MusiXplora: Visualizing Geospatial Data in the Musicological Domain

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Abstract—The musiXplora is an interactive and multimodal tool for the domain of musicology, developed in a collaborative and interdisciplinary fashion. It serves as a research environment that, on the one hand, links large data collections on musicians, musical instruments, events and more, and, on the other hand, offers a set of visualizations which allow users to explore and analyze these data sets comprehensively. In this paper, we discuss our recent work to emphasize the relevance of geovisualizations in the musicological domain and provide detailed insights into how the musiXplora can be used to address geospatial research questions. We introduce two distinct use cases and discuss how musicologists can use the musiXplora's geovisualizations as distant-reading tools. Thereby we demonstrate how the musiXplora can contribute to the confirmation of existing hypotheses and to the formulation of new ones.

Index Terms—geovisualization, musicology, research environment, organology, digital humanities

I. Introduction

In the last two decades, the field of musicology showed an ongoing interest towards the usage of digital data collections, especially for their capabilities to provide tools for visual analytics [1], [2]. This development was both accompanied and enabled by the creation of large digital collections of musicological research data, opening up new possibilities for musicologists' research [3], [4]. These collections allow for new, data-driven, visual approaches to existing musicological research subdomains.

The musiXplora is a prime example of a digital collection contributing to this trend [4]–[7]. Started in the early 2000s the project has been cultivated into a virtual reference work. In a joint effort of musicology scholars and computer scientists it combines a large collection of curated data from primary and secondary sources, as well as numerous tools to explore the data. An essential part of these tools are interactive visualizations, including geovisualizations, which enable musicology scholars to perform visual analyses. Amongst these, geographical visualizations are especially useful tools to graphically display spatial relations and historical developments that could otherwise not be studied easily using traditional qualitative methods.

The musiXplora can be understood as an interactive research environment that is continuously being updated and enhanced. Since its initial release both the underlying digital collections as well as the available tools to interact with them have been continuously expanded. Recent additions of new data to the musiXplora sparked an increased interest of our collaborating musicologists in geospatial analyses.

In this paper, we present two use cases that emerged from this development: First, we offer an insight into the geographical spread of the Prague School of double bass playing techniques across multiple generations (see Section IV-A). Secondly, we take a look at the introduction of the modern tuba instrument and its adaptation in German-speaking and anglophone cultural regions within central Europe in its less than 200-year history (see Section IV-B).

In the context of these use cases we provide a deeper insight into the geospatial visualizations within the musiXplora and highlight how they can support musicological research routines. For the first time we demonstrate how the musiXplora can be used to visualize links between geospatial and temporal attributes. For this purpose, we are showcasing an existing as well as a newly implemented visualization tailored for this application. Hence, we contribute a design study, by demonstrating how the deployment of existing types of visualization designs can assist domain experts in their research and also by showing how the availability of data is influencing musicological research.

II. Related Work: Visualizing Musicological Knowledge

In recent years, visualization of musical data has seen an increasing interest and provided value for the knowledge acquisition in musicological research [2], [8]. Notwithstanding their similarity, musical data needs to be differentiated from musicological data. Only the latter will be the focus of this paper. It refers to all data linked to the parent domain of musicology and includes biographical data of

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composers and instrument makers and, for example, places linked to the manufacturing of specific instruments or important dates of e.g. concerts.

Such data has been the subject of a wide variety of visualization use cases and tasks. Meinecke et al. [9] for example showcased text alignment and text reuse of lyrics in rap music, by means of similarity networks, scatterplots, timeline visualizations, and various other techniques. In contrast, Ono et al. [10] compared similarities in audio features rather than the song lyrics and introduced a similarity graph that allows the user to visually explore similarities between parts of songs.

Furthermore, some projects cater especially to non-experts and casual users. As an example, the PartyVote interface allows attendees of a party to vote on the next song to be played and have a visual representation of the voting decisions [11]. In other cases, visualizations are used for musical education purposes: In the game Rocksmith, users plug in a real electric guitar or bass guitar and are taught to play songs interactively, according to their skill level. The user interface resembles a guitar's fingerboard and displays a visual representation of which notes and chords the player is supposed to play [12].

An essential question for any tool trying to graphically represent musicological knowledge is which types of visualization to use. The answer to that question will most certainly depend both on the types of data available and the task or research question at hand. Providing a comprehensive survey, Khulusi et al. [2] presented an analysis of different visualization techniques in the field of music visualization. While not explicitly stated, these also include visualizations motivated within the musicological domain, although we found this subfield underdeveloped when compared to the music visualization domain.

Typically, visualizations for musicological research include maps for geographical [13] as well as topological [14] analysis and presentation. An example can be seen in a project of Doi [15]. In order to help scholars "draw conclusions about the history of community-based musical activity within the province [of Saskatchewan, Canada]" [15], Doi crawled data on performances of large ensembles in Saskatchewan from a library catalogue, accumulated the data using OpenRefine and offered a geovisualization showing the concentration of bands, orchestras and choirs in the province. Kusnick et al. [6] presented a geovisualization that displays different events linked to specific musical instruments in order to calculate a score of how likely it was for a specific instrument to be used in a live concert, making use of the geographical similarity of the events as well as other features.

Besides scientific applications, there are examples of interactive geovisualizations in the music tourism domain. In the permanent exhibition of the British Music Experience, museum visitors are invited to use an interactive map that focuses on the history of popular music in Britain and Northern Ireland. The map contains glyphs which represent for example hometowns, events, and album covers for the visitors to click on, read about, and to browse and explore [16].

While map-based visualizations make up only a small subset of visualizations in the musicological domain [2], they are commonly used in other domains [17]–[19] and are an important subject in the general field of visualizations [20], [21]. Especially relevant to the approach we present here is the map-based visualization of multivariate data for which glyph maps are a common tool. They are used to mark locations while visualizing multiple data attributes. The glyphs can even include other visualizations like pie charts, as proposed by McNabb and Laramee [22].

While other published works in the domain of musicology make use of map-based visualizations, their data sources are mostly limited to smaller subsets of data, thereby limiting the scope of research questions for which the tools are applicable. The musiXplora [23] constitutes a more generic environment that lets researchers answer their different and multifaceted research questions.

Multiple related works published in recent years on the subject of the musiXplora demonstrated its capability, not only as a source of digitized data [5], [6], [24], but also as a tool for visual analytics itself [23]. Following the approach of visual analytics [25], the musiXplora enables musicologists to analyze large musicological data sets by using state-of-the-art visualization and interaction techniques.

III. Using the musiXplora

To achieve its goal of offering a generic tool for musicological research, the musiXplora does not limit its data to a single type of entity, unlike more specifically tailored projects. There are currently seven types of entities relevant for different musicological facets. These are persons, objects, places, terms, institutions, events, and media [23]. While the data is fragmented into these facets, a high level of linkage between the different parts can be found. This allows researchers to not only view detailed information on individual entities but also to use distant reading approaches to gain perspectives on large scale trends and developments [26].

Offering a faceted search functionality to query the collection of over 175,000 entities with more than 3,000,000 values for various associated attributes, collected and digitized in the last 20 years, the visual representation is of high impact for research in the domains of musicology and visualizations [6], [24], [27]. In multiple published works the platform was used and presented, showcasing multiple use cases that give insight into musicologists' work with the tool. In the previous works, these use cases were focused on temporal analysis and timelines [6], [24], the linkage between facets [26], profiling of musicians [5], comparison of developments of different instruments [27] and institutions [24].

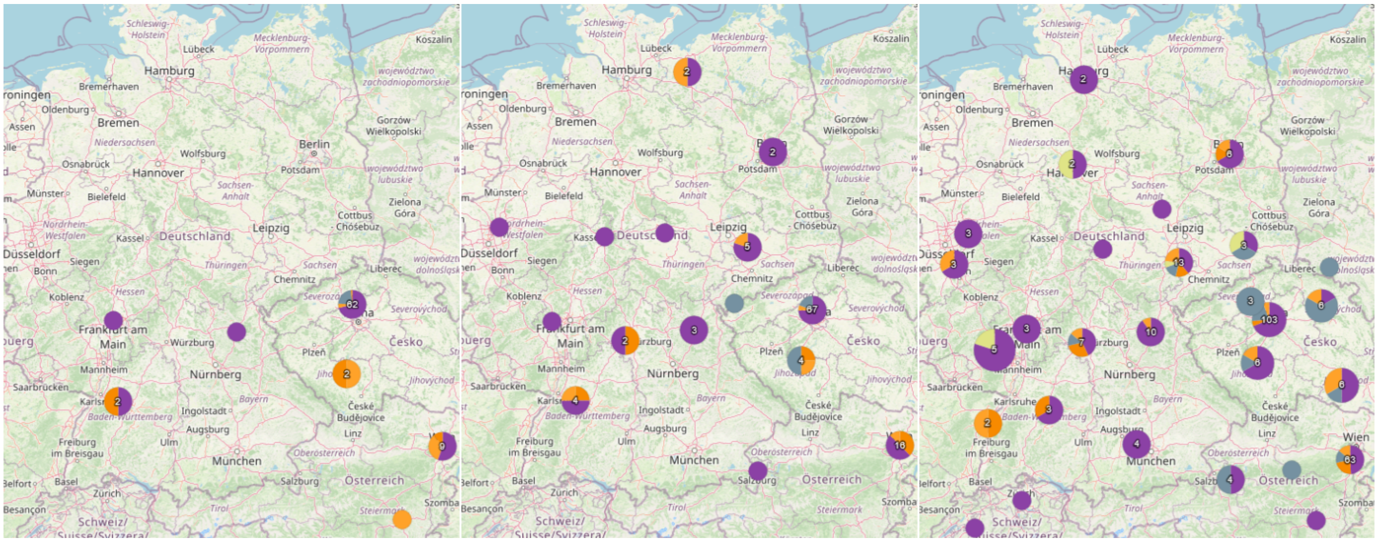

Figure 1. The first three generations of Prague School students within central Europe. Purple marks places of activity while dark orange marks main places of activity.

In this publication, we give a deeper insight into the possibilities of geospatial analysis with the musiXplora.

A. Data

In the use cases shown later (see Section IV), we make use of the musiXplora's person and place entities. A detailed description of the available information in these facets can be found in Khulusi et al. [23]. Especially important for the first use case are the professional relationships between musicians – specifically teacher-pupil relationships –, and the places of activity[1]. For the second use case, we utilize musicians occupations, as well as their places of activity.

The musiXplora is also home to a number of data subsets. These allow musicologists to access smaller, curated selections of its data collection. Each subset corresponds to a specific research project and has a scope that reflects the requirements of that project. While the data in each subset is limited to entries relevant to that project, all of the musiXplora's tools are available to the musicologists.

B. Visualization

A general overview of visualizations offered in the musiXplora was given by Khulusi et al. [23], giving a brief overview over the basic visualizations – timelines, maps, network graphs, and pie charts. Building on this, we provide a more in-depth description of the geovisualizations of the musiXplora and demonstrate their usefulness by introducing use cases.

When showing information about multiple personal records, the musiXplora displays a map containing biographical information like birthplace, place of death, places of activity and places that people performed at (see Figure 1). This information is automatically grouped for each location or, depending on the zoom level, for multiple locations. A glyph is then displayed that shows the aggregated number of data points for each location as well as a color coded pie chart of the individual categories' share for that location. By hovering over the glyph the exact share of each category is displayed and the persons that are associated with that location are highlighted in the result list. This also works in reverse. By highlighting a person in the result list, all locations that the person is associated with will be highlighted in the map view.

Within the field of visual analytics, the interaction techniques used in the visualizations can be classified as exploratory-oriented as they allow users to gain insights by modifying zooms and filtering the data (e.g. by region/time) [25].

IV. Use Cases

A. Geographical Spread of the Prague School for Double Bass

The term "Prague School" refers to a set of playing and teaching techniques for the double bass that were first developed by Wenzel Hause (1754–1845), who held a professorship at the Prague Conservatory. It is considered a major breakthrough in the methodology of the instrument by musicology scholars in the field. Over the next decades, it was further refined and spread throughout Europe – and subsequently the world – by Wenzels students and their students, respectively [28], [29].

The Prague School itself is of high interest for double bass focused research. Its historical beginning coincides with the establishment of the first professorships for the double bass across Europe leading to a dense level of documentation. This, in combination with its peculiarity

[1] In the musiXplora's vocabulary, places of activity refer to a professional association between a person and a location. If a single association is of particular importance to a musicians career, it is denoted as the main place of activity.

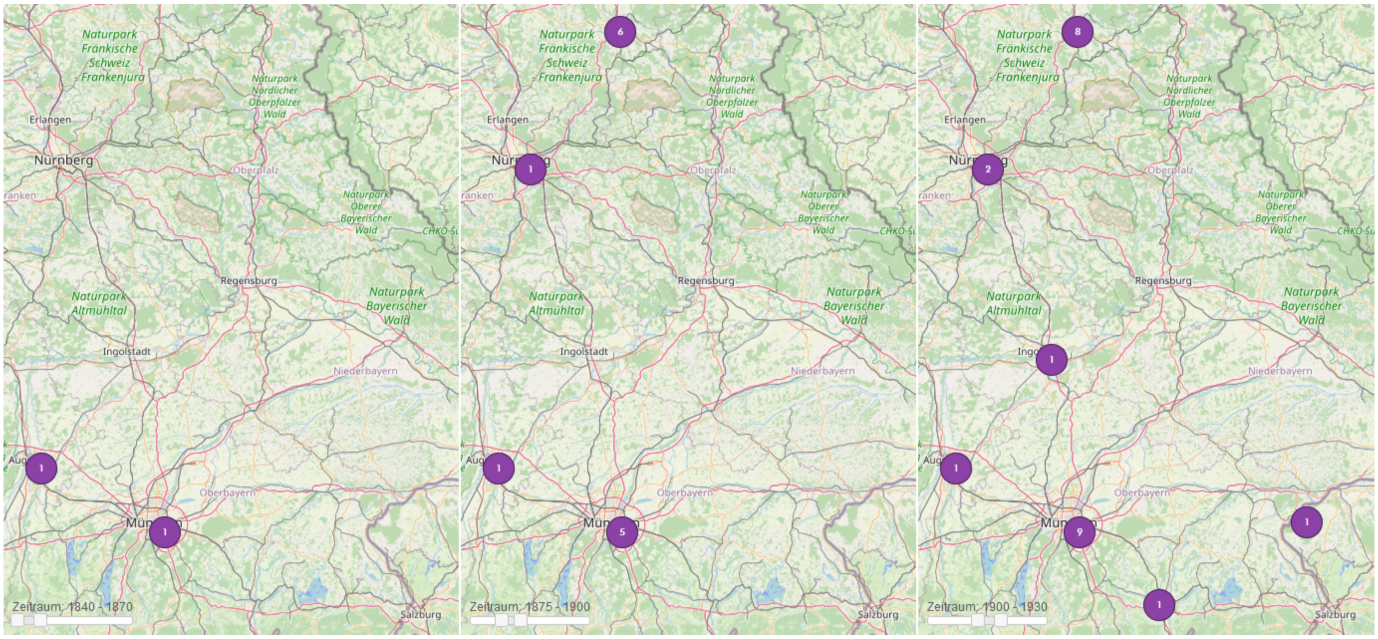

Figure 2. Places of actitivity of tubist in Bavaria throughout three different timespans. The selected timespan is visible in the bottom left corner of each section.

of being traceable to a single person, makes it a prime example for an analysis of the spread of such a playing technique.

To investigate this development we used a recently created, previously unpublished function of the musiXplora: the Kontrabass (German for double bass) subset. In the past two years, musicologists specifically collected new and enriched existing data related to the double bass and its profession. Today this subset contains data on around 3,300 double bass players including professional relationships between them (see Section III-A).

We talked to a resident musicologist whose research is focused on the double bass. He told us that he was interested in looking at how the Prague School spread to different locations throughout its history. To facilitate this task we first selected Wenzel Hause within the double bass subset of the musiXplora data and then recursively added all of his students, their students and so on. We then segmented them into distinct generations of students, resulting in 10 generations, with the 10th generation representing the current one. Each holds an average of 93 musicians with data getting more sparse in the last generations, due to data limitations (see Section V). For each generation we generated a query that allows us to use the visualizations present in the musiXplora to explore the data.

Together with the musicologist, we looked at the generated data (see Figure 1) and discussed relevant findings for his work. He pointed out a general and well documented spread from Prague to Vienna as one of the first cities in which the double bass profession was influenced by this school (1st generation). As a centre of contemporary music culture, the spread to Vienna marked an important milestone in the adaptation of the school. This was accompanied by a relatively early expansion of the school to Berlin and Moscow (2nd generation), which goes along with musicological literature on the subject [28].

Besides these general patterns validating existing hypotheses, our expert was also interested in observing the pattern in which the schools followers spread to other European cities throughout the different generations. Our analysis showed the first followers in Budapest and Kyiv (1st generation), Würzburg and Leipzig (2nd generation) as well as Brno and Cologne (3rd generation).

The visualizations also allowed us to retrace developments on a regional level, e.g. the establishment of a strong presence of students of the Prague School in New York as one of the first oversea locations before its further spread to Philadelphia (3rd generation). As these visualizations utilise the toolset already available in the musiXplora, musicologists have all these tools at their disposal when further investigating any observations of interest. Additionally, these first results may lead to follow-up research questions, like a deeper analysis of the cohort of US-American students of the Prague School and a comparative analysis to European ones.

B. Adaptation of the Tuba

Another example of a development that sparks the interest of musicology scholars is the adaptation and spread of newly developed musical instruments. Being first patented in 1835, the tuba is a relatively young instrument [30]. Compared to most other classical instruments, some of which trace their origins back to antiquity, the adaptation of the tuba is much better documented. This can be attributed to the better established organological methods at the time of its invention, but also to the pure chance of these documents surviving up until today. Documents that were used by the editors of the musiXplora to gather data on the adaption of the tuba were mostly monographs from court chapels, operas, and military musicians, as well as Royal Kalendars and biographical sources of any kind.

Originally used for military music, its ability to provide a loud, good sounding, chromatic bass led to its unusually fast adaptation, first by other brass bands and later by opera and symphonic orchestras of which it quickly became a common part.

Along with the adaptation of the instrument, new positions for tubists had to be created at musical institutions. Musicologists at our institution were interested in the chronology of this adaptation process and its geographical development. They had already created a collection of around 100 tubists containing, amongst other things, information on their places of activity. In the case of tubists these places of activity mostly coincide with positions held at local musical institutions. Using the documented places of activity as proxies for the adaptation at these institution we can thus trace the adaptation of the modern tuba throughout German-speaking and anglophone Europe.

The existing visualization tools in the musiXplora did not provide sufficient capabilities to investigate the temporal aspects we wanted to focus on. To this purpose we implemented a new tool containing a map view of all tubists' places of activity that includes only those that were active during a selected timespan (see Figure 2). The timespan can be adjusted by the user using a slider element. By clicking on a specific location, users can view all tubists who were actively working at that location in the musiXplora, allowing them to use all the well known tools to further explore the data.

The musicologists at our institution reaffirmed the added value of this visualization: It enables them to not only track the quantitative increase of tubists, but to visually analyze the linkage between place and time. It is especially useful for research focusing on when and where the tuba was introduced, and whether there are places and times that are particularly significant for its adaptation. A musicologist pointed out that in the case of the tuba players, there is no significant literature on this subject as the research field is still very young and small.

However, using our visualization the musicologist was able to verify unconfirmed expert hypotheses on the geographical and temporal development of the tuba: Using Bavaria as an example (see Figure 2), we can see that in an early timespan (1840–1870), tubists can only be found in Augsburg and Munich where garrisons were located. Looking at the timespan between 1875 and 1900, tubists have spread to additional cities with garrisons like Nuremberg. A great increase in the number of tubists can be noticed in the years following 1875. This can be traced back to the beginning of the Bayreuth Festival in 1876, which was one of the first major appearances of the tuba in a non-military context. Over the course of the early 20th century (1900–1930) the tuba was also adapted in more rural areas of Bavaria like Bad Aibing, Ingolstadt and Burghausen. After 1950, the tuba was established in the academic world with instrumental training taking place at universities.

These two use cases illustrate the ability of geo-visualizations to not only verify findings from literature, but also to help confirm expert hypotheses.

V. Discussion

As with most visualizations the usefulness of the approaches presented here depends greatly on the underlying data. While a whole team of musicologists work on the (semi-) manual data gathering and validation process, ensuring a high quality of the data, the available data is dependent on available sources, leading to errors, sparse data, and uncertainties which cannot always be resolved. The reliance on primary or secondary sources can also result in significant bias in the data. One example is the under-representation of tubists in non German-speaking or anglophone areas within our data set.

It is also crucial to be aware of other potential shortcomings in the data gathering. While our method for segmenting the Prague School students into generations should generally work well for the earlier generations it can be expected to be less accurate for later generations due to factors as differing age, lifespan and length of teaching career.

Moreover, additional visualization features could help musicology scholars to further investigate the data collections. Regarding our first use case, it would be desirable to provide an interface that enables users to generate the visualization by themselves without requiring a computer scientist to write a query. Additionally, a dynamic view of the different generations instead of separate visualizations would be preferable.

VI. Conclusion

We presented two use cases for geographical visualizations from the musiXplora showcasing the usefulness and need for geovisualizations within the musicologist realm. By focusing on concrete musicological research questions and tasks, we were able to demonstrate that our visualizations make a useful addition to answer those kinds of questions.

Looking at and comparing different generations of a teaching school is not a new approach in musicology. However our distant-reading visualization has shown to make it significantly easier for musicologists to find trends and observe socio-geographical relationships. The interactive nature of the presented visualizations and their integration within the musiXplora tool also improves the ability to follow up on any observations.

Similarly, the adaptation of a new instrument like the modern tuba has already been part of musicologists' research. The presented approach allows scholars to look at the developments in an easier and faster way than traditional methods, providing a valuable addition to the toolset of today's musicologists.

In its entirety, the tools we presented mark a significant improvement for musicologists looking to study geographical adaptation patterns. They can help to confirm existing assumptions found in literature, but also provide evidence for previously unconfirmed assumptions. Additionally, they offer musicologists a rich toolset to follow up on any new observations helping in the creation of new hypotheses.

This further amplifies how a successful collaboration between musicologists and the digital humanities can help provide additional insights into existing data and new research opportunities. In the future we plan to further expand the existing tools to allow musicologists to investigate a wider range of geographical relationships within the data of the musiXplora.

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