Reach, a keyboard-based gesture recognition system for live piano sound modulation

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ABSTRACT

This paper presents Reach, a keyboard-based gesture recognition system for live piano sound modulation. Reach is a system built using the Leap Motion Orion SDK, Pure Data and a custom C++ OSC mapper[1]. It provides control over the sound modulation of an acoustic piano using the pianist's ancillary gestures.

The system was developed using an iterative design process, incorporating research findings from two user studies and several case studies. The results that emerged show the potential of recognising and utilising the pianist's existing technique when designing keyboard-based DMIs, reducing the requirement to learn additional techniques.

Author Keywords

Gesture recognition, augmented piano, sound modulation, computer vision, Leap Motion, Pure Data

CCS Concepts

•Human-centered computing → Gestural input; Activity centered design; •Applied computing → *Sound and music computing;*

1. INTRODUCTION

Pianists spend years crafting and refining their instrumental technique. When placed in front of keyboard-based DMIs they are often required to adapt or learn new gestural techniques to operate them. For pianists, as discussed by Nicolls [4], this turns out to be the most disruptive element of keyboard-based DMIs: learning a new gestural language while retaining pianistic control or freedom. Reach is a keyboard-based DMI with a low degree of invasiveness that utilises pre-existing technique, aiming to foster creativity and reduce the learning curve required for formally trained pianists at a first encounter.

2. BACKGROUND

The ability of performers to communicate through their instrument depends on the fluency the performer has with the instrument itself [7] . Fluency, in this case, is seen as a combination of technical proficiency and expressive charisma, which in turn depend on the time spent practicing an instrument and ways of incorporating ancillary movements that are known to convey expressiveness in musical performance [6].

In recent years, a number of innovative keyboard interfaces have been developed that range from augmented keyboard interfaces to redesigns of the traditional keyboard interface. The ROLI Seaboard [3] redesigns the keyboard interface entirely by turning discrete sound activators into a continuous controller with a touch responsive silicone slate. The TouchKeys [5] augments an existing keyboard's interface by covering the keys with capacitive sensors.

Alongside these two commercial devices a number of prototype devices exist. One such device is the system developed by Yang & Essl [9], providing the pianist with multi-axial gesture controls over audio processing of the keyboard sound using a combination camera based hand detection and visual projections. Another device is the PiaF [10] that combines machine learning with camera based technology to recognise body gestures providing control over audio processing parameters, noting how a pianist's interpretation is communicated through both the sound produced as well as body gestures. The ancillary gestures used in this research show potential for the intuitive control of audio processing with movements not directly related to sound production. Reach develops this concept further focusing entirely on ancillary hand gestures, as a means of manipulating sound processing.

3. THE SYSTEM

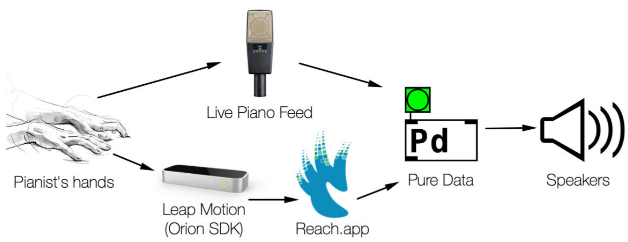

Figure 1: Flow chart describing the Reach System

The Reach system uses a custom-made homonymous application, written in C++ using the JUCE framework and Leap Motion's VR oriented Orion SDK [2], to capture hand tracking data from the Leap Motion. The Leap Motion is placed approximately 30cm above the piano keyboard, where positional data is tracked by Reach, encoded and transmitted as OSC messages. The OSC transfer protocol has been chosen over MIDI because of its ability to transmit data with a higher resolution, thus maintaining a higher level of precision when mapping gestural data to sound mod-

[1]`https://github.com/NiccoloGranieri/Reach`

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ulation parameters. This tracking data, coming from the joints of the fingers, palms and wrists, is then received by a Pure Data patch, where it is mapped to sound modulation parameters.

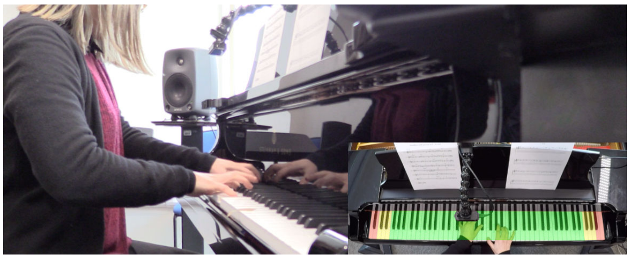

Figure 2: Lateral and eagle eye view of Reach with colour coded detection areas.

The Orion SDK's high level of precision negates the need to de-noise the incoming data. Peak detection audio analysis was performed on the incoming piano signal in Pure Data. When a note was struck, the positional data received from the Leap Motion was 're-centred', meaning that no audio modulation would occur unless the hand moved away from the current position after striking a note. If the hand moved and a key was struck, the process repeated. This prevented constant and erratic behaviour in the audio processing. The Reach system has a fixed set of gesture-sound effect couplings which are described in the following section.

4. GESTURES & MAPPINGS

The Reach system recognised three gestures, each mapped to a different audio processing parameter. These gestures were: the lateral swaying of the hand after a key had been pressed; the vertical movement of the hand after a key had been pressed; and the distance of the hands from the keyboard surface.

The lateral swaying of the hand after a note had been played was mapped to a pitch-shifting algorithm ranging +/- 75 cents of a tone. The centre of the back of the hand was tracked by the Leap Motion where movements to the right raised the pitch and movements to the left lowered the pitch.

The vertical movement of the hands when a key was depressed was mapped to the amplification of the unprocessed piano signal. As the height of the back of the palm and knuckles lowered, amplification of the unprocessed signal decreased, with amplification increasing as the height of the hand was raised. Perceptually, this created an effect similar to amplitude modulation.

The vertical movement of the hand away from the keys controlled a reverb effect. As the pianist moved his or her hands vertically away from the piano, reverb was applied to the live piano sound.

Of the three gestures recognised, the lateral swaying of the hands had also been previously investigated in the first iteration of user testing [1]. From the qualitative analysis of those interviews, the lateral swaying of the hands resulted in being very easy for both classical and jazz pianists to understand and embody due to the close correlation with the gesture performed by string players to obtain a similar effect. This ancillary gesture had previously been noticed by most of them in their own playing.

In the same interviews, pianists expressed interest in being able to modulate the intensity of the piano sound just like string players. Taking into consideration the research of Tits et. al. [8] regarding the correlation between eigenmovements and expertise of the pianist, a mapping between palm height and volume of the unprocessed audio of the piano was chosen.

The vertical movement of the hands away from the keys, was chosen to explore an additional touch-free gesture nature of the sound modulation. This gesture was discovered and explored by a pianist which can be seen in the following recorded performance[2].

5. APPLICATION AND FUTURE WORK

To date the system has been explored by four musicians who have all created performances with it exploring the gesture sets provided by the system[3]. Moreover, in multiple user tests the system has been explored by eighteen pianists, ranging from classical to jazz, that provided useful insight for the development and refinement of the system.

What has emerged from this feedback is how interfaces that exploit ancillary gestures can be successfully used by pianists and keyboard players to intuitive manipulate audio processing parameters at a first encounter.

Taking this research forward, larger user studies could be conducted further examining the tacit findings of the research to date.

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[2] Aria alla Francese - `https://youtu.be/gzLTwMbGjxM`

[3] Video playlist - `https://www.youtube.com/playlist?list=PL8pOR8QNT3sSFIatGuEWYGBRYYSNlyj9P`