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Objects with Multiple Sonic Affordances to Explore Gestural Interactions

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We present a familly of sonic interactive objects called Stonic. They are designed to provide users with different affordances, i.e. action possibilities, associated to specific sound feedback. These objects are used in experimental studies to explore how augmented auditory feedback influences the object manipulation. We selected a set of basic interactions based on studies on the auditory perception of physical interactions producing sound, These interactions correspond to different ways of manipulating the objects, leading to a set of design. requirements. Twenty initial objects were made with acrylic resin and/or polystyrene. Each different shapes were tested in order to select a smaller number of objects affording a wide variety of actions. The selected shape were finalized using 3D printing and equipped with several sensors: Force-Sensing resistor (FSR), Piezos and an Inertial Measurement Unit. Specific software was made to enable real-time recognition of the different interactions and for the mapping of each actions to specific sound processes.

1 Introduction

The development of interactive devices has challenged the traditional design approaches, by extending the concept of product usability to the user experience concept, which includes user's personal goals, expectations and emotional aspects (Pucillo and Cascini, 2014).

Our interaction with physical objects is multimodal by engaging not only the vision, but also touch, proprioception and sounds, leading to a holistic experience. We are particularly intrested in the sonic aspects of the interaction that has generally been less addressed. Namely, our research is part of the emerging field called Sonic Interaction Design (Franinovic and Serafin, 2013) that focuses on the design of sonic feedback, taking into account the user-system relationships from an active and dynamic point of view. One objective of sonic interaction design is to extend the use of interactive object with sounds to achieve a variety of do-goals and be-goals trough different motor-goals (Hassenzahl, 2013). In particular, we are interested here in designing the sonic interaction produced by the manipulation of objects, by augmenting them though sensors and sound synthesis. This implies modeling the different interactions between the user, the object and its environment.

Designers and researchers developed numerous examples of interactive sonic objects, dedicated to experiments (design and/ or artistic). These objects have been also designed to study the impact of continuous sound feedback on different aspects of the user experience: from performance to learning, taking both emotional and aesthetic dimensions. However, these objects generally focused only on one or few basic gesture interactions. For example, the Ballancer (Rath and Rocchesso 2005) allows the user to tilt a wooden fence producing a sound linked to this simple action. Other researchers (O'Modhrain and Essl, 2004) investigated the interaction between sound and touch through different prototypes: the Pebble Box (manipulation of stones) and the Crumble-Bag (crumbling action). The Spinotron (Lemaitre et al., 2009) is an object with a pumping action affordance. Clicking sounds generated by a physical impact model simulates the rotation of a virtual gear inside it. While these different objects can be used with a limited action set, we intend here to develop objects that affords a variety of gesture interactions and sonic feedback, i.e. offering different motor-goals. With this goal in mind, we designed manipulable *sonic interactive objects,* called, *Stonic*, augmented with sensors driving sound synthesis.

While sharing similar technological aspects, this research can be distinguished from most of the objects and interfaces developed in the field of New Interfaces for Musical Expression (NIME). The aim here is not to produce a specifically sound or musical expressive results, but rather to focus on the object manipulation: we are interested to studying how the interactive sound design can inform and influence the object manipulation. Our objects are thus designed to investigate how the action-sound relationship (arbitrary, metaphorical, analogical) can influence the manipulation of the object, and how the different types of morphological sound characteristics can influence the user agency, i.e. producing the sense the user is "in control" of the sound they produce (Knoblich and Repp, 2009).

The paper is structured as follows. We introduce the theoretical bases that guided us in the design of the object's shape and the possible interactions with this object. We present the hardware and software development.

2 Physical Interactions

The theoretical bases that have motivated the object design come from two different sources. The first one draws from studies on environmental sound perception and the second one corresponds to the literature on manual gestures.

The physical interactions producing sounds have interested researchers in order to understand the different mechanisms associated to sound perception. In the continuity of Gaver's work (Gaver, 1993), we have studied the categorization of environmental sounds (Houix et al. , 2012). The results indicated a distinction between discrete solid interactions (e.g., impacts, multiple impacts) and continuous solid interactions (e.g., tearing, shaking, rubbing, ...). These different interactions are the basis of our requirements for the object design, since we are interested in the objects manipulations related to the sound production.

In another domain, Napier (Napier, 1956) has proposed taxonomy of manual gestures during object grasping that differentiates a gesture requiring power and another requiring precision. This framework allows us to analyze how people grasp objects and to relate these actions to sound production.

3 Requirements and Design

Our approach is to define gestures and actions that are relevant in the study of gesture-sound relationships. For this, we started with a set of basic gestures associated with the manipulation of the objects. We then designed appropriate shapes, and equipped some 3D printing versions of the objects with sensors.

3.1 Basic Gestures and Forms

We started with the lexicon that described different types of interactions producing sounds. The lexical analysis of sound categories (Houix et al, 2012) have shown a distinction between discrete interactions, like impacts or cyclic movements and continuous interactions like deformation (to crumple, to crush, to rub, to roll, ...). Actions like to crease or to crumple where excluded in this first study that was restricted to the interaction with solid object. We also removed actions such as cutting or to sawing which would require using tools. We finally selected ten actions: to hit, to rub, to roll, to turn, to swing, to put, to shake, to press, and to play with / to crush. These actions are directly related to lexicon of solid interaction categories (Houix et al, 2012). User can produce these actions directly by manipulating an object with one or two hands, in contact or not with a surface. These actions can imply low or high energy. The actions cover also the different hand manipulations (power & precision grasp, prehensile vs. non prehensile, motion of the hand or within the hand or no motion) that have been classified previously (Bullock, 2013). This repertory of actions and conditions of manipulation consituted the basic requirements for the design of the shape. We started with twenty initial prototypes made with acrylic resin and / or Polysterene (made at scale 1.0). Each object exhbites a different shape and different behaviors, for example offering swinging motion like Weeble[1] . We made a first selection based on the specifications (Figure 1). We tested the different actions produced within the hand, on the object and the object in contact to the surface during an behavioral experiment in order to test the different affordances without sonic feedback.

Fig 1 The selected prototyped shapes and with their associated 3D print version (when available).

1 https://en.wikipedia.org/wiki/Weeble

3.2 Hardware and Software

3D Print objects are built with a neutral material (ABS), and equipped with different sensors. The sensor data are processed in order to recognize the different interactions, and mapped to different sound synthesis systems. The electronic part is based on a Wifi module combined with a micro-controller, that follow-up of previous systems (Rasamimanana et al., 2011). The object contained an integrated 9 DOF inertial measurement unit (a triple-axis gyro, a triple-axis accelerometer and a triple-axis magnetometer) allows us to derive the absolute angles. These sensors give the absolute orientation of the gravity (up or down), the relative rotation speed and the acceleration (for example: shaking). The object contains also a force-sensitive-resistor (FSR) and two Piezo sensors that are connected to the main board through I2C using a Teensy 3.0 development board. The piezos allow us to capture rubbing or tapping and the FSR a gradual pressure. The sensor data are processed in order to differentiate the different actions, such as rubbing, tapping, shacking, ..., and to drive sound synthesis. The mapping strategies, combining both discrete and continuous strategies, are extensively based on machine learning methods that allow performing both recognition and mapping. Specifically, Multimodal Hidden Markov Models (MHMMs) are used to learn the mapping between movement features and sound synthesis parameters. The sound synthesis uses recorded sound material processed with granular synthesis and descriptor-driven corpus-based concatenative sound synthesis (Schnell et al, 2009), optionally complemented with physical models. The system is implemented in the Max6 environment (Cycling'74). We also use a method called "mapping by demonstration", by recording examples of actions performed synchronously with sound examples, and using interactive machine learning techniques. This allows to quickly prototype, experiment and adapt sonification strategies in the design process, and could allow users to craft themselves the sonic interaction without expert programming knowledge.

Summary and Perspectives

We present the design sonic interactive objects that provide affordances for different type of basic gestural interactions. We selected specific interactions that can be related to sounds produced by physical interactions. These experimental devices are equipped with different sensors allowing us to recognize these different interactions and mapped the sensor data to various sound processes. These objects will be used for evaluating the influence of the sound feedback in object manipulation, as well as the change in the perception of the object affordances.

Supplemential materials are online:
http://legos.ircam.fr/stonic/.
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