Towards Intelligent Wearable Assistants

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ABSTRACT

This summary outlines my research toward developing intelligent wearable assistants that provide personalized, context-aware computing assistance. Previous work explored information presentation using smart glasses, socially-aware interactions, and applications for learning, communication, and documentation. Current research aims to develop tools for interaction research, including data collection, multimodal evaluation metrics, and a platform for creating context-aware AI assistants. Future goals include extending assistants to physical spaces via telepresence, optimizing learning with generative AI, and investigating collaborative human-AI learning. Ultimately, this research seeks to redefine how humans receive seamless support through proactive, intelligent wearable assistants that comprehend users and environments, augmenting capabilities while reducing reliance on manual labor.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**; **Mobile devices**; **Mixed / augmented reality**; *Information visualization*; • **Computing methodologies** → **Artificial intelligence**.

KEYWORDS

context-aware system, wearable, AI assistance, notifications, interruptions, smart glasses, HMD, interactions, Augmented Reality, MR, XR

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1 INTRODUCTION

Imagine a future where each individual is equipped with a personalized, intelligent, wearable assistant that is fully aware of both the user and their environment, and is tailored to their specific activities. Such assistants would significantly ease the execution of a broad spectrum of tasks, both familiar and novel, by reducing task load and errors, boosting overall performance, and lessening the dependence on specialized manual labor such as coaching.

This vision, which encompasses the concept of making computing unobtrusive, has already begun to materialize [15]. It has inspired my research interest (Figure 1) in the design of **intuitive and seamless interfaces for intelligent wearable assistants** within the broader field of human-computer interaction (HCI). To turn this vision into reality, I am committed to gaining a deep understanding of user behaviors and requirements through a combination of qualitative methods (such as observations) and quantitative methods (such as surveys). Building on this foundation, my methodology includes the design, development, and validation of systems, interfaces, and interactions that effectively support users in realistic settings, involving both controlled experiments and field studies. Through a detailed understanding of user needs and preferences, coupled with the iterative design and evaluation of wearable assistant systems, I aim to develop proactive, intelligent, context-aware, and personalized solutions that enhance users' productivity, efficiency, and overall satisfaction in their daily lives.

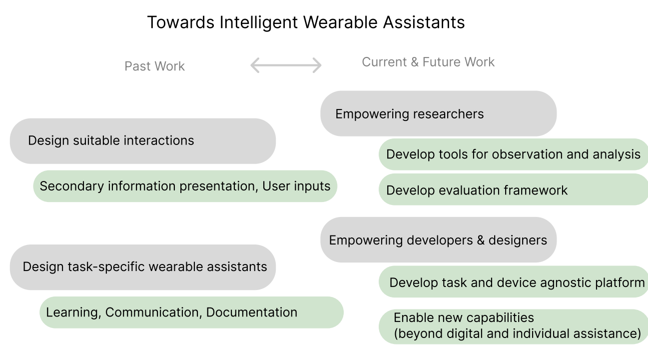

Figure 1: My research interests and goals.

Background and Previous Work

Designing intelligent wearable assistants presents numerous challenges, including identifying appropriate platforms to provide information during daily tasks, creating effective information presentations and interactions, developing applications to offer suitable assistance, and empowering researchers to understand and enhance interactions with such assistants.

While the mobile computing paradigm enables flexibility in accessing information beyond traditional stationary environments, it detracts from situation awareness due to the heightened demand for attention on mobile devices, leading to phenomena like "smartphone zombies" [1]. The emergent heads-up computing paradigm, exemplified by near-eye displays such as augmented reality (AR) smart glasses and optical see-through head-mounted displays (OST-HMDs, OHMDs), promises to mitigate these concerns by fostering

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increased situational awareness and multitasking capabilities without compromising engagement with the physical world [16].

Information Presentation and Interactions. While the heads-up computing paradigm may be suitable for designing the envisioned intelligent wearable assistants, one of the pivotal challenges is **effectively managing heads-up information presentations and interruptions**. This is especially crucial given the potential for distractions when presenting just-in-time information via near-eye displays. It is particularly relevant for important secondary information, such as reminders and notifications, as users receive 60-400 notifications daily [14] that can distract and overwhelm them. In my dissertation [4], I systematically explored the impact of displaying notifications based on human visual perception (Figure 2) and proposed several innovative mitigation strategies to overcome them. These strategies included 1) leveraging the paracentral and near-peripheral visual regions by displaying secondary information [8], 2) converting textual information into graphical formats [12], 3) adjusting the luminance of digital content [10], and 4) implementing a multi-faceted approach to manage the attentional impact of secondary information [5]. Each strategy was evaluated through user studies in both laboratory and simulated real-world environments, demonstrating their efficacy in enabling users to access secondary information with minimal interference to primary tasks. By applying the principles of visual perception to the design of heads-up information presentations, my work contributes to the broader field of information visualization, including presenting secondary information with wearable assistants.

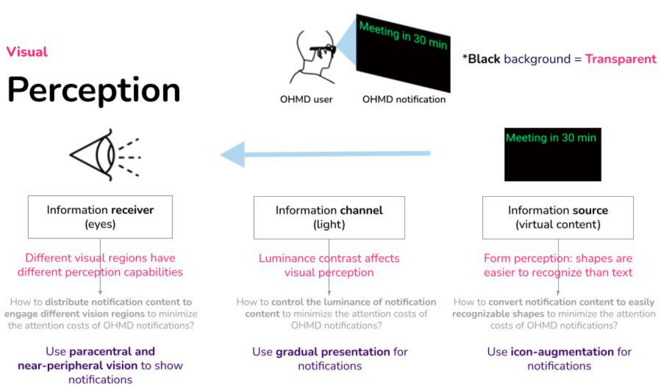

Figure 2: Managing interruptions of heads-up secondary information presentation [4, 5].

Although my dissertation [4] primarily addressed the challenge of presenting heads-up information to users without undue interruption in general, it lacked exploring the reverse flow of information—from users to wearable systems, such as indicating user intentions. In collaboration with Runze Cai, we expanded upon the concept of uni-directional information presentation to include **bi-directional interactions**, allowing for both information display and user input. Our development, the ParaGlassMenu [2], integrates an OHMD to enable attention-maintaining visualizations and a ring mouse to enable subtle interactions, facilitating discreet and intuitive access to digital information in social settings with minimal impact on social engagement. This was contrasted with other interaction techniques like mobile phones and voice assistants, which can be more intrusive. Our evaluations, conducted in both simulated and real conversational contexts while interacting with Internet-of-Things (IoT) devices, shed light on the design of subtle interaction techniques that preserve social engagement while enabling effective information exchange. This work offers valuable insights into the design of socially aware, attention-maintaining interaction mechanisms specifically needed for intelligent wearable assistants when users engage in social settings.

Assistance Applications. To achieve the envisioned wearable assistants, we must understand users' needs and challenges with current interaction paradigms in daily activities and offer the necessary support through intelligent wearable assistants. These needs vary across domains, including but not limited to learning, communication, and documentation.

People spend considerable amounts of time commuting, and the majority of such time is underutilized. What if we utilize a fraction of that underutilized time for more productive tasks such as learning? Thus, I explored *when* and *how* to enable mobile information acquisition and bite-size learning (e.g., learning a new second language word) during commutes [9]. A shadowing study revealed distinct visual behaviors that, when leveraged appropriately, can facilitate the effective integration of learning tasks into daily commutes without detracting from primary activities. Our findings indicate that OHMDs, compared to mobile phones, offer superior support for such bite-size learning by enabling smoother transitions between learning and commuting tasks. This insight led to the development of a workflow designed to maximize the potential for productive microtasks, such as language learning, thereby opening up new avenues for enhancing personal productivity in the context of busy lifestyles and enabling intelligent **wearable learning assistance**.

The hands- and eyes-busy nature of traditional digital messaging presents significant challenges for users attempting to communicate while engaged in other tasks. Through observational studies, we identified key pain points and iteratively developed GlassMessaging, an OHMD-based messaging application designed to facilitate communication via voice and manual inputs in scenarios where traditional messaging methods fall short [7]. Our real-world comparative tests demonstrated that GlassMessaging significantly improves response time and texting speed, enhancing the feasibility of messaging in various contexts using wearable assistants. This development suggests that heads-up wearable messaging could represent a new frontier in digital communication, albeit with specific trade-offs to consider. Additionally, we introduced EYEditor [3], a novel text-editing solution for such heads-up wearable systems, designed to outperform traditional touch-based mobile text editing in multitasking environments, addressing a notable limitation in heads-up text interaction and highlighting the value of wearable communication assistance.

Beyond communication, we explored the enhancement of life experience documentation, supporting sharing experiences, as well as reflecting and remembering. Specifically, we focused on in-context writing experiences during travel, an area traditionally underserved by existing digital tools, which are relatively passive and unintelligent, serving more like instruments rather than companions. Our solution, PANDALens [13], leverages OHMD technology in conjunction with Large Language Models (LLMs) to intelligently assist users in documenting their experiences. By analyzing multimodal contextual data—encompassing user behaviors and environmental cues—PANDALens crafts coherent narratives with minimal user effort, significantly enhancing both the quality of written content and the overall travel experience, providing intelligent wearable documentation assistance.

In summary, my previous work offers a glimpse into intelligent wearable assistants, focusing on presenting information and interacting with them while minimizing distraction to ongoing tasks.

Current and Future Work

As I aspire to become a leading researcher in developing interfaces and guidelines for intelligent wearable assistants using heads-up computing, my overarching goal is to **redefine how humans receive seamless computing assistance during their daily activities**. While my previous work has addressed some challenges in designing these assistants, there are still issues that must be tackled to realize my vision successfully.

Developing Tools and Measures to Enhance Interaction Research with Intelligent Assistants. A fundamental challenge in designing intelligent wearable assistants lies in understanding user interactions with these assistants and ensuring they offer optimal support while quantifying their performance. In the coming years, I aim to equip researchers with the **tools and frameworks** needed to overcome these challenges.

Wearable assistants utilizing Augmented Reality (AR) and Mixed Reality (MR) technologies like OHMDs present unique challenges in conducting user studies due to the complex nature of observing and recording in-context interactions. To address these challenges, my team and I are developing PilotAR [6], an innovative open-source tool that simplifies the collection and analysis of data through features like live first-person and third-person views, multi-modal annotations, and versatile wizarding interfaces. By facilitating a more efficient study process and enabling rapid insight gathering, PilotAR promises to accelerate the research cycle significantly. Furthermore, we are enhancing the capabilities of the PANDALens tool—originally designed for documenting travel experiences—to support ethnographic research. This enhancement will improve data collection, offer AI-driven suggestions, and provide insights into potential researcher biases, ultimately enriching the research methodology with additional perspectives. Such **tools will enable the exploration of user interactions with wearable assistants in diverse application scenarios** and overcome challenges in conducting such studies.

With intelligent wearable assistants, people must use multimodal interactions beyond traditional text or touch interactions to have seamless computing support. Currently, there is a lack of comprehensive evaluation metrics and frameworks capable of capturing the intricacies of multimodal interactions that involve various body parts, such as voice, gaze, and hand gestures. My research aims to fill this gap by establishing a systematic evaluation framework dedicated to understanding how users employ multimodal interactions for receiving assistance (e.g., selecting, searching, querying), assessing user and system performance, and enabling comparison acrosss different types of assistance using benchmarks. This approach will facilitate a **holistic assessment of the effectiveness and benefits of intelligent wearable assistants** as well as heads-up computing, contributing significantly to the advancement of the field.

Developing a Platform to Create and Research Ubiquitous AI Assistants Across Devices. Another fundamental challenge is the significant development effort and resources required for intelligent wearable assistants. Although advanced digital assistants can greatly enhance task performance, reduce user burden, and offer personalized guidance to improve users' abilities, current AI tools and assistants frequently lack a nuanced understanding of user and environmental contexts. To bridge this gap, our proposed work (*The Other Me* [11]) involves the **development of a conceptual architecture and software platform dedicated to the creation of intelligent wearable assistants** using existing commercial hardware. With the collaboration of researchers and developers across AR/MR, HCI, AI/Robotics, and software development fields, I am pursuing this goal so that other researchers and developers can easily create proactive intelligent wearable assistants that are context-aware and attuned to both user and environmental nuances. The ultimate goal is democratizing access to personalized assistance, making expert guidance available to everyone anytime, anywhere.

Extending the capabilities of digital assistants to physical spaces, my research will explore enabling users to interact with and manipulate objects in remote locations. This endeavor involves the integration of human-robot interactions, where the remote robot's perceptions are conveyed to the user via heads-up displays. The challenge encompasses not only the technical aspects of mapping user interactions to remote environments but also understanding which interaction modalities best facilitate this unique form of engagement. This approach opens new avenues for remote work, telepresence, and interaction, thereby expanding the physical boundaries of our digital capabilities via intelligent wearable assistants.

The advent of generative AI technologies presents unprecedented opportunities for enhancing educational experiences. However, a systematic framework for integrating these technologies with learning theories to produce wearable-friendly content remains underdeveloped, and how intelligent wearable assistants can improve learning is underexplored. My research aims to fill this gap by leveraging intelligent wearable assistants to maximize users' learning potential during otherwise underutilized times, creating context-aware, dynamic learning materials. Furthermore, I will explore **collaborative learning dynamics**, investigating how physical and digital interactions between human learners and intelligent digital companions can be optimized for mutual benefit. This exploration promises to significantly impact social learning environments by fostering physical and digital educational opportunities.

Summary

In summary, my research envisions designing and developing intelligent wearable assistants that comprehend both the user and their context, providing proactive support during daily activities with minimal intrusion. With advancements in hardware and software technologies, these assistants are poised to become our invisible daily companions and coaches, offering personalized assistance and guidance while enhancing our capabilities and reducing our reliance on expensive manual labor. Moreover, these assistants will empower us to leverage our full bodily capabilities, freeing us from the constraints of limited interactions or specific tasks. This will enable us to live, work, learn, and play in ways that align with our desires and aspirations.

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