HoloKeys: Interactive Piano Education Using Augmented Reality and IoT

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Figure 1: Augmented Reality User Interface (left) and Piano Playing Apparatus (right)

ABSTRACT

The rise of online learning poses unique challenges in music education, where live demonstration and musical synchronization are critical for student success. We present HoloKeys, a music education interface which allows instructors to play remotely located pianos using an augmented reality headset and wifi-enabled microcontrollers. This approach allows students to receive distance education which is more direct, immersive, and comprehensive than conventional video conferencing allows for. HoloKeys enables remote students to observe live instructional demonstration on a physical keyboard in their immediate environment just as they would in traditional settings. HoloKeys consists of two separate components: an augmented reality user interface and a piano playing apparatus. Our system aims to extend online music education beyond desktop platforms into the physical world, thereby addressing crucial obstacles encountered by educators and students transitioning into online education.

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1 INTRODUCTION

Remote music education poses challenges for teachers and students alike. In a recent survey of more than 400 music educators, nearly 70% reported struggling with remote instruction [3]. Educators face difficulties in maintaining student motivation, with teachers remarking that lessons don't "feel real" [8] and students characterizing online learning as "too indirect"[7]. Music education requires live demonstration and player synchronization, which is difficult to achieve in remote settings [5]. Conventional piano lessons involve a teacher playing near the student, then immediately encouraging imitation [5]. Conversely, remote piano instruction typically relies on single-camera video conferencing. This restricts the student's view of the instructor's live demonstration on the piano, and can obscure the keyboard itself.

In this paper, we present HoloKeys: a piano education interface which allows remote instructors to demonstrate playing technique on a physical piano collocated with the student by utilizing augmented reality (AR) in conjunction with low-cost microcontrollers and actuators. HoloKeys aims to extend remote music education beyond desktop-based learning into the physical world.

2 RELATED WORKS

The use of AR technologies in piano instruction has expanded in recent years. Haung et al. [4] designed PianoAR in 2011, a training application which utilizes AR to overlay a virtual instructor's hands on the student's keyboard. Building on this work, Chow et al. [1] designed an AR piano training interface for novice students that overlays visual note indicators on a physical keyboard. Recently, Das et al. [2] and Molero et al. [6] explored gamification features in AR piano training.

Although existing research provides valuable insights into piano interface design for remote learning, most prior work in AR piano instruction targets single users. Notably, Wang [9] recently presented a collaborative VR piano training tool using haptic gloves to track student finger movements. Despite the strengths of this design, the necessity for students to obtain exotic equipment diminishes its applicability in typical use cases. HoloKeys instead provides an inexpensive collaborative learning system that functions with the keyboards students already own. This allows students to observe a remote instructor's live demonstration on a collocated physical piano.

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3 HOLOKEYS

HoloKeys addresses critical issues encountered in traditional remote education while preserving its most important features. Our system aims to enhance the quality of remote piano lessons by increasing student immersion, enabling direct physical demonstration and supporting comprehensive observation of technique. While using HoloKeys, the instructor sees a holographic copy of the student's piano presented on their AR headset. The instructor uses gestures to play the holographic keys, which presses a corresponding key on the real-world piano simultaneously.

4 SYSTEMS OVERVIEW

HoloKeys transmits real-time event data generated on an AR headset to IoT development boards through PubNub. HoloKeys was developed in Unity engine and Arduino IDE, making use of the Magic Leap, the ESP8266 microchip, the PCA9685 servo driver board, and an array of MG995 servo motors. The Magic Leap collects user interaction data through Lumin SDK's Hand Tracking functionality, while the hardware configuration physically moves keys on the connected piano.

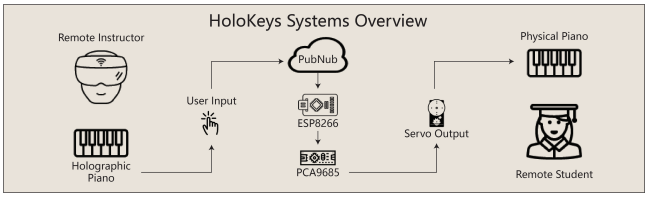


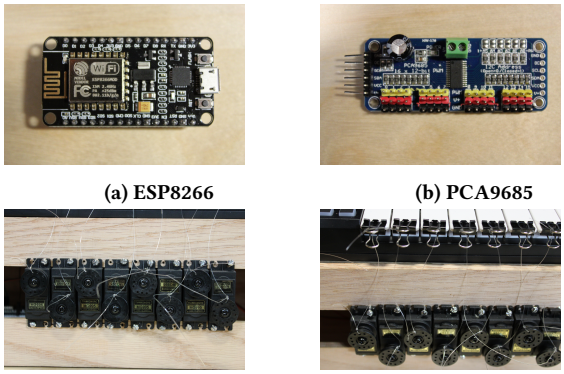
Figure 2: HoloKeys Systems Overview Diagram

4.1 Mixed Reality User Interface

HoloKeys user input mechanics are coordinated through the Magic Leap. When the user initializes the HoloKeys application on the Magic Leap, the device connects to the real-time communication API PubNub. Lumin SDK's hand-tracking functionality is also initialized on start, which uses the Magic Leap's cameras to actively check for hand-gesture input. The user is presented with a 3D model replica of the real-world piano overlaid on the physical environment through the Magic Leap display. When the user extends their hand towards the piano, a raycast is generated which extends to the nearest key. The key becomes highlighted upon raycast hit, indicating that it can be played. The user then performs a "pinch" gesture while the desired key is highlighted, which triggers a key press event. An animation plays on the displayed piano, depressing the selected key. Concurrently, the Magic Leap publishes a message on PubNub indicating that the selected key has been pressed. The displayed piano then returns to its initial state, and the user is free to select other keys.

4.2 Piano Playing Apparatus

The apparatus HoloKeys employs to physically play the remotely located piano is composed of a microcontroller development board (Fig. 3a), a servo driver board (Fig. 3b), eight servo motors (Fig. 3c), a clip system which attaches to the piano key (Fig. 3d), and



(a) ESP8266 **(b) PCA9685**

(c) Servo Motors **(d) Clip System**

Figure 3: HoloKeys Piano Playing Apparatus Components

an external power supply. These are coordinated through code written in the Arduino IDE and operating from the microcontroller. The ESP8266 wi-fi enabled microcontroller serves as the bridge between the input device (Magic Leap) and the output devices (servo motors). It issues commands to the PCA9685, which then instructs the attached servos to pull the piano keys down before returning to the initial position. The servomotors are mounted on a frame, allowing them to remain stable while applying force to the piano key. This also allows the system to remain portable and customizable, for easy application on any piano keyboard.

5 FUTURE DIRECTIONS

To assess the potential impact of this tool, our team has established outlines for user testing. A sample of 10 piano instructors and 10 piano students over the age of 18 will be recruited from the University of Florida School of Music. Participants will have been involved with remote piano education within the last year. Participants will test the app for a period of 15 minuets, then will be prompted to freely respond to evaluation questions. Following the user testing session, an oral, semi-structured question-and-answer session lasting an additional 15 minutes will be administered. Interview sessions will be recorded, transcribed, and subjected to semantic analysis by the research team. The interview data will then be used to establish improved design guidelines in order to polish the online music learning session.

HoloKeys has a variety of applications in the domain of music education. Remote education is one of the primary use cases for this technology, where students and teachers alike benefit from the enhanced capacity to share educational experiences at distance. HoloKeys can also be employed in special needs education, where students with visual impairments are particularly likely to benefit.

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