Demo Abstract: Real-Time Teeth Functional Occlusion Monitoring via In-Mouth Vibration Sensing

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1 INTRODUCTION

Approximately 3.5 billion people worldwide have oral diseases [8], which significantly impact people's quality of life [1] and may lead to mortality if left unattended [7]. Out of these oral diseases, occlusal diseases, such as temporomandibular joint and muscle disorder (TMD), gum recession, fractured teeth, and undesired tooth mobility, are especially hard to diagnose due to the subjective interpretation of many current practices used to test for this condition [9]. Occlusal diseases, associated with the alignment of a person's teeth, are usually caused by excessive wearing of teeth, bruxism, and unbalanced biting [5].

Existing apparatus and methods for occlusion monitoring include dental articulating paper [3] and 3D diagnostic scanners [4]. These clinical procedures are usually one-time measurements when the patient visits their orthodontists, i.e., they are not real-time/continual and call for dental expertise to interpret the result. Therefore, long-term monitoring requires patients to visit their orthodontists repetitively, a time-consuming and costly process for patients. In addition, these measurements are often done when the patients are not in their natural posture, which may not reflect their true functional occlusion conditions.

To provide more accurate and fine-grained long-term functional occlusion information, we present *TeethVib*, a low-cost retainer-formed vibration sensing device to capture the vibration induced by oral activities [6]. In this demo, we demonstrate *TeethVib* and its integrated patient-friendly visualization interface in real-time as illustrated in Figures 1 and 2.

TeethVib provides long-term continuous analysis over different time resolutions and information scales intuitively. The reliable data collection hardware and firmware combined with the effective visualization tool will allow dentists to observe users' teeth biting behaviors in real-time. Additionally, *TeethVib* can also be used by patients who do not have dental expertise to make sense of their data. We believe that the presented retainer-formed wearable system and its intuitive user interface will be a reliable tool for long-term and fine-grained occlusion monitoring in the future.

2 SYSTEM OVERVIEW

Our system consists of three main modules namely 1) data acquisition module, 2) data analysis module, and 3) teeth info visualization module. Together they provide real-time occlusion monitoring.

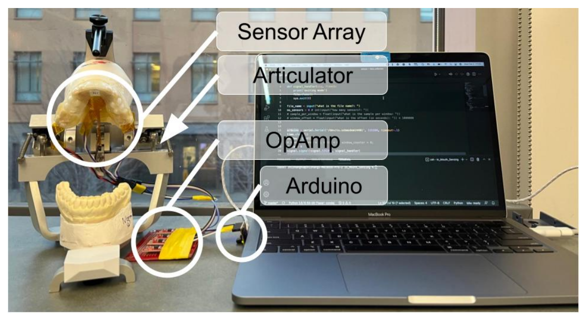

Figure 1: Demo setting. An articulator is used to demonstrate realistic bite from the presenter. A sensor array is installed on the retainer. The OpAmps amplify signals from each sensor unit and the MCU (Arduino) board acquires the signal via its ADC module. The MCU then sends the digitized signals through the serial port to a local computer where the visualization will be demonstrated.

Data Acquisition Module. The data acquisition module captures teeth activity induced vibration signals via a retainer-formed sensor [6]. The retainer-formed sensor consists of two layers of retainers with four piezo film-based sensing units embedded between them. The sensing unit array covers mainly four areas – canine and molar on both sides. As shown in Figure 1, the sensor array connects to the operational amplifier, where the signal is amplified. The amplified signals are then digitized by the Arduino, which then sends the signal to the server for processing.

Data Analytic Module. We first apply a sliding window on the raw vibration signals from the four synchronized channels. Next, we conduct event detection on the sliding window, where the segments of signals induced by teeth activities are extracted. Then, feature extraction and occlusal profiling are done on the detected events. Both time and frequency domain features are extracted for occlusal condition profiling.

Teeth Information Visualization Module. The visualization module depicts the teeth information in multiple scales and forms. *Front-end Design and Implementation.* The front end of the proposed visualization system is primarily created with the D3.js library [1].

[1] https://d3js.org/

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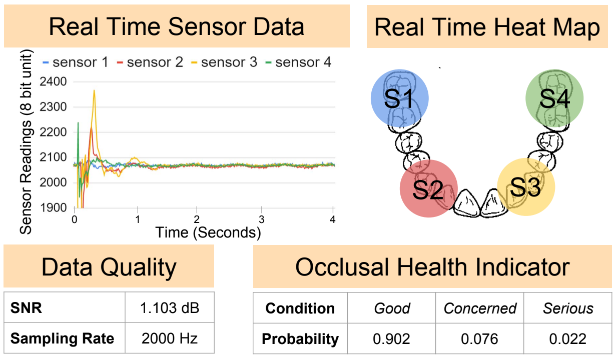

Figure 2: *TeethVib* visualization user interface mock up. On the top, we will demonstrate real time raw signals from four channels sampled at 2000 Hz (left) as well as detected bite heat map updated every 5 seconds (right). The bottom shows latency between data collection and visualization (left), as well as predicted results of detected teeth activities (right).

As shown in Figure 2, the raw signal on the top left figure is shown sample level signal for each channel. We also demonstrate the bite force distribution at four locations marked as S1 to S4 on the top right figure in the form of a heat map. The higher the intensity of the color, the stronger the biting force it is. The occlusal condition profiling results are shown at the bottom right window, where the probability of the prediction is listed. The sampling rate and the signal to noise ratio of the sensor raw data are shown at the bottom left windows.

Back-end Design and Implementation. To make sure that the data are streaming continuously and precisely to the D3js's buffer for visualization, we design and implement a reliable back-end architecture that pushes the limit of UART communication to achieve a 2000 reliable sampling rate on an Arduino platform. We then implement a robust real-time event detection to effectively extract teeth activity-induced vibration signals. Last but not least, we implement a multi-viewer system that allows multiple users to observe the collected *TeethVib*'s data simultaneously. In particular, as long as the device has Internet connectivity and correct log-in information, it will be able to stream the teeth biting signals of the registered user and display them in real-time.

3 DEMONSTRATION PLAN

At the demo booth, we will bring the setup shown in Figure 1. The presenter will bring two sets of retainer-formed sensors built based on their teeth model. We plan to demonstrate 1) how the whole sensing system with the form factor of retainer is being used by the presenter, and 2) how different teeth activities generate different vibration signals with the articulator.

Presenter In-Mouth Demo. Because each retainer-formed sensor is personalized to users, and in consideration of sanitation, we only demonstrate in-mouth sensor setting on the presenter (IRB approved for the safety of this in-mouth sensing system). The audience can interact with the presenter to see the non-intrusive nature of the system design.

Articulator Demo. The audience can interact with the articulator to conduct teeth activities they wish to see. Spare sets of teeth models with different occlusal conditions (Class II and III malocclusion) will be prepared. The audience can switch between these teeth models with different occlusion conditions to understand and observe the functional occlusion differences and their corresponding signals.

4 CONCLUSION AND FUTURE WORK

We present a real-time dental functional occlusion monitoring system *TeethVib*, and demonstrate real-time data acquisition and analysis with intuitive visualization. Our system will allow ubiquitous teeth activity monitoring to enable preventive diagnosis for occlusal diseases. We present an intuitive user interface with comprehensive teeth health information over multiple scales. We hope this study demonstrates the usefulness of the *TeethVib* device for occlusal-related monitoring. *TeethVib* may prove that it can be used for possible preventative care for patients with possible future occlusal problems, as well as for a replacement for a much more technical scanning process, such as 3D intraoral scans or alginate scans [2]. Although it is not a complete replacement for these alternatives, *TeethVib* may be an additional tool dentists can use to aid diagnoses of patients in the future. We plan on continuing to improve the monitoring system with more features, and achieve real-time analysis with these features for anomaly detection. *TeethVib* may make the process of diagnosing patients more streamlined and accessible to increase teeth health of patients as well as aid doctors to work with more patients remotely with new biometrics from long-term continuous monitoring. We hope to inspire future studies to use *TeethVib* in order to further legitimize this tool for future research and dental practice.

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