Visualizing Telematic Music Performance

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ABSTRACT

Telematic music is defined as music performed live and simultaneously across disparate geographic locations facilitated by bidirectional audio (and sometimes visual) transmission over the internet. There are many challenges to overcome when trying to create music together remotely, including but not limited to coordinating actions and gestural cues. This project explores methods of incorporating visual communication of the musician via a mechatronic display into telematic performance to combat the relevant technical issues with video transmission. The goal of this project is to create a mechatronic display that captures the actions and gestures of a musician, while also communicating the ambiance of the music to an audience.

INTRODUCTION

Visualizing Telematic Music Performance (VTMP) is a Faculty Engineering/Arts Student Team (FEAST) project within the Multidisciplinary Design Program (MDP). This project consists of students within the College of Engineering, Language, Science, and Arts, and the School of Music, Theatre, and Dance. The team has a total of 9 students and 3 faculty advisors. The team had been divided into two groups: Robotics with four members (Katie, Nick, Sasha, and Shawn) and Motion Capture (MOCAP) with five members (Logan, Margaret, Reed, Sam, and Yuki). This report will focus on the work that the Robotics group was able to accomplish over two semesters. At the end of the second semester, there will be a live Workshop performance for an audience. At the Workshop Yuki, a violinist, played with another violinist, Matt Albert, a faculty advisor on this project. Both musicians took turns playing alongside the mechatronics system. In addition, Reed played the vibraphone with Yuki as a duet (Petit duo et Ut pour Violons by Francois Aubert) . A qualitative evaluation will be made of the five live duets with the mechatronics system as well as a duet using an abstract visualization as an aid.

Background

In order to understand the motivations behind this project, it is essential to understand telematic music. Telematic music is defined as music performed live and simultaneously across disparate geographic locations facilitated by bidirectional audio (and sometimes visual) transmission over the internet [1]. However, before the internet, musicians had used the telephone lines to play remotely. Tele-transmissions have been successful since the 1860s and have evolved into the cell phones used today. Telephone communication has been developed primarily for voice transmission, so the transmission of music across telephone lines is subject to compression and equalization that degrades the musical sound quality [2]. In the early 1900s, Thaddeus Cahill invented the Telharmonium, which is the first major electronic music instrument and could connect to telephone receivers. The motivation for this invention was to synthesize music electronically and distribute it through telephone lines so that it could play at people's homes and different venues in New York City. In 1905, the New York Telephone Company agreed to lay telephone lines to transmit the Telharmonium throughout the city. However, by 1908 there were many factors such as technical difficulties and the 1907 recession, that caused the demand for the Telharmonium to decrease and eventually stop [3]. But with the adoption of the internet, musicians can now play over the internet with CD quality audio [2]. To achieve this quality of acoustics, a software called JackTrip can be used which allows for low-latency, uncompressed 16-bit audio streaming at 44.1 kHz sampling rates (and above). JackTrip is a free, open source program that allows musicians to play together in "real-time". With JackTrip, the one-way latency between two geographically separated locations is 25-30 milliseconds or less, which is a low enough latency that won't create any significant synchrony problems [4].

Despite the many challenges associated with the acoustics, one of the main issues to overcome in telematic music performance is the delay in transmission of the video of the musician playing. Encoding, transmissmitting, and decoding a digital video is a time consuming process that is too slow to enable rhythmic coordination [2]. But more importantly, video transmission is unable to properly substitute for the live, 3-dimensional musician. Musicians rely on gestural cues to coordinate actions, and video transmission is not always able to capture those important moments. Another essential aspect is to communicate the "effort" and "tension" of the music and the musician. Tension can be measured by its correlation to the emotional response of the musician, but is very subjective between different people. In a study it was shown that visual information can help both increase or decrease the perceived tension at different points in the music [5]. However, video has limited ability to communicate effort and tension since they can be very subtle movements and indications. Research has proven that 3-dimensional movement is a more engaging and effective method of communication for gestures than video transmission. From the early works of Gibson, he proposed a concept called "schematic perception" which is a perception of the world in useful and meaningful signals versus "literal perception" which relies on what is visible to the user [6]. For example, when flying there is an optic flow that is created when moving through the environment and that flow of motion is determined by how the user decides to perceive the world by enabling and disabling specific elements [7]. This is caused by literal and schematic perception because the user can observe the visible world through literal perception, but create more meaningful information, such as measuring distance, through schematic perception. In 2-dimensional videos, there is a lack of schematic perception because the full 3-dimensional literal perception is missing. In addition, the presence of a 3-dimensional agent can impact the quality of social interactions of the people that engage with the mechatronic by adding a layer of trust compared to a 2-dimensional video [8]. People rely on implicit interactions instead of constant explicit communication, and this leads to an expectation of similar implicit interactions with devices. By creating devices that are able to better socially communicate with people, they become more integrated into day-to-day life [9]. This project explores methods of incorporating visual communication of effort into telematic performance without video transmission, but instead as a mechatronic display in 3-dimensional, physical space.

Motion Capture (MOCAP) Team

Although this report is focused on the goals and accomplishments of the Robotics team, the work done by the MOCAP team in parallel with the Robotics team greatly influenced the direction of this project. The MOCAP team has focused on creating 2-dimensional abstract visuals using the motion captured data. One of the most influential visualizations created was the Bounding Box (Figure 1), which places three data points, height, width, and depth, in space and encloses a box around them [10]. To create the Bounding Box, *modosc*, a set of Max abstractions for computing motion descriptors from raw motion capture data in real time, was used. *Modosc* is a critical analysis tool that helps to structure the data in an accessible and meaningful way [10].

To further this design, a feature was added to rotate the box using the more abstract parameters gathered from the data. This global motion on more general parameters, such as quantity of motion and center of mass, provided data for the rotation of the virtual box to create a cube visualization. One of the final iterations of the Bounding Box used the Upper Body parameters (head, right elbow, right wrist, and left wrist) with the rotation of the box determined by the quantity of motion of the Upper Body. The Bounding Box was surprisingly intuitive and expressive and has influenced the Robotics team to add a similar global "tilt" mechanism on the final design.

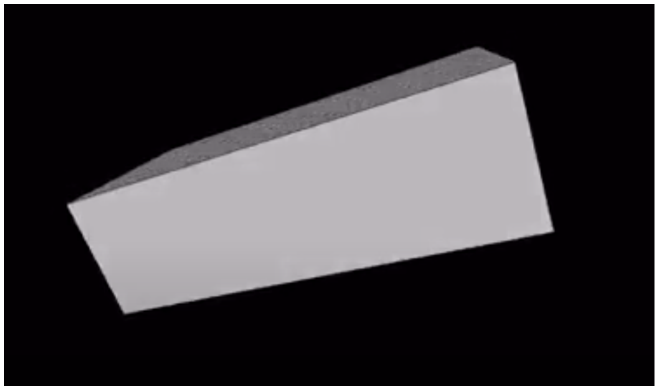


Figure 1. The Bounding Box, a 2D visual created by the MOCAP team to display the motion captured data in a meaningful and expressive way.

Another huge contribution from the MOCAP team has been to collect and filter the motion captured data from the musician's playing. Using Qualisys, a motion capturing system, the team has been able to track specific points on the musician's MOCAP suit (Figure 2) via an array of Miqus cameras located around the Davis Studio. To filter the raw captured data, the MOCAP team uses Max, a software that is able to interpret and analyze the data that will be later sent to the Arduino controller.

Figure 2. Yuki in the mocap suit with data points spread out. The data points are captured by the motion capturing system that is located in the Davis Studio.

Problem Description

The goal of this project is to create a mechatronic display that captures the actions and gestures of a musician, while also communicating the ambiance of the music to an audience. This mechatronic system can be manipulated intentionally and unintentionally by the musician to express cues for important musical moments, such as the start and end of phrases, while playing a duet in real time with a remote player. The objective of this project is not to create a literal robot that captures and re-enacts the direct motions of the remote musician, but rather a kinetic sculpture that is able to transmit important cues and the overall ambiance of the music in a more subtle and expressive way. There are no engineering specifications to this design since it is difficult and subjective to quantify the level of communication for complex concepts such as tension and effort. However, the success of this project can still be measured using the feedback from the Workshop on December 4th.

CONCEPT GENERATION

The typical concept generation process is broken down into four different phases: Brainstorming, Grouping of Diverse Ideas, Initial Selection, and the Final Design. To decide the final design, most projects have a structured method such as a Pugh Chart to filter out the designs to find the best option. However, in this project the concept selection process was more fluid and open to adapting and exploring ideas throughout the process.

Proof of Concept

Before brainstorming, a proof of concept that the motion captured (MOCAP) data was able to be transmitted and control the motor was essential. A simple rapid prototype was created (Figure 3) which was a small fan-like object that was attached to the motor. After the prototype was tested and proved to be controlled by the MOCAP data without significant delay, the brainstorming phase for a more expressive and meaningful design began.

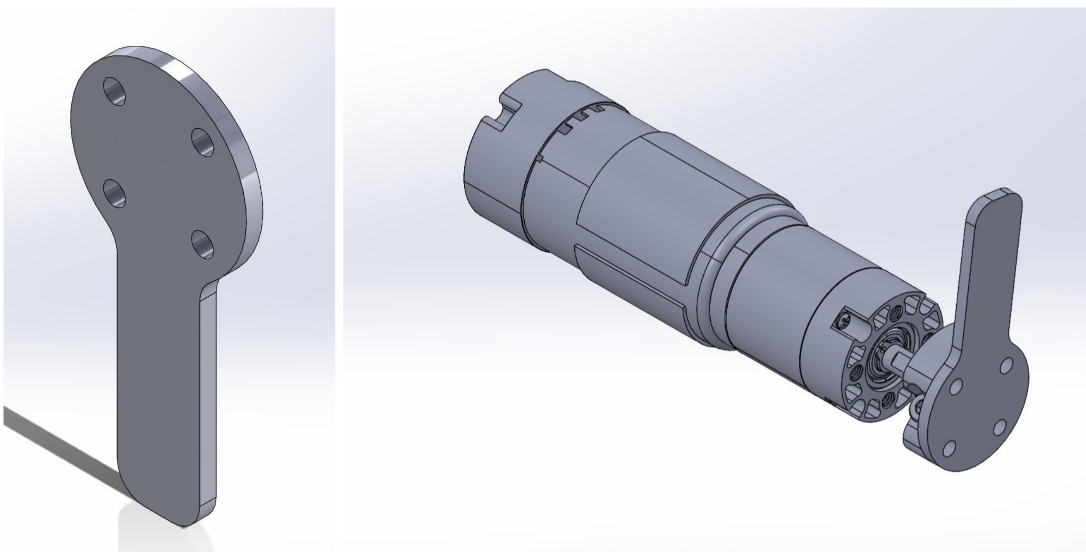
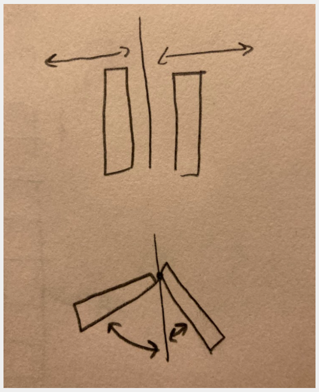
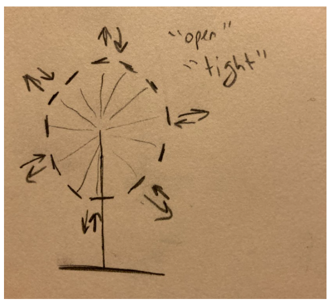
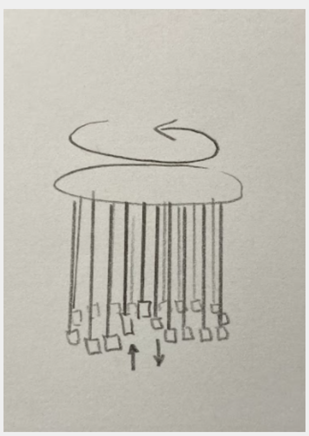
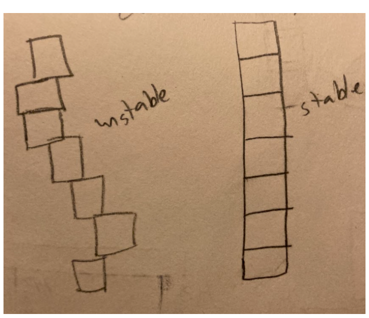


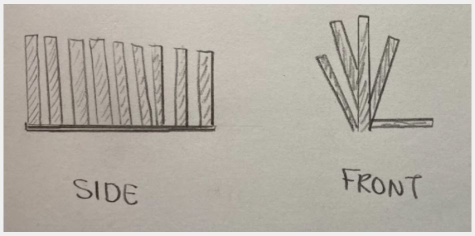
Figure 3. Rapid prototype created for a proof of concept of connecting MOCAP data to a motor

Brainstorming

Brainstorming is an essential step to pushing the innovation process forward. In the brainstorming phase members from back the Robotics and MOCAP team were encouraged to brainstorm as many ideas as possible. The main inspiration was to focus on the typical movements of a musician and to create abstract and artistic designs that represent the motion, these ideas can be seen in Table 1.

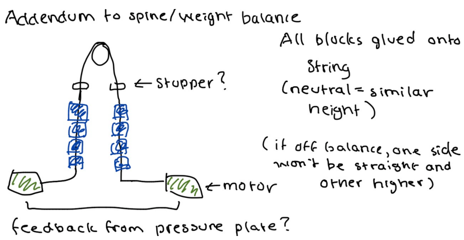
Table 1. Abstract Musician Movements

Picture	Title	Description
	Wingspan	Simple design that could track a musician's arm movement in a representative wingspan
	Body Tension	A device that could compress and expand to help illustrate the body tension of the musician
	Body Tension II Carousel	Inspired by the sketch Body Tension, the Carousel would measure the body tension of the musician but as a continuous flow of data
	Spine	The Spine design has two different states, unstable and stable, and can switch between each state according to the general motion of the musician



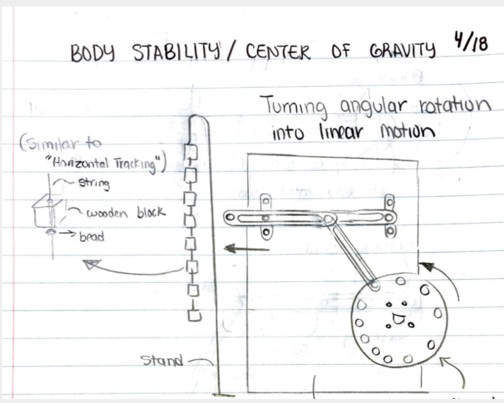
Spine II Horizontal

Similar to the Spine idea, this concept is almost a rotated version of the original idea



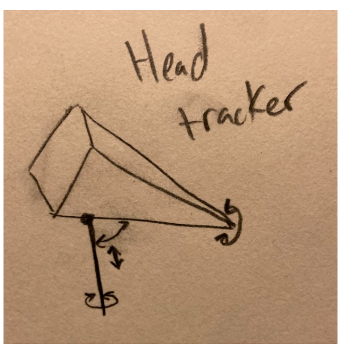
Spine III Two String

Inspired by robotics and the Spine idea there are two states of equilibrium, stable and unstable and a pressure plate would be used for measuring



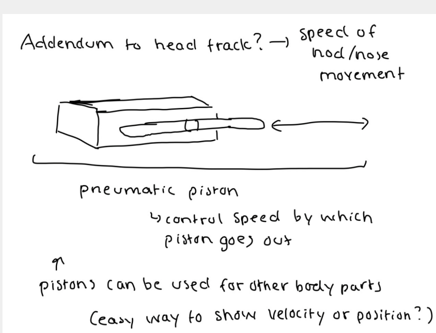
Spine IV Body Stability

Focusing on stability and gravity, this idea is an expansion on the original Spine idea with more details on how it can be pursued



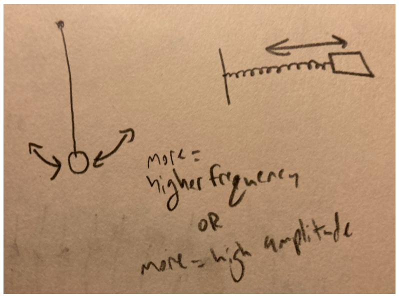
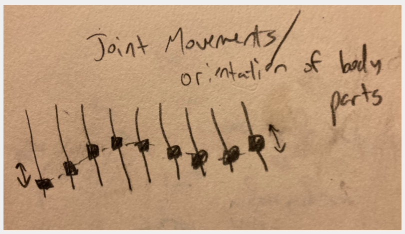
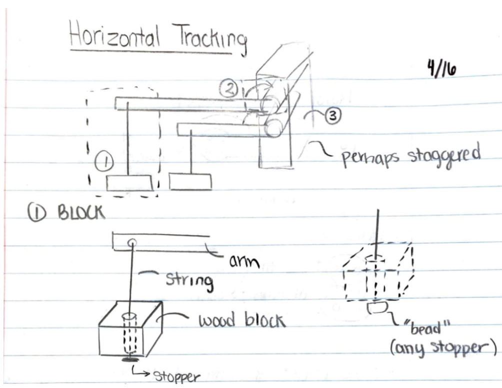
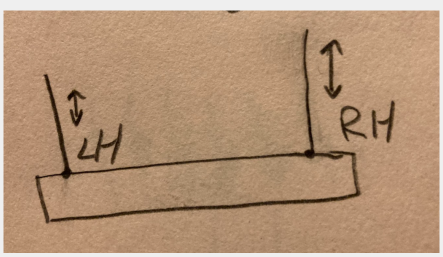
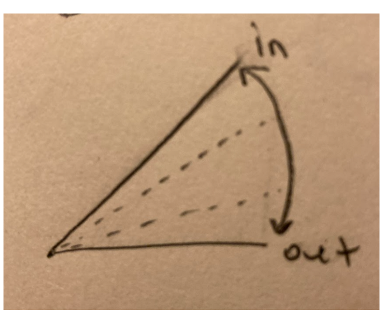
Head Tracker

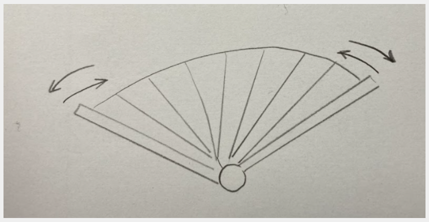
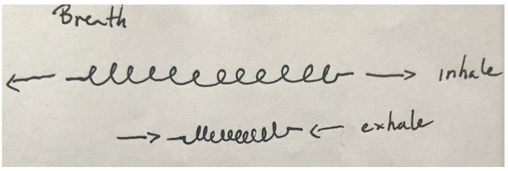
Simple design that tracks the musician's head



Head Tracker II Pneumatic Piston

An expansion on the Head Tracker, this design uses a pneumatic piston

<table>
<tr><td>
</td><td>Overall movement</td><td>In this design, the overall movement of the musician is measured</td></tr>
<tr><td>
</td><td>Joint Movements</td><td>Inspired by the movement of a musician’s hands on the piano or a similar instrument</td></tr>
<tr><td>
</td><td>Joint Movements II
Horizontal Tracker</td><td>An expansion on the joint movement design, but tracking the overall horizontal hand movement</td></tr>
<tr><td>
</td><td>Hand Height</td><td>Simple design that tracks the musicians hand height relative to one another</td></tr>
<tr><td>
</td><td>Breath</td><td>Tracking a musician’s breathing signals</td></tr>
</table>

	Breath II Fan	A different way to represent a musician's breathing signals and patterns
	Breath III Spring	A simple way to represent a musician's breathing motions

Another option is to combine several or all of the abstract musician motion designs and to create one body model (Figure 4) that would represent the remote musician.

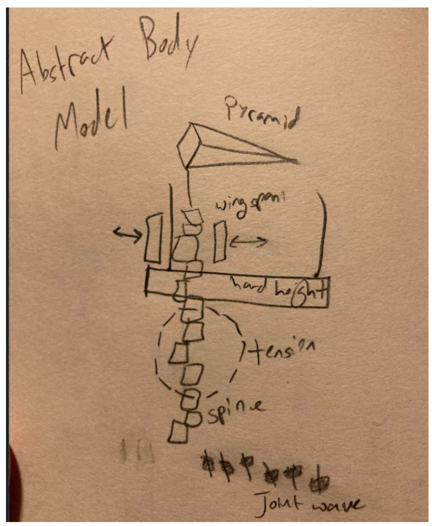


Figure 4. Combination of several designs in Table 1, to create an abstract musician's body

This idea would incorporate the literal and direct motions of the musicians in the individual designs, but it would also show the more overall expressive gestures of the musician by observing the overall display.

Throughout the two semesters there were many discussions on whether or not the mechatronics should be anthropomorphic or not. The argument for a more humanoid robot is that it would ease the learning curve if it was familiar to the musicians. A more human-like robot could just imitate the motions of the other player and communicate the visual cues. However, the downside of an anthropomorphic mechanism is that there are a lot of unnecessary parts. Musicians only look toward their counterparts for a specific signal and anything more would only be more distracting than helpful. Therefore, our team is aware and inspired by how a musician communicates visually, but we do not want to recreate it in our mechatronic.

CONCEPT SELECTION PROCESS

After the ideas were generated, the selection process began with a subjective discussion of which designs would be feasible to create within the semester and useful to the musician and the audience. There were a total of three designs chosen to be prototyped, the first was Hand Height, and then subsequently Spine and Dowel Arm were pursued in parallel. For the first design, the team decided to focus on feasibility and direct usefulness to the musician, which led to the selection of the Hand Height idea.

Hand Height

Hand Height is a simple design that displays the relative height of the musician's hands to one another (Figure 5). In this design, there is only one motor and it was easily made out of wood and acrylic.

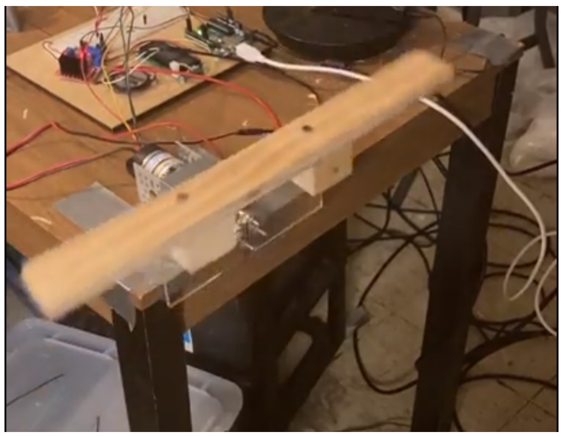


Figure 5. Hand Height measures the relative height of the musician's hands to one another

The design has the mobility to spin in 360°, but additional constraints were added so that the maximum and minimum positions were when the board was perpendicular to the ground (Figure 6). This design was chosen because it was easily produced and was able to be controlled via Arduino.

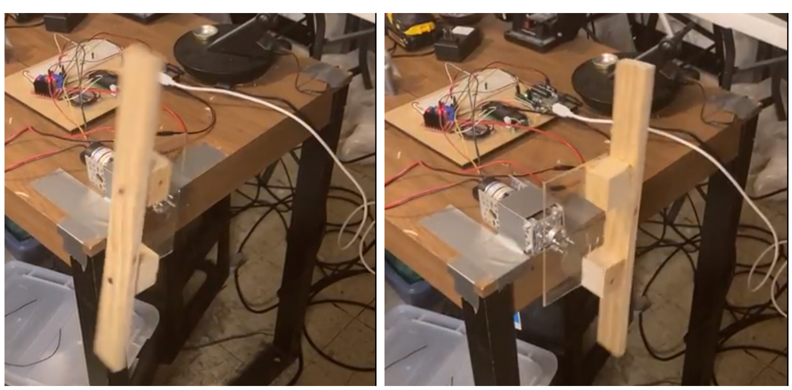


Figure 6. The maximum and minimum positions of Hand Height.

To test this design, our team was able to control the position through Arduino and a Max patch interface and the design was able to respond in real time when we adjusted the position. We also were able to test the data extracted by the MOCAP team for the hand height positions for a piece they had recorded of Reed improvising on the drums. Although this was a success, it was still not the most expressive instrument for communicating important gestures and the overall ambiance. So for the next design, the team wanted to redirect the focus to a less rigid design that would be able to display intentional and unintentional cues that would create a more continuous and natural flow throughout the piece.

Spine

The Spine idea (Figure 7) was one of the brainstormed ideas generated in the concept generation phase. It is meant to capture the musician's overall body stability since musicians often shift their weight while playing and their subtle body language, such as leaning forward, can help communicate important musical moments or just the overall atmosphere of the music. For this design a long piece of brass was used since it would oscillate back and forth when moved to different positions. The added oscillations of the metal stick were more interesting to watch than the Hand Height design, however, there was still opportunity to improve the design and include more information than just one motor could supply.

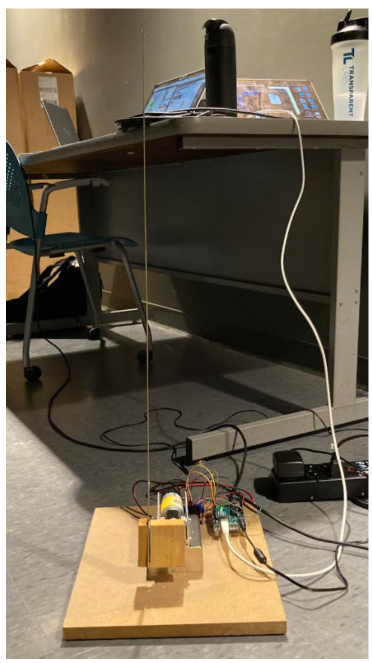


Figure 7. The Spine design created with a piece of aluminum that is able to oscillate back and forth

Similar to the Hand Height design, the Spine idea could be controlled in real time through Arduino and a MAX patch interface. To further test the connection between the MOCAP data and the Robotics system, data from the MOCAP's Bounding Box was fed into the Arduino and the movements of the Spine design were observed. There were three trials taken, the first was with data of the height of the Bounding Box, the second was the right elbow (bow arm) y-position,and the third video was with data of the width of the Bounding Box. The first two videos were with the duet of Histoire du Tango: Café 1930 by Astor Piazzolla and the last video was the Petit duo en Ut pour Violins by François Aubert. The test of connecting the MOCAP data to the Spine design was successful in displaying audio and physical movement. The next important step is to prove that live music would be able to be transmitted through the MOCAP Max patches and then control the motor without a significant lag in the data.

Dowel Arm

The Dowel Arm idea was not a part of the original brainstorming but it was similarly inspired by the body movements of the musicians. In the beginning of the project the musicians playing the duet had not been determined, but by the end of the first semester it was decided that Yuki was to play the violin and have her motion captured while Professor Albert played the violin with the mechatronic display as an aid. The Dowel Arm idea represents the bow arm of the violinist since it will be one of the most expressive movements. This idea was first pursued by one of the Robotics team members, Nick, as part of his summer project. In Figure 8, the dowel arms can be seen disconnected and then also connected. The two dowel sticks represent the upper and lower arms of the musician's arm that is holding the bow and the joint between the dowel sticks can be thought of as the elbow.

Figure 8. The dowel arms as two separate pieces (left). The dowel arms connected in the middle to represent the elbow of the musician (right).

To adapt the Dowel Arm idea to an easier, transportal model that the rest of the Robotics team could work on, a frame was created so that the Dowel Arm could be set up at the Workshop in the Davis Studio (Figure 9).

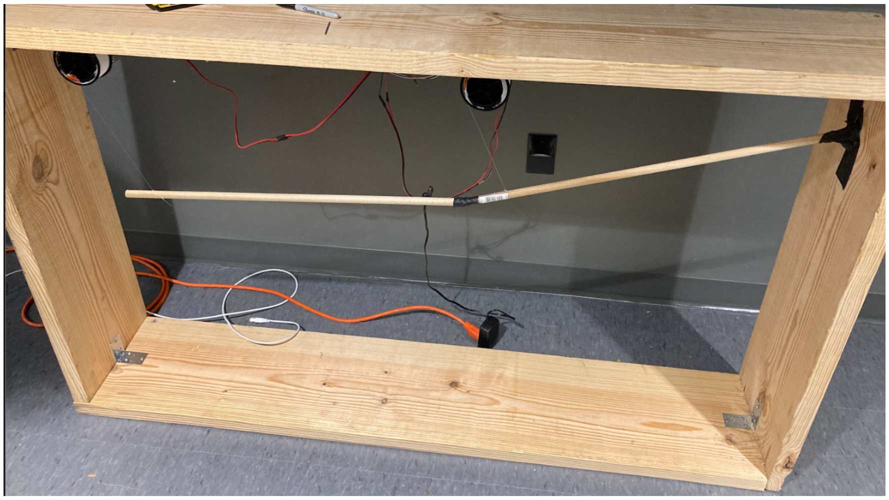


Figure 9. A smaller and more accessible Dowel Arm. The joint connecting the two dowel sticks is to be a hinge and the joint at the right is to be a ball joint.

Fishing line wire is connected to the motor and dowel sticks so that the sticks can move upward and downward in the vertical direction. This design incorporates two motors. Motor 1 will be on the far left and will only move the dowel attached, while Motor 2 will be able to influence both dowel sticks and is attached at the connecting joint. In relation to the MOCAP data collected, motor one could transmit the direct data of the wrist motion and motor two could transmit the motion of the elbow since that is where the motors are connected onto the dowel sticks. An alternative method could be to transmit some of the MOCAP data of the Bounding Box that the team had been working on so that it is a less direct relation and also ties in their progress into the Robotics team's progress.

Originally, a hinge joint was to be added at the connection point of both dowel sticks in representation of the elbow joint and a ball joint would be added to attach the dowel stick rigidly to the frame but still allow rotational motion similar to a person's shoulder joint. However, the Dowel Arm idea had a few major flaws that slowed down the development of the design. The biggest problem was the Arduino code was not working properly and the two motors would not respond, so we were not able to run any tests using MOCAP data. The second issue was that the current design was only 2-Dimensional motion and the purpose of the mechatronics display was to add 3-Dimensional motion. However, the frame was very large and bulky, so it created a lot of weight and was difficult to add additional overall motion to the entire system. Taking into account both of these issues, the Dowel Arm idea evolved into the Box on a Stick, which is our final design.

FINAL DESIGN: BOX ON A STICK

The final design is called Box on a Stick and it is an adaptation of the Dowel Arm idea into a more simplistic model that won't require the large and heavy frame and would include 3-Dimensional movement. Another major change from the Dowel Arm is the transition from GoBilda motors to Dynamixel motors which are much smaller and easier to control in Arduino.

First Iteration

Our team transitioned from GoBilda motors to Dynamixel motors, which are commonly used for robotic arms and other mechanisms. Dynamixel motors are significantly smaller and are easily controlled in Arduino since they have their own library. Transitioning to Dynamixel motors would help resolve any of the previous problems with connecting and controlling two motors. Another huge difference between the Dowel Arm and Box on a Stick was the addition of a third motor. The third motor would help include the 3-Dimensional movement that the Dowel Arm lacked. The first sketch of the Box on a Stick can be seen in Figure 10.

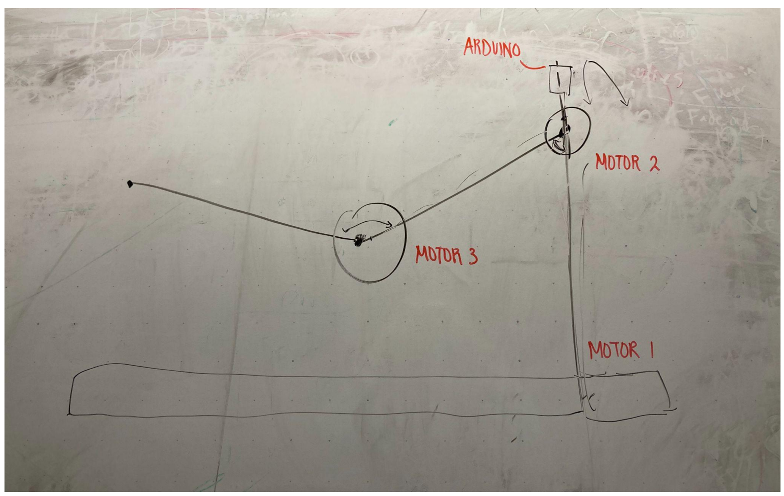


Figure 10. Initial sketch of the Box on a Stick model while keeping most of the features of the Dowel Arm idea.

In the Box on a Stick, there are three motors. Motor 1 is at the base of the stand and it rotates the entire system so it would move in and out of the page, which creates a 3-Dimensional motion. The second motor is at the top of the stand and it connects to the upper arm dowel stick. Similar to the Dowel Arm mechanism, Motor 2 would be able to move the entire arm subsystem including motor 3. Motor 3 attaches at the joint between the two dowel sticks and it only controls the lower arm dowel stick. In this mechanism Motor 2 would need to be stronger than Motor 3 since it would have to support the weight of motor 3 and the dowel sticks. However, motor 1 would have to be even stronger than Motor 2 since it would be moving the entire stand, motors, and arm subsystem.

Second Iteration

To avoid the potential problems of supporting the weight of Motor 3, Motor 3 was moved to the stand and a four bar linkage was used instead (Figure 11, left). This linkage design is typically used in robotics and it helps to decrease the weight that the motor needs to support by lining up the motors onto the same axial, in Figure 11 (right), a side video of the motors can be seen. An additional perk of this design is that it forms a box that appears to change shape as the linkages move, which creates an interesting feature that does not have a direct correlation to the music, but helps with the overall feel of the music.

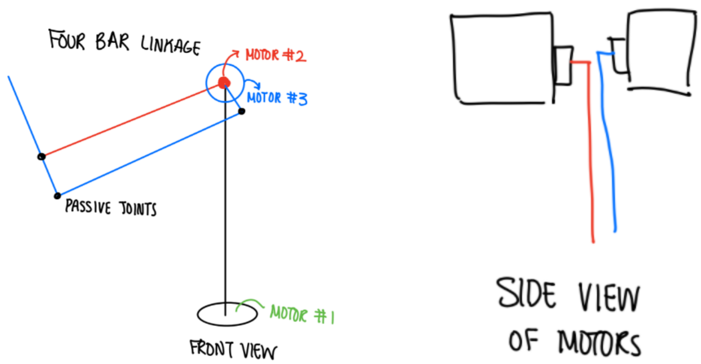


Figure 11. The left image shows a sketch of the new design with a four bar linkage. The right image is a close up image of the side view of the motors.

Final Iteration

To decrease the torque required by Motor 1, the motor was moved to the top of the base structure, so that it is much closer to Motor 2 and 3. The final mechatronics system can be seen in Figure 12.

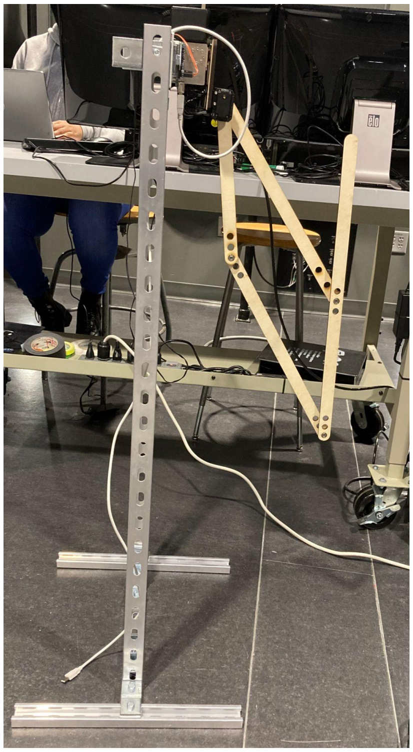


Figure 12. Final iteration of the Box on a Stick. The arm subsystem is connected to the motor mount which is at the top of the base structure.

The lower and upper arm links will be laser cut out of ⅛ inch plywood and the small motor mount will be laser cut from ¼ inch plywood. The large motor side mount and large motor/arduino mount will both be laser cut out of ⅛ inch aluminum since it will be attached to the base and needs to support the entire arm system. The links were connected with bearings. All joints between the links except for where they attach to the motors are passive.

The base was constructed using aluminum struts and bolts. In Figure 13 a picture of the base can be seen with the motor mount and arm subsystem attached.

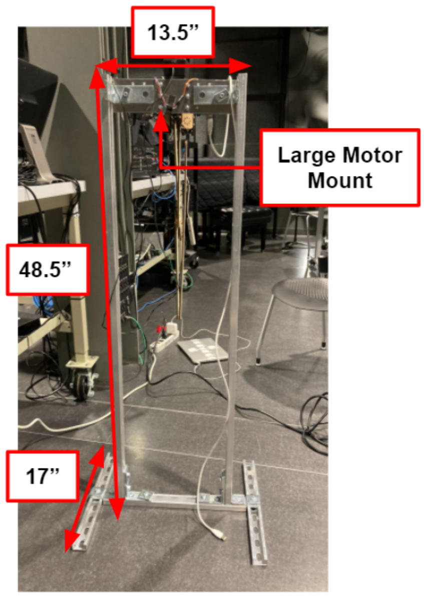


Figure 13. Base made out of aluminum strut and connected with ⅜ inch bolts. The large motor mount connects the Arduino controllers and the arm subsystem to the base.

During testing, it was noticed that the base was not completely stable and would vibrate as the arm subsystem moved. For the final performance large sandbags will be added to the feet of the base to prevent it from falling over and eliminate some of the shaking. However, if there is still some vibration, it is acceptable, if not encouraged because it adds some additional interesting movement.

In Figure 14, a side view of the arm system shows how the large motor/arduino mount attaches to the base.

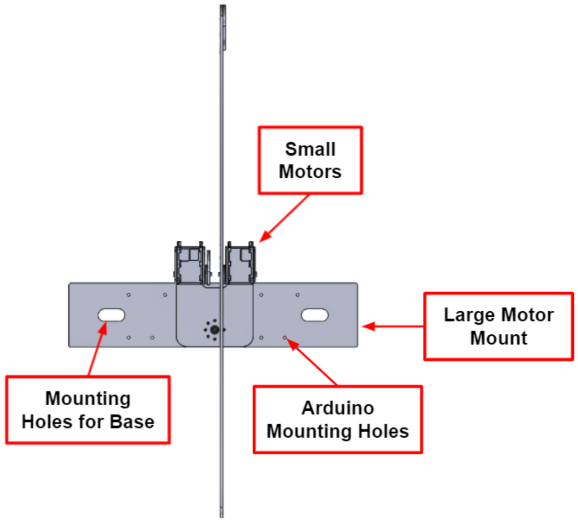


Figure 14. Side view of the arm system. The large motor/arduino mount connects the arm system to the base via the slotted mounting holes. The large motor/arduino mount also supports the arduino and other controller components.

Another major change for the final iteration was to move the links above the mounting system to avoid any interface with the base structure. The small motor mount that connects the small motors (Motor 2 and 3) to the large motor (motor 1) was rotated upwards so the links are now above the motor mounting system.This changed which links are affected by which motors, and a CAD rendering of the arm links and motors of the arm system can be seen in Figure 15.

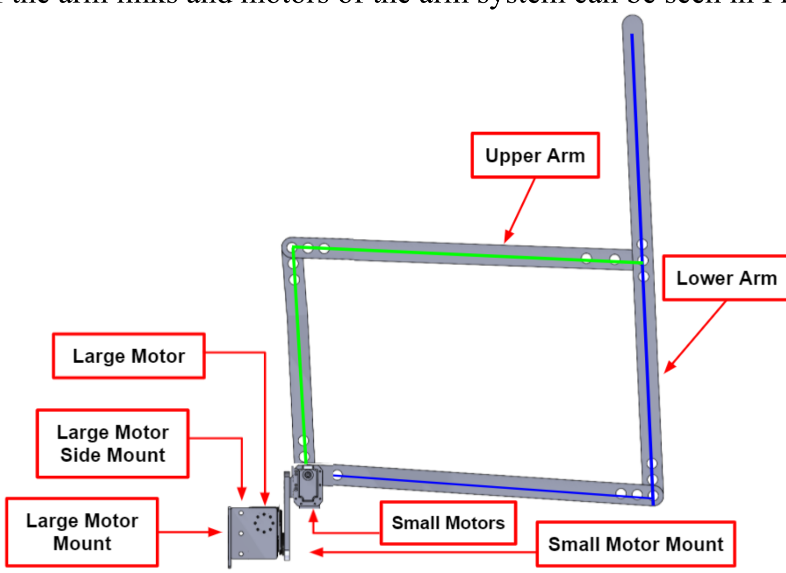


Figure 15. Front view of the arm system. The blue line represents the lower arm and the green line represents the upper arm. The large motor/arduino mount is attached to the base, which is not pictured.

For this new system, Figure 16 shows a breakdown of how each of the three motors move the arm subsystem.

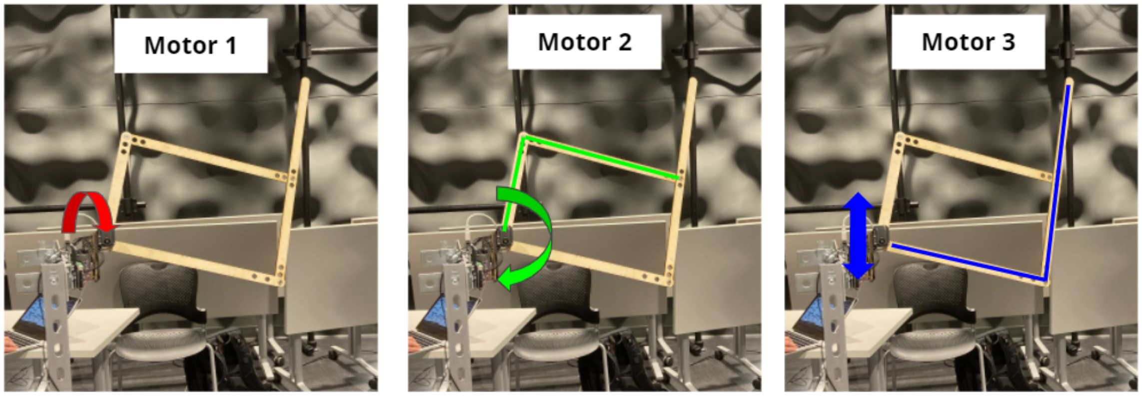


Figure 16. Motor 1 rotates the mechanism in and out of the plane, Motor 2 extends the mechanism to the right, and Motor 3 moves the mechanism vertically and extends to the right.

Motor 1 is controlled by the relative motion of the musician moving in the z-direction. The neutral position is in the middle and Motor 1 is able to rotate forward and backward depending on the musician's movements. Motor 2 and 3 can be controlled by different variables collected by the MOCAP team. For example, for one iteration, Motor 2 was controlled by the inverse width of the Bounding Box and Motor 3 was controlled by the Bounding Box height. This was an interesting combination, and the mechatronic system moved in an intuitive way, but was not a direct relation of the musician's arm. The mechatronic system is not an extension of the musician in a direct way but it can be thought of as a dancer that is able to move with the music in a meaningful way.

RESULTS

A live Workshop was conducted on December 4th and there were five small performances. For the first performance, Yuki, a violinist, played a duet (Petit duo et Ut pour Violons by Francois Aubert) with Reed who was playing the vibraphone. Yuki's motions were tracked and Reed played alongside the mechatronic. For the second performance, Yuki and another violinist, Professor Albert, played the first movement of Sonata for Two Violins, Op 56 by Sergei Prokofiev. In the second performance, Professor Albert played alongside the mechatronic and in the next performance, the same duet was played, but this time Yuki played with the mechatronic. Before the fourth performance, the musicians showed how they can cue each other using the mechatronic in an interactive demonstration with the audience. The fourth performance, Yuki and Professor Albert played the second movement of the Sonata for Two Violins, with Professor Albert's movements captured. For the last performance, the same duet was played but Yuki played with the Bounding Box visualization instead of the mechatronics.

During the Workshop, an optional qualitative survey with three questions was provided. The three questions asked were the following: 1) Considering the entire Workshop, what did you observe that seemed particularly effective? 2) Again considering the entire Workshop, what did you observe that suggested opportunities for greater exploration? and 3)Was there anything particularly surprising about the presentation, in ways that either exceeded or fell short of your expectations? The audience attending the live performance were the team and faculty members involved in the project and anyone invited to participate, ranging from friends and family to peers. There were nearly 20 non-team members in attendance, however there were only three submissions to the survey. Although there were not very many responses to the survey there were a lot of questions and discussions between performances. During these questions and discussion, our team was able to clarify the mechatronics correlation to the musician, the design intent of a non-humanistic robot, and how the motion captured data is collected and transmitted.

From the survey, the first question asked the audience what they found particularly effective from the entire Workshop. One of the responses was that they enjoyed the ease of going back and forth between the two rooms, of the performer with and without the mechatronic system, since it helped them understand the mechanism. They also found the demonstration of cues and the explanation of the Bounding Box to be very clarifying and helpful to understand the mechanism's non linear correlation to the musician. The second question from the survey asked for suggested opportunities for further exploration. One suggestion was to see the direct relation between the mocap performer and robot for at least the demonstration of cues to better understand how the mechanism responds to the musician. Another suggestion was to explore measuring the player's breaths since they were able to hear the musician's breaths before they would begin. Lastly, the third question asked if there was anything particularly surprising about the performance, either good or bad. One of the responses commented on how there was minimal latency to the visualization and robot responses. Also they were surprised by how fine tuned the motion captured could become and are intrigued at the approach to visualizing instruments that have minimal noticeable movement, such as a guitar. Another person noted that they were slightly distracted by the mechatronic's instability and rocking during stronger motions. Although there were not many formal responses to the survey, the answers provided are still helpful and valued by the team. In addition, the questions during the performance helped to foster discussions of design choices and intent behind the iteration of the mechatronic and the possibilities of what the team will explore next semester.

DISCUSSION

The focus of the live Workshop was to help receive feedback and general impressions of the work done so far. This was not a formal performance and the qualitative survey conducted was not mandatory for the audience. A more quantitative survey such as a likert scale was not used because it is too early in the development process of this project and there was not enough time to create a comprehensive survey that would accurately test the results. This is a goal for next semester, and I recommend that there are two separate tests conducted. For both tests there should be at least four groups, a control group of a face-to-face duet, a video transmission, a recording of the mechatronics system, and an in person performance with the mechatronics system. For the first test, there could be an audio recording of each of the four groups and a person would be asked to listen to each group randomly and fill out several questions about the overall quality of the duet compared to the other recordings. Another test that would be helpful is to listen and attend to a live performance of the four groups. This would take away from the randomness and initial biases, but it would also be more interactive to be at a live performance than to only be listening to an audio recording.

CONCLUSION

Telematic music is music performed live and simultaneously across disparate geographic locations through bidirectional audio (and sometimes visual) transmissions over the internet. Telematic music has been a field that has been explored for many years, but with the pandemic it has become an emerging necessity as we have adjusted to the new norm of limited in person events and social distancing. However, there are many difficulties associated with telematic music, especially with visual communication. Visual communication is essential to musicians playing together and video transmission has limited ability to properly communicate all cues and subtle information. The goal of this project is to create a 3-dimensional mechatronic display that captures the actions and gestures of a musician, while also communicating the ambiance of the music to an audience. This mechatronic system can be manipulated intentionally and unintentionally by the musician to express cues for important musical moments, such as the start and end of phrases, while playing a duet in real time with a remote player. The objective of this project is not to create a literal robot that captures and re-enacts the direct motions of the remote musician, but rather a kinetic sculpture that is able to transmit important cues and the overall effect of the music in a more subtle and expressive way.

Through brainstorming and rapid prototyping the development of the final model for the Workshop was developed. However, this project is an on-going project that has just begun. Box on a Stick is far from the final design, but it is a step in the right direction. There are some improvements that could be made to the mechatronic physical system, such as lessening the rattling of the base and the linkages. The oscillations of the linkages added some interesting unintentional motion, but at times it was noted to be distracting, so there is still a balance to be found between keeping and eliminating such motion. There is also some further exploration of what data should be transmitted through the device. For example, our team had tested direct and non direct MOCAP data, and one big difference between the direct raw MOCAP and the non direct Bounding Box data was that the Bounding Box data was more meaningful. There was almost too much information with the raw data because it was able to capture all movements of the musician even if it was not useful for the other musician. In addition, comparing the Bounding Box and the mechatronic showed that the Bounding Box was able to communicate the small movements of the musician with more precision and ease than the mechatronic. This suggests that there needs to be an additional component to the mechatronic that captures and displays these small movements. However, overall, the presence and movements of the mechatronic system was still more powerful and interactive than just watching the 2-dimensional visualization.

For next steps, the team will continue to iterate upon this current design but the ultimate goal is to explore different ways to represent the data besides a box-like shape. At the Workshop there was a discussion of whether or not to create an anthropomorphic robot, but currently the team will continue to create a non-humanistic mechatronic system since musicians only need certain signals or gestures to communicate. Another immediate goal for the team will be to investigate other measurements of data from the musician. In this project the main focus was motion captured data via markers on the musicians, but next semester’s focus will shift to using other forms of measurements such as pressure plates and sensors. This will open doors to exploring the musicians' breathing, eye contact, and weight shifting. Eye contact is a very universal and important cue musician’s use to communicate acknowledgement of one another. From a conversation at the Workshop, a longer term goal for the project could be to create a responsive mechatronic system that is able to interact with both musicians to represent when both musician’s are acknowledging the robot and each other. Another long term goal of this project will be to create a more universal mechatronic system that will be able to be used for any instrument.

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