Combined tracking and vibrotactile rendering with a wearable armband

Marco Aggravi, Tommaso Lisini Baldi, Claudio Pacchierotti, Domenico Prattichizzo

Combined tracking and vibrotactile rendering with a wearable armband

Marco Aggravi, Tommaso Lisini Baldi, Claudio Pacchierotti, and Domenico Prattichizzo

***Abstract*— We introduce a wearable armband interface capable of tracking its orientation in space as well as providing vibrotactile sensations. It is composed of four vibrotactile motors, able to provide contact sensations, an inertial measurement unit (IMU), and a battery-powered Arduino board. We use two of these armbands, worn on the forearm and the upper arm, to interact in an immersive Virtual Reality (VR) environment. The system renders in VR the movements of the user's arm as well as its interactions with virtual objects. Specifically, users are asked to catch a series of baseballs using their armbands-equipped arm. Whenever one baseball hits the arm, the armband closer to the contact vibrates. The amplitude of the vibration is proportional to the distance between the impact point and the position of the activated armband.**

I. Related Works and Motivation

Wearable haptics in Virtual Reality has been proven capable of providing compelling contact sensations in an unobtrusive and comfortable way [1], [2], [3], significantly improving the sensation of presence in the virtual world [4]. However, in addition to provide rich haptic sensations, it is also important to precisely track the position of the limbs involved in the interaction, so as to be able to detect any contact in a timely manner. Recently, IMU-based solutions have become very popular for this purpose, also thanks to their compact form factor, weight, and ease of use. They enable the wearable tracking of the orientation of multiple parts of the body, and they have already been proven rather effective in VR. Nonetheless, most tracking solutions involve magnetometers, which cannot be placed next to metallic objects and magnetic source, *e.g.*, an actuator.

II. The wearable haptic-tracking system

Our system is composed of an arbitrary number of elastic strap bands, each comprising four Precision Microdrives 304-116 vibration motors, a Xsens MTI-3 IMU, an Arduino Pro Mini 3.3 V, a 3.7 V LiPo battery, and a Bluetooth antenna.

Differently from camera-based techniques, the proposed IMU-based tracking approach [5] does not suffer from occlusion- and lighting-related issues. Moreover, it only uses accelerometers and gyroscopes, making it suitable to be used in the presence of iron and magnetic disturbances, guaranteeing good performance even near vibration motors.

For this demonstration, we track the orientation of the user's arm, donning two armbands at the forearm and upper arm (see Fig. 1). After a calibration phase, the system can retrieve the orientation of both links w.r.t. their initial pose with an error of less than 1.5 degrees at 100 Hz. By adding more strap bands, the system can track an arbitrary number of limbs.

M. Aggravi and C. Pacchierotti are with CNRS, Univ Rennes, Inria, IRISA – Rennes, France. E-mails: {marco.aggravi, claudio.pacchierotti}@irisa.fr

T. Lisini Baldi and D. Prattichizzo are with the Dept. Information Eng. and Mathematics, University of Siena – Siena, Italy. D. Prattichizzo is also with the Istituto Italiano di Tecnologia – Genova, Italy. E-mails: {lisini, prattichizzo}@diism.unisi.it

Fig. 1. The orientation of the user's arm is tracked wearing two armbands, one at the forearm and one at the upper arm.

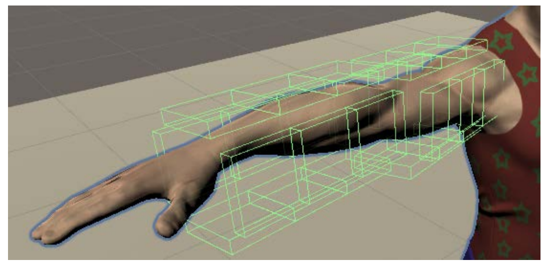

Fig. 2. Arrays of colliders around the virtual avatar.

III. Demonstration task

We tested our system in a baseball-catching experience in VR. A virtual avatar's arm mimicks the movements of the user's arm, who observes the scene via a Head-Mounted Display. Randomly, baseballs are thrown toward the avatar, and the user tries to stop them with his or her arm.

The user receives vibrotactile feedback if a baseball hits the arm. This collision is detected using a set of colliders around the avatar's arm (see Fig. 2). The provided feedback is proportional to the distance between the impact point and the position of the closest armband.

References

[1] M. Aggravi, F. Pausé, P. R. Giordano, and C. Pacchierotti, "Design and evaluation of a wearable haptic device for skin stretch, pressure, and vibrotactile stimuli," *IEEE Robotics and Automation Letters*, vol. 3, no. 3, pp. 2166–2173, 2018.

[2] X. De Tinguy, C. Pacchierotti, M. Marchal, and A. Lécuyer, "Enhancing the stiffness perception of tangible objects in mixed reality using wearable haptics," in *Proc. IEEE Conference on Virtual Reality and 3D User Interfaces*, 2018, pp. 81–90.

[3] S. V. Salazar, C. Pacchierotti, X. de Tinguy, A. Maciel, and M. Marchal, "Altering the stiffness, friction, and shape perception of tangible objects in virtual reality using wearable haptics," *IEEE Trans. Haptics*, 2020.

[4] M. V. Sanchez-Vives and M. Slater, "From presence to consciousness through virtual reality," *Nature Reviews Neuroscience*, vol. 6, no. 4, pp. 332–339, 2005.

[5] T. Lisini Baldi, F. Farina, A. Garulli, A. Giannitrapani, and D. Prattichizzo, "Upper body pose estimation using wearable inertial sensors and multiplicative kalman filter," *IEEE Sensors Journal*, vol. 20, no. 1, pp. 492–500, Jan 2020.