Haptics for Bidirectional Interaction with AI Musical Mappings

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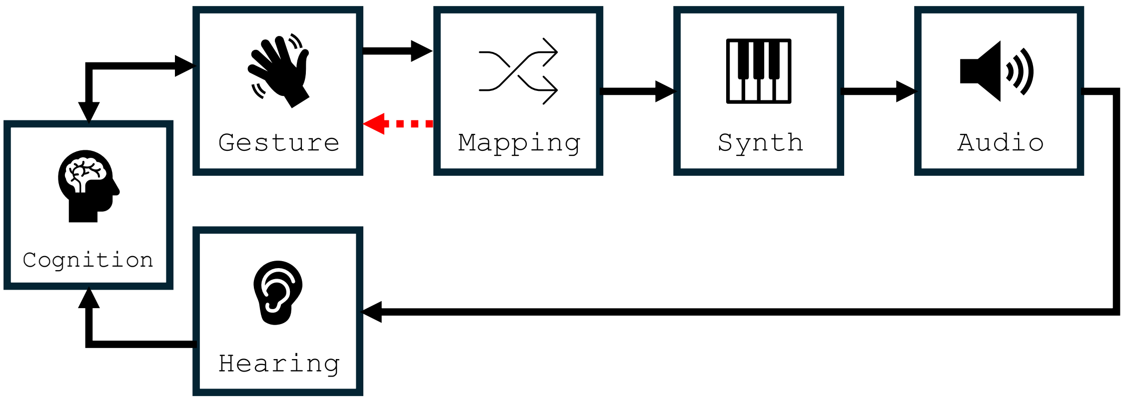

Fig. 1. The conventional workflow of AI-based gesture mappings for sound synthesis. A feedback loop is created via the audio output however the tactile feedback is often missing.

The unidirectional process of mapping gesture to synthesis parameter in digital musical instruments has remained prevalent, even in more recent designs that incorporate machine learning models to performing parameter mapping and synthesis in response gestural input. Haptic feedback provides the opportunity to implement bidirectional interaction through gestures – possibly enabling the exploration of AI mappings that subvert the conventional unidirectional flow. Additionally, machine learning provides the opportunity to implement closely-coupled haptic sensing and actuation systems for use with musical interaction, without the requirement to model complex system dynamics.

Additional Key Words and Phrases: Bidirectionality, Haptic Interaction, Musical Interaction

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1 Introduction

Artificial Intelligence-based tools are increasingly prevalent in music production tools. This can take the form of utility signal processing devices (such as emulation of analogue technology or noise reduction algorithms), or more creative uses [6]. Where they are used for interaction, they are generally used for unidirectional mapping purposes – mapping an input gesture to a synthesis parameter. This presents an opportunity for haptic feedback designers: feedback can be incorporated in a more tightly-coupled manner by providing simultaneous haptic feedback from the AI mapping system in the very same modality as the input gesture (often in the tactile domain).

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2 AI Musical Mappings of Gesture to Synthesis

The mapping of musical gestures to sound synthesis parameters has been a well-established concept since the early days of digital musical instrument (DMI) design [13]. These mappings, by convention, tend to follow a unidirectional paradigm from gesture to synthesis [9]. Limited feedback paths are provided; often the sole form of feedback is the audio output of the synthesis algorithm. This can be observed in Figure 1, where there is a conventional unidirectional flow from gesture to audio output. It can be observed that embodied cognition is represented in this diagram by the two-way arrow between cognition and gesture. The diagram also indicates the possibility for tactile feedback to be returned towards the user, via the red dashed line. This feature, while found within some existing DMI designs [8], is often missing. A closely-coupled sensor and actuator pair with a suitable control loop mapping is able to introduce this to the musicial instrument system.

For the past couple of decades, efforts have been made in the research community to explore the use of machine learning approaches for parameter mapping [3]. This mirrors trends seen elsewhere in HCI for use of AI methods to map input gestures to system outputs [10]. These have the potential to dynamically reconfigure the musical mappings in real-time, as well as facilitating complex mappings between many sensing input from the gesture to many parameters in the synthesis algorithm. Often, musical gestures are mapped using AI models to control parameters continuously using a regression model [6]. While these methods can have interesting creative outcomes, they still often follow the unidirectional paradigms found in traditional mapping techniques.

3 Closely-Coupled Haptic Feedback

As suggested previously as part of a CHI workshop by Strohmeier et al. [12], closely-coupled sensing and actuation can provide a cohesive and immersive experience when used with haptic feedback for interaction. Such closely-coupled sensing and actuating is commonplace in force feedback haptics, where the sensor input is coupled to the actuator output by some form of control loop [4]. Previous research has also explored closely-coupled vibrotactile haptic feedback, with the possibility of synthesising surface textures among other use cases [11]. This coupling is important due to human perception (the sense of touch is an active process that relies upon movement of the body and changing sensations to perceive textures and objects [7]). This coupling enables further embodiment of the interface – the system becomes an extension of the user through the bidirectional coupling.

Previous work by the author has explored bidirectional haptic within digital musical instrument design - creating a self-sensing system that can simultaneously actuate and sense audio-rate vibrations [2]. This work, and other similar closely-coupled haptic feedback systems, are required to mitigate crosstalk between actuation and sensing. In this particular case, the vibrotactile actuation signal must be cancelled from the sensing signal using a model of the transducer's electrical impedance. This scenario highlights another potential use case for AI systems: designing adaptive real-time control systems and filtering that ensures system stability and reduces crosstalk. These systems can be adaptive (in the use case described earlier – adapting to changes in the electrical impedance over time) and account for system complexities and non-linearities that are complex to model empirically. In this vein, an approach using reinforcement learning has previously been taken to deliver localised haptic feedback [5]. Additionally, an overview of machine learning for real-time control systems can be found by Zhao et al. [14].

4 Coupled AI Mapping with Haptic Feedback

I suggest that closely-coupled haptic feedback approaches might be explored to subvert and challenge the prevailing unidirectional machine learning mapping processes commonplace in musical interaction, and elsewhere in HCI. By incorporating tightly coupled sensing and actuation in the haptic domain, with the machine learning model facilitating the control loop, the interaction changes from a one-way exertion of control by the user to a coupled negotiation between the user and the ML model via the tactile domain [1].

Additionally, the use of AI models to create control loops in closely-coupled sensor-actuator systems has the potential to simplify the process of mitigating crosstalk and enable the creation of tightly-coupled, but stable, haptic devices for interaction with a broad range of HCI applications.

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Matthew Davison is a PhD student within the Augmented Instruments Lab at the Dyson School of Dyson Engineering. Supervised by Prof. Andrew McPherson, his research centres around the role of bidirectionality in hybrid physical-digital musical instrument designs, particularly in the tactile domain using haptic feedback. He received a BSc in Music and Sound Recording (Tonmeister) from the University of Surrey and previously worked as an embedded software engineer in the audio industry.