AirFlute: A Virtual Flute and Tutoring System

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ABSTRACT

The AirFlute is an interactive and less-expensive alternative to traditional music lessons. AirFlute uses the Leap Motion Controller within a web browser to track how a student moves their fingers in 3-dimensional physical space. Each movement of the student (e.g., moving or bending a finger) is visualized on the virtual flute display within a web browser and the corresponding note is played through the computer's speaker. By expressing a correct fingering, a student can simulate playing a note on the flute without a physical instrument. AirFlute has three main features: 1) a place for users to free play music, 2) a tutorial for users to learn note fingerings, and 3) a capability for users to practice exercises and receive feedback. This brief abstract summarizes the motivation and implementation of AirFlute as a research application in human-computer interaction. AirFlute has the potential to broaden participation in music performance for students who may not be able to afford a physical instrument.

CCS CONCEPTS

• **Human-centered computing** → *Sound-based input / output*; **Web-based interaction**.

KEYWORDS

3D Motion, Virtual Instruction, Computer Music

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1 INTRODUCTION

Music education has many benefits, from improved test scores [4] to improved social behavior [2]. However, funding for music education continues to be cut in many K-12 schools. This makes it difficult to provide each student with an expensive personal instrument. Also, individual music lessons provide valuable personalized feedback to students, but private lessons are not affordable for every student. Students living in rural areas may not live near music instructors. Furthermore, in a pandemic, it may not be safe for all students to attend physical lessons. Wind instruments cannot be played with a mask on, and cannot be shared, which would increase the risk of spreading germs.

AirFlute addresses the various challenges of student access to music education. Instead of a physical instrument and in-person lesson, students just need a computer and a Leap Motion Controller [1]. AirFlute provides a less expensive and more accessible alternative to music lessons, allowing more students to benefit from music education.

The features of AirFlute include free play, note-learning, and exercises with feedback suggestions. In free play, students can practice the flute with whatever music they like without needing a physical instrument. With the note-learning feature, students click to generate a random note and attempt to play it. If they are incorrect, AirFlute provides them with the correct fingerings for a future retry. After students understand individual notes, they can move to the exercises. This feature allows students to choose from several exercises with varying rhythms, time signatures, key signatures, and notes. They can listen to examples, change the tempo faster or slower, perform the exercise, receive feedback on notes missed and overall accuracy, and listen to their recording.

The implementation section of this paper discusses strategies and technology used to develop AirFlute. The demonstration section demonstrates the three main features of AirFlute. Section 4 recognizes current AirFlute limitations and lessons learned in the development of AirFlute. The related works section introduces similar projects, and the final section discusses future work and concludes the paper.

2 IMPLEMENTATION

The most important component of AirFlute is the Leap Motion Controller, a small device that reads 3-dimensional hand motions in physical space and provides an API for application development. User movement can be recorded as input from the Leap Motion Controller and processed using JavaScript as a series of frames or captures of hand positioning data. AirFlute demonstrates an application of human-computer interaction by displaying the Leap Motion feedback within an HTML web browser that shows the fingerings and plays the notes. For the fingerings, the thumb plays the 1 key, the index finger on 2, middle finger on 3, ring finger on 4, and pinkie on 5. The flute display, the white diagram shown in Figure 1, shows which keys have been pressed with red numbers and is consistent across all features. A key is considered pressed when the angle between the finger and palm is within the correct range. With the correct combination of fingerings, AirFlute activates the Web Audio API to produce the correct frequency for the fingered note.

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3 DEMONSTRATION

The AirFlute has three main features: free play, learning notes, and exercises. By experimenting with all three features, students may gain an understanding of basic flute fingerings and how to read music. (Code is provided at https://bit.ly/air-flute-code).

3.1 Free Play

The Free Play section allows users to experiment with playing a virtual instrument without any music or evaluation. This feature works well for students who want to practice music in a space where playing a physical instrument would not be ideal. The display for Free Play includes the fingering diagram and a button that says "Click Me To Start."

Students click the button to begin the flute audio. As students bend their fingers, the numbers on the corresponding keys turn red. Otherwise, no numbers are visible. When students perform a specific fingering in Free Play, the correct frequency is played on the speaker.

3.2 Learning Notes

The learning notes feature teaches students fingerings for individual notes. This is a fundamental skill that must be learned before musical passages can be performed.

A "New Note" button generates a random note for students to attempt to play, and their fingerings are shown in the flute display. When they perform the correct fingering with 50 percent accuracy on 200 frames of Leap captured data, the program displays a message about the correctness of the fingering at the bottom of the screen with the name of the test note.

The AirFlute displays a different message when the student performs incorrect fingerings for the test note. By default, an incorrect note is recorded when the student demonstrates less than 50 percent accuracy on 500 Leap frames. The correct fingering is displayed in blue on the flute graphic so that students can learn for the next time they see the same note. The name of the correct note is displayed in a message at the bottom of the screen.

3.3 Exercises

The exercises feature of AirFlute is the final step for learners (Exercises video demo at https://bit.ly/air-flute-video). In this feature, students can practice performing excerpts of varying time signatures, key signatures, and rhythms. The Exercises display is shown in Figure 1.

The metronome button in the top-left starts the metronome audio. This provides an audible indication of when students should move to the next beat. This can also be seen in the number under the sliding bar, indicating which count the student should be playing. The sliding bar allows students to adjust practice speeds as needed. They can start at the left with a slower tempo and slide the bar right as they improve through practice. The drop-down menu allows users to select which exercise they want to practice. The Listen button allows students to hear what their performance should sound like. Then, they can click the Record button to tell AirFlute to assess their attempt.

After the student has finished recording the exercise, he or she can click the results button to see the score, showing which notes were missed and what the fingering should have been. Then, the overall percentage correct is displayed to the left of the fingering graphic. Students can click the Play Results button to hear a recording of their attempt. Then, they can click the Reset button to try the exercise again.

4 LIMITATIONS AND LESSONS LEARNED

One limitation of AirFlute is that it does not teach the breathing component of playing the flute. While the program does provide a supportive introduction to fingerings and reading music, students would still need to learn how to breathe and use air with a physical instrument.

Another limitation of AirFlute is that it cannot play every note that is in the range of a flute. On a physical flute, the flautist usually keeps his or her fingers only on the main keys. However, for the lowest and highest notes in the flute range, players must move their fingers off of these main keys. The AirFlute assumes that the student has not moved his or her fingers, limiting the student from playing these notes. However, because the purpose of AirFlute is to teach basic flute fingerings and basic music skills, students will not need to play these notes as early learners, and it is acceptable to leave them out for simplicity.

Another important difference between playing a physical flute and AirFlute is the hand positioning. With a physical flute, musicians hold the instrument with their left palm facing towards the body and the right palm facing away from the body. However, the Leap Motion Controller requires users to have both palms facing away from their body. While using AirFlute, users need to rotate their left hand away from the body.

Furthermore, the accuracy of AirFlute relies on the accuracy of the Leap Motion Controller. If the device cannot properly read the student's hands, the student will not be able to play the flute or receive accurate score results.

The most important lesson learned was how to combine JavaScript, HTML, input from the Leap Motion Controller, and the Web Audio API to create a virtual input. All of these components within AirFlute allow users to move their hands to play music within a web browser.

5 RELATED WORK

There are several earlier research projects that teach music using interactive technology. For instance, the Wiiolin [5] uses a Wii remote and sensor bar to mimic a violin or cello. By pressing different buttons on the Wii remote, users mimic pressing different strings on a string instrument. The sensor bar represents the bow. As one moves the bow back and forth, sound is produced from external computer speakers. Both the AirFlute and Wiiolin provide an introduction to music using a virtual instrument that reads user movement. However, the Wiiolin requires physical equipment to play while AirFlute is hands-free. Another similar virtual instrument to AirFlute is Smule's Ocarina [7]. With the Ocarina app for the iPhone, users cover the finger holes on the touch display and blow into a microphone to play notes. This app also allows users to listen to other people as they play the Ocarina and share music that they have written. AirFlute and Smule's Ocarina include instruction for fingerings and musical excerpts. An important difference is the

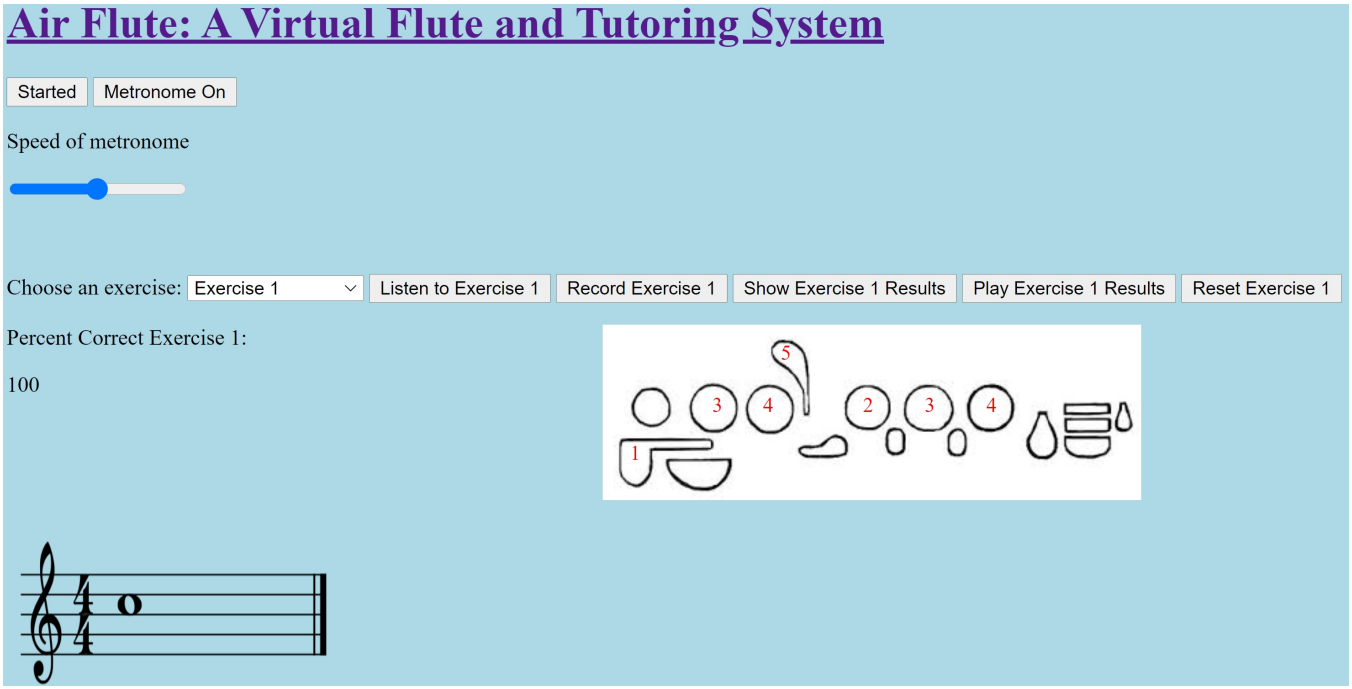

Figure 1: AirFlute Exercises Display

microphone input with the Ocarina app. This adds the breathing element of playing a physical wind instrument that AirFlute lacks.

Several other projects have used the Leap Motion Controller for music education. For example, Silva created the Crystal Piano [6] using input from the Leap Motion Controller. A glass table with marks resembling piano keys can be placed above the Controller's field of view. By pressing the different keys of the table, students can play one octave of a keyboard. The AirFlute and Crystal Piano both provide interactive computer music through the Leap Motion Controller. The Crystal Piano, however, provides tactile feedback while AirFlute does not need any equipment other than the computer and Leap Motion Controller. The iMuSciCA workbench [3] uses a Kinect sensor or Leap Motion Controller to allow students to play the bichord, xylophone, drum set, guitar, and upright bass. Hand motions are visualized on a three-dimensional display showing the interaction with the instrument. This three-dimensional display is more advanced than the AirFlute display and helps demonstrate hand positioning with the real instrument. While the flute is different from the instruments included in the iMuSciCA workbench, AirFlute and the iMuSciCA workbench both provide an interactive musical experience using gesture-based virtual instruments.

6 FUTURE WORK AND CONCLUSION

For future work, more examples will be added to the exercise feature to help students learn additional key signatures, rhythms, and time signatures. It would also be helpful to add features that teach basic music theory and that introduce breathing and playing techniques for the physical flute.

Another future development will expand the types of instruments that users can play. Other types of flutes, such as piccolo, alto flute, or contrabass flute, are not widely available and often cost much more than a traditional flute. Creating virtual instruments for these flutes would allow more students to play music written for these less-accessible instruments.

As access to music education continues to decrease, AirFlute offers a solution to teach more students about music. Students do not need to purchase an expensive musical instrument or attend in-person lessons with this program. Instead, using only a Leap Motion Controller and a computer, students can begin learning basic music concepts like reading notes, time signatures, key signatures, and rhythms at their own pace. AirFlute also addresses the challenge of equity for students who are in schools with reduced resource budgets.

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