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MEDIATION: an eMbEddeD system for auditory feedback of hand-water InterAcTION while swimming

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Abstract

In swimming sport, the proper perception of moving water masses is a key factor. This paper presents an embedded system for the acquisition of values of pressure on swimmers hands and their transformation into sound. The sound, obtained using sonification, is used as an auditive representation of hand-water interactions while swimming in water. The sound obtained is used as an auditive feedback for the swimmer and as an augmented communication channel between the swimming trainer and the athlete. The developed system is self-contained, battery powered and able to work continuously for over eight hours, thus, representing a viable solution for daily usage in swimmers training. Preliminary results from in-pool experiments with both novel and experienced swimmers demonstrate the high acceptability of this technology and its promising future evolution and usage possibilities.

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1. Introduction

Interactions between human beings and technology are quickly increasing, changing people's daily life. Information technology is being increasingly adopted in several sports in order to measure and possibly enhance the performance of athletes and the awareness of trainers. People can positively benefit from the interactions with technology in the training activities. The fast and widespread development of sensors, single-board computers, and other components can be fostered to design user-specific systems. During the last years an ever increasing number of sports disciplines are positively exploiting the possibilities offered by such technologies as monitoring, and off-line (post-action) / on-line (during the action) feedback. Swimming, as well as other water sports and aquatic space activities, represents intriguing activities that can be better studied thanks to technology. However, they take place in a harsh environment, in which electronic components, communication and form factors hinder the fast development that has characterized other "dry" activities. Thus, although swimming has not received many contributions in terms of on-

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line feedback to the swimmer, it seems to be a highly promising field of application of the techniques of sonification, that is the transformation of data (information) into sound. The transformation of water pressure into sound is an intuitive process, also because both phenomena are characterized by similar wave-like behaviours. A device has been developed to measure the dynamics of the interaction of the hands inside the water with the water and to present this interaction in a simple and intuitive way to the user, through sound. That interaction is measured at the level of water pressure.

Auditory and visual *feedback* are stimuli aimed at producing effects on the human nervous system [1]. Auditory stimuli are often used to help disabled people, such as blind people in their daily activities [2] and for people with attention disorders [3,4]. The use of auditory stimulation is also remarkably widespread in sports activities [5]. Functional sounds are those sounds that (can) be functional to the listener: daily life is full of those sounds, e.g., the sound of an approaching ambulance. Further unknown examples can be found in the context of sports for the blind. For example, in the goal-ball game, in which a ball is equipped with a little bell. The moving ball will lead the bell to emit sounds merely communicates the position. Skilled players are able to trace the subsequent positions and derive the direction of motion, and exploit this to catch the ball. The auditory display is a family of techniques that can be exploited to use the auditory dimension as a display, with a duality to graphical displays. With respect to the basic auditory display, sonification introduces a more formal sound definition and the process of its creation: it is a systematic and reproducible transformation of data (information) into sound.

The paper presents the MEDIATION embedded sonification system developed to provide an on-line auditory feedback to both the swimmers and their trainers. In particular, the focus covers three aspects: i) the motivation of the development of the system; ii) its technical implementation; iii) observations and preliminary results of its usage in the context of elite and novice swimmers in Italy. The rest of the paper is organized as follows: Section 2 provides an overview of the related works. Section 3 describes the proposed system. Section 4 presents tests and results. Section 5 discusses the system and the results obtained in the tests, and finally, Section 6 concludes with final remarks and future perspectives.

2. Related Works

Nowadays, measurements of the physiological state of athletes are common practices: Electromyography (EMG), skin temperature (TEMP) and Galvanic Skin Response (GSP), Heart Rate (HR) and Electroencephalogram (EEG) to better understand the athletes fatigue or Oxygen consumption. At the same time, a broad range of measurements can be performed on the physics side: acceleration, speed, force, momentum, power, impact, etc.

Electronic systems can be exploited in sportive environments to provide feedback to athletes. The performance of athletes can be positively affected by exploiting systems to measure and report feedback in the form of workout performances or to provide feedback [6–9]. In particular Havriluk [10] describes a system able to measure pressure on swimmers' hands and presents the obtained pressure data mentioning which component of flow pressure is measured. An increasingly used technique is to provide feedback to the athletes themselves rather than only providing insights about their act to their trainers. For example, in running an auditory feedback has been used to convey information about the quality of the running act, useful to reduce the oxygen consumed by the runner [8].

MEMS (Micro Electro-Mechanical Systems) acceleration sensors (used as an inertial measurement system) and a GPS device situated on a rowing boat have been used to calculate boat acceleration and average speed [11]. The same inertial sensors have been used in swimming to measure the swimmers arms stroke action [12]. Gyroscopes and accelerometers worn on arms and legs during specific exercises have been employed in order to improve athletes posture in the field of aerobics and gymnastics [13]. Accelerometers and gyroscopes have been used also in the field of golf to gain insights into shoulders torsion, golf club speed, and swing [14]. In [15], Brueckner et al., explore the design space of systems for the real-time acquisition and representation of data for motion analysis. The work presented by the authors in [16] concentrates on the intermediate level of the effects of swimming (water pressure) to provide an auditory feedback. That work did not provide any implementation of a complete system, concentrating solely on an off-line exploratory sonification work. With respect to [16], the *MEDIATION* system is a complete real-time capable sonification platform for swimming.