Virtual Reality Software and Technology

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This special issue is dedicated to highlighting recent advances in VR software and technology. The issue received 16 submissions, and some of which were significant extensions of the best papers from the ACM Symposium on Virtual Reality Software and Technology (VRST) 2014, which was held in Edinburgh, on 11–13 November 2014. All the submissions went through strict peer review, and five were ultimately selected to be included here.

Many VR/AR applications use marker/tag tracking (such as probe tracking and calibration). The article "Illumination Independent and Accurate Marker Tracking Using Cross-Ratio Invariance" by Vincent Agnus, Stéphane Nicolau, and Luc Soler presents a novel method that focuses on accurately locating the corners of markers or tags using cross-ratio invariance. Cross-ratio invariance defines a ratio based on the intensity of collinear points that should remain constant, regardless of illumination changes. This approach improves tracking accuracy, particularly along the camera depth axis, up to several millimeters, depending on the marker depth.

The advent of consumer stereoscopic head-mounted displays (HMDs) like Oculus Rift opens up hitherto unexplored ways to use them in VR/AR applications. However, 80 percent of users still report adverse physical discomfort or "simulator (motion) sickness" when using such devices. In "Reducing Visual Discomfort in HMDs Using Dynamic Depth of Field," Kieran Carnegie and Taehyun Rhee study the use of blur effects in decreasing viewer discomfort. Depth of focus blur effects has been studied not only for general visual discomfort as well as symptoms such as fatigue, headache, and eye strain. Their study shows that DoF blur can considerably alleviate most of these discomforts, thereby reducing simulator sickness on the whole. This work has the potential to advance the widespread adoption of VR.

Digitap is an eyes-free, wrist-worn input device that can robustly detect thumb-to-finger taps at different locations on the fingers. In "Sensing Thumb-to-Finger Taps for Symbolic Input in VR/AR Environments," Manuel Prätorius, Ulrich Burgbacher, Dimitar Valkov, and Klaus Hinrichs present an advanced version of the DigiTap device

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that recognizes finger taps based on data from an accelerometer and infrared images. The authors reduce computational cost by only taking images when the accelerometer detects a tap, at which point the image of the hand is processed and the thumb location is recognized. This system frees users from wearing potentially intrusive and distracting digital gloves on their hands.

In "Visual Perspective and Feedback Guidance for VR Free-Throw Training," Alexandra Covaci, Anne-Hélène Olivier, and Franck Multon analyze the performance of beginner basketball players in a virtual environment. The authors compare how the players perform when shown a first-person player view, third-person view (behind an avatar shooting the basketball), and third-person view with visual feedback. Interestingly, the players perform better when playing in the third-person view than when playing in the first-person view. This article provides new insights for developing virtual sports training systems.

Lastly, Marc Ericson C. Santos, Jarkko Polvi, Takafumi Taketomi, Goshiro Yamamoto, Christian Sandor, and Hirokazu Kato's article "Toward Standard Usability Questionnaires for Handheld Augmented Reality" evaluates the usability of handheld augmented reality (HAR) software by designing a new set of questionnaires, called HARUS, consisting of comprehensibility and manipulability statements to distinguish between perceptual and ergonomic issues. The authors investigated the effectiveness of the questionnaire in four experimental settings, where they asked users to annotate text, create status reports, memorize words, and position arrows in AR settings with handheld devices. The experiment results indicate a positive correlation between HARUS and the System Usability Scale. Although HARUS is designed for AR software, it has the potential to be an evaluation standard for VR software in future.

These five articles highlight some of the most exciting development in VR and suggest new research directions in the field. We thank Pak Chung Wong, *CG&A*'s associate EIC, for help with this special issue; the authors for contributing their work; and the anonymous reviewers for providing constructive feedback during peer review.

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