musiXplora: Visual Analysis of a Musicological Encyclopedia

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Keywords: Biography Visualization, Music Visualization, Digital Humanities.

Abstract: Making large sets of digitized cultural heritage data accessible is a key task for digitization projects. While the amount of data available through print media is vast in humanities, common issues arise as information available for the digitization process is typically fragmented. One reason is the physical distribution of data through print media that has to be collected and merged. Especially, merging causes issues due to differences in terminology, hampering automatic processing. Hence, digitizing musicological data raises a broad range of challenges. In this paper, we present the current state of the on-going *musiXplora* project, including a multi-faceted database and a visual exploration system for persons, places, objects, terms, media, events, and institutions of musicological interest. A particular focus of the project is using visualizations to overcome traditional problems of handling both, vast amounts and anomalies of information induced by the historicity of data. We present several use cases that highlight the capabilities of the system to support musicologists in their daily workflows.

1 INTRODUCTION

Traditional musicology has developed into a field with several sub-domains. They differ by their main object of interest and also by their view on the data. Examples are instrument making, dealing with the physical production and often also restoration of instruments, or organology (Tresch and Dolan, 2013), concentrating on methods of research, teaching, and documentation of instruments. Further sub-domains are prosopographical analysis, focusing on the persons associated with musicology (biographical research) rather than instruments. Additionally, some musicologists focus on inspecting developments of and influences on places important for music history. Thus, in musicology, many different types of entities are encountered. Typically, these are classified as persons, (musical) objects, institutions, places, terms, events, media, and titles. This range of entities, combined with different sub-domains, leads to a vast amount of musicology data to be handled. Especially, use cases and research questions with restricted focuses subdivide the field into well-researched and less-researched fragments of data. Tools trying to connect those data fragments are few, because traditional musicological approaches either do not need to get a comprehensive picture of the whole musicological knowledge—knowing in which location an instrument was produced being of less interest for a restorer compared to the three-dimensional instrument model—and handling the vast data is hardly possible by traditional means.

In this paper, we give give an overview of an interdisciplinary collaboration between visualization scholars and musicologists, aiming to link the different fragments of musicological knowledge and offering them to the broad public with the help of an online exploration tool—the *musiXplora*—, supported by different visualizations to allow usage for both experts with specific research questions at hand as well as for casual users interested in browsing musicological information. A screenshot of the system is shown in Figure 1. As part of the digital humanities, we also want to highlight development of a digital tool in the field of musicology, leading to both, new needs and interests in research of *The Musicology* as a single and comprehensive field, and also possibilities arising through deploying computer science technology and digitization, especially for accessing and linking vast amounts of data.

2 RELATED WORK

Throughout the last two decades, a multitude of visua-

Khulusi, R., Kusnick, J., Focht, J. and Jänicke, S.
musiXplora: Visual Analysis of a Musicological Encyclopedia.
DOI: 10.5220/0008977100760087
In *Proceedings of the 15th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2020) - Volume 3: IVAPP*, pages 76-87
ISBN: 978-989-758-402-2; ISSN: 2184-4321

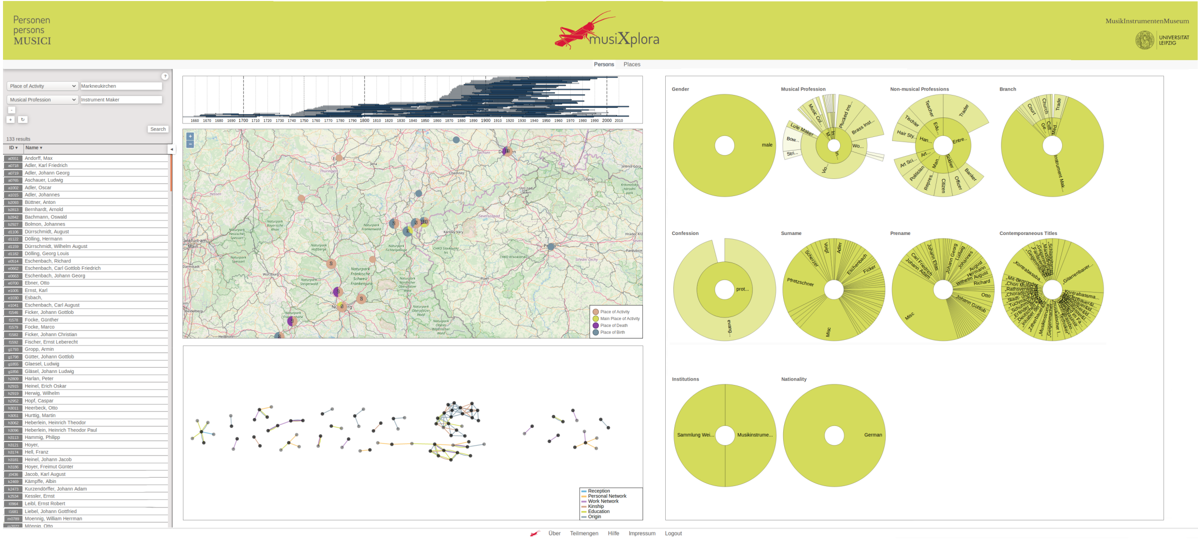

Figure 1: The *musiXplora* showing different visualizations of instrument makers in the German city of Markneukirchen.

lization projects for musicology have been conducted (Khulusi et al., 2020). Through these, different sub-domains and entities of musicology have been analyzed with the aid of visual tools. Some projects focus on a prosopographical inspection of persons. While generic visualization tools for persons (Leskinen et al., 2017) are used to show domain-independent features such as networks (Lu and Akred, 2018; Miller et al., 2012; Gleich et al., 2005; Vavrille, 2017; Crauwels and Crauwels, 2018), places (Doi, 2017) or temporal data (André et al., 2007), musicological research often requires domain-specific, contextual information. For example, regarding musical instruments (objects), typical visualizations use three-dimensional data, gained through CT (Borman and Stoel, 2009; den Bulcke et al., 2017; Hopfner, 2018) or other techniques (Heller, 2017; Konopka et al., 2017) to generate volume or surface renderings (Tuniz et al., 2012). But the sub-domain of organology does not only focus on the physical properties of instruments, other research questions are directed toward contextual metadata like dates, places, and ownerships of instruments, usually not processed by these tools. Not only do single sub-domains suffer from a too strict focus on a small set of information for a specific kind of entity, but also from comprehensive and domain-wide inspection of data not being provided. First ground building work for enabling a more global resource of musicological knowledge has been done by the German research project BMLO.

2.1 BMLO

Short for Bavarian Musician Lexicon Online (Bayerisches Musiker Lexikon Online) (Focht, 2006), the project consists of a database and a website. A group of musicological redactors crawled different analog and digital resources (manually) and put them into a standardized and scalable relational data base, suitable for an automatic processing. Due to the long history of musicology—and missing standards—a (semi-)automated processing of data is mostly only possible after manual preprocessing. The data collected in this process includes the seven categories defined by the musicologists of the project: persons, objects, places, institutions, terms, media, and events. In the active years of the BMLO project (2004–2014) the number of persons in the data set rose to around 30,000, while other categories (institutions, terms, media, ...) were mostly only drafted. Nevertheless, a frontend offers a search interface and list-like presentation of the collected data, enriched with pictures crawled through Wikimedia. Next to typical biographical data, entities also list their identifiers on different domain-related websites, like VIAF[1], GND[2] or Q[3] (Wikipedia's/Wikimedia's identifier), building a linkage between the BMLO and other online knowledge sources. In 2014, the BMLO project moved from Munich to Leipzig University and was extended to the *musiXplora* project, abolishing the focus on Bavaria and collecting generally available data of musicology. A further focus of the project was the inclusion of various interactive visual interfaces aiming to support a broad range of musicological research tasks.

[1] www.viaf.org
[2] www.dnb.de/DE/Professionell/Standardisierung/GND/gnd_node.html
[3] www.wikidata.org

3 DATA

Like the BMLO, the musiXplora database (Focht, 2019) consists of the seven facets of musicology, divided into different repositories and is editorially maintained in the Musikinstrumentenmuseum der Universität Leipzig[4]. Each repository appears in its own color, used in the header, on *Single Result Pages* as well as in the visualizations. Through the usage of the BMLO data, challenges from the former project were also inherited. These include the work with historical, uncertain data, a vastness with potential for distant-reading, but challenges for searching, filtering and finding of specific entities, and the missing of standards for general terms of musicology.

3.1 Musici—Persons

Musicologists may be interested in persons, associated in creating music—like musicians, composer or singers—, but also in people with professions like music instrument makers or restorers. The people associated with music are collected in the *Musici* (person) repository. Persons $m_1, m_2, ..., m_n$, with $n > 32,000$ offer a multitude of metadata for each musician m_i:

1. m_i^{Name}—Different written variants for first and last name, as well as additional names like pseudonyms or maiden name
2. m_i^{Date}—Temporal Data - Life and work years in a range of [0,2019] A.D.
3. $m_i^{Confession}$—List of Confession(s)
4. m_i^{Gender}—Gender(s)
5. $m_i^{MusicalProfessions}$—List of musical professions
6. $m_i^{OtherProfessions}$—List of non-musical professions
7. m_i^{Branch}—List of types of the branch(es) that employed the person like state, court or military
8. m_i^{c}—List of musical institutions c_j, ..., c_k the person belonged to
9. m_i^{l}—List of places $l_j, ..., l_k$ divided by type [Birth, Death, Work, ...]
10. m_i^{IDs}—List of IDs used in related repositories of musicological knowledge [VIAF, GND, Q, ...]
11. m_i^{Links}—List of links using the IDs to reference other resources containing important data of the person

[4]https://mfm.uni-leipzig.de/

3.2 Casae—Institutions

Unions of persons are captured in the *Casae* repository (Institutions), such as opera houses, court orchestras or festivals. For each institution $c_1, ..., c_n$ information, including the following, are given:

1. c_i^m—List of members $m_j, ..., m_k$
2. c_i^{Name}—Name of the institution
3. c_i^{Date}—Founding and closing date
4. c_i^l—List of locations $l_j, ..., l_k$

While, compared to the persons, the range of metadata is rather low, the connectivity from institutions to persons and locations leads to great possibilities for distant reading analyses of the institutions itself or more general trends between multiple ones (Khulusi et al., 2019).

3.3 Loci—Places

While not directly related to music, places are a further aspect of interest for musicologists. As seen above, places are for example included in data sets of persons and institutions. Especially for centuries prior to globalization and fast traveling possibilities, different places have been centers of agglomerations (see Section 5.2). The information for places $l_1, ..., l_n$, with $n > 76,000$, includes production centers for specific instruments or centers of performance, for example at courts. Like the repositories above, given information includes l_i^{Name}, l_i^c, l_i^{IDs}, l_i^{Links}, and l_i^m. Further, topological information is given hierarchically with $l_i^{Hierarchie}$, linking e.g. l_i Germany to l_x Europe as parent and to the German states $l_y, ..., l_z$ as children. More information is given with e.g.: $l_i^{Coordinates}$—in the form of longitude and latitude coordinates—or with linkage to events l_i^e.

3.4 Baccae—Objects

A further important part of music and musicological research are the objects needed for or produced by music (*Baccae*), including instruments and compositions. $b_1, ..., b_n$ have properties about the label b_i^{Name}, a categorization leading to a Res-entry r_j, describing textual data $b_i^{Description}$ and events b_i^{Events} linking an object to places l, persons m, temporal data b_i^{Date} and type of event b_i^{Type}.

3.5 Res—Terms

The repository *Res* includes terms of musicology. While normally dictionaries exist that help in understanding terms and offering descriptions, musicology has the unique issue that a lot of terms are uncertain, thus, leading to challenges for automated processing (Khulusi et al., 2020; Kusnick et al., 2020). This follows from changes in the meaning of terms throughout the time and almost no endeavors to standardize terminology. While in certain centuries a specific string instrument may have had five strings, it may have been overhauled in later years and adopted a six-string construction, still keeping its original name. This leads to the need for more context information to analyze written musicological information and (especially for automatic processing) issues in merging different data sources. Due to these issues, that are still aspects of the present research, the *Res* repository tries to collect different descriptions under the same name. For this purpose, r, as the set of $r_1,...,r_n$, contains $r_i^{Variants}$—labels in different languages or synonyms—, describing elements $r_i^{Description}$, lists of objects of this kind r_i^b and links to other resources holding information about this kind of term r_i^{Links}.

3.6 Catalogus—Media and Titles

While *Baccae* contains physical objects, the digital representatives of objects (books' metadata, objects' 3D data or contents of CDs or Books) are collected in *Catalogus*. While this repository is to be named in the collection of repositories, it does not have a sufficient state of research to be further discussed in this paper.

3.7 Eventa—Events

As seen before, Eventa entries $e_1,...,e_n$ offer connections between the different facets. Each event e_i contains information about its type e_i^{Type}, temporal component e_i^{Date}, associated person e_i^m or object e_i^b and place e_i^l.

4 FEATURES

With the goal to offer a digital knowledge base for musicology, the musiXplora has different core features, taking inspiration from traditional sources and enriching them with computer science technology. These goals—or tasks—fit into Munzner's Task Classification Scheme (Munzner, 2009).

4.1 Searching

The most obvious feature is offering a faceted search, enabling a multitude of ways to find entities. Munzner's second task category *Searching* categorizes

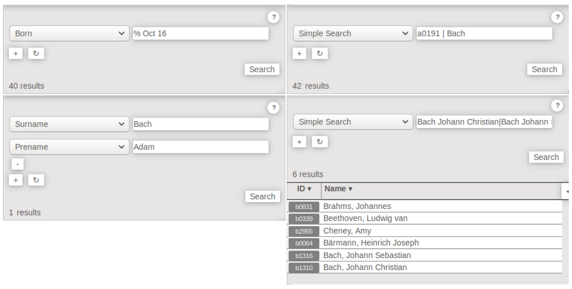

Figure 2: Four different example searches for persons. Different kinds of data (token, ID or date based) and different logic operators can be used.

such tasks by the awareness of target and its location. The musiXplora supports all four subtasks. On the one hand, a known entity can be found with the use of the specific entity's x_n features x_n^f (like x_n^{Name} or x_n^{ID}), called *Lookup* or *Locate*. On the other, a search rather detached from a specific entity can be started by searching for feature-value pairs with high recall like the century of birth or profession (*Exploring* or *Browsing*). *Locate* and *Explore* are defined with an unknown location of the target. For our search, this is reflected by a search not resulting in a single entity x_i but a set of results $x_1,...,x_n$, with $n > 1$. For such scenarios, the next section will provide further information (see Section 4.2).

Additionally, for the search-ability, wildcards and logic operators are included, helping in defining relevant parts of values (e.g. ranges of dates or groups of entities). A so-called *Simple Search* is offered as default. This matches the inserted search tags to a predefined reverse index containing all IDs to each possible tag of an entity. This reverse index allows a quick search and high recall, while the precision is rather low, as tags may be ambiguous (a tag may be the name of a person or a location). For cases where the user needs a high precision or knows exactly what to look for, a combination of type and token can be searched for. In simple cases, this may be *First Name* and *Wolfgang*. Different inputs may also be combined. A search for *First Name: Wolfgang%* and *Place of Work: Vienna* gives 20 results (compared to 243 for just Wolfgang). Also, logical operators like AND (space), OR (Pipe) and NOT (Tilde) are possible and wildcard operators (percentage mark for multiple chars and underscore for a single char) are offered. Figure 2 shows four different example searches by users of the musiXplora. Different use cases exist, where this kind of search is not sufficient to find the entity needed. May it be caused by only uncertain knowledge of the entity (the name only being phonetically known, but not in the written form), only vague knowledge or an indirect search interest. This leads

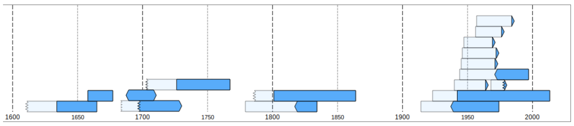

Figure 3: A timeline of working times (darker blue), enriched with living time (lighter blue). Different shapes indicate temporal uncertainties in the data.

to searches having high recall and low precision (e.g. a search only by the place of work, often resulting in multiple thousands of results). In analog dictionaries, this problem also exists, but on a lower scale, as such directories mostly return a much smaller data set and do not offer interactivity to follow up on such a search. This is caused by limited space and also by most directories being specialized on a specific set of entities (e.g. musicians or instrument makers). Hence, with a wider set of data this problem is more crucial. To tackle this issue already encountered in the BMLO, distant- and meso-reading visualizations are included in the musiXplora, helping in distinguishing the entities returned in a search.

4.2 Visualizations, Overview and Filter

These visualizations depict the distribution and range of features for all found entities. The inclusion of those is a real improvement of the musiXplora in contrast to the rather dictionary-like implementation of the BMLO and hold great value for the users of the system. In general, all visualizations follow Shneiderman's Mantra (Shneiderman, 1996) and offer a full overview as default and means for filtering the data set on demand. For the above-mentioned search of *First Name: Wolfgang%* and *Place of Work: Vienna* the following visualizations will be offered. For temporal data, a timeline is used, dynamically adjusting to the range of dates and stacking entities above each other. These timelines communicate the uncertainty of dates with shapes (arrow-like for time ranges and straight edges for time stamps) and a differentiation between lifetime (low saturation) and documented years of work (high saturation) as seen in Figure 3. Geo-spatial data is shown in a glyph based map, where the different types of places—like the place of birth/death/work/... for persons and the construction/restoration/changing ownership/... for objects—are coded with different colors. The problem of overlapping by giving a full overview is met with aggregating glyphs. To combine glyph and color approaches, each glyph aggregating more than one entity is depicted as a pie chart, showing the distribution within. Figure 4 presents dozens of places of work in Europe, with a couple in America and a single occurrence in the Middle-East for our example search.

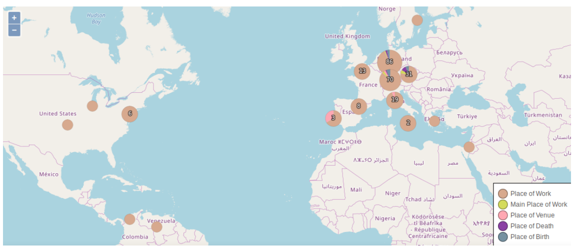

Figure 4: Glyph based map, showing different kinds of places with different colors. Heavily overlapping circles are aggregated to pie charts. The digit indicates the number of aggregated entities.

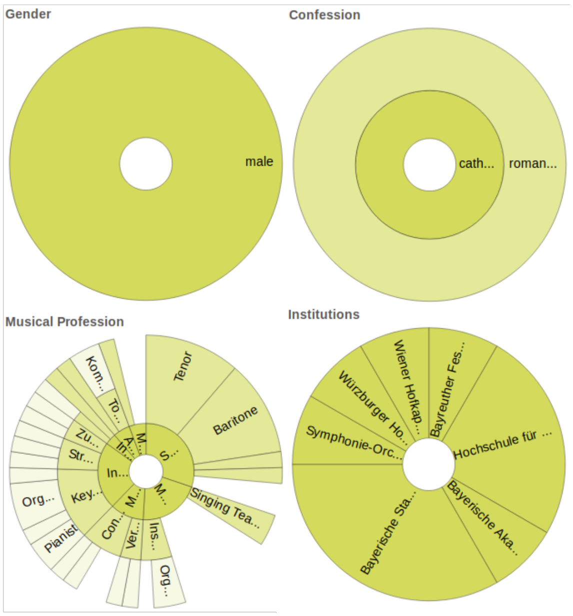

Figure 5: Different examples of pie charts and sunbursts to grasp the distribution of features in the search result.

We also use pie charts' ability to convey distributions to show more general feature distributions like seen in Figure 5. For this, multiple pie charts are added as standalone visualization at the bottom of the page. For persons $m_i, \ldots, m_j$, these may be different $m_n^{MusicalProfessions}$, $m_n^{Non-MusicalProfessions}$, $m_n^{Institutions}$, $m_n^{Confession}$, m_n^{Gender} and others. Similar, for the other repositories, different pie charts show distributions of their specific features. For some of these features, hierarchical information is given. All places have topological information upwards and downwards (earth - continent - country - state - district - city - quarter) placing them in a hierarchical context. Also, professions (e.g. Singer - Soprano/Alto/Tenor/...), Confessions, and more are given hierarchically. As pie charts do not allow for hierarchical information, we adopted the sunburst plot for these features. Figure 5 shows example pie charts for the search above and the musical professions as sunburst in the lower-left corner.

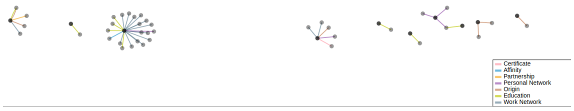

Figure 6: A force-directed graph with each person of the result being initially placed on the center of the y-axis and linearly distributed on the x-axis. Lighter nodes indicate persons added as context and not being part of the actual result.

Technically, the segments on the inner ring are distinct categories (singer, instrument maker, ...) and, if available, child elements will span on an outer ring, bearing the name (soprano, alto, tenor, ...) and the amount of those sub-types. Although deeper hierarchies are available, we only allow for up to three subsections, as each subdivision reduces the available space for labels drastically, which can also be seen in Figure 5.

In the case of relational data, a network graph with a force-directed layout is included (see Figure 6). Typical for this kind of visualization, dots represent entities and relations among them are shown by connections. Color is used to communicate different types of relations. In contrast to the other visualizations, we add contextual data in the visualization that is not included in the actual search result. This helps in getting insight into an entity's connectivity. Such contextual information has the form of additional nodes $mc_0, ..., mc_m$ showing the first level neighbors of the observed entities. Additional entities have a reduced saturation and clicking is deactivated, which all other visualization elements provide to select a single or a range of results for filtering. As observable in the different figures above, some issues with the visualizations still exist. Due to the usage of multiple visualizations at once to give an exhaustive overview of the search results, less space is available for each single visualization. While this lowers the level of detail (e.g. as visible in Figure 5 in which too small labels are hidden), we tackle this problem by enabling interactions like tool tips containing full information (all labels for a hovered pie chart slice, all places aggregated under a map glyph, ...). For tasks requiring a more detailed inspection of results, we offer alternative visualizations.

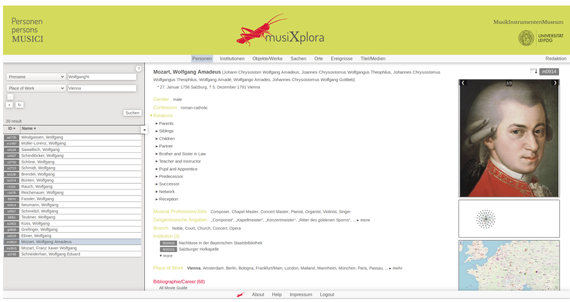

Figure 7: *Single Result Page* of Wolfgang Amadeus Mozart, listing different name variants, dates and further biographical information (left) and visualizations for these (right).

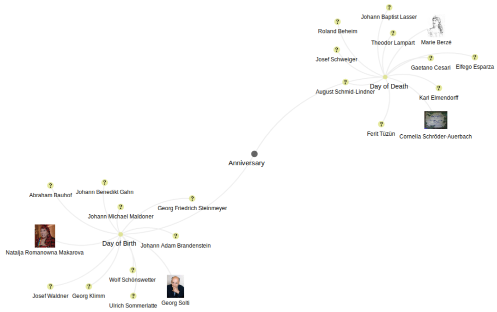

Figure 8: *Start Page Visualization* of Musici showing the persons with dates of birth or death at the current day.

4.3 Finding

After the searching part, the user may click on a single entity x_i or filter until only a single one is left. This can either be done in the result list or through one of the visualizations. The right side of the page is now changed to a *Single Result Page* (Figure 7). Here, all available information listed in the data section (Section 3) are shown in textual form.

Differently from the previous pages, we now deploy more close-reading like visualizations, concentrating on the selected entity x_i and offering a comprehensive overview. These visualizations are placed next to the textual information as small visualization previews. On demand, a user can click on each visualization to get a full view (seen later in the use case Section 5). This presentation allows for more details due to focusing on a single visualization at a time, in contrast to multiple ones in the searching section. While geo-spatial data of persons, places, and objects are again shown on a glyph based map and relations using a graph, novel visualizations are for example deployed for institutions. To allow exploration of temporal developments of an institution *An Interactive Chart of Biography* (Khulusi et al., 2019; Khulusi et al., 2018) is included for each institution. This visualization links membership data of the institution to a time-axis and offers distant-, meso- and close-reading views on the data, allowing it to be used for a broad range of scenarios and research questions regarding temporal developments of institutions. All included close-reading visualizations differ not only through the focus on a single entity but also in terms of interaction. While their distant- and meso-reading counterparts allow filtering and selecting for finding entities of research interest, the *Single Result Page* focuses on linking entities database-wide. As an example, all person's locations m_i^l link directly to their representation in the Loci places directory, indicated by a coloring of the label in the repository's color on mouse-over. Hence, quick navigation between the repositories and entity category is enabled on a high level of detail, which will be discussed in-depth in Section 5.

4.4 Browsing

Besides *Searching* and *Finding*, an explicit *Browsing* of the data is also offered. While this is less useful for specific use cases and research inquiries, it offers interesting and easy access to the data, especially useful for casual users. To support this task, the start page of each repository offers a *Start Page Visualization*, before a search can be performed. The visualized data is selected according to the opened repository. For persons, those are shown having the date of birth or death at the current day (see Figure 8). For places, often searched entities are shown, or a random selection for all other repositories. The different visualizations include a force-directed graph layout for persons, objects, institutions and media, a tag cloud for terms, a map for places and a timeline for events. If available, entities are grouped, e.g. persons being grouped by the type of anniversary, institutions by their location (on a city level) and objects by their instrument type.

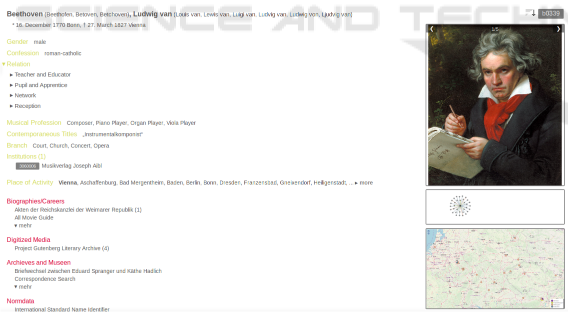

Figure 9: *Single Result Page* for Ludwig van Beethoven, as only result for the string "Beethoven" for a *Simple Search*.

5 USE CASES

During our collaboration with musicologists, we observed their use and utilization of the musiXplora. For this, multiple evaluation meetings where held, where needs and general feedback of the main collaborating musicologist were collected and discussed. Later, we observed daily workflows of musicologists of the Music Instruments Museum of Leipzig University and how the musiXplora was used as a research tool. As

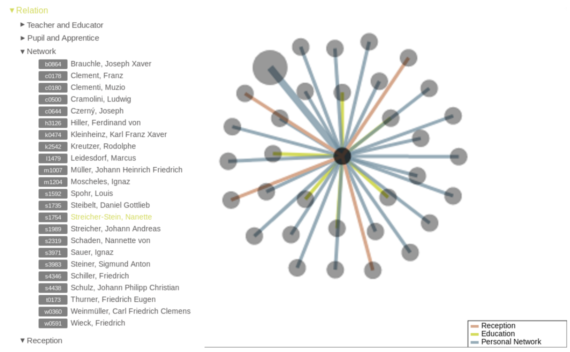

Figure 10: The network of Beethoven as visualization (right), enriched with a categorized listing (left). Instrument maker Nanette Streicher-Stein is selected and highlighted.

expected, the tool itself did not show a specific use case of how it is used, but rather a multitude of different uses for the (different) experts. To elaborate on this, we discuss three different use case types.

5.1 Information Lookup

The most basic use case observed by musicologists working with the tool was a simple information lookup, leading to a more specialized question. In the discussed case, the musicologist wanted information about Ludwig van Beethoven's instrument makers and associated instruments. For this, the expert started by querying the search interface. Through this search, we only get a single result, as Ludwig van Beethoven is the only person with the tag Beethoven in the database. As a well-known person in musicology, the resulting site shows a well-researched state and gives access to a multitude of information as seen in Figure 9.

In the next step, the researcher observed the social network of Beethoven. Figure 10 shows the entire network, accessed through clicking on the network

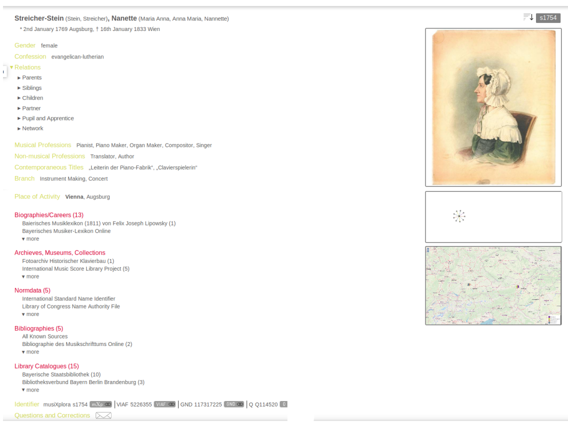

Figure 11: *Single Result Page* for the instrument maker Nanette Streicher-Stein.

Figure 12: Baccae *Single Result Page* for a ”Hammerklavier”, produced by Streicher-Stein and located in the Musikinstrumentenmuseum der Univeristät Leipzig (Music Instrument Museum, Leipzig University).

graph preview on the right side of Figure 9. In this close reading visualization, different colored edges differentiate the various kinds of relations. Through this, the user finds famous instrument makers like the married couple Johann Andreas Streicher and Nanette Streicher-Stein (highlighted) as part of Beethoven's network. A click on the latter leads us to the *Single Result Page* of Streicher-Stein seen in Figure 11. Next to the information about her relations, we also have access to information like different name variants known for her, in this case, her other first names Maria and Anna. Further, her professions list piano player, piano and organ maker, and more. We also get her informal and contemporaneous titles, like ”Director of the Piano-Factory”. Below the green biographical entries, we find the list of links to external sources in red, including Wikipedia, Wikimedia, BMLO, MusikerProfiling (Jänicke et al., 2016), AKS and further important sources for musicology. With the help of the also listed Musical Instrument Museums Online (MIMO), we can query the centralized database of instrument museums and their information about Streicher-Stein with a single click. This leads us to a list of instruments produced by her. One of these instruments can be seen in the screenshot of the Baccae repository of the musiXplora in Figure 12, presenting a brief overview of the instrument with the hint that the object's page is still under construction (which is the cause why the instrument is not yet directly linked on Streicher-Stein's page). Further, we can access a list of all instruments by Streicher-Stein exhibited in European museums. This list consists of only a dozen pianos and contains only known and documented instruments made by Streicher-Stein. While the actual number of produced instruments was without a doubt higher, the number of instruments produced per city was significantly lower than in the following centuries.

5.2 Interest Browsing

The prior use case on a famous instrument maker prior to the 19th century arouse the musicologist's interest in the development of the profession. He looked at the general state and development of instrument makers appearances in the database and filtered for only those that had a place of work in Vienna, which includes Streicher-Stein (see Figure 13, top). For higher precision, the expert then included only those persons with the main place of activity in Vienna (see Figure 13, bottom). An increase of the number of instrument makers around the change of century can be seen. Having musicological expertise, the expert concluded that the beginning of the Industrial Revolution (in Germany around 1815-1835) brought fundamental changes to the production, availability and the demand of music instruments in Europe, causing the beginning of a reshaping of the profession from straight craftsmanship to mass production. Further, the expert reflected hypotheses on abstract concepts influencing musicology, although not directly linked to it but rather to social or cultural aspects. Simultaneously to their existence, tools and means of validation and showing such concepts are missing in traditional musicology and a clear need for such tools exists. In recent years, first visualization approaches dealt with such abstract concepts like chauvinism or historism (Khulusi et al., 2019) and how they are reflected in musicology.

After the browsing of instrument makers in Vienna in the 18th century, the musicologist directed his investigation towards the influence of the Industrial Revolution on instrument making in Central Europe. The hypothesis is an increased demand for music instruments due to easier transportation means and lower prices of instruments, caused by a combination of easier accessibility of raw material and division of labor (not all parts of the instruments were constructed by the same instrument maker). Figure 13 supports this assumption for Vienna, as the number of instrument makers increased at first, which can be seen as an indication of an increase in demand. Further, a view on the instrument makers in Central Europe in general (Figure 19) shows that the rising trend continues throughout this time. Hence, the visualization of the data supports the hypothesis without referring to instruments, for which currently data is rarely

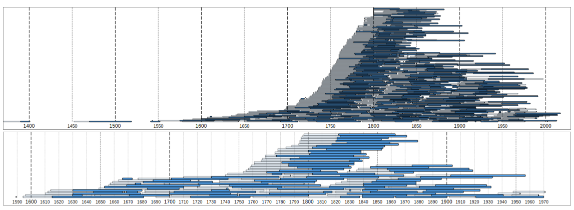

Figure 13: Timeline showing all instrument makers with a general place of activity (top) or main place of activity (bottom) in Vienna.

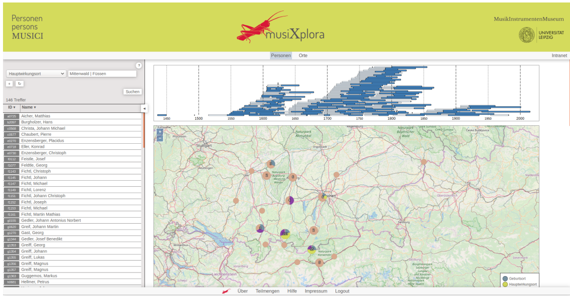

Figure 14: Result for the search of all persons with the main place of activity in Füssen or Mittenwald.

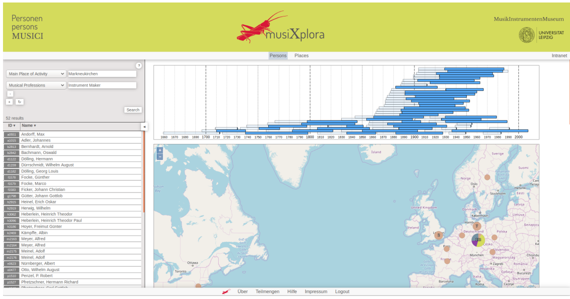

Figure 16: Overview of all instrument makers with main place of activity in Markneukirchen.

at disposal. Thus, using the occurrence of instrument makers to deduct trends for the instruments turned out to be a working strategy of the expert.

Next to such economic developments, the Industrial Revolution brought a wide set of technological advances shaping the every-day life. An example is given with the invention and expansion of the train and the train network. This led to a change in the local production center's location characteristics. Centers of high influence and renown like Vienna lost their standing if they did not ”jump on board” of those advances.

Especially traditional centers like Füssen and Mittenwald in Bavaria suffered from a late connection to the German and Central European train network. In Figure 14, all persons whose main working place was in at last one of these two cities are shown. The temporal development shows that the production centers were in a growth phase that abruptly stopped with the beginning of the Industrial Revolution in Germany (ca. 1815-1835). Close to the German-Austrian border, both locations were close to important courts and cities at the time and their proximity to rivers (Isar and Lech, respectively, both joining, the Donau) allowed early transportation means. The 19th century decrease of instrument makers in Füssen and Mittenwald, that is visualized, is accompanied with an increase of instrument makers in other cities, e.g., Markneukirchen at the German-Czech border. Markneukirchen suddenly developed to one of the most important centers in Germany, producing all kinds of instruments and even shipping them intercontinental. Figure 15 shows the Loci page for Markneukirchen, giving us direct access to all persons with either main place of activity (Figure 16) or general place of activity in the city (Figure 17).

In Figure 18, the temporal development of the three locations is juxtaposed. Instrument makers of Füssen and Mittenwald are shown at the top, and the ones having Markneukirchen as main place of activity are shown at the bottom. Additionally, this transition of instrument makers from former important centers to new ones is supported by a view of all instrument makers in Europe. It shows only a shallow difference in the total number of instrument makers (see Figure 19). A nearly constant amount, paired with a decrease in traditional centers, indicates a transition of locations. In the second half of the 20th century, a sudden drop in the number of instrument makers is seen for Markneukirchen and Europe in general. One reason is that fewer people are included in the database in the past decades as people are mostly too young to be having a meaningful impact on musicology. Nevertheless, actual events also reinforced this development. Economically, the advance of division of labor and political nationalization in the German Democratic Republic lead to a vanishing of instrument makers' names as a kind of brand.

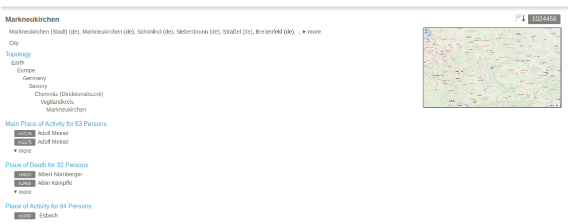

Figure 15: Top of the *Single Result Page* of Loci for Markneukirchen.

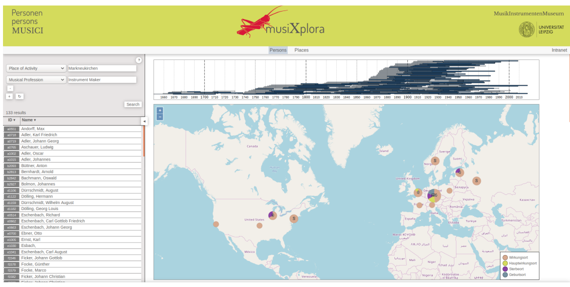

Figure 17: Overview of all instrument makers with place of activity in Markneukirchen.

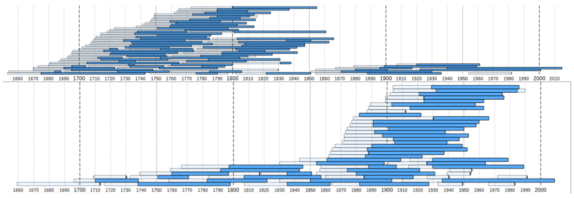

Figure 18: Match up of all persons with the main place of activity in Füssen or Mittenwald (top) or Markneukirchen (bottom) over a synchronized time-axis.

5.3 Exploration

Casual users typically access a repository through its *Start Page Visualization* (see Section 4.4). We take a look at popular places in Loci, the location dictionary. Figure 20 shows a few randomly selected places, from users' frequently accessed places. In the image, we can see places in the USA, Russia, Ukraine, Czech Republic, Germany, Italy, France, and Spain. Interested in the places of southern Germany, Swiss, Austria and Italy, we zoom in to get a more precise view on the glyphs (Figure 21). From this selection, we access the *Single Result Page* of Milan in northern Italy (Figure 22). Next to the precise topological information of Milan, located in Lombardy, we can see all links to persons through their different kinds of activity in the city and a single institution being located here. Next to the listing of entries associated with the links, we can also switch to the Musici (person) repository by selecting an activity of interest. To get an impression on the people strongly belonging to Milan, we select the *Main Place of Activity* label with its 24 results.

Musici's overview page of these 24 persons consists of the visualizations seen in Figure 23. While 24 persons are too few to deduct general trends and developments of groups of persons like in the second use case, this overview may still hold information of interest for a browsing task and show movements of people that used to work mainly in Milan. The network graph of this search (see in the middle of Figure 23) shows low connectivity for these persons. Only the first component consists of more than one person of the search result (two black nodes, while gray ones indicate persons, not included in the result). Indicated by the purple edge, both persons are of the same kin. A click on the nodes shows us the information that these two persons are rather unknown (only a sparse amount of data is given) and that they had a familial relationship (uncle and nephew). The last set of visualizations consists of pie charts and sunbursts (Figure 23, bottom). At first glance, we notice a quite large percentage of employers (branch) of the instrument making section. The sunburst of musical professions adds information about the actual kind of professions by these persons. If we would be interested in getting a full overview of all these instrument makers, we could click on the *Instrument Making* section of the *Branch* sunburst or on one of the segments of the *Musical Professions* sunburst to set a filter to only those persons included in the categories. Other possible paths leading to further inspections could be for example to view the persons in one of the three listed institutions or persons having specific non-music related professions like *statesman*, *painter* or *librarian*.

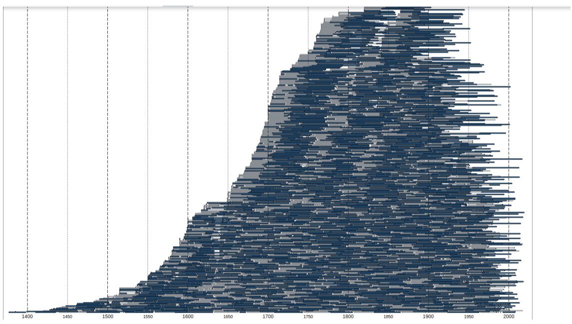

Figure 19: Timeline of all instrument makers in Europe and their temporal occurrence. Nearly constant state during the years 1800 to 1930 supports hypothesis of transitioning of production centers seen in Figure 18.

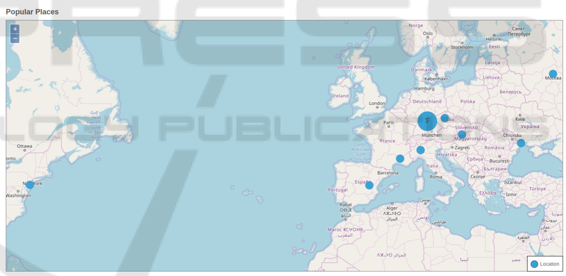

Figure 20: *Start Page Visualization* for Loci, showing a random selection out of the most user searched locations.

6 CONCLUSION

With the growing importance of digital methods in the humanities, the amount of data digitally available is likewise rising continuously (Windhager et al., 2018; Jänicke et al., 2015). Due to the nature of the field, available data in musicology is typically fragmented due to different, loosely connected sub-domains. A single fragment bears a vastness of data but mostly focuses on a specific view on the field. Global trends in musicology can only be hypothesized, and only a few tools and projects give a comprehensive overview. The musiXplora is an on-going project dealing with collecting, standardizing and visualizing information of seven different types of data defined by musicol-

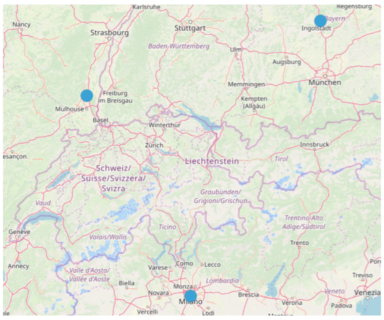

Figure 21: Zoomed in view on the Loci start page.

ogists. Due to close collaboration between visualization scholars and musicologists, the tool does not only make use of digital advantages of data storage and the capability of visualization to make data easily accessible, but also guarantees correctness, quality, and relevance of the content for both, experts and casual users. Different use cases showcase the ability of the system to be used for a wide set of research questions and also enable different ways of accessing resources. Thus, the experts could validate a hypothesis of the abstract concept of the Industrial Revolution and its influence on music instrument makers through visualizations of places and persons. Further, we observed a large interest and fascination during the usage of the tool and through on-going interdisciplinary discourses on the needs and interests of different musicologists. While the tool is generally tailored for the musicological data set, other projects using this data (Jänicke et al., 2016; Meinecke and Jänicke, 2018) have already shown that an adaption to non-musicological data is possible, which offers diverse opportunities for future research.

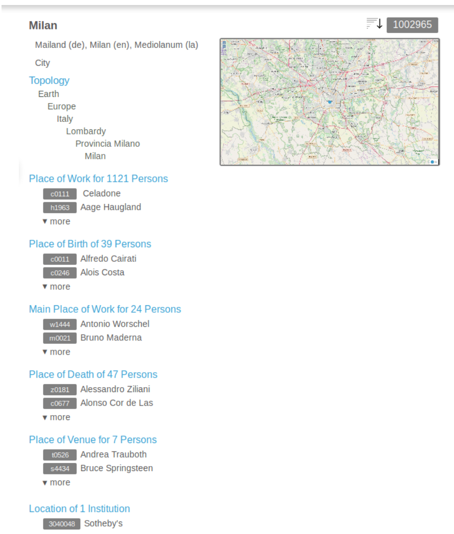

Figure 22: *Single Result Page* of Milan, including all persons and their activity in the city.

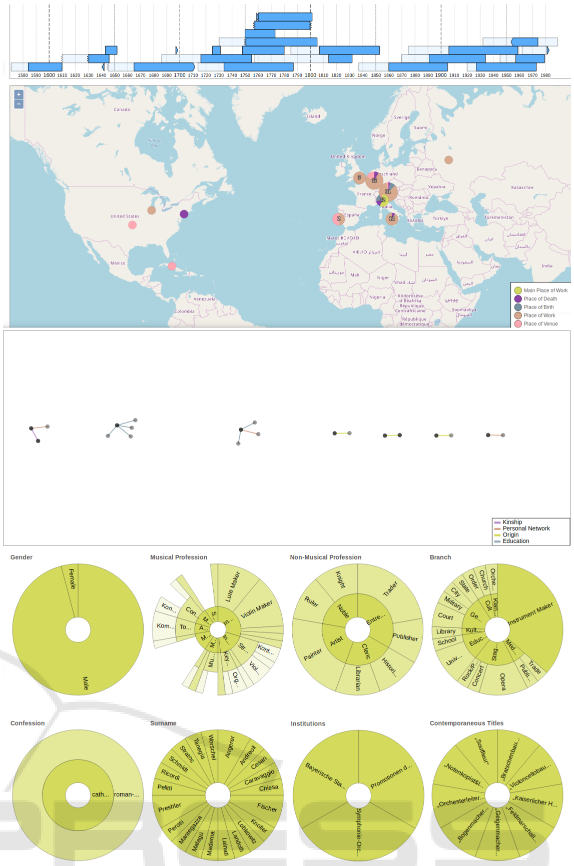

Figure 23: The overview visualizations for all persons with main activity in Milan. From top to bottom: timeline, map, network graph and collection of pie charts and sunbursts.

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