Research Overview and Motivation

Today, the ubiquity of smart devices with embedded sensors offers the potential for sensing a wide range of human activities to a new level. However, current interactions with smart devices do not adequately exploit human behavior. By combining human behavior, we can enable more efficient and immersive interactions. For example, we detect the user's head orientation and regard it as an indicator of attention. In that case, we can reduce false automatic switching of earbuds and foster seamless collaboration across multiple devices by automatically connecting input devices and rearranging windows.

My interdisciplinary background in computer science and product design drives me to explore natural and efficient interaction technology from a human-centered perspective. Recently, I also ventured to interpret behavioral data using language models to facilitate interactions, inspired by the proven efficacy of GPT in processing sequential data. My research goal is to develop novel interaction technology by understanding and leveraging natural human behavior. This goal involves three stages:

1. Model human behavior in emerging scenarios such as AR/VR and multi-device scenarios to discover natural ways of interaction.
2. Build new sensing hardware and algorithms to track these natural behaviors precisely.
3. Develop novel interactions based on these natural behaviors, facilitate interactions with NLP tools, and apply these interactions to health, education, and beyond to benefit more people.

Past Experience

My research journey began in high school at a biology lab at Tsinghua University. The repeated challenges and setbacks during the experiment made me realize that research required persistence and self-motivation. This unique experience drove me to identify a field I wanted to devote myself to. While opting for computer science as my major to contribute tangibly to society, I remained uncertain about a specific research direction.

A pivotal shift occurred in my sophomore year while pursuing a second degree in product design. It prompted a paradigm shift toward a human-centered perspective, leading me to human-computer interaction (HCI). Then I joined the Pervasive HCI Lab at Tsinghua University and researched novel interfaces with the guidance of Prof. Yuanchun Shi and Prof. Yuntao Wang. Upon their recommendation, I pursued an interdisciplinary dual-degree master's program to explore technology innovation from a human-centered perspective in depth. I systematically studied user research and evaluation in this program. I joined Prof. Shwetak Patel's Ubicomp lab at the University of Washington to continue my research, further solidifying my passion for developing novel interactions.

I engaged in several projects targeting building interfaces for natural and immersive interactions. My past research experience has laid a solid foundation for my graduate studies, enhancing not only my creative thinking and human-centered thinking, but also my technical expertise and resilient mindset required to implement my ideas.

Enabling Natural Interactions by Tracking Head Orientation. Attentive user interfaces have been proposed as a natural user interface concept, but realizing them in a non-obtrusive way remains a challenge. This challenge sparked my curiosity in interaction technology and initiated my research journey. The goal of this project was to enable attentive detection in multi-device scenarios. First, we discovered that head orientation could indicate users' attention through a literature review and a pilot user study. Then we focused on detecting head orientation using acoustic ranging on earbuds. I quickly learned and implemented the FMCW-based ranging algorithm and conducted a user study to evaluate our method. Moreover, I overcame a crucial hurdle: the low signal-to-noise ratio when a user's head obstructed the line of sight during head turns. This contribution played a vital role in the acceptance of my first first-author paper [1] at CHI 22. I mastered a new approach to enhancing natural interaction through innovative sensing technology by employing human-centered thinking. The notion of integrating human behavior into technological innovation motivated me to explore this field more profoundly.

In this CHI paper, we needed to calibrate the system by putting the speakers against the microphone for a few seconds, which prevented this system from being widely used. To address this issue, I led a project developing a calibration-free distributed ultrasonic ranging module. I learned the development of nRF52840 from scratch and solved critical engineering challenges during this process, such as 1) achieving a 100 kHz sampling rate on the 64 MHz chip and 2) establishing time synchronization among devices using Bluetooth without slowing 100 kHz sampling. This ongoing project aims to go beyond head motion tracking and build a module that could be integrated into sensor networks and support context-aware interaction leveraging multimodal data. The process strengthened my resilience and ability to solve complex problems and equipped me with the practical skills to implement new interaction technology.

Interpreting Gaze Behaviors in Reading Using NLP Tools. Inspired by ChatGPT and my English as a Second Language (ESL) learning experience, I proposed using pre-trained language models to enhance gaze-based unknown word detection. The precision limitation of eye trackers prevents heuristic gaze pattern recognition from high accuracy. Considering gaze as a type of sequential data whose patterns are highly related to word difficulty, we utilized RoBERTa for prior knowledge of words and an encoder-decoder model to extract relationships between gaze and text. Notably, our method achieved comparable performance on low-precision gaze data acquired by a webcam, only slightly lower than high-quality eye tracker data. Based on this unknown word detection algorithm, I initiated another project to provide users with more efficient interactions such as automatic translation and personalized summarization. The experience bolstered my understanding of NLP and trained my independent problem-solving and paper-writing skills. Additionally, my role in fostering an interdisciplinary team consisting of NLP and psychology backgrounds students highlighted my skill in integrating diverse fields to push the boundaries of technology. The project led to a first-author late-breaking work in CHI 23 [2] and an ongoing paper.

Building New Interface Hardware for Microgestures Recognition. During my master's degree at UW, I was attracted by the interaction within AR/VR due to the announcement of the Apple Vision Pro. How to interact with the AR glass effectively remains a question. I got involved in developing Z-Ring (best demo at UIST 23) [3] and FlowRing (co-first author paper) [4], which support AR interaction by detecting microgestures. I played a key role in prototyping by implementing high throughput BLE transmission and a CNN+LSTM gesture classifier. This experience built my skills in interface hardware prototyping and kindled my interest in exploring the natural interaction in VR/AR as a new scenario of spatial interactions.

Future Plans

Having explored building interaction technology and human-centered thinking, I am eager to develop a comprehensive understanding of human behavior and dive deeper into applying this knowledge to enable natural interactions through rigorous research in graduate school. I hope to leverage my knowledge of machine learning, hardware prototyping, and design thinking to propel the frontiers of human-centered technology and apply it in health and education.

References:
* denotes equal contributions.
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[3] Anandghan Waghmare, **Jiexin Ding**, Ishan Chatterjee, and Shwetak Patel. 2023. Demo of Z-Ring: Context-Aware Subtle Input Using Single-Point Bio-Impedance Sensing. UIST '23 Adjunct.
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