An Augmented Flute for Beginners

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ABSTRACT

Learning to play the transverse flute is not an easy task, at least not for everyone. Since the flute does not have a reed to resonate, the player must provide a steady, focused stream of air that will cause the flute to resonate and thereby produce sound. In order to achieve this, the player has to be aware of the embouchure position to generate an adequate air jet. For a beginner, this can be a difficult task due to the lack of visual cues or indicators of the air jet and lip position. This paper attempts to address this problem by presenting an augmented flute that makes the parameters of the embouchure visible and measurable. The augmented flute shows information about the area covered by the lower lip, estimates the lip hole shape based on noise analysis, and shows the air jet direction. Additionally, the augmented flute provides directional and continuous feedback in real time, based on data acquired from experienced flutists. In a small experiment with five novices, most participants could produce a sound with only minimal instructions.

Author Keywords

Flute, Learning, Augmented Instruments.

ACM Classification

H.5.2 [Information Interfaces and Presentation] User Interfaces — Training, help, and documentation, H.5.5 [Information Interfaces and Presentation] Sound and Music Computing

1. INTRODUCTION

Learning to play an instrument is typically difficult, but while for some, producing the sound is as easy as hitting a key and, therefore, the student can quickly focus on playing songs, other instruments require decent effort to even produce the sound. The transverse flute requires a steady focused stream of air to produce sound, and "is the easiest instrument to play badly" [4]. The simplest sound of the flute is already influenced by a series of parameters: the angles at which the flute is held, the angle at which the air is blown into and over the embouchure, the width of the air jet, and the air jet speed. Some of these factors can be self-observed while playing in front of a mirror, but mostly, corrections require an experienced teacher. As a teacher is not always present during practice, this can easily lead to frustration. In this paper, we present an augmented flute headjoint (Figure 1) that, using various sensors, localizes the problem in generating the proper sound and gives feedback on how to solve the issue. The goal is to support novice users during unsupervised practice by helping them to produce a sound. We iteratively designed our augmented flute following recommendations from experienced flutists and successfully tested it with novices which were able to produce a sound after a short time.

NIME'17, May 15-19, 2017, Aalborg University Copenhagen, Denmark.

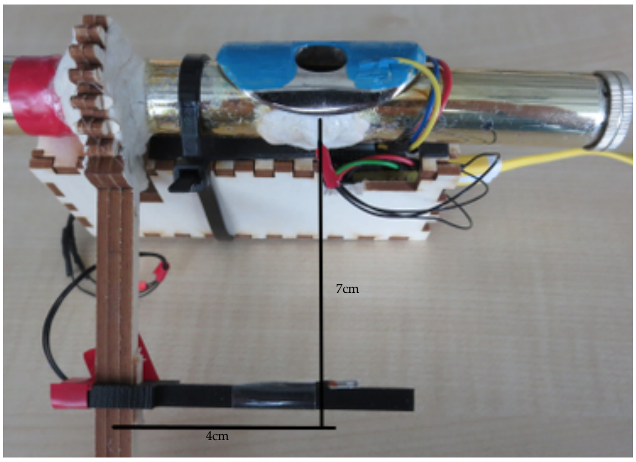

Figure 1: The sensor box attached to the head of a flute. The capacitive sensors for lip coverage are under the blue coating. The beam at the bottom of the image contains an air-flow sensor.

2. MOTIVATION & RELATED WORK

The transverse flute is composed of three parts: headjoint, body, and footjoint. The headjoint contains the lip plate where the embouchure is placed (Figure 2). The body as well as the footjoint contain the mechanism to cover the key holes to produce a particular tone.

To achieve a proper embouchure, the player has to relax the muscles of the mouth, and then drag the lips towards the corners of the mouth. The lip hole is then created by letting the air go through the lips. The shape of the lip hole has to have a longitudinal form; a round shape should be avoided [2]. While the exact placement of the lips on the lip plate is subject to the player's anatomy, as general guideline "the mouthpiece must be placed against the edge of the lower lip where the red part of the latter begins" [1]. Fletcher analyzed the different technical parameters of the embouchure and their influence on sound [6]. According to his measurements, the air jet angle is within a range of 25°-40° down from the horizontal [5]. These guidelines were used as references during the development of our prototype.

Most of the research on augmented flutes was aimed at increasing its expressivity by adding sensors whose readings are used as input to additional effects. Ystad and Voinier proposed a *virtually real flute* [13], an augmented flute that synthesizes the physical aspects and produces the sound of an acoustic flute. They used sensors to feed a synthesis model. The cork of the headjoint was replaced with a microphone to measure the air pressure inside the flute. Magnetic sensors were added to the keypads of the flute to detect the finger position. Additional filters simulating the wave propagation could be applied to add effects to the output sound. The Hyper-Flute [7, 8] added sensors to the flute without compromising the original acoustic of the instrument and technique. Thus, the placements of the sensors were strategically located, e.g., pressure sensors were located on points where the flute was being held. The goal was to gather data (from the sensors) in real time and map them to control digital sound parameters. Another augmented flute was proposed by Da Silva et al. [3]. They measured the airflow velocity at two points (left and right) on the mouthpiece using two stagnation tubes from a pitot tube. The aim of this study was to be able to control a flanger effect by sweeping the frequency up and down.

There are some related projects that use augmentation to assist learning especially for the transverse flute. Siwiak et al. [11] noticed the limited use of technology for flute pedagogy and as feedback tool for musicians. One of the few projects is the tool proposed by Romero et al. [10]. Although it is built around a recorder, the use of technology to assist learning is important to mention. The sensor data collected on the recorder was sent to an application that provided feedback accordingly to assist the student. The feedback addressed air pressure and fingering. The application also combined theory and practice.

A tool like the Blocki Pneumo Pro[1] is a simple helper that allows self-controlled learning, however, it does not produce any sound, which forces the student to switch between the two headjoints.

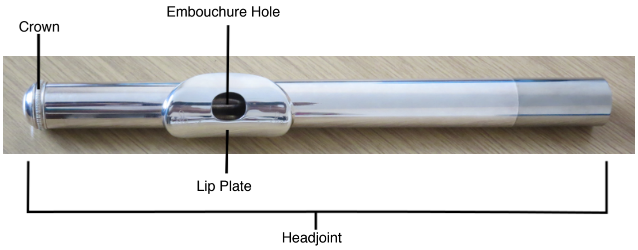

Figure 2: The components of a flute headjoint.

3. THE AUGMENTED FLUTE

To figure out what typical beginners' mistakes are when they learn to play the flute, we analyzed six tutorial videos available on YouTube. We observed what kind of errors the students make, and how the teachers correct these: a wrong placement of the lower lip on the headjoint, a wrong angle of the air jet, an insufficient amount of air, matching the lip hole with the embouchure hole, and the shape of the lip hole. In most of the cases, the teacher intervened by manually adjusting the posture which is, obviously, only possible if the teacher is physically present, and thus not an option if the student is practicing at home. We equipped our flute headjoint with sensors to detect these errors and provide step-by-step instructions through software.

3.1 Lip Placement

To sense the placement of the lower lip on the lip plate, we added three copper stripes as depicted in Figure 3. The stripes are connected to the microcontroller and used as capacitive sensors. They are isolated from the headjoint by a thin sheet of paper and covered with a layer of paint, to avoid direct body contact.

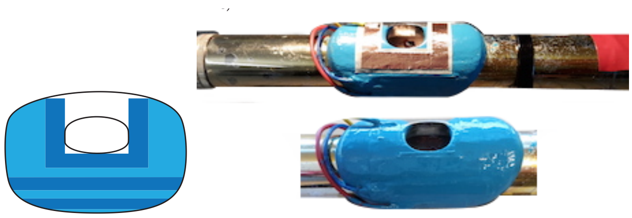

Figure 3: Three stripes of copper foil on the lip plate make the capacitive sensor for the lip placement. They are isolated from the headjoint by a thin layer of paper and covered with blue paint to avoid direct body contact.

3.2 Air Jet Angle

To measure the air jet angle, we use two flow sensors for differential measurement. One sensor is placed inside the bore to measure the amount of air that is blown into the headjoint, while the other sensor is placed on a beam attached to the headjoint (Figure 1). To determine the position of the external flow sensor, we used stripes of thin plastic foil to locate the angle of maximal differential pressure. Playing the flute was not affected by the inner sensor, and only minimal changes in sound could be detected. However, the sound quality can be neglected as our flute is designed for absolute beginners.

3.3 Lip Hole Shape

The lip hole shape determines the width of the air jet. If it is too wide, the air will hit the sides of the embouchure hole and produce a windy sound [9]. Wilcocks indicated that a wide aperture of the lip hole causes an unfocused air jet [12]. Therefore, the amount of windy noise in a tone is highly related to the lip hole shape. We decided to acquire the lip hole shape indirectly by measuring the amount of noise in the resulting sound. The use of cameras could be an alternative, however, this requires additional integration of a camera into the headjoint and challenging image processing.

As the tone produced by a flute can been considered pure due to the short harmonic development [5], we used a simple subtractive approach to measure the amount of noise, and thereby, the width of the lip hole. We determined the fundamental frequency of the tone, and fed it into the *PitchEnv~*[2] patch in PureData to eliminate the harmonic development from the original signal in the frequency domain. The amplitude of the residual signal was then used as a metric for the lip hole shape.

4. SOFTWARE

[1] `http://www.blockiflute.com`

[2] `http://williambrent.conflations.com/pages/research.html`

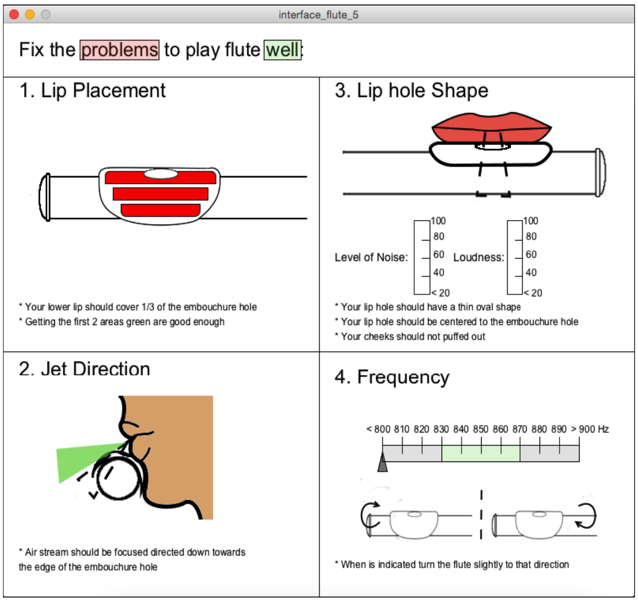

Figure 4: The user interface of our application. Parameters that are not within the specified thresholds are marked red (e.g., lip placement), and green otherwise.

Our software interface basically consists of step-by-step instructions to play the flute's headjoint own tone. We do not consider the remaining body of the flute, as the effects of closing holes to play different tones can be practiced on your own. At first launch, the user is guided through the different steps of placing her lips on the lip plate, blowing air in the correct direction and with the correct jet width, and finally, fine tuning the frequency by turning the headjoint. Successfully achieving one of the steps unlocks the following one. All elements are live visualizations of the sensor data, which means that if one of the parameters drifts out of the specified thresholds it is colored red (Figure 4). Once it is back within the optimal range, it turns green again.

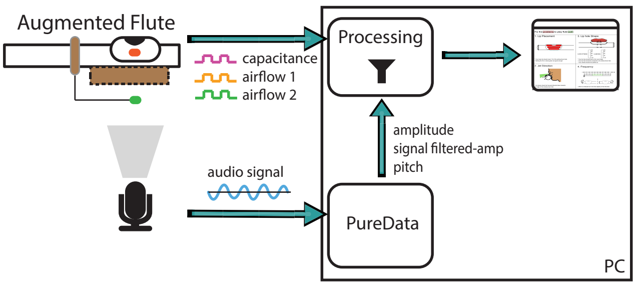

Figure 5: The data flow of our application. Lip position and air stream angle are measured with sensors on the flute headjoint, while lip hole shape is determined using audio processing.

5. IMPLEMENTATION

All sensors were connected to an Arduino Micro[3] board which communicated the data to a host computer for further processing (Figure 5). For the differential air flow measurement, we used two IST *FS1* gas flow sensors, and the capacitive measurements were performed using Paul Badger's *Capacitive Sensing Library*. Audio was recorded using a small diaphragm condenser microphone connected to an M-Audio FireWire Solo audio interface. The audio processing for the lip hole shape detection was implemented in PureData using the *pitchEnv~* and *sigmund~* patches. The microphone was at 1 meter distance from the participant. Finally, the user interface and data analysis was implemented using Processing. To determine whether the air jet angle and the lip hole shape are correct, we used decision trees that check the different parameters against a number of thresholds. For the lip coverage, we used simple minimum-maximum thresholds. The threshold values for all parameters are based on an evaluation with expert flutists, which we will describe in the next section. All sessions were performed in a regular office room (around 46dB) and after office hours to decrease environmental noise.

[3]`http://www.arduino.cc/en/Main/ArduinoBoardMicro`

6. EVALUATION

We iterated over the prototype several times based on the results of smaller evaluations.

Expert Panel: After having tested and calibrated the system based on our own expertise, we presented the system to four experienced flutists who had 12 to 20 years of experience playing the instrument. The main purpose of this evaluation was to calibrate the sensor thresholds to work with a multitude of players and to determine the optimal sensor values. After the calibration phase, we asked the experts for comments and feedback. Three mentioned that they could notice the capacitive sensors and that they had to get used to the new headjoint, but switching to a different flute requires the player to adapt anyways, thus it can be considered a minor issue. One mentioned that he thinks the sound quality was affected by the additional sensors, but was not entirely certain about it. Once the prototype turns into a real product, the sensors can probably be integrated in a way that sound quality remains good. We asked the panel to answer some questions on a five point Likert scale with 1 being the best. Half of the participants believed that this application could be useful for beginners, with the others being undecided (Mdn = 2.5, SD=0.96). All could easily determine which of the parameters they had to change in order to get a proper sound (Mdn = 2, SD = 0). The experts did mostly not feel supported by the augmented flute (Mdn=3.5, SD=1.71), but they could easily find out how to achieve a better result (Mdn=2, SD = 1.26). The low rating for the question about the perceived support was probably due to the fact that the thresholds were not yet optimal for some of the players and therefore, the software gave inappropriate recommendations. However, this was solved in the following iteration, based on the values we recorded with the expert panel.

After integrating the feedback of the expert panel, we ran a small pilot study with four novice users who had never played the flute before. This revealed a lack of guidance and explanations in the interface that remained unnoticed during the tests with the flutists, mostly because they already knew how to solve the issue at hand. These problems were fixed before the final evaluation with novice users.

Novice Users: We recruited 5 novices, 2 male, 3 female to perform the test. None reported to have played the flute before but other musical instruments: recorder, piano and guitar. All participants received a brief introduction on how to produce a sound on the headjoint, and three of the participants were asked to try making a sound on a regular headjoint with no sensors. We did this to estimate whether a simple explanation is sufficient to generate a proper sound, but none of the three users was successful. All participants then followed the instructions of our augmented flute system and only one was not able to produce a sound at all, which was caused by an error that the system could not sense (lips rolled over the teeth). Participants could easily detect which parameter to change to get a better result (Mdn = 1, SD = 0.4), felt supported by the augmented flute (Mdn = 2, SD=0.5), and could easily find out how to get a better result (Mdn = 1, SD = 0.5)

Expert Review: To see whether our software gives proper recommendations, we sent the five video recordings of the novice users' sessions to an experienced flutist and flute teacher, with 18 years of practice playing the instrument and 5 years of experience as an instructor. Overall, our software only achieved partial agreement with the corrections our expert would have given. The differences in recommendations happened because the errors the participants made could simply not be sensed by the ambient flute (e.g., lips rolled over the teeth, high tension in the lips), nevertheless, the effects of these errors could be sensed. Factors like lip tension cannot be measured with our non-intrusive approach. As we do not see our tool as a replacement for the flute teacher, but as an additional help for the students, we believe that things like lip tension, rolling the lips over the teeth, etc. would be covered during the first lesson.

7. SUMMARY & FUTURE WORK

In this paper, we presented an augmented transverse flute headjoint that supports novice users during unsupervised practice by indicating which of the many parameters that influence the generation of sound is out of range and how to correct the error in order to produce a proper sound. Based on literature, we determined the four most important steps to play a sound on the flute and provide sensing mechanisms to control these. We calibrated our sensors and thresholds by recording the readings of four experienced flutists. In an experiment with five novice users, a brief introduction and the augmented flute were sufficient for most of them to produce a sound. The intended user-case of our system is the unsupervised practice time after the first lessons, when a teacher is not available and self-observation is not helpful due to the large number of factors influencing the result, which are partially not directly visible. The goal is to minimize frustration while practicing between the first lessons.

In future iterations, the sensors should be tightly integrated into a beginner's flute. Models made from ABS such as Yamaha's YRF-21 do not require the insulation layer for the capacitive sensing, and the copper stripes could become an integral part of the mouthpiece, eliminating their effect on the player's comfort. Furthermore, the integration of the sensors also reduces the impact on sound. Adding an inertial measurement unit (IMU) to the set of sensors would allow to correct errors in posture and handling of the entire flute.

8. ACKNOWLEDGMENTS

We would like to thank the participants of our study, and the professional flutists for their time, feedback, and recommendations. This work was funded in part by the German B-IT Foundation.

9. REFERENCES

[1] J.-H. Altès. *Method for the Boehm Flute*. Carl Fischer, 1897.

[2] A. Brooke. *The modern method for Boehm flute*. 1912.

[3] A. R. da Silva, M. M. Wanderley, and G. Scavone. On the use of flute air jet as a musical control variable. In *NIME '05*, pages 105–108, 2005.

[4] L. De Lorenzo. *My Complete Story of the Flute: The Instrument, the Performer, the Music*. Instrument, the Performer, the Music Series. Texas Tech University Press, 1992.

[5] N. H. Fletcher. Some acoustical principles of flute technique. *The Instrumentalist*, 28(7):57–61, 1974.

[6] N. H. Fletcher. Acoustical correlates of flute performance technique. *The Journal of the Acoustical Society of America*, 57(1):233–237, 1975.

[7] C. Palacio-Quintin. The hyper-flute. In *NIME '03*, pages 206–207, 2003.

[8] C. Palacio-Quintin. Eight years of practice on the hyper-flute: Technological and musical perspectives. In *Proceedings of the 8th International Conference on New Interfaces for Musical Expression*, 2008.

[9] E. Putnik. *The Art of Flute Playing*. The Art of Series. Summy-Birchard Company, 1973.

[10] K. J. G. Romero, D. A. R. Lopez, L. A. Luengas, and J. C. Guevara. Virtual flute: Electronic device that uses virtual reality to teach how to play a flute. In *IEEE EDUCON 2010 Conference*, pages 211–216, April 2010.

[11] D. Siwiak, A. Kapur, and D. A. Carnegie. Music technology's influence on flute pedagogy: A survey of their intersection. In *ICMC '14: Procedings of the 2014 International Computer Music Conference*, 2014.

[12] G. Wilcocks. *Improving Tone Production on the Flute with Regards to Embouchure, Lip Flexibility, Vibrato and Tone Colour, as Seen from a Classical Music Perspective*. 2006.

[13] S. Ystad and T. Voinier. A virtually real flute. *Computer Music Journal*, 25(2):13–24, 2017/01/30 2001.