SenStick-Eye: A Sensing Platform to Observe Behavioral Insights from Small Everyday Objects

Yugo Nakamura[1⋆], Yuki Matsuda[2], Yutaka Arakawa[1]
[1]Kyushu University, Fukuoka, Fukuoka 819-0395, Japan
[2]Okayama University, Okayama, Okayama 700-0082, Japan
Email: y-nakamura@ait.kyushu-u.ac.jp

***Abstract*—SenStick-Eye is a novel sensing platform that captures behavioral insights from small everyday objects, such as cutlery, toothbrushes, and pens, by integrating a G-sensor (accelerometer) and a monocular RGB camera (480×480 pixels). This compact system enables continuous monitoring of human-object interactions, facilitating object-centric behavioral analysis. By collecting both motion and visual data, SenStick-Eye reveals patterns and triggers in habitual behaviors that often go unnoticed. The platform is designed for applications in just-in-time interventions, habit formation, and behavior change technologies, offering new opportunities for AIoT-based systems to support healthier habits.**

***Index Terms*—Sensing platform, Object-centric behavioral analysis, Behavior change support system.**

I. Introduction

The study of habitual behaviors has drawn significant attention in fields such as human-computer interaction (HCI), ubiquitous computing, and behavioral sciences. Many habits form subconsciously through interactions with everyday objects. Understanding these habits is essential for developing interventions that promote healthier behaviors or enhance productivity. However, capturing the subtle nuances of how people engage with small objects in daily life remains challenging, as existing sensing technologies are often too obtrusive or lack the granularity needed for detailed observation.

Wearable cameras have shown promise in studying habitual behavior. Early examples like the SenseCam demonstrated the potential for memory retrieval and habit analysis through image-based sensing [1]. More recent systems such as HabitSense, which uses RGB, thermal cameras, and IMU sensors, address privacy concerns while detecting behaviors such as smoking and eating [2]. However, while prototype devices like the ESP32-CAM used in HabitSense are small, the addition of a battery and charging circuit increases their size and weight, making them unsuitable for small, everyday objects. Further miniaturization is needed to capture subtle actions more effectively.

To address these limitations, we introduce SenStick-Eye (Fig. 1), an extension of our previous SenStick platform, which combines hardware (a small all-in-one sensor board), data collecting software, and 3D case data to accelerate prototyping for IoT research [3]. As shown in Table I, SenStick-Eye is significantly slimmer and lighter than HabitSense, with a volume of only 8cm^3 and a weight of 8.2g, making it ideal for embedding into small everyday objects such as chopsticks, cutlery, toothbrushes, and pens. By combining a G-sensor (accelerometer) with a monocular RGB camera, SenStick-Eye offers a novel approach to capturing both physical movements and visual context in real-time. This integration allows researchers to uncover patterns of habitual use and identify potential behavioral triggers, which are often difficult to observe through traditional sensing methods.

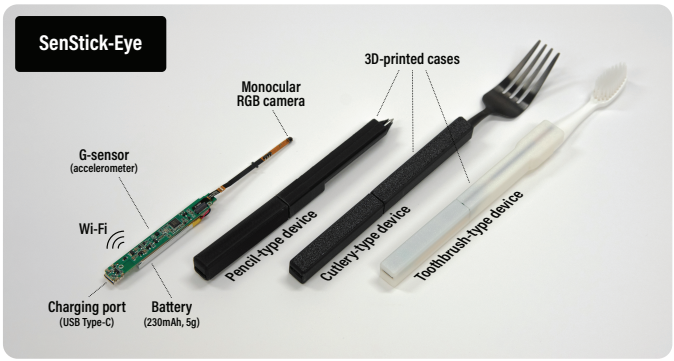

Fig. 1. An overview of the SenStick-Eye.

TABLE I
Comparison of SenStick-Eye and HabitSense (ESP32-CAM based device)

Device	Volume	Weight	Camera Resolution
SenStick-Eye	8.00 cm^3	8.20 g	480 x 480 pixels
HabitSense [2]	93.75 cm^3	87.00 g	1600 x 1200 pixels

SenStick-Eye supports applications in just-in-time interventions, habit formation, and behavior change technologies. It aligns with the IoT-nudge concept [4] demonstrated in examples like WaistonBelt X, a wearable device for health behavior change [5], and eat2pic, an interactive system that promotes healthier eating through sensor feedback [6]. As AIoT (Artificial Intelligence of Things) evolves, platforms like SenStick-Eye can bridge the gap between the physical world and digital interventions by providing real-time, object-centric behavioral insights, enabling more personalized and context-aware interventions that guide individuals toward positive habit changes with minimal disruption to their routines.

II. SenStick-Eye

SenStick-Eye is a compact sensor device designed to observe interactions with small everyday objects by integrating

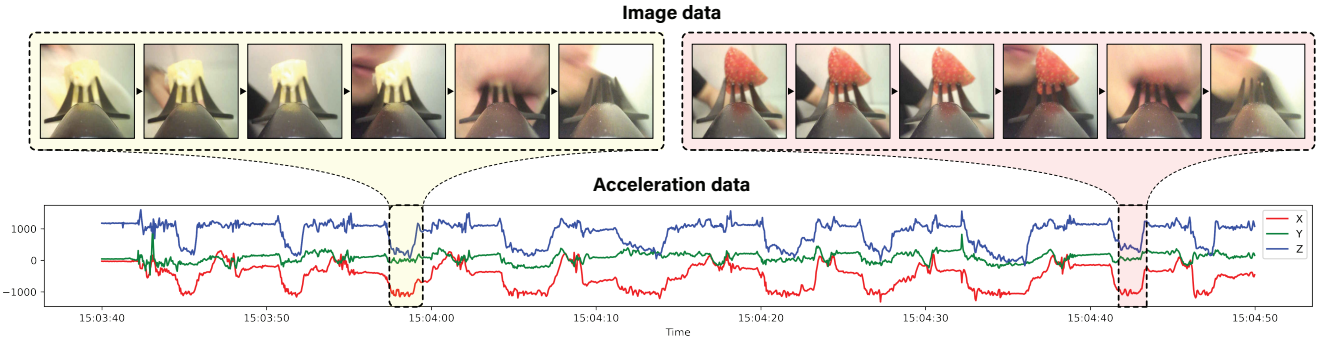

Fig. 2. Example of sensor data (images and acceleration) collected during a meal using a fork-type device equipped with SenStick-Eye.

a G-sensor (accelerometer) and a monocular RGB camera (480×480 pixels). The accelerometer detects subtle changes in how objects are handled, while the camera captures real-time visual information, providing a comprehensive view of user interactions. This combination enables a more natural and context-aware sensing experience by complementing motion data with visual cues, revealing subtleties that traditional sensors alone cannot capture. SenStick-Eye transmits this data to smartphones or PCs via WiFi in real-time using a UDP stream (20 fps), ensuring seamless monitoring without interrupting daily activities. Weighing 8g with a 230mAh lithium polymer battery (3g without the battery), SenStick-Eye can continuously sense for approximately 2 hours, and for longer sensing durations, a larger battery would be required to extend operation time.

As shown in Fig. 1, SenStick-Eye can be easily integrated into cases for everyday items such as pencils, cutlery, and toothbrushes, which are modeled using CAD software. This allows these familiar objects to be transformed into discreet sensor devices that blend naturally into users' environments, enabling more authentic and unobtrusive data collection. The compact design and flexibility of SenStick-Eye make it ideal for applications such as behavioral analysis, health monitoring, and habit formation research, where maintaining the naturalness of user behavior is critical for accurate insights.

III. Use case

A specific use case of SenStick-Eye is tracking eating behavior. By attaching SenStick-Eye to a fork or chopsticks, researchers can monitor how a person handles food, including their eating speed and what kind of food they consume. For example, the accelerometer detects the hand movements associated with bringing food to the mouth, while the camera captures the visual context of each bite. Fig. 2 shows an example of sensor data (both images and acceleration) collected during a meal, where the camera data allows us to distinguish different types of food being eaten despite similar hand movements detected by the accelerometer. This enables the analysis of eating patterns, such as how fast the person is eating and what types of food they are consuming.

With this real-time monitoring, personalized interventions are possible, such as reminders to slow down eating or recommendations for a more balanced meal. Similar technology could be applied to other areas, such as monitoring oral hygiene by tracking toothbrush usage or supporting productivity by analyzing pen usage during note-taking.

IV. Conclusion

SenStick-Eye enhances the capture of detailed behavioral insights by integrating an accelerometer with a monocular RGB camera, providing a unique platform for analyzing interactions with small everyday objects. This system offers valuable opportunities for behavior change technologies and AIoT applications by identifying subtle behavioral patterns. With potential applications like mindful eating, SenStick-Eye can deliver meaningful insights into habits and support real-time, personalized interventions, contributing to the development of tools that encourage healthier and more productive lifestyles.

Acknowledgment

This research was supported by JST, PRESTO Grant Number JPMJPR21P7.

References

[1] S. Hodges, L. Williams, E. Berry, S. Izadi, J. Srinivasan, A. Butler, G. Smyth, N. Kapur, and K. Wood, "SenseCam: A Retrospective Memory Aid," in *Proceedings of the 8th International Conference on Ubiquitous Computing*, ser. UbiComp'06. Springer, 2006, pp. 177–193.

[2] G. J. Fernandes, J. Zheng, M. Pedram, C. Romano, F. Shahabi, B. Rothrock, T. Cohen, H. Zhu, T. S. Butani, J. Hester *et al.*, "HabitSense: A Privacy-Aware, AI-Enhanced Multimodal Wearable Platform for mHealth Applications," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, vol. 8, no. 3, pp. 1–48, 2024.

[3] Y. Nakamura, Y. Arakawa, T. Kanehira, M. Fujiwara, and K. Yasumoto, "SenStick: Comprehensive Sensing Platform with an Ultra Tiny All-In-One Sensor Board for IoT Research," *Journal of Sensors*, vol. 2017, no. 1, p. 6308302, 2017.

[4] Y. Nakamura and Y. Matsuda, "IoT Nudge: IoT Data-driven Nudging for Health Behavior Change," in *Adjunct Proceedings of the 2021 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2021 ACM International Symposium on Wearable Computers*, ser. UbiComp'21 Adjunct, 2021, pp. 51–53.

[5] Y. Nakamura, Y. Matsuda, Y. Arakawa, and K. Yasumoto, "WaistonBelt X: A Belt-Type Wearable Device with Sensing and Intervention Toward Health Behavior Change," *Sensors*, vol. 19, no. 20:4600, 2019.

[6] Y. Nakamura, R. Nakaoka, Y. Matsuda, and K. Yasumoto, "eat2pic: An Eating-Painting Interactive System to Nudge Users into Making Healthier Diet Choices," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, vol. 7, no. 1, pp. 1–23, 2023.