Towards In-Ear Inertial Jaw Clenching Detection

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ABSTRACT

Bruxism is a jaw-muscle condition characterized by repetitive clenching or grinding of teeth. Existing methods of detecting jaw clenching towards diagnosing bruxism are either invasive or not very reliable. As a first step towards building a reliable, non-invasive and light weight bruxism detector, we propose an eSense based in-ear inertial jaw clenching detection technique that detects peaks/dips in gyroscope vector magnitude. We also present results from preliminary experiments that show an equal error rate of 1% when the person is stationary and 4% when moving.

ACM Reference Format:
Siddharth Rupavatharam and Marco Gruteser. 2019. Towards In-Ear Inertial Jaw Clenching Detection. In *Proceedings of 1st International Workshop on Earable Computing (EarComp'19).* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3345615.3361134

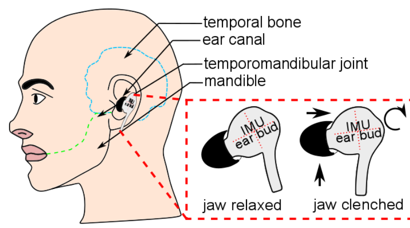


Figure 1: Temporomandibular joint (TMJ) and ear-bud displacement

1 INTRODUCTION

The term *bruxism* is derived from the greek word *brychein* meaning to grind or gnash teeth. More formally, according to F. Lobbezoo et. al. [2], *"bruxism is defined as a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible (jaw bone). Bruxism has two distinct circadian manifestations: it can occur during sleep (indicated as sleep bruxism) or during wakefulness (indicated as awake bruxism)"*. Bruxism also does not occur when a person is chewing or swallowing and hence is clearly distinct from jaw movements made to ingest food.

Bruxism affects the quality of life of a person by manifesting in the form of pain in the jaw, face and head, dental problems such as tooth wear and reducing lifespan or wearing down of dental restorations. Present methods of detecting bruxism are through the use of questionnaires , clinical evaluations , inserting intra-oral splints, measuring jaw muscle electromyograph or by polysomnography [3]. Splints, electromyography and polysomnography use sensors that are bulky and invasive and hence influence the jaw clenching and grinding patterns. Questionnaires and clinical evaluations are less accurate because they depend rather heavily on patients' replies to a subjective survey or the detection itself is not entirely reliable. Hence, there is a need for a non-invasive, lightweight and reliable way to detect grinding and jaw clenching as a first step towards a bruxism detection method.

To address this need, this paper presents an in-ear inertial jaw clenching detection technique and a preliminary evaluation on the eSense platform [1]. In-ear sensing allows jaw clenching data to be collected ambiently and deployment is as easy as using ear-buds to listen to music while performing daily activities.

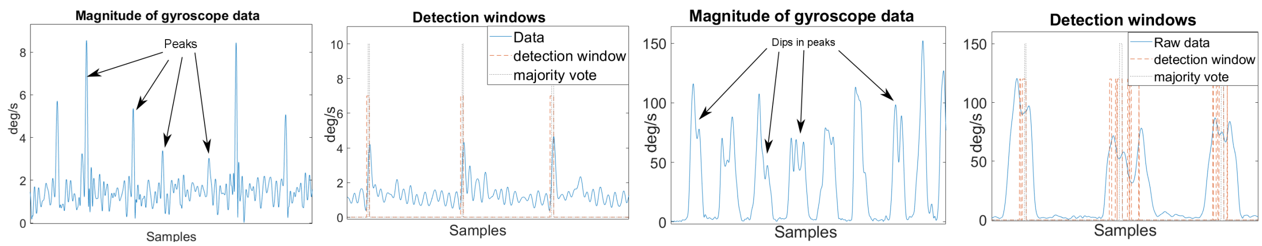
2 DETECTION TECHNIQUE

The observation that enables detection of jaw clenching is that the temporomandible joint (TMJ) is the place where the mandible (jaw bone) meets the temporal bone (on the skull) and the joint is located very close to the ear canal as shown in Fig. 1, hence when the jaw is clenched, the movement of the mandible can be detected through the ear canal. A unique advantage is that both the right and left joints on the jaw bone move together and not independently. Hence, jaw movement can be detected equally in both ears from inside their respective ear canals.

Information regarding the amount of movement of the mandible can be obtained when a person wears ear-buds, such as the eSense, which house an inertial measurement unit (IMU) containing an accelerometer, gyroscope and given that the ear-buds can be inserted sufficiently deep into the ear canal. This is because, when the mandible moves up

EarComp'19, September 9, 2019, London, United Kingdom

ACM ISBN 978-1-4503-6902-2/19/09…$15.00
https://doi.org/10.1145/3345615.3361134



(a) Gyroscope data - stationary case (b) Detections - stationary case (c) Gyroscope data - mobile case (d) Detections - mobile case

Figure 2: Gyroscope magnitude data and detection of jaw clenching

(clenching) and down (relaxing), it creates small depressions in the ear canal which physically displace the ear-bud by small amounts. By observing the amount of displacement and when it occurs, jaw clenching can be detected.

Detection algorithm: Two separate algorithms (peak and dip detection) are used on collected gyroscope magnitude data to detect jaw clenches. Jaw clenches are seen as peaks in gyroscope magnitude data as shown in figure 2(a) in the stationary case. The peak algorithm averages gyroscope magnitude values over a window and compares them to a threshold thr, representing a minimum deg/s. If average window values are greater than thr, a jaw clench is detected as shown in figure 2(b). When the head is in motion, jaw clenches are seen as dips that occur in peaks due to the motion in gyroscope magnitude data as shown in figure 2(c). We explore a separate dip algorithm for this case that averages gyroscope magnitude values in a window and compares them to a threshold window $thrWin$, representing a range (i.e., $upper - lower$ value) in deg/s). If average window values fall within this range, a jaw clench is detected as shown in figure 2(d).

3 EVALUATION

Evaluation is performed for two cases:

(i) Stationary case, when the subject is stationary (i.e., lying down or sitting up but not moving) and only clenches their jaw to mimic sleep bruxism, and **(ii) Mobile case**, when the subjects head is mobile (i.e., working at a desk, looking around, gentle head movements) and clenches their jaw to mimic awake bruxism.

All experiments were performed by a single participant. Each set of experiments was conducted in a window of one minute to reduce IMU sensor drift. The participant was asked to clench his jaws for a duration of 2-3 seconds, every 10 seconds. The experiment was repeated five times, to generate total data of 50 jaw clenches per case. The accelerometer in the ear-buds was calibrated to 0g, 0g and -1g on the X, Y and Z axes respectively and the three gyroscope axes to 0 deg/s by placing on a stationary, flat surface. All collected data was passed through a 2 Hz lowpass filter and then through a peak/dip detection algorithm depending on the case.

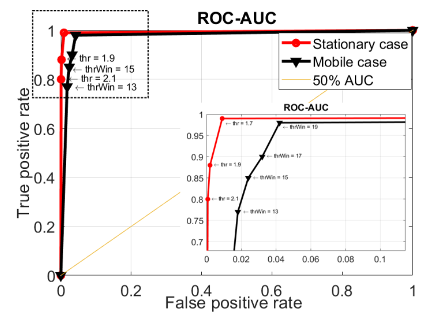


Figure 3: Accuracy in detecting jaw clenching

The detection accuracy is shown in figure 3. The area under curve (AUC) is 99.40% with an equal error rate (EER) of 1% for the stationary case and AUC of 97.66% and EER of 4% for the mobile case.

4 CONCLUSION

In this paper we introduce a novel ear-buds IMU based technique to detect jaw clenching (that might be due to sleep or awake bruxism). In preliminary experiments, the equal error rate of detection is 1% and 4% for a stationary and moving subject, respectively. While these results still need to be validated in a longer study with multiple participants, we believe that these results represent a first step towards a more reliable, non-invasive and light weight bruxism detector through in-ear inertial sensing.

ACKNOWLEDGMENTS

We would like to thank Nokia Bell Labs, Cambridge, UK for providing us with the eSense earbuds.

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