The Hyper-Ney: An Enhanced Traditional Flute

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ABSTRACT

The Hyper-Ney is a hyperinstrument prototype enhancing the traditional ney flute by integrating electronic sensors to expand creative possibilities beyond its affordances. These allow the control of sound synthesis and processing parameters to create a blend of acoustic and synthesized sounds. The core idea is to remap the existing fingering gestures, exploiting acoustically unresponsive holes of the ney flute for enhanced control. Additional interaction methods include lip positioning and instrument movement. We evaluated the system through a study focused on audience reactions, suggesting engaging sonic and visual elements. We complemented this evaluation by including the first author's self-reflections as Hyper-Ney performer.

Author Keywords

Ney flute, Hyperinstrument, Capacitive Sensing, Motion

CCS Concepts

•**Applied computing** → **Sound and music computing;** Performing arts; •**Human-centered computing** → *Interaction Devices;*

1. INTRODUCTION

The ney is a traditional end-blown flute typically made from reed or bamboo, known for its practice in Sufi music [13]. It produces a continuous range of pitch, achieved by altering finger placements, breath intensity, and the instrument's unique embouchure technique. Performing with the ney, as with most acoustic wind instruments, requires blowing into the instrument while operating the finger holes with both hands. However, in this interaction between the performer and the instrument, unused possibilities can be leveraged for gesture-to-sound mapping. Our work focuses on enhancing the ney flute and its playing techniques by adding new control layers that align with the established interaction repertoire. The Hyper-Ney, visible in Figure 1, is a novel instrument integrating various sensors on a traditional ney flute.

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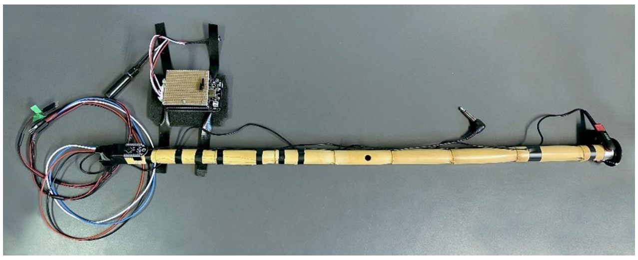

Figure 1: The Hyper-Ney

The primary method for interacting with the Hyper-Ney relies on the existing holes in its body, as used in the traditional playing technique. Specifically, we employ sensors to leverage the playability of the holes when they are not used acoustically. This dynamic utilization of the holes allows for a smooth transition between traditional ney performance and new expressive dimensions. Hence, we use the term "hole availability" throughout the paper to denote the availability of the holes for controlling a separate sound engine without having an impact on the acoustic sound generation process. Other control strategies utilized in the Hyper-Ney involve sensing the positioning of the lip on the mouthpiece and the instrument's motion. A video of a demonstrative performance showcasing the Hyper-Ney is available online[1].

The evaluation of the Hyper-Ney is conducted through two distinct perspectives. The first is from the audience perspective, where participants evaluate the Hyper-Ney through an examination of a live performance. The second is from the viewpoint of the first author, who serves as both the designer and performer of the Hyper-Ney.

The field of novel musical interfaces has explored the enhancement of flutes and the exploration of techniques associated with their interaction paradigms. We review a selection of these works, focusing on the extent to which the resulting instrument offers enhanced control and on its design choices.

These works include augmented flutes that employ various sensors on the instrument body, including accelerometers to detect motion [11, 12] or capacitive sensors on the mouthpiece to capture the lip position and pressure [7], most utilizing complex gesture to sound mappings. Other works incorporated flute's holes [14] or the breath intensity [3] as a source of control data. In addition to flutes, Leeuw [10] designed an augmented trumpet that facilitates simultaneous acoustic and electronic playing, and Impett [9] developed a composition environment around a trumpet, preserving the instrument's core role while adding complementary elements, such as a microphone.

[1] `https://mct-master.github.io/interactive-music/2023/12/01/ahmetem-the-hyper-ney.html`

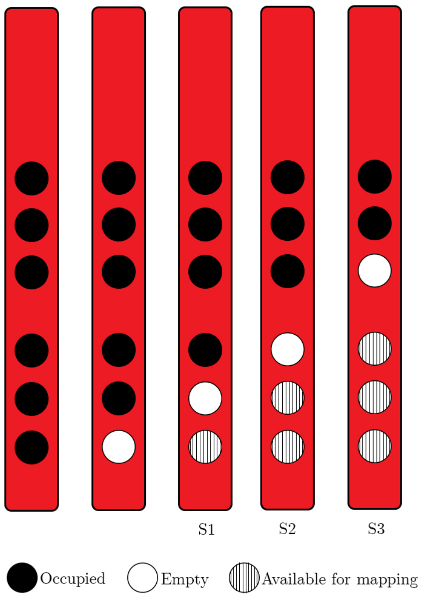

Figure 2: Five availability states of holes in common scenarios

2. DESIGN AND IMPLEMENTATION

2.1 Design

The main design principle of the Hyper-Ney is primarily guided by Cook's *spare bandwidth* concept [4, 5], which looks at using a player's unused capacity to control the instrument. This allows to augment a musical instrument. We aim to maintain the ney's traditional playability while integrating new interaction possibilities that complement its natural characteristics and affordances. These encompass finger controls, lip positioning, and instrument motion. As such, we designed the Hyper-Ney with two modes of operation: one operates by blowing into the flute, while the other allows for controlling through gestures alone, thereby enabling performance without blowing.

The primary control mechanism of the Hyper-Ney is based on conventional finger positioning used in playing the instrument. This method is rooted in the principles of flute acoustics: when a player covers a higher hole on the ney, the lower holes do not produce sound and can, therefore, be used for additional control functions. The responsiveness of each hole depends on which other holes are covered during a performance, varying from situations where no holes are free to ones where all holes can be manipulated. Figure 2 illustrates the availability of ney's front holes for mapping purposes in different scenarios.

In the design and implementation, special attention is given to the concept of separating gesture and sound generation. This aspect allows executing other traditional playing gestures without necessarily producing sound through blowing. From a design standpoint, the instrument opens up new creative possibilities, triggering sound synthesis while maintaining the experience of playing the acoustic instrument.

Dynamics control is crucial in playing the ney. The ney sound is influenced by the pressure of blowing, allowing for continuous pitch modulation and change in timbre. This characteristic, noted for its musical and technical directness in mapping [9], is a focal point in the interaction design of the Hyper-Ney, serving as one of the integral control methods.

Capturing the motion of the instrument is a common strategy in several enhanced wind instrument works [9, 12]. The ney's body motion provides additional data that can be used for sound control.

We chose capacitive sensors, contact microphone, and accelerometer to accomplish our objective as they can detect the desired gestures without hindering traditional acoustic flute performance.

2.2 Implementation

Rings of metal wires, used as capacitive sensors, are placed around the ney's six front holes to detect finger positions and determine usable holes for mapping. Another ring of metal wire, placed at the tail of the ney, allows the sound engine to be switched on or off. We also added a circular aluminum tape to track lip position and pressure on the mouthpiece. These are connected to a Trill Craft [2] mounted at the tail-end of the flute, collecting capacitive sensor data. Wires are placed to not interfere with the performer's fingers, as visible in Figure 3.

A contact microphone attached near the mouthpiece captures the ney's acoustic sound. It allows for tracking the blowing intensity, estimated by extracting the signal's root mean square (RMS) feature. The microphone also allows for capturing sounds from extended techniques, such as touching and tapping the ney's body or blowing directly on the contact microphone.

An accelerometer is on the ney's tail, capturing motion along two axes perpendicular to the flute's body, which exhibit the most significant movements.

These sensors are connected to the Bela[3] board positioned on the performer's lower arm. Such placement ensures that the resulting instrument remains compact and integrated without impeding the performer's physical activity during play. Figure 3 shows the main components of the Hyper-Ney.

The capacitive sensors around the holes are regularly calibrated to account for variations caused by external factors, adjusting each hole's response to the range of 0.0 to 1.0. Additionally, the length of the wire connecting the mouthpiece sensor to the Trill Craft makes the resulting capacitive sensor sensitive to fingers and other wires, producing an unstable sensor output. This issue is addressed in software by continuously adjusting the read values according to the number of actuated capacitive sensors.

To determine which holes are available for mapping and not active during acoustic play, we employ the boolean equations from 1 to 5. In these equations, the variables S denote the availability of each state, while H indicates whether a hole is utilized (i.e., covered is represented as true).

$$S5 = \overline{H6} \tag{1}$$

$$S4 = \overline{H6} + \overline{H5} \tag{2}$$

$$S3 = \overline{H4} + \overline{S4} \tag{3}$$

$$S2 = \overline{H3} + \overline{S3} \tag{4}$$

$$S1 = \overline{H2} + \overline{S2} \tag{5}$$

In the sound engine of the Hyper-Ney, we use various techniques, including both noisy and tonal textures, as well as continuous and transient elements. These techniques comprised various synthesis methods as well as audio effects.

[2] https://shop.bela.io/products/trill-craft
[3] https://bela.io/

Figure 3: Components of the Hyper-Ney. (a) Wires around holes, (b) aluminum tape on the mouthpiece and contact microphone, (c) on/off capacitive switch, (d) Trill Craft, (e) accelerometer, (f) Bela with custom-made perf board board with velcro straps, (g) boards placed on performer's lower arm, (h) instrument handling

We selected additive synthesis, generating short whistle-like sounds, and granular synthesis based on steel hang instrument recordings, with control over grain duration and frequency through gestures, offering a continuous ambient soundscape. A frequency modulator and noise generator are employed with variable characteristics generating complex, noisy elements.

In the Hyper-Ney, we use a many-to-many mapping approach [8] to obtain a complex and rich musical interface. Multiple controls are linked to multiple synthesis and processing parameters, allowing for a broad range of musical interactions.

In the first interaction mode, the player's lips are not in contact with the mouthpiece, allowing the Hyper-Ney to be played without the need to blow air. Here, we use the energy of the signal captured by the contact microphone, capturing extended techniques, to trigger the frequency modulator, noise generator, and additive synthesis, depending on the incoming energy level. All holes are available in this mode for computing a global carrier frequency, which is employed across multiple modules as a control parameter. As soon as the player's lips contact the mouthpiece, the second mode is activated, allowing for traditional ney acoustic performance. In this mode, the synthesized sounds blend into the background, allowing sound effects to continue augmenting the natural acoustic output.

In both modes, audio effects are equally applied. The delay is manipulated by the lower holes and by the accelerometer. The tremolo effect, which employs pulse-width modulation, is influenced by the upper holes and by the accelerometer, affecting the microphone input, frequency modulator, and noise generator. Additionally, the accelerometer data is utilized across different synthesis and processing modules. The software for the Hyper-Ney is developed in Pure Data and runs on Bela. The data flow of the Hyper-Ney is illustrated in Figure 4.

Table 1: Responses to the questionnaire from individual participants

Question	P.1	P.2	P.3
General Impression of the Performance	10	6	8
Cause Comprehension	7	5	7
Effect Comprehension	7	7	8
Mapping Comprehension	7	6	4
Intention Comprehension	8	7	8
Error Comprehension	2	2	2

3. DISCUSSION

To preliminarily evaluate the Hyper-Ney, we employ two approaches: a study of the audience in a live Hyper-Ney performance and the first author's reflection as a performer.

3.1 Audience's Perspective

As discussed by Barbosa et al. [1] and by Fyans et al. [6], we adopted the approach proposed by Bellotti et al. [2] to evaluate the Hyper-Ney from the audience's perspective. This approach aims to evaluate the spectators' comprehension of the instrument by considering five aspects: cause, effect, mapping, intention, and error comprehension.

Spectators attended a 5-minute live performance and then compiled a questionnaire, which included five questions related to the above-mentioned aspects, one question on the overall impression of the performance, and a field for open feedback. Three audience members with expertise in musical interface design answered the questionnaire, assigning scores from 1 to 10 for each question and providing open comments. Table 1 shows the average scores obtained from the questionnaire.

The evaluation of the Hyper-Ney from the audience perspective revealed generally positive feedback. Participants found it moderately challenging to identify specific body parts and instrument interactions. The system and performance provided sufficient audiovisual input for understanding the relationship between the performer's intentions and output, while the mapping of gestures to sound was perceived slightly less clearly. The audience demonstrated a relatively high level of understanding regarding the performer's intentions during the performance. Notably, the lack of perception of errors, as reflected in a low score, although potentially suggesting a smooth and technically sound execution, may also suggest a potential disconnect or low engagement with the technical aspects of the performance, as there were some errors during the performance.

Written feedback results indicated overall positive feedback, praising its captivating sound and the good integration of synthesis and ney sound. Participant 1 mentioned that the sensors around the mouth were particularly apparent as they necessitated a very visual action from the performer. The mapping of each hole was appreciated for efficient utilization. However, some participants stated that they found it challenging to grasp the correlation between gestures and specific parameters and suggested improvements to enhance this understanding.

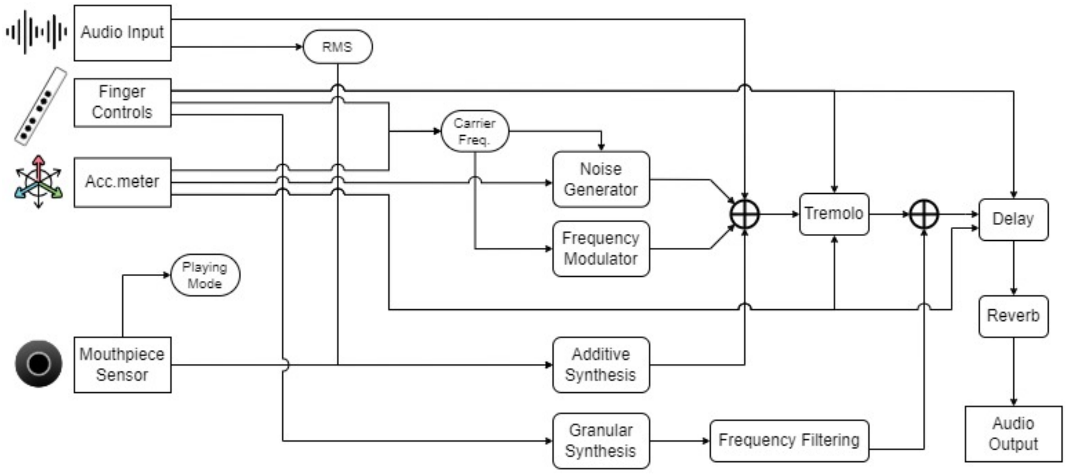

Figure 4: Block diagram and control mapping of the Hyper-Ney

3.2 Author's Reflection

Overall, the design and implementation of the Hyper-Ney as a standalone instrument successfully captured the performer's intended gestures and translated them into sound processing parameters.

From a performer's perspective, playing the Hyper-Ney remained in line with traditional ney techniques. The first author engaged extensively in practicing with the Hyper-Ney, and it allowed him to play as he would normally do with the ney and maintain the intrinsic connection to the instrument's traditional form.

The dynamic mapping of holes necessitated a parallel way of thinking about finger utilization, requiring a substantial learning curve. Specifically, the complexity introduced by the dynamic mapping system underscores the need for continued exploration and adaptation to harness the instrument's expressive potential fully. Interacting with the instrument without blowing into the ney proved engaging and in line with the existing affordances of the ney. The functional diversity of holes and current mapping present an opportunity to integrate more controls with room for added complexity.

The sound design proved to be a fitting complement to the ambiance and inherently noisy nature of the ney sound. However, considering the diversity of control the Hyper-Ney allows, the generated sound lacked variety, suggesting potential areas for diversification and enrichment in future iterations.

4. CONCLUSION

This paper described an approach for enhancing the ney, a traditional wind instrument, by remapping its existing gestures as an extended controller to augment musical capabilities. The overall design of our prototype effectively utilizes the performer's spare capacity through sensors, introducing new control methods and musical elements while preserving its existing acoustic nature.

The interchangeable use of the holes for extended and acoustic control increased complexity. It expanded opportunities for expressivity, introducing a learning curve and a more nuanced engagement with the instrument.

Future iterations of the Hyper-Ney can enhance the complexity of gesture-to-sound mapping. Expanding the scope of user studies, especially with ney practitioners and traditional audiences, is needed to evaluate the prototype better and validate its relevance and significance.

5. ETHICAL STANDARDS

The evaluation session with human participants was conducted in accordance with the ethical guidelines set forth by the University of Oslo. The participants were informed that their responses would remain anonymous and could be used for research purposes.

The prototype instrument was built using electronic components provided by the University of Oslo, all of which were reused from previous projects. Upon completion of this study, these electronic components and the Bela system will be repurposed for educational purposes and future research endeavors.

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