The Clarinet as a Tangible Acoustic Interface: New Features

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Abstract
This article supports the concept that a clarinet can be transformed and considered as a Tangible Acoustic Interface (TAI), when under the influence of new media art or digital components, and several approaches to achieve it. The traditional instrument, developed over centuries by *luthier´s* handcraft in collaboration with instrumentalists and composers, underwent an evolution triggered by digital means in the twentieth and twenty-first centuries. Instrumentalists became researchers and began to explore digital paths by augmenting and actuating their instruments. This exploration brought new properties and directions for its performance and conceptions regarding the connection between the actors involved - instrumentalist, instrument, computer, microphone, software, and others. By comparing and analysing concepts of Human-Computer Interaction (HCI) focused on the instrumentalist-clarinettist -, this paper discusses new features which have arisen from the new concept of TAI. These data result from an expanded vision of the subject and first-person experience. Lastly, the TAI concept offers a point of view where the instrument can also be a communication channel between different domains, connecting the instrumentalist with other realities and giving the possibility to seek new artistic paths.

Keywords: Clarinet, Digital, Interaction, Interface, Instrument, Instrumentalist

Introduction

Keeping in mind that this article focusing on musical instruments from the Western orchestral tradition, musical instruments are machines invented and designed by the art of the *luthier* to express non-vocal sounds (Gati, 2015). It is therefore important to mention the art of the *luthier* because it is an art that is disseminated in a traditional way, reflected in the transmission of cultural heritage from a master to an apprentice who creates and develops the instruments over centuries (Magnusson, 2019). Over the years, *luthiers* and instrumentalists have been working together to make the instruments ergonomic and playable and to try to make the instrument a kind of extended part of the instrumentalist´s body. It is safe to say that all traditional musical instruments are tangible. In other words, they all require physical contact to function. However, this is not true for all instruments. If we look outside the orchestra, instruments such as the theremin, for example, are instruments of intangible execution. Another aspect to consider - regarding Western art music - is the instrumental music performance, which for centuries focused on interpreting a score - by instrumentalists - for a passive audience. Nevertheless, this type of performance has changed significantly in the last decades, especially under digital influence - not exclusively (Travasso et al., 2022). The instrumentalist has taken on a multidisciplinary role, and the instrument has expanded its functions. Instrumentalists had to adapt to this new reality, using the instrument in different ways and for various purposes, taking on the role of creator and researcher several times. Summarising, this type of instrument underwent several digital additions beyond its traditional design and acoustics properties, and they also started to be used to communicate with the computational component and/or with other actors involved in the instrumental music performance.

Tangible Acoustic Interface

Tangible Acoustic Interface (TAI), as the name means, is something tangible, acoustic, and interface, employing solid vibrations. In this way, musical instruments under a TAI system differ from an augmented or actuated one, but they can support both designs. In other words, musical instruments used as TAI can be - or not - under digital augmentation. The difference between a TAI system and actuated/augmented instruments is that the latter is developed to achieve digital features - beyond the traditional acoustic purposes of the instrument - by modifying the acoustic characteristics and/or changing the performance´s conditions/environments. On the other hand, instruments under a TAI system are prepared to allow the instrumentalist to interact with digital component(s) by means of its solid vibration, but not necessarily with the instrument´s sound.

Nevertheless, an instrument with a TAI system could also work as actuated/augmented. According to Crevoisier and Polotti (2005), regarding classical musical instruments, the instrumentalist interacts closely and directly with the source vibration, having control of the sonic generation. For these authors, to consider an instrument as TAI, it should combine the sonic production with the interaction through the instrument. At the same time, this process also takes over the processes to generate sound or other components employing a computer.

TAI uses two techniques: active and the passive (Chou & Lo, 2013). The active is when the parameters used are based on the absorption of a solid acoustic energy; the passive is based on analysing the solid acoustic produced, such as tamping or the touch on a surface. In the specific case of a musical instrument, it can be used as both techniques, active and passive. It is possible to analyse the vibrations produced by an instrument on its surface, and it is also possible to analyse the vibrations from the touch on the instrument.

In sum, a musical instrument, under a TAI system, is part of a process developed to offer the instrumentalist the opportunity to trigger/interact with new features - concerning or not to sound - using the instrument and through its solid vibration. In these systems, the instrument is a crucial interface for interaction with digital components, and this interaction cannot be reached in any other way.

Musical Instruments: Tangible or Intangible?

There are two manners to observe a musical instrument: (1) a device played by an instrumentalist - working as an interface that allows the instrumentalist the possibility to make his musical interpretation and communicate with other components; (2) a cultural artefact with historical value (Howard, 2022). Concerning this second approach, the instrument can be observed in its function as a device to be played, enabling the recreation of a traditional performance, preserving these traditions, and making them possible through a live performance by serving as a vehicle for something intangible - for example, all baroque orchestras with period instruments. It is possible to imagine the artisans working on it and all the processes and developments it underwent over years and decades until it reached the shape and characteristics from nowadays. In this last case, the instrument itself could be considered a tangible heritage - for example, the Stradivarius´ violins (Howard, 2022). Still related to tangible heritage, Michael Horn (2013) gives the example of an experience with two small groups of children in a room with two different ropes, one with and one without wooden handles. The rope with wooden handles has the connotation of a cultural artefact because of its traditional heritage, so it is more likely that the children who were in the room with the rope will use it to jump. Like the rope with wooden handles, a traditional instrument has a cultural connotation. For this reason, its cultural image cannot be separated from the object itself, which inevitably makes it a tangible heritage object. Concerning the first manner to observe a musical instrument, it occurs when someone uses it as an object to achieve sonic or performative purposes.

A musical instrument can be considered a tangible heritage because of its history, tradition, and construction. However, it can also be considered an intangible heritage if the sonic result is the focus. In this last case, the instrument is the interface that connects the instrumentalist and the audience with this intangible heritage, albeit from different perspectives - the instrumentalist as the promoter and the audience as the receiver.

A Tangible Interface (TI), something physical around the user that works as an interface between human and computer, enables a system for human-computer interaction (Manovich, 2022). In this perspective, the musical instrument can be seen as TI, exploring the relationship between the physical and the digital components (Ullmer & Ishii, 2000), transforming the traditional instrument into something we might define as a tangible interface.

Interaction Tangible or Intangible

The musical instrument as a device played by an instrumentalist is tangible, as well as all the traditional instruments, because they are touchable, allowing physical contact by the instrumentalist. The same physical principle does not apply to the parameterisable features of a clarinet to obtain a TAI system, and it needs some discussion about its tangible or intangible definition.

Firstly, discussing the sound´s (in)tangibility is essential. Physically, sound has a form that should be considered - moving air particles and travelling through bodies and objects. The movement and impact of air particles is the fundamental basis for hearing, listening, and feeling, enabling the tangible concepts of sound/music, speech, embodiment and spatial orientation (Novak & Sakakeeny, 2015). Gaver (1993) considers three distinct ways for sound to be generated: solid vibrations, changes in the surface of a liquid body, and sounds introduced directly into the atmosphere by aerodynamic causes. In this way, O´Callaghan (2007) states that sounds are the objects of the auditory experience. We can figure out through the sound if a glass has broken, or if a bell is ringing in a room or if a train is passing nearby. In this way, O´Callaghan affirms that the auditory experience has the sound as an object with its characteristics like a physical object has shape, colour, and size. Also, Ihde (2007) states, regarding the auditory experience, that through sound, we can distinguish *shape aspects* and distances, concluding that we can *hear shapes*. The vibration nature of sound and the possibility for people to feel it is undeniable. Even when the sound is inaudible, we can still feel the vibrations if we are in physical contact with the source (Franinović & Serafin, 2013).

On the other hand, for many authors, the sound is intangible because, although it is a physical phenomenon, it cannot be touched employing any physical action, and it does not have properties such as colour, shape and size, which makes it of intangible nature (Cox, 2011; Oliveira Pinto, 2018). However, the sound could become tangible if we consider recording possibilities through its transformation to something material as a recording (Oliveira Pinto, 2018). Gupfinger and Wolf (2019) refer to sound as something intangible, and to give it a tangible form, they created a system with a 3D printer transforming sound into sculptures. Regarding pitch and sound, according to ISO (2014), the auditory sensation is a function of neurological processes, and the sound has to be interpreted unconsciously - for example, during sleep - or consciously.

It is not the purpose of this article to discuss if sound is tangible or intangible. However, to catalogue the different parameterizations which allow the new features brought by a clarinet as TAI, and due to the nature of this article - exploring solid vibrations - it will be considered the concept in which the sound could be tangible. In this way, all the interactions regarding using a clarinet under TAI systems will be considered tangible.

Clarinet Anatomy and Techniques

This section will present terms and usages of several clarinet techniques, making understanding the following ones easier.

The clarinet is an instrument member of the woodwind family and, generally, is made of wood - a cylindrical bore with keys and holes - and a single reed. Its sound is produced by blowing between the reed and the mouthpiece, vibrating the reed. This vibration sets the motion of air inside the tube, making the sound (Hoeprich, 2008). Nowadays, the clarinet has five parts: mouthpiece, barrel, upper body, lower body, and bell.

There are several contact points between the instrumentalist and the instrument. The first one, because without it, the clarinet does not produce sound, is the mouth with the mouthpiece.

This contact could be done with lips, teeth, and tongue. Also, it is here that the instrumentalist sends the airflow. Another contact could be made by the hands in the clarinet body, especially in the keys and wood. However, it is normal to see, especially in the orchestra, because the instrumentalists are playing seated, the clarinettist using their knees involving the bell - serving as mufflers - helping to play a soft *pianissimo*. In fact, the clarinettist could use any part of his/her body to come into physical contact with the clarinet.

There are also several techniques to be considered for this article, such as ***vibrato*** - pitch fluctuations that could be achieved by changing the pressure on the reed or the air pressure; **flutter tongue** - produced by the tongue pronouncing d-r-r-r, or using the throat making g-r-r-r; **slap tongue** - using the tongue to create a vacuum between the reed and the mouthpiece and them release it suddenly provoking a slapping of the reed on the mouthpiece; **throat tremolo** - doing series of breath articulations with the sibyl *ha*; **vocal sounds** - using the air pressure to play and to sing into the clarinet tube; **air sounds** - blowing to the instrument with an embouchure pressure insufficient to produce the normal tone; **key slaps** - making noises through pressuring the instrument keys (Rehfeldt, 2003).

The techniques mentioned are not a list of all the clarinet techniques because it is impossible to mention something that is in constant evolving. Nevertheless, it is a list containing several parametrisable aspects useful to be used in TAI systems in a clarinet.

Usage Models

The first example of this analysis uses the normal acoustic sound production and the use of a solid vibration sensor placed inside the bell. This sensor captures the solid vibration resulting from the acoustic sound and uses this data as a parametrizable feature. It is also possible to transform the received data in *hertz* and/or dBs to use it for trigger functions. For example, the project *MAD Clarinet 2.1.* (Travasso, 2022), uses the sound of the clarinet with that intention. The computer identifies the pitch captured from the clarinet´s sound and matches it with a matrix. If the pitches produced are between 21*hz* and 192*hz*, the computer draws a quadratic Bezier curve; between 193*hz* and 390*hz* a line; between 391*hz* and 500*hz* a straight line; between 500*hz* to 792*hz* an arc; between 793*hz* and 993*hz* a circle; and upper 994*hz* a triangle. With this system of TAI, the clarinettist, through its playing, can choose which figures to draw. The musical dynamics are also explored on *MAD Clarinet 2.1.*, in this specific case, dB is used as a gate. All sounds produced by the clarinet, with a level lower than -25 dB, do not trigger any geometrical figures. In this way, the system represented in Figure 1. can works as the system explained, transforming the solid vibrations in *hertz*. However, it can be used in several other parameters and purposes. Due to its position inside the bell, the sensor will receive many vibrations, and even air sounds or/and key slaps can be easily detected.

Figure 1. A system with a solid vibration sensor.

Using a different sensor, more precisely a Tilt Switch installed in a key - *D#3* - placed on the upper body, transform the key into a switch. This switch could be used as an on/off button.

This key was chosen because there is an alternative to it, and it is possible to play whatever the instrumentalist wants, avoiding its use. Therefore, the clarinettist could use the key - switch - to trigger something or switch and play simultaneously. A solid vibration sensor acting on the mentioned key could have the same effect.

Figure 2. Switch placed over the bell.

Also, the clarinet can have a Tilt Switch positioned on the bell - as Figure 2 shows - programmed, for example, to block or unblock the other sensors installed.

In Figure 3, it is possible to observe the signal emitted from the switch when it is placed on the vertical and the absence when it is placed on the horizontal. This position could be defined through the sensor position or choosing a switch with another definition. However, in any case, the clarinettist can use this signal as an on/off button of a predefined process.

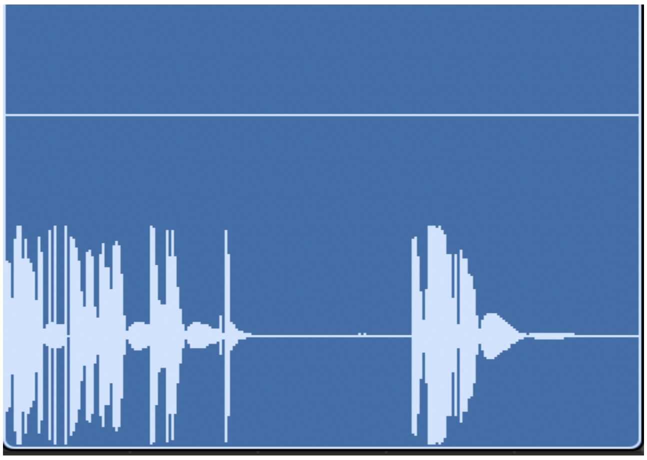

Figure 3. Soundwaves resulting from the switch.

The mouthpiece is also an excellent spot to place sensors - Figure 4. There is a point between the reed and the mouthpiece that a polymer vibration sensor - a piezo vibration sensor in the specific case of Figure 4. - can be placed without disturbing the sonic production. This sensor could be used to read the reed vibration when the clarinettist is playing in the traditional manner or/and also when he/she uses different techniques - flutter tongue, growling, slap tongue, vocal sound, air sounds, among others. Even the simple touch of the reed could be detected with this technique. However, detecting vibrations produced in the clarinet´s body could be difficult.

Figure 4. Sensor placed between the reed and the mouthpiece.

Between the rubber protection for the upper teeth and the mouthpiece or over the rubber protection - as we can observe in Figure 5. - is another good place to use the same sensor. In this place, it could be measured the impact in vibrations of different bites, and it is also a good place to measure the vibration of the mouthpiece.

Figure 5. Sensor on the rubber of the mouthpiece.

The Figure 6 is an example of the signal captured by the system shown in Figure 3. It is possible to observe different types of soundwaves resulting from playing and different strengths made by the upper teeth.

Figure 6. Soundwaves resulting from the sensor on the rubber of the mouthpiece.

Parameter	**Technology**
Instrument vibration - playing and/or pressing the instrument keys	Solid vibration sensors
Using a key as a switch	Solid vibration sensor or a tilt switch device
Reed vibration	Polymer vibration sensor between the reed and the mouthpiece
Teeth pressure	Polymer vibration sensor between the teeth rubber and the mouthpiece

Table 1 - Models of TAI application.

Summarising, the clarinet can be used as TAI for several purposes and in various manners. The systems mentioned are not - and far from it - a closed list. However, it is possible to state that a clarinet can be used as a TAI through physical positioning, pitch, dynamics, throat and tongue techniques, air and teeth pressure and others. These kinds of interactions are distinguished from the general TUI or actuated/augmented instruments, making the clarinet an interface for interaction between the instrumentalist and the digital component(s) through solid vibrations.

Author´s Experience

Through the author´s experience as a clarinettist, collaborating with the project *Comprovisador* and with the project *MAD Clarinet* - Figure 7. -, it is possible to verify that the experience regarding the musical performance, playing the clarinet, has changed. These projects change the traditional manner of playing the clarinet. For example, in an orchestra, the clarinettist interprets music with other musicians, using the clarinet only for sonic purposes, with the well-defined goal of interpreting the score. Performances that use the clarinet to interact with digital components presuppose - possibly - different clarinet techniques and certainly different focuses of attention and concentration. For example, if an artefact requires physical movement to interact and/or has a sonic response to random possibilities, the clarinettist faces several issues that diverge from his traditional performance.

Regarding the movement, the non-stability of the instrument could be a problem in maintaining an excellent airflow to play it or even having control of the reed if the angle between the body and the clarinet is constantly changing. However, interaction with physical movements could bring several advantages regarding the visual context and add new features to different types of performance. In addition, the physical condition of the instrumentalist could be a problem because it could substantially reduce the thoracic capacity. Related to sonic matter, different and unexpected responses triggered by the digital component give rise to various reactions. In sum, there is no limit to the use of TAI, and every project/model has its specificity, using the clarinet in different ways for different purposes. All these kinds of projects have in common that they change the relationship between the clarinettist and the clarinet. Beyond its normal function, the instrument becomes a channel and/or device to communicate with others - digital or non-digital - allowing the instrumentalist to connect to different domains.

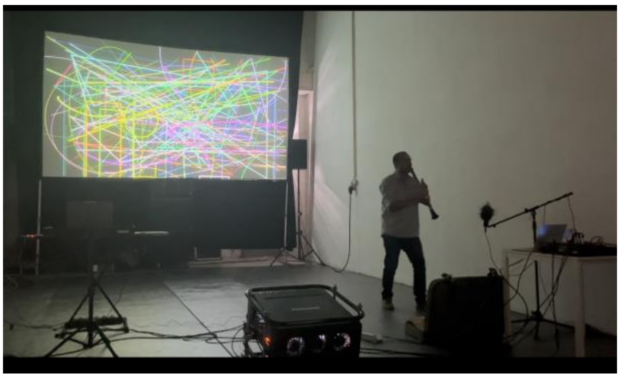

Figure 7. MAD Clarinet 2.1. Live Performance.

Conclusion

The use of musical instruments has evolved in the digital world, and with this evolution, new definitions and concepts have emerged. As mentioned, this article attempts to identify one of these moments by bringing up the concept of identifying the clarinet as a Tangible Acoustic Interface (TAI), which changes how the clarinet can be used and understood under the influence of a new digital reality. Also, it was discussed new features and possible systems through examples to use the clarinet as a TAI. The instrument is no longer used only for musical purposes but also as a device that allows the instrumentalist to communicate with digital components. In this sense, a clarinet as a TAI is when the musical instrument acts as an intermediary between the instrumentalist and the digital component through solid vibrations. This connection enables the instrumentalist to interact with the digital component and other actors involved in the performance.

In summary, the clarinet as a TAI is a sonic device that acts as a remote control for digital music performance under the command of the instrumentalist. Indeed, the clarinet has seen its responsibilities extended, evolving from a sonic transmitter to a control device for various purposes. Lastly, this TAI definition could serve as a basis for new similar situations with other instruments, thus broadening this definition.

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