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Extending *defoe* for the Efficient Analysis of Historical Texts at Scale

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***Abstract*—This paper presents the new facilities provided in *defoe*, a parallel toolbox for querying a wealth of digitised newspapers and books at scale. *defoe* has been extended to work with further Natural Language Processing () tools such as the *Edinburgh Geoparser*, to store the preprocessed text in several storage facilities and to support different types of queries and analyses. We have also extended the collection of XML schemas supported by *defoe*, increasing the versatility of the tool for the analysis of digital historical textual data at scale. Finally, we have conducted several studies in which we worked with humanities and social science researchers who posed complex and interested questions to large-scale digital collections. Results shows that *defoe* allows researchers to conduct their studies and obtain results faster, while all the large-scale text mining complexity is automatically handled by *defoe*.**

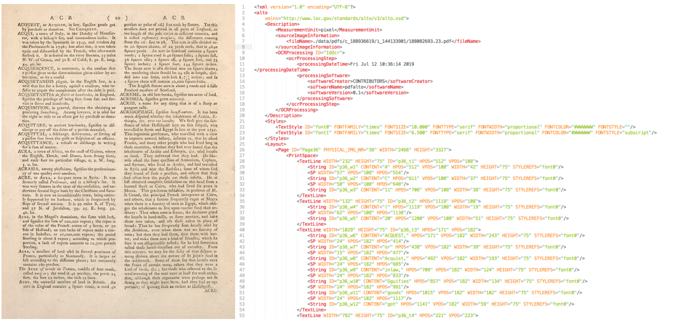
***Index Terms*—text mining, distributed queries, High-Performance Computing, XML schemas, digital tools, digitised primary historical sources, humanities research**

I. Introduction

Libraries, archives, and museums [1], [2] offer a wide range of digital collections of textual resources, which have the potential to provide an invaluable resource to historians, humanities, and computational linguistics researchers. However, enabling these users to take advantage of advanced computing environments, analytics frameworks, and text mining techniques to mine large scale digital collections effectively remains challenging [3].

We have contributed to this area by creating *defoe* [4] [1], a scalable, parallel and portable toolbox which aims to enable the analysis of digital historical datasets in a consistent way and returns results for further analysis and interpretation. *defoe* can be used in any HPC cluster or cloud platform, as it has been designed to avoid imposing any specific constraints on the compute environment.

Another aim of the design of *defoe* was to make it flexible so it can consume historical textual collections scanned via OCR from a variety of XML schemas. In this work we have added a new XML schema in *defoe* to extract the knowledge from the data collections offered by the National Library of Scotland[2] (NLS), so that the system now supports four different XML schemas. Among the digital collections offered by NLS, we have the *Encyclopaedia Britannica* (see Figure 1).



A C R (20) A C R

ACQUEST, or Acquist, in law, ſignifies goods got by purchaſe or donation. See Conquest.

ACQUI, a town of Italy, in the Dutchy of Montferrat, with a biſhop's ſee, and commodious baths. It was taken by the Spaniards in 1745, and retaken by the Piedmonteſe in 1746; but after this, it was taken again and diſmantled by the French, who afterwards forſook it. It is ſeated on the river Bormio, 25 miles N. W. of Genoa, and 30 S. of Caſal, 8. 30. E. long. 44. 40. lat.

ACQUIESCENCE, in commerce, is the conſent that a perſon gives to the determination given either by arbitration, or by a conſul.

ACQUIETANDIS *plegiis*, in the Engliſh law, is a writ that lies for a ſurety, againſt a creditor, who refuſes to acquit the complainant after the debt is paid.

ACQUIETANTIA *de ſhiris et hundredis*, in England, ſignifies the privilege of being free from ſuit and ſervice in ſhires and hundreds.

ACQUISITION, in general, denotes the obtaining or procuring ſomething. Among lawyers, it is uſed for the right or title to an eſtate got by purchaſe or donation.

ACQUITARE, in ancient law-books, ſignifies to diſcharge or pay off the debts of a perſon deceaſed.

ACQUITTAL, a diſcharge, deliverance, or ſetting of a perſon free from the guilt or ſuſpicion of an offence.

ACQUITTANCE, a releaſe or diſcharge in writing for a ſum of money.

ACRA, a town of Africa, on the coaſt of Guinea, where the Engliſh, Dutch, and Danes, have ſtrong forts, and each fort its particular village, 0. 2. W. long. 5. 0. lat.

ACRASIA, among phyſicians, ſignifies the predominancy of one quality over another.

ACRE, or Acra, a ſea-port town in Syria. It was formerly called *Ptolemais*, and is a biſhop's ſee. It was very famous in the time of the cruſadoes, and underwent ſeveral ſieges both by the Chriſtians and Saracens. It is now an inconſiderable town, being entirely ſupported by its harbour, which is frequented by ſhips of ſeveral nations. It is 20 miles S. of Tyre, and 37 N. of Jeruſalem, 39. 25. E. long. 32. 40. lat.

Acre, in the Mogul's dominions, the ſame with lack, and ſignifies the ſum of 100,000 rupees; the rupee is of the value of the French crown of 3 livres, or 30 ſols of Holland; an 100 lacks of rupees make a couron in Indoſtan, or 10,000,000 rupees; the pound Sterling is about 8 rupees; according to which proportion, a lack of rupees amounts to 12,500 pounds Sterling.

Acre, a meaſure of land uſed in ſeveral provinces of France, particularly in Normandy. It is larger or leſs according to the different places; but commonly contains 160 perches.

The Acre *of woods in France*, conſiſts of four roods, called *vergées*; the rood is 40 perches, the perch 24 feet, the foot 12 inches, the inch 12 lines.

Acre, the univerſal meaſure of land in Britain. An acre in England contains 4 ſquare roods, a rood 40 perches or poles of 16½ feet each by ſtatute. Yet this meaſure does not prevail in all parts of England, as the length of the pole varies in different counties, and is called *cuſtomary meaſure*, the difference running from the 16½ feet to 28. The acre is alſo divided into 10 ſquare chains, of 22 yards each, that is 4840 ſquare yards. An acre in Scotland contains 4 ſquare roods; 1 ſquare rood is 40 ſquare falls; 1 ſquare fall, 36 ſquare ells; 1 ſquare ell, 9 ſquare feet, and 73 ſquare inches; 1 ſquare foot, 144 ſquare inches. The Scots acre is alſo divided into 10 ſquare chains; the meaſuring chain ſhould be 24 ells in length, divided into 100 links, each link $8\frac{22}{25}$ inches; and ſo 1 ſquare chain will contain 10,000 ſquare links.

The Engliſh ſtatute acre is about 3 roods and 6 falls ſtandard meaſure of Scotland.

ACREME, in old law-books, ſignifies ten acres of land.

ACRIBEIA, ſignifies great accuracy.

ACRID, a name for any thing that is of a ſharp or pungent taſte.

ACRIDOPHAGI, ſignifies *locuſt-eaters*. It has been much diſputed whether the inhabitants of Arabia, Ethiopia, &c. ever eat locuſts. We ſhall give the ſubſtance of what Haſſelquiſt ſays on this ſubject, who travelled in Syria and Egypt ſo late as the year 1752. This ingenious gentleman, who travelled with a view to improve natural hiſtory, informs us, that he aſked Franks, and many other people who had lived long in theſe countries, whether they had ever heard that the inhabitants of Arabia and Ethiopia, &c. uſed locuſts as food. They anſwered that they had. He likewiſe aſked the ſame queſtion of Armenians, Cophtes, and Syrians, who lived in Arabia, and had travelled in Syria and near the Red-ſea; ſome of whom ſaid they heard of ſuch a practice, and others that they had often ſeen the people eat theſe inſects. He at laſt obtained complete ſatiſfaction on this head from a learned ſheck at Cairo, who had lived ſix years in Mecca. This gentleman told him, in preſence of M. le Grand, the principal French interpreter at Cairo, and others, that a famine frequently rages at Mecca when there is a ſcarcity of corn in Egypt, which obliges the inhabitants to live upon coarſer food than ordinary: That when corn is ſcarce, the Arabians grind the locuſts in hand-mills, or ſtone mortars, and bake them into cakes, and uſe theſe cakes in place of bread: That he has frequently ſeen locuſts uſed by the Arabians, even when there was no ſcarcity of corn; but then they boil them, ſtew them with butter, and make them into a kind of fricaſſee, which he ſays is not diſagreeably taſted; for he had ſometimes taſted theſe locuſt-fricaſſees out of curioſity. From this account, we may ſee the folly of that diſpute among divines about the nature of St John's food in the wilderneſs. Some of them ſay that locuſts were the fruits of certain trees, others that they were a kind of birds, &c.; but thoſe who adhered to the literal meaning of the text were at leaſt the moſt orthodox, although their arguments were perhaps not ſo ſtrong as they might have been, had they had an opportunity of quoting ſuch an author as Haſſelquiſt.

ACRI-

```xml
<?xml version="1.0" encoding="UTF-8"?>
<alto
    xmlns="http://www.loc.gov/standards/alto/v3/alto.xsd">
    <Description>
        <MeasurementUnit>pixel</MeasurementUnit>
        <sourceImageInformation>
            <fileName>./data/pdfs/c_188936619/i_144133901/188082693.23.pdf</fileName>
        </sourceImageInformation>
        <OCRProcessing ID="IdOcr">
            <ocrProcessingStep>
                <processingDateTime>Fri Jul 12 10:36:14 2019
</processingDateTime>
                <processingSoftware>
                    <softwareCreator>CONTRIBUTORS</softwareCreator>
                    <softwareName>pdfalto</softwareName>
                    <softwareVersion>0.1</softwareVersion>
                </processingSoftware>
            </ocrProcessingStep>
        </OCRProcessing>
    </Description>
    <Styles>
        <TextStyle ID="font0" FONTFAMILY="times" FONTSIZE="10.000" FONTTYPE="serif" FONTWIDTH="proportional" FONTCOLOR="#WWWWWW" FONTSTYLE=""/>
        <TextStyle ID="font1" FONTFAMILY="times" FONTSIZE="6.500" FONTTYPE="serif" FONTWIDTH="proportional" FONTCOLOR="#WWWWWW" FONTSTYLE="subscript"/>
    </Styles>
    <Layout>
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                    <String ID="p36_w1" CONTENT="A" HPOS="512" VPOS="108" WIDTH="42" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="57" VPOS="108" HPOS="554"/>
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                    <SP WIDTH="58" VPOS="108" HPOS="648"/>
                    <String ID="p36_w3" CONTENT="11" HPOS="706" VPOS="108" WIDTH="38" HEIGHT="75" STYLEREFS="font0"/>
                </TextLine>
                <TextLine WIDTH="132" HEIGHT="75" ID="p36_t2" HPOS="1119" VPOS="108">
                    <String ID="p36_w4" CONTENT="(" HPOS="1119" VPOS="108" WIDTH="19" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="62" VPOS="108" HPOS="1138"/>
                    <String ID="p36_w5" CONTENT="20" HPOS="1200" VPOS="108" WIDTH="51" HEIGHT="75" STYLEREFS="font0"/>
                </TextLine>
                <TextLine WIDTH="1029" HEIGHT="75" ID="p36_t3" HPOS="171" VPOS="182">
                    <String ID="p36_w6" CONTENT="ACQUEST," HPOS="171" VPOS="182" WIDTH="243" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="24" VPOS="182" HPOS="414"/>
                    <String ID="p36_w7" CONTENT="or" HPOS="438" VPOS="182" WIDTH="39" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="15" VPOS="182" HPOS="477"/>
                    <String ID="p36_w8" CONTENT="Acquist," HPOS="492" VPOS="182" WIDTH="193" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="24" VPOS="182" HPOS="685"/>
                    <String ID="p36_w9" CONTENT="inlaw," HPOS="709" VPOS="182" WIDTH="124" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="24" VPOS="182" HPOS="833"/>
                    <String ID="p36_w10" CONTENT="Gguifies" HPOS="857" VPOS="182" WIDTH="134" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="24" VPOS="182" HPOS="991"/>
                    <String ID="p36_w11" CONTENT="goods" HPOS="1015" VPOS="182" WIDTH="102" HEIGHT="75" STYLEREFS="font0"/>
                    <SP WIDTH="24" VPOS="182" HPOS="1117"/>
                    <String ID="p36_w12" CONTENT="got" HPOS="1141" VPOS="182" WIDTH="59" HEIGHT="75" STYLEREFS="font0"/>
                </TextLine>
                <TextLine WIDTH="792" HEIGHT="75" ID="p36_t4" HPOS="221" VPOS="223">
```

Fig. 1: Page 36 of the First Edition of the *Encyclopaedia Britannica* (Volume 1), and its corresponding XML file.

Working with domain researchers we discovered key functionalities missing from *defoe*. For example, it did not provide support for i) storing ingested and preprocessed data, ii) running several text-mining queries at once, iii) running queries across different XML schemas, among others. In this paper we have investigated how to extend *defoe*, so it supports the needs of the research communities by enabling a better complex

[1] https://github.com/defoe-code

[2] https://data.nls.uk/

analysis of digital datasets at scale. The new contributions of this work are:

- Supporting the ingestion of NLS digital collections.
- Employing new techniques to mitigate OCR errors
- Integrating geoparsing capabilities
- Extracting commonalities across digital collections schemas
- Storing pre-processed data in different storage solutions
- Providing different query and analysis modalities.

We demonstrate the feasibility and benefits of this work using eight case studies, two computer infrastructures, and four digital collections.

The remainder of the paper is structured as follows. Section II presents *defoe* background and Section III reviews relevant text analysis tools. Section IV describes the new *defoe* functionalities. Section V details the features of the computer infrastructures used in this work. Section VI describes the use cases conducted. We conclude with a summary of achievements and outline future work.

II. Background

This section gives an overview of our previous work on *defoe* [4], providing the necessary background for the functionalities presented in Section IV.

defoe is a Python toolbox that uses Apache Spark [5], an open-source distributed HPC framework for large-scale data processing. Spark *Resilient Distributed Datasets (RDD)* are the fundamental data structures of Apache Spark, which is an immutable distributed collection of objects partitioned across cluster nodes.

The historical textual collections we consider can have different XML schemas describing either the structure of a digital document or the actual textual content, depending on the OCR scanning technique employed. All of these schemas are slightly different from each other, and none of them is universally used. Therefore, we initially created three object models (*PAPERS*, *NZPP* and *ALTO*) to map the physical representations and XML schemas. These allow *defoe* to ingest digital collections into Spark RDDs, which is the only requirement to select the appropriate object model the digital collection to analyse is mapped onto. This means that we could only ingest collections that share the same object model at the same time.

Previously, in the first version of *defoe*, we provided *on-the-fly single query analysis*, which consisted of 1) ingesting a digital collection (by using the corresponding object model) into RDDs in memory; 2) pre-processing data; 3) running a single text mining query in parallel; and 4) returning results as YAML files. These four steps (we refer to them as the *text analysis pipeline* – see Figure 4) are repeated every time we want to run a text mining query over one or several collections.

All *defoe* text mining queries are based on a number of operations (e.g. `filter`, `flatMap`, `map`, `reduce`, etc.) that are combined to perform text mining analyses. Figure 2 shows as an implementation example, the `total_pages` query, in which a `flatMap operation` is applied to an archive to return the list of documents it contains (e.g. volumes, books). For each document, the `map operation` extracts the number of pages, gathering the total number of documents (volumes, books) and the total number of pages within those.

```
def do_query(archives, config_file=None, logger=None, \
                                             context=None):
    # [archive, archive, ...]
    documents = archives.flatMap(lambda archive:\
                                  list(archive))
    # [num_pages, num_pages, ...]
    num_pages = documents.map(lambda document: \
                                    document.num_pages)
    result = [documents.count(), num_pages.reduce(add)]
    return {"num_documents": result[0],\
            "num_pages": result[1]}
```

Fig. 2: *defoe* `total_pages query`: Iterates through archives and counts the total number of documents (e.g. volume, book etc) and total number of pages.

As an example, we run this query using the six volumes of the 1st Edition of the *Encyclopaedia Britannica* (see Figure 3).

```
Result:
num_documents: 6
num_pages: 5462
```

Fig. 3: *defoe* `total_pages query` results using the six volumes of the 1st edition of the *Encyclopaedia Britannica*. This archive compromises six documents, one per volume.

defoe was complemented with *defoe visualisation*, a repository of Jupyter notebooks enabling researchers to visualise and explore further the results obtained.

III. Related Work

There are other computational text analysis tools that allow scholars to explore their texts and perform textual analysis. Some of the most relevant among those include:

- *Voyant* [6][3] is a web-based, dashboard-style tool that allows users to upload a corpus and visualize patterns in various ways. For instance, users can experiment with colorful word clusters that represent word frequency and visualize how specific words and phrases appear across texts in line graphs.
- *Mallet* [7] is a machine learning software program that is used through the command line with Python. Though it requires some technical skill to install and run, it can produce powerful results by generating ‘topics’, or lists of words that frequently appear together in corpora.
- *Natural language toolkit* (NLTK) [8] is a suite of Python tools that allows users to analyze human language data using classification, tokenizing, tagging, and more. Though it requires some technical expertise to run, it can be very useful for both teaching and analysis.
- *spaCy* [9] is an open-source library for advanced natural language processing in Python. It is designed specifically

[3] https://voyant-tools.org/

for production use and helps build applications that process large volumes of text. Some of the features provided by *spaCy* are: Tokenization, Part-of-Speech (PoS) Tagging, Text Classification and Named Entity Recognition (NER).

- *Google N-Grams* [10] [4] allows users to plot single words and short phrases over time in a large subset (5 million books) of the corpus.
- The *Stanford Natural Language Processing Group* [5] provides statistical NLP, deep learning NLP, and rule-based NLP tools for major computational linguistics problems, which can be incorporated into applications with human language technology needs. These packages are widely used in industry, academia, and government.
- *Weka* [11] is Java-based data mining, visualization, and machine learning software. The algorithms can either be applied directly to a dataset or called from your own Java code. *Weka* contains tools for data pre-processing, classification, regression, clustering, association rules, and visualization.

defoe complements these tools, as it has been designed to analyse digital historical texts. With a single command-line, users indicate a directory(ies) containing the XML files describing a collection(s), and *defoe* analyses them in parallel automatically.

IV. New functionalities

The main improvements we have implemented set across the *text analysis pipeline* mentioned in Section II and the *defoe* query submission and analysis systems (see Figure 4). The following subsections detail each of them.

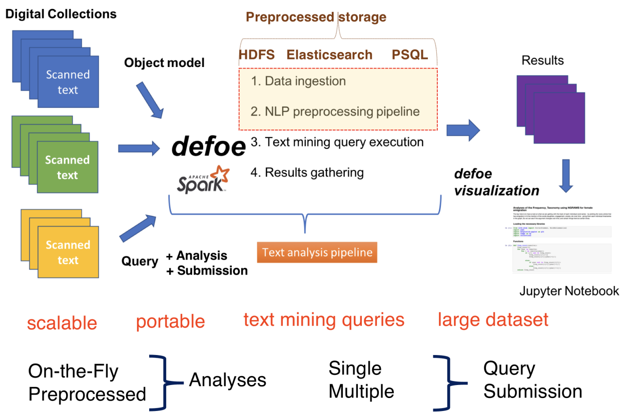


Fig. 4: Overview of *defoe*.

A. Ingestion of NLS digital collections

The NLS Digital Scholarship Service [6], has published 19 different digital textual collections. The *Encyclopaedia Britannica*, the *Gazetteers of Scotland*, or the *Chapbooks printed in Scotland* are three of these. They use the same two XML schemas in all their collections: METS XML schema[7] for descriptive, structural, technical and administrative metadata; and ALTO XML schema[8] for encoding OCR text.

Each NLS digital collection (archive) usually compromises several volumes or books. For example, the *Encyclopaedia Britannica* has 195 volumes, and each of them has a METS XML file. Then, for each of those volumes, it provides an ALTO XML and one image file per page. These make up a total of 195 METS files, 155,388 ALTO XML files, and 155,388 image files for the entire collection.

In our previous work, we created an *ALTO* object model to ingest METS and ALTO XMLS files. We used this object model to ingest the *British Library Books* and *Find My Past* collections. However, the NLS METS and ALTO XML schemas have some differences from those: i) they employ a different naming of documents and namespaces that affects their XML files; ii) the XML schemas provide a larger number of attributes. To accommodate these, we created a new object model, called *NLS*. See Figure 5.

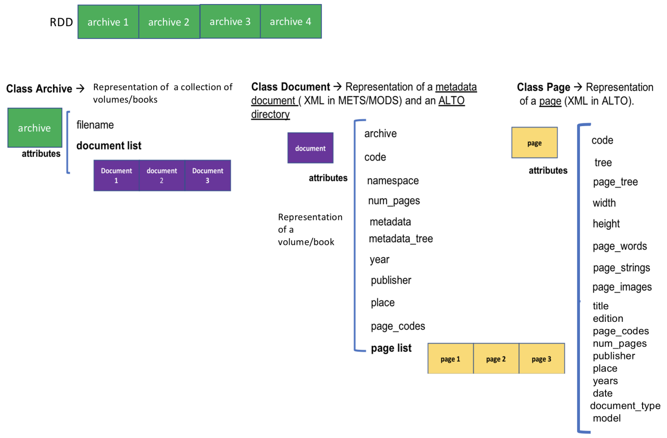


Fig. 5: New *NLS* object model. This allows *defoe* to ingest NLS digital collections into Spark RDDs.

The new *NLS* object model is added to our previous collection of object models [4]. We have used it to analyse the *Encyclopaedia Britannica*, the *Gazetteers of Scotland*, and the *Chapbooks printed in Scotland*, as described in Section VI. Note that this object model can be used to analyse any of the other digitised collections offered by NLS.

B. Mitigation of OCR errors

Another significant improvement over previous versions of the tool has been the mitigation of two types of optical character recognition (OCR) errors. To do so, we updated the NLP preprocessing pipeline by adding a new cleaning step after each sentence has been tokenised. See Figure 6.

This new step employs two techniques, described in [12], to mitigate the 'long-S' and the line-break hyphenation OCR errors. In most works printed before about 1800 two forms

[4] https://books.google.com/ngrams
[5] https://nlp.stanford.edu/
[6] https://data.nls.uk/data/digitised-collections/
[7] http://www.loc.gov/standards/mets/
[8] https://www.loc.gov/standards/alto/

of the lower-case ‘s’ were used. One was the ‘s’ that is still in use today; the other was the ‘long-S’, a character which looks like ‘f’ without the right-hand part of its crossbar. These ‘long-S’ characters often generate OCR errors where they are mistaken for ‘f’ characters, resulting in misspellings (e.g. ‘Congress’ misspelled as ‘Congrefs’). Regarding hyphenation, the OCR scanned text usually preserves the line breaks from the original paper, which include hyphenated words (e.g. ‘de-partment’). However, it is still desirable to remove the hyphen (e.g. department) in order to increase text mining accuracy. Both techniques are able to detect and fix automatically both issues, increasing the quality of tokens generated.

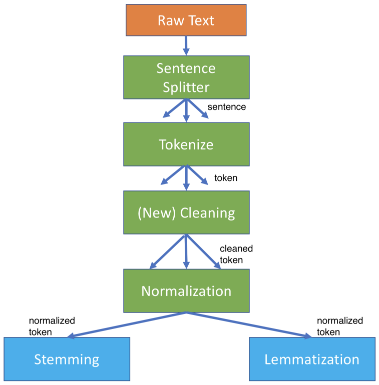


Fig. 6: Updated *defoe* NLP pre-processing pipeline.

Finally, after cleaning and normalising each token, we apply stemming and lemmatisation. Details of other steps of this pipeline can be found in [4].

C. DCOM: defoe Common Object Model

One of the drawbacks of the previous tool was only being able to run queries across collections that share exactly the same XML schemas, and therefore use the same object model. To remove this barrier and allowing users to run queries across collections, independently of their XML schemas, we identified and extracted commonality across the four object models (see Section IV-A for more details) currently supported. Following this, we created a new model with these common attributes. Table I contains a description of each *DCOM* attribute and an example of mapping an *Encyclopaedia Britannica* page to *DCOM*.

In order to map digital collections to our new common object model, we have created a special query called `DCOM_mapping` query (see Figure 7). This query ingests a collection using the appropriate object model (e.g. *NLS*, *PAPERS*, *NZPP*, *ALTO*) into Spark RDDs, pre-processes the text of each of the text units of the collection, maps them as *DCOM* objects, and stores them in one of our storage solutions.

Attribute	Description, Options and Examples
Title	Title of the collection Example: *Encyclopaedia Britannica*
Subtitle	Subtitle of the collection Example: *Null*
Edition	Edition of the collection Example: *Seventh edition,Volume 13, LAB-Magnetism*
Authors	Authors related with the collection Example: *Dugald Stewart, Sir James Mackin-tosh, etc ...*
Publishers	Publishers of the collection Example: *A. & C. Black*
Genre	Genre of the collection Example: *Null*
Topic	Topic of the collection Example: *Null*
Year	Year of the collection Example: *1842*
Place	Place of the collection Example: *Edinburgh*
Archive_Filename	Path of the collection Example: *../EB/193108323/*
Text_Unit	Unit representing each XML Options: Page, Article Example: *Page*
Source_Text_Filename	Path of each text unit Example: *alto/193202213.34.xml*
Text_Unit_ID	Id of the unit Example: *Page72*
Text_Unit_Tittle	Title of the text unit (e.g. Article title) Example: *None*
Num_Text_Unit	Number of text units of the collection Example: *810*
Type_Archive	Type of archive of the collection Options: Newspaper, Book, Volume Examples: *Volume*
Model	Object model used to ingest the collection Options: *PAPERS*, *NZPP*, *ALTO*, *NLS* Examples: *NLS.*
Source_Text_Raw	Raw text extracted from each text unit (XML) Example: *62 LANG Language, having lived ... , merely by considering the nature of speech, and the men- tal ...*
Source_Text_Clean	Cleaned text from each text unit (XML) Example: *62 LANG Language, having lived ...., merely by considering the nature of speech, and the mental ...*
Source_Text_Norm	Normalized text from each text unit (XML) Example: *lang language having lived ... merely by considering the nature of speech and the mental ...*
Source_Text_Lemma	Lemmatized text from each text unit (XML) Example: *lang language having ... merely by considering the nature of speech and the mental ...*
Source Text Stem	Stemmed text from each text unit (XML) Example: *lang languag have live ... mere by consid the natur of speech and the mental ..*
Num_Words	Number of words detected in the Source_Text_Raw Example: *1409*

TABLE I: Description of *DCOM* attributes, using examples from mapping page 72 of the Seventh Edition (Volume 13), of the *Encyclopaedia Britannica* [9] to *DCOM*. Note that some attributes for this example do not have values, as, for this particular collection, this information is not available in its original XML files.

Note that for each of the text units of a given collection, `DCOM_mapping` creates a new Spark RDD with a *DCOM* object in it. For example, the Volume 13 of the *Encyclopaedia*

[9] https://digital.nls.uk/encyclopaedia-britannica/archive/193108323#?c=0&m=0&s=0&cv=71&xywh=-348%2C-499%2C6940%2C5144

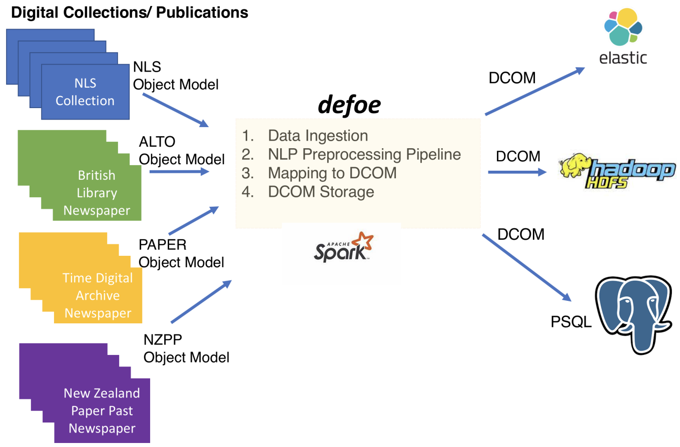


Fig. 7: Overview of `DCOM_mapping` query, which maps collections to *DCOM* and stores them in the selected storage facility.

Britannica has 810 pages, which means that our query has generated a list of 810 *DCOM-RDDs*. Once we have the collections represented with the same model, we can run queries across them, independently of their XML schemas.

D. DCOM Storage

The improved version of the tool provides additional solutions to store digital collections as *DCOM* objects:

- *Hadoop HDFS* file system [13]: Very often Apache Spark and Hadoop Clusters are installed together. Therefore, *Hadoop HDFS* is very often used in combination with Spark applications to write or read data to/from RDDs.
- *ElasticSearch* engine [14]: This popular engine provides storing and indexing facilities for structured or unstructured text, which enables fast searches.
- *PostgreSQL* (*PSQL*) database [15]: As a powerful, open source object-relational database system that uses and PSQL combines SQL with many features to safely store and scale data workloads.

These storage solutions bring different benefits to *defoe*. While many *Spark* applications use *Hadoop HDFS* for storing RDDs, *PSQL* is very popular among researchers. *ElasticSearch* offers additional functionalities with text data that complement *defoe* very well. We provide support for all of these by exporting *DCOM* objects to these formats, allowing users to chose which storage solution to use depending on their familiarity with them or availability in their computing facilities.

E. Query Submission and Analyses Types

Initially, *defoe* only supported *on-the-fly* analysis, ingesting and pre-processing data every time a query was submitted, and limited the analysis (performed in the same query submission) to collections that share the same XML schema.

We have now enabled *defoe* to run analyses using the pre-processed collections previously stored using any of the solutions listed in Section IV-D. We refer to this feature as *pre-processed* analysis, and it enables us to query collections without the necessity to re-ingest and pre-process data repeatedly across different XML schemas.

We have also improved the ability of *defoe* to run more than a single query at once. In the presented version, we can indicate a list with multiple text mining queries that we want to run using either of the two analyses previously described. With this new query submission modality, data is ingested once, and all queries indicated in the list are run against the data loaded in memory. This modality is very efficient when we already know what queries will be run on a collection.

F. Integrating the Edinburgh Geoparser

A further important improvement is the integration of *defoe* with the *Edinburgh Geoparser* [16] and *spaCy* NLP tools for automatically tagging place names in text and resolving them to their correct latitude and longitude coordinates or gazetteer entry. The *Edinburgh Geoparser* is a language processing tool designed to detect place name references in English text and ground them against an authoritative gazetteer, so that they can be plotted on a map. The available download on the *Edinburgh Geoparser* website[10] was developed for contemporary newspaper text but the Geoparser team has also adapted it to historical [17] and literary text [18].

The geoparser is implemented as a pipeline with two steps:

- *geotagging*, in which place name entities are identified, and
- *georesolution*, which grounds place name entities against locations contained in a gazetteer.

the available download on our website was developed for contemporary newspaper text but that the Geoparser team has also adapted to historical [1] and literary text [2].

With the integration of the *Edinburgh Geoparser* and *spaCY* we have added more ready-to-use text-mining analyses to *defoe*, and enabled parallel geoparsing of text data. We also support two different geoparsing methods by using different tokenization and NER techniques (the *geotagging* step above). These are:

- The original *Edinburgh Geoparser* for *geotagging* and *georesolution* of historical text.
- Using *spaCy* for *geotagging* in combination with *Edinburgh Geoparser georesolution*.

Our aim behind this new functionality was not only to provide a parallel geoparsing facility, but also to employ different tokenization and NER techniques. Such re-combining of techniques helped to develop more accurate geoparsing for historical text collections.

For each of the previous geoparsing methods, we created two different queries (`original_geoparser` for the first method and `spacy_georesolver` for the second one). Both queries work either loading the preprocessed clean stored text (using *Source_Text_Clean* attribute - see Table I) or directly ingesting the collections' XML files and executing the queries after the NLP pre-processing pipeline shown in Figure 6. Next, each query identifies entities by employing

[10] https://www.ltg.ed.ac.uk/software/geoparser/

a different *geotagging* technique. Finally, both queries apply *Edinburgh Geoparser georesolution* to place name entities.

G. *Further improvements*

We also improved other aspects of *defoe*, while we were working on the use cases presenting in Section VI. For example, we have doubled the number of text mining queries supported by *defoe*, offering now a total of 64. We have developed new Jupyter notebooks[11] for analyzing and visualizing the results obtained with the new *defoe* queries.

V. Compute Infrastructures

We have run the use cases presented in the next Section VI with the new updated *defoe* in two compute environmens:

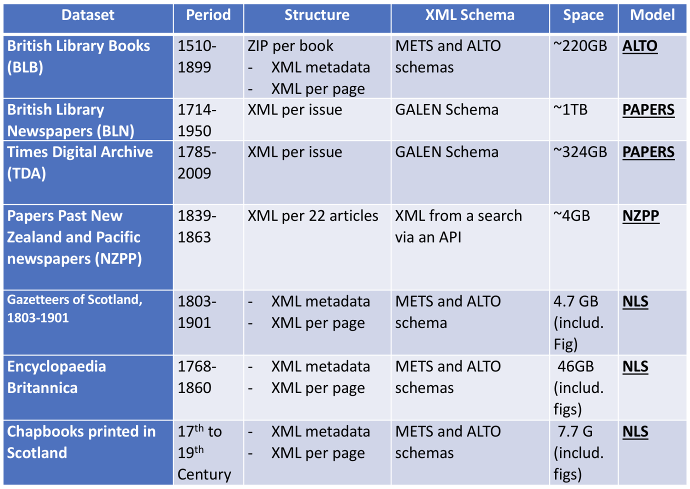
- *Cirrus* HPC-Cluster [12]: This environment uses a state-of-the art SGI ICE XA system with 280 compute nodes with Lustre as the file system and CentOS Linus as the OS, and Slurm to schedule jobs. *Cirrus* standard compute nodes contain two 2.1 GHz, 18-core Intel Xeon E5-2695 (Broadwell) series processors and 256 GB of memory with support for hyperthreading. This means that we can use up to 72 processes per node for running *defoe*. In our case, we used up to three nodes (216 processes), depending on the size of the collection to analyse and the cluster availability.
- *Google Cloud Platform* [13]: Offered by Google, it is a suite of cloud computing services (such as computers and hard disk drives, or virtual machines (VMs) that runs on the same infrastructure that Google uses internally for its end-user products. For this work, we have configured a Debian VM with 500GB of disk, 96 vCPU and 1.4 TB of memory.

Since *Apache Spark* is not available in *Cirrus* as a module, we have created a new set of scripts to provision an *Spark Cluster* on demand and for a specific period of time within a *slurm job*. It starts the Spark master, Spark workers, and registers all workers with the master [14]. We also have created another set of *slurm jobs* for running our text-mining analyses on the provisioned *Spark Cluster* [15]. *defoe* was installed in our `HOME` directory using a *conda* Python3 environment.

In the case of the *Google Cloud Platform*, we installed *Apache Spark* in the VM along with *defoe*, also using a *conda* Python3 environment. Once again, we have documented the full installation process [16] to provide full reproducibility.

VI. Use Cases

New *defoe* functionalities have been evaluated using a number of studies funded by the University of Edinburgh Centre for Data, Culture & Society (CDCS) Text Mining Lab [17]. In these studies, we worked with several humanities and social science researchers, using *defoe* to mine the *Times Digital Archive* (TDA) newspapers and the NLS collections displayed in Figure 8.



Dataset	Period	Structure	XML Schema	Space	Model
British Library Books (BLB)	1510-1899	ZIP per book - XML metadata - XML per page	METS and ALTO schemas	~220GB	**ALTO**
British Library Newspapers (BLN)	1714-1950	XML per issue	GALEN Schema	~1TB	**PAPERS**
Times Digital Archive (TDA)	1785-2009	XML per issue	GALEN Schema	~324GB	**PAPERS**
Papers Past New Zealand and Pacific newspapers (NZPP)	1839-1863	XML per 22 articles	XML from a search via an API	~4GB	**NZPP**
Gazetteers of Scotland, 1803-1901	1803-1901	- XML metadata - XML per page	METS and ALTO schema	4.7 GB (includ. Fig)	**NLS**
Encyclopaedia Britannica	1768-1860	- XML metadata - XML per page	METS and ALTO schemas	46GB (includ. figs)	**NLS**
Chapbooks printed in Scotland	17th to 19th Century	- XML metadata - XML per page	METS and ALTO schemas	7.7 G (includ. figs)	**NLS**

Fig. 8: Updated list of digital collections analysed with *defoe*. The last three rows are the new additions to this list.

In total, we conducted eight CDCS text mining studies [18]. We are describing three of them in the following subsections.

A. *Extracting articles within Encyclopaedia Brittanica*

As mentioned before, for each page of the *Encyclopaedia Britannica* (see Figure 8) we have an ALTO XML with the OCR recognized text. However, these do not tell us when an article of the encyclopaedia starts or when it finishes within pages. In this study we have focused on extracting the articles represented in the encyclopaedias, so they can be analysed independently without the surrounding text.

We have developed a new query, called `extract_articles_eb` for this end, which loads pages directly into memory from one of our storage solutions (using the *Source_Text_Clean* attribute - see Table I). Alternative, the query can also ingest the *Encyclopaedia Britannica* XML files into memory using the *NLS* object Model introduced in Section 5, and to pre-process the text of each page by applying the updated NLP pre-processing pipeline (see Figure 6). After the text in each page is cleaned and loaded in memory, the query detects in parallel the articles contained within each page by making use of page headers and text patterns. We have detected two types of articles with two different patterns at page level:

- Short articles we refer to as ’articles’: Usually presented by a *term* in the main text in uppercase, followed by a “,” (e.g. *ACQUEST,*) and then a description of the term (similar to an entry in a dictionary). This description is normally one or two paragraphs long, but of course there are exceptions. An example of a page containing ‘articles’ is shown in Figure 9

[11] https://github.com/defoe-code/defoe_visualization

[12] https://www.cirrus.ac.uk/

[13] https://cloud.google.com/

[14] https://github.com/defoe-code/CDCS_Text_Mining_Lab#1-spark-installation-steps

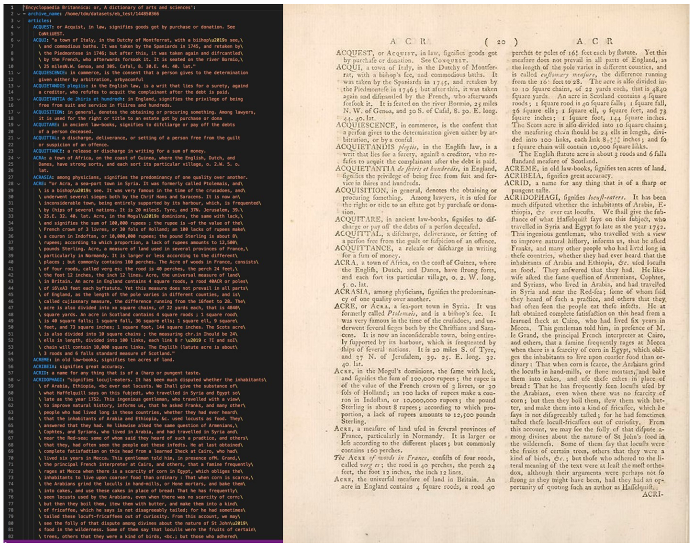
[15] https://github.com/defoe-code/CDCS_Text_Mining_Lab/blob/master/Round2.slurm

[16] https://github.com/defoe-code/defoe/blob/master/docs/setup-VM.md

[17] https://www.cdcs.ed.ac.uk/cdcs-text-mining-lab-call-projects

[18] https://github.com/defoe-code/CDCS_Text_Mining_Lab

- Long articles we refer to as ‘topics’: In this case, the encyclopaedia introduces a term in the header of a page (which is not the case for short articles). A ‘topic’ is typically described across several pages, often combining text, pictures, tables, etc. For example, the topic *Language* is described across 34 pages. An example of a page describing the *Language* topic is available online[19].



```
'Encyclopaedia Britannica: or, A dictionary of arts and sciences':
- archive_name: /home/tdm/datasets/eb_test/144850366
  articles:
    ACQUEST: or Acquist, in law, signifies goods got by purchase or donation. See
      CoNtiUEST.
    ACQUI: "a town of Italy, in the Dutchy of Montferrat, with a biihop\u2019s see,\
      \ and commodious baths. It was taken by the Spaniards in 1745, and retaken by\
      \ the Piedmontese in 1746; but after this, it was taken again and difrcantled\
      \ by the French, who afterwards forsook it. It is seated on the river Bormio,\
      \ 25 milesN.W. Genoa, and 30S. Cafal, 8. 30.E. 44. 40. lat."
    ACQUIESCENCE: in commerce, is the consent that a person gives to the determination
      given either by arbitration, orbyaconful
    ACQUIETANDIS plegiis: in the English law, is a writ that lies for a surety, againd
      a creditor, who refufes to acquit the complainant after the debt is paid.
    ACQUIETANTIA de Jhiris et hundredh: in England, signifies the privilege of being
      free from suit and service in fliires and hundreds.
    ACQUISITION: in general, denotes the obtaining or procuring something. Among lawyers,
      it is used for the right or title to an estate got by purchase or dona
    ACQUITARE: in ancient law-books, signifies to difcliarge or pay off the debts
      of a person deceased.
    ACQUITTAL: a discharge, deliverance, or setting of a person free from the guilt
      or suspicion of an offence.
    ACQUITTANCE: a release or discharge in writing for a sum of money.
    ACRA: a town of Africa, on the coast of Guinea, where the English, Dutch, and
      Danes, have strong sorts, and each sort its particular village, o. 2.W. 5. o.
      lat.
    ACRASIA: among physicians, signifies the predominancy of one quality over another.
    ACRE: "or Acra, a sea-port town in Syria. It was formerly called Ptolemais, and\
      \ is a bishop\u2019s see. It was very famous in the time of the crusadoes, and\
      \ underwent several sieges both by the Chrif Hans and Saracens. It is now an\
      \ inconsiderable town, being entirely supported by its harbour, which, is frequented\
      \ by (hips of several nations. It is 20 milesS. Tyre, and 37N. Jerusalem, 39.\
      \ 25.E. 32. 40. lat. Acre, in the Mogul\u2019s dominions, the same with lack,\
      \ and signifies the sum of 100,000 rupees ; the rupee is -of the value of the\
      \ French crown of 3 livres, or 30 fols of Holland; an 100 lacks of rupees make\
      \ a couron in Indoftan, or 10,000,000 rupees; the pound Sterling is about 8\
      \ rupees; according to which proportion, a lack of rupees amounts to 12,500\
      \ pounds Sterling. Acre, a measure of land used in several provinces of France,\
      \ particularly in Normandy. It is larger or less according to the different\
      \ places ; but commonly contains 160 perches. The Acre of woods in France, consists\
      \ of four roods, called verg es; the rood is 40 perches, the perch 24 feet,\
      \ the foot 12 inches, the inch 12 lines. Acre, the universal measure of land\
      \ in Britain. An acre in England contains 4 square roods, a rood 40ACR or poles\
      \ of i6\xA3 feet each byftatute. Yet this measure does not prevail in all parts\
      \ of England, as the length of the pole varies in different counties, and is\
      \ called cujiosnary measure, the difference running from the 16feet to 28. The\
      \ acre is also divided into xo square chains, of 22 yards each, that is 4840\
      \ square yards. An acre in Scotland contains 4 square roods ; 1 square rood\
      \ is 40 square falls; 1 square fall, 36 square ells; 1 square ell, 9 square\
      \ feet, and 73 square inches; 1 square foot, 144 square inches. The Scots acre\
      \ is also divided into 10 square chains ; the measuring chr.in Ihould be 24\
      \ ells in length, divided into 100 links, each link 8 r \u2019 c ?I and soI\
      \ chain will contain 10,000 square links. The Englilh (latute acre is about\
      \ 3 roods and 6 falls standard measure of Scotland."
    ACREME: in old law-books, signifies ten acres of land.
    ACRIBEIA: signifies great accuracy.
    ACRID: a name for any thing that is of a (harp or pungent taste.
    ACRIDOPHAGI: "signifies locujl-eaters. It has been much disputed whether the inhabitants\
      \ of Arabia, Ethiopia, <bc ever eat locusts. We Ihall give the substance of\
      \ what Haffelquill says on this fubjedt, who travelled in Syria and Egypt so\
      \ late as the year 1752. This ingenious gentleman, who travelled with a view\
      \ to improve natural history, informs us, that he asked Franks, and many other\
      \ people who had lived long in these countries, whether they had ever heard\
      \ that the inhabitants of Arabia and Ethiopia, &c. used locusts as food. They\
      \ answered that they had. He likewise alked the same question of Armenians,\
      \ Cophtes, and Syrians, who lived in Arabia, and had travelled in Syria and\
      \ near the Red-sea; some of whom said they heard of such a pradtice, and others\
      \ that they, had often seen the people eat these infedts. He at last obtained\
      \ complete fatisfadtion on this head from a learned Iheck at Cairo, who had\
      \ lived six years in Mecca. This gentleman told him, in presence ofM. Grand,\
      \ the principal French interpreter at Cairo, and others, that a famine frequently\
      \ rages at Mecca when there is a scarcity of corn in Egypt, which obliges the\
      \ inhabitants to live upon coarser food than ordinary : That when corn is scarce,\
      \ the Arabians grind the loculls in hand-mills, or Hone mortars, and bake them\
      \ into cakes, and use these cakes in place of bread: That he has frequently\
      \ seen locusts used by the Arabians, even when there was no scarcity of corn;\
      \ but then they boil them, itew them with butter, and make them into a kind\
      \ of fricaffee, which he says is not disagreeably tailed; for he had sometimes\
      \ tailed these locuft-fricaffees out of curiosity. From this account, we may\
      \ see the folly of that dispute among divines about the nature of St John\u2019\
      s food in the wilderness. Some of them say that loculls were the fruits of certain\
      \ trees, others that they were a kind of birds, <bc.; but those who adhered\
```

A C R (20) A C R

ACQUEST, or Acquiſt, in law, ſignifies goods got by purchaſe or donation. See Conqueſt.

ACQUI, a town of Italy, in the Dutchy of Montferrat, with a biſhop's ſee, and commodious baths. It was taken by the Spaniards in 1745, and retaken by the Piedmonteſe in 1746; but after this, it was taken again and diſmantled by the French, who afterwards forſook it. It is ſeated on the river Bormio, 25 miles N. W. of Genoa, and 30 S. of Caſal, 8. 30. E. long. 44. 40. lat.

ACQUIESCENCE, in commerce, is the conſent that a perſon gives to the determination given either by arbitration, or by a conſul.

ACQUIETANDIS *plegiis*, in the Engliſh law, is a writ that lies for a ſurety, againſt a creditor, who refuſes to acquit the complainant after the debt is paid.

ACQUIETANTIA *de ſhiris et hundredis*, in England, ſignifies the privilege of being free from ſuit and ſervice in ſhires and hundreds.

ACQUISITION, in general, denotes the obtaining or procuring ſomething. Among lawyers, it is uſed for the right or title to an eſtate got by purchaſe or donation.

ACQUITARE, in ancient law-books, ſignifies to diſcharge or pay off the debts of a perſon deceaſed.

ACQUITTAL, a diſcharge, deliverance, or ſetting of a perſon free from the guilt or ſuſpicion of an offence.

ACQUITTANCE, a releaſe or diſcharge in writing for a ſum of money.

ACRA, a town of Africa, on the coaſt of Guinea, where the Engliſh, Dutch, and Danes, have ſtrong forts, and each fort its particular village, o. 2. W. long. 5. o. lat.

ACRASIA, among phyſicians, ſignifies the predominancy of one quality over another.

ACRE, or Acra, a ſea-port town in Syria. It was formerly called *Ptolemais*, and is a biſhop's ſee. It was very famous in the time of the cruſadoes, and underwent ſeveral ſieges both by the Chriſtians and Saracens. It is now an inconſiderable town, being entirely ſupported by its harbour, which is frequented by ſhips of ſeveral nations. It is 20 miles S. of Tyre, and 37 N. of Jeruſalem, 39. 25. E. long. 32. 40. lat.

Acre, in the Mogul's dominions, the ſame with lack, and ſignifies the ſum of 100,000 rupees; the rupee is of the value of the French crown of 3 livres, or 30 ſols of Holland; an 100 lacks of rupees make a couron in Indoſtan, or 10,000,000 rupees; the pound Sterling is about 8 rupees; according to which proportion, a lack of rupees amounts to 12,500 pounds Sterling.

Acre, a meaſure of land uſed in ſeveral provinces of France, particularly in Normandy. It is larger or leſs according to the different places; but commonly contains 160 perches.

The Acre *of woods in France*, conſiſts of four roods, called *verg es*; the rood is 40 perches, the perch 24 feet, the foot 12 inches, the inch 12 lines.

Acre, the univerſal meaſure of land in Britain. An acre in England contains 4 ſquare roods, a rood 40 perches or poles of 16½ feet each by ſtatute. Yet this meaſure does not prevail in all parts of England, as the length of the pole varies in different counties, and is called *cuſtomary meaſure*, the difference running from the 16½ feet to 28. The acre is alſo divided into 10 ſquare chains, of 22 yards each, that is 4840 ſquare yards. An acre in Scotland contains 4 ſquare roods; 1 ſquare rood is 40 ſquare falls; 1 ſquare fall, 36 ſquare ells; 1 ſquare ell, 9 ſquare feet, and 73 ſquare inches; 1 ſquare foot, 144 ſquare inches. The Scots acre is alſo divided into 10 ſquare chains; the meaſuring chain ſhould be 24 ells in length, divided into 100 links, each link 8 [illegible] inches; and ſo 1 ſquare chain will contain 10,000 ſquare links.

The Engliſh ſtatute acre is about 3 roods and 6 falls ſtandard meaſure of Scotland.

ACREME, in old law-books, ſignifies ten acres of land.

ACRIBEIA, ſignifies great accuracy.

ACRID, a name for any thing that is of a ſharp or pungent taſte.

ACRIDOPHAGI, ſignifies *locuſt-eaters*. It has been much diſputed whether the inhabitants of Arabia, Ethiopia, *&c.* ever eat locuſts. We ſhall give the ſubſtance of what Haſſelquiſt ſays on this ſubject, who travelled in Syria and Egypt ſo late as the year 1752. This ingenious gentleman, who travelled with a view to improve natural hiſtory, informs us, that he aſked Franks, and many other people who had lived long in theſe countries, whether they had ever heard that the inhabitants of Arabia and Ethiopia, *&c.* uſed locuſts as food. They anſwered that they had. He likewiſe aſked the ſame queſtion of Armenians, Cophtes, and Syrians, who lived in Arabia, and had travelled in Syria and near the Red-ſea; ſome of whom ſaid they heard of ſuch a practice, and others that they had often ſeen the people eat theſe inſects. He at laſt obtained complete ſatisfaction on this head from a learned ſheck at Cairo, who had lived ſix years in Mecca. This gentleman told him, in preſence of M. le Grand, the principal French interpreter at Cairo, and others, that a famine frequently rages at Mecca when there is a ſcarcity of corn in Egypt, which obliges the inhabitants to live upon coarſer food than ordinary: That when corn is ſcarce, the Arabians grind the locuſts in hand-mills, or ſtone mortars, and bake them into cakes, and uſe theſe cakes in place of bread: That he has frequently ſeen locuſts uſed by the Arabians, even when there was no ſcarcity of corn; but then they boil them, ſtew them with butter, and make them into a kind of fricaſſee, which he ſays is not diſagreeably taſted; for he had ſometimes taſted theſe locuſt-fricaſſees out of curioſity. From this account, we may ſee the folly of that diſpute among divines about the nature of St John's food in the wilderneſs. Some of them ſay that locuſts were the fruits of certain trees, others that they were a kind of birds, *&c.*; but thoſe who adhered to the literal meaning of the text were at leaſt the moſt orthodox, although their arguments were perhaps not ſo ſtrong as they might have been, had they had an opportunity of quoting ſuch an author as Haſſelquiſt.

ACRI-

Fig. 9: List of ‘articles’ extracted from Page 36 of the First Edition (Volume 1) of the *Encyclopaedia Britannica*.

Our query is able to detect both ‘articles’ and ‘topics’, and classify each page accordingly. An *Encyclopaedia Britannica* page can contain just ‘articles’, or a ‘topic’, or can have a mix of both [20]. An *Encyclopaedia Britannica* page may also contain information not related to articles, such as the cover of a volume, preface, tables, figures, etc. Therefore, our query performs pages classification (‘articles’, ‘topic’, ‘mix’, ‘other’) depending on the type of articles detected.

Since the aim of detecting articles is to perform further analyses on them, we have enabled storing the extracted information in several formats, e.g. files (YAML or CSV) and in our storage facilities described in Section IV-D.

In summary, the `extract_articles_eb` query automatically extracts the articles (if any) within pages, along with metadata, such as the number of articles per page, the number of words per article, header, and page classification. Figure 9 shows a list of ‘articles’ extracted by our new query using the example introduced in Section I.

B. Geoparsing the Scottish Gazetteers

The *Gazetteers of Scotland* [21] is a collection of twenty volumes of the most popular descriptive historical gazetteers of Scotland in the 19th century, providing ‘dictionaries’ of places such as towns, cities, castles and antiquities. In this study, we have applied the new *defoe* geoparsing functionalities introduced in Section IV-F to the *Gazetteers of Scotland* (see Figure 8).

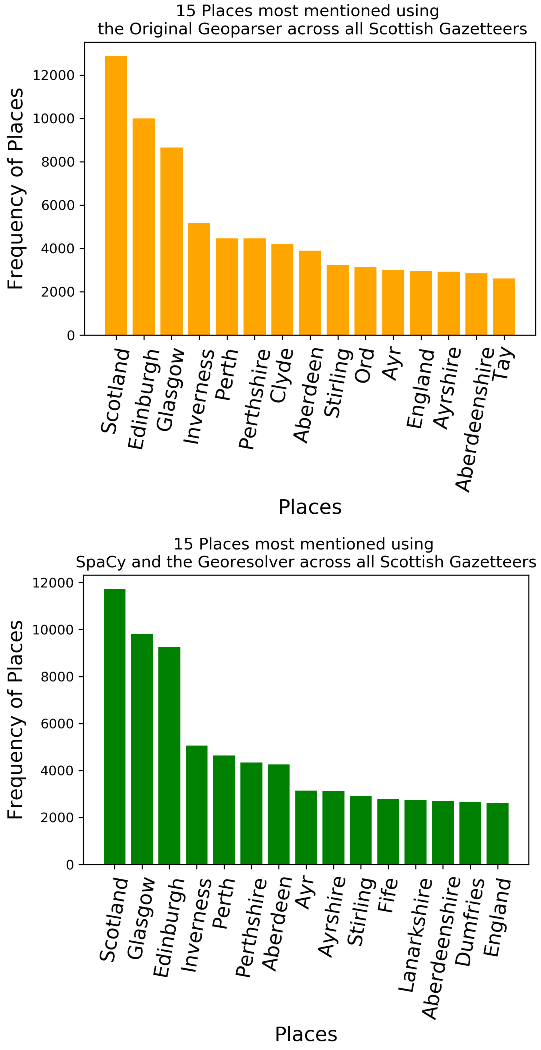


Fig. 10: Most frequent georesolved locations using both *defoe* geoparsing queries

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Figure 10 shows the 15 most frequent places names extracted using the `original_geoparser` (above) and `spacy_georesolver` (bellow) queries from the *Gazetteers of Scotland*. Note that the five most frequent locations mentioned among both techniques are *Edinburgh, Scotland, Glasgow, Inverness* and *Perth*. More preliminary results of geoparsing the *Gazetteers of Scotland* can be found in [19].

Furthermore, we have used the results of the `original_geoparser` query to create an interactive map for visualising the detected places from the *Gazetteers of Scotland* (see Figure 11). For each place name on the map we have access to snippets of the text where the place name is mentioned, number of mentions per edition, or population. For the mapping visualisation we used OpenLayers [22], a javascript library which allows us to display the place names

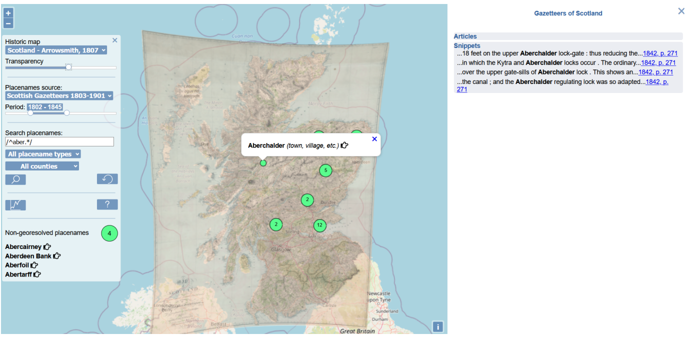
[19] https://digital.nls.uk/encyclopaedia-britannica/archive/193108323#?c=0&m=0&s=0&cv=71&xywh=-348%2C-499%2C6940%2C5144

[20] https://digital.nls.uk/encyclopaedia-britannica/archive/144133901#?c=0&m=0&s=0&cv=99&xywh=37%2C-207%2C3751%2C2780

[21] https://data.nls.uk/data/digitised-collections/gazetteers-of-scotland/

[22] https://openlayers.org/

on a base map (OpenStreetMap in this case). Figure 11 shows the mentions of *Aberchalder* in the Gazetteers over a given period (1802-1845) in the right panel. These also include a link to the respective page of the digitised edition of the Gazetteer. Extracted place names that fit the search criteria but for which no map coordinates are given are listed in the bottom left. A historic map of Scotland (*Arrowsmith, 1807* [23]) is overlayed on top of OpenStreetMap.



Historic map
Scotland - Arrowsmith, 1807
Transparency
Placenames source:
Scottish Gazetteers 1803-1901
Period: 1802 - 1845
Search placenames:
/^aber.*/
All placename types
All counties
Non-georesolved placenames 4
Abercairney
Aberdeen Bank
Aberfoil
Abertarff

Aberchalder (town, village, etc.)

Gazetteers of Scotland
Articles
Snippets
...18 feet on the upper **Aberchalder** lock-gate : thus reducing the...1842, p. 271
...in which the Kytra and **Aberchalder** locks occur . The ordinary...1842, p. 271
...over the upper gate-sills of **Aberchalder** lock . This shows an...1842, p. 271
...the canal ; and the **Aberchalder** regulating lock was so adapted...1842, p. 271

Fig. 11: Map of Scotland showing placenames starting with ‘aber’ in the *Gazetteers of Scotland* for the period 1802-1845. Marker numbers show locations with multiple place names.

While the other two use cases presented in Section VI were run on *Cirrus*, this particular use case was run on *Google Cloud*. This is mainly because the *Ediburgh Geoparser georesolution* needs access to online gazetteers to ground place names. *Cirrus* nodes (as many other HPC-Clusters) cannot directly access the Internet because they have a private IP. This is not the case for *Google Cloud*.

C. *‘Scots for the masses’? Exploring the use of Scots in 19th century digitised Chapbooks*

Since the 16th century, Scots has been increasingly influenced by English, particularly in writing. Written Scots came to be seen as less appropriate or lucrative for text genres such as newspapers. On the basis of this, in this study we explored the use of written Scots in the digitised 19th century *Chapbooks* collection [24], to investigate (i) whether Scots survives in the printed world, and, if so, (ii) in what contexts Scots is used and how this indicates the status it had as a written medium during this time.

Scots in print was increasingly rare in this time period, as printing practices were heavily modelled on English print culture, with works aimed at the (larger) English audience. To perform this study, we run five *defoe* queries (available at [25]) across the *Chapbooks* collection (see Figure 8), using two lexicons, one for English words, and the other for Scots words [26]. These queries allow us to obtain the frequencies of words in each lexicon by applying two different hit-counting methods (by page and by term) and grouping the results by time and by words. Figure 12 shows the normalised frequencies results (dividing the total instances of terms per year between the total number of words per year) of four Scots terms and their corresponding English terms.

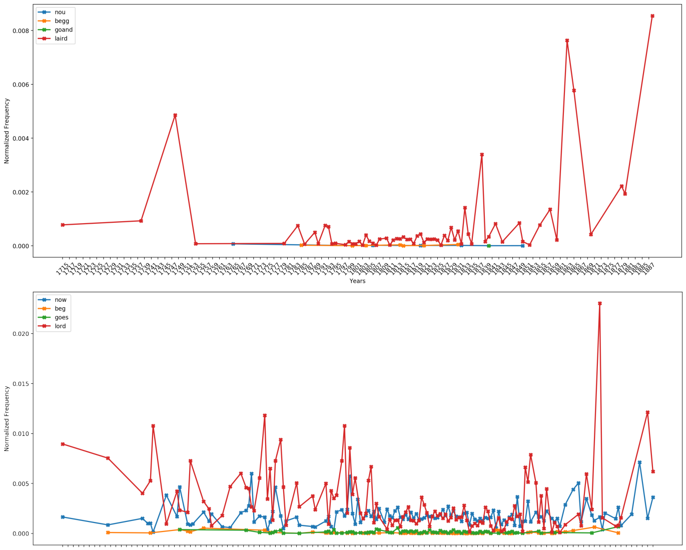
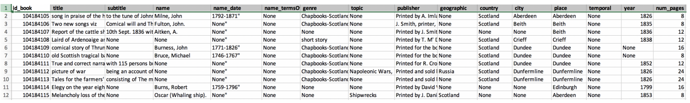


Fig. 12: N-grams for visualising the normalised frequencies of four Scots terms (above): ‘nou’, ‘begg’, ‘goand’ and ‘laird’; and their corresponding English terms (bellow): ‘now’, ‘beg’, ‘goes’, ‘lord’.

Despite these anglicising pressures, the results obtained from the previous *defoe* queries indicate that Scots clearly had not disappeared from the public eye entirely. Through *defoe*, we were able to extract Scots tokens from previously unmined historical data, but also important metadata attributes about the text such as *genre* and *place* — factors that we will take into consideration in our analysis of which factors encouraged or suppressed possible use of Scots in these publications. To obtain these attributes, we created a new query, `extract_metadata`, to extract all the information associated with this collection (see Figure 13).



1	id_book	title	subtitle	name	name_date	name_termsO	genre	topic	publisher	geographic	country	city	place	temporal	year	num_pages
2	104184105	song in praise of the h	to the tune of Johnr	Milne, John	1792-1871"	None	Chapbooks-Scotlanc	None	Printed by A. Imla	None	Scotland	Aberdeen	Aberdeen	None	1826	8
3	104184106	Two new songs viz	Comical will and Th	Fulton, John.	None"	None	Chapbooks-Scotlanc	None	J. Smith, printer,	None	Scotland	Beith	Beith	None	1835	8
4	104184107	Report of the cattle sł	10th Sept. 1836 wit	Aitken, A.	None"	None	None	None	Printed by J. Smit	None	None	None	Beith	None	1836	12
5	104184108	Laird of Ardenoaige ar	None	None	None"	None	short story	None	Printed by T. M' [	None	Scotland	Crieff	Crieff	None	1838	12
6	104184109	comical story of Thrun	None	Burness, John	1771-1826"	None	Chapbooks-Scotlanc	None	Printed for the bc	None	Scotland	Dundee	Dundee	None	None	16
7	104184110	old Scottish tragical ba	None	Bruce, Michael	1746-1767"	None	Chapbooks-Scotlanc	None	Printed for the bc	None	Scotland	Dundee	Dundee	None	None	8
8	104184111	True and correct narra	with 115 persons b	None	None"	None	Chapbooks-Scotlanc	None	Printed for R. Cro	None	Scotland	Dundee	Dundee	None	1852	12
9	104184112	picture of war	being an account of	None	None"	None	Chapbooks-Scotlanc	Napoleonic Wars,	Printed and sold I	Russia	Scotland	Dunfermline	Dunfermline	None	1826	24
10	104184113	Tales for the farmers'	consisting of The m	None	None"	None	Chapbooks-Scotlanc	None	Printed and sold I	None	Scotland	Dunfermline	Dunfermline	None	1826	24
11	104184114	Elegy on the year eigh	None	Burns, Robert	1759-1796"	None	None	None	Printed by David \	None	None	None	Edinburgh	None	1799	16
12	104184115	Melancholy loss of the	None	Oscar (Whaling ship).	None"	None	None	Shipwrecks	Printed by J. Dani	Scotland	None	None	Aberdeen	None	1853	8

Fig. 13: Snapshot of metadata from the first 12 *Chapbooks*. We are currently updating the `extract_metadata` query to extract metadata in Dublin-Core format [20].

The results indicate that written Scots was still present in print, but primarily in narrative prose, with a clear preference for Scots in garlands, humorous material and verse. Thus, using the results from the *defoe* queries, we can statistically analyse the normalised frequency of Scots by chapbook, topic,

[23] https://maps.nls.uk/joins/747.html

[24] https://data.nls.uk/data/digitised-collections/chapbooks-printed-in-scotland/

[25] https://github.com/defoe-code/CDCS_Text_Mining_Lab/tree/master/Round2_Requirements/Sarah_Lisa#defoe-queries

[26] https://github.com/defoe-code/CDCS_Text_Mining_Lab/blob/master/Round2_Requirements/Sarah_Lisa/Lexicon_Scots_English.xlsx

genre and author. The notebooks and visualisations [27] were useful to get an overview of the data, and to do initial explorations of the results.

VII. Conclusions

The new *defoe* functionalities described in this paper enable us to mine different historical collections more efficiently, supporting the research of different disciplines such as the social sciences, history, and computational linguistics. *defoe* has been enriched with a larger number of analyses readily available to users and has also been integrated with further NLP tools such as the *Edinburgh Geoparser*. We have also enabled *defoe* to run multiple queries at once across digital collections. We have proposed a new *DCOM* model to map collections independently of their XML schemas, and store them in several storage facilities. We provide support for analysing both i) XML files (*on-the-fly* analysis); and ii) preprocessed data stored (*preprocessed* analysis). And we have also created a new *NLS* object model for ingesting NLS digital collections and employing new techniques to mitigate more OCR errors. With all these improvements, we have made *defoe* more efficient for searching and analysing large-scale historical textual data. Most of the current analyses supported by *defoe* are keyword searches or frequencies, in which users can configure several parameters. In the future we plan to extend this work, and employ more sophisticated analyses by using more advanced machine learning and NLP algorithms.

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