Gesture Extraction for Music Performance

CMSC 199: UNDERGRADUATE SEMINAR

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Abstract

Music, in its nature, is bound by time. Even musical recordings cannot replicate one thing: the performance itself. Thus, gesture extraction and digitization techniques have been developed not only to preserve the performance, but also to enhance it. This seminar aims to discuss several systems used to capture gestures in musical performance for a variety of applications.

History of Gesture Extraction in Music

Radio Baton/RadioDrum

- Developed by Max Mathews and Bob Boie (AT&T Bell Labs) in 1985 and further improved with Andrew Schloss (University of Victoria) and Tom Oberheim.
- Originally meant as a three-dimensional mouse-like device, but later converted into a music controller. (Turi, 2014)

Fig. 1: Andrew Schloss Performing with the RadioDrum

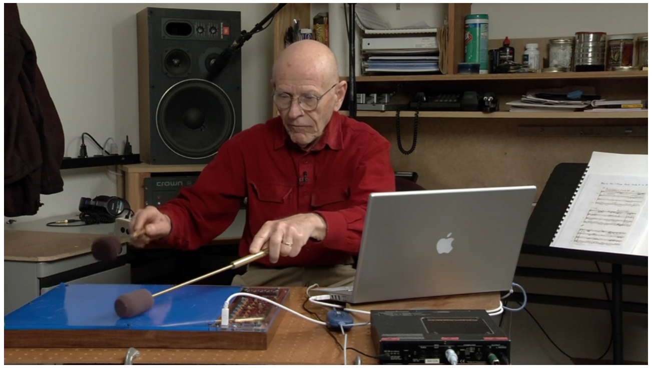

Fig. 2: Max Mathews demonstrating the Radio Baton

Radio Baton/RadioDrum

- Senses locations of two baton transmitters along the X, Y and Z coordinates over a drum surface of receiving antennae over time using the capacitance between the drum and batons (Schloss, Boie, & Mathews, n.d.)
- Primarily used as either a drum instrument or as a controller for a musical piece, similar to a musical conductor's role (Turi, 2014)

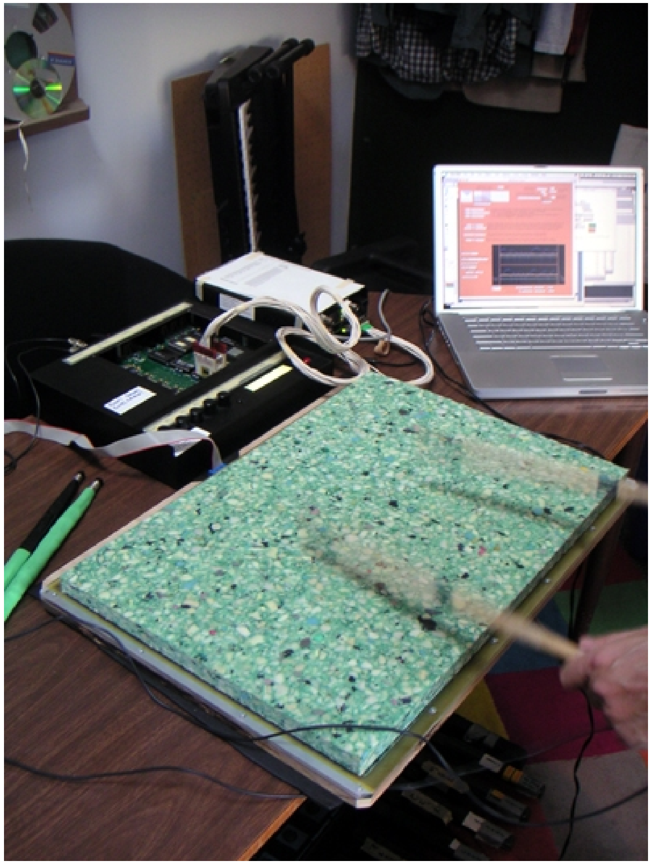

Fig. 3: The RadioDrum/Radio Baton

Motivation for MIDI

- Rise of synthesizers in the late 70s and early 80s
- Issue: different manufacturers produced different interfaces for their own synthesizers

MIDI's Predecessor

- 1981: Universal Synthesizer Interface (USI)
- Proposed by Dave Smith and Chet Wood (Sequential Circuits) to the Audio Engineering Society
- Used 1/4" phone jacks with a bandwidth of 19.2 kBaud (kbps)

Birth of MIDI

- Dave Smith met with Ikatura Kakehashi (Roland) at 1982 Winter NAMM (National Association of Music Merchants) Show
- Musical Instrument Digital Interface (MIDI), improved USI
- added opto-isolation circuit to reduce interference
- expanded bandwidth to 31.25 kBaud (kbps)
- First MIDI instruments: Sequential Prophet-600 synthesizer keyboard and Roland JP6 synthesizer keyboard

Fig. 4: Sequential Prophet- 600 (top) and Roland JP-6 (bottom)

Overview of MIDI's features

- 16 channels
- simultaneous note playing through polyphony and channel pressure
- pitch bend
- communication with controllers
- ability to change sound patches
- rhythm controls
- song playback

Fig. 5: MIDI 5-pin ports

Keyboard Capture Devices

Buchla Piano Bar

- Created by Don Buchla in 2002 and produced by Moog Music Inc. (History, 2017)
- Allows MIDI capture for traditional pianos without permanent modifications
- Scanners detect notes played and the velocity of which they were played
- A scanner bar is placed above the piano keys, and a separate sensor is placed under pedals. (Mowat, 2004)

Fig. 6: The Buchla Piano Bar installed on a grand piano

Real-Time Fingering Detection System for Piano Performance

- created by Yoshinari Takegawa, Tsutomu Terada, and Shojiro Nishio of Osaka University
- designed to capture expressiveness of piano fingering playing in real time without interfering with the performance
- inspired by lack of fingering information on standard music notation
- primarily useful for piano technique instruction
- The system does not interfere with piano performance
- Musical rules for piano playing are used to correct the results of fingering detection

Real-Time Fingering Detection System for Piano Performance

- Differently colored markers are attached on fingernails.
- System detects color markers captured by camera by extracting HSV values
- System takes input from a MIDI keyboard when the user is playing a key
- Some simple rules on fingering correction are used to correct discrepancies between the input and the graphically detected fingering.

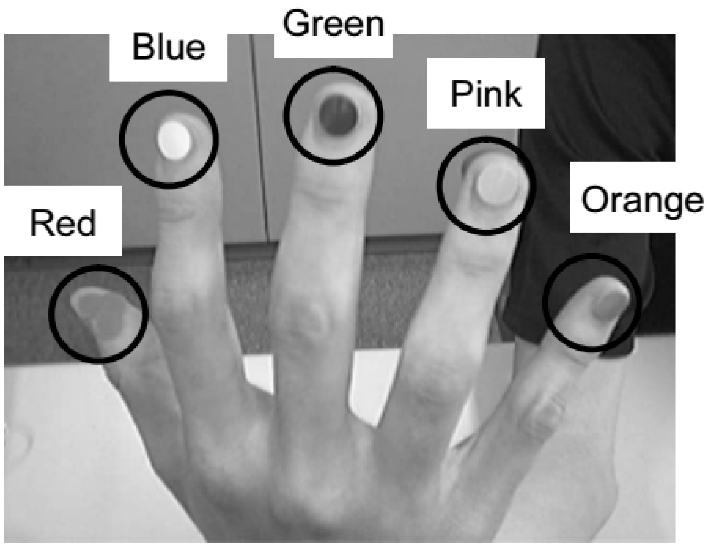

Fig. 7: Colored Markers placed on fingers

Rule 1: The horizontal order of fingers 2 to 5 does not change

- Fingers 2 (index finger) and 5 (little finger) do not cross over to each other in the list of possible marker configurations (Orderly Markers Groups)

(1, 2, 3, 4, 5)
(2, 1, 3, 4, 5)
(2, 3, 1, 4, 5)
(2, 3, 4, 1, 5)
(2, 3, 4, 5, 1)

Real-Time Fingering Detection System for Piano Performance

Rule 2: The keying finger does not change from pressing the key to releasing the finger from the key.

- A finger should not be detected again in another key

Rule 3: Piano players usually use the same finger for the same pitch tones that appear at a nearby site.

- If Rules 1 and 2 cannot be applied, assume that the previous finger used in a note is the same

Rule 4: The same musical structure usually takes the same fingering

- After applying Rules 1 to 3, the system recognizes similar musical phrases. A repeated phrase, checked from the history, should presumably have the same fingering. (Takegawa, Terada, & Nishio, 2006)

Drum Capture Devices

Roland V-Drums

- A line of electronic drum kits produced by Roland since 1997 (Roland Corporation, n.d.)
- Currently uses their custom multi-element sensor system to capture the full dynamic range of drum playing with minimal latency (Roland Corporation, n.d.)

Fig. 8: Roland V-Drums TD-50KV drumkit

E-Drum (Part of the E-Drumset)

- Created by Adam Tindale (University of Victoria) in 2009
- Aims to capture expressiveness of drum playing by following these design requirements:
  - Position Tracking
  - Flexibility
  - Expandability
  - Programmability
  - Openness

Fig. 9: Adam Tindale performing on the E-Drumset

E-Drum (Part of the E-Drumset)

- Makes use of piezo-electric transducers as they are commonly used with commercial electronic drumsets
- Chose mesh head pads instead of rubber pads to better capture subtler responses from brushes and scrapes
- Gesture mapping system allows for use of brushing and scraping gestures by utilizing timbre recognition to extract position data. This allows for more responsive data without outside controllers like sliders or knobs and the use of subtler playing techniques like sweeps (sliding from one drum to another) and the use of a brush. (Tindale, 2009)

E-Drum (Part of the E-Drumset)

- Timbre Recognition
  - Signal processing, feature extraction and classification through neural networks
  - Pre-processing: input is segmented and normalized/gated
  - Feature extraction with Marsyas (Music Analysis, Retrieval and Synthesis for Audio Signals): Features from different analysis functions turned into feature matrix for classifier
  - Classification with Weka: artificial neural network verified with k-Nearest Neighbors and Support Vector Machines

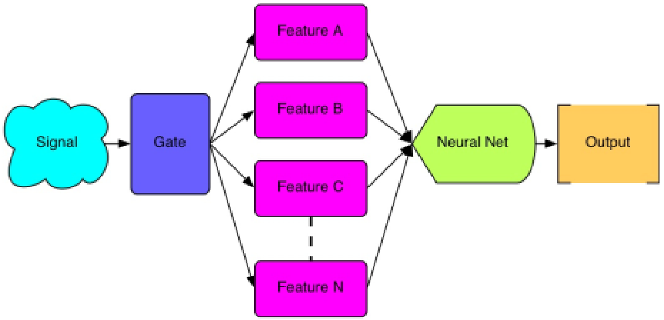

Fig. 10: Layout for data processing and classification

String Capture Devices

Fishman TriplePlay

- Released in 2014 by Fishman Transducers, Inc.
- A wireless guitar-to-MIDI system
- Uses a hexaphonic magnetic pickup for note input
- Wirelessly transmits MIDI data to a USB receiver

Fig. 11: The Fishman TriplePlay MIDI pickup installed on an electric guitar

ESitar

- created by Ajay Kapur (University of Victoria) in 2007
- an effort to digitally capture the intricacies of Sitar playing and enhance Sitar performances by installing sensors into a modified Sitar
- inspired by the death of Ustad Vilayat Khan, a master of Sitar, in 2004

Fig. 12: Ajay Kapur with the ESitar Electronic Sitar Controller

Esitar: Hardware

- PIC 18f2320 microcontroller
  - 8-bit
  - CMOS Flash-based
  - 256b EEPROM
  - C compiler friendly
  - i/o functions (buttons and switches)
  - analog-to-digital converters (convert sensor information)
  - 2 pulse width modulators (motors and solenoids)
  - AUSART serial communication pins (Addressable Universal Asynchronous Receiver Transmiter) (Microchip Technology, Inc., n.d.)
- power regulation
- sensor conditioning circuits
- MIDI out
- enclosure behind sitar's tuning pegs

Fig. 13: The controller module behind the sitar's headstock

Esitar: Gesture Capture

- Frets are detected by measuring the voltage drop between the strings and a network of military grade resistors (1% tolerance) soldered to holes drilled into the frets. The note played is determined by using a lookup table mapping the fret/string combinations and is sent as a MIDI message.
- Bends are detected using a piezo-electronic pickup attached to the tumba (body). Its output is sent to ac pitch detector. The system can detect up to eight half-tones above the original fretted tone.

Fig. 14: Close-up of ESitar frets

Esitar: Gesture Capture

- Mizrab pluck direction and some rhythm information is determined using a force-sensing resistor placed under the thumb detecting the differences in pressure in the rha (upstroke) and ra (downstroke). The data is sent throuch a continuous MIDI stream.
- Pluck time is determined by two condenser microphones attached on the soundboard (tabli) above the sympathetic strings bridge (ara), one near the steel strings and another near the copper strings. An envelope detector determines how long the strings are plucked, and the microcontroller sends the data as a MIDI message.
- The controller box contains a three-axis accelerometer to capture the sitar's movements, which may indicate the start or end of a passage. Another accelerometer is attached on a headset to collect head tilt information, which can be used to determine rhythm.

Fig. 15: Force-sensing resistor used to detect plucking motions

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Resources

Images:

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