# Encounter-type Haptic Interfaces for Virtual Reality Musical Instruments


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## ABSTRACT

This paper summarizes the author's interest in haptic interfaces for Virtual Reality Musical Instruments. The current research focuses on finding interfaces that can improve physical interaction and presence with such instruments. Musical expression is a topic rarely addressed in the field of Virtual Reality. During the years, the author has explored different systems and concepts while finding the thesis topic for the Ph.D. research. They include the development and evaluation of deformable input surfaces and Shape-Changing interfaces. The results from these implementations led us to investigate *Encounter-type haptics*, a method that has never received a proper consideration in the design of virtual musical instruments. This represents the current stage of our research. However, the exact direction towards the Ph.D. thesis topic is still in search. Through this paper, we will describe the background and motivations behind this research together with the research hypothesis developed until now.



**Keywords:** Virtual reality, Music, Haptic feedback, Deformable interfaces, shape-change, Expressivity.

**Index Terms:** H.5.1 [ Information Interfaces and Presentation Multimedia: Information Systems - Artificial, augmented, and virtual realities]: ;—H.5.2 [User Interfaces]: Haptic I/O; H.5.5 [Information Interfaces and Presentation]: Sound and Music Computing.


## 1 RESEARCH INTERESTS AND BACKGROUND

The general goal of this research is to investigate novel classes of haptic interfaces for Virtual Reality Musical Instruments (VRMIs) that can promote musical creation through physical engagement and expression. Serafin et al. [16] have defined Virtual Reality Musical Instruments as multi-sensory instruments that should provide to users an environment through which they can express musically and feel immersed. Haptic feedback can play an essential role in improving user performance and sense of presence. Previous research showed the importance of such feedback modality is equal -if not more- of the quality of the sound model used in a virtual instrument [7]. This because a haptic interface can establish a close and physical relationship with the instrument, while its absence can negatively impact the playability of it [14]. Even if researchers have developed several VRMIs [11] [10] [1], very few of them have considered the use of haptic interfaces [5]. We hypothesize that haptic in VRMIs should not focus on producing kinesthetic sensations, but on creating a more realistic and robust physical coupling between a player and a virtual instrument. When playing an instrument musicians get physically in touch with it, by triggering and manipulating sounds with their hands. That is in contrast to previous work, where researchers have looked at haptic feedback as a way of augmenting the auditory channel [12] through the use of vibrotactile [22] and force-feedback interfaces [6]. We think that in a VRMI a user gets in touch with the instrument as an *object*, not as a sound. It is through this *object* that the user generates sounds. Because of this, we consider that a haptic interface should facilitate a direct encounter with such virtual *object*, and make it a place for physical expression (Fig.1).

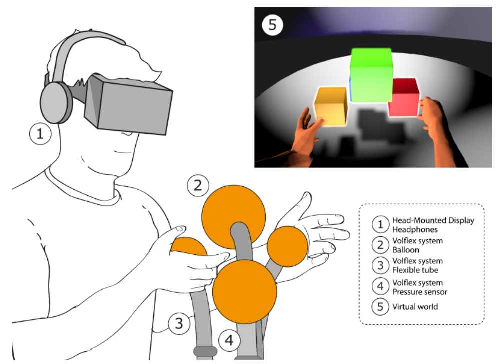


Figure 1: Proposal for an *Encounter-type haptic* interface for Virtual Reality Musical Instruments.

## 2 PREVIOUS WORK

In this section, we will introduce the background, motivations, and experiences that led to the current state of the research. The work done will be reviewed in chronological order.

*Deformable Interfaces*: The proposed research started with a work that the author developed during his graduate studies. Here the focus was to investigate tangible interfaces for musical expression. Inspired by an early VRMI [13], we examined the concept of *sound sculpting* through the design and evaluation of malleable interfaces. We aimed to reach a substantial coupling between input gestures and sounds through a material that can be directly manipulated by the user. In this sense shaping the material is an equivalent of shaping the sound. Deformable and malleable input surfaces have caught the attention of researchers in the areas of NIME (New Interfaces for Musical Interfaces) and Tangible User Interfaces as a powerful way to enhance expression and promote an active engagement with digital sounds. We explored such elements through the development of a novel deformable interface named SculpTon [2]. Such interface can provide passive haptic feedback, allow simultaneous control of musical parameters, direct manipulation, and expressive gestures (like press, squeeze, twist). Our results showed that such combination seems particularly relevant for musical expression. Other researchers have later confirmed our assumptions through a user study involving several deformable interfaces including SculpTon [20]. The exploration of such interfaces for music continued when the author worked in the context of the Metabody EU project[1]. However, because of their immovable physical properties, integrating such kind of tangible interfaces in VR is problematic. The absence of actuators makes them not suitable for presenting the shape of a virtual object. This consideration led us to look


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[1] http://www.albertoboem.com/index.php/project/metabody/

at the research on Shape-changing interfaces [15] and the concept of "Digital Clay" as an ideal reference point [8].

*Shape-changing Interfaces*: At the beginning of the doctorate course, the author started to investigate the use of shape-change to present digital information physically and promote communication among users. Through the design of "Vital+Morph" [4] and a consequent user study, we tried to understand how users relate and interact with shape-changing interfaces. Even if this project was not related to music, it helped to get better insights related to the design and evaluation of such kind of interfaces. We found that Shape-changing interfaces can convey to users a sense of aliveness and presence. However, they can also be perceived very invasive [3]. These two strands of research have some elements in common. We can summarize them by reporting two users comments: in the case of SculpTon was "*I feel I have a sound between my hands*", in Vital+Morph was "*Its like holding a human heart*". We concluded that a combination of deformable surfaces and shape-change could be a powerful way to enhance expressivity and create a more sense of presence in VRMIs. However, Shape-changing interfaces have been mostly used as physical displays, with a minimal possibility of direct interaction and haptic feedback. The need of coupling shape-change with deformable surfaces led us to look at other approaches.

## 3 Encounter-type Haptics: a promising approach?

In the field of VR several haptic systems and paradigms have been developed. Among them, *Encounter-type haptic* interfaces [18] [21] are aimed to facilitate direct and realistic contact between a user and a virtual object. In an *Encounter-type haptic* system is the interface that moves or deforms itself to simulate the shape and the characteristics of a virtual object [17]. The user gets directly in contact with a physical surface that approximates the virtual one. One example is the Volflex system [9], a volumetric haptic interface developed in our laboratory at the University of Tsukuba. Volflex can simultaneously represent the shape of a virtual object and the characteristics of its surface.

### 3.1 Volflex: characteristics and implementations

Volflex consists of a lattice of computer-controlled air balloons. Each balloon is composed of a non-expandable material and equipped with a pressure sensor, which can measure the amount of pressure applied by the user. Through a particular mechanism, it is then possible to control the volume and rigidity of the balloons separately. They then are then mounted on a series of actuated flexible tubes. With such system, it is then possible to change the position in three-dimensions of each balloon. Volflex can then approximate the geometry of a virtual shape, and at the same time can present to the user some characteristics of its surface, like rigidity and volume. At the moment, we are using the latest implementation of this system, which was assessed only in its technical components [19]. For realizing and testing our concept, we need to integrate Volflex in a VR system. Firstly, we need to get the position of the balloons in Cartesian coordinates to present them in a 3D virtual environment. Secondly, we must represent the balloons and their characteristics (volume, rigidity) as a 3D objects. We are considering different techniques. However, we aim to provide the more general solution possible. Thirdly, we have to present such visual elements through a Head-Mounted Display and combine them with user's hands and head tracking. For the moment we left out the discussion on sound generation techniques. We will consider them at a later stage.

## 4 Research hypothesis

To our knowledge, Encounter-type haptic interfaces have never been considered in VRMIs. Because of this, we have elaborated some hypothesis to guide our next steps through this research. We detailed our hypothesis in three macro areas of inquiry.

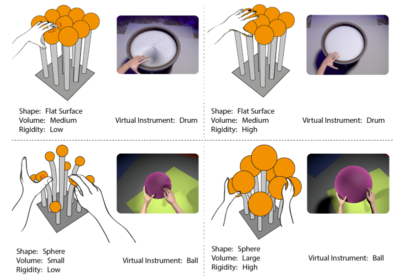


Figure 2: Two VRMIs represented through the Volflex interface.

First, with an *Encounter-type haptic* interface, a user can experience direct contact with a surface that represents a virtual object. We think that this can improve the sense of presence in a VRMIs. Also, the possibility of controlling surface properties, such as volume and rigidity, can provide a more compelling and realistic experience.

Second, through an interface like Volflex different virtual objects can be presented to a user physically. We believe that this can not only contribute to improving the sense of presence but the understanding and playability of the virtual instrument itself since a user can experience edges and geometry of the virtual object.

Third, *Encounter-type haptic* interfaces make users free from any constraints, such as additional hardware or loads. We think that this can impact the playability of a VRMI positively. Such separation between the interface and users mean that if they do not touch anything, nothing is displayed, and then felt. We believe the combination of these two elements can improve the sense of immersion and create a more realistic experience.

Besides, we should support such hypothesis through an investigation on how the use of an *Encounter-type haptic* interface can improve users expression (Fig.2). However, it is complicated to define what musical expression in a VRMI is, and how to measure it. We think that, in the case of a virtual instrument, the expression is related to the level of presence and playability of the instrument itself. For this, we are considering to develop a series of user studies inspired by both the research on NIME and VR. In the context of our investigation, this represents one of the next significant challenges.

## 5 Conclusion

We firmly believe that a fundamental aspect of the advancement of the field is the investigation of VR as a medium for artistic creation. However, the research on virtual musical instruments still represents a minority. Inside these few studies, haptic feedback and technologies are often left out. In our opinion, finding a satisfying way to engage the user physically can lead to more immersive and expressive creative experiences. In this paper, we have discussed different present and past projects that have tried to assess several elements of how to rethink the role of haptic feedback in a VRMI. We claim that *Encounter-type haptic* interfaces can positively impact the design and use of VRMIs. The proposed research presents a vast scope and builds up from different fields that are rarely combined. Because of this, the formulation of a precise topic for the Ph.D. thesis requires further narrowing down and identification of common and unique elements of the research as mentioned earlier projects and results.

## Acknowledgements

The author wants to express his gratitude to Prof. Hiroaki Yano, Prof. Hideaki Kuzuoka, and Ass. Prof. Yuuki Enzaki for their continuous support.

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