

A Novel Human Interaction Game-like Application to Learn, Perform and Evaluate Modern Contemporary Singing: “Human Beat Box”

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Abstract: The paper presents an interactive game-like application to learn, perform and evaluate modern contemporary singing. The Human Beat Box (HBB) is being used as a case study. The game consists of two main modules. A sensor module that consists of a portable helmet based system containing an ultrasonic (US) transducer to capture tongue movements, a video camera for the lips, Kinect camera for face gestures, and a microphone for sound. A 3D environment game module is used to visualize a 3D recording studio as game world with all of its unique elements like guitars, mixer, amplifier, speakers and a microphone in front of the 3D avatar to simulate the recording ambience. The game also features a 2D virtual tutor to help the learner by giving oral and written feedback during the game. He also gives feedbacks during the practice session to improve the student’s performance. The game is still at its early stages of development and it is been tested using simple HBB plosive sounds for percussion such as “PTK”.

1 INTRODUCTION

The adoption of Serious Games (SGs), namely games expressly designed with explicit educational purposes (Breuer & Bente, 2010), in the teaching practice is a quite well consolidated trend in the Technology Enhanced Learning field. At present digital games are increasingly adopted to sustain learning and training in a variety of educational fields: school education as well as military and medical training, etc. (Bellotti, et al., 2012) (Graafland, et al., 2012) (Chatam, 2009). This is done for a wide range of target populations,

ranging from children to adults (Charlier, et al., 2012).

The use of digital games also is not new in the field of Cultural Heritage (Ott & Pozzi, 2008). As could be expected, games are more widespread in the Tangible Cultural Heritage (TCH) area, but a number of games have also been developed in the field of Intangible Cultural Heritage (ICH), where they are also considered very promising (Mortara, et al., 2014). The educational potential of games has been widely explored and highlighted by researchers within the wider research area of Game Based Learning. Beside

other important advantages, such as promoting learners motivation (Garris, et al., 2002) engagement (Susi, et al., 2007) and self-regulated learning (Zap & Code, 2009), games are also widely recognized as potentially adaptive to support the learning of procedures and gestures (and also of sequences of gestures, physical actions); in this flow, they are widely adopted in professional training (Martínez-Durá, et al., 2001). The i-Treasures project (i-Treasures, 2013) aims to exploit this potential of SGs in the ICH field: their capability of training motor skills and then the possibility to support sensorimotor learning for the teaching/learning of intangible cultural expressions, which are based mainly on procedural knowledge (namely, knowing how to do something).

Performing arts such as traditional or modern singing is usually learned under the supervision of a master or an expert. So it can be said that such features requires physical actions to survive as they are transferred through a master apprentice approach. A major objective of the i-Treasures project is to provide students with innovative multi-media human game-like application for sensorimotor learning feedback to train specific articulatory strategies for different type of rare singing, considered an endangered Intangible Cultural Heritage (UNESCO, 2012).

The i-Treasures project also includes research about a newly expanding contemporary singing style: the “Human Beat Box”, where the vocalist imitates percussive and drum instrument sounds. Beatboxing is a form of vocal percussion primarily involving the art of producing drum beats, rhythm, and musical sounds using one's mouth, lips, tongue, and voice. It may also involve singing, vocal imitation of turntables, and the simulation of horns, strings, and other musical instruments. Beatboxing today is connected with hip-hop culture, being one of "the elements", although it is not limited to hip-hop music.

The proposed game-like application is expected to help those who want to learn the basic of singing or even make a practice. The game will use 3D visualization techniques and tools to support the users in learning or mastering different type of singing styles. The domain knowledge of real masters will be transferred to the virtual tutor. Thus, the virtual tutor will be able to evaluate the user as a real master does.

2 GAME ARCHITECTURE

The game architecture of the system is shown in Figure 1. The system is composed of the following modules: Sensor input capture module, Communication module and 3D game environment module.

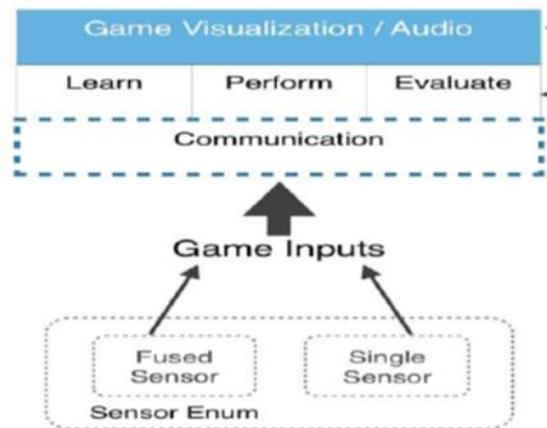


Figure 1: Game System Architecture.

2.1 Data Acquisition Module

One of the challenging tasks in developing the proposed game apprentice is to interface little known sensors in the game industry such as ultrasound. To meet the requirement, a portable helmet based system has been used to capture motor behaviour during singing and other oral-motor functions in a non-laboratory experimental environment (Al Kork, et al., 2014) (Chawah, et al., 2014) (A Jaumard-Hakoun, et al., 2013). The system, based on vocal tract sensing methods developed for speech production and recognition, consists of a lightweight “hyper-helmet” containing an ultrasonic (US) transducer to capture tongue movement, a video camera for the lips, and a microphone for audio capturing as seen in Figure 2.

Moreover, facial data are captured using a Kinect v1 sensor. Synchronized colour and depth image streams are used for facial feature tracking and recognition of facial action units based on an improved version of the approach presented in (Tsalakanidou & Malassiotis, 2010). This data is used to visualize the facial movements of the 3D avatars.

2.2 Architecture of the Communication Module

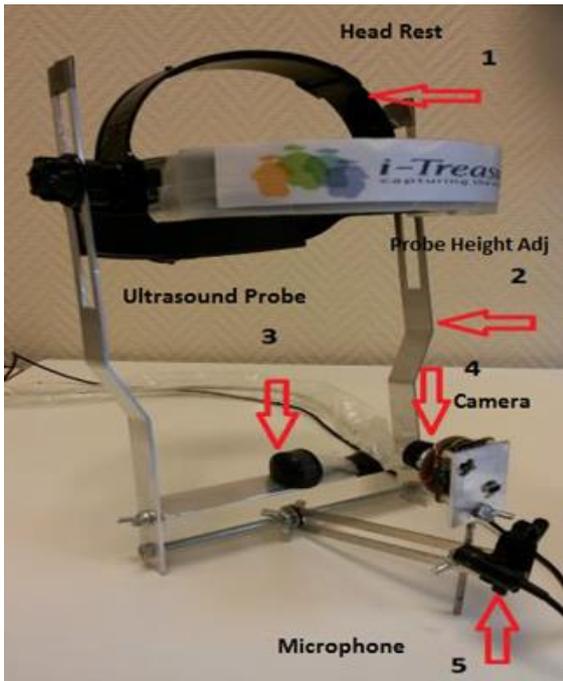


Figure 2: Multi-sensor Hyper-Helmet.

The communication module is responsible for providing bilateral data transfer between the sensors and the game. The application communicates with various external entities such as the hyper-helmet,

audio comparison and evaluation server. Figure 3 illustrates the communication architecture.

The module is capable of acquiring multiple video streams in real-time from the sensors of the hyper-helmet by using a third party sensor integration and controlling software called as RTMaps (S.A.-RTMaps, 2012). Thus the system actually communicates with RTMaps via Transmission Control Protocol. Besides video, the module also supports real-time transfer of the 3D Tongue Model's vertex positions. The module supports up to 60 fps data transfer either for video or 3D animation. The game also gets facial data from the facial expression data capture and analysis module using TCP/IP messaging. The communication module also lets the player control the data capture by sending relevant commands to the data capture system as well.

The sensor capture module also streams audio data from learners to an external server. This communication is done by a web service. This server provides the result of audio comparison to the game via web service. 3DSML communicates with LMS/CMS via web services. This communication covers user authentication, expert data download and learner performance upload. Currently only user authentication is supported in this first version.

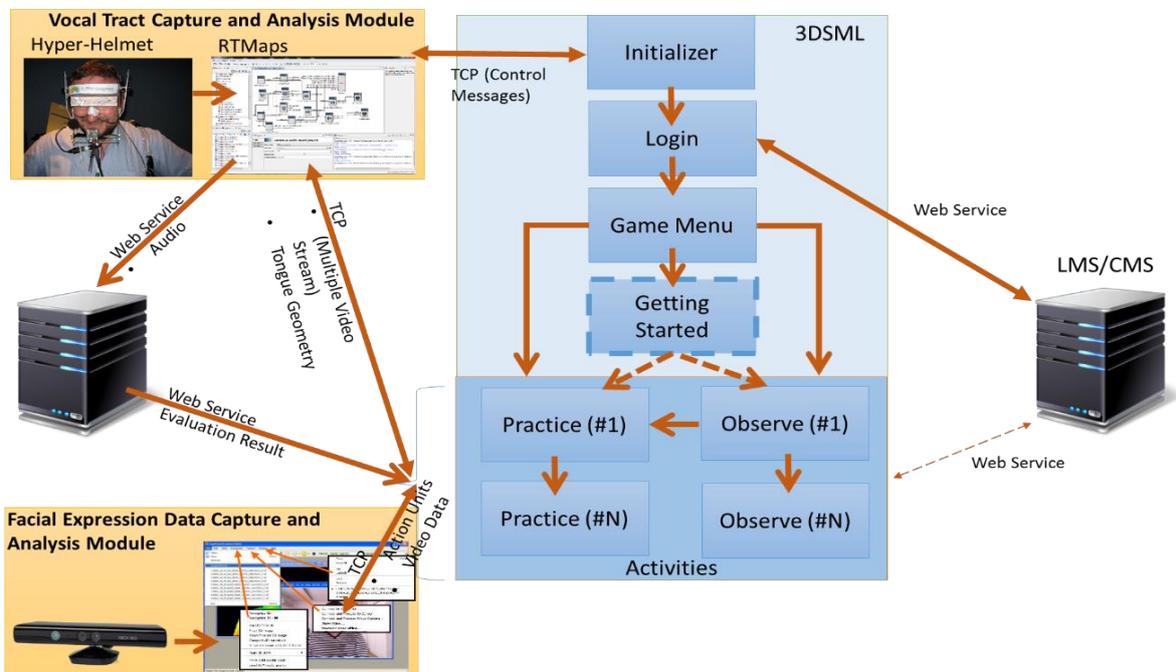


Figure 3: Communication Architecture of Singing Game-like Application.

2.3 3D Game Environment Module

The game module will basically provide an interface for students to learn, and practice HBB and it will also evaluate the performance and progress of the student. The performance of the student will be assessed based on his/her tongue movements and the pitch of the student's sound as compared to the expert's.

2.3.1 Learning Scenario

The Human Beatbox is an artistic form of human sound production in which the vocal organs are used to imitate percussion instruments, but also wind and string instruments. Therefore, facial and intra-oral movements of the tongue, lips and jaw are involved in sound production. The apprentice will be guided by some description of the sound to be produced and listening to the sounds to imitate them. These descriptions can be related to natural sounds such as imitating animal sounds or mouth noise.

The apprentice will also look at the mouth and tongue of the expert to try to produce different sounds. The rhythm is an important dimension in HBB and hand movement or a metronome can be added in the scenario. The HBB game will consist initially of a single lesson, where each isolated sound will be described and will be demonstrated by the expert and then imitated by the learner. The apprentice will go from one step to another until he succeed and finishes all the stages of the lesson. The Stages are described as follows:

Stage 1: Imitate the plosive sounds for percussion "PTK".

During this stage the student will repeat several times the three consonants at different rhythm, slow Pp; Tt; Kk...and fast... prolong each consonant, try to make an "echo" (Ppppp, Ttttt...). In reverse order KTp aiming in maintaining the rhythm and the speed of the articulators' movement and quality of sound Play with loudness P(loud) tk (whisper) and alternate pTk ; ptK The time it takes the student to perform this task will also be taken into account.

Stage 2: Introduce vowels.

During this stage the student will add a vowel (PTKki; Peu; Ti...). The vowels will be produced in loud and whispered mode.

Stage 3: Add sound effects and nasality.

During this stage the student will add other consonants (PTK e PT one = Wan ; Wa a wan...) make a fricative sound (Tsss ; Tsi ; Pfff ; Kiwi ...)

Stage 4: Succession of sounds, rhythms and loudness. The learner should practice each stage a number of times, and finally perform all the stages at once. Once the evaluation score of the student increases, he will be asked to make other sounds from other instruments and try to combine them in a harmonious way. The game will provide auditory and visual feedback. Figure 4 shows the learning progress approach of this game.



Figure 4: Learning Progress of the HBB Game.

2.3.2 Game Play

In order to develop the human beat box game, the following assets were prepared: a 2D virtual tutor, 3D avatars for expert and learner, a 3D tongue model and a 3D sound recording studio environment.

2.3.2.1 2D Virtual Tutor

The virtual tutor is a 2D illustrated NPC (Non Player Character), who is designed as a young male beat box artist. His role is to navigate and help the student by giving oral and written feedback during the game. He also gives feedback during the practice phase to improve the student's performance. Besides, he explains the sensors used in this game such as the components of the hyper-helmet during the getting started phase. The Virtual Tutor has five different states for different moods such as happy, explanatory, unsatisfied, neutral and not bad as shown in Figure 5.



Figure 5: 2D Virtual Tutor Moods in HBB.

The mood posture is selected by the system based on the student's performance during the practice phase.

In addition, all the written feedback provided by the virtual tutor can be configured via XML files, which ensures which ensures easy manipulation and multilingual capabilities. It is also possible to set the visual style of the expert throughout the game.

2.3.2.2 3D Expert and Learner Avatars

The avatars of the HHB expert and learner are prepared by using 31 bones for the face and a simple skeleton for the body. It is possible to map Face Action Units to these facial animation bones. Currently, we have prepared 52 blend shapes for the face. Blend Shapes, which is also known as morph target animation, is a popular computer animation technique mainly used for facial animation (Joshi, 2005). Even though this technique is very labour-intensive, it is useful for generating good looking animations. For the following versions of the game, we plan to mainly focus on lips, since the lip movement is quite important in singing, and produce more blend shapes for lips. In this way, it will be possible to visualize the lips more realistically.

3D expert and learner avatars are shown in Figure 6. Figure 7 shows the blend shapes and various interpolations used for the current version. The expert avatar is designed as a professional musician while the learner avatar is designed with casual clothes.



Figure 6: Expert Avatar (Left) and Learner Avatar (Right).

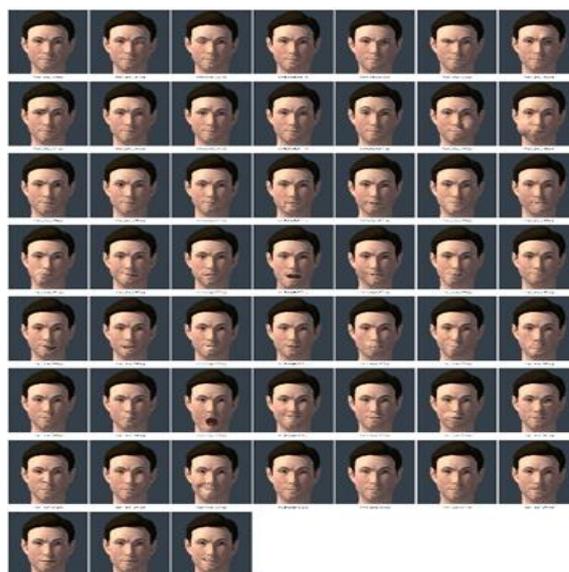


Figure 7: Blend Shapes Prepared for Face Modelling.

2.3.2.3 3D Studio Environment

A 3D recording studio is designed as the game’s world with all of its unique elements like guitars, mixer, amplifier, speakers and a microphone in front of the 3D avatar to simulate the recording ambience as shown in Figure 8.



Figure 8: 3D Environment of HBB.

2.3.2.4 User Interface

Distinctive parts of the beat box game are explained in this section.

2.3.2.4.1 Main Screen

As explained in section 2.3.1, there are four *Activities*. Each activity has two different options, which are “observe” and “practice”, and also a “Getting Started” activity, which serves as game tutorial, as shown in Figure 9. The user can click the “Observe” button to observe the expert performing or click the “Practice” button to start practicing the beat box himself. A short description of each activity is provided on each activity panel, so that the learners can track the content of the selected activity. Under each activity description, there is a progress bar that represents the success rate of the student. Activity 2, 3 and 4 are locked and this is represented with a key lock on the related panels, because of the fact that the progress of the student is not enough to unlock further activities. Activity 1 is also locked at the beginning. However, when the user completes the “Getting Started” the first activity is unlocked without any further process. All of the description texts, buttons, labels etc. are configurable via the configuration XML.

2.3.2.4.1.1 Getting Started

When the student clicks on the “Begin” button of the “Getting Started” panel of the Main Menu, the tutorial of the beat box game starts. The main purpose of the “Getting Started” is to teach the basics of the game to the student. To do so, the 2D virtual tutor explains each user interface element and how to use them to play the game. The 2D virtual tutor comes up from

bottom left of the screen to say what will happen next as shown in Figure 10.

Afterwards, tutorial continues with the explanation of the techniques, which are used for giving feedbacks to the student in beat boxing, respectively; (a) Tongue position, (b) Using ultrasound for tongue movement, (c) Description of the tongue-air interface, (d) Ultrasound image of tongue, (e) The tongue model. This is shown in Figure 11.

The tutorial proceeds to observe screen as illustrated. Virtual tutor continues with the explanation of observe screen elements respectively; (a) 3D avatar, (b) Animation player, (c) Expert video clip, (d) Ultrasound image of the tongue, (e) 3D tongue model. Then 2D virtual tutor navigates student to practice tutorial. This tutorial works exactly like observe tutorial. 2D virtual tutor explains each element on the screen in plain text and verbally. In practice tutorial, 2D virtual tutor describes each element respectively: (a) Animation controller of practice section, (b) All other views on the screen.

Thereafter the virtual tutor explains the usage and functionality of the sensors and software used in this game. It is planned to include video tutorial for the sensors that are not well-known and not easy to use. In this way it is believed that the user will have the required knowledge. When the “Getting Started” ends, it is expected from student to continue to play the game-like application to learn and improve his knowledge about human beat box.



Figure 9: Game Main Menu Screen of HBB Game.

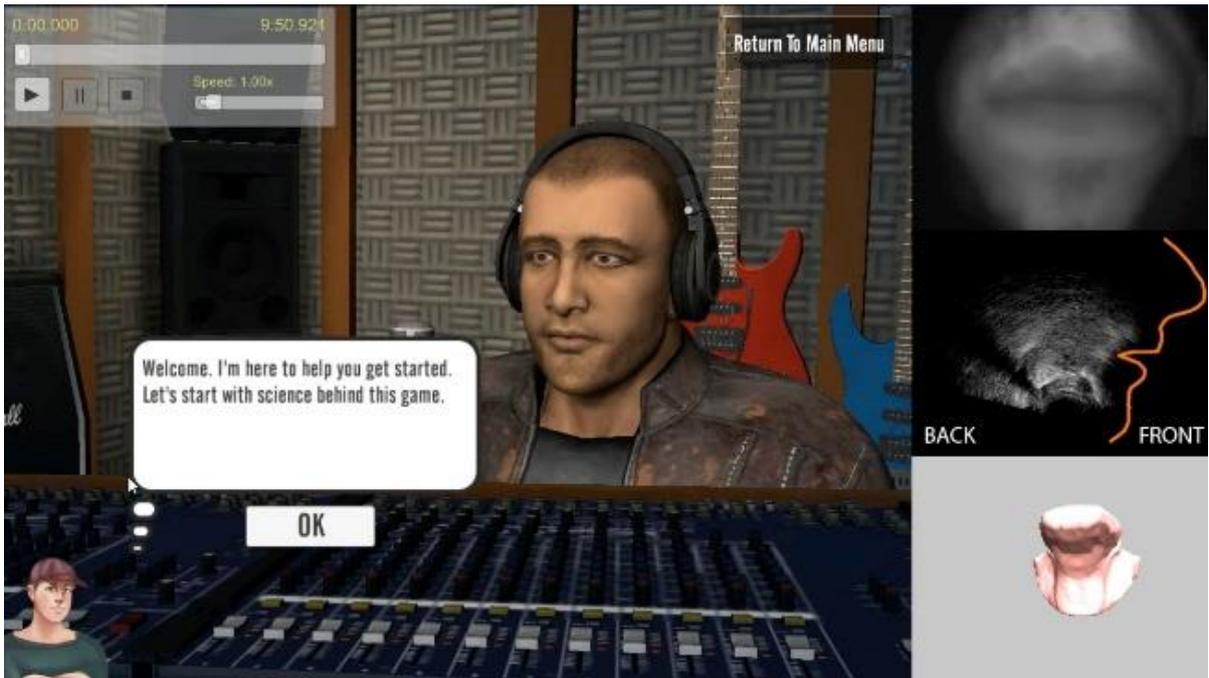


Figure 10: Tutorial beginning of HBB Game with 2D virtual avatar.

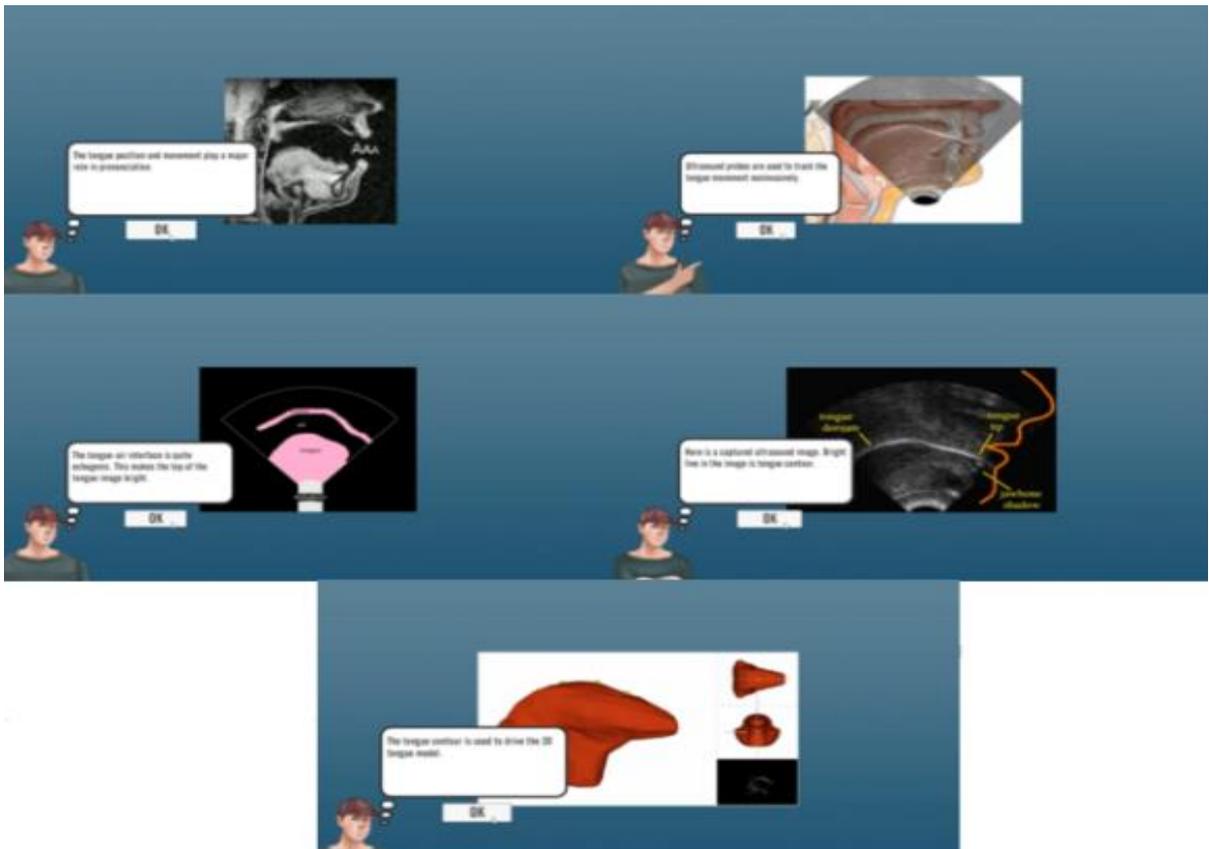


Figure 11: Illustrations of HBB Game Components.

2.3.2.4.1.2 Observe Screen

All of the four activities in this game have an observe scene, which shows the performance of the expert captured by various sensors. The aim is to let the user observe the details of each performance before s/he starts the practice. All of the sensor outputs and recordings are synchronized. These outputs are all controlled by the animation controller, which is located at the bottom center of the screen as shown in Figure 12. The Observe screen consists of different visual and functional elements such as the animation player, expert lip video (window on right top corner), ultrasound image of the tongue (second window on the right) and 3D tongue model view (window on bottom right corner) as shown in Figure 12. There are also several windows on the right part of the screen that show the outputs of different sensors.



Figure 12: Observe Screen of HBB Game.

It is possible to determine which sensor output windows will be displayed via configuration XML. Another important aspect of the observe screen is the way we can change the size of the windows. By default, the 3D recording studio is displayed as the big central view. However when the user double clicks on any window, the views are changed and the selected window is displayed at the big central window as shown in Figure 13.

Throughout the observe phase, the 2D virtual tutor comes up

from the bottom left of the screen and explains the HBB sounds to the student. The text of the virtual tutor's narration can be modified via the XML file. The features of the observe screen are all described in the following sections.

2.3.2.4.1.3 Animation Player

The student controls the animation of the expert lip/face video, expert tongue ultrasound video, 3D tongue model and 3D expert avatar through the animation player. These are all synchronized. It should also be noted that the audio is also synchronized with these data. The user is free to control both the 3D expert avatar and tongue model by using a freely navigable camera. The animation player has "Play", "Pause" and "Stop" buttons like most of the video players. The animation can be rewind or forwarded. The speed of the animation can be controlled as well. The total time of the animation

and video with the current time position on the animation timeline is also provided as labels on the animation player.

2.3.2.4.1.3.1 Expert Video Lips

The expert video is provided at the top right of the observe screen. This video shows either the lips or face of the expert. Currently, only the lips video is provided. However, we can display any type of video content. It is also possible to change the video content

in real-time if both the lip and face videos are available.

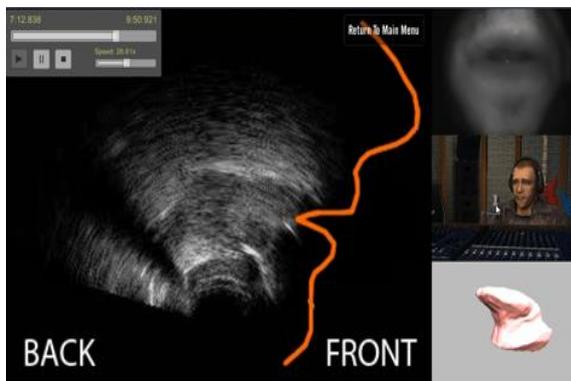


Figure 13: Maximized window of 2D Tongue Ultrasound mid-sagittal view.

2.3.2.4.1.3.2 Expert Video (Ultrasound)

The observe screen provides the ultrasound sensor video output which is captured by the “hyper-helmet” system. The user is expected to observe the upper contour of the tongue on the mid-sagittal plane. The video shows the movement of the tongue during singing. In this window a face silhouette and directional info are provided to help the user to easily distinguish the tongue movements. These features are drawn as an overlay.

2.3.2.4.1.3.3 3D Tongue Model Visualization

The observe screen provides the 3D interactive tongue model (Kele Xu, et al., 2014) which shows the animation of the tongue of the expert. Our simulations use ArtiSynth (J. E. Lloyd, et al., 2012), a 3D finite mesh model of the tongue consisting of 14,000 nodes. In Figure 14, six nodes (yellow points) are chosen as anchor nodes corresponding to the hyoid bone and the short tendon as discerned in the ultrasound image. These anchor nodes are held fixed during the simulation. We must then set several constraint nodes (green points) lying on the mid-sagittal contour in the ultrasound images, in order to drive tongue motion. The assumption is that the behaviour of the 3D model will be approximately correct if the movement of the driven 2D sagittal points is correct. Linear constraints on 3D movements can be integrated into an Euler-Lagrange equation using the Lagrange multiplier method. In Figure 15, the smaller images next to the main 3D display show two ultrasound frames, from which displacements are calculated. These displacements are then passed to the constraint nodes

on the 3D tongue model mid-sagittal surface in order to drive the model.

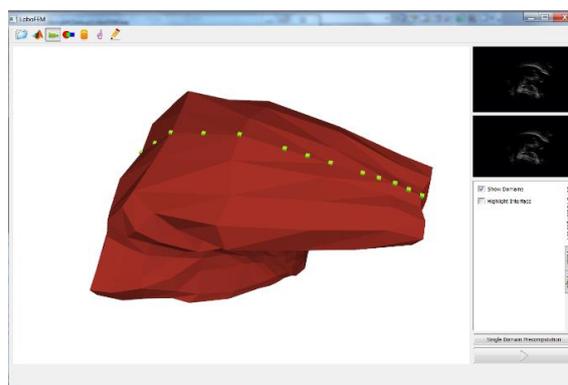


Figure 14: An overview of interface for the proposed system.



Figure 15: Six Anchor nodes (yellow nodes) on the tongue mesh at the rest position and Constraint Nodes (green nodes) on the mid-sagittal contour at the rest position of tongue model

Currently, we visualized and presented the same tongue model used in ArtiSynth in Unity 3D as an interactive window. The learner can freely navigate this tongue model. It is possible to change the view to top, lateral etc, and to zoom in and out. The research to transfer animation results to the game environment is still under progress. However, the technical implementation for tongue animation has been completed; thus, in future versions the game will display the full tongue animation. The system has been tested with simulation data and real time data streaming. Figure 16 shows the highly detailed 3D tongue model which is made of 14,000 vertices.

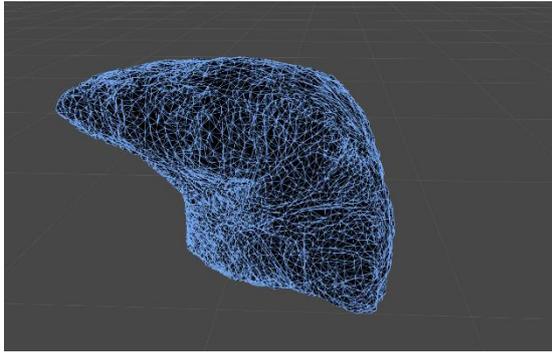


Figure 16: 3D Interactive Tongue Model in Game Environment

2.3.2.4.1.4 Main Window-3D Expert Avatar

This 3D virtual environment represents a recording studio. In this environment, the user is free to navigate by using the virtual camera. The face of the avatar is animated by using the data derived from the Kinect sensor through the facial analysis software. This animation is also synchronized with the rest of the other sensor outputs.

2.3.2.4.1.4.1.1 Sound Progress Window

The sound that the expert imitates is shown at the center top as shown in Figure 12. Here the plosive sounds P/T/K are visualized. It should be noted that this text is also synchronized with the other outputs. This text and the length are also defined in the configuration XML. The played part is highlighted with green to show the current location of the performed sound.

2.3.2.4.1.5 Practice Screen

All of the four activities in this game have a practice scene enabling the learner to practice the selected activity. The practice scene shows the 3D avatar at the center screen, the sensor data of the expert on the right panel and the sensor data of the player on the left as shown in Figure 17

Similar to the observe scene, the sensor data windows are all configurable. Thus, whenever it is required to simplify the scene, some windows may not be displayed. This can be easily set via the configuration XML. The practice starts with the introduction of the virtual tutor. After providing some basic instructions, the virtual tutor asks the user to get ready and counts down. The learner imitates the requested sound.



Figure 17: Practice Screen of HBB Game.

After the performance is completed, the recorded sound is sent to the remote server that is responsible of audio analysis and comparison. This server receives the audio file including the sound produced by the learner and compares it with the corresponding expert sound (which is part of the Human Beat Box experts' database). Following the completion of comparison, the software generates a detailed text file that contains the similarity ratio, sub-parts and corresponding similarities etc. This text file is send back to the game via web-service. This output is used to evaluate the performance of the learner. It should be noted that this remote evaluation takes very short time and it does not introduce any lag or latency. This evaluation approach was designed for the first version of the game However, in future versions there will be improvements regarding this approach and more information will be taken into account by the evaluation algorithm such as the position of the tongue, the opening of the mouth, etc.

After getting the evaluation result, the virtual tutor provides feedback about the performance of the learner by using the corresponding grading text, e.g. *"You need to improve! Let's do it again!"*, *"Good performance! Just needs a little bit more!"*, *"Outstanding performance! You are ready for the next activity"* etc. The animation controller in the practice screen is used to record the learner's performance and repeat it whenever needed.

3 CONCLUSIONS

A first version of an interactive game-like application to learn, perform and evaluate modern contemporary singing focusing on the Human Beat Box case study was developed in the context of the i-Treasures project. The game integrates several state-of-the-art

sensors such as Kinect for facial data capture and a prototype multi-sensor hyper-helmet for vocal tract capture. It provides a user-friendly interface including an engaging 3D recording studio environment and singer avatars and visualizes a variety of sensor outputs on user demand. A virtual tutor guides the user through the game and provides real-time feedback for the evaluation of the user's performance in different singing activities.

The developed game framework is capable of providing bilateral communication with external sensors and third party sensor control software such as RTMaps. The framework supports UDP and TCP/IP based network communication as well as web services. More sensors can be included in the system without additional effort. Besides communication utilities, the framework enables game designers and domain experts to configure the application easily by setting the fields of an XML file.

4 FUTURE WORK

An updated version of the HBB game is currently under development. We plan to update the game design, improve the game play and integrate learning analytics so as to increase user engagement and improve the game's educational effectiveness. We also plan to focus more on educational aspects, since without meeting specific educational targets, the final output will be more a technology demonstration rather than an educational tool.

From a technical perspective, we plan to integrate Kinect v2 in future versions. This sensor will help us to better visualize and animate the lips and the face. We also plan to develop a mobile version of this game, mainly intended for observation and learning rather than practicing HBB.

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