New England Jazz Hall of Fame Interactive Audio Augmented Reality Posters

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Sponsored by WICN Public Radio

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Abstract

In the modern digital age, radio stations such as WICN Public Radio are navigating an ever-changing user base to attract and retain listeners, as the changing environment affects traditional revenue sources. The goal of this project was to design an application or device to help expand WICN's connection to the local community and attract more listeners. An ideal solution would utilize WICN's vast library of Jazz Music to augment local artwork or exhibitions, enhancing the experience of visitors and exposing them to the station's work. This project resulted in a series of Audio Augmented Reality JavaFX interactive posters and a framework for the creation of further posters and recommends future work to integrate the posters onto WICN's own website.

Acknowledgements

Several people provided significant support to this project throughout its many transformations as the world around us shifted in the effort to combat COVID-19. Thank you to our sponsor, David Ginsburg for understanding and supporting the many changes made to the project as we all adjusted to life in COVID. Also thank you to Professors Richard Falco and Douglas Olsen for the many suggestions on potential paths to explore and vast libraries of interviews and music.

Finally, thank you to Professor Scott Barton for his constant support and guidance throughout this ever-changing project.

Executive Summary

In an ever-faster world, the methods by which we present and communicate information are continually evolving. In this journey to convey more information in a shorter time or allow the recipient to better absorb the same information, and thereby improve the ability of the user to learn, modern museums and educational institutions have sought to combine multiple sensory inputs to create a fuller, more intuitive experience for the user. This project explores the advance of spatial recording and playback technology, and its integration into learning experiences that are traditionally visual or purely audio.

This project attempts to create a framework by which the gap between visual and audible arts can be closed to create a versatile and adaptable application presenting a combined sensory output that will allow a developer to generate a series of digital images with interactive audio components that react to the location of the user's mouse.

As this project is sponsored by WICN public radio, it is important to understand the advances made in radio since its inception, and the connections therein to the technology involved in recording, transmission and playing back a sound clip. The project explores the origin or information transmission from electronic blips and morse code over wires, to the recognizable voice over airwaves and its transition of a military technology to a common way for the public to receive information and relax with music from radio stations. It delves into how the rise of the internet and the digital age has damaged decades old radio stations as the public transitions away from radio-based technology to more instantaneous and interactable web solutions, and how this forces radio stations to seek alternative methods to interest and interact with the public.

On a similar note, I examine museums and their audiences, and how exhibits are changing to better disseminate information. Exploring the different types of audiences that a museum can expect to be host to, from a casual visitor to one that studies the material in depth, we see how the transition from a static display to an interactive one intends to engage the different visitors differently to best suit interest. Ranging from interactive push buttons to augmented reality tablets superimposing information over a user's view, the advances in curation provide the gap available for this project, as visual augmented reality or virtual reality is relatively common, while audio augmented reality (AAR) is a lesser-known alternative. By utilizing only audio, it is up to the end-user to find meaningful connections of their own between the audio and visual components. Although connections may be implied or intended by the designer, by not explicitly displaying the intended outcome and letting the user intuitively discovering them we can preserve the abstract nature of artwork.

Following this exploration into the background of the potential for both audible and visual components, a series of objectives were set for the design of the project:

1. Explore the connections between music and art
2. Determine the experience specifications
3. Design the experience

The first objective was accomplished through extensive research into the various ways that music and art can be interpreted and the connections between them and their interpretations, including color, textual content, and form. Various studies and research projects into the psychology of colors and form and their connections to musical scales and form were instrumental in the analysis of the Jazz Hall of Fame Posters. The second objective was largely achieved through discussions with David Ginsburg, the general manager of WICN. We determined that the project should focus on building a multiplatform framework for future work to progress upon, where several sample posters would be created, with the potential for additional posters to be added, either by WPI Students, or WICN staff in the future. Tying into the last objective, these goals were accomplished through the development of a JavaFX application for compiling an executable file for each poster.

In the development of this project from inception to completion, there were two main challenges. First, the ever-changing conditions of the world due to Covid-19 forced several major reworks to the core of the project, shifting from an in-person art exhibition utilizing personal wearable AAR devices, to the final form of the online downloadable AAR Posters. These changes were particularly problematic as over the year the project ran, conditions were continually changing, thus changes made to the project were often insufficient to deal with the situation. Second, we originally intended to complete the research objectives through the interview of professionals in the fields of museum curation and exhibit design, as well as radio DJs, however in nearly all the cases, our potential interview subjects either never responded in the first place, or promised interviews, which they then never scheduled.

The main conclusion we drew from this IQP is that there are extensive connections between music, the visual arts of any kind, and how the human mind interprets them. Through this research, we have found that there is a correlation between colors and the diatonic musical scale, as well as the human emotional state at seeing those colors, among many other interactions.

If this IQP continues into the future, we recommend that the researchers put significant effort into reaching out and securing interactions with professionals very early into the project, explore ways to access more significant portions of musical content, or integration of the project to WICN’s website.

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Introduction

Humans have the incredible ability to take multiple sensory inputs and synthesize them into a coherent understanding of the environment around them, enabling them to process and understand vast amounts of information in a relatively short period of time. Unfortunately, many traditional learning processes tend to engage only one of our senses at a time, limiting the potential learning power of the human mind, or not making use of our ability to connect relevant material. Classwork or rote memorization often depend solely on reading a quantity of information, but do not engage the sense of touch, smell or taste. Mathematics for example, may benefit from memorization of theorems, however many other subjects leave open the opportunity for different ways of teaching. Take for example a chef, whose education would be considered incomplete without the ability to judge a dish on taste, smell or feel. These differences in education styles are slowly changing, where increasing numbers of subjects are expanded and taught differently to better use this human ability to learn.

This change has led to an ever-increasing number of virtual reality or augmented reality applications, for educational or recreational purposes as more and more applications or groups take advantage of improving technology to better reach or better provide services for their uses. VR and AR have continually pushed the boundaries of human sensory input, as they seek to virtually simulate conditions for our senses.

This project seeks to use Audio Augmented Reality to improve a series of posters commemorating famous Jazz Musicians through bridging the senses, to provide an improved educational experience, expanding our sponsor, WICN’s connection to the local community.

Background

The purpose of this section is to review existing research relating to the implementation of an audio augmented exhibit experience. It will briefly cover the history of radio technology, our sponsors WICN Radio and Arts Worcester and Museums and the changing dynamics of exhibits before covering the opportunity this presents.

History of Radio Technology and WICN

Radio has long shaped the modern world, although not many today would recognize it in its original form. The origins of the modern radio lie within inventions such as the semaphore and telegraph. Industrializing countries were always looking for faster or more convenient ways to transmit information over long distances. In 1844, Samuel Morse demonstrated his invention, the telegraph by sending the message “What hath God wrought?” from Washington DC to Baltimore in 1844(*Invention of the Telegraph | Articles and Essays | Samuel F. B. Morse Papers at the Library of Congress, 1793-1919 | Digital Collections | Library of Congress*, n.d.). The instantaneous transmission of a message over such a distance was unheard of that time, and the telegraph quickly became a fast and convenient method of transmitting information over long distances, though it had one critical flaw: it was a point-to-point system. Since the telegraph operated by encoding letters and numbers into a series of short or long pulses of electrical energy known as Morse Code, transmitted to the destination over an electrical cable, the system required a wire for each route. While not a problem on land, many images of cities from the late 1800s and early 1900s show dozens of wires on poles that nearly obscure the sky (Figure 1), the telegraph was completely impractical for transmitting information to ships at sea.

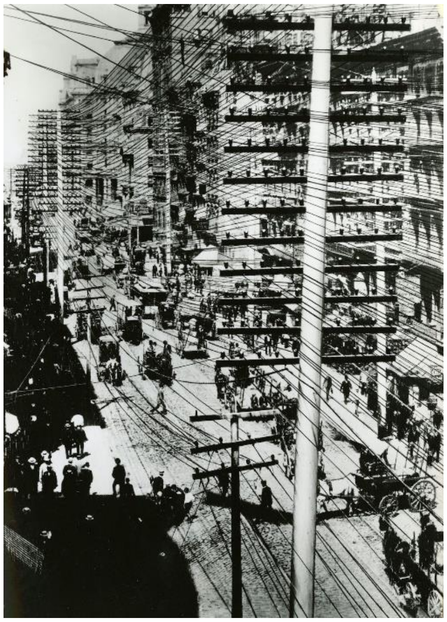

Figure 1: Telegraph Wires

This gap was filled by Samuel Marconi’s invention of the Wireless Telegraph, or “Wireless” in 1896 (*Marconi’s Wireless Telegraph (1899)*, n.d.). By varying electrical fields with immensely powerful antennas, information could be passed wirelessly using the same Morse Code as the telegraph, and more importantly, broadcast without requiring dedicated links from sender to receiver. While transmission of human voice became possible with the invention of the first true Radio by Reginal Aubrey Fessenden in 1900 (*Radio’s First Voice*, n.d.), morse code and transmissions between ships and land stations remained the primary use of wireless technology until World War 1. Following the conclusion of World War 1, radio began to spread to civilian use and broadcasting stations like the BBC were established (*History of the Radio: A Complete Radio Timeline*, n.d.) and by 1926, radio began to overtake traditional newspapers as the primary source of news for families as they gathered around the family radio (Figure 2). Following World War 2, during which time radio again played an important role in relaying news from the front lines to military commands and back, radio began to refocus to playing music(*History of the Radio: A Complete Radio Timeline*, n.d.). The popularity of music and radio continued to rise to the point where it became difficult to distinguish where one ended and the other began. Unfortunately, the relentless march of time has not been kind to radio.


Figure 2: Family Radio

While a 2015 survey found that 90% of American Adults still listen to radio at least once a week (Wu, 2017), radio has become a less predominant source of news and music. In 2018, the average number of radio listeners (excluding holiday listeners) declined by 5.95% (*Radio in the U.S.*, n.d.). Digital publications accessible from computer browsers or smart devices have quickly overtaken the radio as a quick and easy source of news in day-to-day life. Services and applications such as Apple's iTunes, Spotify, Pandora and YouTube have also reduced the convenience of radio as a source of music as the population pivots to customizable playlists, with 57% of the US population listening to online radio (*Radio in the U.S.*, n.d.). This drop in the traditional radio listening base over the years has led to a corresponding loss of revenue for radio stations as advertisers started pulling ads or simply paid less due to the reduced number of listeners (*Radio in the U.S.*, n.d.). To make things worse, the COVID-19 pandemic has forced much of the workforce to stop commuting thus, at least temporarily, removing car radios as one of the last remaining bastions of the radio.

Due to mounting revenue losses, many radio stations have been forced to seek new sources of listeners and income, from online applications streaming music to renting out their studios for third party use (*D. Ginsburg, personal communication, September 2020)*. One of these stations native to Worcester MA is WICN, a Jazz radio station begun by Worcester's college community, including The College of the Holy Cross and our own Worcester Polytechnic Institute. A nonprofit public radio, WICN has long seen itself as a "Voice for the Arts," seeking to "promote and preserve the best in music with a strong focus on jazz," (*90.5 WICN Public Radio – Jazz+ for New England*, n.d.). Seeking to be more than a radio station, WICN often holds or contributes to events such as "Music in the Gallery," or community celebrations like the Women's Initiative's "Stepping Up For Girls" fundraisers.

Unfortunately, many of these events have been forced online, or cancelled altogether as restrictions imposed for public safety severely limit the number of people allowed to gather for events. As a result, WICN has been forced to look elsewhere for ways to both connect with their community and gather revenue to fund not only their outreach projects, but their operation as a station. One of their ongoing projects is to reinvent themselves as more of an arts institution, covering more than just music, but reaching into the visual arts as well. To this extent, WICN is continuing to reach out and connect with Visual Arts groups such "Pow! Wow! Worcester" and galleries or art museums such as the Worcester Art Museum or Arts Worcester. Facing similar changes to demographics and their own respective userbase, museums too have been searching for new ways to attract audiences.

Museums and Exhibits

Museums and exhibits have long been an important part of preserving and teaching history, be it art, nature, science or engineering. Prior to the pandemic, museums regularly attracted 850 million people annually across the United States (*A History Of Museums, "The Memory Of Mankind,"* n.d.), more than 6 times the number of people who attend sports events. Taking their name from the Greek term "*mouseion"* for a temple to the Muses in honor of the Greek deities responsible for the various arts and sciences(*A History Of Museums, "The Memory Of Mankind,"* n.d.), these institutions were officially defined as "permanent organizations in the service of society and its development… which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment," in 1955 by the International Council of Museums (Günay, 2012). Many different styles and designs for an exhibition, changing to fit the needs and interests of their curators depending on the visitors the exhibition intends to attract.

While visitors can be separated into many specific groups such as families, school groups, tourists or the elderly, it is more useful to generalize these specific groups into three broader ones, Casual Visitors, Cursory Visitors and Study Visitors (Najbrt & Kapounová, 2014), where casual visitors glance over the material, cursory visitors show genuine interest in at least some of the material, and study visitors thoroughly examine the majority of the material on display. This disparity in user interest creates a dilemma for exhibit designers as they attempt to create an installation that can interest all three groups of visitors. Traditionally, exhibitions have utilized descriptive textual installations near a display as a catch all solution (Figure 3), where casual visitors are not overwhelmed by information, however for the cursory or study visitor, there exists enough information to catch their attention and hold it.

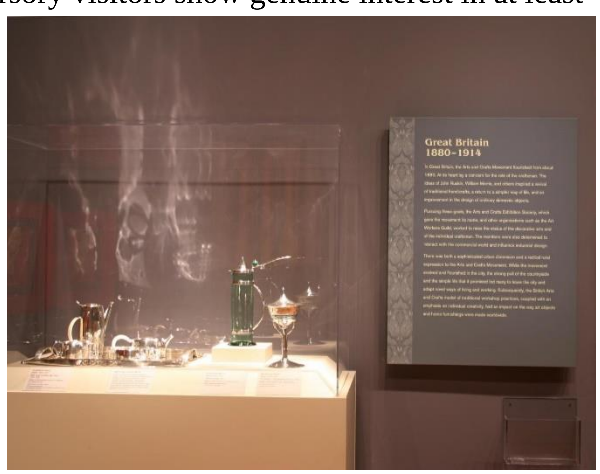

Figure 3: Museum Explanation Text

Modern exhibitions however have been subject to societal and educational changes as the world transitions from “passive educational systems consisting of rote learning and information transfer” (Günay, 2012) towards more student-based education promoting self-driven research. This change has pushed museums and their exhibits from a more traditional passive learning experience to an active part of education, almost an extension of the classroom, resulting in the installation of an ever-increasing number of active exhibits. Figure 4, for example, shows buttons and dials through which a user can control an exhibit display. A step up from a textual information panel, these exhibits continue to ensure casual visitors are not overstimulated, while providing extensive additional information for those who seek a more in-depth experience.

Figure 4: Interactive Exhibit

While these exhibits are a significant step towards being more versatile for the user, they are not always the most intuitive solution to interacting with a wide and varied audience, and often create other problems. Due to the physical nature of the exhibits, controlling the interaction is often limited to one visitor at a time, and any audio components are broadcast to the general vicinity. This limits the number of visitors who can benefit from the additional depth of a particular exhibit at a particular time as each visitor spends a differing amount of time engaged with the exhibit. Any audio being broadcast also has the chance of putting off casual visitors, or even cursory visitors not interested in the exhibit if merely too much information is present, or in a worse case, if misbehaving visitors trigger exhibits randomly and excessively. Additionally, in a world currently dealing with a global pandemic, users are increasingly aware and wary of potential sources of pathogen transmission, and these interactive exhibits are sure to be a potential source of contamination.

These problems point to the necessity of an even more versatile experience, able to provide varying levels of information based on the user. Some museums have experimented with Augmented Reality (AR) as an immersive way to introduce varying levels of immersion to match the user’s interest level, however most solutions involve visual overlays of the existing exhibit, which can in some ways detract from the exhibit itself, especially in the case of visual artwork. The Archaic Gallery of the Acropolis Museum for example utilizes a tablet to superimpose a visual of period clothing, armor or information (Figure 5) on statues (Keil et al., 2013). This expands the user’s understanding of the history of an artifact, yet at the same time it

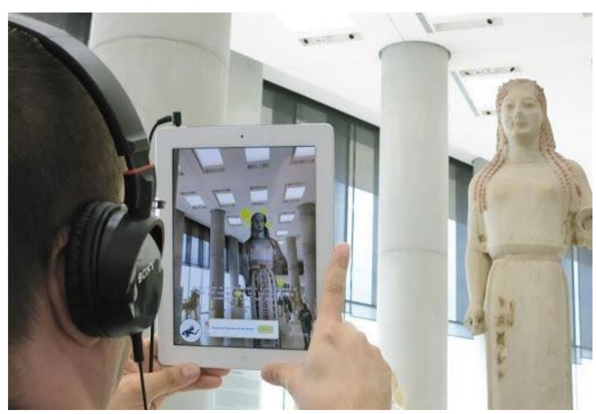

Figure 5: Augmented Reality at the Acropolis

takes away from the experience, as such imagery could simply be viewed online. Audio Augmented Reality, a lesser-known technology involving only the superposition of audio over a scene provides a potential solution, as it would allow the user more control, yet not impede the visual experience of a work in a museum.

Augmented Audio Reality

Ever since Thomas Edison developed the first sound recording device in 1877 (*An Audio Timeline*, n.d.), sound engineers have sought to perfect recording and playback to create a more immersive audio experience for end users. While the mono (single channel) recording of "Mary Had a Little Lamb" on a tin foil cylinder was an incredible accomplishment given that it was the first time a sound was capable of being replayed after it had occurred, the quality of the experience left much to be desired. Given the majority of the sound that we hear comes from multiple sources scattered around us, replacing the entirety of these sources with a single source creates a rather unrealistic experience. Consider for example a flock of birds in an orchard, each bird creates its own sound from its own location, if this sound were recorded in mono, the user listening would perceive the resulting recording as a series of birds all sitting in the same location on the same tree.

Stereo (dual channel) sound was accidentally produced in 1881 by Clement Ader over adjacent telephone lines(*An Audio Timeline*, n.d.), and effectively doubled the user experience. By recording the same audio stream in two different places, and playing back one stream to each ear, the listener can perceive where each sound originated from, vastly improving the user experience. Further improvements delivered ever increasing quality of sound as more channels were recorded and played back. Many movie theatres, or even home TV setups are now capable of various levels of surround sound, in which multiple speakers are used to project slightly different streams of sound from different angles (Figure 6), weaving an audio illusion of being in the middle of the action. This illusion is the basis for audio augmented reality (AAR) in which the user's experience in an environment is enhanced through the addition of sound, like how a 3D movie experience is an enhanced form of the same 2D movie.

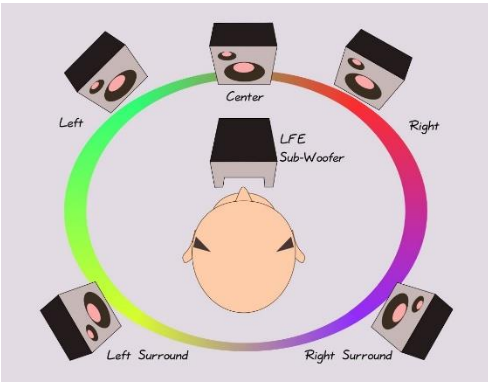

Figure 6: Surround Sound

The quality of these enhancements often comes down to the technology utilized to create the effect. Movie theatres for example use a massively powerful array of speakers strategically located around the theatre to project sound from many different directions (Figure 7). Such installations are relatively easy to set up, the speakers are placed in locations around the intended audience and a soundtrack is created that transmits sound from each location. Although the area-of-effect setup makes designing the sound track simpler to design than mobile variants due to the static and known location of the viewer, it also exhibits a distinct lack of control for the user. Barring minor deviations due to proximity to one speaker bank over another, every person in the vicinity is subjected to the same sound at the same time, with no control over volume or amount of information being given.

Figure 7: Theatre Sound System

By downsizing the technology to a personal level, many of the design requirements for the room disappear. Since the perceived volume increases by about 6 decibels, or about 60% every time the distance is halved (*Digital Sound and Music*, n.d.), by placing the speakers on the listener, the power requirement is vastly reduced from about 15000 watts in an IMAX theatre (*Imax Sound System*, n.d.) to mere watts or milliwatts on headphones. In addition, the acoustic design of a room does not have to be considered, as sound is directly projected around the user without unusual reverberation or other wave interference due to room configuration. While the physical design requirements for such personalized experiences are vastly reduced, software and audio requirements are higher as the experience must be capable of adapting to the listener's actions. Whereas patrons in a theatre are always facing the same general direction, AAR users are free to move about a location and face anything that interests them. This forces the technology to compensate its virtual sources of sound to maintain a relatively stable source of sound relative to the user.

Many examples of successful projects involving AAR exist, from broad localization through sound to interactive exhibits. Students at McGill University in Canada designed an AAR experience to augment a visually impaired user's ability to navigate cities (Blum et al., 2012), stepping beyond simply guiding the user from one point to another. While the guide dog has long been a traditional aid to the visually impaired, a guide dog does not necessarily provide their human any information about their surroundings other than to avoid physical objects or dangers. By combining location services present on smartphones and easily recognizable sounds, the AAR project sought to project intuitive representations of restaurants, shops or other places of interest without disruptive voice messages such as "There is a restaurant on your left."

The tourism industry has also benefited from the integration of AAR. By using similar technology to the city navigation for the visually impaired project, self-guided tours can be created with audio "beacons" drawing a tourist's attention to various landmarks or points of interest without using a map. One such example of this was an implementation of AAR at a medieval archeological dig site (Sikora et al., 2018) where not many visual cues exist leading visitors from place to place, yet by superimposing a soundscape (Figure 8) involving

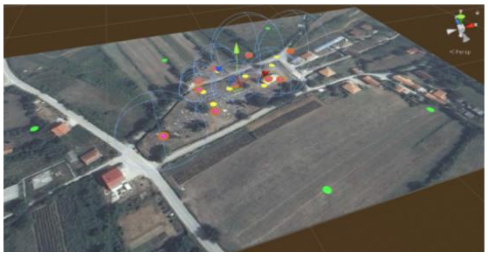

Figure 8: 3d Soundscape of an Archeological Site

period specific sounds, users could be led to specific places. For example, a blacksmith's shop projected a field of sound with its hammer and anvil sounds ringing out across the area. Another project provided real time feedback and information to the user by embedding RFID tags within a model of a building façade (D'Agnano et al., 2015). When the user waved a RFID receiver in their hand over a tagged location, audio describing the history or architectural significance of that part of the façade was sent to the user's device (See Figure 9).

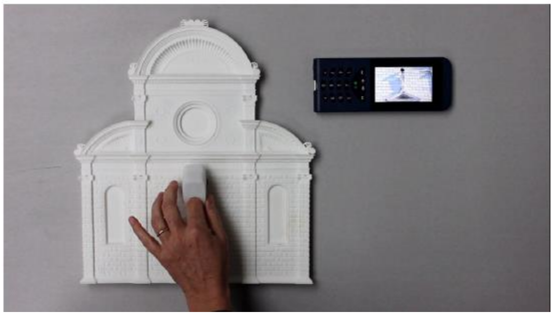

Figure 9: Facade with RFID Tag and device

Given these past examples of successful projects using AAR to enhance a visitor's experience in various settings and locations, it is completely feasible to incorporate background AAR into a visual arts exhibition such as posters in an interactive manner.

Color

Humans as a species are able to perceive many different colors, however it should be noted that there are several different methods by which color can be measured, each with its own uses. RGB for example describes a color as an addition of the primary light colors, Red, Green and Blue and is a simple and useful way to choose colors for reproduction on common computer screens and televisions, where and image is produced from light by emitters of the afore mentioned colors. CMYK on the other hand, is a more useful color scale for printed media, where the combination of a shade of the 3 primary colors, red, yellow and blue create a new hue, however it requires the addition of black to create the different shades perceivable to our eyes. While both these scales are popular and are extremely useful in their given medium, they do not universally describe colors, thus necessitating the use of a different color scale. HSV, or Hue, Saturation, Value and is useful for reproducing color on a screen. CMYK on the other hand, describes a color in terms of the most common printable colors. While RGB and CMYK are more useful for the reproduction of color, the HSV color model can provide a more consistent color selection translatable to the other scales for reproduction in the required medium.

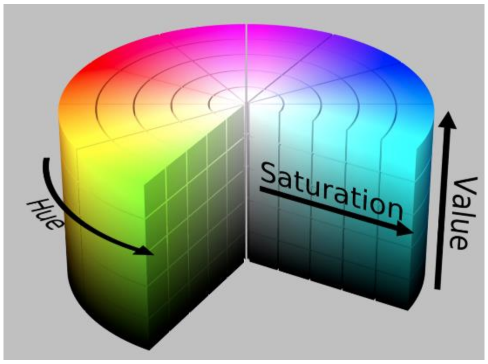

Figure 10: HSV Cylinder

Project Opportunity

Given the gap presented in exhibitions and the needs of WICN, there exists an opportunity to build an augmented reality audio experience promoting WICN. WPI's Jazz History database contains a series of posters commemorating famous Jazz musicians that are loaned to exhibitions or viewed online. These posters are already available for the community to view, however an audio augmented reality exhibition of some form using the posters improves the educational content available to the community. The Jazz music component also serves as a sneak peek at the content that WICN plays daily. Overall, this would emphasize WICN's connection and commitment to working with the community.

Methodology

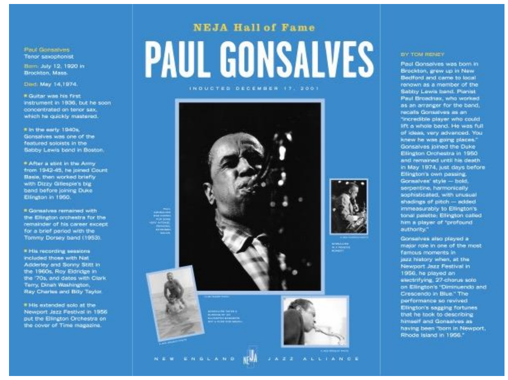

Figure 11: Jazz Hall of Fame Poster on Paul Gonsalves

The goal of this project was to design and build an AAR experience to compliment the Jazz Hall of Fame Poster series, expanding the user's experience reading the poster from a purely visual one, to a combination of visual and an accompanying soundtrack related to the visual material. This series of posters details various famous Jazz musicians, and include several pictures, as well as a brief biography and information about their work (see Figure 11). This section intends to detail the process in which the design of the final product was researched, designed, and created. The following questions guide the process of developing the project: First, how do the visual and aural arts connect and complement each other? Any implementation of an experience designed to bridge the two arts without understanding the quirks, connections and intricacies of each, and how human interpretation bridges them leaves the project prone to failure. Second, what application design best fits our sponsor's requirements, and can best implement the connections noted in the first question.

Objective 1: Explore the connections between music and art

There are many facets and metrics for music and art, some of which overlap. For example, there are "color scales" similar to the diatonic musical scale and could serve as a potential major tie. In addition, both music and art have their own "form" which may be a promising connection point. Finally, the textual content of a poster is important to consider for pairing musical content. For this objective, I intended to find the extent to which color and music can be related, if musical and art form correlate, and to what extent textual content should matter. I did so by examining studies into music and art by fine arts institutions, as well as psychological studies into the same, to explore how the human mind interprets the arts.

Objective 2: Determine the Design Requirements

With there are many different potential applications capable of building an audio augmented reality exhibition, ranging from mobile single user applications to computer-based applications or multiuser experiences it is important to identify some constraints for the design. The metrics examined are cost, skill requirement, expandability, environment and use of AAR.

For most of these constraint criteria, we explored the pros and cons of several different potential solutions and presented our sponsor with the various options. We also considered several other variables, including our own technological abilities and the current world environment. Once an agreement was reached with our sponsor on a path towards a solution, we designed and implemented that solution to the best of our abilities.

Objective 3: Design an AAR Experience, and measurement of success

After determining ways to connect art and music, and setting our design constraints, we chose a medium and developed the AAR exhibit. Since we knew our visual component was comprised of the Jazz Hall of Fame posters, we knew we would be developing either an individual physical wearable device, a local area of effect sound projection field, or a purely virtual exhibition. Upon completion, we believe that the project should be judged based on fulfillment of our sponsor's criteria.

Results

Connecting Music and Art

The research conducted into this project turned up several important areas where the aural and visual arts are bridged, sometimes in unexpected ways. Due to its near instant recognition, Color can be a significant connection, matching hues and saturations agreed upon by most of the world with the lesser known, but well-defined musical scales, as well as induced moods (Jolij & Meurs, 2011). Similarly subtle, form too can connect music and art, as way pieces are structured may be similar, however proves difficult to implement due to the necessity of listening to a significant portion or whole musical composition to identify its form. The most obvious connection to be made however is the textual content of the poster, where examples of the information described can be directly understood from the music.

Color is perhaps the most important visual component to consider in this project as it has such an immediate impact on a viewer, particularly with the Jazz Hall of Fame posters (see Figure 11) due to the predominant blue background. From Ancient Greek mathematicians and philosophers to modern day physicists, many intellectual minds have formulated different "scales" by which color can be matched to the commonly accepted diatonic musical scale. Pythagoras for example discovered that varying the length of a vibrating string resulted in different audible pitches, and that various ratios control sound, similar to how ratios of black and white affect a color (Lill, 2012) long before the properties of light and sound waves were discovered. Thinkers such as Aristotle and Vincent Beauvais in tern formulated finite scales of color separate from music, however it was Isaac Newton who began to pair a color to a specific note. Over time, this pairing of scales developed to a range of colors arranged in a color wheel like the chromatic musical scale as shown in Figure 12 (Wells, 1980).

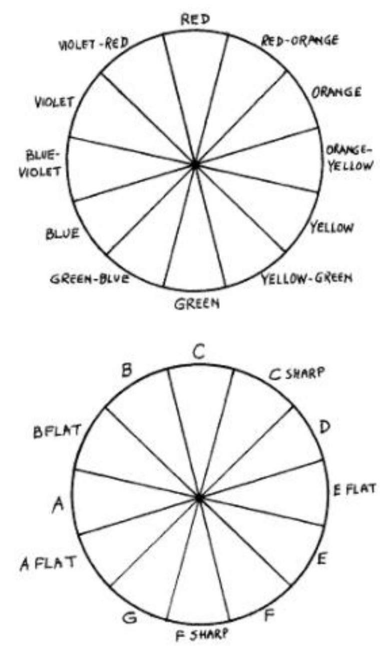

Figure 12: Color and Chromatic Scale Wheels

More modern studies, however, have sought to connect music and color through a viewer's mood rather than direct correlation. Several studies have found that music and sound can directly influence the mood of the user, while others have found that mood can directly influence the visual perception of a user, thus creating a feedback loop by which the first perceived part, either musical or visual affects the further perception of both.

A Swedish study for example, graded a series of musical performances with colors (Bresin, 2005). Although the purpose of the study was to train the students to improve their musicality and understanding of musical cues, it also discovered a common correlation between several emotions felt and particular colors (see Figure 13). After instructing the students to perform the same melodies with the intent of projecting different emotions, they were asked to rate each other's performances with colors, thus associating the colors with the emotion the listener perceived.

In addition, a study conducted in the Netherlands found that music, and particularly the mood the music induced in the user had a direct affect on a user's perception (Jolij & Meurs, 2011). Working off the principle that the human brain has a preconcieved notion of how something should be and will attempt to fit a sensory input to that notion (Hansen et al., 2006); for example, when participants were given a purely black and white picture of a banana, many reported percieving it as slightly yellow, caused by their knowledge that bananas are yellow.

Emotion	Hue
Happiness	0.167 (Yellow)
Love	0.667 (Blue), 0.75 (Violet)
Pride	0.167 (Yellow)
Tenderness	0.75 (Violet)
Curiosity	0.5 (Cyan)
Contentment	0.083 (Orange)
Anger	0 (Red)
Sadness	0.75 (Violet)
Fear	0.667 (Blue)
Disgust	0.75 (Violet)
Shame	0.083 (Orange)
Jealousy	0 (Red)

Figure 13: Emotion and Hues

Delving further into the emotional side, the Jolij and Meurs study requested participants to bring songs that the participant self-identified as inducing happy or sad feelings (Jolij & Meurs, 2011). When a non-verbal assessment was conducted after various neutral tasks, the study found that participants rated the tasks more in line with the mood they reported feeling from the music (Jolij & Meurs, 2011). As an example, when presented with a picture of a face with a neutral expression, a participant listening to happy music was more likely to percieve the face as smiling, while the same participant listening to sadder music was more likely to percieve the same face as frowning.

These connections between colors and moods lead to a likely feedback loop, where the first perception sets the user's mindset for the rest of the stimulus. For example, the Jazz Hall of Fame posters for this project happen to have a predominant blue background, potentially leading to feelings of love, curiosity or fear depending on the user. If the user percieves the initial impression as Love of Curiosity, ignoring any prior moods from external factors, this would likely put the user in a more receptive state where they would view the information contained by the poster in both musical and textual forms in a positive light, wheras a negative mood would put a damper on the user and hinder learning.

Unlike color, form provides a more challenging connection due to the limitations of the use of musical content. Due to copyright restrictions upon music, where both the music itself and the recording of the music are copyrighted, the rights to use of significant portions a musical recording can be both diffiucult to obtain, and extremely expensive. For example, a piece composed prior 1924 is considered "Public Domain" and is free to use as its copyright has expired, however, it is illegal to use a recording of the same piece made in the 1970s as it has its own copyright. Further, in order to legally use a recording of a piece composed and recorded in 1960, one would have to aquire permission both from the composer, as well as the recording artists.

While copyright law allows for use of copyright material without permission "fair use", several conditions apply, and still severely limit the usable material, where clips of ~20 seconds are generally acceptable.

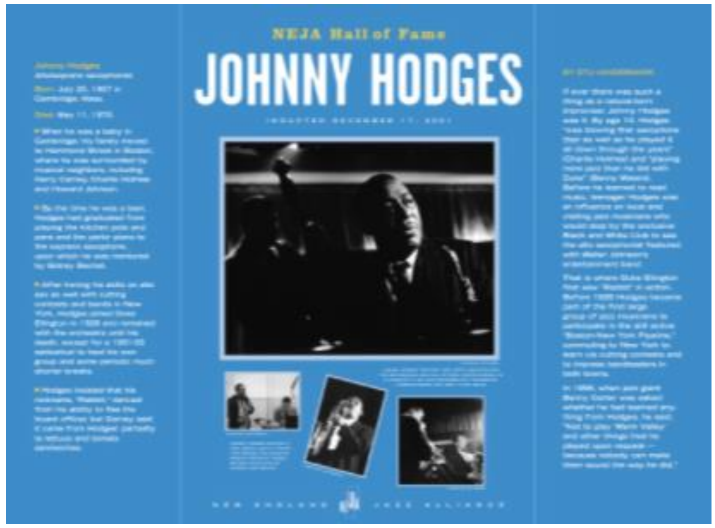

Figure 14: Jazz Hall of Fame poster of Johnny Hodges

In our situation, the Jazz Hall of Fame Posters were created in the ABA form (see Figure 14 for example), where the left pane of text is followed by a pane of images, and then another pane of text. Since music too has different forms, including ABA form, a good connection would be the use of ABA form, however due to the restrictions mentioned earlier, it would be difficult to use enough of a recording to show different forms without infringing copyright. Even if permission to use a whole song were given, many users are unlikely to make this connection due to the necessity of listening to the majority of the piece to hear the repeating sections. While more methods of analysing the form of a piece exist, they more relate to the fine visual arts, such as paintings, sculptures as opposed to posters. For example, a common metric of form in artwork is the scale of how geometric or organic the piece is, but as Figure 14 shows, the poster is primarily a display of flat text, without any particularly geometric or organic figures.

Regarding text, while text can be a form of visual art in itself, the Jazz Hall of Fame posters use a simple typeface resembling the common "Calibri" font, the text is intended to convey information rather than artistic intent. Although a more artistic font may stand out more, the choice of a simple and easy to read study of font can likely be attributed to the intent of the poster designer to impart information, and the general correlation between easy to read fonts such as "Calibri" or "Times New Roman" and retention of information (Kaspar et al., 2015). An alternative to connecting to the consistant form and text, a musical connection can be definitively formed directly from the textual or visual content of the poster in various locations. Common throughout the series of posters, the left hand pane of text gives a brief history or biography of the artist, mentioning for example work with a particular group, or the mastery of a particular instrument, while the right hand pane gives a more in depth analysis of the artist's work. As such, meaningfull connections might be formed where for example a mention of the artist's mastery of the piano would be accompanied by a clip of a piano solo, or the in depth discussion of the artist's use of a particular rhythm includes a clip of the rhythm.

Application Design

After consulting with WICN, given the current world conditions due to COVID-19, we decided to build a purely virtual AAR exhibition of the Jazz Hall of Fame posters, with the preference of an updatable, modular design. In order to reduce the work of future editors, we determined that the application should be cross-platform so that any updates made would not need to be duplicated on different versions and chose to implement a modular zone based audio design. In addition, we decided that the application would require the abilities to embed audio, interact with the user through the current location of the mouse, crossfade audio as the user moved their attention around, and create a sense of spatial movement for the user as if they were actually moving their head while reading a physical poster.

Many different application design paths exist, from mobile Android/iOS applications, to computer-based Adobe Flash or Java. Purely web based solutions were ruled out due to the extensive amount of variation of different hosting sites, and work necessary to integrate a major section into an existing website. Similarly, mobile applications were ruled out due to the major differences between Android and iOS, in addition to the licenses required to keep an application listed long term, and the yearly updates necessary to keep the application up to date with phone software. With Adobe Flash reaching its end of life stage, the project focused on Java, and its subcomponents JavaFX to design and build the application.

Although we ruled out other applications due to their unsuitability, leaving Java as our final option, Java has several strengths that make it suited for the project. First, Java is an increasingly popular programming language, used for multiple purposes, thus futureproofing the project. Second, Java applications are incredibly versatile, and the same application can be used on a multitude of platforms due to the Java Runtime Environment (JRE), which is a software layer that acts as an interface between the Java application and the operating system of the device. As each device or operating system utilizes and interacts with its own version of JRE, which is updated by the developers of Java, the application does not directly interact with the operating system and therefore does not need to be updated or rebuilt for different operating systems, or when the operating system is updated.

A further benefit to the application's compatibility with existing hardware is the low cost to use the application. No licenses are required to develop or use Java, and any user with enough computer storage and an audio device of any kind (including earphones, earbuds, or built-in speakers) can use and view the posters. Further development could make the application cloud based and installed on WICN's website; however, this would require careful planning and collaboration with WICN's IT Provider and webhost.

For our modularity design criteria, we built a framework with a 1920x1080 pixel window with 9 separate audio zones (Figure 15). Each zone can be assigned its own audio track independent of the others and can be resized or moved depending on the information conveyed by the poster.

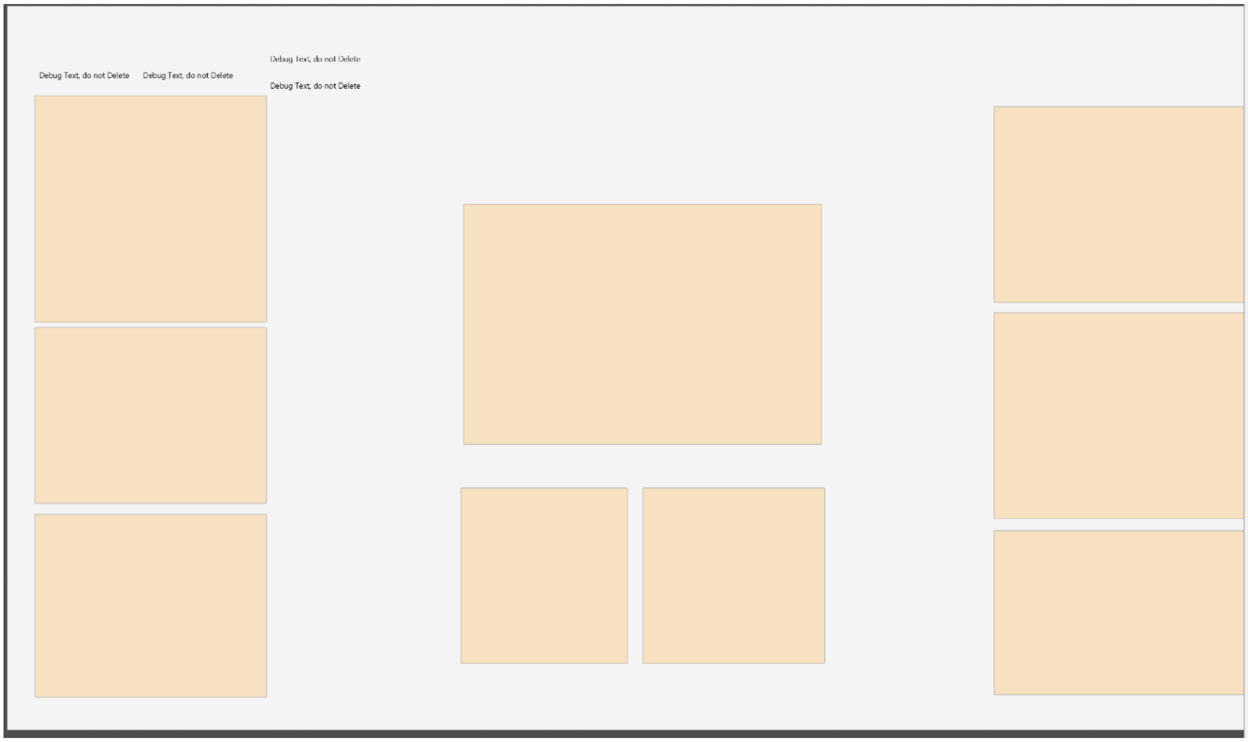

Figure 15: Application Zone Examples

The application interacts with the user by crossfading the audio of each zone depending on the distance of the user's cursor from the center of a zone. Since the locations of the zones are known, the static center of the zone is computed when the code compiles. This was unexpected, but necessary, as Java by default treats the location of a zone as the top left corner of the rectangle, thus initially creating an incorrect fading of tracks. Once each zone's location is recorded, every time the user moves their cursor, the application records the location and calculates the distance to each zone and sets the volume according to an inverse relationship to the distance, with a maximum cap to prevent equipment or hearing damage. This creates a crossfading effect where the closest two zones are the loudest and the other zones are unnoticeable, with the volumes constantly changing as the user moves their mouse. An introduction text was also included for the user to confirm prior to activation of the audio clips to prevent confusion and rapid changes in volume levels.

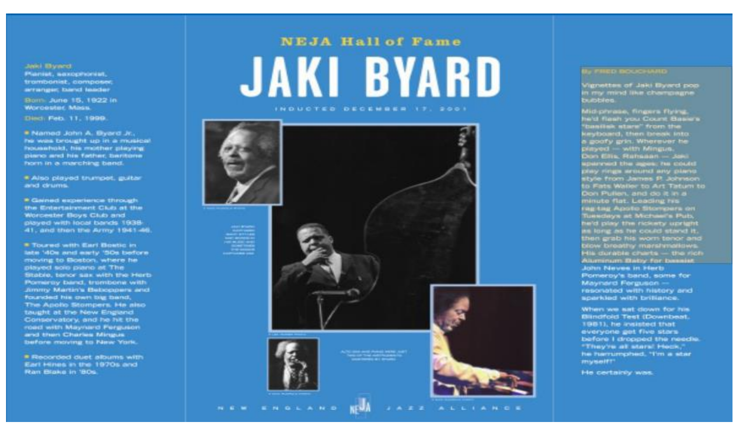

Figure 16: Jaki Byard Poster with active zone

The audio tracks themselves are created through JavaFX's MediaPlayer library, and are each assigned a number corresponding to an audio zone, thus allowing the application to track and change the volumes of the appropriate zone. Visual feedback is also provided by highlighting the active zone as shown in **Error! Reference source not found.**

Discussion

As discussed with WICN, this project prioritized the development of a framework over delivery of the full series of posters, and as such source code and 3 sample posters were delivered. These posters on Boots Mussulli, Jaki Byard and Serge Challof demonstrate the modular functionality, Audio Augmented components, and the interactive components of the design goals, however there is much room for expansion in the future, including the ability to use more music, improved updatability and better integration into WICN's website.

The application successfully meets the stated goals of creating a framework, generating an AAR experience that interacts, and presents additional sensory inputs that help the user understand the material present in the poster, and the AAR Component delivers a sense of direction, where the orientation of the music depends on its spatial location on the poster. These files can be found in Appendices 1 and 2. In terms of modularity and updatability, while the source code successfully delivers a modular design, with different zones, the recompile process is long and convoluted for the first time set up (requires the setup of an integrated development environment). Although subsequent changes made require fewer steps, I would have liked to see a slightly different outcome, where the code focused less on versatility, and perhaps drop the ability to custom resize the audio zones for a more simplistic update process, where replacing an audio file with another automatically updates the poster without requiring a recompilation, or an overarching executable providing a menu for the user to select a poster. In an ideal world, this would also be integrated into WICN's website, however this in itself is a major project, involving a significant collaboration with WICN's IT support team and Webhosts to program the interface, and actually host the materials on the cloud.

Finally, and most importantly, is the choice of music clips for these posters. Due to the lack of many significant clips of music available for use, primarily due to copyright law, the pairings of music and poster were determined primarily due from textual content, where the short music clip directly related to information described in the poster. I would have much preferred to pair these clips based on the more subtle, but interesting connections that can be formed off of the form, mood and emotion bridging the posters and the music performed by their subjects, but simply due to the lack of enough clips, I was unable to do so. Perhaps through the modular design, and potential future improvements, the current music selections can be swapped out if future researchers can get the rights to use more significant portions of recordings.

Challenges

Originally, we intended to fulfill the learning goals for our objectives by interviewing professionals in the fields of exhibit creation and design, to explore how museums and exhibitions put together an exhibition, and their thoughts on AAR. We also intended to interview music professionals such as DJs and Professors for their thoughts and suggestions on mixing music and how it can complement nonmusical components. Unfortunately, none of the 7 museum/exhibit professions we contacted to request interview responded, and only 5 of the 12 musical professionals responded. Of the 5 musical professionals, only 1 completed an interview, even though they informed me the project was outside of their area of expertise and were unfortunately unable to help. The other 4 music professionals I was able to get in contact with promised interviews however never responded afterwards. One of these members did promise to provide written answers to the questions I had deemed most important, however again failed to respond afterwards. Since I had positive responses, I can only believe these potential interview subjects forgot to respond despite my repeated emails or became disinterested and neglected to tell me.

As noted earlier, copyrighted music also was a significant issue. WICN was unable to provide the clips used as they are in the process of changing their content access system and are themselves unsure about the copyright ramifications of providing the clips and therefore erred on the side of caution. Thus the only way we were able to use any clips was through the “fair use” consensus of ~20 seconds or less being acceptable, and even so, we still struggled to find any significant amount of content, and had to mainly stick to connecting to the content of the text for our sample posters.

Conclusions and Recommendations

The main conclusion for this IQP is that there is always room to explore and improve the connections between the human senses, specifically visual and audible. Throughout my research, I discovered the incredible amount of effort museums and other industries expend in order to project their content to an audience, tailoring the experience to deliver the maximum impact, and the incredible complexity of human connections to arts through the various senses. I would have liked to gain insight into the professional design side of exhibitions in addition to my own research.

To continue this IQP in the future, we can only recommend the researcher prioritize the gathering of any information from people directly, and continue researching the connections between the senses and interpretations of art and music. We hope that the research and framework designed are useful for future projects. Perhaps future researchers with more experience in designing applications in code can further streamline the recompile process necessary for creating a new poster or editing existing ones, as while the current process allows for more versatility in assigning zones and music, a more simplistic approach with static zones could allow for less experienced members to update off a template or rename files without requiring changing fields in code and recompile the whole project. Another potential field for expansion is the significant work and contact that would allow the project direct access to full length recordings.

Furthermore, while this project already can reach users who download the content, we would hope someday a project like this could be used on a live website to reach many more users without the need to download the content.

Appendices

Appendix 1: Project Files

The Project can be downloaded at https://drive.google.com/drive/folders/1fNHvo5jfv1AeWp4k_ydUZyZzBqJX2BML

Appendix 2: Selected Project Code

This section of the code determines the distance to the mouse from the center of each audio zone, identifies the two closest zones and assigns volumes for each zone.

```
public void mouseMoveDetected(MouseEvent mouseEvent) {
  if (introDone) {

    //Get the xy coordinates of the mouse
    mX = mouseEvent.getX();
    mY = mouseEvent.getY();

    //Calculate the current distances from mouse
    distanceFromMouse();
    currClosest = closest();

    //If the closest box is within range, set the current closest distance
    if (currClosest != -1) {
      dClosest = d[currClosest];
    }

    //If the second closest box is within range, set the second closest distance
    if (nextClosest != -1) {
      d2Closest = d[nextClosest];
    }

    //If no boxes are within range, set all boxes invisible
    if (currClosest == -1) {
      setInvisible(-1);
    }

    //Set the boxes invisible when mouse leaves
    else if ((!enable[currClosest])) {
      setInvisible(-1);
    }

    //Make only the current box visible
    setVisible(currClosest);


    //Print debug text if its enabled
    if (debugEnable) {
      debugText(currClosest);
    }
```

```
//Set the volumes of each box
for (int i = 0; i < numberBoxes; i++) {
  //Check if this box is within minimum range
  if (d[i] < maxDistance) {
    //if within range, set volumes (left hand side boxes)
    if (i == 0 || i == 1 || i == 2) {
      volume[i] = (-d[i] / 220) + 1.2;
    }
    //if within range, set volume (focus image)
    if (i == 3) {
      volume[i] = (-d[i] / 300) + 1.5;
    }
    //if within range, set volume (non focus images)
    if (i == 4 || i == 5) {
      volume[i] = (-d[i] / 100) + 1.5;
    }
    //if within range, set volume (right hand side boxes)
    if (i == 6 || i == 7 || i == 8) {
      volume[i] = (-d[i] / 100) + 1.6;
    }
  } else {
    //if not within range, set box volume to 0
    volume[i] = 0;
  }
  //if volume exceeds max volume, set volume to max volume
  if (volume[i] > 1) {
    volume[i] = 1;
  }
  //if volume is under minimum volume, set volume to 0
  if (volume[i] < 0) {
    volume[i] = 0;
  }
}


//Sets the volume of each player (if it is active)
if (enable[0]) {
  mp3Player1.setVolume(volume[0]);
}
if (enable[1]) {
  mp3Player2.setVolume(volume[1]);
}
if (enable[2]) {
  mp3Player3.setVolume(volume[2]);
}
if (enable[3]) {
  mp3Player4.setVolume(volume[3]);
}
if (enable[4]) {
  mp3Player5.setVolume(volume[4]);
}
if (enable[5]) {
  mp3Player6.setVolume(volume[5]);
}
```

```
      if (enable[6]) {
        mp3Player7.setVolume(volume[6]);
      }
      if (enable[7]) {
        mp3Player8.setVolume(volume[7]);
      }
      if (enable[8]) {
        mp3Player9.setVolume(volume[8]);
      }
    }
```

This section of the code initializes each audio zone, sets its balance and the audio track to be played.

```
    if (!playersInitialized) {
      if (enable[0]) {
        Media hit1 = new Media(Paths.get(music[0]).toUri().toString());
        mp3Player1 = new MediaPlayer(hit1);
        mp3Player1.play();
        mp3Player1.setCycleCount(-1);
        mp3Player1.setBalance(-1 * balanceShift);
        mp3Player1.setVolume(volume[0]);
      }
      if (enable[1]) {
        Media hit2 = new Media(Paths.get(music[1]).toUri().toString());
        mp3Player2 = new MediaPlayer(hit2);
        if (isVideo[1]) {
          vid = new MediaView(mp3Player2);
        }
        mp3Player2.play();
        mp3Player2.setCycleCount(-1);
        mp3Player2.setBalance(-1 * balanceShift);
        mp3Player2.setVolume(volume[1]);
      }
      if (enable[2]) {
        Media hit3 = new Media(Paths.get(music[2]).toUri().toString());
        mp3Player3 = new MediaPlayer(hit3);
        mp3Player3.play();
        mp3Player3.setCycleCount(-1);
        mp3Player3.setBalance(-1 * balanceShift);
        mp3Player3.setVolume(volume[2]);

      }
      if (enable[3]) {
        Media hit4 = new Media(Paths.get(music[3]).toUri().toString());
        mp3Player4 = new MediaPlayer(hit4);
        mp3Player4.play();
        mp3Player4.setCycleCount(-1);
        mp3Player4.setVolume(volume[3]);
      }
      if (enable[4]) {
        Media hit5 = new Media(Paths.get(music[4]).toUri().toString());
        mp3Player5 = new MediaPlayer(hit5);
        mp3Player5.play();
        mp3Player5.setCycleCount(-1);
```

```java
        mp3Player5.setBalance(-0.5 * balanceShift);
        mp3Player5.setVolume(volume[4]);

    }
    if (enable[5]) {
        Media hit6 = new Media(Paths.get(music[5]).toUri().toString());
        mp3Player6 = new MediaPlayer(hit6);
        mp3Player6.play();
        mp3Player6.setCycleCount(-1);
        mp3Player6.setBalance(0.5 * balanceShift);
        mp3Player6.setVolume(volume[5]);

    }
    if (enable[6]) {
        Media hit7 = new Media(Paths.get(music[6]).toUri().toString());
        mp3Player7 = new MediaPlayer(hit7);
        mp3Player7.play();
        mp3Player7.setCycleCount(-1);
        mp3Player7.setBalance(balanceShift);
        mp3Player7.setVolume(volume[6]);

    }
    if (enable[7]) {
        Media hit8 = new Media(Paths.get(music[7]).toUri().toString());
        mp3Player8 = new MediaPlayer(hit8);
        mp3Player8.play();
        mp3Player8.setCycleCount(-1);
        mp3Player8.setBalance(balanceShift);
        mp3Player8.setVolume(volume[7]);

    }
    if (enable[8]) {
        Media hit9 = new Media(Paths.get(music[8]).toUri().toString());
        mp3Player9 = new MediaPlayer(hit9);
        mp3Player9.play();
        mp3Player9.setCycleCount(-1);
        mp3Player9.setBalance(balanceShift);
        mp3Player9.setVolume(volume[8]);

    }
    playersInitialized = true;
}
```

This section of the code governs the visible poster.

```xml
<AnchorPane fx:id="prototype" onMouseMoved="#mouseMoveDetected" prefHeight="1080"
prefWidth="1920" GridPane.rowIndex="3">
  <children>
    <ImageView fitHeight="1089.0" fitWidth="1943.0" layoutY="-9.0">
      <image>
        <Image url="@../images/byard.jpg" />
      </image>
    </ImageView>
    <Text fx:id="debugText1" layoutX="210.0" layoutY="81.0" strokeType="OUTSIDE"
strokeWidth="0.0" text="Debug Text, do not Delete" />
```

```
    <Text fx:id="staticMouseLocation" layoutX="49.0" layoutY="81.0" strokeType="OUTSIDE"
strokeWidth="0.0" text="Debug Text, do not Delete" />
    <Text fx:id="debugText2" layoutX="407.0" layoutY="97.0" strokeType="OUTSIDE"
strokeWidth="0.0" text="Debug Text, do not Delete" />
    <Text fx:id="debugText3" layoutX="407.0" layoutY="56.0" strokeType="OUTSIDE"
strokeWidth="0.0" text="Debug Text, do not Delete" />
    <Rectangle fx:id="box1" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="352.0"
layoutX="42.0" layoutY="108.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="360.0" />
    <Rectangle fx:id="box2" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="479.0"
layoutX="42.0" layoutY="467.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="360.0" />
    <Rectangle fx:id="box3" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="70.0"
layoutX="42.0" layoutY="970.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="360.0" />
    <Rectangle fx:id="box4" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="560.0"
layoutX="706.0" layoutY="276.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="556.0" />
    <Rectangle fx:id="box5" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="146.0"
layoutX="702.0" layoutY="842.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="140.0" />
    <Rectangle fx:id="box6" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="304.0"
layoutX="1134.0" layoutY="701.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="283.0" />
    <Rectangle fx:id="box7" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="523.0"
layoutX="1528.0" layoutY="125.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="401.0" />
    <Rectangle fx:id="box8" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="320.0"
layoutX="1528.0" layoutY="648.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="401.0" />
    <Rectangle fx:id="box9" arcHeight="5.0" arcWidth="5.0" fill="#ffa51f" height="62.0"
layoutX="1528.0" layoutY="974.0" opacity="0.25" stroke="BLACK" strokeType="INSIDE"
width="401.0" />
    <MediaView fx:id="vid" fitHeight="500.0" fitWidth="500.0" layoutX="703.0" layoutY="29.0" />
    <Rectangle fx:id="introBox" arcHeight="5.0" arcWidth="5.0" fill="#21adff" height="346.0"
layoutX="489.0" layoutY="355.0" stroke="BLACK" strokeType="INSIDE" width="966.0" />
    <Text fx:id="IntroBoxText" layoutX="558.0" layoutY="450.0" strokeType="OUTSIDE"
strokeWidth="0.0" text="Text" textAlignment="CENTER" wrappingWidth="842.803466796875">
      <font>
        <Font size="30.0" />
      </font></Text>
    <Button fx:id="introButton" layoutX="951.0" layoutY="619.0" mnemonicParsing="false"
onAction="#closeIntro" prefHeight="42.0" prefWidth="57.0" text="OK" />
  </children>
</AnchorPane>
```

The full source code and update instructions can be found at
https://github.com/ptsiegler/NEJA_InteractivePoster

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