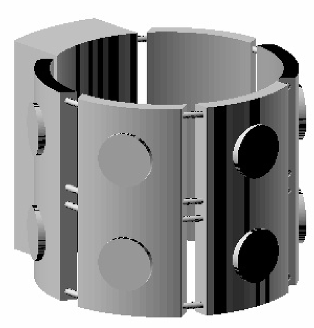
Haptic pattern representation using music technologies

Michael Cumming, Adam Tindale, Sara Diamond
OCAD University, Toronto, Ontario, Canada
mcumming@ocadu.ca, atindale@faculty.ocadu.ca, sdiamond@ocadu.ca

Wrist-wearable vibrotactile arrays can serve many functions: typically they are used for non-disruptive notification from social media. They can also be used for direction finding, gaming and entertainment. Authoring and programming of wrist-wearable vibrotactile arrays can be difficult because of the lack of standardized notational systems and file formats. Typically, each implementation of haptic arrays uses bespoke programming. This tends to isolate creative and technical development into non-communicating silos that discourage standardization and sharing. We propose that standard musical notation is an appropriate method for standardization and compositional expressiveness.

Introduction

We are developing a MIDI-driven, wrist-wearable device that integrates with a gaming app on an accompanying smartphone. The wrist device includes LED lights, vibe motors and buttons that activate when vibe motors are touched. A wrist-wearable vibrotactile device, or what we call a *vibe bracelet*, needs activation patterns to operate. It is unclear how to design such patterns in a standardized way using the technology closest at hand, which in our case is low-level code written in the C or Wiring languages.



Bracelet design with 2x5 tactor array.

Use cases for wrist-wearable device

1. Interpret wrist gestures and recognize overall physical activity of the wearer (using the microcontroller's accelerometer),
2. notify the wearer when crystals and treasures are earned,
3. offer vibrotactile clues about where crystals and treasures can be found, and
4. provide aesthetically attractive and evocative vibe and light displays corresponding to narrative points in a story.

TEXT BOX TEMPLATE

It is use case no. 3 that we consider for its potential musicality and the applicability of musical-inspired pattern design. These patterns must be suitable for low resolution vibrotactile arrays – in our case a 2x5 circular array of vibe motors, or *tactors*, that encircle the wrist (Figure ??).

Research Problems

Haptic feedback and communication

The largest organ of the human body is the skin and has great potential for the transmittal of information and sensation.

touch is useful in generating intimacy in normal social situations.

Wearable vibrotactile devices

Tactile authoring for vibrotactile devices

Multiple actuator devices

Designing patterns using music notation

Basic mapping conventions

Our notational approach for our wrist-wearable device is to follow music notation conventions and to see where these conventions lead us in the domain of vibrotactile devices:

- Represent time horizontally from left to right. Notes to the right occur later.
- A note represents an activation of a component. A component can be of several types (vibe motor, LED, etc.). Place notes on normal, five line staves.
- Represent note durations by note type (for example, quarter, half and whole notes), dots and by ties between notes of the same pitch.
- If notes are pitched, indicate their pitch through their vertical placement on a staff. If notes are unpitched, represent different components (e.g. different types of vibe motors or LEDs) using various note heads or annotations.
- Different *parts* are on separate staves. One tactor type playing the same notes at the same time represents playing in *unison*. For example, eight vibe motors playing in unison can be represented as one part.
- Simultaneous notes, or *chords*, are stacked vertically as in music notation.

We also need to translate the nomenclature from the domain of wrist wearables to that of music notation. This mapping is shown in the following table:

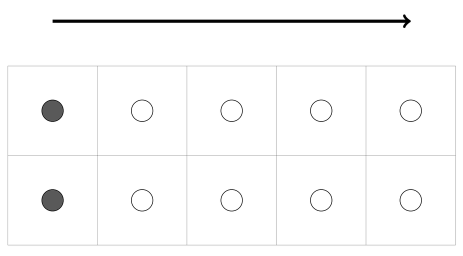
Vibrotactile term	Music notation term
Activation of one component	Note
Activation duration	Note duration
Frequency of an activation	Pitch
One type of component	Instrument
Series of activations for one component	Part
Simultaneous activations w/ multiple pitches	Chord
Integrated series of activations	Composition

Pitch

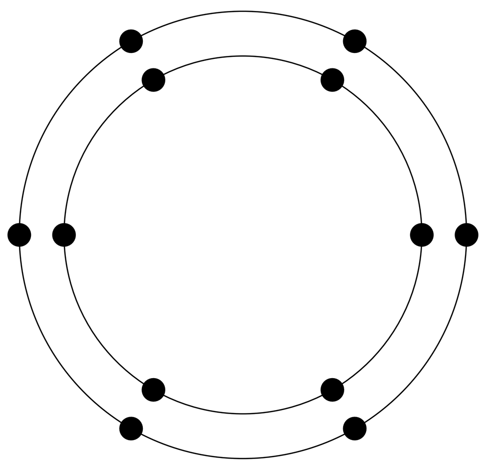
Intensity

Duration

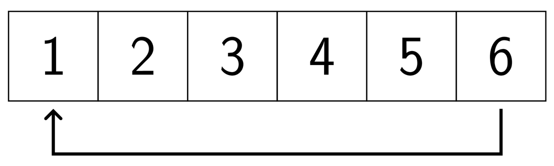
Spatial patterns and vibrotactile clues



2x5 array of tactors with directional activation.



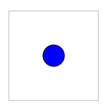
Circular array of tactors.



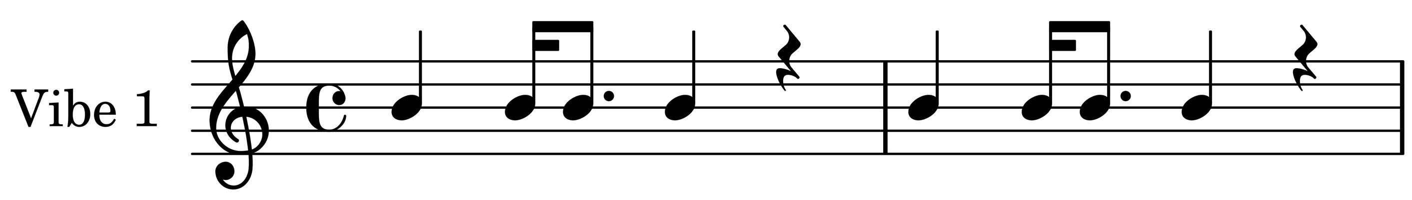
Linear array of tactors.

Controlling Components using Musical Notation

Device with no spatial dimension (0D = point)



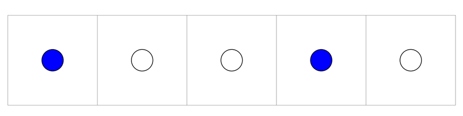
Device with a single vibe motor



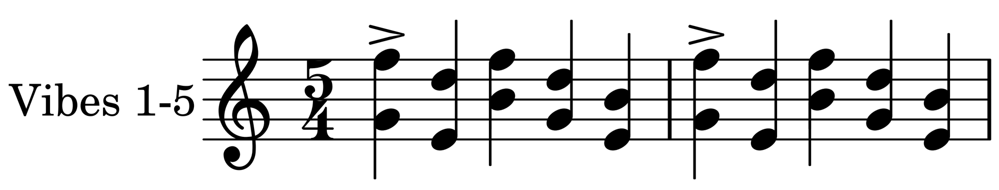
Score for single vibe motor playing simple solo rhythm

- Time = horizontal, x-axis
- Pitch = vertical, y-axis; single pitch for single component
- Unpitched notation also suitable
- Notation affects only one component

Device with one spatial dimension (1D = linear)



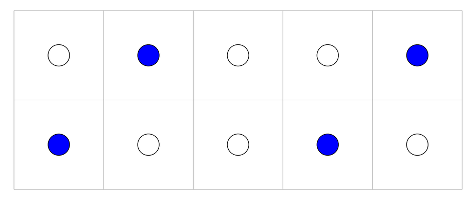
Device with a line of vibe motors.



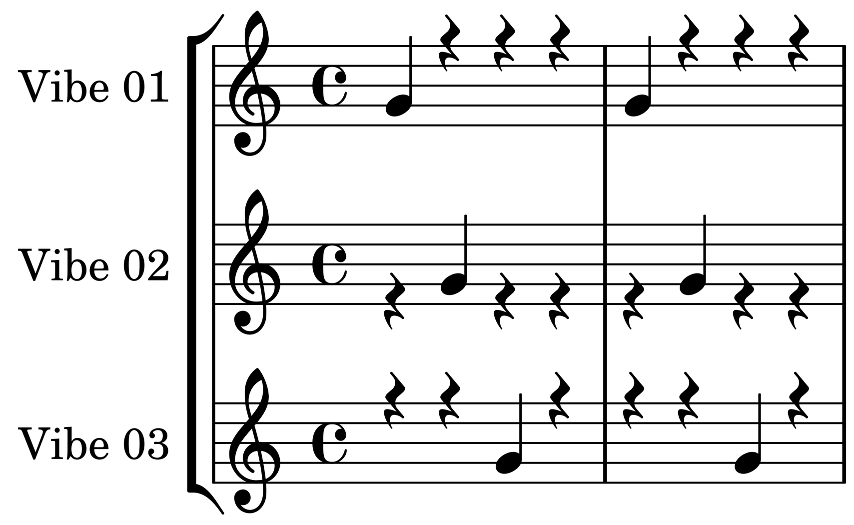
Score for a linear array of vibe motors

- Time = horizontal, x-axis (rests are hidden)
- Vertical staff position (EGBDF) = vibe motor address
- Vertical position no longer signifies pitch
- Separate part for each vibe motor
- Each component is independently addressable through notation
- Accents and other articulations possible

Device with two spatial dimension (2D = planar)



Device with an array of vibe motors



Score for an array of vibe motors

- Time = horizontal, x-axis (rests are hidden)
- Vertical staff position (EGBDF) = vibe motor address
- Vertical position no longer signifies pitch
- Separate part for each vibe motor
- Each component is independently addressable through notation
- Accents and other articulations possible

Music with additional spatial dimensions (2D = planar)

Conclusion

Acknowledgements

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