EMPiano: Electromyographic Pitch Control on the Piano Keyboard

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Figure 1: EMPiano offers a seamless integration for piano playing to add a soft pitch vibrato to played notes. Electrodes (purple) capture muscular activity allowing the system to recognize corresponding activation gestures.

ABSTRACT

The piano keyboard offers a significant range and polyphony for well-trained pianists. Yet, apart from dynamics, the piano is incapable of translating expressive movements such as vibrato onto the played note. Adding sound effects requires additional modalities. A pitch wheel can be found on the side of most electric pianos. To add a vibrato or pitch bend, the pianist needs to actively operate the pitch wheel with their hand, which requires cognitive effort and may disrupt play. In this work, we present EMPiano, a system that allows pianists to incorporate a soft pitch vibrato into their play seamlessly. Vibrato can be triggered through muscle activity and is recognized via electromyography. This allows EMPiano to integrate into piano play. Our system offers new interaction opportunities with the piano to increase the player's potential for expressive play. In this paper, we contribute the open-source implementation and the workflow behind EMPiano.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**.

KEYWORDS

Electromyography, expressive piano play, seamless integration, piano interaction.

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1 INTRODUCTION AND BACKGROUND

The piano is a popular musical instrument, and its keyboard is a well-established interface. Yet, it still lacks opportunities for adding effects to the notes played. Adding effects is desired by piano players and has already been explored in research [4, 10] and commercial products (e.g. *Neova*[1]). Today, most electric pianos provide a variety of auxiliary inputs (cf. *Nord Stage*[2]) allowing the player to add, among others, pitch bends and vibratos. However, this introduces an additional modality and usually fully occupies one hand of the player during the modulation.

Research has already investigated alternatives to hand-operated controls in pianos. For example, Mcpherson and Kim [8] equipped an acoustic grand piano with electromagnetic actuators above the strings for sound modulations, and a modified Moog Piano Bar for key positioning [8]. This system allowed for fixed keyboard gestures such as deliberate aftertouch, sweeps, and vibratos. In another work by McPherson et al. [9], a sensor system was added to the surface of the keys of an electric piano [9]. These sensors responded to finger actions, enabling two different gesture movements, triggering vibrato and pitch bend effects. This work allowed the use of finger gestures that lay within the task language of the musical play, integrating seamlessly into the playing process. Players were able to use specific gestures - common to stringed instruments - to modulate tones. Commercial products that make use of these techniques are already available as well, e.g., the *Seaboard RISE*[3].

However, these approaches require modification of the instrument and only allow for fixed gestures to trigger the modulations. Karolus et al. [7] showed that electromyography (EMG) could successfully be used for detecting specific musical gestures and potentially avoid the challenges above. An EMG-based system can be tailored towards the user, calibrating gestures to their individual needs while not requiring alteration of the instrument itself. EMG has already been employed for musical performances [2, 3] and evaluated in terms of gesture expressivity [1].

Consequently, EMPiano draws on the possibilities offered by EMG sensing. By measuring the pianist's muscle activity, we aim to augment the user rather than the instrument. Additionally, EMPiano provides the benefit of using any desired finger or hand gesture for the modulation. The user is free to choose what works best for them and their play style. We evaluated our system in a user study and found that people enjoyed using EMPiano and found it intuitive to use their muscles to trigger the pitch vibrato [5].

In this paper, we contribute the design and implementation of EMPiano, a system that allows pianists to incorporate a soft pitch vibrato into their play, by leveraging muscle activity, captured via EMG. We contribute the system as an open-source software toolkit[4] that (1) allows users to self-calibrate activation gestures for pitch modulation and (2) offers a live mode for interactive piano play.

2 EMPIANO

The EMPiano system uses EMG as a secondary input channel for the interaction with the piano keyboard [5]. EMG meets a lot of user requirements for such a system. First, necessary measurement electrodes are sufficiently comfortable to wear and do not hinder the play. Secondly, EMG is accurate enough to reliably detect finger gestures with sufficiently low latency. These finger gestures can fit within the same muscle movement of the standard piano play, minimizing play interruptions, which constitute a significant issue with standard pitch wheels. Finally, EMG provides flexibility in terms of the detectable gesture space and the possibility to be used on any instrument. During the calibration, any finger or hand gesture can be trained to trigger the modulation, and the sound effect itself can be reprogrammed. Leveraging electromyography allows EMPiano to function as an extension for the pianist, not limiting play by restricting the player to using one hand or specific finger gestures.

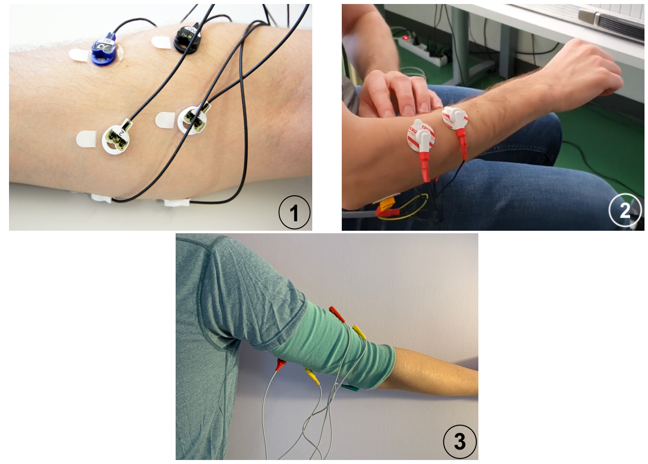

Figure 2: Different electrode setups. BrainVision LiveAmp[5] (1), EMBody [6] prototype setup with adhesive electrodes (2) and integrated into sleeves (3).

The EMPiano system is designed to be easy to use for anyone who owns the required hardware: an electric piano and any set of electrodes (see Figure 2). For detailed information about the hardware and electrode setup, please refer to the manual on GitHub[4]. Once these necessities are met, both the system's GUI and the manual on GitHub guide the user through each step of modulating with EMPiano, from selecting an appropriate EMG input stream to performing the calibration procedure. Here, EMPiano offers a calibration functionality that allows users to define their activation gesture. The calibration is available in two modes: a video calibration mode where the user plays a given piece and a custom mode where the user actively tells the system when they want to modulate. In the background, our system performs the filtering and classification steps. These features allow EMPiano to make EMG-based piano interaction available to non-experts and beginners. The implementation is open-source[4] and optimized for both Windows and macOS.

Implementation

The implementation of our system is based on the setup shown in Figure 3. The Recording PC captures and sends the EMG stream into the network via *Lab Streaming Layer* (LSL)[6]. The EMPiano system runs on the Controlling PC, grabbing the EMG data from the network. Additionally, the Controlling PC handles the audio playback through a music software that interprets the MIDI signal. Note that Recording and Controlling PC may be the same device.

[1]https://www.enhancia-music.com/neova/
[2]https://www.nordkeyboards.com/products/nord-stage-3
[3]https://roli.com/products/seaboard/rise-49
[4]https://github.com/HCUM/empiano
[6]https://github.com/sccn/liblsl

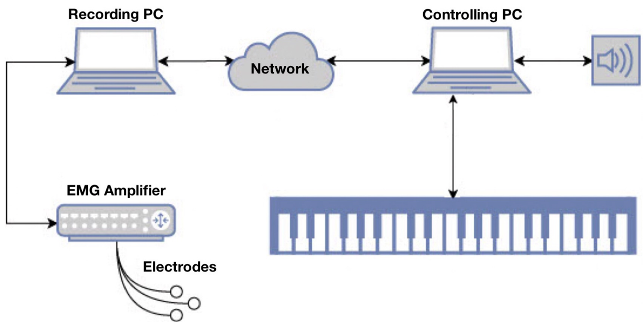

Figure 3: Hardware setup of EMPiano, consisting of a recording unit (electrodes and amplifier) and a recording PC streaming data into the network. A controlling PC takes care of audio playback from the keyboard and engages pitch modulation when detected.

We implemented the EMPiano system by playing back the piano sound via a music software and having our system perform the recognition of the finger gestures. Modulation is then implemented by sending pitch-wheel messages to the music software.

Both calibration modes track the ground truth of performing the chosen finger gesture. The video calibration requires the user to play a simple one-handed piece and modulate at notes marked in red (see Figure 4). The custom calibration allows the user to play freely and modulate whenever they want, but the modulation has to be tracked using the GUI's button. During the calibration phase, the software provides a wizard that guides the user through the calibration. The video calibration can be easily performed without any help from a third person and has a total duration of fewer than two minutes. Both calibration modes can be reset and restarted should any mistakes occur.

After the calibration, we employ a support-vector machine (SVM), using a radial basis function kernel to train the binary classification (sound effect ON/OFF). One feature vector consists of the last three sliding window features[7], where, for one window, the RMS (Root Mean Square) values of each electrode channel[8] plus their pairwise ratios are calculated. Please refer to the algorithm described in the original paper [5] for further details.

After training the SVM, EMPiano allows the user to activate the live mode. In this mode, the electrodes will continue to pick up the muscle activity and send it to the program via LSL. Once our system receives enough samples, the classifier predicts whether to engage the modulation. If so, EMPiano sends additional MIDI messages with oscillating pitch values via a virtual MIDI cable to the music software. Apart from the MIDI signals coming from the piano, the music software now additionally interprets the incoming pitch messages, resulting in the desired pitch vibrato.

Our system offers an open implementation, which means that any finger or gesture can be used. In our studies, moving the thumb in a vertical motion was most effective. We recommend using a medical-grade recording setup for best accuracy, but off-the-shelf consumer devices provide a sufficient signal-to-noise ratio. Our system's complete source code is available on GitHub[4], offering extension points for players and researchers. To better illustrate the workflow of using EMPiano, we provide a typical scenario for the system.

[7]The size of one window can be adjusted in the settings, and is initially set to 150ms worth of data [5].

[8]The number of electrode channels can be adjusted in the settings, and is initially set to 8 [5].

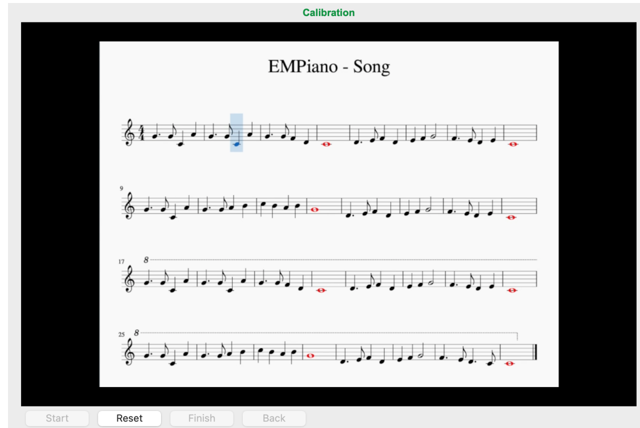

Figure 4: Video calibration functionality of EMPiano. The blue marker provides a playback orientation, while red notes signal for the pianist when to use the activation gesture.

3 EMPIANO—A USAGE SCENARIO

Meet Thomasio, an amateur piano player who desires to add more expressiveness to his play, as he knows it from other stringed instruments. Simply replicating songs no longer lives up to his standard, so he is looking for an easy way to add a vibrato sound effect to his play without having to use the pitch wheel on the side of his electric piano. Thomasio finds the EMPiano system on GitHub and decides to download the source code. Luckily, he finds an old EMG/ECG shield for his Arduino and asks a friend who works in the medical sector for some electrodes.

As described in the manual, Thomasio connects all hardware parts. Having done that, he starts sending electrode data over an LSL-stream. Further, after testing the playback of the electric piano using his favorite music software, Thomasio is ready to start the EMPiano system. The first thing Thomasio does is checking and adjusting the settings, especially the number of channels used. Regarding all the other settings, he trusts the program and its suggestions. The next time Thomasio will open the program, he will find that all adjusted settings were saved and are recalled whenever the program is launched.

Thomasio proceeds by connecting EMPiano to the LSL-stream of his electrodes. Here, EMPiano displays an overview of all available LSL streams in his network. Since Thomasio only has one EMG stream running, he quickly selects the only available stream. The program double checks whether the number of electrode channels in the settings is consistent with the number of channels found in the stream. On the next GUI page, Thomasio gets to know both calibration options and decides to perform the video one. First, he plays the song in the video calibration together with a forth-and-back wiggle motion performed with his right thumb. During the calibration, he then plays the given song at the given speed and performs the thumb gesture at notes marked in red. Since it is Thomasio's first time playing the song, he uses the reset-function of the calibration until he is satisfied with his performance. Afterward, he finishes the calibration and starts the live system. He is now able to add the pitch vibrato to his regular play by merely performing the back-and-forth wiggle motion of the thumb, as he defined the gesture during the calibration. He now enjoys the freedom of having a simple way of adding expressiveness and personality to his play. Thomasio decides to include the EMPiano calibration song into his practice routine, allowing him to easily calibrate for EMPiano-enhanced play when he desires it.

4 CONCLUSION

EMPiano presents an alternative way of increasing the piano keyboard's expressiveness, without modifying the instrument itself [5]. The system offers a pitch vibrato sound modulation on the piano, which increases its expressive range. The sound effect can be triggered by the muscle activity of the pianist. EMPiano can offer a broad finger gesture space by using EMG, allowing individual activation gestures for users. This characteristic can be used for implementing more gestures mapped to different sound modulations and a wider range of possible finger gestures. Hence, EMPiano is not only an easy way for amateurs to add expressiveness but also a proficient tool for experts. Consequently, we publish EMPiano as open-source software. We hope that this work can help establish EMG as a key modality in musical interaction and inspire music enthusiasts and researchers.

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