BiL-Explorer

Building an interactive, web explorer for Biodiversity-in-Literature data

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Declaration of Independence

I hereby certify that I have written this paper independently and only with the and only with the use of the indicated aids. All quotations are marked as such.

Leipzig, 29-09-2022

1. Prelude

To begin with, the context of this paper is to create a report that describes the practical portion of my bachelor thesis at the University of Leipzig. After having chosen Prof. Dr. Manuel Burghardt as my supervisor for this thesis, we worked together to find feasible projects for my Bachelor's thesis. I'd like to extend a special thanks to Prof. Dr. Manuel Burghardt, Lars Langer, and Dr. Ing. Andreas Niekler for their regular feedback and support throughout the project.

2. Abstract

In the wake of increasingly urgent ecological issues, new cross-disciplinary methods are being tested and developed to reestablish and better understand the nature/culture connection. (L.Langer, M.Burghardt, R. Rogards et al., 2021) This paper reports the creation of an exploratory tool, which a broad spectrum of scholarly disciplines can use to apply 'distant reading' and 'close reading' methods synergistically, using the Biodiversity-in-Literature dataset as a foundation.

3. Introduction

Amidst the challenges of our time, climate change and increasing biodiversity loss certainly take their places as two of the most pressing measurable issues in the current zeitgeist. (S. Cooke, M.Kearnes, E.Gorman et al., 2012) (L.Langer, M.Burghardt, R. Rogards et al., 2021) It can often become overlooked that anthropogenic crises related to the 'nature of the human' are inevitably tied to the roots of empirically-observable effects on nature. In order to contribute to rebuilding the bridge between the nature/culture divide, I plan to build an information system that can be of use to scholars in the domain of the 'Digital Environmental Humanities', an emerging mixture of disciplines and methods which I will introduce in subsequent chapters.

3.1. Environmental Humanities

The humanities have been becoming increasingly interested in ecology (D.Rose, T.van Dooren, M.Chrulew et al., 2012); likewise, ecologists and natural scientists are also interested in the humanities. (J. Rockström, W. Steffen, K. Noone et al., 2009) The result of the emergence of this fruitful intersection has birthed the field of the environmental humanities (EH), which ultimately attempts to address the aforementioned nature/culture divide in a collaborative, interdisciplinary fashion. These movement exists since the 1960s, and has crystallised into a plethora of research agendas, amongst which 'environmental history', 'environmental philosophy', 'political ecology', 'ecocriticism' and many other disciplines in the humanities share common interest in intersecting with the environmental sciences (D.Rose, T.van Dooren, M.Chrulew et al., 2012, pg. 1). Rose et al. see the development of the environmental humanities as:

> "-an effort to enrich environmental research with a more extensive conceptual vocabulary, whilst at the same time vitalising the humanities by rethinking the ontological exceptionality of the human."

Rose et al. places the EH in the role of critiquing and unsettling 'dominant narratives', and describes that environmental historians remind us how traditional human stories are embedded in the context of earth's history, and require a symphony of expertise in geology, evolutionary biology, climate science, and not-to-mention human history, to draw conclusions that align with historical markers. Additionally, Rose et al. further map the discourse of academic discussion surrounding the EH, in highlighting the role of ecocriticism - namely highlighting and interpreting the nuanced interdependent interactions between nature and human poems, songs and stories - and the role of environmental philosophy in addressing multispecies ethnography, as-well-as the discussion of biocentrism, ecocentrism, among other areas of analysis. (D.Rose, T.van Dooren, M.Chrulew et al., 2012, pg. 4)

3.2. Digital Humanities

With the emergence of digital tools and methods, they have allowed researchers to analyse and answer questions using quantitative methods that were previously difficult to answer. Traditionally-speaking, literary-studies scholars would use methods of analysis like 'close reading' to analyse literature, but with the advent of computational methods, literary analysis can be performed at a scale which was previously insurmountable. Franco Moretti has demonstrated the power in these digital methods in his clearly influential effect on the field of digital humanities (DH) as a whole with his work in coining the term 'distant reading' (F. Moretti, 2013), a methodology which is forewarned by literary scholars for fear of the lack of a combined approach that includes traditional methods such as close reading. (M.Ascari, 2014)

A common reoccurrence in the field of the DH is the question of its own identity within the landscape of academia. Among papers that debate the DH typology, (P. Svensson, 2010) there are attempts within DH to use computational methods

such as aggregate topic modelling to visually-map the academic landscape that DH is placed in. (J. Luhmann, M. Burghardt, 2022) The scholarly discourse shows that despite initial criticism as to its place within academia, (M. Kirschenbaum, 2014) DH is its own discipline in its own right, as-well-as being a “cross-interdisciplinary endeavour that brings digital information technology to existing humanities disciplines”. (J. Luhmann, M. Burghardt, 2022)

As to understanding what DH does, Roth (C. Roth 2019) identifies 3 communities of practice within DH, namely: the “digitized humanities”, which is the practice of creation, use and analysis of traditional mediums of data into those which can be computationally processed - the “computational humanities”, which is the application of computational methods on humanities questions - and the “humanities of the digital”, digital phenomenology within the humanities. To these, Burghardt (M. Burghardt, 2020) adds the “public humanities” - essentially the involvement of DH in scholarly communication.

3.3. Synthesis

Consequently, one could argue that the synergy of EH and DH could be a fruitful endeavour, applying the interdisciplinary-affine fields and their respective methods and interests could create fertile ground for an increasing urgency of ideas and innovation. This field of potential has in-fact already been dubbed as the “Digital Environmental Humanities”, an alias for the synthesis of the computational humanities and literary biodiversity studies. (L. Langer, M.Burghardt, R. Borgards et al., 2022)

3.4. Related Literature

There are few projects and initiatives that could fit the intersection of methods that are computational, and draw from the humanities, with an environmental focus; thus falling underneath the umbrella of the ‘digital environmental

humanities'. This chapter will present these individual case-studies; the first of which being the digitisation of the historical fish revolution data between the years of 1400 - 1700. (C. Travis, 2016, pg. 195) A geographical information system was created to visualise the various hypotheses of the involved researchers, and to share the assembled knowledge publicly. In particular, 3 main research questions were pursued: 1. What were the natural and economic causes of the fish revolution? 2. How did marginal societies adapt to changes in international trade and consumption patterns around the North Atlantic? 3. How did consumers, investors, and politics in the major European countries respond? A unison of the humanities and natural sciences proved capable of helping create a new environmental history of the late mediaeval/early modern North Atlantic, its politics and culture, the importance of the fish revolution, and its impact on cultures and societies across the North Atlantic. Further examples of projects in this intersection of study include smart-city social and informational-infrastructure projects; and real-time analyses of geospatial twitter data, that hone-in on the public's reaction to political events. (C. Travis, 2016, pg. 202) A recent attempt to connect nature back into cultural discourse in the form of 'nature's contribution to people' has been made in the hopes of facilitating governments decision-making towards a sustainable future. (L. Langer, M.Burghardt, R.Borgards et al., 2021) In order to reestablish this nature/culture connection, an attempt to quantify human valuation of biodiversity was made, in "The rise and fall of biodiversity in literature", where a comprehensive list of 240,000 english biological taxon labels were assembled and used in combination with automated language processing tools to quantify diversity patterns associated to the taxons, using the Project Gutenberg text corpus. A method-mix of ecological theory, and the computational humanities were brought together and shown to be consistent with historical markers such as the industrial revolution. (L. Langer, M.Burghardt, R.Borgards et al., 2021)

3.5. Motivation

It is clear that there is a need for publicly-accessible research that also helps bridge the digital-divide between the environmental humanities and computational methods used in the digital humanities. There is also clearly an abundance of research like the BiL paper, that could be interesting to biodiversity researchers, who may-or-may-not have the technical expertise to begin to answer research questions related to the data produced by the paper. In any case, lowering the barrier-to-entry for the average researcher could be applied to the Biodiversity-in-Literature (BiL) paper data. This could be achieved in the creation of a web portal, by which biodiversity researchers or possibly even researchers of unrelated fields with less technical backgrounds could access in order to explore the dataset as a preliminary supplement to more in-depth data-science research. Setting the goalposts around having a tool with good usability, good performance, and high accessibility; might allow researchers to generate insights they would not otherwise be able to, through fast exploration; increasing the level of public access, could also aid the paper's original goal of facilitating governments decision-making towards a sustainable future. (L. Langer, M.Burghardt, R.Borgards et al., 2021)

4. Methodology

4.1. Requirements Analysis

Out of the project's general motivation, requirements crystalised. The app should be a web portal, making its ability to be accessed as broad as possible, by any device with access to a relatively modern web browser. It should also have a high usability, so that it is intuitive for researchers to use, and requires the bare minimum of context and training to be able to generate insight. (From

the perspective of a biodiversity researcher.) At the same time, the data should be presented accurately, and with similar rigour as that of a classic form of data analysis.

4.2. Provided Data

After agreeing on the project terms with the creators of the BiL paper. I received two .csv files, the first containing what seemed to be an SQL JOIN of two database tables that relate to *Author* and *Work data*. (12.7MB, with 13519 entries.) This file contained a 'works' header, which contained the various foreign key IDs (fileIds) that belonged to the works respective authors. (See fig. 1 for a complete list of metadata that the first .csv contained, separated into their respective *Work* and *Author* tables.)

No information referring to the type of database that was previously used to store the data was provided, nor any information as to the database schema. Questions about the metadata were directed to Lars Langer, who thankfully took the time to clear up fundamental questions about the derivation of certain parameters.

The other file, (of considerably larger file size, 1.15GB with 5733514 entries) contained data relating to the individual occurrences of taxa in their respective corpera - which were relationally-connected via the foreign key, fileID. An example of a line of occurrence data would include the ID as an identifier, the occurrence ID ("occId") was presumably the string used by the automated language processing tools mentioned in the BiL paper (L.Langer, M.Burghardt, R. Rogards et al., 2021) to match occurrences in the corpera, the term - or in other words the scientific nomenclature that related to a distinct taxon, the scientific name - or organism type, the fileId as a foreign key, the sentence - or context of given occurrence, the frameId, column, and spalte which were used

internally as part of the BiL paper's ecological method. (L.Langer, M.Burghardt, R. Rogards et al., 2021)

4.3. Data Preprocessing

4.3.1. JOINed Table Extraction

Due to the nature of the data that was provided - in addition to the data cleaning that was needed to perform to get the data to conform to a format which my chosen database would eventually harbour - it was necessary to extract the JOINed *Author* and *Work* tables to their respective individual tables, so that it was feasible to work with tables in a way that preserved relationality within my database, and minimised the excess duplicate data that is a byproduct of two JOINed tables. (Considering the limitations of the browser.) This was achieved using a 'seed' script, (written in, but not necessarily bound to, Typescript) see repo in footnotes (N. O'Hara, 2022) which serves the purpose of preprocessing data and making database inserts. The script took each line of the JOINed table, and mapped the author-related metadata to the *Author* table, and vice versa; after which it then made an individual database insert with separated data for *Author* and *Work* tables.

4.3.2. Data Cleaning

After the extraction of the data from the .csv, cleaning was necessary to transform the data into a format which the database could accept, and in some cases convenience Tables were created (see *Taxon* table in fig. 1) so that the data could be easily-consumed in the frontend.

The two files were individually preprocessed as a step in the aforementioned 'seed' script, (see above chapter) within which the authors/works file had 'NA' occurrences replaced with the more javascript-friendly 'null' - headers were

typed in a way which was intuitive to their semantic description, irregularities (like edge-case numbers in a column which would otherwise contain only strings) were typed to be consistent with the type of its respective column. Delimited strings were transformed to array types and finally, the string ‘1 (?)’ was replaced with ‘1’ of type number, to make data type-consistent to be consumable in the frontend. All occurrence preprocessing included only the nullification of the ‘NA’ string.

4.4. Mockup

The mockup (in other words, design specification) was created through a series of iterative feedback sessions with Manuel, where we evaluated the translation of the functional requirements into design requirements. The iterations followed a human-centred design (S. Oviatt, 2006) approach, (with Manuel as the sole stakeholder) where each iteration consisted of a presentation of the current state of the mockup, followed by feedback, which was incorporated into the mockup for the next iteration.

Three iterations of the mockup exist as versions, attached in the footnotes. Version 1 (N. O’Hara, 2022) displays the different functionalities we initially agreed upon, each as 3 individual views which could be navigated to, (under book, diachronic and search views) we initially had a large number of default form elements related to the filtration of the data placed underneath the taxon search bar. We found this overcomplicated the UI, and aimed to reduce the complexity of any given representation of a view to the function that it intended to perform.

Version 2 attempted to reduce the 3 views we previously conceptualised as 3 different pages, to a single page application, with different functionalities that were to be discovered interactively by the user.

Version 3 featured a reduction of visual complexity and therefore cognitive overload, as we limited the scope of the project, and reduced the visual elements to their most minimal form. Considering the breadth of the metadata provided to the database tables, we decided that dynamically-rendering user-selected form elements was a way to reduce visual complexity on the data-filtering view, additionally, this minimises the number of unused form elements visible to the user. Additional to this, export functionalities were added to the graph view, so that researchers could easily export their graphs, and share results.

4.5. Design Decisions

Ben Schneidermann's mantra "Overview first, zoom and filter, then details-on-demand", amongst other guidelines specified in subsequent reviews (B. Craft, P. Cairns, 2005) of the influential paper, inspired the design process that brought together each iteration of the mockup. In addition to these guidelines, Google's Ngram Viewer (Google Ngram Viewer, 2022) also played a role in representing the current status quo and frame of reference for interactive exploratory visualisation.

For the search input on the visualisation page, a Searchable Select Input was used, this is a clear improvement over the Google Ngram viewer's comma-separated search input, which requires the use of custom markup within the search input. Having a more accessible, and markup-less alternative may increase the ease-of-use for non-technical researchers.

Sidebars instead of dropdowns were adopted as deviation to the mockup, as hoverable funnels pose risk of the user accidentally exiting the hover funnel, creating a potentially undesirable user-experience.

The granularity of the presentation of data was handled in 3 steps, (in accordance with the B. Schneidermans mantra) overview of the

literary-relevance, followed by a user interaction which opens a sidenav that displays the frequency data relevant to the datapoint of interaction

Dynamic form element selection was incorporated in the filtration sidenav to reduce the visual complexity, and trim unnecessary fields from view. Draggable dual slider form inputs were incorporated to communicate to the user that the filtering parameter was a numerical range, which could be specified by dragging and dropping either the left or the right slider in a tactile manner to set maximum and minimum points for the numerical range.

4.6. Architecture

4.6.1. Database

After cleaning the data, it was necessary to create a relational schema. Postgresql was used as the relational database.

4.6.1.1. Prisma as a Database ORM

Prisma is a layer of abstraction that sits on-top of classical SQL queries, otherwise known as an object relational-mapper (ORM). Database ORMs claim to ensure consistency while managing database interactions. (Prisma ORM, 2022)

4.6.1.2. Schema

The following relational database schema is representative of a high-level overview of the relationality between the database tables. A more implementation-specific schema can be found in the schema.prisma file in the project repository. (N. O'Hara, 2022)

Figure 1 - Relational Database Schema (Generated using: https://dbdiagram.io)

4.6.2. Frontend

For the frontend, React was used (ReactJS, 2022) as the javascript framework to create the single page application, styling was configured using a modern css framework: tailwind css (TailwindCSS 2022). Typescript was added to augment the basic level of type-safety throughout the project (Typescript, 2022). D3 (D3, 2022), a javascript-based visualisation library, was used to visualise the graphic.

4.6.3. Backend

For the backend, expressjs (ExpressJS, 2022) was used to create API routes to serve and process the data that was being fetched from the database via prisma client.

4.6.4. Deployment

For the dockerisation of the application, 2 containers were created that contain the app (frontend and backend) and the database. The application was dockerised to ensure that the server could recover from any crashes, given that users may use the application in unexpected ways, and the project time and resource limitations did not allow for extensive testing.

4.6.5. Visualisation & Normalisation

Figure 2 - Graph View

The multi-line chart was initially taken from a D3 template (M. Bostock, 2018) and then customised to fit our project's needs. (See fig. 2) The graph was normalised using the formula in fig. 3. The document frequency for a given taxon, in a given year, was divided by the total document frequency for the given year. This method of normalisation focuses on the ratio of publications with occurrences in a given year, to total publications for a given year; as a more representative normalisation for literary relevance of a given occurrence in any given year. A normalisation focused on a ratio of occurrence frequencies was decided against, due to outliers with large occurrence frequencies; i.e. a collection of poems about dogs, would have a very disproportionally high amount of 'dog' occurrences, and would consequently introduce advertently-large peaks for individual years in comparison to other years with works including less thematically-specific references to taxons.

$$\frac{df_{ty}}{df_{y}}$$

Figure 3 - Normalisation Equation

4.6.6. Sequence Diagram

Fig. 4 represents a sequence of interactions that are available to the user, and the communication between different parts of the application in order to handle functionality at different stages of the application lifecycle involved with visualisation inspection.

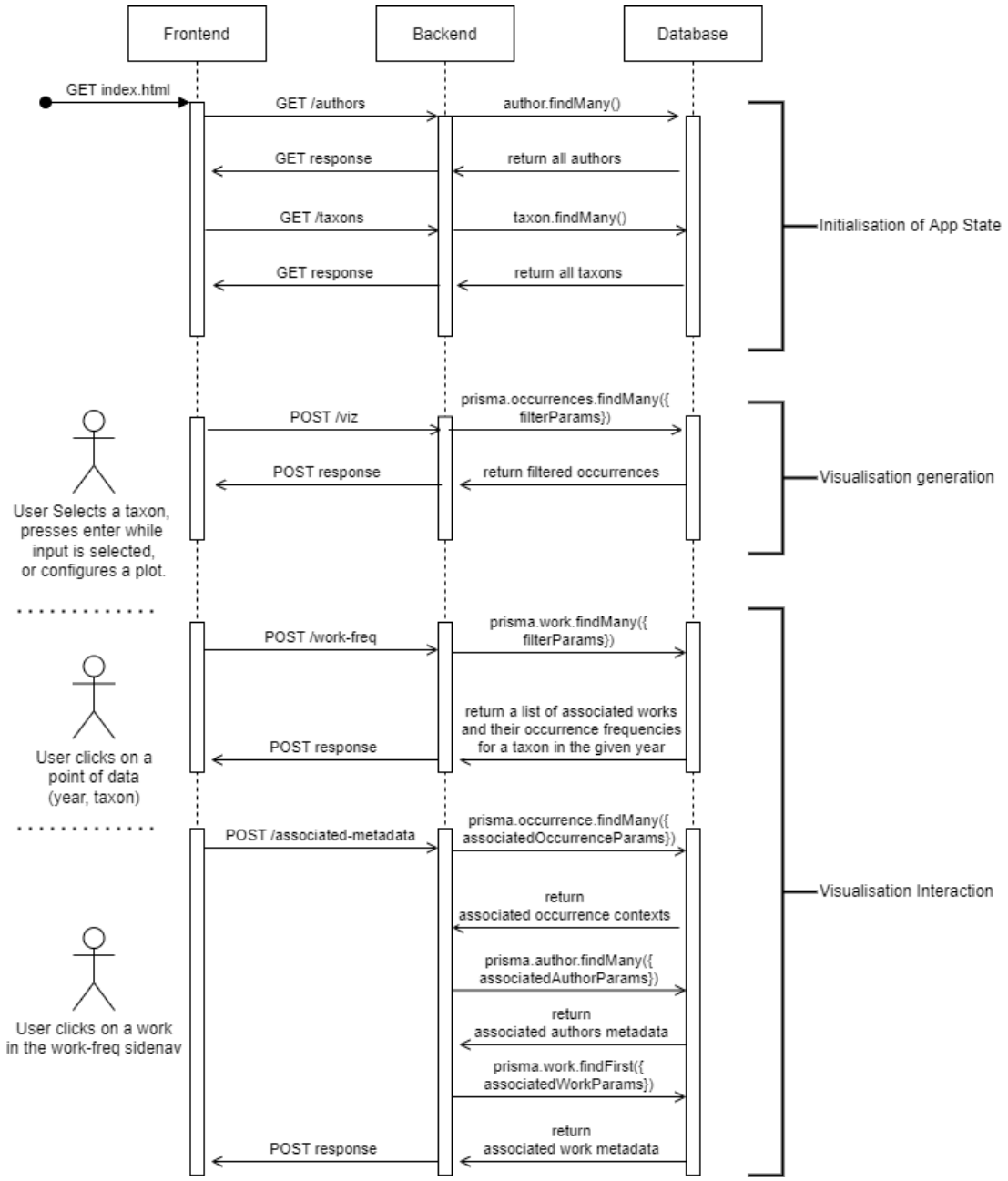

Figure 4 - Sequence diagram that represents visualisation inspection

5. Results

Fig. 2 shows a multi-taxon comparison of the taxa ‘dog’ and ’cat’, the legend on the left of the graph shows which colour corresponds to which taxon. On the y-axis you have the relative literary importance, which is the normalised value mentioned in the visualisation section above. On the x-axis you have the year of publishing, which ranges from 1705 to 1969, the range of the data gathered by the BiL project, (L. Langer, M.Burghardt, R. Borgards et al., 2022) selected due to 3 reasons:

> *“(a) It provides sufficient digitised print products for building a corpus; (b) its starting point predates the peak of the industrial and agricultural revolution and thus allows us to study its potential effect over time; (c) its endpoint predates the digital revolution that has fundamentally changed access to knowledge with potential consequences for label usage in literature.”*

On the top left, underneath the title is the searchable-select component, which allows the user to select taxa. On the top right is an ‘export graph’ button, which exports the currently shown graphic as a scalable vector graphic (SVG). The 3 green dots on the right of the searchable-select input open the left sidenav (i.e. the ‘Data Filtration View’, fig. 8), which allows the user to filter the dataset specifically by individual taxon. The ways in which taxa can be filtered include filtering by *Work* metadata (fig. 8), *Author* metadata (fig. 9), specific author(s), and time range. Interacting with the graph by selection of a point of data (fig. 5) opens the right sidenav (i.e. the ‘Work Occurrence Frequency View’, fig. 6). Within which, works can be selected and their related data (*Author* metadata, *Work* metadata, occurrence contexts) can be analysed exploratorily within the ‘Work Inspection View’ (fig. 7). All views that display data of varying granularity contain a storage functionality, either via the ‘Export Graph’ button, or the green ‘Save file’ icons shown in fig. 6 and fig. 7. It is possible to select

multiple of the same taxon, and configure filtering of the different instances of the taxon, individually (fig. 12). The Quagga, an animal deemed to be extinct since 1883, (NABU e.V., 2022) can also be seen to disappear from the literary context (fig. 10). However, popular extinct animals like the Dodo (fig. 11), don't seem to have the same distribution.

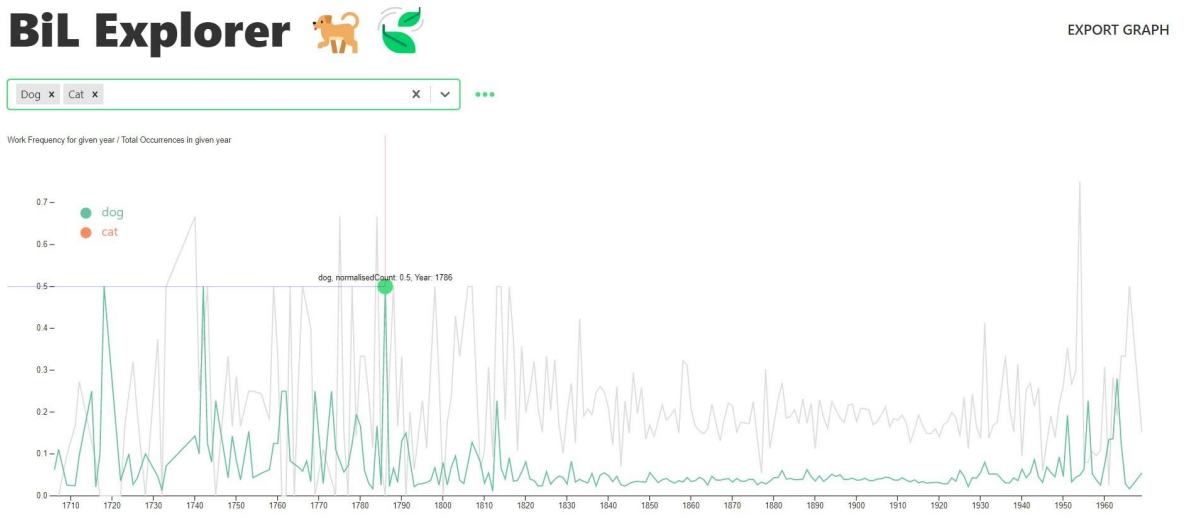

Figure 5 - Interactivity of the graph view

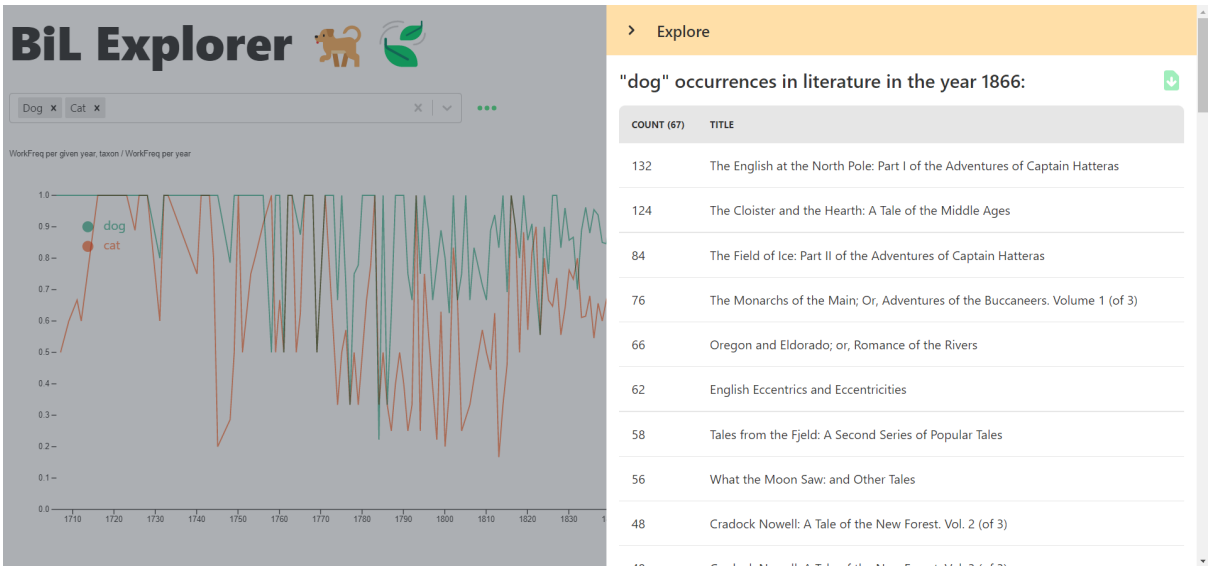

Figure 6 - Work Occurrence Frequency View

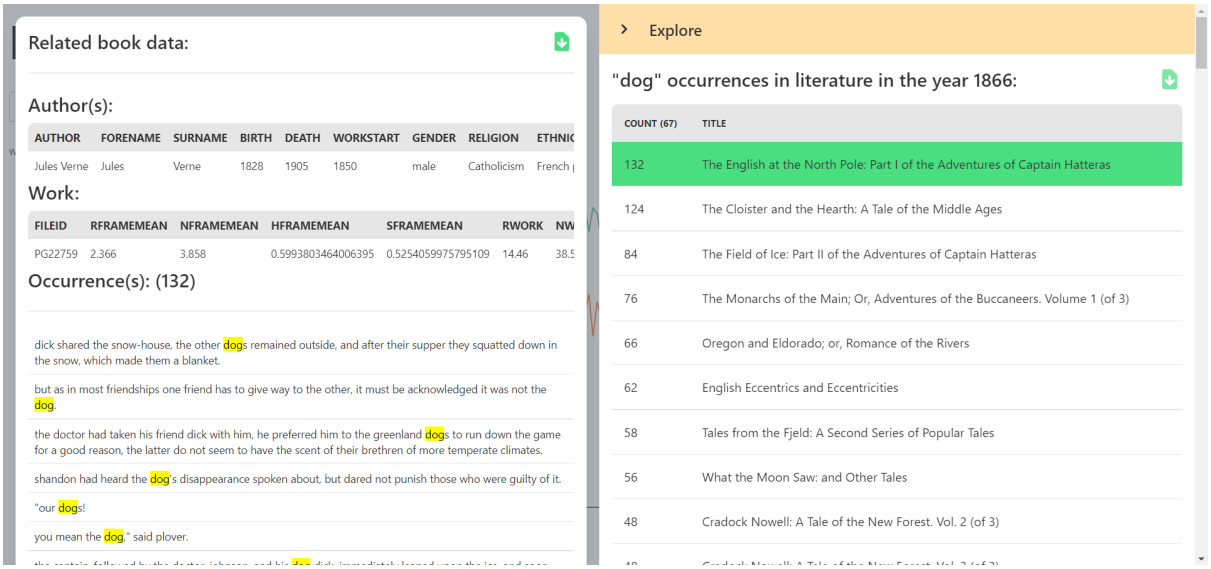

Figure 7 - "close reading" Work Inspection View

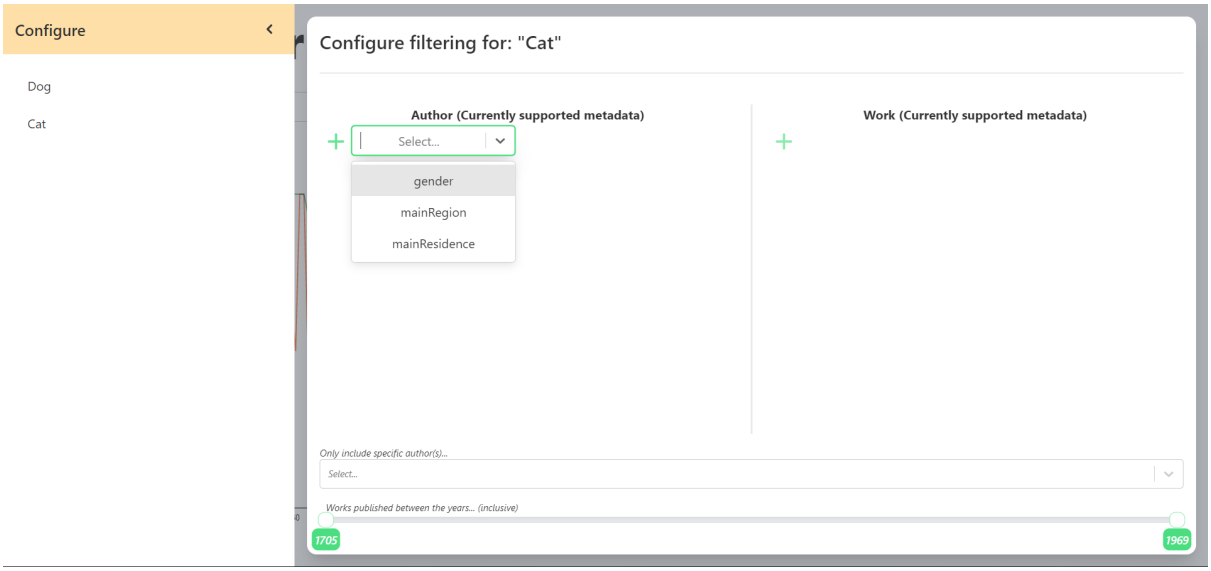

Figure 8 - Data Filtration View - Author filtering Parameters

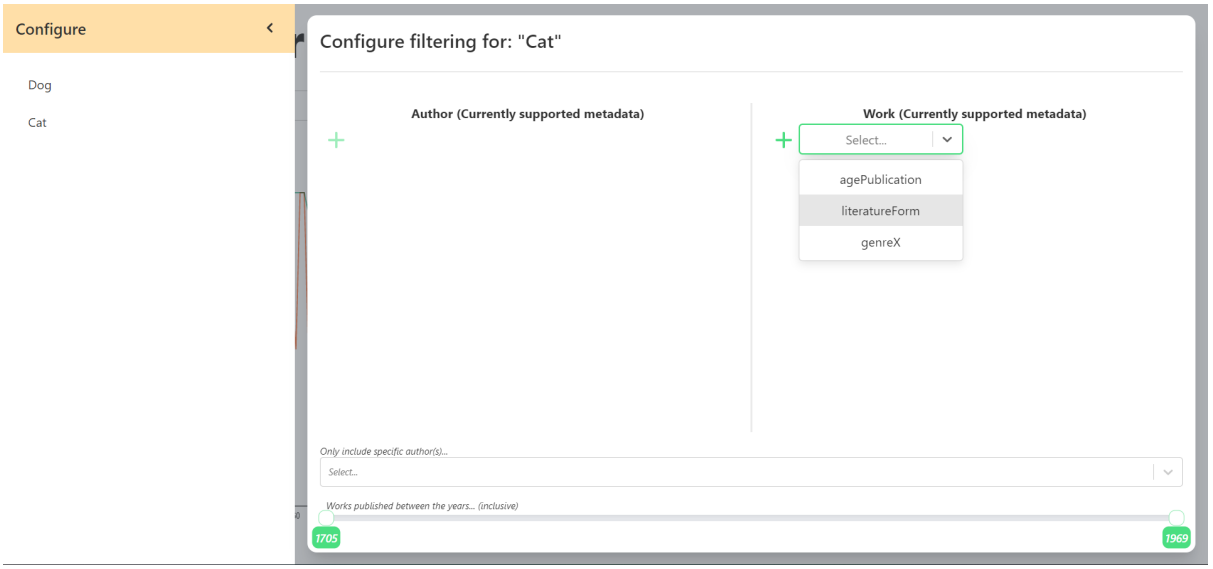

Figure 9 - Data Filtration View - Work filtering Parameters

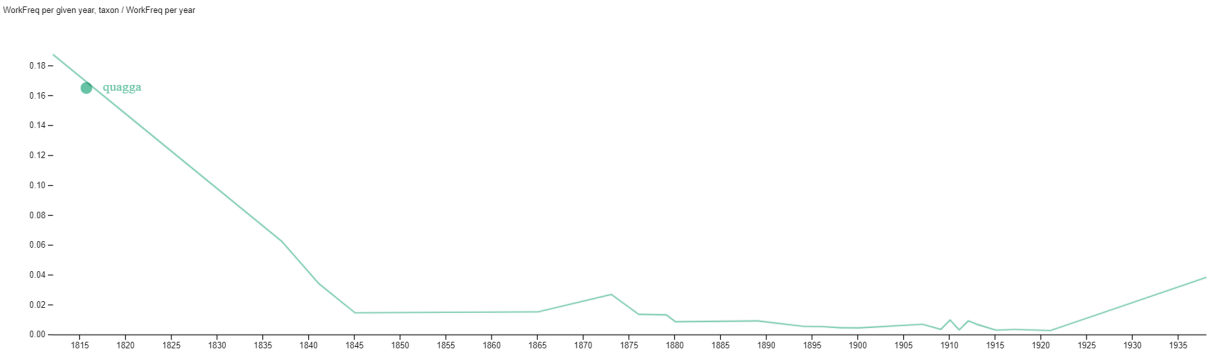

Figure 10 - Extinct Quagga

Figure 11 - The Dodo

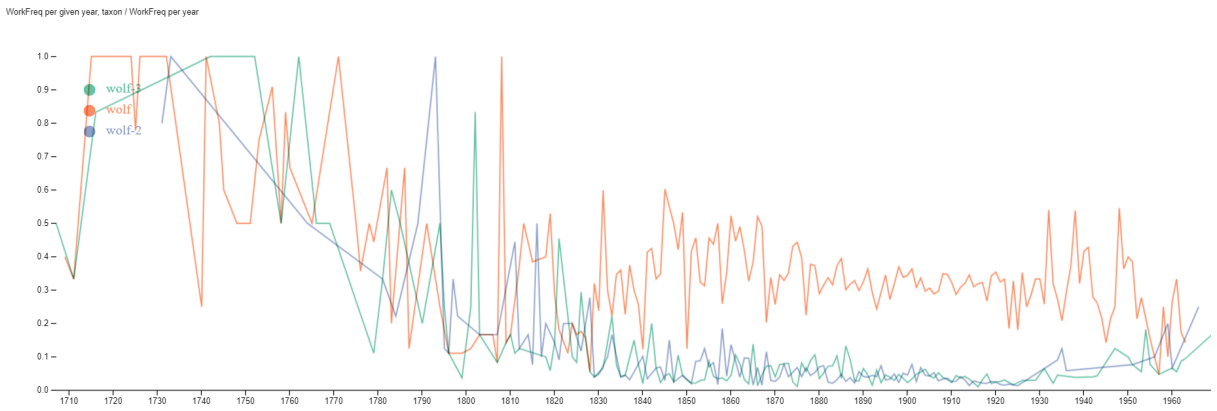

Figure 12 - 'Wolf' filtered by authors from cities, villages, and towns

6. Discussion

This exploratory tool could potentially be used to answer a broad range of questions for scholars in the humanities, and the environmental sciences. Its affordances allow comparison of different taxa, including comparison of the same taxa, with different filtration parameters. These features allow the exploration of relative importance of taxa in historic western literature; additionally they allow the investigation of the culture of authors that wrote literature containing the investigated taxa. A method-mix of traditional literature studies (LS) 'close reading', and Moretti-inspired, traditional DH 'distant reading' was applied; allowing for an exploratory experience, which allows the user to zoom in-and-out of perspective scales; honouring and bringing together the traditional methods of the DH and LS, which often have been antagonist to another in the past. (L. Paradise, 2015) However, it is important to mention that the nature of analysis-by-comparison limits the user to a relative, comparative, frame-of-reference. Perhaps future work can attempt to visualise and make diversity metrics explorable, whilst incorporating the same hybrid of close and distant reading methods.

7. Conclusion

An exploratory tool was created, which provides a frame of reference for discussions in the new cross-disciplinary field of Digital Environmental Humanities, and the methods that may result at the intersection of these complementary disciplines.

7.1. Limitations

Given time and resource limitations, some elements of the user interface were not given enough time and attention to within the design-phase of the project, in order to be presented in a way that was visually appealing (see *Author* and *Work* metadata in fig. 7), as these are large amounts of metadata and require additional design conceptualisation to be presented in a visually-aesthetic way that reduces cognitive overload in accordance to human-centred design. (S. Oviatt, 2006) It should be mentioned that the format of the provided data was quite unusual, as a JOIN of *Author* and *Work* related table data was provided. This required the additional creation of a schema, architectural selection of a database and data reformatting for the selected database; more time could have been spent on the consistency and features of the project, had the data been provided as a complete database export. Amongst these issues include those of data inconsistency, and incompleteness - often occurrences contained fileIds which were not contained in *Author* or *Work* related data. *Works* were also not completely able to be mapped to their respective authors, this would imply that perhaps some *Works* or *Authors* were missing or had been omitted from the original data. As pertaining to the consistency of the data, some taxons included their plural form in the list of taxons available, where others had theirs removed. This doesn't cause any issues on the part of data analysis, as the user can always use the singular form to encompass all matches of a given occurrence including the plural form; but practically-speaking, users may not

have prior textual processing knowledge, and may be confused as to which lexical form to choose for their exploratory analysis.

7.2. Future Work

In addition to addressing the aforementioned issues, further work could be done in extending the amount of parameters available to filter in the Data Filtration View (fig. 8 and 9), as these could be extended to be complete with the large amount of *Author* and *Work* metadata provided in the BiL dataset (See the complete metadata in fig. 1).

More work needs to be done in the verification of the visualisation, and the collaborative interpretation of the results by domain specialists. Ideally, user feedback from researchers of the humanities and environmental sciences should also be collected and incorporated into the user experience of the tool.

The data visualisation is also crude, and could use some smoothing.

Should the BiL dataset include more 'lazarus taxa' in future, (animals that were thought to be extinct but were then rediscovered), the data would become easier to validate based on known historical markers, new research questions may be able to be answered, and the tool may be able to answer more research questions in these instances.

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