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Correspondence

An interactive experiment combining ultrasound, magnetic resonance imaging, and force feedback technology to physically feel the fetus during pregnancy

Dear Editor,

We would like to bring to the attention of your reader that the evolution in image-scanning technology has led to vast improvements in fetal assessments. Ultrasound (US) is the main technology for fetal evaluation, and magnetic resonance imaging (MRI) is generally used when US cannot provide high-quality images. This paper presents an interactive bidirectional actuated human–machine interface experiment involving the combination of a haptic device system (force-feedback technology) and noninvasive medical image technology.

Haptics refers to manual interactions with real or virtual environments that enable touching, feeling, and manipulating objects in these environments [1]. In the context of virtual reality, haptic sensations are created by actuators or motors of specific devices, which generate vibrations to the users, and are controlled by software. The potential of haptics in medical training through simulations has been recognized as a way to acquire clinical and surgery skills [2]. Haptics is also studied as a technology to improve success ratio in tele-operated, robot-assisted surgeries [1,2].

Advances in the technology of haptic devices as well as in image scanning technologies have provided new opportunities in medical diagnosis and surgical planning. Within this context, the experiment presented here is part of a study involving additive manufacturing models of fetuses and virtual reality technologies to generate immersive three-dimensional (3D) images in fetal medicine [3–5].

US was performed transabdominally using a high-resolution electronic probe with harmonic imaging (2–7-MHz transducer, Voluson E10, GE Medical Systems, Zipf, Austria). MRI was performed using a 1.5-T scanner MR 450 w (GE, Waukesha, USA). The protocol used for 3D MRI reconstruction was FIESTA sequence in the sagittal plane (TR, 3.4 ms; TE, 1.4 ms; voxel size, $1.6 \times 1.6 \times 1.6$ mm^3; FA, 70; PAT, 2; acquisition time, 0.23 s).

For this experiment, the haptic device used was the touch 3D stylus system from the American company 3D Systems. The 3D files of the fetuses' bodies were modeled through the superimposition of several slices obtained from MRI and fetal faces from 3D US.

Once the 3D shape was obtained, its virtual characteristics and the womb ambience were created considering illumination, color textures, shades, positioning, and bumpiness using a plugin developed for Unity 3D y, a game engine used to develop 3D games and simulations. We manipulated the physical responses of the device when the fetus shape was virtually touched (Figs. 1 and 2). These interactions included collision responses based on the friction coefficient and stiffness of the touched area (physical contact with the fetus). To complement the physical interaction, we introduced visual effects, such as shape deformation based on the properties of the involved area and animations to simulate fetus motion (Videos S1 and S2). Several tests with patients have been performed to date, and improvements have been discussed and implemented. After the initial period of tests and successful reports, the team aims to improve the experiment using new haptic devices. In particular, we intend to develop a haptic glove to provide a more realistic experience of touching the fetus which could mimic real-time examination interactions for parents-to-be.

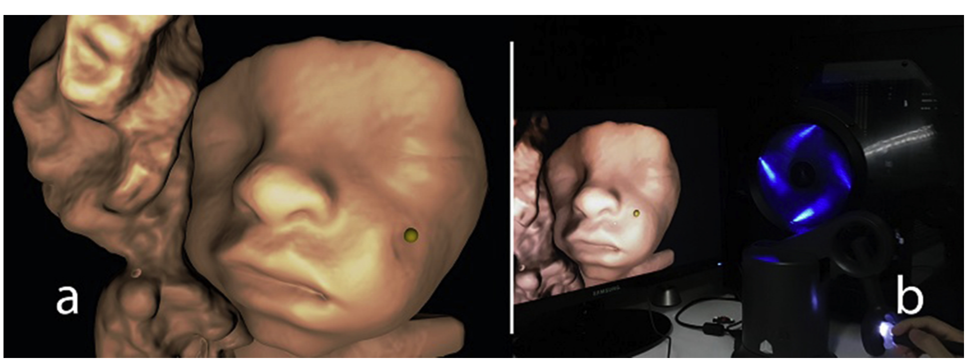

Fig. 1. (a) Ultrasound image of the fetal face (28 weeks). (b) Physical contact with collision responses.

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Fig. 2. (a) Magnetic resonance image of the fetal body (27 weeks). (b) Physical contact with collision responses.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ejrad.2018.11.020.

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