

# VibViz: Visualizing a Vibration Library

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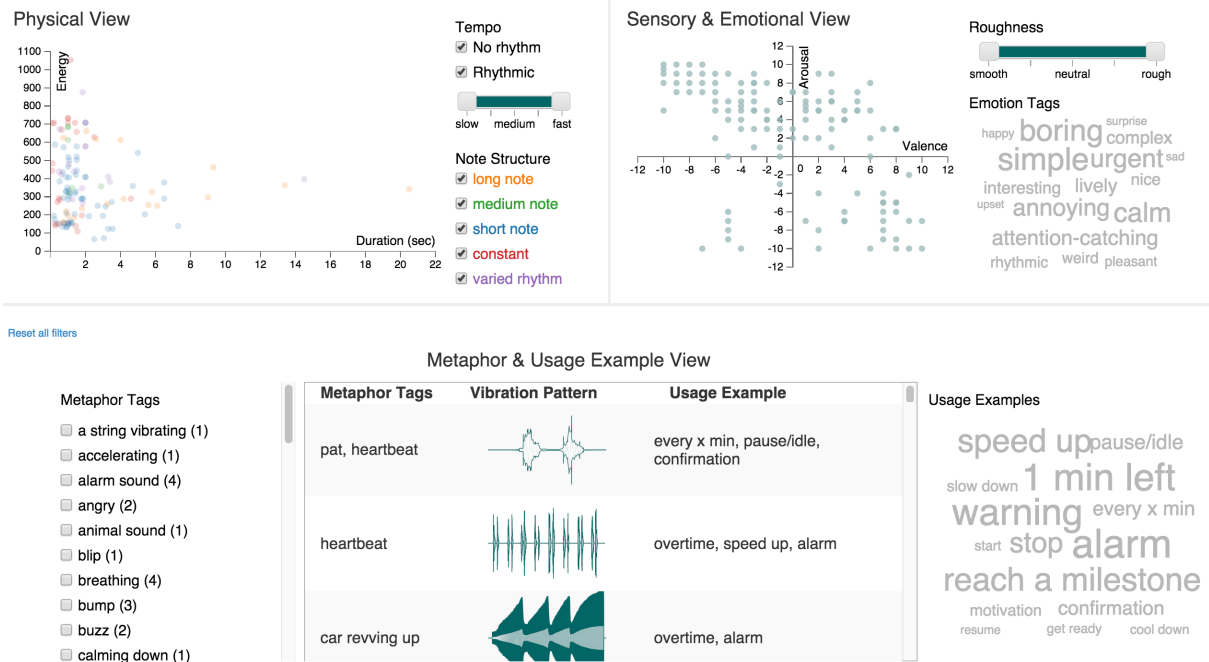


Fig. 1: VibViz features three separate views: 1) *physical*, 2) *sensory & emotional*, and 3) *metaphor & usage* view.

**Abstract**—This paper describes VibViz, an interactive visualization system for a vibration library. The high level goal of VibViz is to support 1) end users to explore and browse the vibration library, and 2) researchers to investigate properties of vibrations. The system visualizes physical, sensory, emotional, metaphor, and usage example vibration attributes using three multi-form views. We employed linked-highlighting to coordinate multiple views in the system. Further, We designed a saturation-coded vibration envelope for more intuitive end-user experience in VibViz. Some preliminary end user feedback suggests VibViz to be an effective tool for exploring vibrations. As the next step, we plan to use VibViz as a research prototype to investigate end-users’ perception of various vibration taxonomies.

**Index Terms**—Information Visualization, Vibration Library, Vibration Taxonomies, End-User Customization

## 1 INTRODUCTION

The rapid proliferation of vibrotactile (VT) devices and applications calls for vibration library tools that can support end users in customizing their vibration notifications without prior haptic knowledge. Two past projects in SPIN lab at UBC studied using vibration notifications for tracking timing and progress of a presentation or exercise. Both projects highlighted the need for enabling end-user customization of vibration notifications.

Based on our data thus far, we believe easy and highly navigable access to a large collection of vibrations is essential for end-user customization.

VibViz is a part of a larger vibrotactile project. The high-level research question we try to address in this project is: how can users find their desired effects in a collection of vibrations? What organization and representation of the collection can best support users? Which vi-

bration attributes can better support users in browsing the library and finding their desired effects?

Although haptic designers usually use low-level engineering parameters, such as energy and tempo, to design vibrations, past researches [11, 12, 16] suggests that end users describe vibrations in different ways. Some of these include describing 1) *physical* properties of vibrations, such as duration and energy, or 2) *sensory* and *emotional* words, such as simple and urgent, or 3) *metaphors*, such as heartbeat, or 4) *usage examples*, such as overtime. Each of these ways can be used to categorize vibrations, and we refer to each as a *vibration taxonomy*.

We designed VibViz (Figure 1), an interactive visualization of a library of vibrations. Each vibration is described and visualized according to the five abovementioned vibration taxonomies: *physical*, *sensory*, *emotional*, *metaphor*, and *usage example*.

VibViz aims to support two groups of users: 1) end users who want to customize vibration notifications for their everyday applications but with no haptic background, and 2) haptic designers and researchers who want to investigate users’ perception of vibration and find patterns in a library of vibrations. The second group of users differentiates us from previous library visualization designs and influences our design decisions.

- <http://www.cs.ubc.ca/~kzhang2/VibViz/>
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- Hasti is auditing the course, but this project fits into her PhD thesis work. E-mail: seifi@cs.ubc.ca.

In the next section, we present related work in the area including studies of user interactions with media libraries and past visualization tools proposed for such libraries. Section 3 includes the design and implementation details of VibViz, followed by two scenario walk-through and a preliminary evaluation of VibViz in Section 4. We discuss the strengths and weaknesses of VibViz in Section 5 as well as lessons learned from working on this project. Section 6 includes future work and conclusion. At the end, we present the division of work for this project.

## 2 RELATED WORK

VibViz is the first visualization system for a library of vibrations. In addition, to our knowledge, VibViz is the only media visualization system, aiming to support both end users and researchers. In this section, we review previous work on media libraries and media visualization systems that informed the design of VibViz.

### 2.1 End-User Interaction with Media Libraries

Past studies on music and photo collections indicate that end users usually **browse** collections rather than search for specific media items [7, 3]. In fact, users usually have difficulty articulating their desired media in a search query. Further, people usually satisfice rather than optimize, meaning they look for the first media item that matches their criteria and welcome serendipity [7, 3].

Past studies suggest that, compared to textual media archives, visualizing media collections can better support open exploration and serendipitous discoveries [14, 8]. Since the media visualization systems usually target non-expert users, engagement and aesthetics are important factors in their design. According to Thudt et. al. [14], supporting playful interaction is one of the important interface factors for serendipitous discoveries.

### 2.2 Visualization Tools for Media Library

Several interfaces have been designed for browsing, exploration, and searching through large collections of books, music, photos, and films [15, 5, 2, 6, 1, 14]. Torrens [15] proposed three visualizations for personal music collections but did not evaluate them with users. He suggested to use treemap visualization for a music collection overview. PhotoMesa [6] utilizes treemap and bubble maps to visualize different media collections; it also provides a zoomable interactive visualization for image browsing.

Apart from the usual visualization approach, some media visualization systems use machine learning algorithms such as clustering to group and present media items based on their similarity [4, 9, 10].

Among the interactive media library visualization systems, Musicoverly and Bohemian bookshelf are the two most relevant to our work. Musicoverly [1] is an online music streaming tool that visualizes its music collection based on mood and emotional content of music tracks. The interface makes good use of space and color coding in various filters types including genre, date, artist, intended activity, and etc.

Bohemian bookshelf [14] is a visualization interface for browsing a book collection with the goal of supporting serendipity. The interface includes five interconnected views that encode physical and/or semantic properties of the books in various ways. The interface is designed to support playful interaction and provide various access points to explore the collection.

Our work shares many characteristics with the above examples. However, we think what distinguishes our project from the abovementioned is that the field of vibrotactile perception is much less understood. The a priori knowledge about the importance of various metadata has presumably guided the design of all previous library visualization works. In contrast, part of the goal for our visualization is to allow vibration researchers to better examine importance of vibration metadata.

## 3 VIBVIZ

In this section, we explain the design and implementation details of VibViz.

### 3.1 Users and Tasks

We designed VibViz with the goal of supporting both 1) end users who are not familiar with vibration, and 2) researchers/designers to better study vibrations.

End users can use VibViz to search for vibrations in the library. This search is usually for unknown vibration targets. In some cases, end users might have a set of vibration characteristics in mind and thus the search becomes a **browsing** task on VibViz. In other cases, the user could open VibViz without having any idea of their desired vibration characteristics. Thus, VibViz must also support the **exploration** task. In addition to search, the user might want to **identify** specific characteristics of a subset of the vibrations. Finally, VibViz must be engaging to use and encourage playful interaction in order to allow for serendipitous discoveries by users.

VibViz is also designed to support haptic designers and researchers. VibViz must support haptic researchers in **discovering** correlations among the vibration attributes. For example, VibViz shall help researchers to answer questions such as “how physical attributes linked to emotional attributes?” or “what is the relation between emotional attributes and usage examples?” VibViz is designed to present the overall vibration space of a library so that researchers can quickly **summarize** and identify 1) outliers, 2) low-quality vibration annotations 3) less-represented groups of vibrations.

The above-mentioned tasks and users informed our design decisions and implementation for VibViz.

### 3.2 Dataset

VibViz visualizes a library of 123 vibrations, collected and annotated by Hasti. Each vibration in the library has the following attributes.

- Physical attribute
  - Duration (quantitative)
  - Energy (quantitative): measured as Root Mean Square of the waveform
  - Note length (categorical): short note, medium note, long note, variable note, or constant
  - Tempo (ordinal): slow, medium, fast, or constant
- Sensory attributes
  - Roughness (ordinal): -10, -5, 0, 5, 10
  - Tags (categorical): descriptive words such as “sharp”
- Emotional attribute
  - Valence (ordinal): -10 to 10
  - Arousal (ordinal): -10 to 10
  - Tags (categorical): descriptive words such as “calm” or “urgent”
- Metaphor
  - Tags (categorical): words and phrases such as “heartbeat”
- Usage example
  - Tags (categorical): words and phrases such as reach a “milestone”

Note that, we interchangeably use *attribute* and *taxonomy* in the following sections.

### 3.3 Design Exploration

Before actual implementation, we explored the space of possible design solutions and featured two design decisions in our system. **Mixed/separate Taxonomy** are two possible overview design options for visualizing the vibration library. We chose to implement Separate Taxonomy to better support researchers. **Glyph design** refers to the design of representing glyphs for each vibration in the library. Our design combines the envelope and waveform for each vibration to provide novice end users with an intuitive sense of a vibration pattern.

### 3.3.1 Mixed or Separate Taxonomy

Reflecting on our user groups, we identified two design possibilities for the general structure of the system.

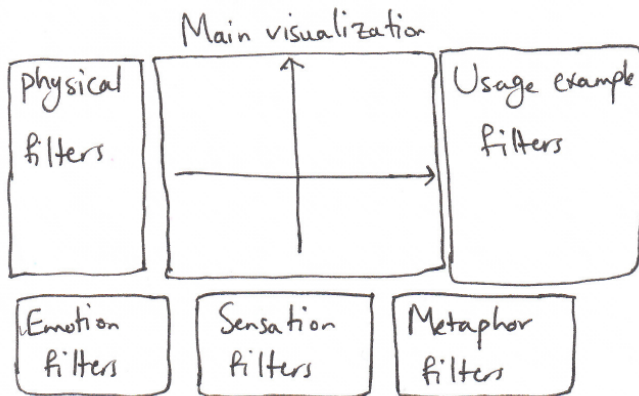


Fig. 2: Sketch of a **Mixed-taxonomy** design with one overview in the center and all filter attributes on the sides

The first option was to mix attributes from all the taxonomies in one main visualization view and provide filters for all attributes on the sides (Figure 2). We call this **Mixed-taxonomy** design. The main advantage of this approach is saving the screen space and allowing the users to focus their attention on one area.

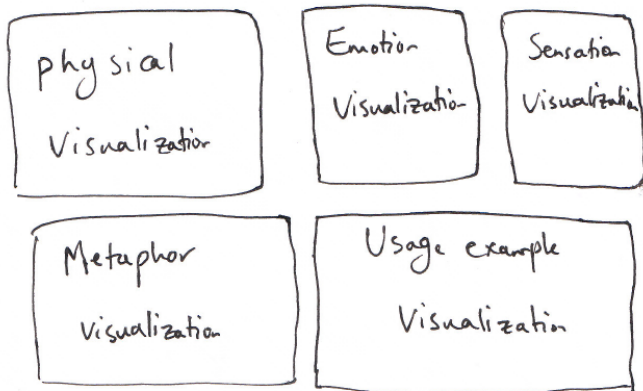


Fig. 3: Sketch of a **Separate-taxonomy** design with separate overviews and filters for each taxonomy

The second design option was to have a separate view for each taxonomy (Figure 3). We refer to this approach as **Separate-taxonomy** design. This approach draws a clearer distinction between various taxonomies, thus can better support haptic researchers to investigate usage pattern in each taxonomy as well as importance of each taxonomy for satisfying users' customization tasks.

VibViz is part of a larger research project that aims to provide a better understanding of the vibration taxonomies and their importance for the haptic community. We chose the **Separate-taxonomy** design as it better support study and analysis of the taxonomies in the next steps.

### 3.3.2 Glyph Design for Each Vibration

We explored three possible ways to more intuitively represent each vibration.

1. The **vibration waveform**, used by haptic designers, can communicate the vibration duration and pattern over time as well as

Table 1: Analysis of VibViz solution idiom

System	VibViz - visualization of a vibration library
What: Data	Table form. Each data point has 5 main attributes, 10 detailed attributes. Include quantitative, ordinal, and categorical attributes.
Why	End user: browse, explore, identify, enjoy Researcher/designer: discover, summarize
How: Encode	scatterplot, color code, range slider, tag cloud, glyph
How: Facet	Partition: multi-form views Coordinate: linked highlighting Overview + detailed views
How: Reduce	Filtering
How: Manipulate	Focus+zoom
Scale:	100-200 data points; a dozen attributes Possibly 500+ data points w/ better implemented zooming

the vibration frequency at each time point. However, a vibration waveform has a lot of unnecessary details which can make the visualization crowded. Furthermore, the vibration pattern and energy is difficult to inspect for small glyph sizes.

2. An **abstract icon** that encodes vibration characteristics with various visualization channels such as size, shape, color, and etc. Such icons can be useful for the overview of the library. However, these icons are less ideal for individual vibration inspection. Unlike wave patterns, they do not present the trend of single vibration over time. VibViz uses abstract dot icons only at the overview level.
3. A **saturation-coded VT envelope** uses *saturation* to encode vibration frequency and a darker stroke width *envelope* to highlight the vibration amplitude and pattern over time. The glyph is designed to highlight the most important characteristics of a vibration waveform and be inspectable for small glyph sizes. VibViz includes a full-size saturation-coded VT envelope in the detailed view of each vibration and a smaller version of such glyph when the user hovers over a vibration dot in the overview.

### 3.4 Description and Analysis of Solution Idiom

The analysis of VibViz is summarized in Table 1.

VibViz consists of three separate taxonomy views (Figure 1). Each view has an overview and some filters on the side. We combined the *sensory* and *emotional* taxonomies because of the considerable overlap in their tags. During our implementation phase, we decided to combine *metaphor* and *usage example* views. Both views have a tabular list as their overview, and given the cross-filtering among views, the list of glyphs for both views are the same, causing redundancy in the interface.



Fig. 4: The tempo filter consists of two checkboxes and a slider to represent the categorical and ordinal nature of tempo attribute.

Among the three overviews, two use scatterplots and one is a tabular list of data points of interest. We implemented three types of filters:

list of checkboxes, range slider, and tag cloud. We use slider to convey the ordinal nature of some attributes to users. The tempo filter (Figure 4), for example, uses a checkbox to convey the categorical difference between no rhythm and rhythmic vibrations as well as a slider to represent the ordinal scale of slow/medium/fast tempo within the rhythmic category.

We utilize tag clouds to allow filtering by tags. We are aware of the possible caveats in tag cloud usage. A tag cloud is not an efficient idiom if users are to search for a specific tag [13]. Also, the smallest text in the tag cloud can be too small to be readable. Despite its disadvantages, we still decide to use tag cloud for two main reasons. First, it is a fun and engaging idiom for users. Second, it provides a visual summary of the vibration library. We coded the font size of the text so that tags with larger font represent more popular tags in the vibration library and vice versa. Similar to the idea of scented widget [17], the tag cloud encoding gives users a summary of the tag distribution and helps them to narrow down to the tags of interest. To mitigate the font size issue, we scaled the tag font so that the smallest text is at least 10px, and increase the tag size by 2px when a user hovers over a certain text. We plan to put a search box aside the tag cloud that allows users search for specific tags, but we have not implemented it in the current version due to time limitation.

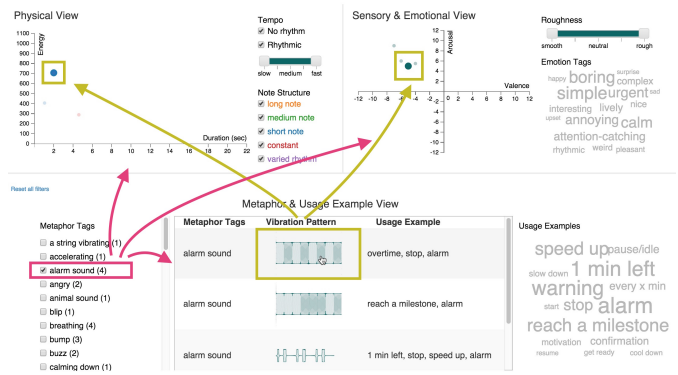


Fig. 5: Pink marks show that filtering by a metaphor tag results in cross-filtering in all three overviews. Olive marks show hovering over a list entry results in linked-highlighting in the two other views.

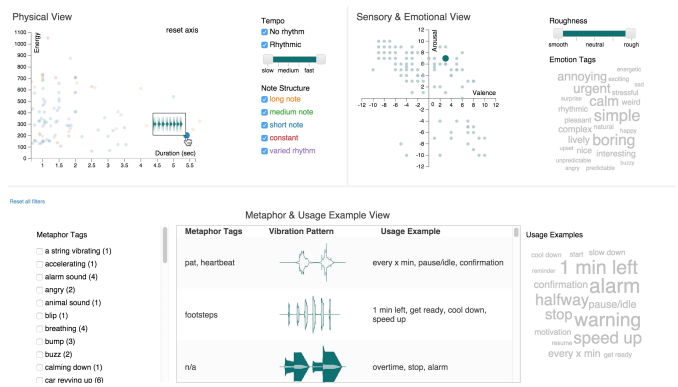


Fig. 6: Hovering over a data point in the physical views highlights the corresponding dot in the sensory and emotional view, but not in the tabular list view.

We used linked highlighting to help users coordinate across views. First, filtering in one view reduces data displayed in all three overviews (Figure 5 pink mark). Second, when the user hovers over a data point in one view, its corresponding data points show up in the other views (Figure 5 olive mark). Note that we have not yet implemented second type of highlighting for the tabular list, so hovering over a data point

in any of the two coordinate views will not result in a linked highlighting effect in the list view (Figure 6). The linked highlighting also happens at a group level; when selecting a set of data points, all the corresponding points in the other views are highlighted (Figure 7 and Figure 8).

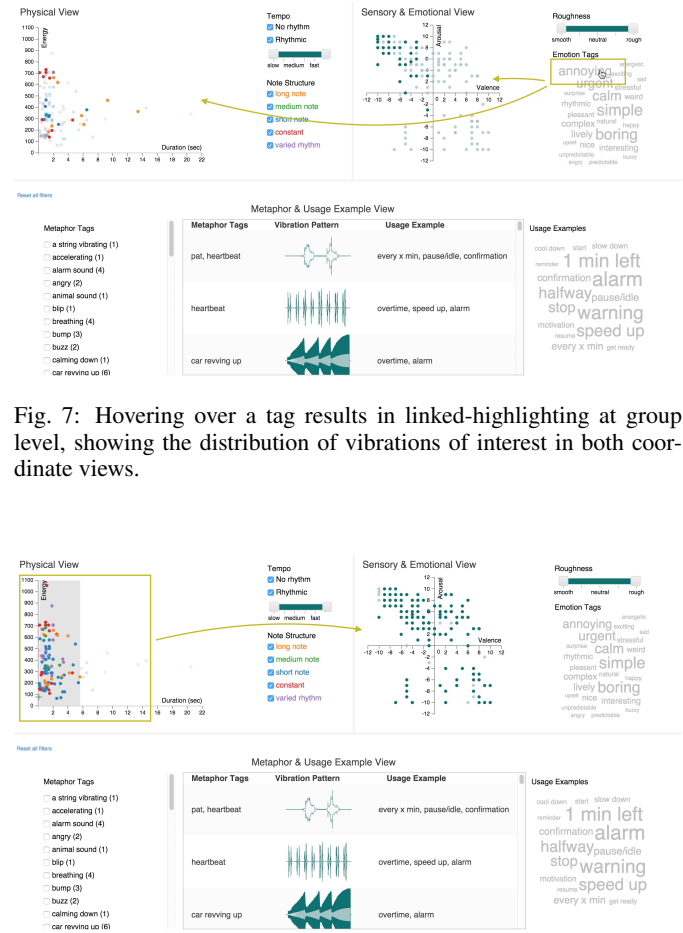


Fig. 7: Hovering over a tag results in linked-highlighting at group level, showing the distribution of vibrations of interest in both coordinate views.

Given most of the vibrations in the library have short duration, the low end of the duration axis is cluttered. We implemented select and zoom to allow users zoom in along the duration axis and get a less cluttered view (Figure 8). The zooming functionality is only implemented in one dimension because we are only handling a couple hundred data points, and this limited version works perfect for the current scale.

To identify specific characteristics of the data points, users can hover over any of the data points in one of the three overviews. The mouse-over action plays the corresponding vibration and results in the vibration glyph to appear (Figure 6). A detailed card view pops up when the users click on a specific data point (Figure 9).

### 3.5 Implementation Details

**Libraries:** VibViz is implemented in Javascript using d3, d3 tagcloud, d3 slider, and buzz libraries. We used Bootstrap to structure the UI elements as well as Matlab to generate the saturation-coded VT envelopes for the vibrations.

**Data preparation:** The vibration library was designed as part of Hasti's PhD research. Hasti prepared the dataset in JSON format. Some vibration attributes, like duration and energy, are measured and some others reflect Hasti's perception of the vibrations. Currently, she is running an annotation study to collect people's perception of the vibrations. A next step for this project is to consolidate real-user annotations into a dataset for VibViz.



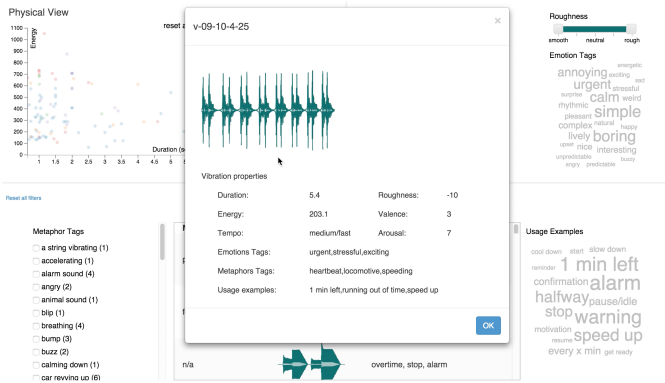


Fig. 9: A card view with all attribute details for a selected vibration

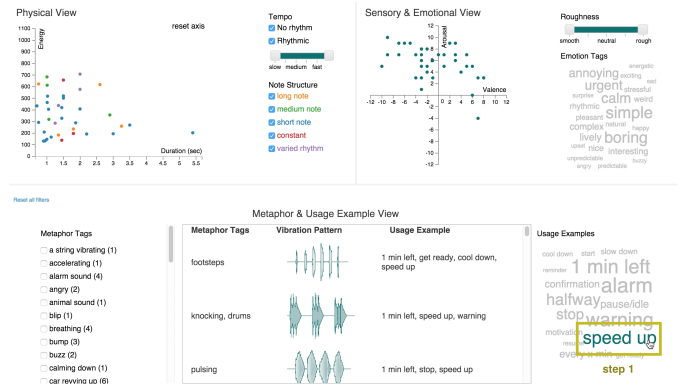


Fig. 10: Step 1: filtering by the “speed up” tag

*Structure of code:* `index.html` contains the html code for three main views and a detailed card view. `main.css` includes all custom styling. Each view has its own js file which supports static drawing as well as mouse interactions and linked highlighting. Whenever a cross-filtering is required, the js file updates the *filter reference object* and calls `data.js` to redraw. The *filter reference object*,  $f$ , is an object we used to achieve cross-filtering. It is declared in `data.js` and stores the filtering query for the dataset.

`data.js` handles all data-related scripts. It reads the JSON data file and initializes the system. Specifically, `createTags` function creates a summary data structure to feed into tag cloud. `draw_cardView` function draws the detailed card view and feeds it with corresponding data information. In addition, `data.js` creates a *filter reference object* which checks the filter requirements for each data points whenever cross-filtering is required and only displays the dots or table entries that are not filtered out.

*Glyph generation:* We wrote a short matlab code to generate the glyphs for our project. The code uses Hilbert transform to calculate the envelope for a given vibration. Various vibration frequencies, when plotted, have different saturation levels on the final glyph.

## 4 RESULT

We provide usage scenarios for both end users and researchers. We also get some preliminary feedback from our fellow students.

### 4.1 End User: Scenario of Use

Susan uses a smart watch that can give her vibration notifications during her exercise. She wants to customize the vibration notification for the speed up event in jogging.

She launches VibViz and browses for the possible filters. She decides to first filter based on *usage examples* and selects the “speed up” filter from the tag cloud (Figure 10). She is interested in longer vibration patterns to make sure she would not miss the notification, so she zooms into the vibrations that are longer than 1.5 sec (Figure 11). Finally, she applies the “simple” tag from emotional tags (Figure 12). These three rounds of filtering leaves her with a relatively small subset of vibrations of interest. She hovers over each dot to feel the vibration (Figure 13) and click on each to see all their information in the card view and chooses one of them as her “speed up” notification (Figure 14).

### 4.2 Researcher: Scenario of Use

As vibration researchers ourselves, we have played with VibViz and found some interesting insights that would not be obvious from just staring at a table of vibration attributes.

VibViz helps us to find some correlation between attributes across taxonomies. For example, we found a correlation between roughness attribute and the emotional attributes (Figure 15). The vibrations that are smoother tend to cluster at the right bottom corner of the emotional coordinate and with the increase of roughness level, vibrations tend to

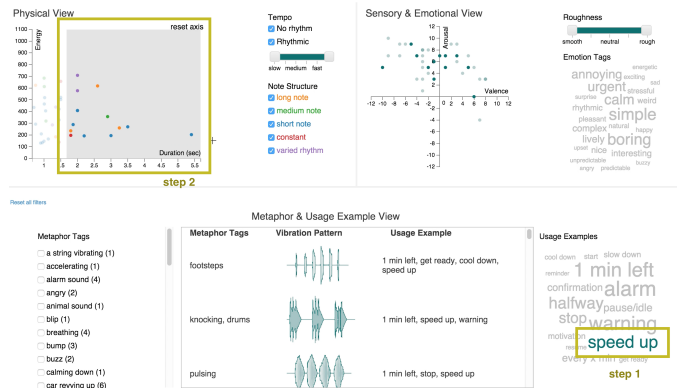


Fig. 11: Step 2: selecting vibrations longer than 1.5 sec

increase in arousal and decrease in valence. That is to say, the rough vibrations are usually high in arousal and low in valence, whereas the smooth vibrations are usually low in arousal and high in valence.

In another example, we found that vibrations with the “alarm” usage example tag are usually high in arousal (Figure 16). However, there are two vibrations below the neutral arousal level. They can be outliers or wrong annotation of specific vibrations.

### 4.3 Informal Evaluation

We showed VibViz to 4 fellow graduate students in the information visualization class, and asked what they liked or not liked about the system. There are a few converging opinions. First, they all liked the glyph design and thought it was an intuitive representation of the vibration. Note that we showed them the system while they were holding

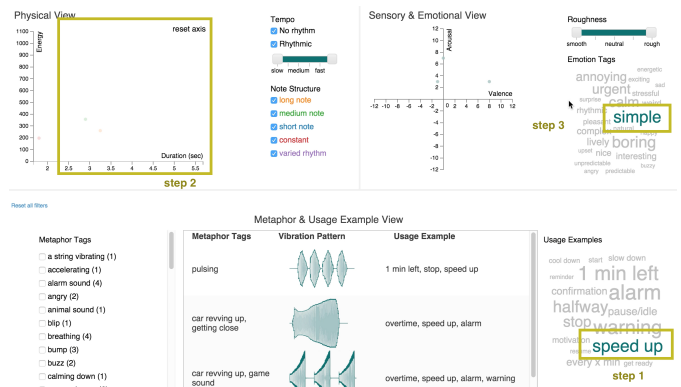


Fig. 12: Step 3: apply the “simple” tag

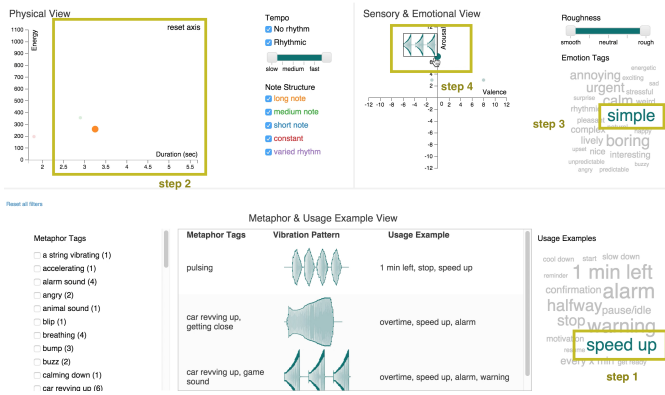


Fig. 13: Step 4: hovering over each vibration to identify its characteristics

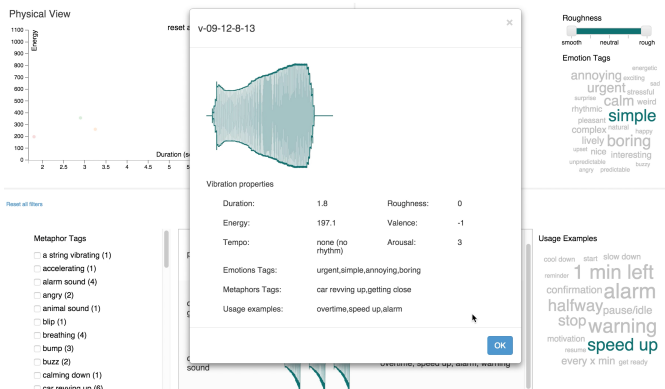


Fig. 14: Step 5: checking details of the desired vibration

to a vibration actuator so they could feel the vibrations when seeing the glyphs. Second, they all found the tag cloud very engaging, whereas they found the list of checkboxes, especially the metaphor checkboxes, long and dull to read through.

Interestingly, the users started commenting on the usefulness of certain vibration attributes. One person said that she would “never use the metaphor tags for filtering,” not because the list of checkboxes is hard to search, but because she felt the metaphor attribute is less useful in filtering vibrations. She would prefer to skim metaphor tags only when a couple of vibrations are present. Note that we were just asking their opinion about the visualization. Such a comment suggests that the interface could support our future research on the effectiveness of various vibration attributes.

## 5 DISCUSSION

Overall, we believe VibViz is a decent first prototype of a vibration library visualization system and achieves many of its goals.

Our informal evaluation suggests that VibViz is engaging and intuitive and does not need much training for the users. This was one of the main goals of our design. Our glyph design is successful; people think it is a proper and intuitive representation of the vibration sensation. This is very important as vibration glyphs can support quick visual inspection of the vibration library.

Besides, VibViz achieves a reasonable separation of vibration taxonomies for our future research. Although *metaphor* and *usage example* taxonomies are sharing the glyphs in the list view, they have separate filters and tag lists. This level of separation allows us to study taxonomy usage by software logging or eyetracking.

On the other hand, VibViz has a number of drawbacks. First, having a separate view for each taxonomy might not be the best design choice for end users. We had to make a trade-off and prioritize researcher

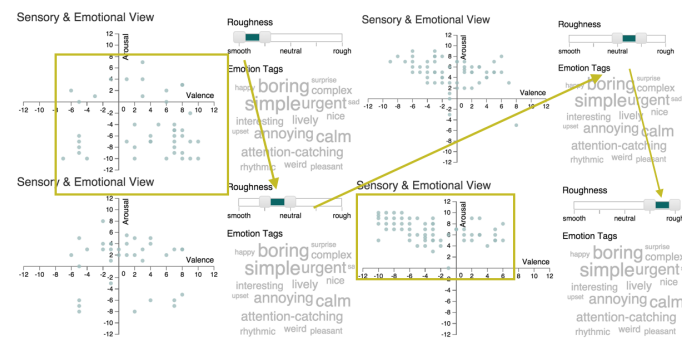


Fig. 15: Correlation between roughness and emotional attributes (valence and arousal): following the direction of the arrows on the four screenshot shows that as we change the roughness attribute from smooth to rough, the vibration distribution changes in the emotional view.

requirement as VibViz is mainly a research tool. In turn, researching the effectiveness of various taxonomies and attributes on VibViz can lead to more effective vibration visualization systems for end users in future.

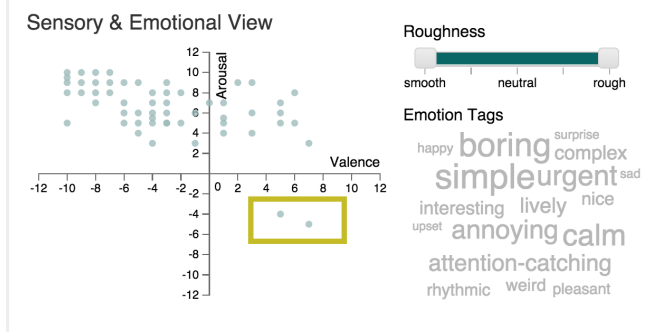
Another drawback of our current design is that adding additional taxonomies to the visualization can be very difficult and requires interactive scaling and switching among the views. Further, VibViz cannot save context between user visits which could be important for vibration customization.

Due to lack of time, some features are not fully implemented in VibViz.

1. Given more time, we would fully implement linked highlighting for the *metaphor* and *usage example* list view. In the current version, if the user hovers over a data point in the *physical* or *emotional* view or hovers over a *usage example* tag filter the corresponding item(s) is not highlighted in the list view.
2. For *emotional* and *usage example* filters, we would like to provide a way to switch between the tag cloud filter and a non-scaled list of tag filters. Including a search mechanism for the tag cloud could also mitigate some of its problems while preserving the visual engagement of the interface.
3. The tag cloud library we used generates a new tag cloud whenever redraw happens. It would be ideal to have a stabilized tag cloud layout to support multiple user visits.
4. We would like to improve the *metaphor* filters visually. Informal feedback from our classmates suggest a lack of engagement and enthusiasm to use the current long list of metaphor checkboxes.
5. In a longer time frame, VibViz should support comparison of multiple vibrations by end users.

This project has been a valuable learning experience. We learned some new lessons, and confirmed some old thoughts.

1. We found it difficult to separate the visualizations completely. For example, we decided to partially merge the view for *metaphor* and *usage examples* as we found a similar encoding effective for both cases.
2. Simple encodings can build an effective and engaging interface. This seems to be specially true for walk-up-and-use interfaces like ours. Initially, we started thinking about more complex visual encodings for all the taxonomies. However, during our discussions, we realized simpler encodings such as lists and dimensional coordinates to be much more effective for our purpose.



sample View

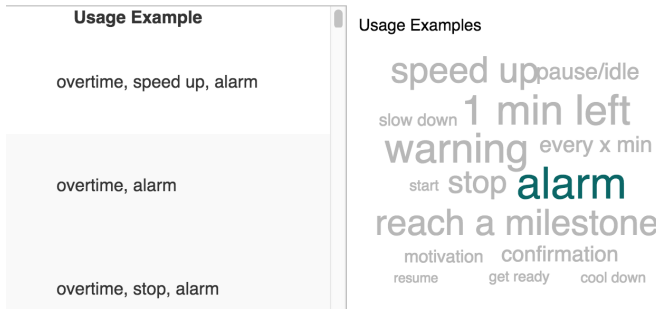


Fig. 16: Vibrations with “alarm” tag are usually high in the arousal attribute, but there are two outliers with negative arousal score.

Our informal evaluation of the interface suggests that the combination of our relatively simple encodings are appealing and engaging.

- This is Kailun’s first web programming experience and her first programming project at this scale.
- Working in a team, we could discuss and refine a lot of our initial ideas and anticipate problems that could become critical if we were working alone.

## 6 CONCLUSION AND FUTURE WORK

This paper introduces VibViz, an interactive visualization system for a vibration library. We used 1) **multi-form views** to allow researchers study vibration taxonomies with VibViz, 2) **saturation-coded vibration envelopes** to provide more intuitive vibration glyphs for end-users, and 3) **linked-highlighting** to coordinate multiple views in the system. The preliminary end-user feedback on Vibviz are promising. Our next step is to import data from from our ongoing user study and consolidate annotation data from many users.

We plan to do a formal evaluation of VibViz for the tasks mentioned in section 4. It will include pilot studies to refine the design and future lab-based and field studies to investigate its use for vibration customization.

As part of her PhD research, Hasti plans to study the importance and effectiveness of the five vibration taxonomies and their attributes for customization. Empirical data from such studies can help to refine the visualization and to encode the more effective vibration attributes with more expressive visualization channels.

We anticipate the need to personalize VibViz for individual users in future. This can include allowing individual users to import new vibrations or change the attributes of vibrations that already exist in the library according to their perception. Further, providing a mechanism to mark certain vibrations in the library and/or a personal sketchpad can also help users to retain context between repeated visits to VibViz.

Table 2: Division of work

Task/Contribution	Kailun	Hasti
design	50%	50%
Implementation	100%	0%
Proposal	50%	50%
Final Report	50%	50%
Presentation	50%	50%

## 7 DIVISION OF WORK

Table 2 shows the division of work for this project according to our previous conversation.

## REFERENCES

- Musiccovery. <http://musiccovery.com/>.
- C. Ahlberg and B. Shneiderman. Visual information seeking using the filmfinder. In *Proc. Conf. on Human Factors in Computing Systems (CHI)*, pages 433–434, 1994.
- F. Bentley, C. Metcalf, and G. Harboe. Personal vs. commercial content: The similarities between consumer use of photos and music. In *Proc. Conf. on Human Factors in Computing Systems (CHI)*, pages 667–676, 2006.
- A. Girgensohn, F. M. Shipman III, T. Turner, and L. Wilcox. Flexible access to photo libraries via time, place, tags, and visual features. In *Proc. Joint Conf. on Digital Libraries (JCDL)*, volume 10, pages 187–196, 2010.
- H. Kang and B. Shneiderman. Visualization methods for personal photo collections: Browsing and searching in the photofinder. In *IEEE Intl’ Conf. Multimedia and Expo (ICME)*, volume 3, pages 1539–1542, 2000.
- A. Khella and B. B. Bederson. Pocket photomesa: A zoomable image browser for pdas. In *Proc. Conf. Mobile and Ubiquitous Multimedia (MUM)*, pages 19–24, 2004.
- D. Kirk, A. Sellen, C. Rother, and K. Wood. Understanding photowork. In *Proc. Conf. on Human Factors in Computing Systems (CHI)*, pages 761–770, 2006.
- T. Merčun and M. Žumer. Visualizing for explorations and discovery. In *Proc. Conf. on Libraries in the Digital Age*, 2010.
- B. Moghaddam, Q. Tian, N. Lesh, C. Shen, and T. S. Huang. Visualization and user-modeling for browsing personal photo libraries. *Intl’ J. of Computer Vision*, 56:109–130, 2004.
- G. P. Nguyen and M. Worring. Interactive access to large image collections using similarity-based visualization. *J. of Visual Languages & Computing*, 19(2):203–224, 2008.
- M. Obrist, S. A. Seah, and S. Subramanian. Talking about tactile experiences. In *Proc. Conf. on Human Factors in Computing Systems (CHI)*, pages 1659–1668, 2013.
- S. Oliver and M. Karon. Haptic jazz: Collaborative touch with the haptic instrument. In *IEEE Haptics Symp.*, 2014.
- J. Sinclair and M. Cardew-Hall. The folksonomy tag cloud: When is it useful? *J. of Information Science*, 34(1):15–29, 2008.
- A. Thudt, U. Hinrichs, and S. Carpendale. The bohemian bookshelf: Supporting serendipitous book discoveries through information visualization. In *Proc. Conf. on Human Factors in Computing Systems (CHI)*, pages 1461–1470, 2012.
- M. Torrens, P. Hertzog, and J. L. Arcos. Visualizing and exploring personal music libraries. In *ISMIR*, 2004.
- J. Watanabe, T. Hayakawa, S. Matsui, A. Kano, Y. Shimizu, and M. Sakamoto. Visualization of tactile material relationships using sound symbolic words. In *Haptics: Perception, Devices, Mobility, and Communication*, pages 175–180. Springer, 2012.
- W. Willett, J. Heer, and M. Agrawala. Scented widgets: Improving navigation cues with embedded visualizations. *IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis)*, 13(6):1129–1136, 2007.