A web-based 3D environment for gestural interaction with virtual music instruments as a STEAM education tool

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ABSTRACT

We present our work in progress on the development of a web-based system for music performance with virtual instruments in a virtual 3D environment, which provides three means of interaction (i.e physical, gestural and mixed), using tracking data from a Leap Motion sensor. Moreover, our system is integrated as a creative tool within the context of a STEAM education platform that promotes science learning through musical activities. The presented system models string and percussion instruments, with realistic sonic feedback based on Modalys, a physical model-based sound synthesis engine. Our proposal meets the performance requirements of real-time interactive systems and is implemented strictly with web technologies.

Author Keywords

Leap Motion, 3D User Interface, Virtual Reality, gestures, web-based music application, physical-modeling sound synthesis, STEAM education

CCS Concepts

•**Human-centered computing** → **Web-based interaction;** *Virtual reality;* •**Applied computing** → *Sound and music computing;*

1. INTRODUCTION

Gestural interaction gained an increasing interest in applications such as 3D User Interfaces (3DUI) and Virtual Reality (VR). Their significance in the context of virtual interaction lies on realistic feedback, which is also refereed to as *"immersion"* [1]. However, most projects that experiment with virtual music instruments are platform dependent, while their setup is usually difficult to reproduce. In this sense, web technology standards, such as HTML5, provide a common framework for developing real-time and platform independent applications.

Our system combines modern web technologies and examines their potentials on supporting a cross-platform virtual 3D environment where the user would be capable of interacting in real-time with virtual music instruments. Our proposal promotes the aspect of musical expressiveness by providing realistic aural feedback based on a physical model-based sound synthesis engine called Modalys [2]. As a hand tracking system we employ the Leap Motion (LM) sensor, which comes with a JavaScript client library that can be integrated conveniently in any web application. The proposed system is part of a novel STEAM (Science, Technology, Engineering, Arts, Mathematics) education platform, that helps secondary education students to learn basic science principles, through creative and interactive music activities. For instance, a use-case includes the designing of 3D music instrument models based on mathematical principles, which can be performed in a virtual environment.

2. ARCHITECTURE OVERVIEW

The proposed architecture (Figure 1), consists of three main components; the first provides the environment in which the user designs 3D virtual music instruments by altering those parameters of the instrument that affect directly its sound (e.g. shape, string material and tension); the second component is the physical model-based sound synthesis engine that simulates the physical parameters of the virtual instrument; the third component is the 3D environment in which the user performs the virtual instrument by using the LM sensor. It takes under account the geometrical parameters of the designed instrument, in order to compute the corresponding interaction feedback between the captured hand motions and the virtual instrument. Gesture data are processed specifically and sent in real-time to the physical model-based sound synthesis engine.

Currently we model two instrument families, string and percussion. As for string instrument we consider a two stringed monochord instrument, where each string is divided by a bridge, resulting to four components. Regarding percussions we consider simple drum membranes with circular or square shape. An example of the design and performance environments are presented in Figure 2

The 3D Instrument Design environment enables the designing of 3D graphical models without requiring previous knowledge in graphics design. The proposed design system benefits from the web-port of the 3D modeling engine that

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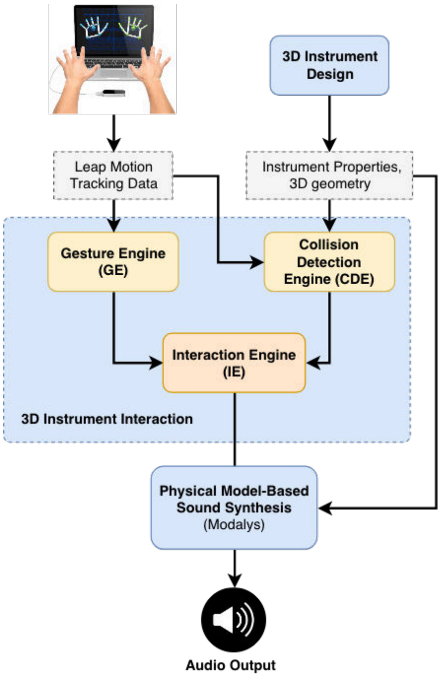


Figure 1: General overview of the system architecture.

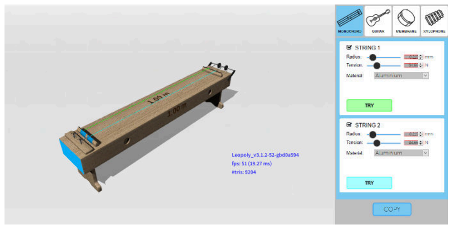
was made with emscripten[1] from C++ to JavaScript. Additionally, the 3D modeling engine is enabled to work with 3D printers and VR HMDs. Consequently, the physical model-based sound synthesis engine simulates in real-time the resulting sonic physical system by modeling the "object" resonances as linear combinations of modes. In order to integrate Modalys to our system, we used emscripten to port its code base from C++ to JavaScript.

The performance environment provides three modes of interaction, namely *Physical*, *Gestural* and *Mixed-Based* interactions, all three being encoded in the architecture that is presented in Figure 1. The input to the proposed method is the geometrical parameters of the instrument and the output data from the depth sensor. This information is fed to the two core components of the interaction environment, which are the Collision Detection Engine (CDE) and the Gesture Engine (GE). The CDE detects in real-time whether the hands collide with the instrument, as well as additional information such as the collision point, speed, direction etc. On the other hand the GE takes as input only the hands' data and detects if certain gestures are performed. The Interaction Engine (IE) module triggers the corresponding messages to Modalys, according to the specified interaction type, by taking as input the results of the CE and GE. Furthermore, the 3D performance environment was developed using the Three.js[2] 3D library, a mature and lightweight WebGL JavaScript library. A video demonstrator of the virtual instrument performance environment can be found in this URL[3].

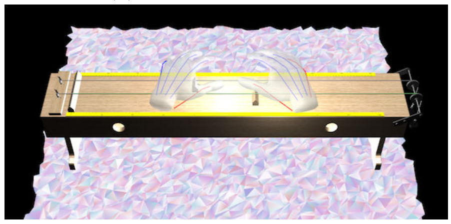
3. USABILITY TESTING

The evaluation of the 3D environment was mainly focused on the user experience of the interface, according to the feedback received from students between ages 13 and 16, during usability testings in the context of *iMuSciCA* project[4].

[1]`http://emscripten.org`
[2]`https://threejs.org/`
[3]`https://zenodo.org/record/1213560`
[4]`http://www.imuscica.eu/`



(a) Design Environment



(b) Performance Environment

Figure 2: The considered monochord instrument in: (a) The design environment; blue elements on the instrument model indicate the modular body parts; on the right, string materials and tension can be specified. (b) the performance environment.

These tests were carried out at schools in Belgium (11 students), France (10 students) and Greece (29 students), where participants were provided with a use-case scenario and its corresponding questionnaire, incorporating questions answered in a Likert scale from 1 to 5, regarding whether the user had an enjoyable experience, if the UI elements of the environment were accessible and intuitive, as well as whether the setup was audio-visually pleasing. Readers interested on the overall scope of the STEAM educational platform and its technical aspects are referred to the Work Packages documents hosted at the *iMuSciCA* home URL.

4. CONCLUSION AND FUTURE WORK

Preliminary results involving students from three different EU countries are promising, since their answers regarding the overall usability and design of the environment where positive. Since our system is still under development, future road map includes multiple tasks, including the addition of a xylophone and a bell, as well as optimizing the performance of the 3D environment by improving the GE with better interaction mappings and reducing the latency of the sound. A VR version of the environment is also under development.

5. ACKNOWLEDGEMENTS

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