AudioDent: Toothbrushing Monitoring with In-ear Microphones

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Inadequate toothbrushing techniques persist as a leading cause of oral health problems like cavities and gum disease. Many people are unsure if they brush adequately or excessively focus on certain areas. While upscale electric toothbrushes provide some assistance, manual toothbrushes remain popular globally due to their simplicity and affordability. In this study, we harness the widespread use of earphones, a common wearable device utilized for various tasks like listening to music and communication, to enhance manual toothbrushing. Specifically, we introduce AudioDent, a system utilizing earable technology to enhance manual toothbrushing with features typically found in high-end electric toothbrushes, such as surface detection and brushing duration estimation. The high-level idea of AudioDent is to utilize in-ear microphones on earables to capture toothbrushing sounds transmitted through the oral cavity to the ear canals via facial bones and tissues, allowing us to extract features for surface detection. Compared to existing methods based on Inertial Measurement Units (IMUs)[1], [2], AudioDent is inherently resistant to variations in hand and head movements due to its focus on audio cues relevant to toothbrushing.

To achieve this, we propose the following technical approaches. First, we develop a model to characterize the propagation channel of toothbrushing sounds from various brushing positions to both ear canals, enabling us to extract channel-related features and minimize external influences. Second, considering the subtle differences between surfaces in the same area, we leverage temporal and spatial continuity constraints inherent in toothbrushing to refine recognition results, enabling precise surface identification. Finally, we employ transfer learning to update the AudioDent model with data from a new user's brushing session, ensuring adaptation to user-specific variations and minimizing user intervention.

Our comprehensive evaluation confirms the effectiveness of AudioDent under realistic conditions, with an average accuracy of 81.3% in detecting sixteen tooth surface areas. By enhancing manual toothbrushing with in-ear microphones, AudioDent has the potential to transform oral hygiene practices on a large scale.

Reference

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