Proposal Defense  
Doctor of Philosophy in Computer Science  

“Spatial Computing Inside the Operating Room” by Talha Khan

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Abstract:

Spatial computing or mixed reality allows users to overlay and interact with virtual content in 3D space often without interactive limitations on the physical placement and size of virtual elements. This differs fundamentally from traditional interactive mediums like monitors or smartphones, where interaction is confined to the physical dimensions of the device. One prominent use case of spatial computing is in healthcare, especially in complex surgical operating rooms (OR). In these settings, surgical information is spread out across physical screens forcing surgeons to constantly shift their attention to obtain relevant information, or to rely on others to provide it. Additionally, traditional displays provide limited 2D approximate representations of 3D visual information, which can impact spatial reasoning. Spatial computing has been proposed as a solution to these workflow issues. It can provide in situ visualizations in 3D, and condense important surgical information as holograms; which can improve surgeons’ efficiency, cut down on operating costs, and result in better patient outcomes. Yet, the scientific community understands very little about the feasibility or practical use of combining virtual and physical medical information inside an OR.

This dissertation addresses four core fundamental socio-technical barriers to a functional holographic OR, specifically it: 1) Explores if mixed reality hardware can accurately capture physical surgical tools to provide intra-operative guidance on surgical care. The work contributes a LiDAR camera-based system that can track surgical tools and anatomical targets with sub 2mm and 2 degrees accuracy. 2) Explores if surgeons can use holographic displays to perform fine motor surgical tasks. The work contributed a system and evaluation that investigates task performance and cognitive load using holograms in comparison to contemporary displays in support of key surgical tasks. 3) Explores the impact of different visualizations in establishing awareness of personal virtual interfaces in collaborative spatial computing settings. The work
contributed a collaborative system and evaluation that investigates occlusions and user preferences for visualizations in settings where both personal and shared virtual interfaces coexist. 4) Explores the effectiveness of projector-based visualizations in enhancing bystander awareness of virtual content. This work will contribute a system for projecting virtual content location using spatial augmented reality. This will be followed by an evaluation investigating the impact of proactive, reactive, and preemptive visualizations on occlusions and user preferences.

This dissertation makes several contributions, it shows that: 1) registration of virtual and physical objects, combined with mm-level tracking can assist surgeons to achieve higher accuracy for pinpointing surgical targets; 2) holograms are a viable alternative to physical displays, as they do not impact surgical task performance or accuracy; 3) visualizations of personal virtual interfaces shown to other spatial computing users can improve collaborative user experiences by mitigating occlusions and improving user comfort; and 4) spatial augmented reality could be used to foster better awareness of virtual interfaces among bystanders. This body of work collectively helps understand how spatial computing technologies can make surgery less risky and more efficient, proving that it has a real place in advancing medical practices.