Design process and rapid prototyping of animated music visualizations

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Abstract. *The production of animations for Musical Information Visualization is still scarce and has challenges in the way of visually communicating information. Due to the need for domains of editing software, demanding technical skills and specific knowledge related to each area: animation, music, design and computing. In this article, we present a systematic review of the animated visualization area and, based on its conception processes, we elaborate an experimental model for the creation, prototyping and construction of musical animations. And through sessions developing quick prototypes, where we obtained qualitative results with feedback collection. We conclude that the importance of animation is exceptional, as an ally in the process of designing and creating a musical visualization, as it facilitates the representation of time to communicate structural elements of music, as they are dynamically arranged in a graphic area.*

1. Introduction

This work permeates two major areas: Musical Visualization and Animation. Music Visualization is the area of intersection between Music and Information Visualization, aiming to develop applied studies to communicate musical information with the aid of visual resources [1]. Animation, on the other hand, is a simulation of movements created from the exposure of images, or frames [2].

Specific knowledge alone is not enough to understand the complexity of the studied phenomena. Interdisciplinarity is the combination of knowledge from several different specialties in order to give new approaches to a real problem [3]. This combination of specialties adds value to the process, and it is possible to see that the result obtained by the joint study is more interesting than the sum of the individual contributions of the parts [4].

Given the difficulties in finding research and debates that relate the areas addressed in this research and assuming that animations facilitate the understanding of musical visualizations [1] [5] [6] [7] [8], we verified through a systematic review that several authors recognize the importance of the representation of time through animation in visualizations. As described by Chen, Zhou and Chen [9], information can be represented and arranged as a function of time, in order to understand the chronological order of events or happenings. Heer and Robertson [10] and Robertson et al. [11], reinforce the importance of time representation through animation, as its temporal elements - beginning and end - and movement are highly effective and easily noticed by peripheral vision, making observers remain oriented during the animation execution, improving interaction and understanding of information.

Although some static visualizations can be visually interesting, to be used in musical analysis they require training, practice and/or sound to be fully understood. For Barisic [12], image, sound or video resources allow the user experience to be more pleasant and interactive, since users have the possibility to discover more information about a certain event.

In an animation, the presence of the temporal element, despite being an ally to fix visual attention and aid in the understanding of information, can be a distraction for the viewer, as the excess of information in motion also hinders the concentration of observers, as well as very slow animations can be tedious Robertson et al. [11]. Therefore, authors such as Baudisch et. al [13]; Tversky, Morrison and Betrancourt [14]; Heer and Robertson [10] still advocate the use of static views, and describe animation as the least effective form of analysis as well as complicating the comparison of flowing items.

Considering this exploratory scenario involving the areas of Musical Visualization and Animation, we realize the importance of using animation in contexts where its presence is not only a creative or entertainment ally, but necessary, as without its presence the understanding of musical information would be misunderstood , as is the case with very popular games: Bandfuse [2], Guitar Hero [3], Rock Band [4], Rocksmith [5] and Audiosurf [6]. We realized that communicating information through static views is a difficult task [7] and communicating information through animations is an even more difficult task [11] [13] [14] [10] , because in addition to the technical difficulties presented by Robertson et al., knowledge in more than one area is necessary, such as: animation, design, music and computing. We also realized that the association of music with animation, improves the user experience and consequently introduces notions about musical information. We emphasize that this joining must happen synchronously, that is, the visual events of the visualization must happen at the same time the music is played and the animation is executed graphically. Thus, this work aims to develop a process of design and rapid prototyping of animated musical visualizations.

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[2]Bandfuse: www.hamster.co.jp/bandfuse/
[3]Guitar Hero: https://www.guitarhero.com /de
[4]Rock Band: www.rockband4.com/
[5]Rocksmith: www.ubisoft.com/en-us/game/rocksmith/pluss
[6]Audiosurf: www.audio-surf.com

2. Conception prototype design

In order to build animated musical visualizations, we need to immerse ourselves in fast prototyping and conception processes. Rapid Prototyping has as its main resource the ability to quickly build complex physical forms, difficult or even impossible to be built by the technologies established for a long time [15]. Therefore, we will use this method to identify the technical and creative capabilities of developing animated visualizations.

For Canciglieri and Selhorst (2015)[16], it is necessary to understand the limitations of each technology and process used during rapid prototyping, helping in decision making for the design of rapid prototypes, which can happen in three phases:

Phase 1 Descriptions of the product's characteristics: Which are subdivided into two stages, the first of which is an analysis of the physical characteristics of the product with an A/B test to find out which is the best option. And the second, defines the criteria for decision-making in the development of the prototype, with analysis of its use, functionality, available resources, definition of material, dimensions, geometric complexity, total execution time and completion of the prototype. The **Phase 2**, of evaluation of decision-making criteria, evaluates the most relevant characteristics of the product and of the prototyping technologies available for designing the prototype. The composition of these "decision criteria" aims to define the degree of priority for the characteristics presented in Phase 1 of the method, generating a priority ranking through a discrete scale from 0 to 9, with a value of 0 indicating no importance and 9 extreme importance . And finally, **Phase 3**, in which decision-making analysis and final prototyping of the product are performed, taking into account the metrics of the analyzed data and evaluation metrics.

Considering all this, the methodology of this work based on the Design Thinking approach. Essentially defined as a human-centric innovation process that emphasizes observation, collaboration, rapid learning, idea visualization, rapid concept prototyping and simultaneous business analysis, which definitively influences innovation and business strategy [17]. According to IDEO [18], there is no fixed Design thinking process, as the innovation or new idea can go through many iterations before the process is completed. But in summary, considering the many successful efforts include a variation on four intertwined steps: inspiration, synthesis, ideation / experimentation and implementation.

The process of knowing the problem or challenge is inspiration. Synthesis is the process of collecting data and information about the problem or challenge. Ideation/experimentation is the creative process of solving the problem or challenge and implementation/validation is the process of analyzing the prototype.

3. Designing Musical Visualizations

Visualizing music in a meaningful and intuitive way is a challenge Ciuha, Klemenc and Solina [7], as there is a need for an entire design process that involves a certain technical knowledge about both areas (visualization and music).

The design processes of musical and animated visualizations are used as a basis for systems development and generation of musical visualizations, the musical data inputs can be transmitted via *input* of MIDI files *(Musical Instrument Digital Interface)* , as described in the works of [7] [6] [19] [5] [1]. There are also records of graphic experiments created by Design professionals who conceive visualizations based on musical perception, such as HALL[7] in *"Sheet Music Visualization"*.

Therefore, we identified that there is a graphic choice of visual structure that varies depending on the objective of communicating musical information. For example, as shown in the figure 1 on the left the *Mandrit*, the automatic static visualization generation system for rhythm analysis [1] and on the right the *MusicVis* [19], a web application for automatically generating sound visualization using an MP3 music file or microphone capture as input.

Figure 1: Mandrit end MusicVis

Both use the style Bubble Chart, which are bubble charts to represent musical data by circles in different sizes and colors [20]. Applying graphical form with different goals in static and animated views respectively.

Another step in the process of designing a musical visualization is to understand the best reading orientation. Human beings tend to observe and analyze something visual, from left to right, a pattern naturalized due to writing and reading. For this reason tools bet on this visualization style as well established as HOOK THEORY[8]. Another form of visual reading naturally imposed is clockwise and counterclockwise [21], alluding to the visual representation of the hand clock, existing since the year 1335.

3.1. Conception of Animated Music Views

As well as in the conception of musical visualizations, at this stage the assistance of the areas of Music and Information Visualization is considered. However, the design of animated music visualizations has a third guiding area: animation.

3.1.1. Animation design process

Animation can be defined in different ways. Like a movie made frame by frame, providing an illusion of movement [22]. As a process of dynamically generating a series of

[7] www.behance.net/gallery/6529923/Sheet-Music-Visualization?isa0=1

[8] HOOK THEORY: https://www.hooktheory.com/

frames from a set of objects, where each frame is an alteration of the previous frame [23]. For these authors, animation can be a technique in which the illusion of movement is created by photographing a series of individual drawings in successive frames of the film. The illusion is produced by projecting the movie at a certain rate (usually 24 frames/second).

During the progress of animation, Walt Disney and his Disney company had a great prominence, for promoting studies and courses, improving animation techniques and making new artists learn these practices as rules of commerce. After a while, each technique was named and became known as the fundamental principles of animation [24]:

(1) **Squash and Stretch** - Define the rigidity and mass of an object, distorting its shape during an action.
(2) **Time** - Spacing actions to set the weight and size of objects and character personality.
(3) **Anticipation** - The preparation for an action.
(4) **Staging** - Unambiguously present an idea.
(5) **Tracking and Overlay Action** - The completion of an action and the establishment of its relationship with the next action.
(6) **Direct Ahead Action and Pose-to-Pose Action** - The two contrasting approaches to creating movement.
(7) **Slow In and Out** - The spacing of the intermediate frames to achieve subtlety of time and movement.
(8) **Arcs** - The visual path of action for natural movement.
(9) **Exaggeration**- Accentuating the essence of an idea through design and action.
(10) **Secondary action**- The action of an object resulting from another action,
(11) **Appeal** - Create a design or action that the public likes to watch.

Knowing what are the principles of an animation and what they are necessary to produce an animation, it is also important to know the processes of designing an animation. Wells [25], in his book *"The Fundamentals of Animation"*, says that to be conceived animation must go through 25 stages, these: Concept: the stimulating idea; Creating Work Schedule; Resource review; Research; History; Preparatory View; Formal Design; Storyboard; Road map; Initial soundtrack; Animatic; Filming script; Animation Analysis; Aesthetic Analysis; Layout; Dope Sheet; Development soundtrack; Backgrounds; Animation Sequences; Creation of sequences; Construction; Post-production analysis; Mixing; Output in chosen format and Display.

For Tschang [26], animation has five stages, conceptualization, pre-production, production, post-production and the next look, as shown in the figure 2:

In the conceptualization stage, the main idea and the story are conceived. In the pre-production stage, the conceptual art and the first scenes that will constitute the *storyboard* are developed. In the production stage, it involves most of the intensive work, which includes the art

Stage 1 **Conceptualization**	**Stage 2** **Pre-production**	**Stage 3** **Production**	**Stage 4** **Post-production**	**Next cycle (for tech intensive firms)**
Idea for series or production (short concept and final script); planning	**Storyboarding; concept art to flesh out script; story reels; script changes**	**Animating**: Very large investment of resources (animators, supporting technical staff); voice acting	Some **editing** of scenes, retakes	Development of software tools for next generation animated features

Figure 2: Stages of Production Process for General Animation in Tschang

development, modeling and animation itself, as well as the intermediate tasks necessary to obtain it. The stage is post-production where editing and rework are carried out [27].

3.2. Process of designing animated music visualizations

To conceive an animated visualization of a song, all conception processes seen so far must be taken into account: conception of music visualizations and conception of animations.

In the literature, some processes of designing visualizations of synchronous musical animations are reported, such as Musanim [8] by Stephen Malinowski [6] and others [5] [7] [8].

A relevant example in the study of musical harmony is the Isochords [5], a system for visualizing musical structure in musical animation format that helps in the classification of musical structure. The preview highlights consonant intervals between notes and chords common in music, it also conveys information about interval quality, chord quality, and chord progression synchronously during digital music playback.

Isochords, as shown in the figure 3 uses the representation originally developed by Leonhard Euler - the Tonnetz - to represent the chord progression and communicate visually and musical harmonics, also using the foundation of the circle of fifths as a reference to determine subsets of notes with equivalent intervals, such as pitch signatures, helping to find relative pitches [5].

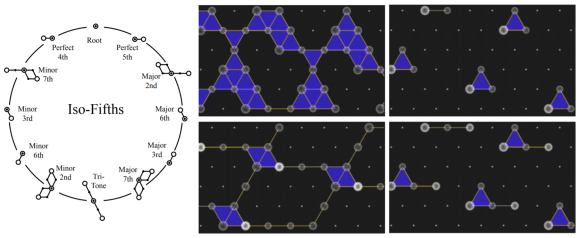

Figure 3: Isochords

The conception of this project takes place through decision making in relation to how the input of information in the system would be done, being defined the MIDI file of the songs with the records of the musical sequences as input data. As for the selection of visual elements, it was defined that the representation of musical information of the graphic choice would be Tonnetz's own structure, using its elements, triangular geometric shapes and color

[8] Musanim: http://www.musanim.com/Renderers/

variations. Finally, the animation is performed, inserting the soundtrack and the sequence of the progressions of the Tonnetz triads, using as a reference the time already defined in the beat of the music, conceiving a synchronous musical animated visualization.

Ciuha, Klemenc and Solina [7], produced an animated musical visualization, aiming to interconnect similar aspects in music and visual perception, through the modeling of harmony: affinity of tones and consonance with colors. The authors sought to facilitate the understanding of harmonic relationships in music, which can sometimes be difficult for untrained people to understand, but can be clarified through visual cues 4.

We identified similarities in the process in the conception of animated visualization, as the authors also carry out a study of the graphic choices in relation to the musical information to be represented, namely: the tone scale in a circle of fifths. They extracted information from MIDI files of the songs, attributing in the visual representation the association of musical tones to the colors represented in the circle of fifths 4.

Finally, an animated visualization system in the style piano roll was developed, this is a representation in the timeline type, where the sequences are recorded in a horizontal line. Providing a better understanding of the information that is associated with a period of time, allowing its users to understand what types of events occurred over time [28].

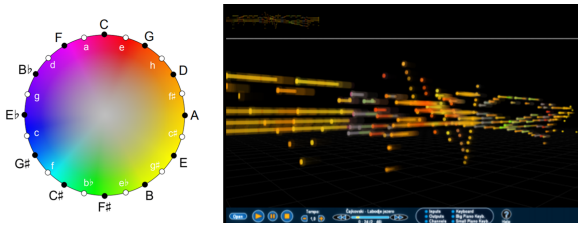

Figure 4: Visualization of concurrent tones in music with colours

Other authors such as Malinowski [6], and Wu et al. [8], also explore the process of designing animated musical visualizations, experimenting, and bringing contributions to the community. Considering this whole exploratory context, we also used as a reference the animation model proposed by Tschang [26], shown in figure 5, Describing the process of creating a musical animation.

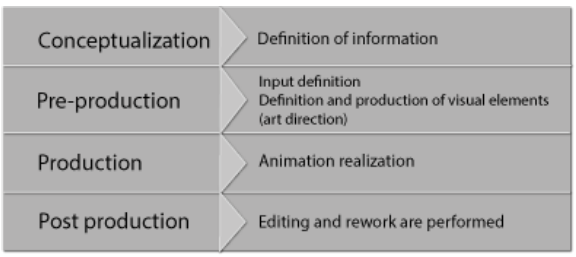

Figure 5: Process of designing animated music visualizations

Which allows us to structure the process of conception, pre-production, production, and post-production of animation. Thus, standardizing these processes, we can say that to build animated visualizations of music we need to choose the musical information, make production choices such as input definitions, choose the visual elements (art direction), as well as which tools to carry out the animation.

4. Experimental Process

Based on the methodological steps of Design Thinking [18] and the design processes of animated musical visualizations, a process of rapid prototyping of musical animations was developed. In this process, the user will design their own animation, through three phases:

Phase 1 - Inspiration and Synthesis: In this phase, the user will be inserted into the problem, immersing himself in the context and asking the following questions: "If you could see an animated song, which song would you choose and which musical information from the chosen song would you like to portray?". The objective of this phase is to define the choice of music, understand and discuss which musical concepts the user wants to address in his animation.

Phase 2 - Ideation: In this phase the user will answer the questions from the previous phase. When choosing the music, the user will also specify which moment of the music and make sketches of graphical representations creating a prototype of your animation.

Phase 3 - Validation: The authors conceive the animation digitization process and present the graphic result for prototype validation with the expert user who designed the prototype, aiming to analyze whether the final animation meets the proposed objectives considered when performing the prototype.

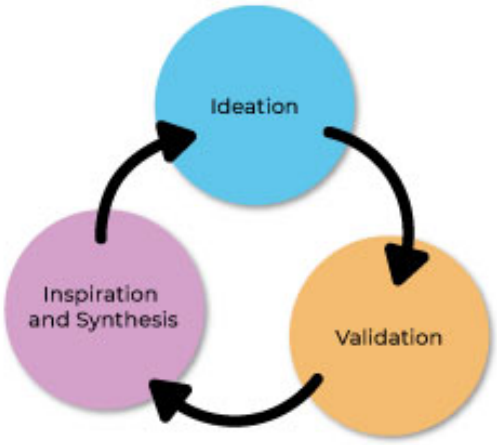

Figure 6: Phases of the Design Thinking methodological process

It is worth noting that in Design Thinking the phases of the methodological process must be repeated as

many times as necessary, revisiting and understanding the already explored content figure 6.

The application of the experimental process will be done through video conference with experts in the field of music. To carry out technical and targeted data collection, aiming to enable new perspectives on how to visualize and communicate musical information through animations. Focusing on potential users with collaborative participation in the experimental process and in the creation of animations.

4.1. Pilot experiment

Here we describe the execution process of the experimental model, with its first session performing a pilot experiment through video conference, with five participants. It is important to note that only one of them had basic knowledge about music, but was not an expert.

Participants took 5 to 10 minutes to choose the music and information they would use in their prototype. At this time, the participants reported difficulty in choosing musical information, as they did not have technical knowledge about music theory. However, all made their choices and the information they mentioned were: BPM, voice, rhythm, tempo, music speed, music intensity, high-pitched sound, bass sound, representation of instruments and voices.

In the prototyping phase, participants used paper and pen to draw their representations. They were instructed to write down all the information on paper, to record such as: song name, color, song lyrics and whatever they thought necessary about the description of the animation. Participants took 10 to 15 minutes to produce their prototypes. The process ended with a shared presentation in which each one explained their animation result.

It is worth noting that all participants were able to understand and perform the experiment, completing it within an estimated time of 30 minutes. We highlight the difficulties recorded by the authors as mediators of the experiment, who, during the individual monitoring of the design process of each participant, faced technical challenges with the video conference camera as it was aimed at people and not at the design, so it was impossible to follow the construction of your sketches.

The pilot experiment served to validate the target audience, realizing that people who are not specialists in music have difficulty in portraying musical concepts. The following experiments were applied only with Music specialists.

4.1.1. Experimental Model: Building Animated Views

After the challenges faced through the pilot experiment, we had technical support to develop a new experimental model that were also carried out by video conference, however with a more controlled digital environment for data collection. Therefore, we requested that the camera be directed to the drawing and we determined an average duration of 10 to 15 minutes. And we held 3 sessions with a music specialist, resulting in 3 experimental prototypes.

In experiment 1, the music specialist followed the methodological phase, choosing the song "Mambembe, by Chico Buarque" seeking to represent the musical information of chord progression. Choosing to cut out your prototype with the first stanza of the song, writing all the chords and assigning through a rectangle the chord pattern that is repeated in pink and the other chords in rectangles in green. The specialist had the idea of creating a visual element that would demarcate the chords for accompaniment, as in the figure 7.

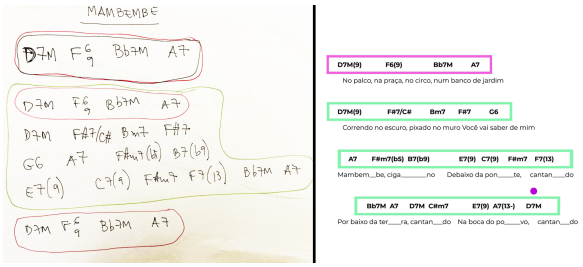

Figure 7: Specialist prototype and animation prototype designed by the authors

Thus, in the validation phase, an animation prototype was generated by the authors according to the information provided by the expert. The first feedback suggested by the expert was to add an indicator on the chords synchronized with the music. As a solution, the pattern was kept throughout the animation (green and pink) and a cursor that jumps in purple was added to make it easier to follow the music.

In experiment 2, as shown in figure 8, the participant chose the song "Piano na Mangueira, by Tom Jobim and Chico Buarque". Musical information was the dissonance between harmony and melody.

After automating the animation, the specialist requested a red trail that shows the path taken by the car on the road.

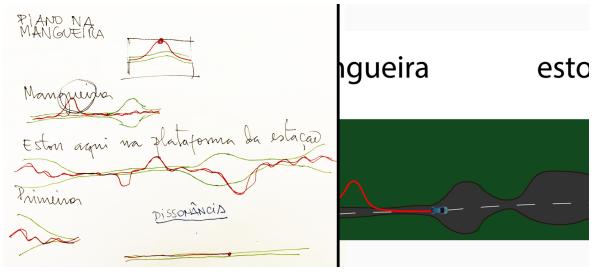

Figure 8: Specialist prototype and animation prototype designed by the authors

While listening to the music, the specialist wrote the part he would like to animate and drew two green paths representing the outline of a road and a red path representing the trail made by a car. The green path was defined as the harmony of the music and the red path the melody of the music. For the participant, the harmony of a song is

sometimes ”strange”, as it presents a larger set of notes (associated the representation of the road with the more open path) and more obvious (associated the representation of the road with the narrowest path), for the participant, there are moments in the music where the red path (car) leaves the harmony (of the road) and it is particularly interesting to see these moments. The specialist also pointed out that his prototype would be in the timeline style, with the entire road being drawn in a static way and requesting that in the animation only the car would move, however it would have a camera revealing the path and following the movement of the car.

In experiment 3, shown in the figure 9, the specialist chose to analyze the aspect of the music's rhythm: ”Brigas Nunca Mais, de João Gilberto”.

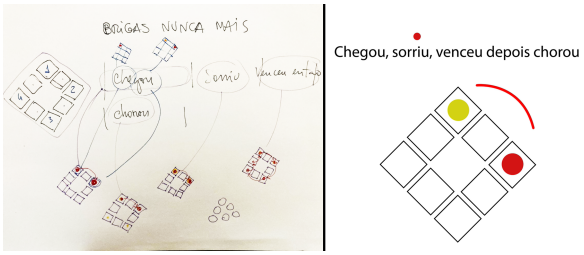

Figure 9: Specialist prototype and animation prototype designed by the authors

The specialist separated the lyrics of the song into cells, drawing eight diamonds in a figure 9 diamond shape, symbolizing the measures of the music. For the expert, it would be interesting if there was a cursor that represented the notes that run through the cells while the music is playing, that is, when the note is playing, the cursor must be red and the previous note must appear as a ”ghost” of reference in yellow color.

After presenting the result of the animation of prototype 3, no adjustments were requested, that is, the participant considered the criterion of prototype fidelity in relation to its sketch.

We conclude with the application of the experimental model, that the possibilities of graphic representation and development of animated musical visualizations are wide. And with rapid prototyping exploring the creative process in a practical way, observing and collecting continuous qualitative feedback. Therefore, we consider that animated visualizations are potential tools to quickly communicate musical information, as it facilitates its real-time and synchronous monitoring in relation to the sound.

5. Discussion

This is a research in progress, but we noticed that the refinement of the process after the application of the pilot experiment directed the new experiments to richer results of information and musical conceptualization. Thus, we highlight some interesting points in the construction of the animations, having musical information as exploratory potentials - the lyrics or the chords of the music -, as it was frequently present in the temporal reference of the participants' representations. We emphasize that it is necessary to expand, produce and continue this study for the academic community, investigating which are the best prototyping and design techniques, proposing a design pattern for animated music visualizations through rapid prototyping. In future work, we will refine the experimental process and work on the development of an automation software that will reproduce the work of animator that is currently performed by the authors.

References

[1] Rute Moura. *Visualização Computacional de Informação Musical: Um estudo de caso para análise rítmica*. Dissertação de Mestrado., Universidade Federal de Pernambuco, Recife, 2021.

[2] Andréia Prieto Gomes. HISTÓRIA DA ANIMAÇÃO BRASILEIRA. page 25, 2008.

[3] Garry D. Brewer. The challenges of interdisciplinarity. *Policy Sciences*, 32(4):327–337, December 1999.

[4] Homero Dewes. Os desafios da pesquisa e ensino interdisciplinares. *Revista Brasileira de Pòs-graduação*, v. 4,:42–65, 07 2007.

[5] Tony Bergstrom, Karrie Karahalios, and John C. Hart. Isochords: Visualizing structure in music. In *Proceedings of Graphics Interface 2007*, GI '07, page 297–304, New York, NY, USA, 2007. Association for Computing Machinery.

[6] Stephen Malinowski. Music animation machine renderers, 2012.

[7] Peter Ciuha, Bojan Klemenc, and Franc Solina. Visualization of concurrent tones in music with colours. In *Proceedings of the 18th ACM International Conference on Multimedia*, MM '10, page 1677–1680, New York, NY, USA, 2010. Association for Computing Machinery.

[8] Yongmeng Wu, Leshao Zhang, Nick Bryan-Kinns, and Mathieu Barthet. Open symphony: Creative participation for audiences of live music performances. *IEEE MultiMedia*, 24:48–62, 01 2017.

[9] Bingkun Chen, Hong Zhou, and Xiaojun Chen. E-embed: A time series visualization framework based on earth mover's distance. *Journal of Visual Languages Computing*, 48:110–122, 2018.

[10] J. Heer and G. Robertson. Animated transitions in statistical data graphics. *IEEE Transactions on Visualization and Computer Graphics*, 13:1240–1247, 2007.

[11] George Robertson, Roland Fernandez, Danyel Fisher, Bongshin Lee, and John Stasko. Effectiveness of animation in trend visualization. *IEEE Transactions on Visualization and Computer Graphics*, 14(6):1325–1332, 2008.

[12] Renato Barisic. Cross-curricular education using interactive visualizations. *Procedia - Social and Behavioral Sciences*, 47:2157–2161, 2012. Cyprus International Conference on Educational Research (CY-ICER-2012)North Cyprus, US08-10 February, 2012.

[13] Patrick Baudisch, Desney Tan, Maxime Collomb, Dan Robbins, Ken Hinckley, Maneesh Agrawala, Shengdong Zhao, and Gonzalo Ramos. Phosphor: Explaining transitions in the user interface using afterglow effects. In *Proceedings of the 19th Annual ACM Symposium on User Interface Software and Technology*, UIST '06, page 169–178, New York, NY, USA, 2006. Association for Computing Machinery.

[14] Barbara Tversky, Julie Bauer Morrison, and Mireille Betrancourt. Animation: Can it facilitate? *Int. J. Hum.-Comput. Stud.*, 57(4):247–262, October 2002.

[15] Marcelo Fernandes de Oliveira. *Aplicações da prototipagem rapida em projetos de pesquisa*. Mestre em Engenharia Mecânica, Universidade Estadual de Campinas, Campinas, December 2008.

[16] Osiris Canciglieri Junior, Aguilar Selhorst Junior, and Ângelo Márcio Oliveira Sant'Anna. Método de decisão dos processos de prototipagem rápida na concepção de novos produtos. *Gestão & Produção*, 22(2):345–355, June 2015.

[17] Thomas Lockwood. *Design thinking : integrating innovation, customer experience and brand value*. New York, NY : Allworth Press [u.a.], 3 edition, 2010.

[18] IDEO: Design Thinking, 2018.

[19] Van Huynh and David Comberg. Musicvis a web application for visualizing sound., 2017.

[20] Leandro Soares Guedes. *MusicVis: Interactive Visualization Tool For Exploring Music Rankings*. Dissertação de Mestrado., Universidade Federal do Rio Grande do Sul, Porto Alegre, 2017.

[21] LANDR. O Círculo de Quintas: O que é e como usá-lo em suas composições, October 2020.

[22] Jill Nelmes. *Introduction to Film Studies*. London: Routledge, 5 edition, 2011.

[23] N.Magnenat Thalmann and D. Thalmann. Computer graphics and animation. *Computer Physics Reports*, 11(1):221–291, 1989.

[24] John Lasseter. Principles of traditional animation applied to 3d computer animation. *SIGGRAPH Comput. Graph.*, 21(4):35–44, August 1987.

[25] P. Wells. *The Fundamentals of Animation*. Fundamentals (Ava) Series. Bloomsbury Academic, 2006.

[26] T. Tschang and A. Goldstein. Production and political economy in the animation industry: Why insourcing and outsourcing occur. 2004.

[27] Elisangela Lobo Schirigatti and Ilan Avrichir. Processo de produção de uma animação: Uma abordagem teórica. *Diálogo com a Economia Criativa*, 4(11):32, August 2019.

[28] Richard Lipka. Scalable timeline visualization. In *2016 9th International Conference on Human System Interactions (HSI)*, pages 150–156, Portsmouth, United Kingdom, July 2016. IEEE.