data/roots_pt_wikivoyage
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bigscience-data/roots_vi_binhvq_news_corpus
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bigscience-data/roots_vi_vinbigdata_monolingual_vlsp_2020
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bigscience-data/roots_vi_wikibooks
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bigscience-data/roots_vi_wikiquote
bigscience-data/roots_vi_wikisource
bigscience-data/roots_vi_wikivoyage
bigscience-data/roots_vi_wiktionary
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bigscience-data/roots_zh-tw_wikipedia
bigscience-data/roots_zh_du_reader
bigscience-data/roots_zh_multi_un_2
bigscience-data/roots_zh_open_subtitles
bigscience-data/roots_zh_project_gutenberg
bigscience-data/roots_zh_pseudocrawl-filtered_503_www_zaobao_com_sg
bigscience-data/roots_zh_pseudocrawl-filtered_674_ai_baidu_com
bigscience-data/roots_zh_ted_talks_iwslt
bigscience-data/roots_zh_uncorpus
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bigscience-data/roots_zhs_oscar
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bigscience-data/roots_zhs_qedcorpus
bigscience-data/roots_zht_qedcorpus
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