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# Ultrasonic bone localization algorithm based on time-series cumulative kurtosis

G. Robles, J.M. Fresno, R. Giannetti

**Abstract— The design and optimization of protective equipment and devices such as exoskeletons and prosthetics have the potential to be enhanced by the ability of accurately measure the positions of the bones during movement. Existing technologies allow a quite precise measurement of motion—mainly by using coordinate video-cameras and skin-mounted markers—but fail in directly measuring the bone position. Alternative approaches, as fluoroscopy, are too invasive and not usable during extended lapses of time, either for cost or radiation exposure. An approach to solve the problem is to combine the skin-glued markers with ultrasound technology in order to obtain the bone position by measuring at the same time the marker coordinates in 3D space and the depth of the echo from the bone. Given the complex structure of the bones and the tissues, the echoes from the ultrasound transducer show a quite complex structure as well. To reach a good accuracy in determining the depth of the bones, it is of paramount importance the ability to measure the time-of-flight (TOF) of the pulse with a high level of confidence. In this paper, the performance of several methods for determining the TOF of the ultrasound pulse has been evaluated when they are applied to the problem of measuring the bone depth. Experiments have been made using both simple setups used for calibration purposes and in real human tissues to test the performance of the algorithms. The results show that the method used to process the data to evaluate the time-of-flight of the echo signal can significantly affect the value of the depth measurement, especially in the cases when the verticality of the sensor with respect to the surface causing the main echo cannot be guaranteed. Finally, after testing several methods and processing algorithms for both accuracy and repeatability, the proposed cumulative kurtosis algorithm was found to be the most appropriate in the case of measuring bone depths in vivo with ultrasound sensors at frequencies around 5 MHz.**

**Index Terms— Ultrasound; Time of flight; Biomedical transducers; Ultrasonic transducers; Localization**

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