Statement of Research

The nascent field of augmented reality (AR) is highly multi-disciplinary, integrating knowledge from computer graphics, computer vision, system development, and Human-Computer Interaction (HCI). Whereas virtual reality (VR) attempts to create a completely immersive environment, synthesizing most, if not all aspects of a user's experience, augmented reality integrates virtual objects seamlessly into the physical world in real time[1]. Unlike VR, AR participants are able to interact with objects that exist in their everyday environment; there is no need to render existing physical objects, virtual likenesses for each participant, or the complexity of the environment that surrounds them. This fact is especially beneficial in the domain of *co-located collaborative augmented reality*, in which multiple participants occupy the same physical space; by preserving many of the important non-verbal communicative cues such as gesturing, facial expressions, hand, lip and eye movements, users can maintain work context and interaction can occur in a natural manner.

As application domains emerge, they bring with them a variety of new interaction techniques; the emergence of 3D applications brought with it spatial techniques to manipulate virtual objects within the environment. Similarly, as applications become more collaborative, interface designers must find ways to gracefully support awareness between participants that are appropriate to the task domain. For example, for successful collaboration to occur, a workspace must support *inter-referential awareness* – or the ability for one participant to refer to a set of artifacts in the environment, and for that reference to be correctly interpreted by others. While referring to objects in our everyday environment is a straight-forward task, the non-tangible nature of digital artifacts presents us with new interaction challenges, as ideally these objects would give tactile feedback and naturally interact with the surrounding environment by providing proper occlusion and depth cues. It is natural to believe that the re-integration of physical artifacts into the computing workspace makes referencing tasks easier; however, we find that these environments combine the referencing challenges found in several computing disciplines, which compound across scenarios. These collaborations often occur across distance and rely on computer-mediated communication and interactions. Thus, in addition to providing a set of techniques that are flexible enough to work with multi-modal content, designers of collaborative augmented reality systems must support communication and awareness while addressing the contextual properties of the environment.

Unlike other forms of computer-supported collaborative work (CSCW), collaborative augmented reality is inextricably linked to the physical world and challenges many of the mental models we have developed for interacting within the environment. Consequently, there are still many outstanding challenges that must be examined for successful collaboration to occur within these environments; these include how to support natural interactions across a variety of scenarios, such as references, annotations, information visualization and collaborative manipulation tasks. It is the goal of this research to provide techniques and methodologies for successful collaboration in AR. In addition, it is important to understand how this field can be integrated into the closely-related disciplines of wearable computing and ubiquitous and pervasive computing – all of which are becoming more human-centric. It is hoped that this research will stimulate ideas in the community and help to positively shape how we interact in future computing environments.

[1] The term *real time* here is loosely defined as "interactive rates", and does not require the system to meet hard deadlines.