Research Statement

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The integration of lightweight eye-tracking systems into augmented reality (AR) headsets is revolutionizing human-computer interaction, with significant potential in medical applications. Eye-tracking enables the precise measurement of cognitive workload, attention, and interest, offering critical insights for both individual and collaborative tasks. My research addresses a key limitation of current systems: the insufficient understanding of how AR technologies influence social dynamics during interaction. I aim to develop innovative methodologies to study the effects of AR on social behaviors, with a focus on enhancing collaboration in both medical and interdisciplinary applications. This includes investigating context-sensitive interactions, measuring behavioral changes, and designing tools that provide real-time support based on eye-tracking insights. By pushing beyond conventional approaches to collaborative systems, my work seeks to advance human-machine interaction and contribute to the development of intelligent systems that improve user outcomes in complex environments. This research will have particular impact in medical robotics and healthcare applications, where effective collaboration, cognitive workload management, and precise attention tracking are critical.

Past Research Work

A characterization of user understanding of spam call warnings

The Federal Communications Commission (FCC) mandated that cell phone service providers implement a new framework to combat the rising number of spam calls, a significant privacy concern. This framework requires providers to alert users of incoming spam calls through potential authentication states. However, no existing guidelines or understanding address how users interpret these warnings. To address this gap, we conducted surveys, interviews, and transcript analyses. Through qualitative analysis, we identified key challenges in the current approach. Our work provides a detailed understanding of these challenges and offers design recommendations based on participant responses. My contributions to this research were featured in a journal publication at TPRC49 2021 and a conference presentation at USEC 2024.

An electromyography (EMG) -based human-machine interface (HMI) for upper limb prosthetics simulation in virtual reality

Existing methods of prosthetic devices are limited in their functionality and accessibility. In response, we explored EMG-based methods for automatically controlling prosthetic devices simulated in a virtual reality testbed environment. These methods included direct control, pattern recognition, and continuous control, aiming to create a low-cost testbed for prosthetic devices. The testbed simulated daily living activities and integrated workload measurements using eye-tracking metrics, such as blink rate and pupil dilation. Prior to our work, there was no established method for testing and assessing virtual prosthetic devices. The system was evaluated using data from human subjects, incorporating physiological, subjective, and performance metrics. We also compared the virtual testbed to a physical prosthetic device from a prior study. My research efforts resulted in a publication in a peer-reviewed conference, IEEE SMC 2023. Additionally, this work further contributed to an ongoing project where the prosthetic device approach was adapted to control a simulated steering wheel in a driving simulator.

Identifying user needs for perceptual task guidance (PTG) systems through a contextual inquiry

To address the general lack of guidelines for designing perceptual task guidance systems, we focused on cooking, a domain that shares similar executive functions with other applications and contexts. To develop an in-depth design methodology, we conducted a series of contextual inquiries during cooking demonstrations. Using qualitative methods, such as affinity diagrams of transcripts and notes, we identified common obstacles faced by participants and established user needs in areas such as object interaction, safety, knowledge base, and task coordination. This resulted in a comprehensive set of user needs for designing task guidance systems, alongside an evidence-based argument for extending our findings to domains beyond cooking. My contributions to this research project led to a publication and presentation at ACM DIS 2024, while also advancing ongoing research into designing effective perceptual task guidance systems.

Current Research Work

Enhancing collaborator communication in industrial tasks through shared-gaze visualizations (SGV)

Shared gaze visualizations enable collaborators to see their partner's eye focus during shared tasks, addressing social limitations of augmented reality headsets, such as the occlusion of face-to-face communication. However, existing methods often lack privacy and control. In my dissertation, I explore various implementations of shared gaze visualizations, including gaze rays, hover, and automatic control methods like gaze triggers. I analyze and compare uni-directional and bi-directional visualizations to understand user perceptions of their own visualizations versus only seeing their partner's. Through user studies in industrial-adjacent contexts, such as assembly and sorting tasks, I evaluate these methods by collecting quantitative and qualitative data, including NASA-TLX scores, collaborator experience, automatic eye-tracking analytics, and measures of shared focus, eye contact, and partner glances. My contributions have resulted in a first-author publication in IEEE VR 2024 and another currently under review at IEEE ISMAR 2025.

Future Research Work

Building on my research experience in privacy and security, human-machine interfaces, perceptual guidance, and collaborative eye-tracking applications, I plan to explore how social dynamics are influenced by shared gaze visualizations (SGVs) within context. Augmented reality (AR) has the potential to enhance workers' capabilities by providing guidance, optimizing decision-making, and improving occupational and situational awareness. Modern AR headsets, equipped with lightweight eye-tracking technology, offer valuable insights into user interactions and enable real-time support. This support extends to collaborative interactions in AR, fostering a deeper understanding of group dynamics. However, AR headsets often obstruct natural social interactions, such as face-to-face communication.

SGVs offer a promising solution by allowing collaborators to observe their partners' focus and attention through visualizations like gaze pointers. Despite their potential, existing SGV implementations face challenges related to privacy, control, and usability. Moreover, SGVs present opportunities to enhance user capabilities, such as enabling seamless communication through eye movements alone. My research aims to address these challenges while maximizing AR's contextual benefits, particularly in medical and industrial applications.

My plans are outlined as follows:

- [Plan 1] Social implications of shared-gaze visualizations
- [Plan 2] Design methodologies for overcoming limitations
- [Plan 3] Creating interdisciplinary collaborations
- [Plan 4] Beyond conventional eye-tracking applications

To investigate the social implications of SGVs, I plan to examine the social differences between non-SGV and SGV contexts through case studies, contextual analysis, and interviews. Data collection will include transcripts, video recordings, and eye-tracking data, with a focus on phenomena such as eye contact and shared focus. I aim to study how the awareness of eye-gaze affects natural human interactions and to uncover privacy limitations. For example, prior research has shown that eye-tracking data alone can uniquely identify users, posing significant security concerns. To address these issues, I will employ human-centered design approaches to redefine what data is collected and how it is utilized, ensuring both privacy and usability.

These insights will inform the development of design guidelines for effectively communicating eye-gaze information in collaborative interactions. Based on these guidelines, I will develop novel visualizations and interaction techniques, which will undergo rigorous user evaluations. I intend to submit this work to leading conferences, such as ACM CHI and ACM DIS, which focus on interdisciplinary design and human-computer interaction.

Interdisciplinary collaborations will be central to my research. My prior experience with user evaluations of virtual prosthetics and SGV applications in industrial settings has provided a strong foundation for developing context-specific methodologies. I aim to expand on this experience by collaborating in medical applications. For instance, in surgical settings, annotating regions of interest is often performed using hand controls, which can limit maneuverability. I plan to design alternative visualizations that accommodate the needs of medical professionals and effectively communicate critical information. These methods will be evaluated using workload measures, such as NASA-TLX surveys, and automatic eye-tracking metrics.

Finally, while current SGV implementations convey basic intentions, such as interest and attention, I plan to explore how SGVs can communicate more complex concepts. Additionally, I intend to investigate unconventional SGV applications, such as enhancing communication of occluded objects, conveying anticipatory user behavior, and integrating multimodal interactions for richer collaboration. This work will involve developing machine learning models to interpret unique gaze interactions and map them to specific intentions, advancing the potential of SGVs for collaborative and adaptive systems.