

Augmenting the Piano Keyboard: From the Lab to the Stage

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Types of augmentation

Performance Sensing



Quantify the performer's gestures with new sensors

Acoustic Actuation



Manipulate the instrument's sound electromechanically

Gesture-Sound Mapping

performer's reaction

Motivation

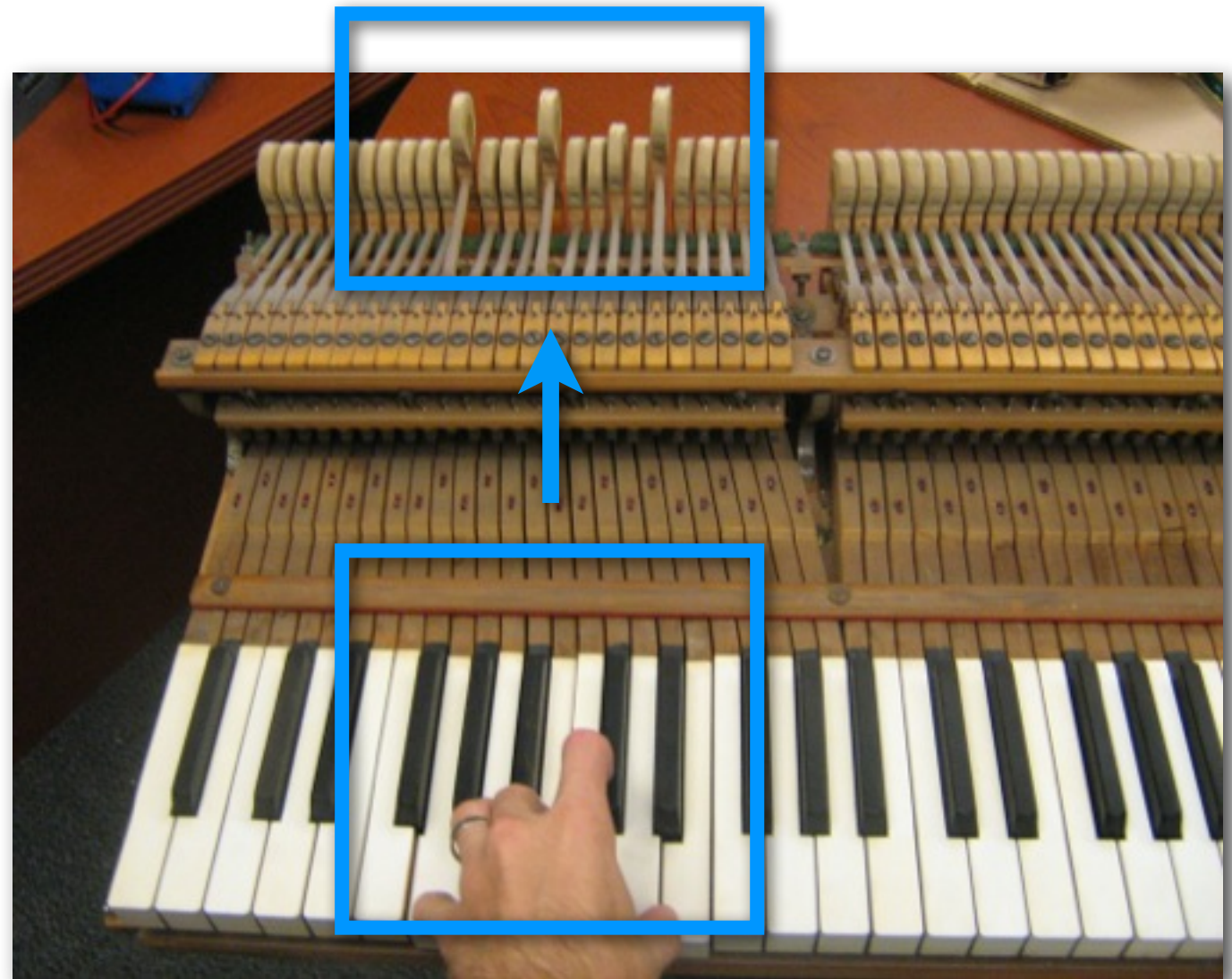
How do we play this...



...on the piano?

The piano is a discrete instrument

...cause hammers to strike strings



Keys pressed...

No continuous note shaping

Magnetic Resonator Piano

Electromagnetically-augmented acoustic piano



Electromagnetic string
actuation

Gesture-sound
mapping

Continuous key position sensing

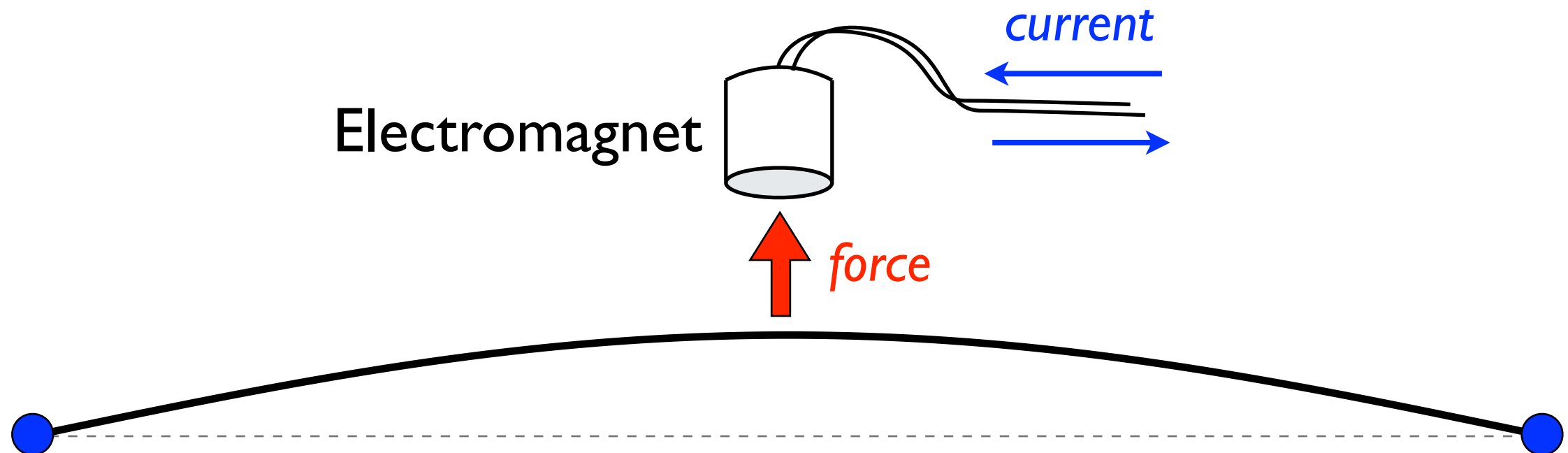
The magnetic resonator piano

Continuous note shaping on the acoustic piano

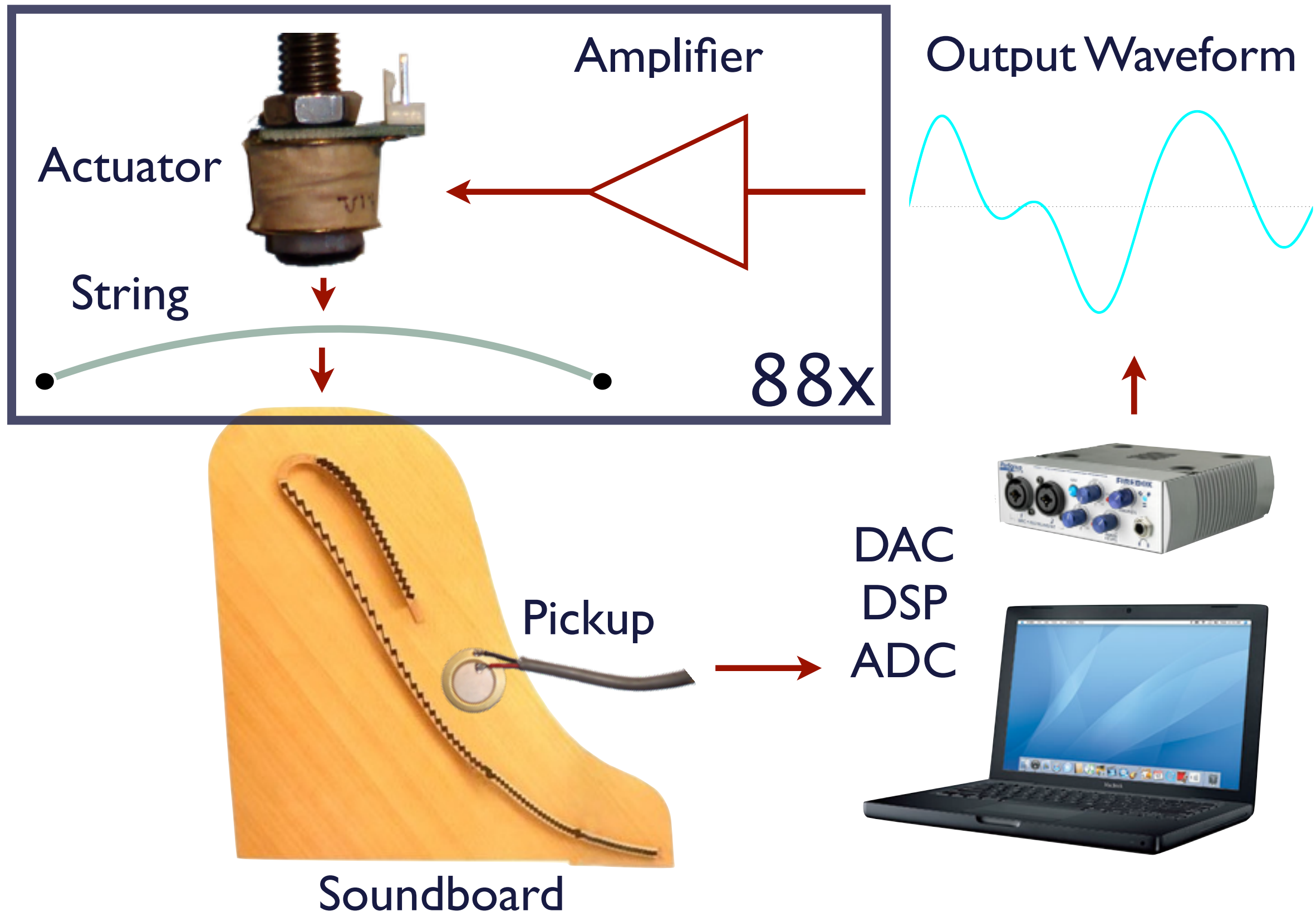


Basic principle

- Magnetic fields exert a force on certain objects
 - **Time-varying** fields exert a time-varying force
 - Time-varying force will cause an object to vibrate
- Use of **electromagnetic actuators**
 - Magnetic field relates to electrical current
 - Manipulate the instrument with a time-varying current



MRP: actuation



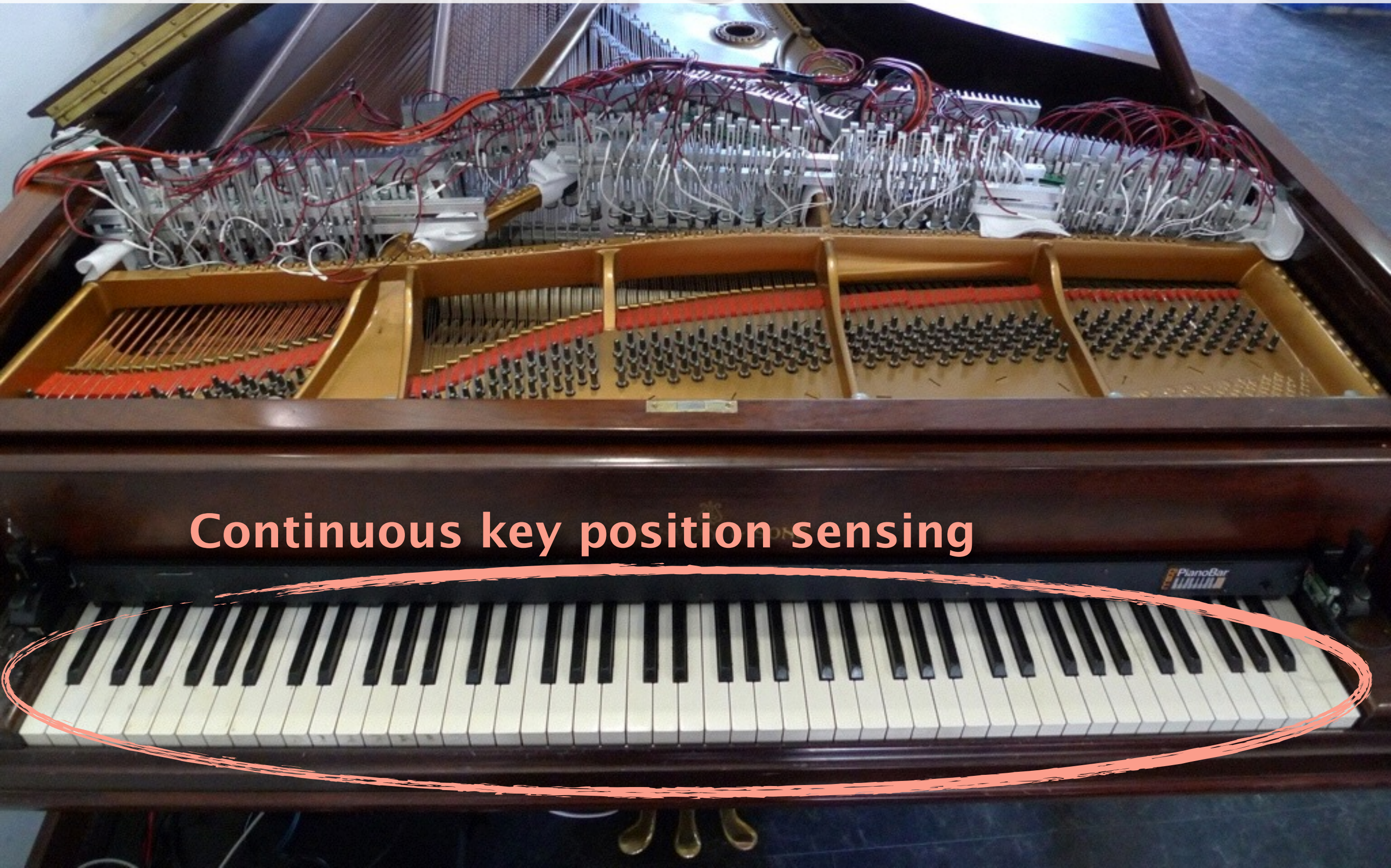






Magnetic Resonator Piano

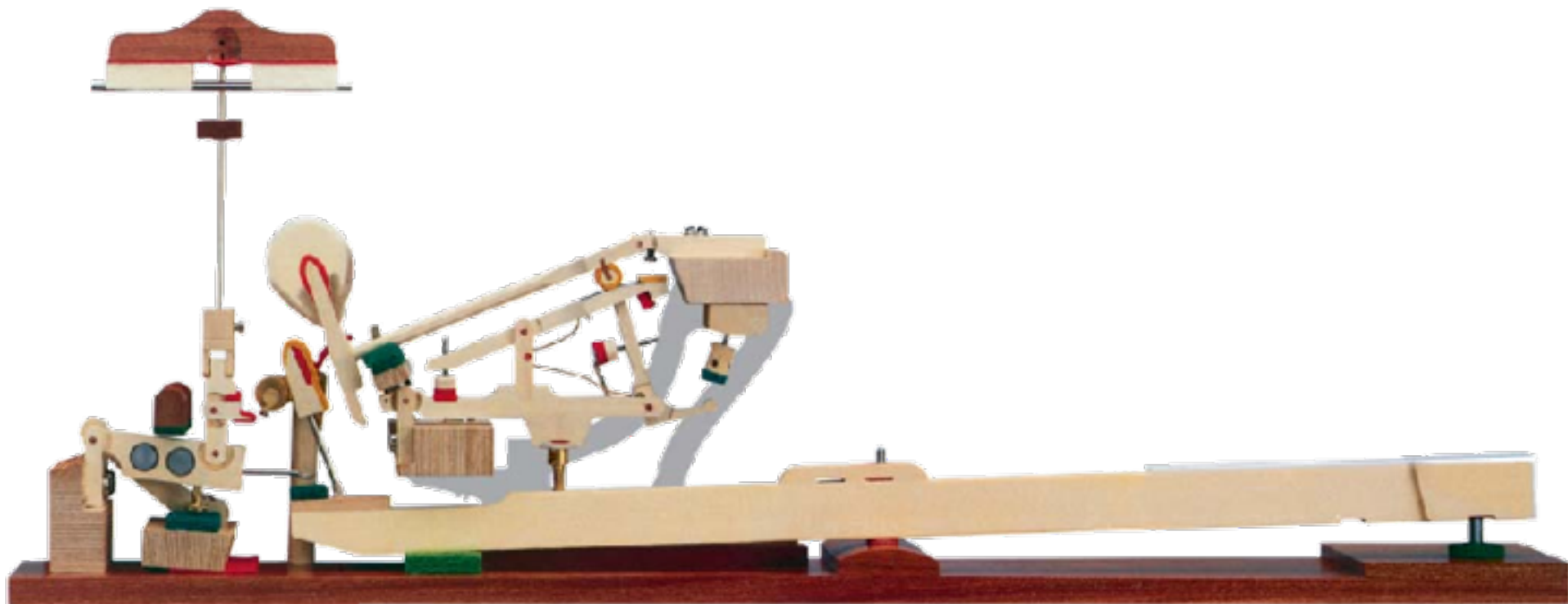
Electromagnetically-augmented acoustic piano



Continuous key position sensing

MRP: performance interface

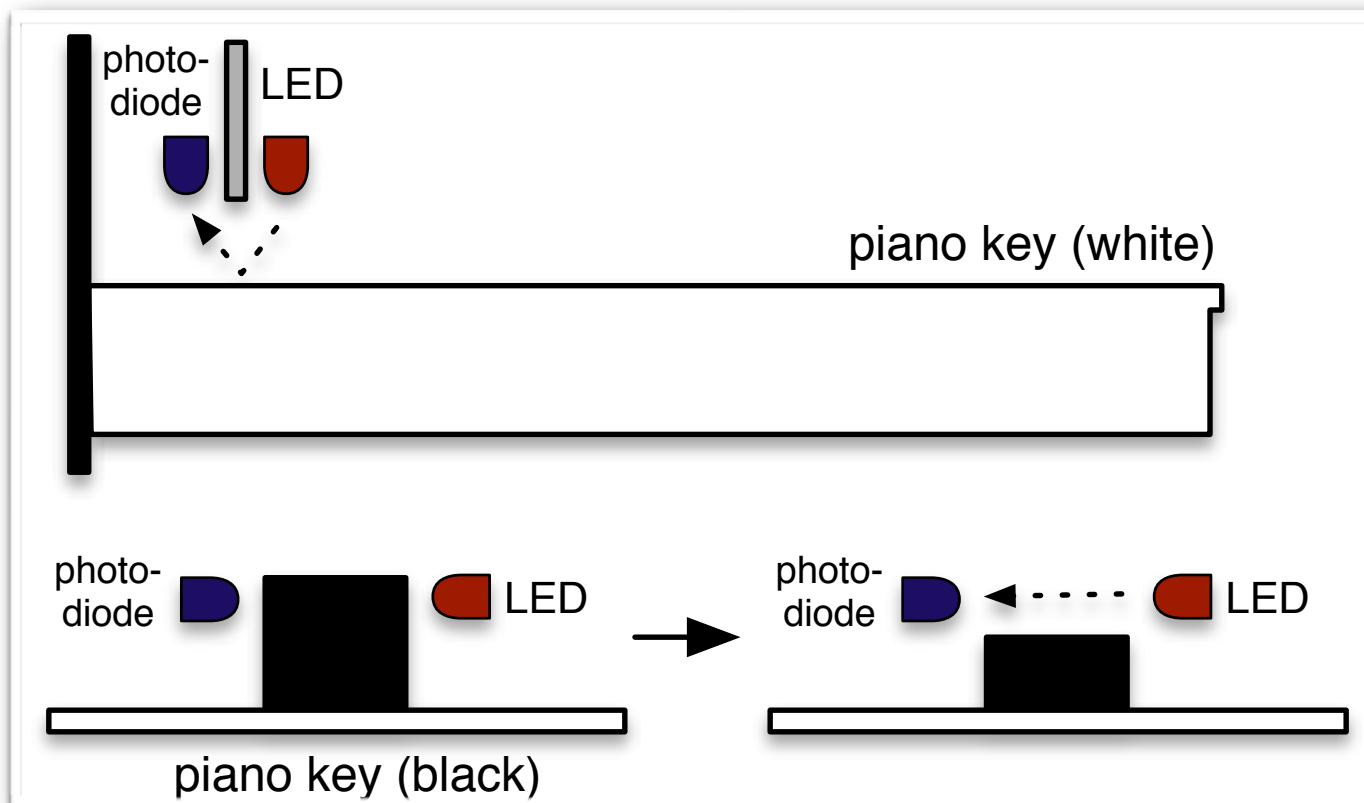
- Actuators allow continuous note shaping
 - Amplitude, frequency, timbre, ...
- But how can this be **performed**?
 - The MIDI keyboard is a discrete interface
 - Note On (single velocity metric), Note Off
 - **Continuous control** directly from the piano keyboard?



Continuous key position



Modified Moog PianoBar



White keys:
Reflectance sensing

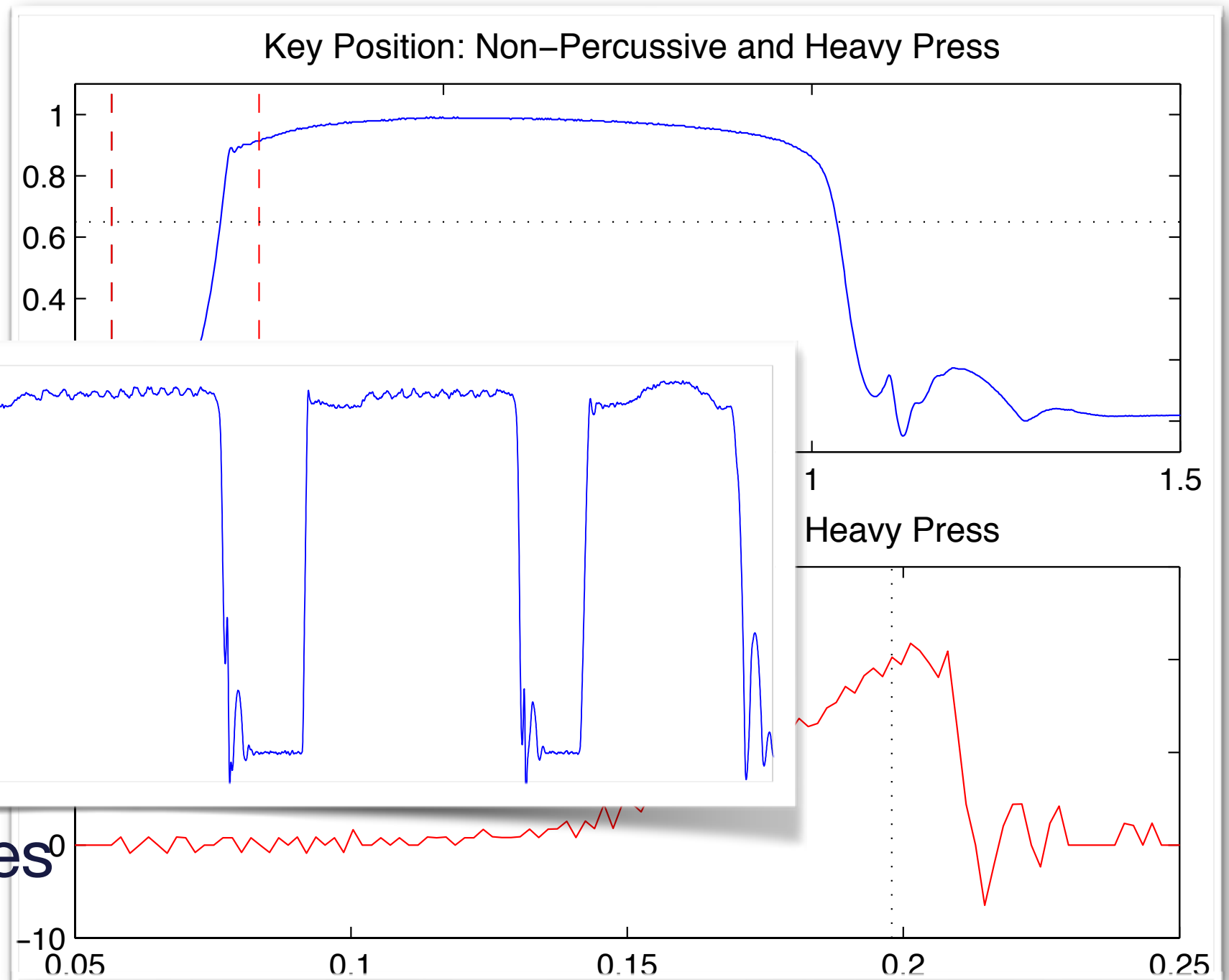
Black keys:
Interruption sensing

Continuous key angle

MIDI

NoteOn [key] [vel.]
NoteOff [key]

Continuous Sensing



Extended techniques

New scanner design



- ▶ Engineered from ground up for continuous key position
- ▶ Reflectance sensing on every key
- ▶ 12-bit ADCs, 1000Hz/key sample rate
- ▶ USB connection to computer (~2 Mbps data rate)



SC11246

MRP
magnetic resonance piano



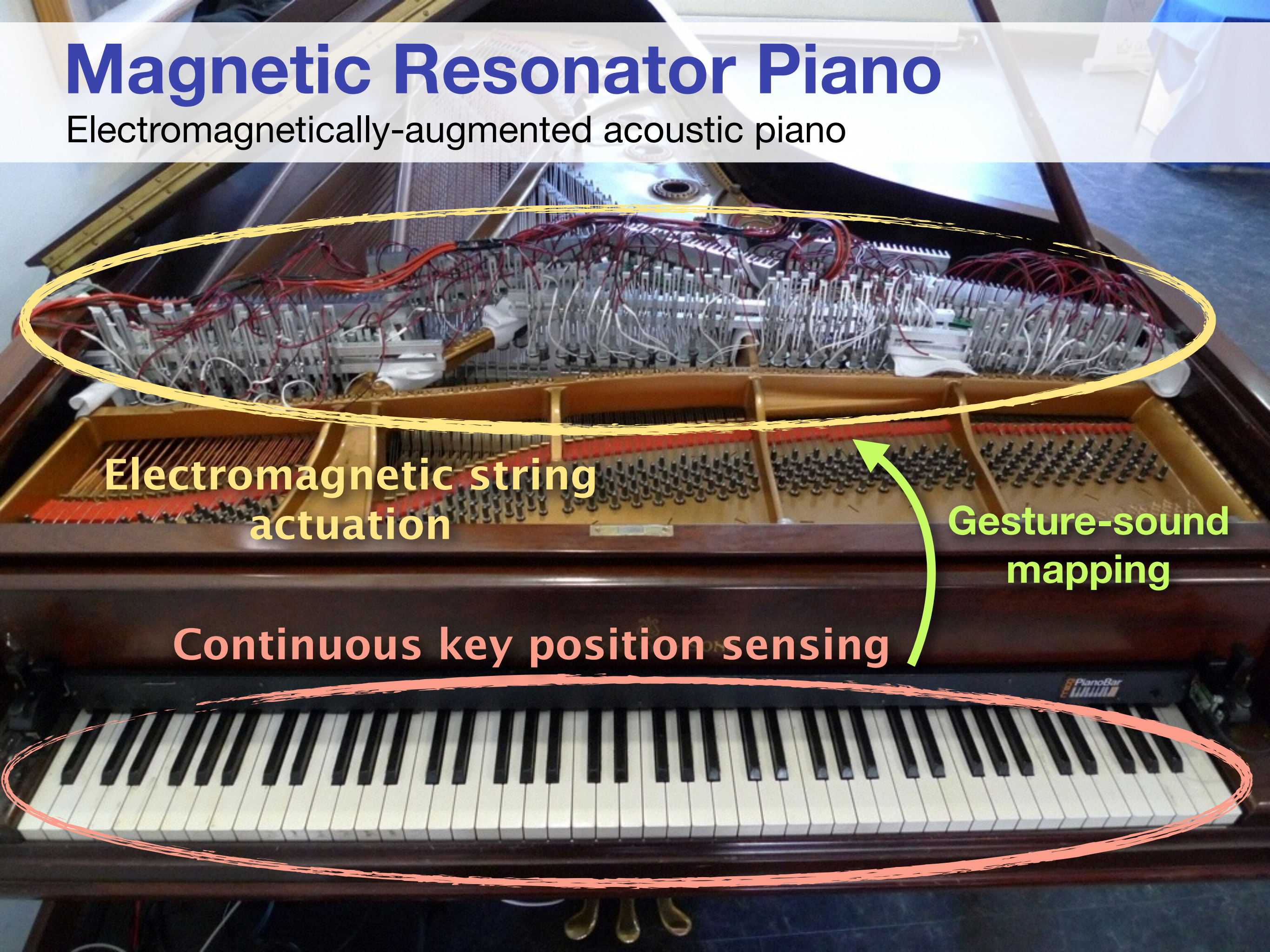
Magnetic Resonator Piano

Electromagnetically-augmented acoustic piano

Electromagnetic string
actuation

Gesture-sound
mapping

Continuous key position sensing

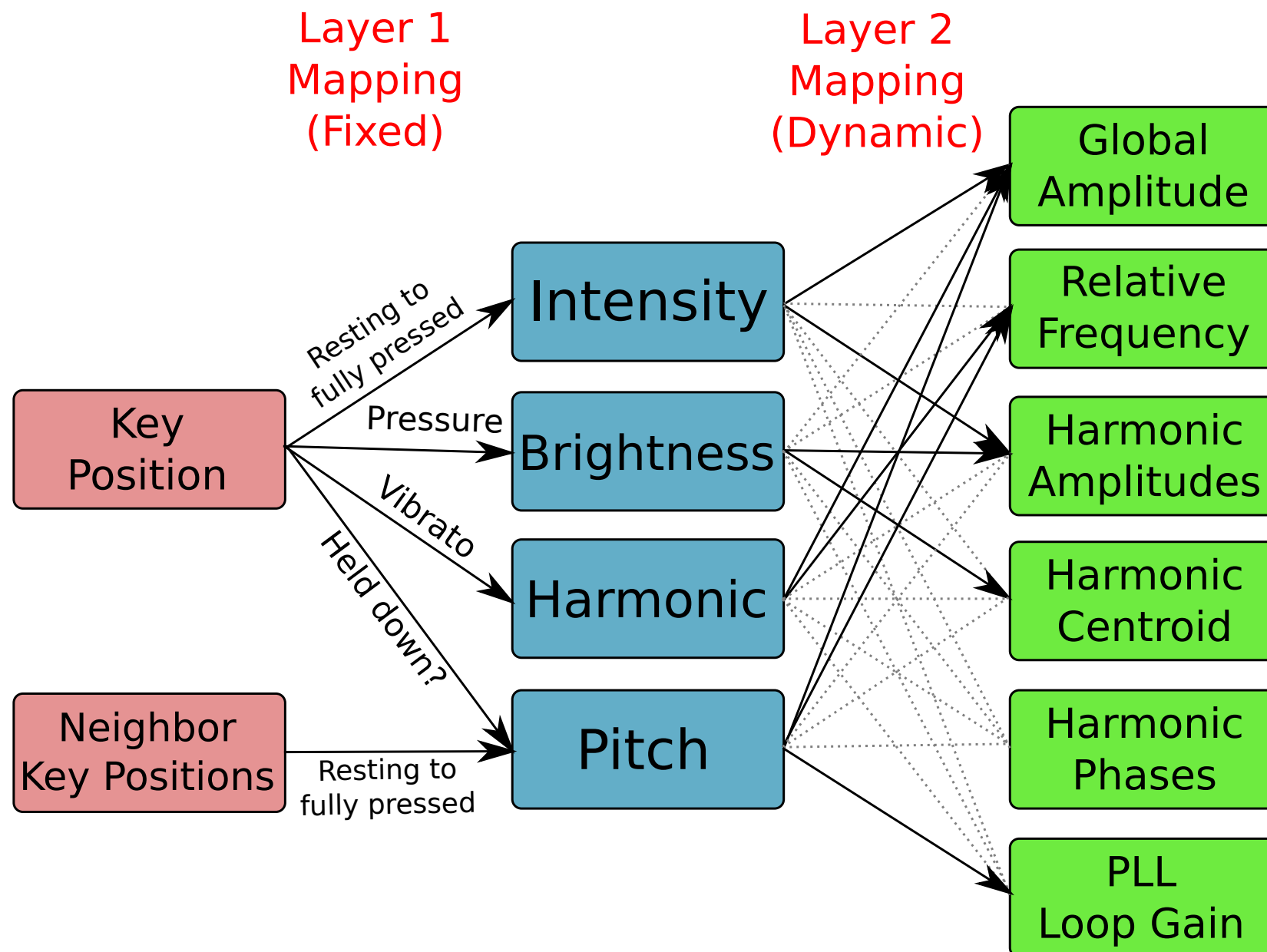


Gesture-sound mapping

- Preserve the feel of a traditional instrument
 - Physical motions produce corresponding sounds
 - 1 gesture = 1 musical event
- Three (sometimes conflicting) goals
 1. Preserve **all** of traditional instrumental technique
 2. Add new techniques for continuous note-shaping
 3. **No harder to play** than the original instrument
- General principles
 - Simultaneous execution of old and new techniques
 - Familiar gestures (close to traditional technique) produce familiar sounds; unusual gestures for unusual sounds

Mappings

- Two-layer mapping strategy for MRP
 - Key motion to intermediate qualities to sound attributes & LEDs
 - Second layer adjustable in XML parameter file



These New Puritans

- MRP used on 2013 album Field of Reeds
 - Concert at the Barbican, April 2014
 - Interactive exhibition alongside concert









PHILIPS | noisy

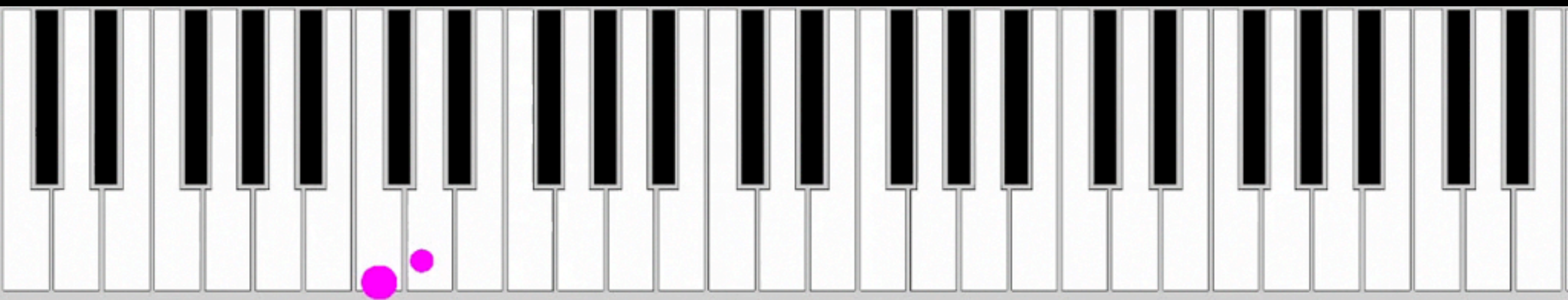


TouchKeys

*Capacitive touch sensing for **existing** keyboards*



- Retains the physical response of the underlying keyboard
- Adds measurements of **finger-key contact location**



The Space Between the Notes

Adding Expressive Pitch Control to the Piano Keyboard



Andrew P. McPherson
Adrian Gierakowski
Adam M. Stark

Centre for Digital Music, Queen Mary University of London

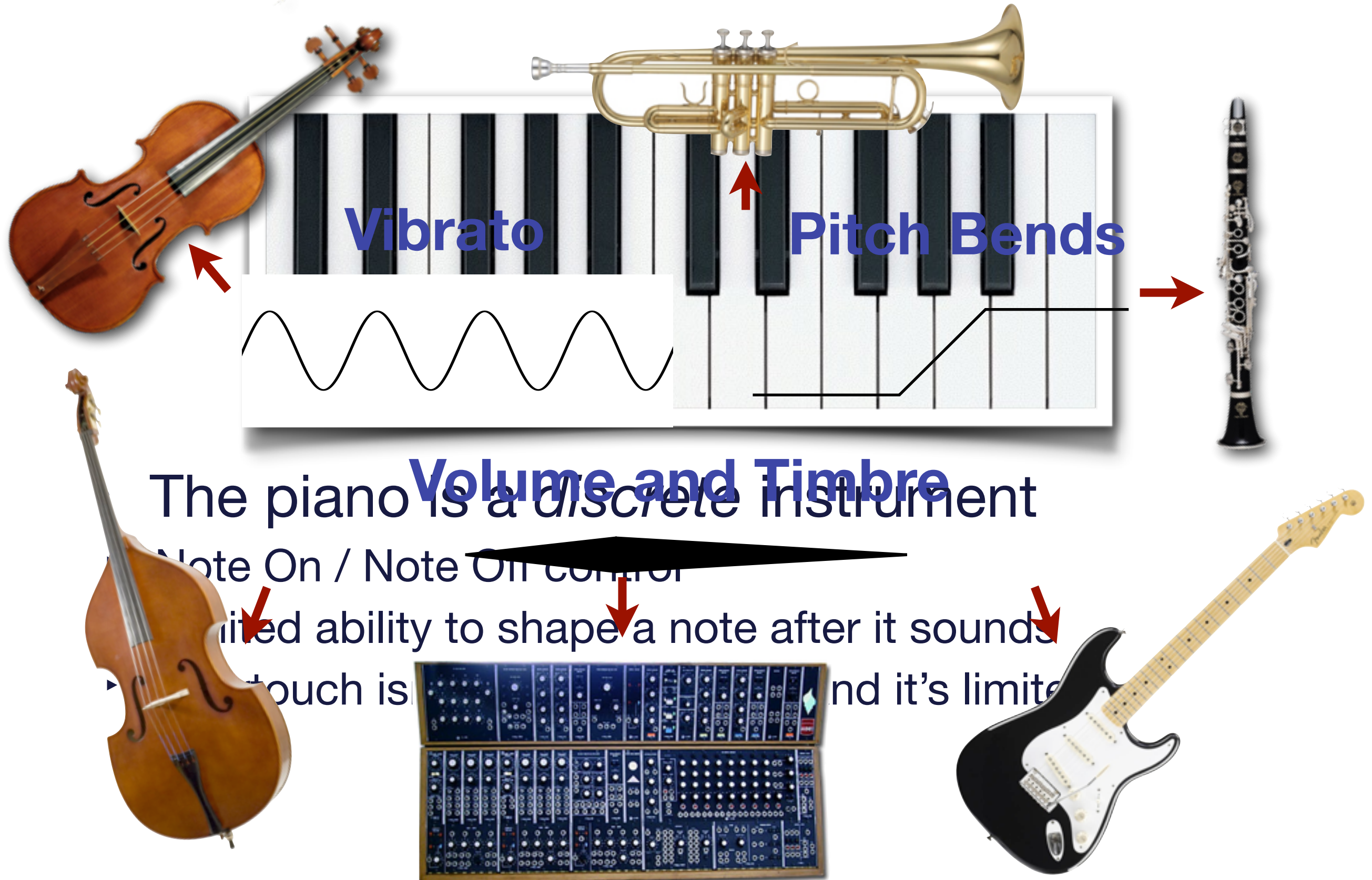
Motivation

Why build a touch-sensing keyboard?



- Many trained pianists and keyboardists
- Goals:
 1. Expand the expressive range of the keyboard
 2. Respect the existing training of skilled performers
 3. Make a flexible, economical system usable on many keyboard instruments

Motivation



Related work

pitch wheel



needs an extra hand
controls all notes together

touchscreen



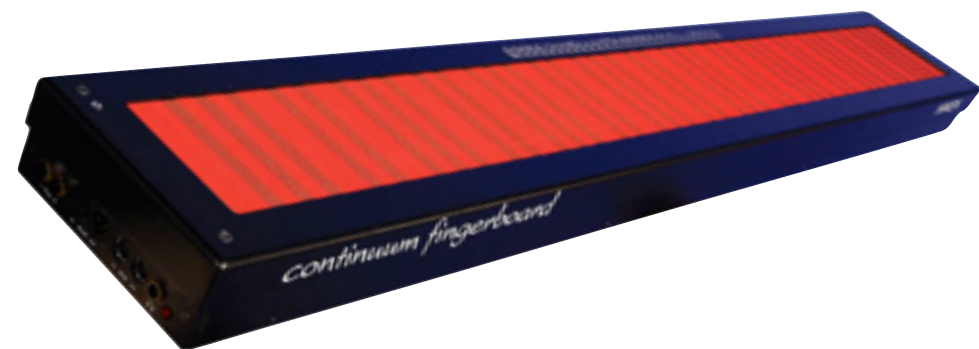
no tactile feedback

ribbon / slide controllers



separate from keyboard
monophonic

novel controllers (Continuum, Eigenharp, ...)



great, but lack feel of keyboard
less existing expertise

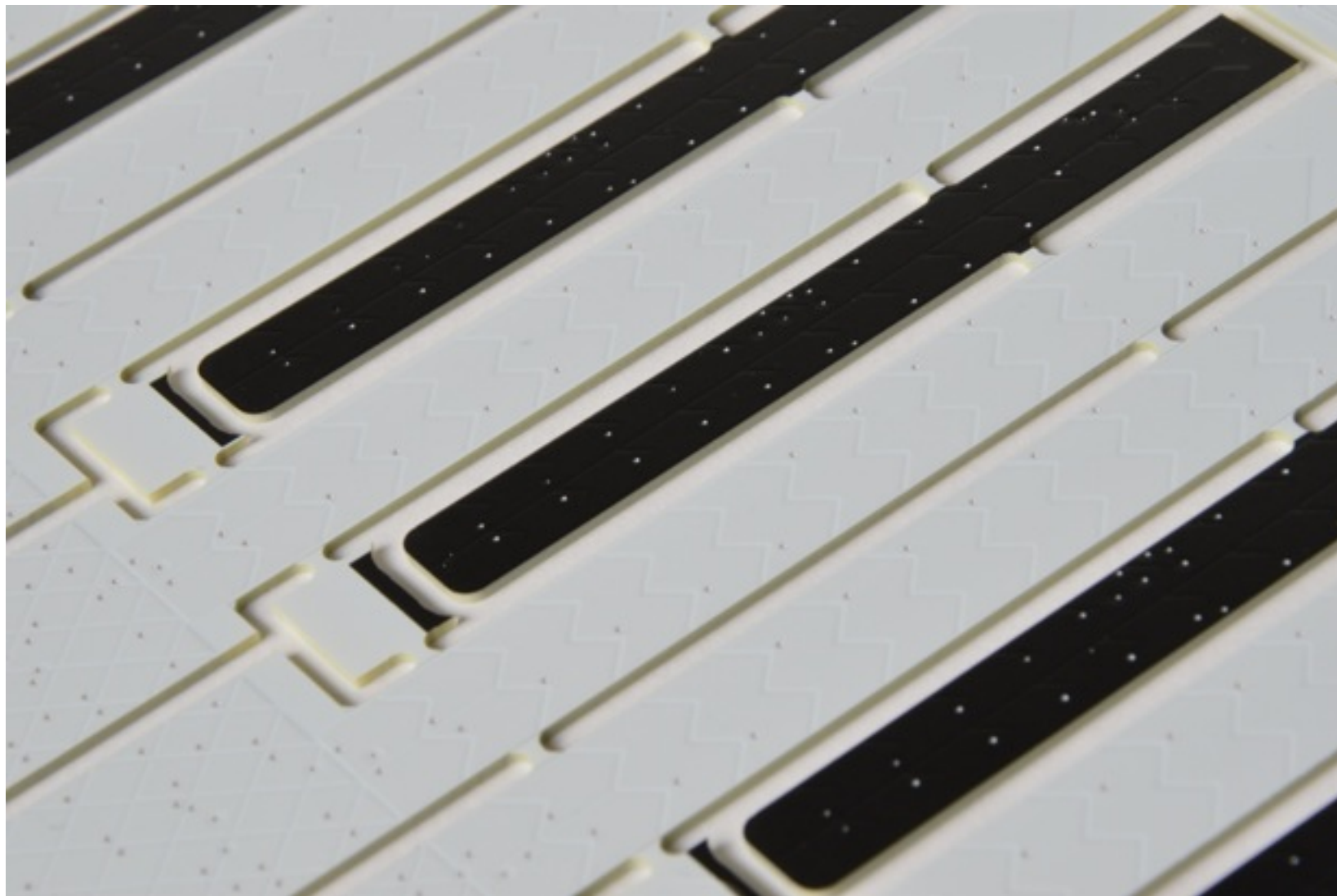
Related work

- Moog Multiply-Touch-Sensitive keyboard
 - Built for composer John Eaton, used in performances though not commercially produced
 - Continuous 2D finger position on each key



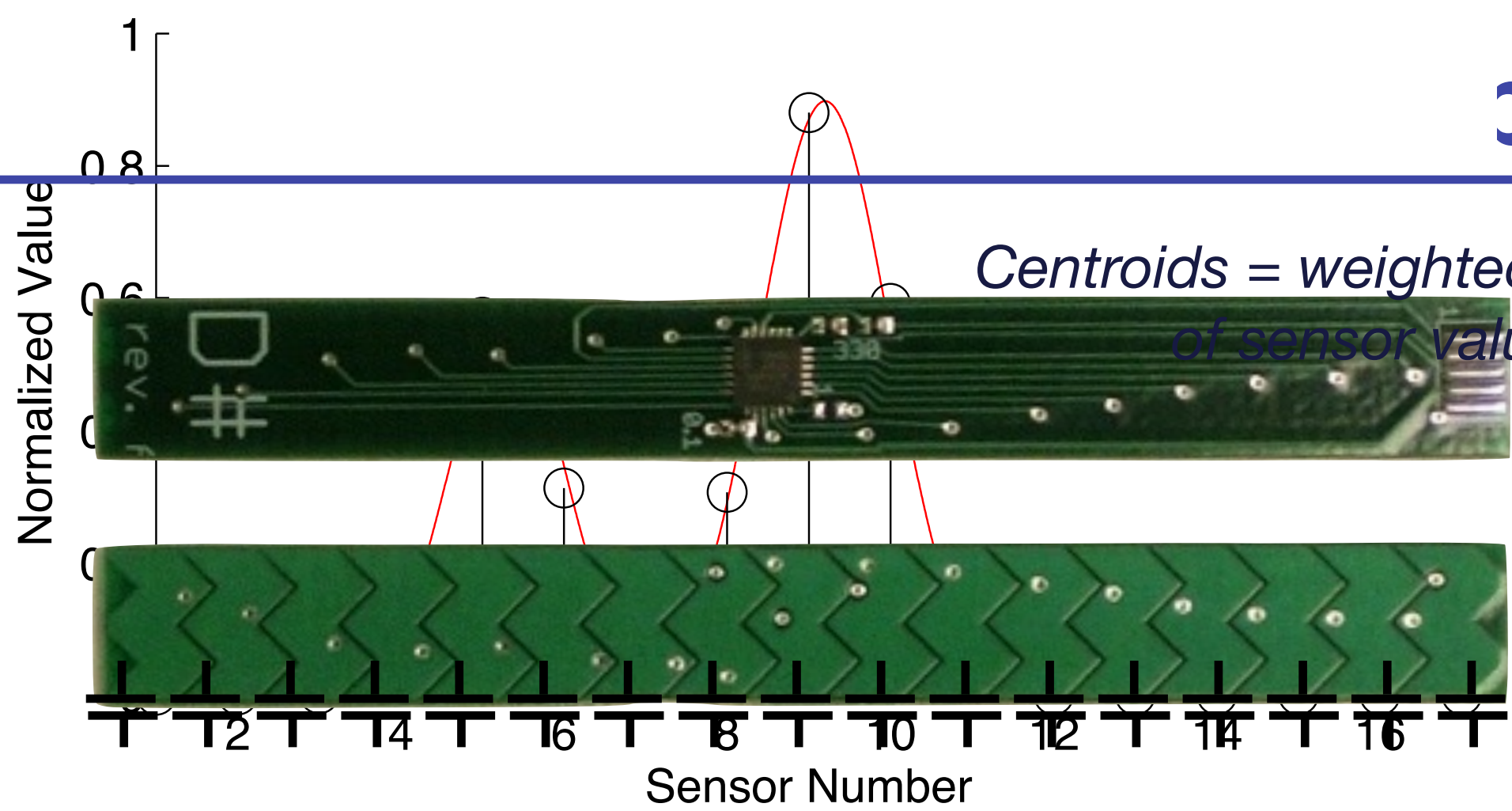
TouchKeys

*Capacitive sensor overlays for **existing** keyboards*



- Thin and lightweight; preserves keyboard action
- XY position sensing, plus contact area
- 200Hz scan rate; 1536(+) \times 256 points resolution

oles

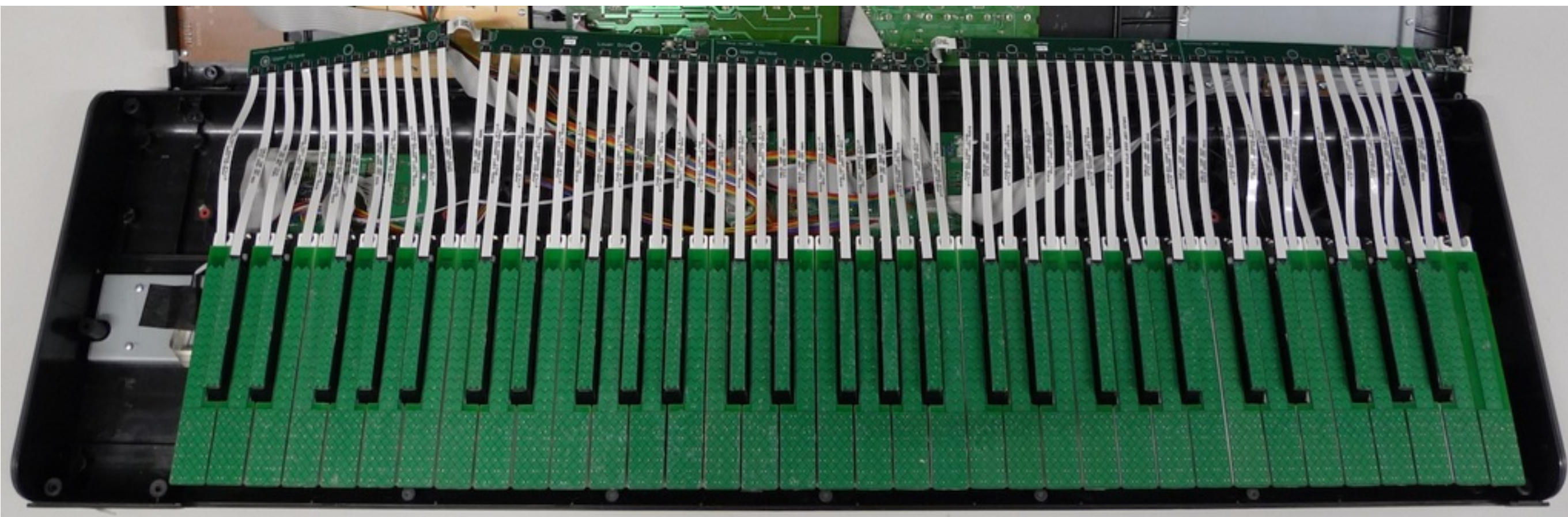


17 sensors
1024-point resolution





Version 1 (June 2011)



Version 2 (December 2011)



Version 3 (April 2012)



Version 4 (April 2013)



Kickstarter Demo Unit (July 2013)



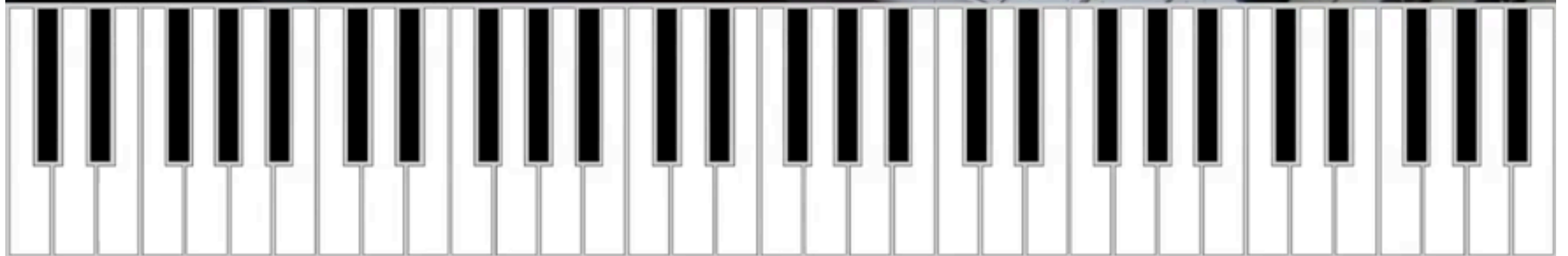
Kickstarter Production Units (December 2013)

Constraints of piano technique

- The fingers are different lengths
 - They don't all fall in the same place on the keyboard
 - Vertical location depends on which keys are played

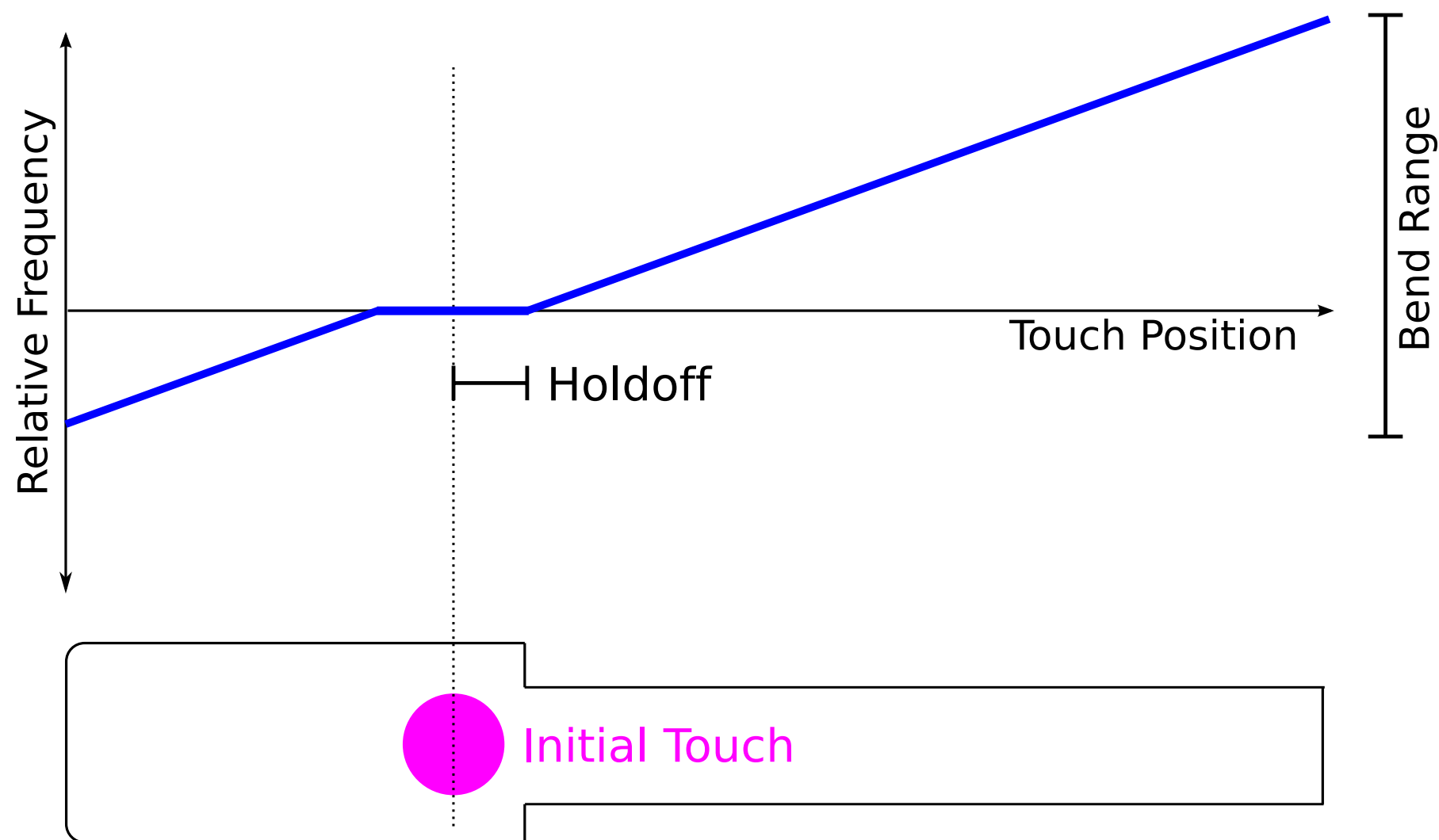


Conclusion: raw finger position cannot be used as an expressive variable



Constraints of piano technique

- Possible solution: onset-relative position
 - Performer moves the finger after an initial touch
 - Implement a *holdoff* to avoid accidental triggers



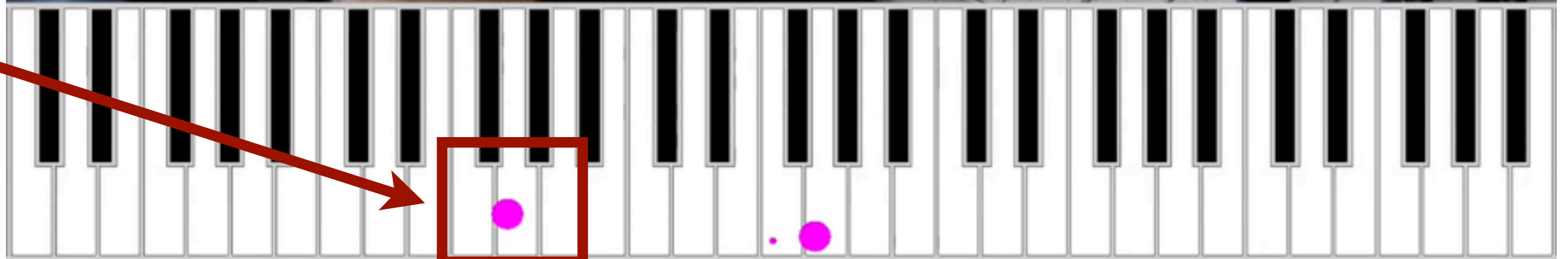
- Works reasonably for larger holdoff values, but...

Constraints of piano technique

- The fingers move as the hand moves
 - Shifting wrist or arm position produces motion on the key surfaces

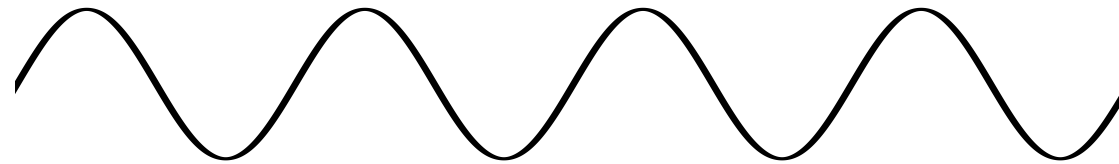


Conclusion: relative finger position
must be used with caution

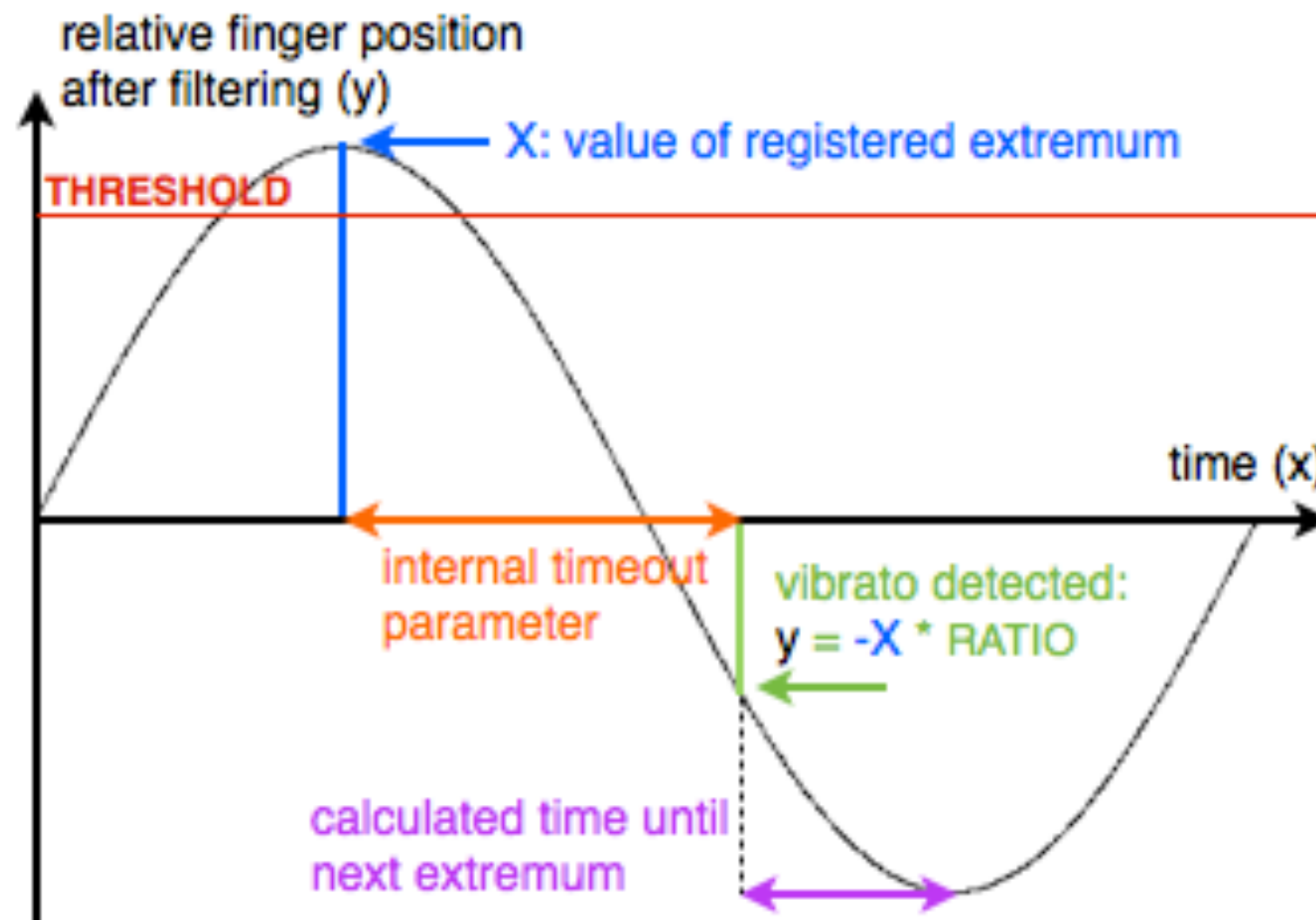


Vibrato

- **Periodic** adjustment around center pitch

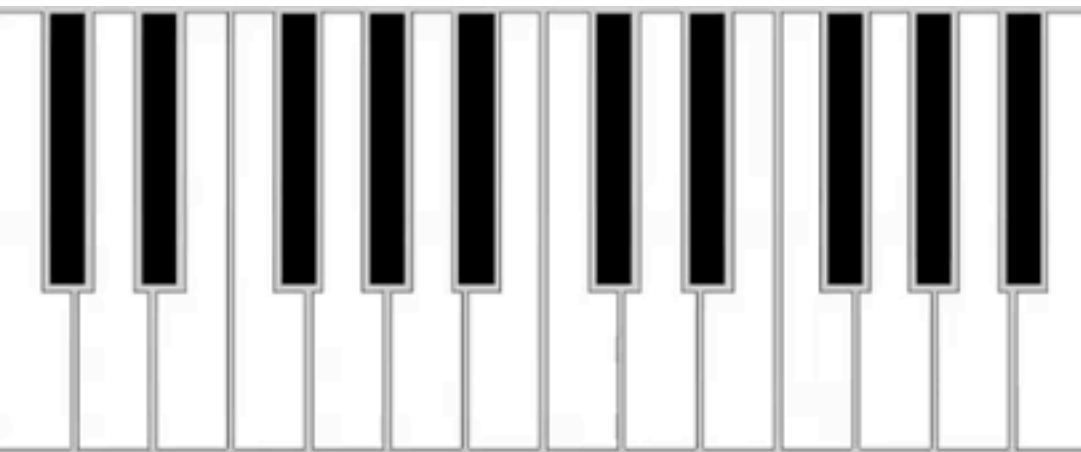


- Use X (horizontal) motion where possible
- Pitch should remain centered: bandpass filter on position
- Detection should look for both directions of motion



Vibrato

- **No vibrato** (finger moves in one direction)



Relative Position X

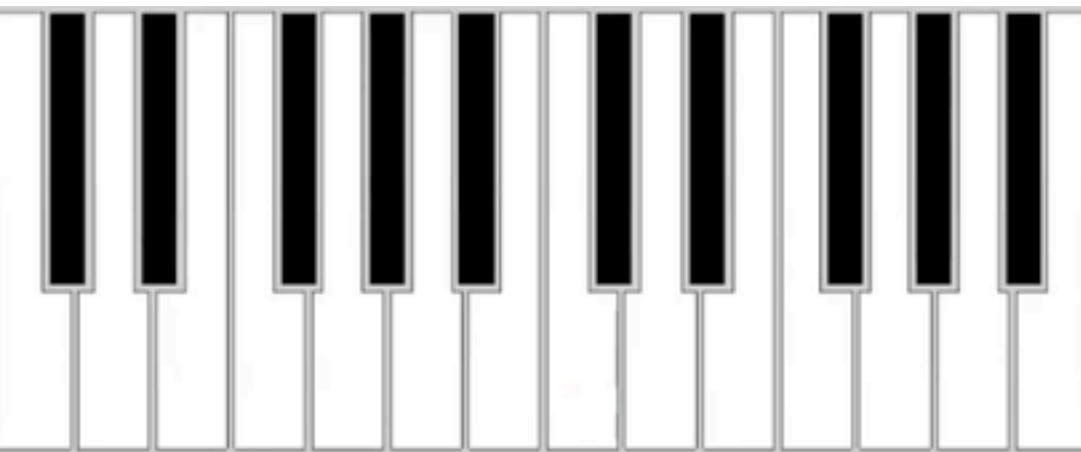


Vibrato Output



Vibrato

- **Vibrato** (finger moves back and forth)



Relative Position X



Vibrato Output





THEORY

EXERCISES

Kickstarter

Primary goal: make new music!

1. New music means working with musicians
2. Musicians need their own instrument to practice and compose with
3. Building instruments is expensive without quantity manufacturing
4. Quantity manufacturing requires significant up-front funding
5. Funding and musician outreach can be combined on Kickstarter!

TouchKeys Multi-Touch Musical Keyboard

by Andrew McPherson

[Home](#)

[Updates](#) **14**

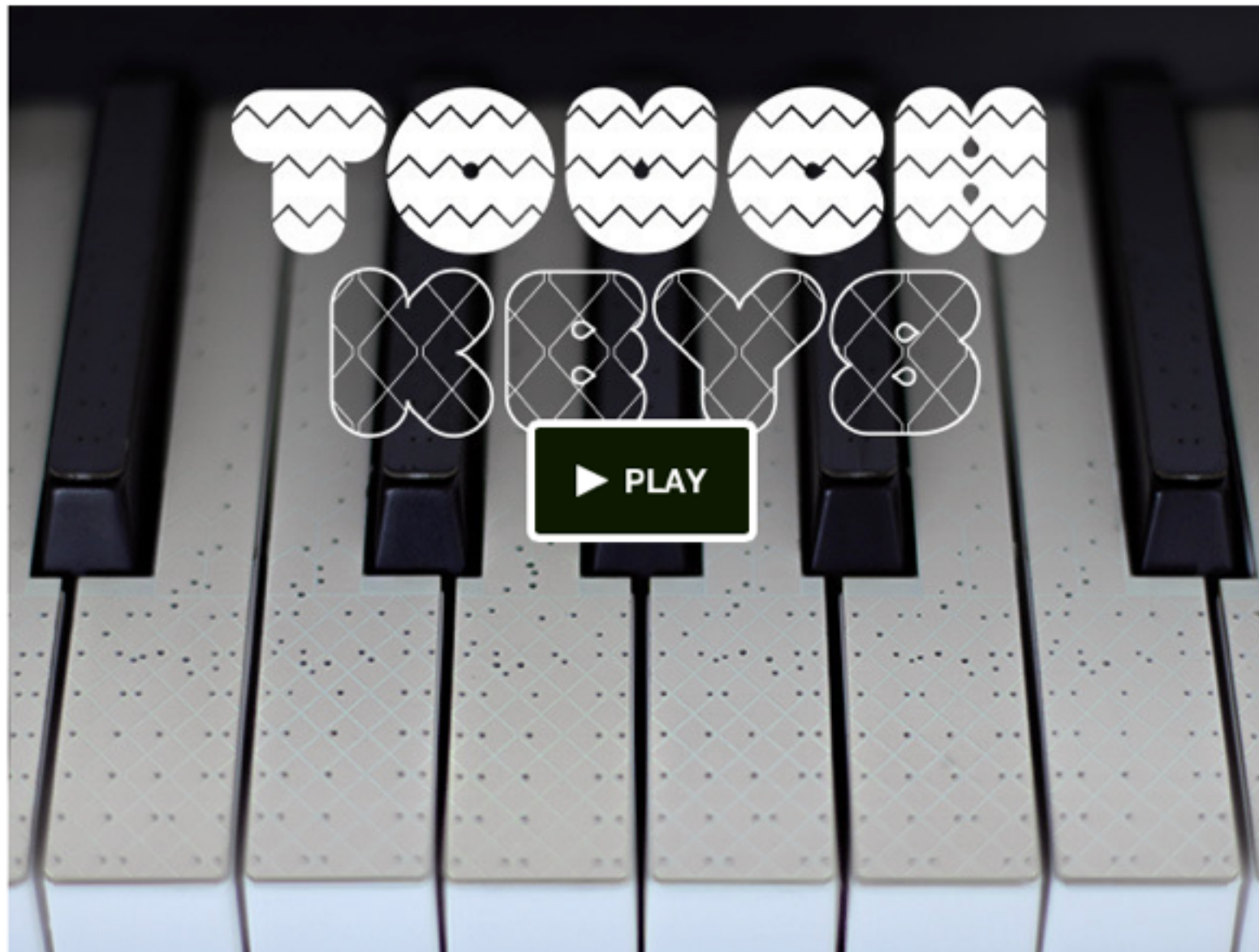
[Backers](#) **198**

[Comments](#) **1**

[London, United Kingdom](#)

[Hardware](#)

Funded! This project successfully raised its funding goal on Sep 2.



[Share](#) **7,619** [Tweet](#) [Embed](#)

Add continuous expressive control to any keyboard with this DIY touch sensor kit.

198

backers

£46,682

pledged of £30,000 goal

0

seconds to go

Funding period

Jul 29, 2013 - Sep 2, 2013 (35 days)



Project by

**Andrew
McPherson**

London, United
Kingdom

[Contact me](#)

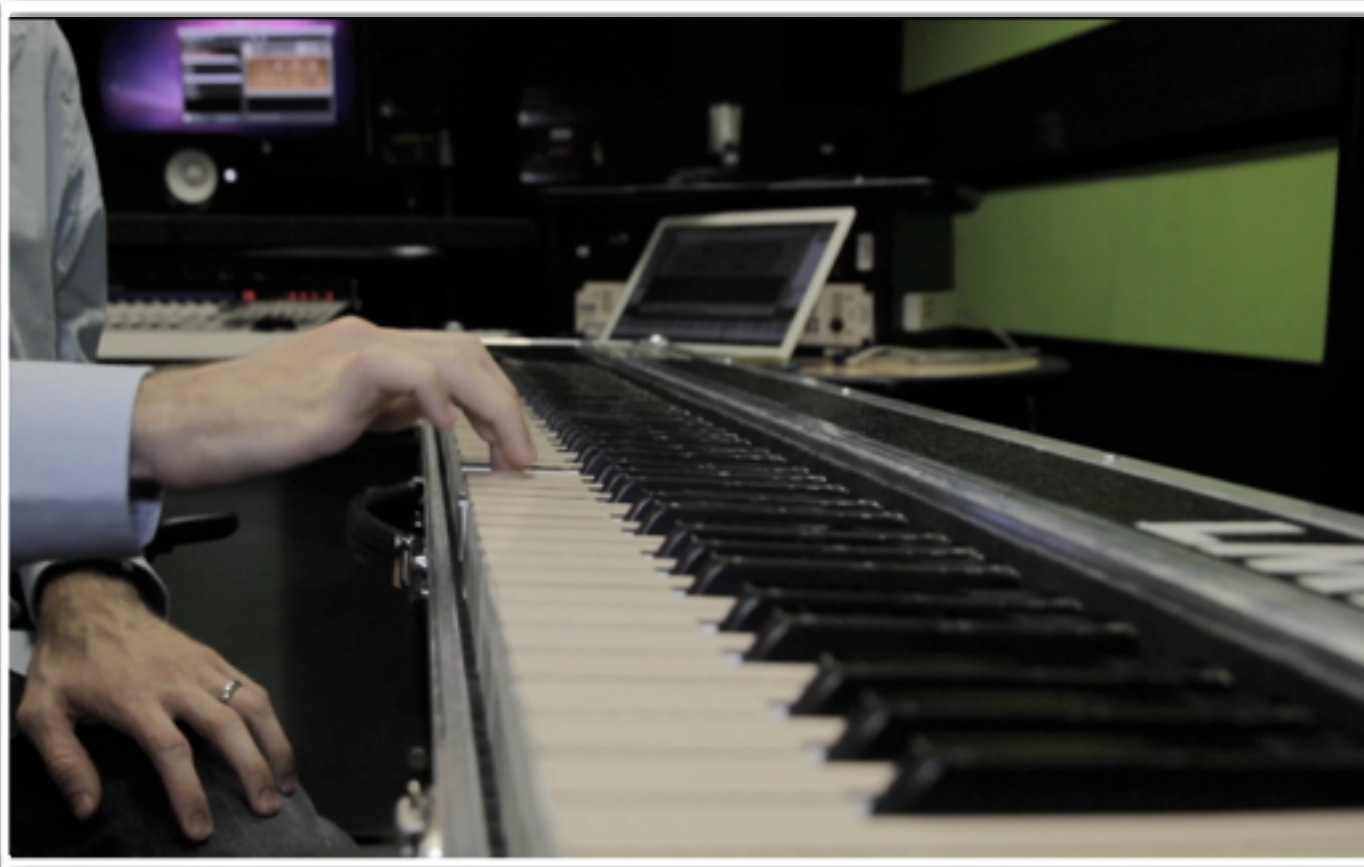
K First created - 2 backed

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Preparing for a campaign

Media, media, media!



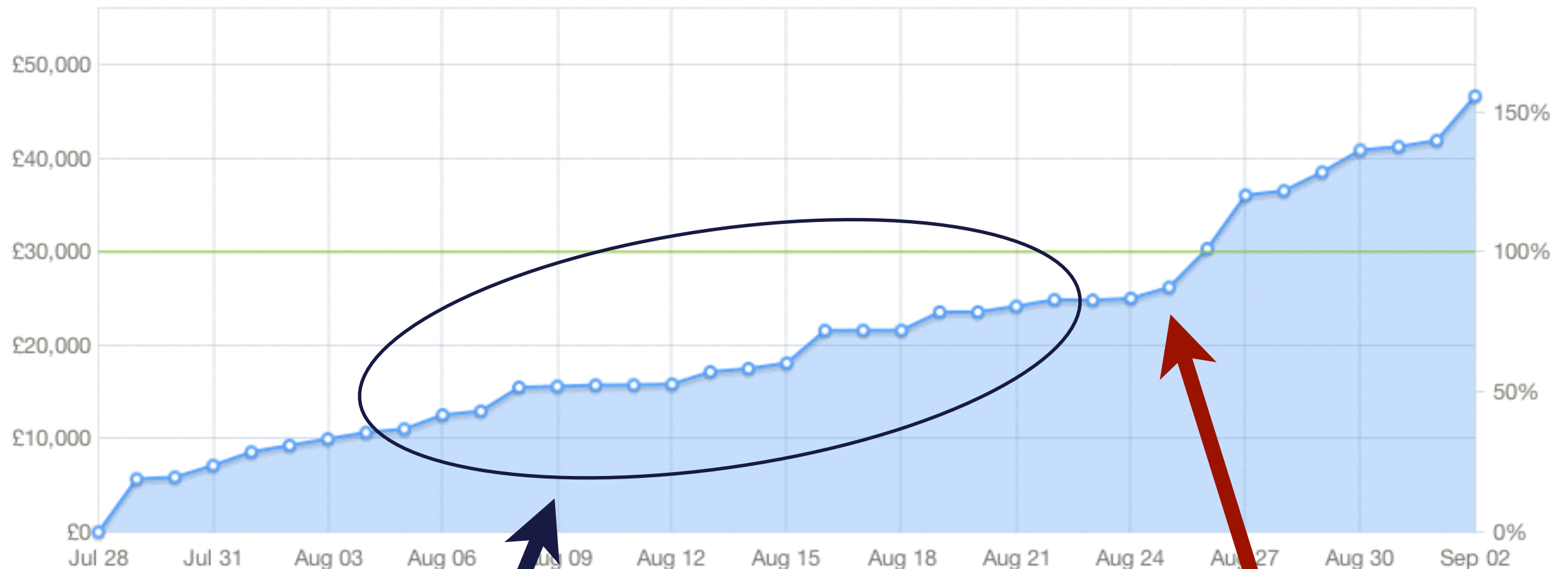
Video by Mind the Film; logo and graphics by Matt & Han Ltd.

- Have a plan for media outreach
 - Print / online news, social media, mailing lists, forums, ...
- I had lots of help here... *(thank you everyone!)*

Results

*Goal: £30k in 35 days; **Result: £46k***

Funding progress



*Most campaigns are
fast at beginning and end,
slow in the middle*

What happened here?

<http://youtu.be/q8txlpJj9E8>



Jordan Rudess, keyboardist with Dream Theater
(It was about 36 hours after I posted this that the campaign took off. Related? Probably, but hard to tell.)

Challenges

- **Running a campaign is a full-time job!**
 - Media contacts, forum participation, answering emails, making videos, posting updates
 - Actually working on the thing (if there's any time left...)
- **Maintaining awareness and interest**
 - After first news stories, how to sustain a campaign?
 - Need new updates, new videos, new applications
 - I aimed for 1-2 videos a week throughout the campaign
- **Campaign reward structure**
 - It's a good idea to have rewards at all price levels
- **Know your community**
 - What features are needed?



More info:

<http://www.eecs.qmul.ac.uk/~andrewm>

<http://touchkeys.org>