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Introduction to the Special Issue on Computing, Sensing, and Networking for Immersive Systems

Immersive computing systems, encompassing technologies such as **Augmented Reality (AR)**, **Virtual Reality (VR)**, **Mixed Reality (MR)**, and the emerging metaverse, have experienced rapid advancement in recent years. These systems introduce a paradigm shift in human–computer interaction by seamlessly blending virtual content with the physical world through multi-modal sensing, intelligent computation, and high-performance networking infrastructures. By leveraging diverse sensory inputs—including visual, auditory, motion, and physiological signals—immersive systems enable rich, context-aware, and interactive user experiences across domains such as healthcare, education, manufacturing, entertainment, and digital collaboration.

Despite their tremendous potential, immersive computing systems face significant challenges that hinder their widespread adoption. These challenges include stringent latency requirements, massive data generation, limited sensing and computing resources on mobile devices, networking constraints, security and privacy concerns, and the need for robust and scalable system designs. Addressing these challenges requires interdisciplinary research efforts that integrate advances in sensing technologies, edge and cloud computing, networking protocols, artificial intelligence, and human-centered system design.

This Special Issue aims to bring together researchers and practitioners from academia and industry to present cutting-edge research and innovative solutions in computing, sensing, and networking for immersive systems. The Call for Papers attracted a strong response from the research community, resulting in a large number of high-quality submissions covering a wide range of topics related to immersive computing technologies and applications. After a rigorous peer-review process, 13 papers were accepted from 28 submissions, reflecting both the maturity and the growing diversity of this research field.

The accepted papers in this Special Issue span several important directions, including immersive system architectures, advanced sensing and perception techniques, intelligent data processing, networking and transmission optimization, user interaction methods, privacy-aware system designs, and application-driven evaluations. Together, these contributions provide a comprehensive view of the state of the art and highlight emerging trends and open research challenges in immersive computing systems.

Below, we briefly summarize the accepted papers included in this Special Issue.

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User Experience, Comfort, and Visual Attention

Maintaining user comfort remains a fundamental challenge in immersive VR systems. Qi et al. address this problem in [CPNet: Real-Time Cybersickness Prediction without Physiological Sensors for Cybersickness Mitigation](#) by proposing a real-time prediction model that estimates cybersickness severity without relying on intrusive physiological sensors. The proposed deep learning model leverages multimodal inputs, including head-tracking data, eye-tracking signals, visual complexity metrics, and experience duration. Results from a controlled user study demonstrate that CPNet achieves higher prediction accuracy than existing state-of-the-art approaches, enabling timely mitigation strategies to improve user comfort in immersive environments.

Visual attention also plays an important role in shaping users' experience in VR, particularly in content delivery and interaction design. In [RL-Ad: Integrating Eye-Tracking into a Reinforcement Learning Model for VR Video Ad Implantation](#), Zhang et al. propose a reinforcement learning framework that incorporates eye-tracking information to dynamically adjust the position and size of advertisements in VR videos. By aligning advertisement placement with users' visual attention, the approach increases ad visibility while minimizing disruption to immersion. Experimental evaluations show that the proposed method significantly improves user attention compared to static ad implantation strategies.

Gaze, Eye Movement, and Visual Perception

Eye movement signals provide rich information for perception modeling, interaction, and security in immersive systems. Zhao et al. introduce [EV-GazeLock: A User Authentication System Based on Eye Movements Captured by Event Cameras](#), a novel eye-based authentication system that leverages event cameras to capture fine-grained eye movement dynamics. By processing asynchronous event streams through a custom spatiotemporal feature extraction network, the system enables accurate and privacy-preserving user authentication without recording detailed eye appearance. Extensive evaluations demonstrate that EV-GazeLock significantly outperforms existing gaze-based authentication methods while maintaining low latency and energy efficiency on VR devices.

From a gaze estimation perspective, Li et al. explore the application of visual state space models in [Gaze Estimation Based on Visual State Space Model with Hybrid Features](#). The authors propose two VMamba-based approaches, including a hybrid architecture that integrates convolutional neural networks with visual state space blocks to jointly capture local appearance features and long-range contextual relationships. Experimental results across multiple public datasets show that the hybrid model consistently outperforms state-of-the-art gaze estimation methods while preserving linear computational complexity.

Tracking, Attention Prediction, and Spatial Understanding

Accurate tracking and attention prediction are essential for delivering responsive and visually coherent XR experiences. Ding et al. propose [FoANet: Focus of Attention Prediction for Foveated Pre-rendering to Enable High-Quality Edge VR](#), an edge-based foveated pre-rendering framework that jointly predicts users' head and gaze movements. By leveraging the intrinsic correlation between head and gaze motion through a multi-task learning model, FoANet enables accurate focus-of-attention prediction and supports predictive foveated rendering. Experimental evaluations demonstrate that the approach achieves higher prediction accuracy and lower inference overhead than state-of-the-art baselines, leading to improved visual quality and reduced latency.

While predictive models improve responsiveness, robust tracking remains a broader systems-level challenge. Chandio et al. present an extensive empirical study in *Lost in Tracking Translation: A Comprehensive Analysis of Visual SLAM in Human-Centered XR and IoT Ecosystems*, analyzing the performance of state-of-the-art visual SLAM and tracking algorithms across diverse application

domains, including XR, autonomous vehicles, drones, and human-centered IoT systems. Their results reveal that environmental conditions, user locomotion patterns, and algorithmic design choices jointly affect tracking performance, and that no single tracking solution generalizes well across all scenarios. The authors provide a taxonomy of tracking challenges, quantitative performance comparisons, and data characterization insights to guide the design of robust and adaptable tracking systems.

Interaction Techniques and Training Systems

Interaction beyond traditional vision-based sensing remains an active area of research in XR. Liu et al. propose [Mring: Contactless MR/AR Extended Input Method Based on Magnetic Signal](#), a contactless interaction technique that leverages wearable magnetometer sensors combined with advanced signal calibration and learning-based reconstruction. The system enables accurate trajectory reconstruction and interaction even outside users' visual fields. Experimental evaluations demonstrate high localization accuracy and improved usability, providing an effective and low-cost interaction solution for MR and AR applications.

XR technologies are also increasingly adopted for professional training and skill acquisition. In [Design and Development of a Real-Time Virtual Bariatric Endoscopy \(ViBE\) Simulator for Endoscopic Sleeve Gastropasty](#), Erden et al. present the ViBE simulator, a fully integrated VR system designed to support training for endoscopic sleeve gastropasty procedures. The simulator combines real-time soft-body simulation, custom-designed haptic hardware, and immersive VR interfaces to deliver realistic surgical interactions. Performance evaluations report low end-to-end latency, high rendering frame rates, and precise haptic feedback, highlighting ViBE's potential as a cost-effective and effective training platform.

Immersive Networking, Visualization, and Media Delivery

Scalable networking and efficient media delivery are critical to supporting large-scale immersive applications. Rowden et al. investigate the effectiveness of immersive visualization techniques for representing large WiFi networks in [Assessing the Scalability of Immersive WiFi Visualizations](#). By evaluating multiple visualization designs under varying network sizes through a controlled user study, the authors analyze how scalability affects users' ability to interpret signal strength and network performance. Their results provide practical insights into design tradeoffs and highlight challenges in scaling immersive visual analytics tools.

Real world data acquisition is essential for constructing immersive environments in cyber physical immersive networking systems, but maintaining data quality while protecting user privacy remains challenging. In [A Quality Aware Data Collection Scheme with Privacy for Cyber Physical Immersive Networking Systems](#), Lin et al. study this problem in mobile crowd sensing, where reliable participants must be identified without exposing their sensing data. They propose a privacy preserving data collection scheme that combines reputation calibration with two tier truth discovery, estimating user reliability through comparisons of user weights with those of trusted participants. This enables reputation based participant selection and truth discovery while limiting access to sensitive sensing information. Experiments on real world datasets show that the approach achieves accurate reputation estimation and improves the quality of collected data under privacy preservation.

Latency-sensitive immersive systems can further benefit from intelligent edge computing. In [Latency Reduction in Immersive Systems through Request Scheduling with Digital Twin Networks in Collaborative Edge Computing](#), the authors propose a digital twin-based collaborative edge computing framework for efficient request scheduling. By constructing federated digital twin networks that enable real-time awareness of distributed edge resources, the framework coordinates cross-regional edge collaboration and optimizes request placement. Extensive experimental

results demonstrate significant reductions in end-to-end latency compared to cloud-based and non-collaborative edge solutions.

Efficient volumetric media streaming is addressed by Wu et al. in [Cell Configuration for QoE-Aware Volumetric Video Streaming via Hierarchical Reinforcement Learning](#). The authors propose a hierarchical reinforcement learning framework that jointly optimizes cell size selection and bitrate allocation by considering computation overhead, transmission efficiency, and user viewport dynamics. Trace-driven simulations demonstrate that the proposed approach significantly outperforms fixed-configuration baselines under diverse network conditions and user behaviors.

The challenge of transmitting high-dimensional immersive content is explored in [Efficient Light Field Transmission via Enhanced Resampling Reconstruction and Angular Attention Estimation](#). By exploiting spatial and angular redundancies in light field data and optimizing transmission strategies based on visible content, the proposed framework reduces bandwidth consumption and transmission latency while maintaining visual quality. Experimental evaluations show substantial performance gains over conventional light field transmission methods.

We would like to express our sincere gratitude to all authors for their high-quality and insightful contributions, and to the reviewers for their thorough and constructive evaluations that ensured the quality of this Special Issue. We also thank the editorial team of ACM Transactions on Sensor Networks for their invaluable guidance, support, and efficient coordination throughout the review and publication process. We hope that this Special Issue will serve as a valuable reference and a catalyst for future research and innovation in computing, sensing, and networking for immersive systems.

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