Sonification of the coordination of arm movements

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Summary— **We investigate sonification of arm movements for the rehabilitation of stroke patients. This involves providing patients with auditory feedback relative to the coordination between shoulder and elbow motion, and relative to movement smoothness. To this purpose, we are exploring different types of sonification and musical metaphors, including source-filter, concatenative-granular and physical modeling sound synthesis methods.**

INTRODUCTION

We are currently experimenting with various approaches to providing auditory feedback related to the quality of arm movement. Sonification of human movement is a growing research topic, with early results showing promise in a wide range of applications, such as performing arts, rehabilitation and sports training[1,4].

We are concerned with the specific case of patients recovering from strokes. These patients generally suffer from important motor impairments that alter the normal coordination of their arm movement[2], and diminish movement smoothness. A continuous auditory feedback mechanism, linked to the Knowledge of Performance (KP), might be beneficial in the rehabilitation process[3]. In particular, we propose here to associate the movements to specific continuous sound qualities that should be "targeted" by the patients. We report here a cost-effective system that implements different sonification strategies.

MOTION SENSING AND ANALYSIS

The setup is illustrated in Figure 1. The arm is equipped with two wireless sensing modules containing Inertial Motion Units with 6 DOF (accelerometer and gyroscope)[4]. The data is streamed at a frame rate of 200Hz and is analyzed by custom software built with Max6 (Cycling'74). Different types of real-time data analysis are available, including:

- Computation of the θ(t) and β(t) angles, and their relative angular velocities (Fig.1).
- Various smoothness parameters based on peaks detection, zero-crossing, or Fourier analysis of angular velocities and acceleration data.

SONIFICATION SRATEGIES

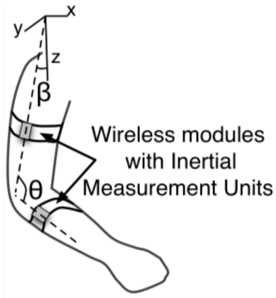
Multiple sonification strategies are implemented, utilizing different sound synthesis techniques. These different cases are studied experimentally in order to establish *pros* and *cons* of each technique.

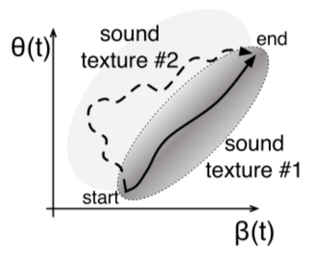
In particular, the following synthesis methods are used:

- Source-filter synthesis.
- Concatenative and granular synthesis (MuBu software, see http://forumnet.ircam.fr)
- Physical modeling sound synthesis

The motion parameters are mapped to synthesis parameters using either "direct mapping" or intermediate models[1,4]. In some cases, the motion/sound relationships can be perceived as "metaphorical".

Figure 2 illustrates one of the cases we implemented. The time profiles θ(t) and β(t) can be represented as 2D trajectories that traverse different regions, which are mapped to different sound textures. These textures are controlled with granular or concatenative sound synthesis, using recorded sounds that are automatically segmented, analyzed and labeled.





Left: Figure 1: Sensing system for the arm motion.

Right: Figure 2: Trajectories θ(t) and β(t) mapped to different continuously parameterized sound textures.

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