Supporting University Research and Administration via Interactive Visual Exploration of Bibliographic Data

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Abstract: Bibliographic data and bibliometric analyses play an important role in the professional life of academic researchers, and the quality of the respective publication records is essential for establishing the big picture of the relationships between particular publications, their authors and affiliations, or further data facets associated with publications. In this paper, we report on the design and outcomes of an interactive visual data exploration project conducted within the scope of a university with the goal of gaining overview of the university publication data. The project has been carried out by information visualization researchers in collaboration with several groups of stakeholders, including the university library and administration staff. We describe the design considerations, the resulting interactive visual interface, and the feedback received from the stakeholders with respect to the tool functionality and the insights discovered in the bibliographic data.

1 INTRODUCTION

Scientific publications constitute an important part of the research output produced by the majority of academic researchers. While the views and policies regarding the publishing forms and bibliometric models may differ across individual researchers and institutions, the importance of the bibliographic data quality would arguably be accepted by most. Reliable publication data provides a rich source of information not only on the particular publications themselves, but also various derived data such as the publication statistics for individual researchers or groups, co-authorship networks and collaborations at various levels, and many more. The respective insights might be sought after with manual exploration of bibliographic data, bibliometric and scientometric analyses (Small, 2006), and interactive visual approaches (Federico et al., 2017; Liu et al., 2018).

While the related work includes impressive examples of advanced computational and interactive analyses—and furthermore, some commercial solutions are available—application of such approaches is not always feasible or does not always address the needs and preferences of particular stakeholders. This leaves room for design and implementation of custom solutions tailored for particular data, users, and tasks.

In this paper, we report on the design/application study initiated by the university library and university administration staff and resulting in an interactive visualization tool for publication data available within our home university (see Figure 1). The contributions of this paper are the following:

- domain task characterization for several groups of stakeholders;
- analysis of the data-centric and user-centric design requirements;
- proposed design of the backend and interactive visual interface for publication data exploration from the perspectives of data hierarchy, heterogeneous network, and further facets; and
- discussion of the feedback from two groups of stakeholders, namely, the university library and university administration staff.

Section 2 provides an overview of the related work in library and information science as well as the interactive approaches developed mainly within the visualization research community. Then we focus on the analysis of stakeholders and their requirements for the planned approach in Section 3. Since the challenges to be addressed can be roughly divided into

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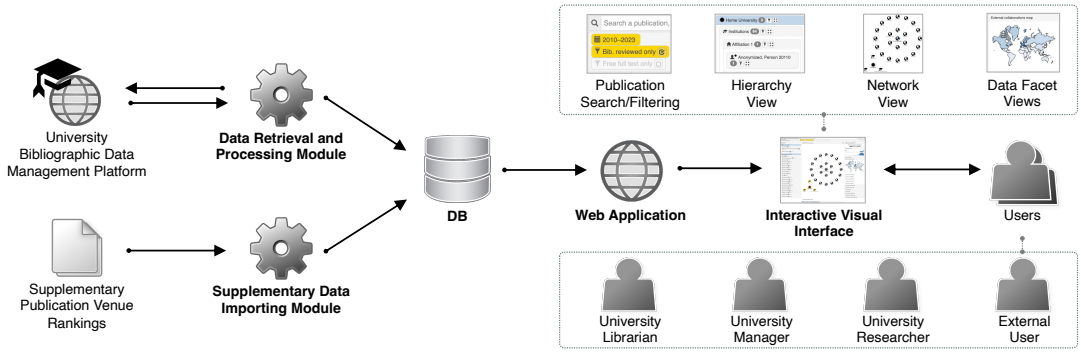

Figure 1: Overview of our proposed interactive visual approach for bibliographic data exploration.

two groups, we first discuss the data-related concerns in Section 4 and then the interactive visual interface design in Section 5. We report on the stakeholders' feedback and discuss further concerns in Section 6, and conclude this paper with Section 7.

2 RELATED WORK

Application of computational methods involving statistical, temporal, and graph/network-based models has a long history in bibliometrics and scientometrics. The researchers in library and information science also make use of visualization, especially for graphs/networks constructed from publication data. For example, Small describes computational and visual approaches for (co-)citation networks, which can be eventually applied to predict emerging areas of growth across scientific disciplines and fields (Small, 1999; Small, 2006). While such studies, conducted and published primarily by library and information science researchers, mainly make use of traditional statistical charts and static node-link diagram representations, Salaba and Merčun report the results of an interesting user study that compares a traditional faceted user interface for bibliographic data exploration with several interactive visualization techniques less widely used in the community, such as a sunburst diagram (Salaba and Merčun, 2020), with encouraging results for particular user tasks.

Within the visualization community, bibliographic data and bibliometric analyses have also attracted the researchers' attention for years. The variety of studies focusing on publication data are discussed in several existing surveys (Federico et al., 2017; Liu et al., 2018), for instance, the CiteSpace tool (Chen, 2006). Some of the noteworthy recent contributions in this field include, among others, GRAM by Burd et al., an approach that generates interactive map-like representations of aggregated research topic data (Burd et al., 2018). GRAM does not directly rely on bibliographic records, though, as it uses self-reported research topics from Google Scholar profiles. One of the goals of the approach by Burd et al. is to facilitate the university administration policy-making regarding research strategies and resources. This is related to the goals of our project, too; however, the data sources and user tasks are quite different, leading to different design choices for the visual representations and interactions.

With respect to the focus on the network data extraction and representation for scientific publications, OLGAVis (Jo et al., 2021) provides OLAP functionality and node-link visual representation. Some of the other existing approaches focus on the temporal perspective, typically with the goal of representing the publication data from a particular conference over time, e.g., CiteRivers (Heimerl et al., 2016) or VISTory (Zeng et al., 2021). VisualBib (Dattolo and Corbatto, 2022) provides a rich set of bibliography management functionality in addition to exploration capabilities. In contrast to these approaches, ReviewerNet (Salinas et al., 2020) shifts the focus to individual researchers rather than venues or publication records. The study by Rosenthal et al. (Rosenthal et al., 2019) is one of the most relevant to our work with respect to the underlying motivation and stakeholders, although their focus is entirely on the temporal perspective.

3 DESIGN REQUIREMENTS

The overall process of design and realization of this project fits the general framework of design/application studies as discussed by the visualization community (Sedlmair et al., 2012). The requirements for this work were motivated and communicated by the representatives of several groups of stakeholders within the university over the course of months via email and in-person meetings. Table 1 provides an overview of the main groups of stakeholders. The representatives of the first two groups were directly involved in the discussions regarding the de-

Table 1: The main groups of stakeholders involved or considered in our project, and their respective needs.

Stakeholder group	Needs to be addressed by the interactive tool
University librarians	(1) Gain overview of university-wide bibliometric results; (2) identify issues with bibliographic data
University administration	(1) Gain overview of university-wide or more detailed bibliometric results; (2) assess and compare the publication output at various levels within the university; (3) identify productive existing and potential collaborations at the internal, national, and international levels
University researchers	(1) Gain overview of university-wide or more detailed bibliometric results; (2) identify potential collaborations and research opportunities at various levels
Potential external users	(1) Gain overview of university-wide bibliometric results; (2) identify particular publications, researchers, groups, or projects at the university for potential collaborations, supervision, expert duties, outreach activities, etc.

Table 2: The main design requirements established for our project.

R1	The interactive tool shall retrieve and use the publication data from the existing bibliographic data management platform DiVA (Müller et al., 2003) used at the university
R2	The interactive tool should support data augmentation with respect to the publication venue ranking according to the specific ranking data used at the university and available at the national level
R3	The interactive tool should allow for the potential quality issues in the existing publication data, such as missing or misspelled affiliation titles, for instance
R4	The interactive tool shall be available as a web-based application (and it will be primarily used from desktop/laptop computers rather than other device classes)
R5	The interactive tool shall provide the bibliometric information based on the existing publication data, including the temporal overview, top publication venues, research subjects and disciplines, keywords, and external collaborations mentioned within the publication metadata entries
R6	The interactive tool shall support browsing, search, and filtering across the publication data with respect to the affiliations mentioned within the publication metadata entries, including the support for affiliation hierarchies, when possible
R7	The interactive tool should support the exploration of relationships between publication entries, authors/editors, and affiliations based on the existing publication data
R8	The interactive tool should provide its functionality to the users with limited training/instruction required (and the documentation on the main modules, representations, and interactions should be provided within the tool)

sign and implementation of the proposed approach, and the authors of this work represent the third group themselves. The fourth group represents further potential end-users, such as students or external actors.

Based on these considerations, the main design requirements listed in Table 2 could be established for our project. We should mention that the stakeholders (besides ourselves as the authors of the tool) did not initially provide any hard requirements with respect to the visual representations or interactions to be included/excluded from the user interface, but the last requirement on the list captures the expectation for techniques that would not be overwhelming for the users without extensive training or background in information visualization (Börner et al., 2016; Russell, 2016). Later during the project development, the stakeholders actually expressed a requirement for one particular visualization technique to be added—this will be discussed below in Section 5.3.

4 DATA-RELATED CONCERNS

As described above, a considerable number of requirements and constraints for the interactive tool concern the data retrieval, storage, and processing functionality, since the project aims to make use of the existing bibliographic data management platform DiVA (Müller et al., 2003) used at our university. The respective platform has been in active use for many years, which explains the peculiarities and quirks of the data schema and export formats provided by it.

As presented in Figure 1, the backend consists of several components, starting with the database client module. The modules for retrieving and importing the main publication data sets as well as publication venue rankings are designed to be either launched as one-off scripts, or set up to be launched periodically.

In order to accommodate the design requirements discussed above, the publication entries are not sufficient on their own. The backend module thus extracts the information about the authors of the publications, the editors (in case at least one of them is detected to be the staff member at our university), and the respective affiliations. Furthermore, the information about publication venues (and their rankings, if available), publishers, funders, keywords, research subjects, and disciplines is extracted from the bibliographic records and stored in the DB to be used by the frontend.

We should note that even when dealing with the data within a single university, our tool had to address the challenges of matching and disambiguating author/editor entries, inconsistent affiliation records, and further data quality issues. While the platform used by our university encourages the researchers to specify their local account details within the publication records, it does not enforce a consistent way to specify the external collaborators and their affiliations. This is beneficial in some cases (too much validation and restriction would probably be cumbersome and inflexible in some scenarios), but for the purposes of data extraction, analysis, and visual exploration, this results in additional challenges. For example, to make use of the external collaborations data, the external affiliation strings are parsed by our backend using the *coco* (country converter) library (Stadler, 2017) and additional heuristics.

Finally, on importing and processing the publication data sets nightly, the backend prepares and caches the JSON representation of the processed data set to be used by the Flask web application and served to the interactive visual interface, as discussed next.

5 VISUAL INTERFACE

The frontend of our tool is implemented in JavaScript using D3 and further libraries mentioned below to provide a rich custom user interface (see Figure 2) with multiple coordinated views (Roberts, 2007).

The top panel includes the text search and the filter controls (cf. Figure 2(a)). The search query is compared to multiple text-based fields in the data entries, e.g., publication venues or affiliation titles. Some of the filters can be adjusted only (e.g., the temporal filter) or completely removed (e.g., the filters associated with a particular author, etc.). The motivation for including the permanent, non-removable filters and for their default values lies with the suggestions and requirements expressed by our stakeholders: for instance, the optional filter for selecting only the publications with explicit funding notes was requested by the university administration in order to focus on the respective data. The filtering eventually affects the underlying set of the currently displayed publication entries (as the rest of information such as authors and affiliations is linked to particular publications) and thus triggers the updates of the other views discussed below.

5.1 Hierarchical Data View

The left panel displayed in Figure 2(b) represents the hierarchical data extracted from the publications: publication entries are nested under persons (authors/editors), persons are nested under affiliations (institutions/departments or external affiliations), and affiliations are nested under aggregate affiliations (e.g., external affiliations are grouped into countries and world regions). Thus, a single publication record from the DiVA platform might be represented by several entries in the hierarchy view, being nested under several co-authors or co-editors, for instance.

Color coding is used sparingly in this part of the GUI, with blue color used to indicate the entries related to the expanded network view nodes (see below), and gray color used to indicate the publication entries with editor rather than author contributions from the respective persons. The person entries related to the home university are additionally marked.

Clicking on a panel header in the hierarchy view (e.g., for the aggregate entries “Home university” and “External collaborations” visible by default) folds/unfolds the corresponding nested hierarchy data, thus allowing the user to dive deeper into details, if desired. Hovering over an icon prepended to each hierarchy entry title reveals a tooltip with additional details. The details are also displayed when hovering over a badge label appended to the title. The respective numerical label represents the number of non-filtered children nodes for the respective hierarchy node, such as the number of persons for an affiliation. The next control element included in the hierarchy entry node is a filter button (e.g., to only display publications with a specific author or affiliation). Additionally, clicking on a button with four arrows will trigger a node expansion + highlighting update in the network view (see the next subsection).

For publication entries in particular, a link to the respective page in the DiVA platform is displayed as well as the publication venue ranking, if available (cf. R2 in Section 3). Finally, full details about a publication are presented in a dialog window when clicking on a button with an information icon.

5.2 Network Data View

The central panel displayed in Figure 2(c) provides a heterogeneous network view comprising node representations of publications, persons, affiliations, and aggregate affiliations. The person and affiliation nodes related to the home university are additionally marked. In contrast to the hierarchy view, the data used for the network does *not* include duplicate nested

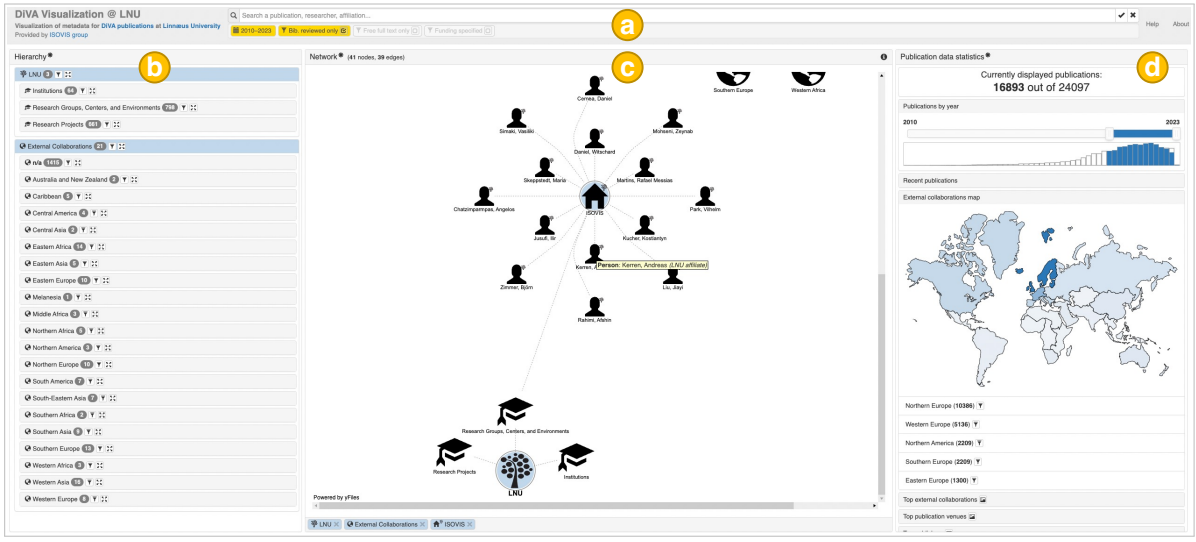

Figure 2: The interactive visual interface of our bibliographic data exploration tool: (a) the search and filter controls; (b) the hierarchical data view; (c) the network view; and (d) the data facet views. Here, in addition to the filters applied by default (which affect all of the views), the user has expanded the network node corresponding to the *ISOVIS* research group, and hovered the mouse pointer over the node corresponding to *Kerren, Andreas* in the network view, triggering the tooltip.

entries—instead, the relationships between various nodes are represented by edges (lines), e.g., a single publication node can be connected to several co-authors or co-editors. Most of the contents of the network are folded (hidden) initially and can be revealed through interactions. This decision was inspired by the *egocentric* network exploration approach (Fisher, 2005) in order to allow the users focus on the parts of the network most relevant to their current focus; furthermore, representing the complete network of thousands of nodes (publications, authors, etc.) and edges is not always feasible with a node-link diagram.

The network view is implemented using the *yFiles for HTML* library (Wiese et al., 2004), which supports a number of layout algorithms and interactions while providing a high degree of customizability and performance. The choice of the layout currently used in our tool was driven by the underlying data and expected interactions: while the set of nodes and edges visible on accessing the tool initially is quite predictable (top-level aggregate nodes), an arbitrary subset of the nodes and edges might eventually be displayed, based on the user's actions. Currently, the organic layout approach is used with yFiles, with further enhancements regarding the identification and radial layout for star substructures, as well as organic edge routing.

The network view supports panning, zooming, node tooltips on hover, and node highlight on clicking: the node itself is highlighted with orange-red, and its currently visible network connections (edges and nodes) are highlighted in yellow. This functionality is useful to trace particular relations at a glance. Furthermore, right-clicking a node creates a new publication filter (e.g., an affiliation filter in case of an affiliation node).

Finally, double-clicking on a network node will expand it. This action will reveal the edges and nodes connected to the double-clicked node, if they are not displayed already. For example, double-clicking on a publication node will reveal the related persons as well as affiliations. The network layout will adapt accordingly. Expanded nodes are highlighted in blue, and they are *not* affected by filtering applied in the user interface, effectively "pinning" them (not with respect to the spatial position, though). To keep track of the currently expanded nodes, the corresponding labels are displayed below the central panel.

Further examples of the outcomes of network view interactions are demonstrated in Figure 3. Here, the user has identified a publication of interest (e.g., via the hierarchy or data facet views) and chosen to expand and highlight the respective node (Chatzimparmpas et al., 2020). The adjacent nodes are then displayed in the network view, meaning authors/editors for the respective publication. The user decides to focus on one of the persons not affiliated with the home university, *Rossi, Fabrice*, and expands the respective network node. This leads to the appearance of the adjacent nodes, i.e., publications and affiliations for the respective person. No further publication nodes appear, though, indicating that the respective external collaborator has not contributed to any other publication in the current data set (given the current set of filters); however, an additional ex-

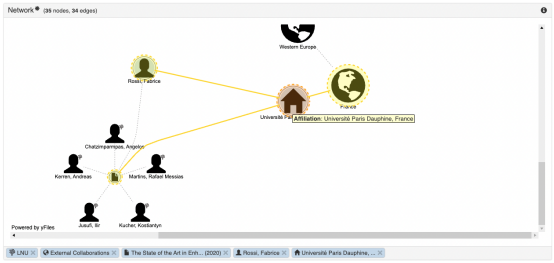

Figure 3: Example of interactions within the network view.

ternal affiliation node appears. The user decides to expand and highlight the respective node *Université Paris Dauphine, France*. The results of this interaction are demonstrated in Figure 3: the adjacent aggregate affiliation node *France* appears in the network, and the layout is automatically adjusted to accommodate the edges between the affiliation, aggregate node (country), aggregate node (region), and top-level aggregate node for external collaborations.

5.3 Data Facet Views

The right panel displayed in Figure 2(d) comprises several views related to specific aspects or attributes in the publication metadata, most of which are folded by default to save space and avoid overwhelming the user. Hovering over most of the elements in the right panel will reveal a tooltip with additional details, and buttons are also available to create corresponding filters (e.g., to only display publications with a specific keyword or research subject).

The temporal view provides a slider for filtering the visible data based on the publication year. It also includes a bar chart representing the total number and the currently displayed number (affected by the currently applied filters) of publications by year.

The list of recent publications is located below to provide the user with a simple way to browse the latest publications within the currently displayed data subset without the need to navigate through the affiliations or authors.

The map view provides a simple choropleth representation based on the world region data extracted from the external affiliations listed for the publication records. The intensity of the color used for each world region is proportional to the number of the currently visible publications (affected by the applied filters). Under the map view, the corresponding information about world regions is additionally represented with a list ordered by the respective numerical value.

The rest of the views in the right panel represent sorted lists of external affiliations, publication keywords and venues, etc., based on the number of the currently visible publications (affected by the applied filters). These lists allow the user to quickly browse through the top publication venues, for instance.

The headers for these lists also include buttons for an additional functionality that was explicitly requested by our collaborators from the university administration. They asked for the option to generate a word cloud (Viégas and Wattenberg, 2008) for the respective set of weighted labels representing top publication venues, funders, etc. for the currently displayed subset of publications. The motivation for this request was related to the need to export their findings from the exploration or specific analyses within the tool in a form that would be suitable for further dissemination and presentation purposes, e.g., as a figure included in presentation slides for the use within or outside of the university. While we mentioned the existing concerns raised within the visualization community in relation to word clouds (Viégas and Wattenberg, 2008; Felix et al., 2018), our collaborators saw this technique as familiar, suitable for their needs, and aesthetically pleasing. Thus, we implemented this technique, while limiting the max number of entries for each respective list, allowing for horizontal and vertical alignment only, and providing a dialog with the options to exclude the particular elements and to edit the respective text labels. The latter functionality was motivated by the nature of the underlying data, which might result in very long titles of journals or funding agencies, for instance, and result in deteriorated quality of the layout.

6 DISCUSSION

In this section, we report on the feedback received from several groups of stakeholders throughout the project, as well as lessons learned, limitations, and considerations for future work.

6.1 Feedback from Stakeholders

As part of our communication with the colleagues from the university library, early on we managed to find common ground and the understanding that the interactive visual tool would be complementary and would not be designed to replace the existing bibliographic data management platform DiVA (Müller et al., 2003) used at our university, which was beneficial for the project. The librarians were also very helpful with respect to clarifying the particular data format peculiarities found in DiVA, and were eager to investigate the bibliographic data quality issues identified with both the backend processing and interactive exploration within our tool.

One interesting example was related to a bibliographic entry that posed issues for the CSV parser: on closer inspection, we discovered that the respective publication author managed to use the rich text editor within DiVA to upload a screenshot of their paper's title page instead of providing the abstract as text. The colleagues from the university library also used our tool to identify inconsistent spellings and typos even for internal affiliations and authors/editors, especially for older publication entries, which is facilitated by browsing the hierarchical data view.

One particular suggestion that we received (and implemented) from the librarians was related to the network exploration: while navigating through the network and hierarchy views, they discovered that it could become cumbersome to look up the network nodes to fold within the network view; thus, the controls for folding the nodes directly from the labels situated below the network view were added.

Our colleagues from the university administration also demonstrated interest and provided encouraging feedback for the design and functionality offered by our tool. Some particular adjustments or interactions that they requested during the project included, for instance, the search by research subject; representation of local research groups and projects as affiliations within the hierarchy and network views; filtering the publications by the explicit funding status; and also the word cloud functionality, with the ability to exclude or adjust the particular items that could be considered noise.

Some of the interesting findings discovered by using our tool were related to the role of particular research funding agencies in the available publication data for our university. Further comments made by the university administration representatives included the notes about the inconsistently specified affiliation titles/abbreviations (as specified by the respective authors) and the potential way to address this issue by integrating our tool further with the internal university administration IT systems, e.g., in order to retrieve more accurate data about the ongoing projects, groups, etc. and the respective staff allocation.

6.2 Limitations and Future Work

From the point of view of the data availability and backend aspects of our project, we should mention the potential inaccuracies occurring with respect to the inconsistent or incomplete data—for instance, our approach essentially tries to "guess" the country for external affiliations by using text parsing and heuristics, however, the results are not always perfect. We acknowledge this issue within the tool documentation and instruct the users to refer to the underlying publication records, for instance.

With respect to the interactive visual interface, we acknowledge the potential issues with the network view, such as the exact layout reproducibility concerns after a series of interactions, or the classic trade-offs between the aesthetic criteria (Purchase, 2002) such as edge crossings vs. edge length. Given the dynamic nature of exploration and the dense relationships between the network nodes, an ideal solution is most likely not achievable here, but further efforts should still be made, accompanied with user studies (Lam et al., 2012; Purchase, 2012) to evaluate and compare the resulting design alternatives, for instance. Future work for the interactive visual interface also includes further support for temporal analyses of data subsets. Finally, we see opportunities for applying text mining and visual text analytics (Kucher and Kerren, 2015; Alharbi and Laramee, 2019) for publication abstracts or full texts as part of our future work.

7 CONCLUSIONS

In this paper, we present a project in supporting university research and administration via interactive visual exploration of bibliographic data. We describe the stakeholders and design requirements for this work, including the constraints related to the use of the existing publication data available from the bibliographic data management platform DiVA established at our university. The implemented tool addresses the respective data peculiarities and provides multiple perspectives and interactions for exploring and investigating the publication data, the respective authors/editors, their affiliations, and a variety of additional data facets. The tool has been used by the university library staff to identify data quality issues with the publication data, and by the university administration to gain understanding of the research output of particular local research groups and environments as well as their collaborations outside of the university, among other application scenarios.

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