Digital media, networking, and information technologies are now adding a new, third dimension to all forms of visual communications. Emerging 3-D media services are expected to further blur the lines between the physical and virtual worlds, and the experience associated with 3-D media will transform the way people live, work, and play. Three-dimensional media will allow greater flexibility and choices for the entertainment, broadcast, education, and telecommunications industries, as well as consumers.

2010 was a breakthrough year for 3-D media. Numerous 3-D movies were released to theaters and created large revenues. The most successful films ever made are now in 3-D. Three-dimensional consumer items entered the shops and stereo displays are now in the living rooms. Major events, such as the 2010 FIFA World Cup, were broadcast in 3-D, and the first commercial 3DTV channels are now on the air. Global players in consumer electronics predict that in 2015 more than 30% of all high-definition (HD) panels at home will be equipped with 3-D capabilities. Gamers can also enjoy interactive and immersive entertainment in a new dimension. Mobile phones, personal digital assistants (PDAs), laptops, and similar devices can provide us the extended visual sensation anytime, anywhere. Three-dimensional camera systems are already available for professional and private users. Unlike previous attempts to make 3-D media widely available, there are good reasons to believe that this time it will be a sustainable trend. Stereoscopic 3-D technology is now mature enough for the market in terms of quality of experience and content. There is a clear demand from the user side and attractive business opportunities are visible. The content and value chains are in place for various application scenarios.

I. TECHNICAL CHALLENGES

Despite high standards that stereoscopic 3-D has reached today, there is still room for improvement of the technology. Furthermore, a number of central problems for new technologies such as autostereoscopic multiview displays, 3-D integral imaging, or holographic video displays as well as advanced functionalities such as free viewpoint navigation remain partly unsolved. There is a clear
need for further research and development to achieve ultrarealistic 3-D media technologies; and interest within the scientific community towards 3-D media related research is rising with many ongoing 3-D media-focused projects in Europe, Asia, and North America. This Special Issue aims to provide an overview of recent advances and discuss future directions in diverse 3-D media technologies ranging from current stereoscopy to ultrarealistic holographic 3-D video, and transmission of this media over the current and future, wired and wireless Internet. This Special Issue is organized under four main 3-D areas: media displays, media content creation, media representation and compression, and media transport and storage. A brief introduction to the papers in these areas is given in the following.

II. MEDIA DISPLAY

Even though the production and delivery chain plays an essential role in the user quality of experience of 3-D media, it is indeed the display that the end user actually interfaces with; and therefore, 3-D display technologies deserve special attention. This Special Issue features three papers on displays. The first paper, “State of the art in stereoscopic and autostereoscopic displays” by Urey et al. presents a comprehensive overview of a category of displays that covers most of the 3-D displays that are in use today. It also presents recent developments and advances in this field. The second and third papers are on more futuristic approaches to achieve true 3-D displays: one of these papers by Cho et al., “Three-dimensional optical sensing and visualization using integral imaging,” looks at the current state of the art, recent research results, and potential applications of integral imaging, and the other by Onural et al., “Digital holographic three-dimensional video displays,” covers ultrarealistic holographic 3-D video displays. The paper on integral imaging also presents pickup schemes associated with this mode of imaging systems in addition to related displays. The paper on holographic displays gives an overview of the state of the art, and then provides basic signal-processing-based analysis of diffraction of light by spatial light modulators. Specifications for a satisfactory quality digital holographic video display are also derived.

III. MEDIA CONTENT CREATION

Formerly, limitations in understanding human 3-D perception and understanding capabilities of 3-D display technologies often led to poorly designed 3-D content and dissatisfying user experience. Now that human 3-D perception and capabilities/limitations of 3-D display systems are well understood and incorporated into content-design technology and art, content creation for stereoscopic 3-D has reached a high level of maturity. However, some aspects in stereoscopic 3-D content creation can still be improved. Furthermore, many aspects of content design for advanced display systems such as autostereoscopic multiview displays, integral imaging, or holographic displays and free viewpoint navigation remain unresolved and raise new challenges for content technology and art.

Two papers in this Special Issue reflect the state of the art and open challenges in the area of content creation. The first paper, “Production rules for stereo acquisition” by Zilly et al., covers aspects of stereoscopic 3-D camera systems, related onset production technology, and stereography. It focuses on the actual capturing process and related technology. The second paper, “Three-dimensional video postproduction and processing,” by Smolcic et al., emphasizes the offset components and processes in the content creation workflow. It elaborates on advanced algorithms applied to captured signals in order to create high-quality 3-D content, stereoscopic and beyond.

IV. MEDIA REPRESENTATION AND COMPRESSION

The representation and compression of 3-D media has made significant advances in recent years to enable efficient delivery of high-quality audio and visual content over a broad range of distribution channels. Compression efficiency remains a key issue especially for multiview video with several views. The data format must satisfy not only the constraints imposed by various distribution channels, such as bit rate and compatibility with existing services, but it must also be easily adaptable to various types of 3-D displays and interfaces, and must adhere to constraints in the production environment.

This Special Issue includes three survey papers on 3-D media representation and compression. In the paper by Vetro et al., “Overview of the stereo and multiview video coding extensions of the H.264/MPEG-4 AVC standard,” techniques that provide a compact representation of multiple views of a video scene are described, with emphasis on recent extensions to the widely deployed and state-of-the-art H.264/ MPEG-4 advanced video coding (AVC) standard. This paper reviews compression methods that could be applied to exploit the correlations that exist between different views of the scene, as well as representations that enable stereo services to be delivered through existing 2-D infrastructures. While these data formats offer significant advantages in terms of compression efficiency and compatibility, it has been recognized that conventional multiview representations are not ideally suited to support autostereoscopic displays, which typically require a very large number of discrete viewpoints as input. Depth-based representations of 3-D video scenes have been proposed to overcome this limitation and are discussed in the paper “3-D video representation using depth maps” by Müller et al. It is shown that such representations have the advantage of being able to generate a large number of views at the receiver, thereby decoupling the acquisition format and transmission constraints with the display requirements. Advanced methods to compress depth-based 3-D video formats are also presented in this paper. Three-dimensional media cannot be
complete without multichannel audio to support perception of sounds within a 3-D space for a more complete immersive experience. Efficient coding techniques for multichannel audio are described in the paper by Elfitri et al., “Multichannel audio coding based on analysis by synthesis.” This paper provides an overview of some well-known multichannel audio coding techniques and presents a new coding framework for improving the objective fidelity of the decoded signals.

V. MEDIA TRANSPORT AND STORAGE

In recent years, a number of different distribution mechanisms, such as Blu-Ray disc, cable and satellite transmission, terrestrial broadcast, and download/streaming over the Internet and mobile networks, have been augmented to enable the delivery of 3-D media to home. The four papers presented on this topic address the required infrastructure for home delivery, as well as transport and signaling protocols in order to provide interoperability of the overall distribution system and among various devices with the highest quality of experience.

The paper “Transport and storage systems for 3-D video using MPEG-2 systems, RTP, and ISO file format” by Schierl and Narasimhan gives an overview of the standards that provide systems-level support for transport and storage of 3-D video. The paper describes extensions that have been made to MPEG-2 systems for digital broadcast and storage on Blu-Ray discs, RTP for real-time transport over the Internet and IPTV, and the ISO media file format for progressive download over the Internet. The paper by Broberg, “Infrastructures for home delivery, interfacing, captioning, and viewing of 3-D content,” provides an insightful examination of the infrastructure that will be used for delivery of 3-D media to the home. It also considers several practical issues that are necessary to enjoy 3-D at home including audio–video signal interfaces between consumer products, rendering of captions without introducing depth conflicts, as well as the need for standardized eyewear. While it is possible to broadcast 3-D stereo video (two views) over digital TV platforms today, streaming over IP provides a more flexible approach for distribution of stereo and free-view 3-D media to home and mobile with different connection bandwidths and different 3-D displays. In the paper, “Flexible transport of 3-D video over networks,” Gürel et al. take a look at beyond the state of the art in 3-D video transport research, including asymmetric stereoscopic video streaming, adaptive and peer-to-peer streaming of multiview video, view-selective streaming and future directions in broadcast of 3-D media over IP and jointly over DVB and IP. Finally, the paper “Three-dimensional media for mobile devices” by Gotchev et al. provides an overview of technologies enabling the delivery of 3-D media to next-generation mobile devices. A case study of 3-D video broadcast over DVB-H is presented in order to illustrate the importance of joint source-channel optimization of 3-D video for its efficient compression and robust transmission over error-prone channels. Next-generation mobile devices are characterized through their display and user interface components. Novel methods for studying the user experience of 3-D media are also presented.

It is indeed an exciting time for 3-D media and displays. Investments in this technology have never been greater and we are finally at a stage that a high-quality 3-D experience could be provided to viewers. We hope this Special Issue provides a thorough and comprehensive set of survey papers for both researchers and practitioners that describe not only the current state of the art, but also indicate the trends in this field, as well as where future challenges and research opportunities exist.

ABOUT THE GUEST EDITORS

A. Murat Tekalp (Fellow, IEEE) received double major B.S. degrees in electrical engineering and mathematics from Boğaziçi University, Istanbul, Turkey, in 1980 and the M.S. and Ph.D. degrees in electrical, computer and systems engineering from Rensselaer Polytechnic Institute, Troy, NY, in 1982 and 1984, respectively.

After working briefly at Eastman Kodak Research, he joined the University of Rochester, Rochester, New York, as an Assistant Professor in 1987, where he was promoted to Distinguished University Professor. He joined Koç University, Istanbul, Turkey, in 2001, where he is currently the Dean of Engineering. He authored the book Digital Video Processing (Englewood Cliffs, NJ: Prentice-Hall, 1995). He holds eight U.S. patents.

Prof. Tekalp is a member of Turkish Academy of Sciences (TÜBA), and a member of Academia Europaea. He has been elected a Distinguished Lecturer by IEEE Signal Processing Society in 1998 and received the TÜBİTAK Science Award in 2004. He has been a member of the IEEE Signal Processing Society Technical Committee on Image and Multidimensional Signal Processing from 1990 to 1999, and chaired it during January 1996–December 1997. He has been the Editor-in-Chief of the EURASIP Journal Signal Processing: Image Communication published by Elsevier (1999–2010). Formerly, he has served as an Associate Editor for the IEEE TRANSACTIONS ON SIGNAL PROCESSING (1990–1992) and the IEEE TRANSACTIONS ON IMAGE PROCESSING (1994–1996). He was also on the Editorial Board of the IEEE Signal Processing Magazine (2006–2009) and Academic Press Journal Visual Communication and Image Representation (1995–2002). He was appointed as the Special Sessions Chair for the 1995 IEEE International Conference on Image Processing, the Technical Program Co-Chair for the 2000 IEEE International Conference on Acoustics, Speech and Signal Processing, Istanbul, Turkey, the General Chair of the IEEE International Conference on Image Processing (ICIP), Rochester, NY, in 2002, and Technical Program Co-Chair of the 2005 European Signal Processing Conference (EUSIPCO), Antalya, Turkey. He is the founder and first Chairman of the Rochester Chapter of the IEEE Signal Processing Society. He was elected as the Chair of the Rochester Section of IEEE in 1994–1995. He is a member of the Advanced Grant panel for the European Research Council, and a project evaluator and referee for the European Commission. He is also appointed as a National Expert for the European Commission.
Aljoscha Smolic received the Dr. Eng. degree in electrical and information engineering from Aachen University of Technology (RWTH), Aachen, Germany, in 2001.

He joined Disney Research Zurich, Zurich, Switzerland, in 2009, where he leads the “Advanced Video Technology” group. Prior to that, he was a Scientific Project Manager at Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institute (HHI), Berlin, Germany. He conducted research in various fields of video processing, video coding, computer vision, and computer graphics, and published more than 100 refereed papers in these fields. Since 2003, he had teaching appointments at Technical University of Berlin, ETH Zurich, Universitat Politècnica de Catalunya (UPC), Universidad Politecnica de Madrid (UPM), and Universitat de les Illes Balears (UIB).

Dr. Smolic is an Area Editor for Signal Processing; Image Communication and served as Guest Editor for the PROCEEDINGS OF THE IEEE, the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE Signal Processing Magazine, and other scientific journals. He chaired the MPEG ad hoc group on 3DAV pioneering standards for 3-D video. In this context, he also served as one of the Editors of the multiview video coding (MVC) standard. He received the “Rudolf-Urteil-Award” of the German Society for Technology in TV and Cinema (FKTG) for his dissertation in 2002. He is a Committee Member of several conferences, including the IEEE International Conference in Image Processing (ICIP), the IEEE International Conference on Multimedia and Expo (ICME), and the European Signal Processing Conference (EUSIPCO) and served in several Chair positions of conferences.

Anthony Vetro (Fellow, IEEE) received the B.S. and M.S. degrees in 1996 and the Ph.D. degree in 2001 in electrical engineering from Polytechnic University, Brooklyn, NY.

He joined Mitsubishi Electric Research Labs, Cambridge, MA, in 1996, where he is currently a Group Manager responsible for research and standardization on video coding, as well as work on display processing, information security, speech processing, and radar imaging. He has published more than 150 papers in these areas. He has also been an active member of the ISO/IEC and ITU-T standardization committees on video coding for many years, where he has served as an ad hoc group chair and editor for several projects and specifications. Most recently, he was a key contributor to the Multiview Video Coding extension of the H.264/MPEG-4 AVC standard. He also serves as Vice-Chair of the U.S. delegation to MPEG.

Dr. Vetro is active in various IEEE conferences, technical committees, and editorial boards. He currently serves on the Editorial Boards of the IEEE Signal Processing Magazine and IEEE Multimedia, and as an Associate Editor for the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY and the IEEE TRANSACTIONS ON IMAGE PROCESSING. He served as Chair of the Technical Committee on Multimedia Signal Processing of the IEEE Signal Processing Society and on the steering committees for ICME and the IEEE TRANSACTIONS ON MULTIMEDIA. He served as an Associate Editor for IEEE Signal Processing Magazine (2006–2007), as Conference Chair for the 2006 IEEE International Conference on Consumer Electronics (ICCE), Tutorials Chair for ICME 2006, and as a member of the Publications Committee of the IEEE TRANSACTIONS ON CONSUMER ELECTRONICS (2002–2008). He is a member of the Technical Committees on Visual Signal Processing & Communications, and Multimedia Systems & Applications of the IEEE Circuits and Systems Society. He has also received several awards for his work on transcoding, including the 2003 IEEE Circuits and Systems IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY Best Paper Award.

Levent Onural (Fellow, IEEE) received the B.S. and M.S. degrees in electrical engineering from the Middle East Technical University (METU), Ankara, Turkey, in 1979 and 1981, respectively, and the Ph.D. degree in electrical and computer engineering from the State University of New York at Buffalo (SUNYAB), Buffalo, in 1985.

He was a Fulbright scholar (1981–1985). He joined the Electrical and Electronics Engineering Department, Bilkent University, Ankara, Turkey, in 1987, where he is currently a Professor and Dean of Engineering. His current research interests are in image and video processing, with emphasis on video coding, 3DTV, holographic 3DTV, and signal processing aspects of optical wave propagation. He was the coordinator of European Commission (EC)-funded 3DTV Project (2004–2008), and the Coleader of 3D Media Cluster (2008–2010), which is an umbrella organization formed by many EC-funded 3-D related projects.

Dr. Onural is the recipient of a TÜBİTAK Incentive Award (1995), an IEEE Third Millennium Medal (2000), and the 2011 IEEE Haraden Pratt Award. He served IEEE as Director of IEEE Region 8 (2001–2002), Secretary of IEEE (2003), a member of the IEEE Board of Directors (2001–2003), and IEEE Assembly (2001–2002). He is the founder (1989) and first chairman of IEEE Turkey Section. He has been the General Co-Chair of the 2000 IEEE International Conference on Acoustics, Speech and Signal Processing and the General Co-Chair of many 3DTV-CON series of conferences. He is an associate editor of the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS ON VIDEO TECHNOLOGY, and a member of the editorial board of SPIE Reviews.