Context-Aware Sit-Stand Desk for Promoting Healthy and Productive Behaviors

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ABSTRACT

To mitigate the risk of chronic diseases caused by prolonged sitting, sit-stand desks are promoted as an effective intervention to foster healthy behaviors among knowledge workers by allowing periodic posture switching between sitting and standing. However, conventional systems either let users manually switch the mode, and some research visited automated notification systems with pre-set time intervals. While this regular notification can promote healthy behaviors, such notification can act as external interruptions that hinder individuals' working productivity. Notably, knowledge workers are known to be reluctant to change their physical postures when concentrating. To address these issues, we propose considering work context based on their screen activities to encourage computer users to alternate their postures when it can minimize disruption, promoting healthy and productive behaviors. To that end, we are in the process of building a context-aware sit-stand desk that can promote healthy and productive behaviors. To that end, we have completed two modules: an application that monitors users' computer's ongoing activities and a sensor module that can measure the height of sit-stand desks for data collection. The collected data includes computer activities, measured desk height, and their willingness to switch to standing modes and will be used to build an LSTM prediction model to suggest optimal time points for posture changes, accompanied by appropriate desk height. In this work, we acknowledge previous relevant research, outline ongoing deployment efforts, and present our plan to validate the effectiveness of our approach via user studies.

KEYWORDS

Sedentary Postures, Context-Awareness, Metadata, Healthy and Productive Behaviors, Interruption, Working Context Analysis

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1 MOTIVATION

The prevalence of sedentary posture among knowledge workers has significantly grown due to the nature of knowledge-driven work, which involves extended periods of sitting, such as document writing, programming, playing games, and video editing. Previous studies indicated that, on average, students and workers who primarily use computers at work spend a longer time, approximately 50 hours [18, 20, 25]. Indicated by investigations, prolonged sitting has been revealed to be associated strongly with a range of health concerns, such as cardiovascular diseases [23], back & shoulder pain [6], mental wellness [2, 19] and even premature death [8]. Furthermore, extended static sitting behaviors — such as at a desk, behind wheels, or in front of a screen — can also be harmful.

Based on this fact, sit-stand desks and adjustable-height surfaces are suggested and used to counteract unhealthy sedentary behaviors by standing intermittently [4, 16, 17]. However, while researchers have suggested switching between postures for health benefits, establishing such a habit is left to workers. Therefore, it is easy to forget about sit-stand desks unless conscious efforts are put into forming a desirable habit, and sit-stand desks are often underutilized. The state-of-the-art approach to facilitate physical postural alterations is using notifications that alert workers to switch their postures or automatically switch to standing mode at fixed intervals (e.g., standing 10 to 20 minutes after one hour's working or sending a notification every two hours) [1, 3, 22]. One limitation of the notification or automated approach is that regular external interruption could disrupt the continuity of cognitive focus on ongoing tasks [5], which is considered a significant barrier to workers' productivity. Specifically, routine notifications during computing tasks are more likely to result in losing track of task goals [12]. Indeed, a study showed that individuals prefer sitting for cognitively demanding tasks while favoring standing postures for less cognitively demanding ones [3]. Considered as "natural breakpoints," switching ongoing activities and completing a task are acceptable situations for posture transitions with low side-effects after interruptions [7, 11, 21].

2 CONTEXT-AWARE SIT-STAND DESK

To address these challenges and provide a holistic solution given the consideration of well-being, willingness, working context, and efficiency, we propose an intelligent sit-stand system that can foster *healthy and productive* behaviors by comprehending contextual activities and personal preferences. By incorporating insights from sit-stand desk research and context-aware productivity tools [9, 13, 14, 17], we propose the idea of leveraging workers' contextual properties (e.g., metadata of working context) and personal routines (e.g., preferred physical postures at a particular time)

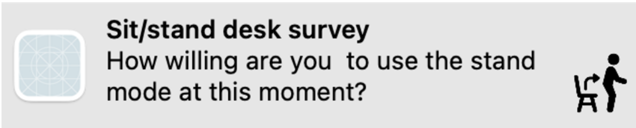

Figure 1: ScreenTracker notification for acquiring user willingness to switch current postures.

to find suitable time blocks in which users are willing to adopt comfortable positions and avoid distractions. Our ongoing process involves collecting data to develop a predictive model and conducting a follow-up interview to identify the factors we should consider in designing the context-aware sit-stand desk. We introduce the following three development components that constitute context-aware sit-stand desks:

Collection of metadata for computer activities ScreenTracker collects work context information to gain insights into users' ongoing tasks based on the frontmost application. ScreenTracker, is a software that can track, analyze and record the metadata of a computer's frontmost application (e.g., website title and URL for browsers and document name and file path). We encrypt all the collected data as the metadata may contain personal information that should not be shared in case of data leaks. ScreenTracker also notifies users every 30 minutes to collect their willingness to switch current postures via a 6-point Likert scale question at the moment, shown in Figure 1, which we can collect more information about whether they would be willing to switch to standing mode given the types of tasks that they are working on. For example, if they are in the middle of Zoom meetings, it would be awkward to switch the mode, which may look distracting to people in the meeting.

Real-time detection of working space height The second type of data we collect, critical to predicting their optimal moments, is users' actual usage of sit-stand desks. We prototyped a sensor module (shown in Figure 2) that uses Raspberry Pi with a distance sensor to detect desk height persistently in real-time and collect their behavioral dataset. We utilized Raspberry Pi 3 Model B+ and an HC-SR04 Ultrasonic Sensor to constantly track desk height in inches. By monitoring the desk height in seconds, we can associate contextual data and willingness data that ScreenTracker collects with users' desk usage. The sensor sampling rate is 60 Hz, so we use exponential smoothing to log the desk height every second. We will analyze in sync with contextual data collected from ScreenTracker.

Development of an LSTM model for prediction We will build an LSTM model with these two data types to predict the proper timing when users are willing to switch postures based on computer activities. Using the bi-LSTM model for forecasting time-series probabilities, our approach focuses on developing a statistical model to predict workers' willingness to switch between sit-stand postures at different time periods, as shown in Figure 3.

3 ONGOING EFFORTS

In the current stage, we are collecting work context metadata, willingness to switch postures, and real-time desk height by installing the ScreenTracker on computers and the sensor module in working spaces via field studies. We plan to ask them to use ScreenTracker

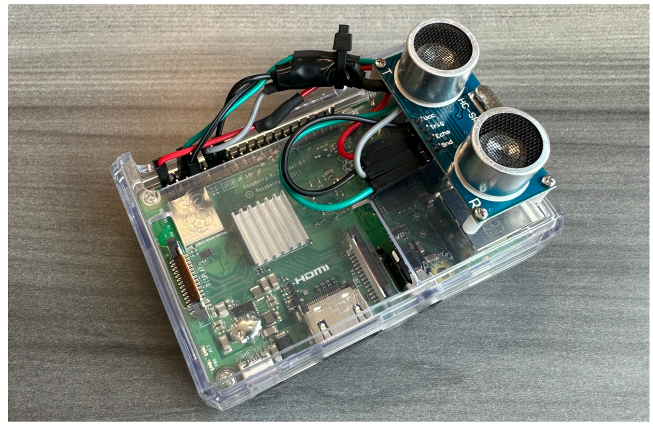

Figure 2: Raspberry Pi model with a distance sensor to monitor and log desk height in real-time.

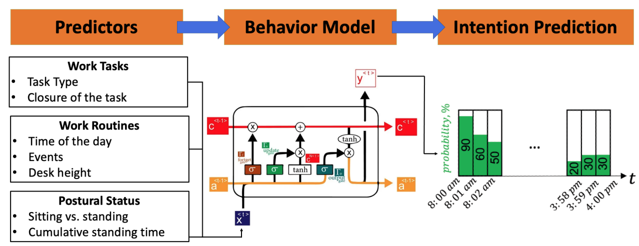

Figure 3: A bi-LSTM model for intention prediction. The outcome variable is a time-series forecast on the willingness to change postures at a given time interval.

and the sensor module for three weeks to collect data and allocate one week for a cool-down period as their behaviors immediately after installing modules can change due to the experiment condition. Thus, we have two weeks for data collection. Additionally, in one or two weeks, we will turn off the willingness questionnaire to understand how their behaviors are affected by the willingness questions on ScreenTracker. We plan to conduct an exit interview after the data collection period to gain qualitative insights that should be considered in sit/stand desk automation for healthy and productive behaviors. Subsequently, by utilizing data collected in the "Predictors" phase (shown in Figure 3), we will apply a bidirectional long short-term memory (bi-LSTM) model for intention and behavior modeling, known for its robust performance in maintaining long-term storage of internal states and exploiting distant temporal dependencies within the data [10, 15, 24].

We will connect this developed prediction model with sit-stand desks to control the height automatically based on workers' ongoing and imminent computer activities. By completing this study, we believe that the outcome can confirm the effectiveness of the intelligent system, which integrates contextual metadata, the predictive model, and sit-stand desks for promoting healthy behavior and working productivity.

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