Non-Invasive Monitoring of Human Hygiene using Vibration Sensor and Classifiers

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***Abstract*—This paper presents the concept and idea of a non-invasive monitoring system for human hygiene using only vibration sensors. The approach is based on a geophone, a digitizer, and a cost-efficient computer board (raspberry pi). Personal hygiene is how people take care of their bodies. Maintaining hygiene practices reduces the spread of illness and the risk of medical conditions. With the current pandemic situation, practices like washing hands and taking regular showers have taken major importance among people, especially for senior populations that live alone at home. Having an understanding of the human hygiene habits of our seniors is fundamental to monitoring health conditions.**

***Index Terms*—Non-invasive monitoring, human hygiene, vibration sensors, classifiers.**

I. Introduction

The saying "a healthy heart starts with a healthy lifestyle" often gets passed around but does not get the attention it deserves as people often take their health for granted. In the times of a global pandemic that affected nearly every country and millions around the world, people have come to realize that their health is their biggest wealth, and they need to be doing more for each other as a community.

People's daily habits indicate a lot about their health and well-being. It is no surprise that age brings a forgetful nature. Questions such as "are you washing your hands regularly?" or "are you taking long enough showers?" may not seem as important during the early adult years but these questions become essential with age as they could be an indication of a developing health crises. Elderly community is at the most risk for this as majority of them either live alone at home or live in an assisted living facility where the staff may be stretched too thin. Being aware of these issues, we can either sit back and point fingers at the broken system or we can think about different ways of mitigating potential risk.

Since a proper hygiene is the first step to a healthy life, we need to be thinking of different ways that we can assist the ones that need our help the most. We need to question the current methods of monitoring seniors and think of ways we can improve their health and lifestyle. One of the most common ways to perform remote monitoring is the use of cameras [1]. A vast majority of people will think of cameras and surveillance when considering ways of monitoring but there is a huge problem with this solution: Privacy. Adding camera in bathrooms and kitchens is a direct attack on someone's privacy and even unlawful [2], then, the solution needs to be nonintrusive and respectful of people's privacy.

In this paper, we present the concept and idea of a non-invasive monitoring system for human hygiene using non-invasive vibration sensor. The vibration sensor is placed in bathroom faucet, showers and toilets in order to capture the vibration water signal from those places. Using classifiers, we classify the different collected signals to determine the time and duration of the different hygiene activities. The data collected can be also used for further analysis to draw conclusions on health, hygiene, and safety. When the sensor is placed in the bathroom by the toilet or faucet, it can detect vibrations from the running water and capture the activity in a log. Once the data is recorded, we can use signal-processing algorithms to find patterns and classify these patterns as activities. The sensors not only tell when the faucet was opened, but it can also tell us how long the water was running for.

We propose to leverage the power of these sensors to help better understand the everyday habits and the goal here is to raise awareness – if we are able to provide this data to healthcare workers, they can take proactive measures in remediating a potential health crises. When it comes to health and safety, time is always of the essence – the sooner we can detect an issue, the faster our healthcare workers can respond and help with recovery.

II. Related Works

Previous works on this idea have relied on acoustics to recognize and categorize daily activities or wearable devices that use accelerometers. For example, Mondol et al. [3] present a hand washing detection system using wrist wearable inertial sensors. The approach reported 77% of accuracy; however, the system requires people to wear a device while washing their hands, which can be impractical for senior population. Camilus et al. [4] present a automated hand hygiene compliance monitoring system based on a Intel RealSense 435 device, which is a camera. Again, the concerns of privacy of using cameras in bathrooms or private places arise for elder monitoring.

With vibration sensors, few studies have been presented. For example, Fargert et al. [5] presented in 2017 a monitoring mechanism of hand-washing practices using structural vibration. In this study, the authors used a geophone and an operational amplifier attached to a sink structure. First, the hand-washing activity was isolated from the signal using an anomaly-based detection algorithm. Then, the system used the isolated signal to estimate multiple features like the energy distribution using a Power Spectral Density (PSD) function

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and the sum across frequency bands centered on the natural frequencies of the sink structure. Finally, the detected hand-washing activity was classified using a support vector machine algorithm. The accuracy of the proposed detection reached 95.4%. Even though the work is similar to ours, the authors did not present results on faucet, toilet, and shower usage.

III. System Hardware

We use a smart sensor composed by a geophone (seismic sensor) [6], a digitizer board and a single-board computer (Raspberry Pi 3B). It is shown in Figure 1. The geophone detects the velocity of the movements. The digitizer transforms analog vibration signals to digital that is read by the single-board computer. The single-board computer reads and processes the signal to detect the water vibration and duration of the hygiene events.

Fig. 1. Prototype used for data collection.

The extracted data is saved inside the sensor device using a InfluxDB database [7]. The data is visualized using Grafana tool [8]. Figure 2 shows an example of vibration sensor collected in a faucet when it is opened or closed. Note that the difference is captured by the vibration signal.

Fig. 2. Vibration signal visualized with Grafana [8]

IV. System Overview

Figure 3 presents an overview of the proposed system. After data is collected, we apply a signal pre-processing to enhance the signal and to isolate the potential hygiene events in a segmentation process. We then extract the most significant time and frequency domain features of the isolated signals such as event duration, event amplitude, power spectrum, etc. We plan to use Support Vector Machines (SVM) to classify then the events in faucet usage, toilet usage, and shower usage. The idea of using SVM is because we want to utilize a lightweight computer algorithm as we plan to run the classification process inside the device itself. The classified information will be also measured in time to estimate the duration of the events and provide a better understanding of the subject's hygiene habits.

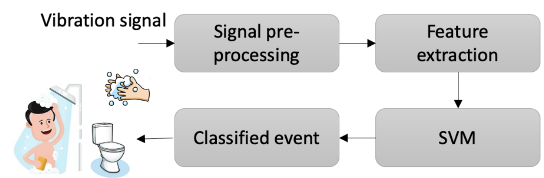

Fig. 3. Overview of the proposed system.

V. Future Work and Conclusion

Currently, we are in the data collection phase. We have collected multiple events in the bathroom's faucets, toilets, and showers. We plan to apply simple classifiers like SVM to classify the hygiene events and estimate their duration. Also, we plan to develop a real-time communication framework that can inform healthcare providers or family members about the senior's habits in real-time. To sum up, in this paper, we presented the concept idea of a non-invasive monitoring system for human hygiene using only vibration sensors and classifiers. We expect to have a system that can communicate in real-time the up-to-date information of the monitored person to their family members or healthcare providers.

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