Poster Abstract: Sleep Position Management System for Enhancing Sleep Quality using Wearable Devices

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ABSTRACT

Sleep position is directly related to sleep quality especially in patients with sleep disorders such as sleep apnea or snoring. We propose SleeP-Manager, a wearable embedded system, that is designed to aid Sleep Positional Therapy (SPT). SleeP-Manager with two wristbands monitors the sleep position of the user and gives a vibration feedback when a poor position is detected. We experimentally evaluate the effectiveness of SleeP-Manager. In order to accomplish this, an additional device of chestband is designed. The chestband provides the true sleep position and also measures the response of users to the vibration feedback. The results indicate that the accuracy of sleep position detection higher than 80%, and the ratio of desired sleep position per night increased significantly by the use of SleeP-Manager. Our questionnaire survey shows the wristband-typed device is most preferred for SPT due to the cost-effectiveness, easy-to-wear, and practicality.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; • **Human-centered computing** → *Human computer interaction (HCI)*;

KEYWORDS

Sleep position therapy, sleep quality, sleep apnea, wristbands

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1 INTRODUCTION

Sleep position is one of important factors affecting sleep quality [1]. Management of the sleep position is necessary for sound sleep especially in patients with sleep disorders such as sleep apnea or snoring. Since a supine position, i.e., lying on your back, makes an upper airway narrow and deteriorates the sleep disorders. Continuous Positive Airway Pressure (CPAP) is used for a standard treatment method for obstructive sleep apnea (OSA) patients [3]. However, sleeping with a nasal mask is very uncomfortable and not suitable for a long-term sleep aid. Sleep Positional Therapy (SPT) that avoids a supine sleep position is recommended for patients with mild sleep apnea or snoring as a practical treatment method [4]. Although portable wearable devices that can wear on neck and chest have been developed to help the long-term SPT, the devices that are directly related to breath may cause a discomfort in sleep environments.

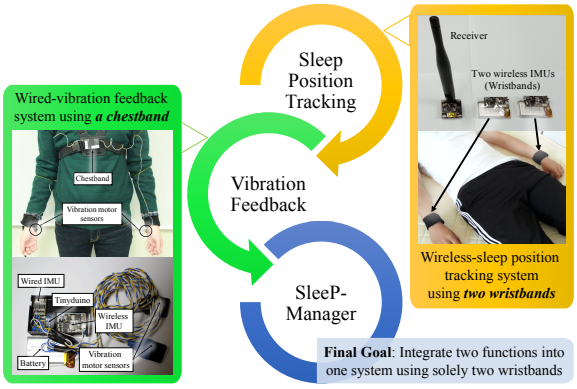

Figure 1: Overview of SleeP-Manager

In this paper, we propose Sleep Position Management system using two wristbands for enhancing sleep quality (SleeP-Manager). To the best of our knowledge, we are the first approach using two wristbands for SPT, and the approach has advantages such as cost-effective, easy-to-wear, and practical solution in sleep environments. From the perspective of human-computer interaction, SleeP-Manager monitors sleep positions and give vibration feedback to a user when a poor sleep position is detected. Our final goal is to integrate two main functions (i.e., sleep position tracking and vibration feedback) into one device solely using two wristbands as shown in Fig. 1. As a preliminary study, we demonstrate system performance in the two functions with a proof-of-concept.

2 PROOF-OF-CONCEPT EVALUATION

SleeP-Manager consists of two main functions, i.e., sleep position tracking and vibration feedback. In order to evaluate the two main functions, we design an additional chestband for providing the true sleep position and measuring the reaction of users. In the chestband, there are two IMU sensors, i.e., wireless IMU and wired IMU sensors. The wireless IMU sensor is used to verify the function of sleep position tracking as a ground-truth of sleep positions. On the other

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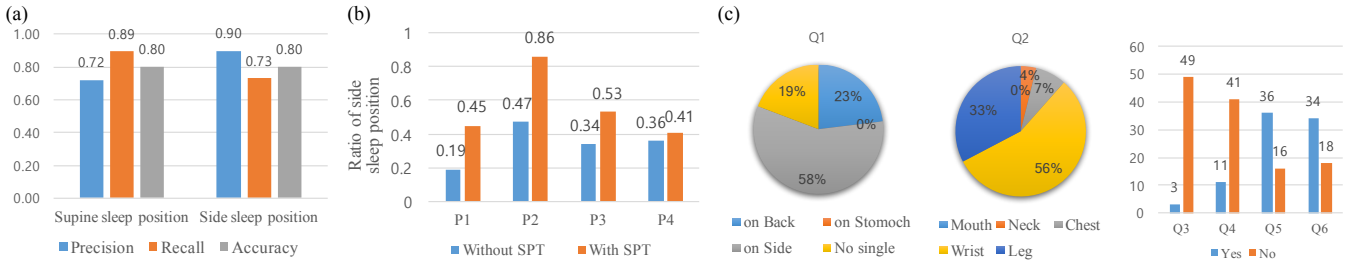

Figure 2: Performance evaluation in SleeP-Manager: (a) Sleep position tracking performance evaluation (b) Vibration feedback performance evaluation (c) Questionnaire items in a survey on user preference

hand, the wired-IMU sensor is used to give vibration feedback in real-time by detecting a supine position as an embedded system. We collect on-site sleep data from four participants for two days (with/without vibration feedback) in their home, and evaluate the two main functions. Besides, we carry out a questionnaire survey for investigating user preference.

2.1 Sleep Position Tracking

In our previous work, i.e., *SleePS* [2], we proposed sleep position tracking system using two wristbands. Although there are limitations with one wristband due to sensing noise, sleep position tracking is possible with two wristbands. We use one of deep learning models, i.e., VGG 16, and train the VGG model with motion data of a pilot experiment in the previous work. And then, we evaluate classification performance of sleep positions with on-site sleep data in this work. Fig. 2(a) shows classification performance in two sleep positions, i.e., *Supine* and *Side* sleep positions. In total 601 motions of the on-site sleep data, SleeP-Manager shows the average classification accuracy of 80%.

2.2 Vibration Feedback

In order to evaluate the function of vibration feedback, we assume that SleeP-Manager can estimate sleep positions with the accuracy of 100% and attach two vibration motor sensors to both wrists for investigating the reaction of the user. 3-axis accelerometer sensor of wired IMU sensor in a chestband is used to monitor a supine position with a heuristic threshold, and SleeP-Manager gives a vibration feedback to the user when it detects a supine sleep position in real-time. Fig. 2(b) shows the effectiveness of SPT using vibration feedback of wristbands. All participants show that the ratio of side sleep position per night is increased with SPT of SleeP-Manager.

2.3 Questionnaire Survey on User Preference

We carry out a questionnaire survey to investigate user preference. We make a questionnaire consisting of six items as shown in Table 1, and get questionnaire survey results from 52 people in their 20s as shown in Fig. 2(c). Most preferred sleep position is a side sleep position (58%) in Q1, and no one selects a sleep position lying on their stomach. In Q2, most people (56%) think their wrist is the most comfortable place to wear a device on a body during sleep. Most of the people do not use smart-band or smart-watch for sleep monitoring (92%) in Q3, and do not have sleep disorders (79%) in Q4. However, many of them know the sleep position is directly connected to the health condition (69%) in Q5, and they prefer wristbands-typed SPT device (65%) like our system in Q6.

Table 1: Questionnaire survey on user preference

	Questionnaire items
Q1	My usual sleep position? (Answer: lying on my back, lying on my side, lying on my stomach, no single position is usual)
Q2	If you want to wear a device while sleeping, where do you prefer to wear? (Answer: Mouth, Neck, Chest, Wrist, Leg)
Q3	Do you use activity tracker to monitor your sleep using smart-band or smart-watch (Answer: Yes or No)
Q4	Do you have sleep disorders such as sleep apnea or snoring (Answer: Yes or No)
Q5	Do you know that your sleep position has a direct impact on your health condition? (Answer: Yes or No)
Q6	Do you prefer to wear two wristbands during sleep if they track your sleep position and manage your sleep position (Answer: Yes or No)

3 CONCLUSION AND FUTURE WORK

We propose SleeP-Manager for a long-term sleep aid. SleeP-Manager consists of two main functions, i.e., sleep position tracking and vibration feedback. Experimental results show that the average classification accuracy of 80% in sleep position tracking while increased the ratio of desired sleep position per night in vibration feedback. In addition, questionnaire survey results support that most of people prefer to use wristbands-typed device like our system. We expect that SleeP-Manager will improve the quality of sleep for patients with sleep apnea or snoring as an effective SPT. In the future work, we will further develop an optimal sleep position tracking algorithm considering individual sleep characteristics and integrate two main functions into one embedded device. Besides, we plan to test our system in actual patients with sleep disorders.

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