DeSound: A Toolkit for Building Functional Prototypes of Digital Musical Instruments

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Abstract. Digital Musical Instrument (DMI) design often involves Haptic and Audio Interaction Design of the key DMI elements of gestural control, sound production, and mapping strategies. However, rapid prototyping of functional DMIs can be difficult as designers need to be skilled in a diverse range of technologies such as microprocessors, sensing technologies, and programming languages. To address this challenge, a toolkit, DeSound, for generating ideas and prototypes of DMIs was created and described in this paper. The toolkit allows designers to explore materiality and gestural interaction in DMI design by quickly making functional prototypes, exploring and playing with tangible components and sensors, and rethinking the role of material and haptic interaction in DMI design. This paper provides details on constructing custom DMI sensors focusing on the materiality and their gestural affordances. The intention is to provide guidance and inspiration for others to create their haptic sensors for new DMIs.

Keywords: Design Toolkit · Digital Musical Instruments Design · HCI · Audio Interaction · Materials and Haptic Interaction

1 Introduction

Digital Musical Instruments (DMIs) are often described as combinations of two main components: a gestural controller and a sound production, connected by mapping strategies. For example, the model presented by Birnbaum [1] includes a bi-directional mapping between the gestural interface and the feedback generator which produces sound and other feedback such as vibration. Combined the models presented by Bongers [2], Wanderley [3], and Birnbaum [1], the physical interface of DMI consists of the sensors used to detect gestures and actuators which produce feedback to the performer. Without the constraints of the physical design and fabrication in acoustic instruments, DMI allows more freedom for designers regarding the materials of the instrument and haptic and audio interaction [4, 5]. Sensors' and actuators' limitations could be regarded as the primary technical problems, including the real-time, the richness of information, and the embodied relationship and haptic feedback [4]. Previous research shows the importance of materiality in the embodied interaction, sound design, and affordances in DMI [6–8]. However, the unfamiliarity with sensor materials makes

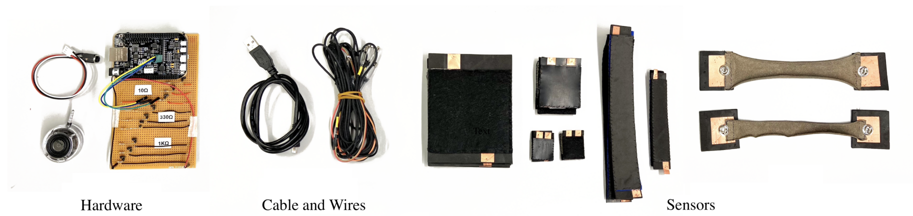


Fig. 1: The Toolkit:(a) USB cable for power; (b) audio cable for speaker; (c) speaker; (d) Bela embedded computer and breakout board; (e) sensors.

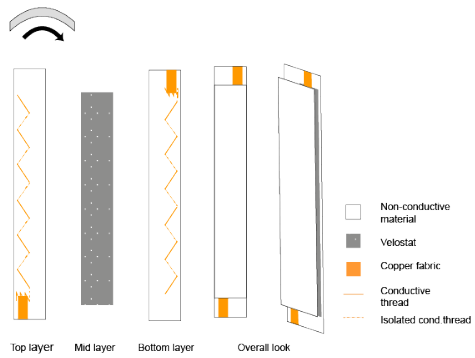
it challenging in the early prototype stages of DMI design, especially when using soft materials (e.g. fabric, foam, rubber). To address these challenges, we proposed a method that allows DMI designers quickly build functional prototypes while experimenting and exploring materials and haptic interactions during the design process.

Perner-Wilson et al. present A Kit-of-No-Parts approach to "build electronics from a diverse palette of craft materials", which researchers argue is a "more personal, understandable and accessible than the construction of technology from a kit of pre-determined components" [9]. Calegario et al. propose a method and toolkit including functional components for DMI design to generate ideas and prototypes [10]. The above literature indicates that the toolkit needs to be designed to give enough openness, flexibility, and easy access and address the technical barriers to making functional DMIs.

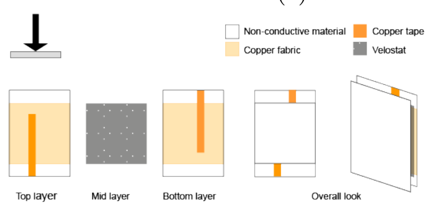
Instead of focusing on new interactions enabled by technological advances, we intend to explore the haptic interactions in DMI by rethinking their materials in the prototyping phase. A selection of sensors in different materials gave designers options and constraints, allowing them to build functional prototypes quickly. Although the sensors are pre-made, designers can still create personalised gestural interactions by selecting and combining different sensors in various materials and sizes. The following sections introduce the toolkit in detail, including the selection of materials, the sensors' construction, and the design consideration rationale.

2 DeSound: The Toolkit

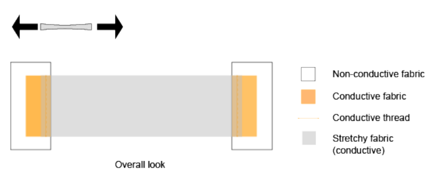
DeSound was designed for DMI designers to explore the materiality and gestural interaction in DMI design by quickly building functional prototypes. The toolkit's design was informed by the most frequently used deformable input and mapping strategies identified in [11] along with the gestural interaction and understanding of materiality of deformable materials identified in [8]. The toolkit including four core components: (1) different types of sensors in different materials, such as foam, fabric, rubber (see Figure1), (2) Bela embedded computer, USB cable, and a mini speaker, (3) a breakout board to connect deformable sensors to Bela, and (4) some supporting materials such as wood stick, rubber



(a) Construction of bend sensor



(b) Construction of pressure sensor



(c) Construction of stretch sensor

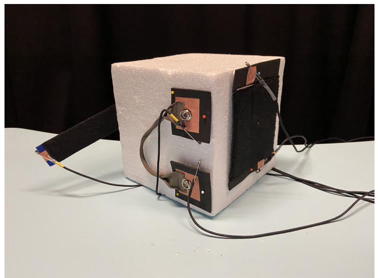
Fig. 2: Construction of sensor

bands, sewing pins, craft foam cube (polystyrene, 15*15*15cm), and different sizes of polystyrene balls. The reason to chose above materials is because the sensors are easier to attached on wood stick or polystyrene by pin, which more suitable for rapid prototyping and testing ideas.

2.1 Hardware, Software, and Sensors

The embedded computing platform we used is Bela [12], which provides ultra-low latency, integrates audio and sensor processing, and supports multiple audio programming languages, such as Pure Data [13], which makes it ideal for DMI projects.

The construction of the sensors followed an online E-Textile tutorial [14] and is reported here to allow designers to construct their own sensors and toolkit for rapid prototyping. To provide different haptic interaction, the sensors were made in four types of materials: (1) rubber, (2) foam, (3) fabric, and (4) foam-filled fabric. For the pressure sensor, sandwich the velostat between two squares of copper fabric connected to the copper tape. One copper tape goes to 3.3V, and the other side goes to the ground (the direction does not matter)(see Figure 2b). The bend sensor has a similar construction to the pressure sensor Figure 2a. The conductive stitches are designed to only overlap at one point to reduce the conductive surface overlap to a minimum. We used stretchy fabric (Shieldex TechnikTex P-130+B) to make the stretch sensor in our toolkit, as (1) this type



(a) The Instrument Made by Participant 3

(b) Performing with the Instrument

Fig. 3: Example of Participant's Construction

of material has been used as stretch sensors in other E-textile research [15], (2) it could be stretched in multiple dimension, and (3) the output data is stable. The construction of this stretch sensor was stitching both ends of the conductive stretchy fabric to copper fabric, one end to 3.3V, and another to the ground (see Figure 2c).

2.2 DeSound in Use

To test and collect feedback on the toolkit, we conducted a preliminary study with 11 participants. We invited participants using the toolkit to build functional prototypes within limited time (45 min), and then performing with the prototype DMIs (for example, see Figure 3). Participants described their design process as "playing with different musical gestures," and then finding subtle control mechanism via the haptic interaction with the sensors.

3 Remarks and Future Work

In user testing (analysis in progress, unreported), the toolkit received positive feedback regarding testing design ideas and rapid prototyping. Initial analysis suggests that the toolkit provides an approach to generating ideas and prototypes that retain openness. We are currently undertaking in depth thematic analysis of interviews with designers and analysis of video observations of their design work to better understand the opportunities and challenges for our toolkit. One direction for future research would be how to make the toolkit more adaptable to long-term iterative design and give designers more flexibility in making sensors. Following that, a possible study could be a longitudinal study. Following designers to develop the design over a longer period may provide insight into how the toolkit to support designers develop their instruments.

4 Acknowledgement

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