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COST Action IC1105
(22-05-2012 – 30-04-2016)

3D Content Creation, Coding and Transmission over Future Media Networks

FINAL ACHIEVEMENT REPORT
(22-05-2012 – 30-04-2016)

This report on the full lifetime of the Action is submitted by the MC Chair on behalf of the Management Committee and is validated by the Scientific Committee of the COST Association.

Executive summary of the Achievement Report:

During its lifetime, the Action created a research collaboration framework among its partners, covering a wide range of research topics in all main elements of a 3D multimedia delivery chain. The general objective of promoting scientific networking among European researchers was fully achieved through the use of available COST instruments, namely the Meetings involving researchers and PhD students from all working groups, Short Term Scientific Missions and Training Schools.

The Action enabled several relevant scientific results, jointly achieved by its participants, in regard to the various elements of the 3D multimedia communications chain, from acquisition to user consumption. In the acquisition and processing side, 3D multiview and light field capturing systems were developed towards arbitrary camera positions (i.e. beyond linear arrangements), multi-sensor capture and calibration methods using time-of-flight and video, depth data denoising and estimation algorithms. 3D multiview video and light field databases were made available for research and development. 3D video and depth coding algorithms were successfully investigated, achieving better results than the current HEVC standard in terms of rate-distortion efficiency. The Action also actively contributed to advance the state of the art in coding of light field images and video by developing novel coding schemes, which extend current standards and better cope with the specific characteristics of this type of visual information. There are also scientific advances on the network side, addressing specific issues regarding 3D and multiview delivery. A delivery system for multivew video-plus-depth over hybrid networks combining broadcast and broadband was proposed, including novel features, such as an adaptation mechanism based on user preference and adaptive redundant chunk scheduling for increased robustness.

On the receiving side of the communication chain, the Action also produced relevant scientific results. A stereo client based on open SVC was developed and it is available online to be used as a tool for QoE evaluation in end-to-end 3D video communications under lossy conditions. In the same line of research, new error concealment methods for efficient reconstruction of lost depth data in multiview video-plus-depth were devised, also contributing to advance the state-of-the-art. An optimization methodology for a light field display-camera configuration was proposed to determine the optimal distribution of ray generators in projection-based light field displays and a system for user interaction with such type of displays was also developed for applications with large-scale 3D maps. Further relevant scientific results were achieved in models and metrics for quality evaluation of 3D video, driven by user factors and validated through subjective testing. Quality metrics specifically suitable for testing multivew and light field content were proposed and first results about the effects of 3D content distortions on visual discomfort and emotions in 3DTV viewers were achieved. It was found that physiological correlates of emotions were affected by visual discomfort conditions, and that these measures were more sensitive than traditional self-reported measures. Still in regard to quality evaluation, a new system was developed to collect and compare subjective quality grades originating from different sites, to study the effect of different observation conditions and observer/graders populations on the DMOS obtained for 3D video depth and comfort.

The Action also enabled joint organisation of scientific events, namely workshops and special sessions at IEEE ICC and IEEE ICIP conferences and two editions of the 3DTV-Conference (2014 and 2015).

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Summary assessment of outcomes and impacts by Action Rapporteur:

The 3D-ConTourNet COST Action covered a range of research topics related to the 3D multimedia delivery chain. The network, composed of the most active researchers and industry experts in the field of 3D multimedia networked services and applications from Europe and associated countries, helped in promoting the scientific knowledge by means of regular meetings, Short Term Scientific Missions and Training Schools. 3D-ConTourNet was organized in six working groups and seven task forces for managing the various works conducted within the action. The 3D-ConTourNet COST action permitted to several members to start research projects related to the field 3D multimedia delivery chain. Moreover, several joint actions as for instance co-supervised PhDs have been started.

The outputs of this COST Action are diverse although most of them have only been partially achieved. The amount of targeted actions was probably too high to be achieved within the lifetime and the allocated budget. Among the different objectives, one can notice the important contribution to 3D coding focusing on the harmonization among content, displays, printers and sensor devices. Several publications and input to standards (MPEG) have been produced. Another aspect is related to QoE-aware networking for 3D multimedia delivery that could not be totally achieved. It is unfortunate since it represents an important problem of 3D delivery that deteriorates the user's experience. Fortunately, the part regarding the methodologies for QoE assessment using multi-modal content has fully achieved. Several initiatives have been launched and many important results have been obtained in addition to a significant part of test materials. The dissemination part is very high and many conferences such as 3DTV-con and special sessions (in IEEE ICIP for example) have been organized under the flagship of 3D-ConTourNet. Based on the achievements of this Action, a proposal for a new COST Action on light field technology for medical applications has been submitted.

The impacts of 3D-ConTourNet are multiple and their timing is from short to long term: 1) scientific: it includes the (co)supervision and the finalization of several PhD works allowing to make a progress to the knowledge in the field, the dissemination in highly recognized conference and journals, training a number of early-stage researchers and the creation of qualified consortia able to submit proposals for EU-funded projects. 2) Societal: The organized training schools allowed undoubtedly to create strong links between early-stage researchers across Europe. This will lead to increase the connections and collaboration in the future, and 3) Technological and economic: These aspects relate to the organisation of international conference and to the contribution to standard bodies like ITU-R VQEG and ISO/IEC MPEG.

The success of the Action is based primarily on the fact of putting together researchers and industry experts across Europe in order to discuss, work and make a progress towards improving 3D multimedia delivery. The participation of Holografika has most likely stimulated the consortium and provided a concrete view of the problems and their solutions. Also, co-supervising PhD by partners from different countries is for sure one of the successes of 3D-ConTourNet.

Action Rapporteur	Action Rapporteur name : Chaker Larabi Affiliation: University of Poitiers Country: France

Validation by Scientific Committee

This report was validated by the Scientific Committee on: <COST insert date of SC validation>

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I. Achievement Report

I.A. COST Action Profile

Objective/ Aim

The main objective of the Action is to create a cooperation network among European researchers and industry experts in the field of 3D multimedia networked services and applications with the objective of increasing the added value of S&T in scattered R&D projects, for the benefit of academia, industry and ultimately the users of future 3D media technology, jointly integrating 3D content creation and encoding, 3D network-aware applications in ubiquitous network architectures and 3D end-user devices, to reach high levels of user acceptance and quality of experience.

Details

MoU:	4176/11	Start of Action:	22-05-2012
CSO approval date:	1/12/2011	End of Action:	21-05-2016

COST Member Countries and Cooperating State having accepted the MoU

Country	Date	Country	Date	Country	Date	Country	Date
Austria	16/07/2014	Croatia	13/09/2012	Cyprus	18/05/2012	Czech Republic	13/02/2014
Denmark	02/04/2012	Finland	20/01/2012	France	16/05/2012	Germany	28/03/2012
Greece	13/03/2012	Hungary	07/03/2012	Ireland	17/01/2012	Israel	25/06/2012
Italy	13/01/2012	Malta	28/12/2011	Netherlands	22/03/2012	Norway	21/05/2012
Poland	09/02/2012	Portugal	06/01/2012	Romania	05/04/2012	Serbia	25/10/2012
Slovenia	23/06/2012	Spain	03/01/2012	Sweden	11/05/2012	Turkey	16/04/2012
United Kingdom	06/12/2011	fYR Macedonia	23/03/2012				

Total: 26

Intentions to Accept the MoU

0

Other participants:

Institution Name	Country
Universidade Federal do Rio de Janeiro, Programa de Engenharia Eletrica / COPPE	Brazil
University of Southern Queensland, Faculty of Engineering and Surveying	Australia

Contacts

Chair/ Vice Chair

Position	Name	Contact details	Country	Date of PhD:	Gender
Chair:	Pedro Assuncao	Instituto de Telecomunicacoes / IPLeiria, Campus 2, IPLeiria/ESTG Morro do Lena – Alto Vieiro 2411-901 Leiria, Portugal amado@co.it.pt	Portugal	1998	M
Vice Chair:	Atanas Gotchev	Tampere University of Technology Department of Signal Processing FI-33101 Tampere, Finland atanas.gotchev@tut.fi	FInland	1996	M

Working Group Leaders

WG#	WG Title	WG Leader	Country	Date of PhD:	Gende	Number of participants
1	Content Creation	Michael Schöberl	Germany	2013	M	20
2	3D Media Coding	Carl James Debono	Malta	2000	M	39
3	3D Media Coding	Evangelos Pallis	Greece	2002	M	32
4	3D QoE-QoS Evaluation	Alexandre Pereda	Spain	2007	M	51
5	End-User Devices	Péter Tamás Kovács	Hungary	2017	M	27
6	Next Generation 3D Multimedia	Mårten Sjöström	Sweden	2001	M	36

Other positions if applicable (STSM Coordinator, WG Vice Leader, Task Force Leader…)

Position	Name	Country	Date of PhD:	Gender
STSM Coordinator	Jürgen Seiler	Germany	2011	M
TF Leader (Simulation tools & testbeds)	Emil Dumic	Croatia	2012	M
TF Leader (Light Field capture and display)	Robert Bregovic	Finland	2003	M
TF Leader (Datasets)	Karel Fliegel	Czech Republic	2011	M
TF Leader Emaotional state and 3D Content	Giulia Boato	Italy	2005	F
TF Leader Quality metrics for multiview	Federica Battisti	Italy	2010	F
TF Leader (Depth Sensing with ToF)	Michael Schöberl	Germany	2013	M
TF Leader (Optimisation of video codecs)	Caroline Conti	Portugal	2016	F

Action website:	http://www.3d-contournet.eu

I.B. Achievement of MoU objectives and deliverables and additional outputs

MoU objectives

MoU objective	Achieved Yes/ Partially/ No	Evidence of (partial) achievement
Define guidelines and expand current end-user based content production model, existing within game and virtual world communities, into the design for the near future interactive and collaborative services. Previous research on QoS and QoE issues has been mainly focusing on cases where streamed media is the key. This approach has not been able to solve the issues with interactive media consisting of soft real-time elements. The basic understanding and solid background about end user behaviour will be pursued with the aid of rich interaction models. This knowledge will be applied to service design and development in order to make sure the quality of end user experience is as high as possible. The concept of rich interaction relates to the possibilities of the multi-user game and virtual environment users to act and express themselves in flexible and non-predefined ways. The future application of this concept will consist of (i) multi-modality in terms of forms and media for effective utilisation of various senses; (ii) high level of interactivity in terms of range, frequency and impact of individual interaction forms; (iii) flexibility to select corresponding actions and reactions through simulations and interaction models (e.g., physics model) with limited number of pre-programmed solutions; (iv) automation to allow reduction of mundane tasks and to support simulation of sub-conscious actions; (v) abstraction to enable various levels of control in interaction processes.	Partially	The Action partially achieved this objective through low-level approaches targeting free hand gesture interaction within the field of view of light field display and also optimisation of visual content for light-field displays, including evaluation and modelling, as part of 3D technologies to support interactive and collaborative services. Different application-based techniques to produce 3D contents for target communities have been tested. The outcomes of such studies indicate that techniques like free viewpoint, light field or integral imaging requiring multi-camera setups offer promising results. A Training School was organised partially addressing the theme of interaction. The underlying technologies were focused without reaching high-level models for virtual environments. The following STSMs also developed work related with acquisition and evaluation of multimodal data with potential application in interactive models. i) Tao Wei, Evaluating the performance of skeleton fusion of Multiple Kinects for 360 degree motion tracking. ii) Marcus Bednara, Sensor fusion for 3D content generation on embedded systems. iii) Aleksander Väljamäe, Studying the emotional modulation of 3D sound-induced circular vection. http://www.3d-contournet.eu/stsms/granted-stsm/ An interaction setup combining the visualization of objects within the Field Of View (FOV) of a light field display and their selection through freehand gesture tracked by the Leap Motion Controller, was investigated. The following joint papers were selected as representative of this achievement. ADHIKARLA, Vamsi Kiran, SODNIK, Jaka, SZOLGAY, Peter, JAKUS, Grega. Exploring direct 3D interaction for full horizontal parallax light field displays using leap motion controller. Sensors, Apr. 2015, vol. 15, no. 4. http://www.mdpi.com/1424-8220/15/4/8642 ADHIKARLA, Vamsi Kiran, JAKUS, Grega, SODNIK, Jaka. Design and evaluation of freehand gesture interaction for light field display. V: 17th International Conference, Los Angeles, CA, USA, August 2-7, 2015, Human-computer interaction: interaction technologies : proceedings. Part 2, (Lecture Notes in Computer Science, ISSN 0302-9743, 9170). http://link.springer.com/chapter/10.1007/978-3-319-20916-6_6

		Galloso, I., Feijóo, C., & Santamaría, A. (2015). Novel approaches to Immersive Media: from enlarged field-of-view to multi-sensorial experiences. In A. Kondoz & T. Dagiuklas (Eds.), Novel 3D Media Technologies (pp. 9–24). New York: Springer New York. doi:10.1007/978-1-4939-2026-6_2 Galloso, I., Palacios, Juan F., Feijóo, C., Santamaría, A. On the influence of individual characteristics and personality traits on the user experience with multi-sensorial media: an experimental insight. Multimedia Tools and Applications, Special Issue on "Immersive Media Experiences". doi: 10.1007/s11042-016-3360-z A Training School under the theme "Rich 3D: Content Creation, Perception and Interaction" was organised by the Action. http://www.3d-contournet.eu/interaction-2014/ The following research outcomes (selected scientific papers with authors from different countries) were produced in regard to the underlying technologies related with potential use of light field content and displays in interactive systems. Kovacs, P. T., Lackner, K., Barsi, A., Balazs, A., Boev, A., Bregovic, R., Gotchev, A., Measurement of Perceived Spatial Resolution in 3D Light-field Displays, CIP 2014 IEEE International Conference on Image Processing, October 27-30, 2014, Paris, France. p. 768-772. http://dx.doi.org/10.1109/ICIP.2014.7025154 Bregovic, R., Kovacs, P. T., Balogh, T. & Gotchev, A. Display-specific light-field analysis 2014 Proceedings of SPIE, Three-Dimensional Imaging, Vizualization and Display 2014, Baltimore, Maryland, USA, 5-7 May, 2014. Javidi, B., Son, J-Y., Matoba, O., Martinez-Corral, M. & Stern, A. (eds), http://dx.doi.org/10.1117/12.2062010 Kovacs, P. T., Lackner, K., Barsi, A., Adhikarla, V. K., Bregovic, R., Gotchev, A., Analysis and Optimization of Pixel Usage of Light-Field Conversion from Multi-camera Setups to 3D Light-Field Displays, ICIP2014, IEEE International Conference on Image Processing, October 27-30, 2014, Paris, France. http://dx.doi.org/10.1109/ICIP.2014.7025016 Navarro, H. , Saavedra, G. , Martinez-Corral, M. , Sjöström, M., Olsson, R., Depth-of-field enhancement in integral imaging by selective depth-deconvolution. IEEE/OSA Journal of Display Technology, vol. 10: 3, ss. 182-188, 2014. http://dx.doi.org/10.1109/JDT.2013.2291110

		The Action did not focus its research activities directly in game and virtual environments as mentioned in this objective, which was mainly due to the fact that these topics were not under research by any of the active participants. This is the main reason for not fully achieving this objective.
Develop harmonization mechanisms, providing an evolution and roadmap for 3D coding architectures and algorithms. The current 3D research results reveals a spread of technologies and diversity, such as MVC, Multiview Coding + Depth (MVD), Free Viewpoint Video(FVV), Video + Depth (V+D), Video + DELTA, Side-by-Side (SbS), Multiview Scalable Wavelets, and others, incompatible each other, and trammelling a quick deployment of 3D technology on the marketplace. The Action has the objective of defining a new framework to facilitate a 3D video coding interoperability ecosystem. Within such framework, the objective of the Action is also to extend the current concept of 3D media compression-efficiency into amore sustainable concept of energy-efficiency coding, by developing and integrating concepts of green computing into novel 3D video coding architectures.	Partially	The Action developed significant research work towards this objective. In particular with respect to coding and harmonization among content, displays, printers and sensor devices have been covered to optimize the results obtained for 3D video coding. Action members (WG2) made joint (i.e., authors from different countries) contributions to MPEG standards. Luís F. R. Lucas, Krzysztof Wegner, Nuno M. M. Rodrigues, Carla L. Pagliari, Eduardo A. B. da Silva, Sérgio M. M. de Faria, “Intra depth-map coding using flexible segmentation, constrained depth modeling modes and simplified/pruned directional prediction”, ISO/IEC JTC1/SC29/WG11 MPEG2014/M34292, Sapporo - Japan, July 2014. Gauthier Lafruit, Krzysztof Wegner, Tomasz Grajek, Takanori Senoh, Peter Kovacs, Patrik Goorts, Lode Jorissen, Beerend Ceulemans, Pablo Lopez, Sergio Lobo, Qing Wang, Joel Jung, Masayuki Tanimoto, FTV software user guidelines, ISO/IEC JTC1/SC29/WG11 MPEG2015, Doc. M36590, Warsaw, Poland, 20-27 June 2015, A white paper was produced to highlight the state-of-the-art in 3D video coding. http://www.3d-contournet.eu/category/wgs/wg2/ Different coding schemes were developed, by authors from different countries, beyond current standards highlighting improvements in coding efficiency and complexity reductions. Luis Lucas, Krzysztof Wegner, Nuno M.M. Rodrigues, C.L.P. Pagliari, E. Silva, S.M.M. Faria, Intra Predictive Depth Map Coding using Flexible Block Partitioning, IEEE Transactions on Image Processing, Vol. 24, No. 11, 2015, pp. 4055-4068, http://dx.doi.org/10.1109/TIP.2015.2456509 A.F. Vieira, H.F. Duarte, C. Perra, L.M. Távora, P.A. Assunção, Data Formats for High Efficiency Coding of Lytro-Illum Light Fields, International Conference on Image Processing Theory, Tools and Applications IPTA, Orléans, France, pp. 494-497, November 2015. http://dx.doi.org/10.1109/IPTA.2015.7367195 L. F. R. Lucas, N. M. M. Rodrigues, C. L. Pagliari, E. A. B. da Silva and S. M. M. de Faria, "Sparse least-squares prediction for intra image coding," Image Processing

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		(ICIP), 2015 IEEE International Conference on, Quebec City, QC, 2015, pp. 1115-1119. http://dx.doi.org/10.1109/ICIP.2015.7350973 Carl J. Debono, Sérgio de Faria, "3D Video Coding: Current State and Research Directions". IEEE COMSOC MMTC E-Letter, 2013. http://mmc.committees.comsoc.org/files/2016/04/E-Letter-May13.pdf P.A. Assunção, L.F.H.P. Pinto, S.M.M. Faria, 3D Media Representation and Coding, Chapter in, 3D Future Internet Media, Ahmet Kondoz and Tasos Dagiuklas, Springer, New York, 2014 http://www.springer.com/in/book/9781461483724#reviews C. Conti, P. T. Kovacs, T. Balogh, P. Nunes, and L. D. Soares, "Light-field video coding using geometry-based disparity compensation," in 2014 3DTV-Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON), 2014, pp. 1–4. http://dx.doi.org/10.1109/3DTV.2014.6874724 The Action was also involved in new initiatives such as JPEG PLENO where members of the group are following the work being done. One of the members has hosted one of the meetings of JPEG PLENO (ISO/IEC JTC1/SC29/WG1, wg1n69022, Warsaw, Poland, June 23, 2015) – jpeg.org. Action members also partipate in the ICME 2016 challenge for Light Field coding. http://www.icme2016.org/ Although new coding schemes were developed and optimised within the Action, the more general objective of developing a new 3D video coding framework did not reach the status of "fully achieved". For this reason, the objective is considered only partially achieved.
Develop QoE-aware networking framework where novel adaptation and congestion control mechanisms are devised to optimise 3D multimedia delivery over future media networks in heterogeneous technological environments. Since QoE is not only influenced by dynamic networking conditions, but also by the quality and perceptual relevance of each element of the coded source stream (e.g., stereoscopic view, audio channel), cross-layer methods shall be used in order to make QoE metrics available to network control and adaptation mechanisms. This Action will	Partially	The Action made contributions to the field of 3D media networking and related QoE aspects. Deployment of current networks architectures, including software defined ones, have been performed in order to adapt 3D contents to available bandwidth. Hardware simulations through Machine Learning techniques have been developed as well to infer most relevant network features. These contributions were accomplished through joint papers, simulation tools and COST instruments: STSM and a Training School in the theme of 3D audiovisual Communications. Crowd3D: newly designed program based on javascript/php. The system presented can be used to collect and compare subjective quality grades originating from different sites to study the effect of different observation conditions and observer/graders populations on the DMOS quality values for 3D video depth and

provide an ecosystem in terms of transport protocols, seamless mobility and continuity in wireless systems, rate control and transcoding and end-to-end QoE-aware mechanisms. The Action also targets to organise quality assessment sessions in several centres across Europe along with the necessary service emulators or prototypes that will encompass multiple use contexts and ambiances for users. The joint analyses of the acquired subjective assessments will be reflected back to the researchers and standardization bodies in the field to consider them as reliable references		comfort. It can be installed on any platform using Apache/php server. Example can be found on the link: http://crowd3d.co.it.pt/suis3d/suis.php *S. Marcelino, S. Faria, R. Pepion, P. Le Callet, S. Soares, et P. Assuncao, Quality evaluation of depth map error concealment using a perceptually-aware objective metric, in 3DTV-Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON), 2015.* http://dx.doi.org/10.1109/3DTV.2015.7169373 The following STSMs also developed work related with acquisition and evaluation of multimodal data with potential application in interactive models. i) Cristian Perra, Robust coding of holoscopic video for heterogeneous networks ii) Nelson Francisco, Video codec design and assessment collaboration iii) Pedro Correia, Advanced MDC techniques for 3D and multiview video coding iv) Hana Khamfroush, Network Coded Cooperation for Time-Sensitive Content http://www.3d-contournet.eu/stsms/granted-stsm/ A Training School under the theme “3D Audiovisual Content Processing and Communications” was organised by the Action. http://www.3d-contournet.eu/activities/3davcom2015/ The Action did not fully achieve the objectives related to novel congestion control, rate control, transcoding and end-to-end QoE mechanisms specifically targeting 3D media. As a consequence, this objective is considered as only partially achieved.
Develop methodologies and procedures for subjective assessment of QoE using 3D multi- modal content, extending existing standards and knowledge for evaluation of the quality and comfort. To achieve this objective, the Action will seek for interdisciplinary expertise and methodologies by exploring measures of quality and comfort derived from psychophysical, psychophysiological and behavioural methods. Such exploratory research will include subjective evaluation of 3D audio because, despite the existence of standards for the subjective evaluation of audio tracks, the introduction of fully spatialised	Yes	Techniques to assess the objective quality for stereoscopic 3D video content, related to motion and depth map features have been implemented improving results from the state of the art. In addition, subjective evaluations from observers after watching pairs of video sequences with different levels of parallax have been collected in order to reduce visual discomfort. A research study on the subjective assessment of 3D video quality using a newly constructed 3D video database (3DVCL@FER). This database consists of 8 original 3D video sequences, each degraded with 22 different degradation types, including degradations specific to stereoscopic systems. The subjective assessment was done with the support of a purpose-built easily customizable grade collection platform and conducted in two research laboratories from different countries. The 3D video grade-annotated database described is publicly accessible and can be used in research-related activities like assessment of existing objective measures, using the entire database or parts of

sound introduces some assessments factors of its own, as happened with the transition from 2D to 3D visual displays. The goal is to find out the best suited methodology to evaluate perceived quality and comfort of 3D audio and conjoined presentations of 3D video and audio, by taking into consideration the specific issues of 3D audio.		it, and construction of new objective measures specific to 3D video degradations. The system presented can also be used to collect and compare subjective quality grades originating from different sites to study the effect of different observation conditions and observer/graders populations on the DMOS quality values for 3D video depth and comfort. Dumić, Emil; Grgić, Sonja; Šakić, Krešimir; Rocha, Pedro Miguel Regalo; da Silva Cruz, Luis A. 3D video subjective quality: a new database and grade comparison study, Multimedia tools and applications. (2016); http://dx.doi.org/10.1007/s11042-015-3172-6 database can be found on the link: http://goo.gl/wSEkHd Another research presents newly constructed STESCAL3D (Stereoscopic Scalable 3D) video database processed by scalable encoding Stereo (Left-Right View) video sequences that are transmitted over a network with heterogeneous conditions in terms of packet loss occurrence to each View and Layer. The subjective assessment was conducted in three research laboratories from different countries using an experimental platform. It is shown that the asymmetry in terms of encoding parameters and packet loss ratio (PLR) between the two views leads to the worst quality experience. Mysirlidis, Charalampos; Dagiuklas, Tasos; Rocha, Pedro M.R.; Da Silva Cruz, Luis A.; Kotaranin, Dino; Gruicic, Savina; Dumic, Emil; Skodras, Athanassios. STESCAL3D: Subjective evaluation of HD stereo video streaming using H.264 SVC in diverse laboratory environments // 2015 Seventh International Workshop on Quality of Multimedia Experience (QoMEX) / Skodras, A. (ed.). 2015. 1-6 http://dx.doi.org/10.1109/QoMEX.2015.7148151 database can be found on the link: http://goo.gl/wSEkHd Generator of 3D sbs video sequences: This generator produces side-by-side 3D video sequences with up to 22 different degradation types specific to 2D and 3D cases. Those sequences can be then played using "Crowd3D" application. download link: http://goo.gl/wSEkHd Several joint papers were published in the field of quality modelling and evaluation. Some selected papers are the following: Battisti, F., Carli, M., Stramacci, A., Boev, A. & Gotchev, A. A perceptual quality metric for high-definition stereoscopic 3D video, 2015 Image Processing: Algorithms and Systems XIII. SPIE, 939916. (SPIE Conference Proceedings; vol. 9399) http://dx.doi.org/10.1117/12.2086901

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		M. Barreda-Angeles, R. Pepion, E. Bosc, P. Le Callet, et A. Pereda-Banos, Exploring the effects of 3D visual discomfort on viewers' emotions, in 2014 IEEE International Conference on Image Processing (ICIP), 2014. http://dx.doi.org/10.1109/ICIP.2014.7025151 Marcelino, S. T., Faria, S. M. M. de, Pepion, R., Le Callet, P., Soares, S. S., Assunção, P. A., "Quality Evaluation of Depth Map Error Concealment using a perceptually-aware objective metric", 3DTV-CON 2015, Immersive and Interactive 3D Media Experience over Networks, Lisbon - Portugal, July 2015. http://dx.doi.org/10.1109/3DTV.2015.7169373 Barreda-Ángeles, M., Pépion, R., Bosc, E., Le Callet, P., Pereda-Baños, A. (2014). How visual discomfort affects 3DTV viewers' emotional arousal. 3DTV-CON. Budapest, Hungary. July, 2-4, 2014. http://dx.doi.org/10.1109/3DTV.2014.6874718

MoU deliverables

MoU deliverable	Delivered Yes/ Partially/ No	Evidence of (partial) delivery
The MoU does not define deliverables. The following simulation tools and video sequences are considered deliverables.		Crowd3D: newly designed program based on javascript/php. The system presented can be used to collect and compare subjective quality grades originating from different sites to study the effect of different observation conditions and observer/graders populations on the DMOS quality values for 3D video depth and comfort. It can be installed on any platform using Apache/php server. Example can be found on the link: http://crowd3d.co.it.pt/suis3d/suis.php Stereo Open SVC Client that can receive and decode two SVC video files via RTP and extract them locally in YUV format. A presentation of the scenario and the functionality of the software. http://cones.eap.gr/?q=node/5 A set of 3D video sequences was made available and used by Action participants for different research studies. http://www.3d-contournet.eu/results/test-sequences/ http://goo.gl/mvxw4l The levels of image quality, depth quantity, and visual comfort were rated by a group of subjects (14) on a set of available and self-recorded stereoscopic test videos. The stereo videos along with subjective quality scores are publicly available at the SCCH 3D Visual Discomfort

		Database (www.scch.at/en/id-3d-visual-discomfort-database).

Co-authored publications and FP7/ H2020 proposals

The co-authored publications and FP7/ H2020 proposals/ projects resulting from the Action are listed on the page following the "Additional outputs and achievements" section.

Additional outputs and achievements

Please describe any other outputs and achievements, focusing in particular on those that contribute to the COST mission of "COST enables break-through scientific developments leading to new concepts and products and thereby contributes to strengthen Europe's research and innovation capacities."
Different types of additional outputs maybe identified either as directly driven by the Action or enabled by active participation in the international research environment created by the Action. During the Action lifetime, some institutions started national projects and research studies involving MSc/PhD students in technical fields related to 3D multimedia. These were also driven by participation in the Action and are considered outputs with potential to further increase the scientific impact of the Action in the near future. Some examples are shortly described below. Within the DEMOLA initiative (http://slovenia.demola.net/) and within the LTMMFE/LTFE of the Faculty of Electrical Engineering, University of Ljubljana activities, two 3D gesture based projects were initiated, aiming at conceptualising of two interactive games for ADHD treatment using gesture based control through MS Kinect sensor device. Focusing in the multimedia and the end-user devices, a project aimed at the implementation of an improved prototype for distribution of web content using DVB-T broadcast was initiated. The project's goals aim to alleviate the digital divide by providing multimedia rich services over the traditional DVB-T broadcast channels. A national project started at Instituto de Telecomunicacoes, Portugal, focused on research and development of new methods and tools for acquisition, computational analysis and efficient coding of plenoptic medical imaging content, specifically related to melanoma. The project aims to advance the state-of-art of computational methods used in first diagnosis, taking advantage of the most recent advances in imaging technology by relying upon melanoma high resolution plenoptic images, using both spatial RGB intensity and directional information of light rays. At international level the Action also produced relevant outcomes, some of them will last beyond its lifetime: A new COST Action was proposed by several participants and it is now under evaluation. This new COST Action aims at addressing emerging challenges related with scientific developments of light field technology for medical applications. This output is also a potential contribution of this Action to strengthen the European research area. Two joint PhDs are currently running under co-supervision. One involving participating institutions from the Czech Republic and France and another involving Portugal and the United Kingdom. Such joint work based on joint supervision of PhD students is regarded as highly beneficial for all parties involved. A book on 3D video content processing and delivery is being written with contribution of a great majority of participants. ERASMUS+ agreement was signed between the University of Malta and Universita' di Roma 3, both participants in the Action. A significant number of collaborations on conference organisation – technical programme committee members, organising committee members. The organisation of several workshops, conferences and special sessions in scientific events, which contributed to raise the visibility and relevance of European research at international levels. The Action, through active collaboration among its members, was able to organise the following events: Workshop NEM Summit (Istanbul, 2012); IEEE ICC workshop on Immersive & Interactive Multimedia Comm. over the Future Internet (Budapest, 2013); 3DTV-Conference (Budapest, 2014); IEEE

ICIP Special Sessions (Paris, 2014); 3DTV-Conference 2015 (Lisbon, 2015), IEEE ICC workshop on QoE (Kuala Lumpur, 2016).

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Co-authored publications and FP7/ H2020 proposals

Co-authored publications

This table contains the (up to) ten most significant co-authored publications resulting from the Action. All publications are on the topic of the Action, co-authored by at least two Action participants from two different countries participating in the Action.

NO.	Bibliographic data (including: Title, Authors, Title of the periodical or the series, Issue number or volume, Publisher, Year of publication, Relevant pages)	Main author	Number of authors	Action participants listed among the authors (Name, country and role[1])	WGs involved in publication	Date of submission (must be after Action start date)	Expected date of publication (if not already published)	Persistent link to publicly available version of the paper (if available) or the abstract	Is/Will open access[2] provided to this publication?	Is/ will COST be cited/ acknowledged in the publication?	Are/ will COST funds (be) implicated in this publication	Relevance to H2020 Societal Challenges[3]?	Is it peer-reviewed?	Was the added value of the Action Networking necessary for the publication	Impact Factor (if applicable)
1	Erhan Ekmekcioglu, C. Goktug Gurler, Ahmet Kondoz, A. Murat Tekalp, Adaptive Multi-View Video Delivery using Hybrid Networking, IEEE Transactions on Circuits and Systems for Video Technology, 2016	Erhan Ekmekcioglu	4	Erhan Ekmekcioglu (WG member, UK), Ahmet Khondoz (MC member, UK), Murat Tekalp (MC member, Turkey)	*WG2, WG3*	*June, 2015*		*http://dx.doi.org/10.1109/TCSVT.2016.2527318*	*no*	*yes*	*no*	*no*	*Yes*	*Yes*	*2.615*
2	Antoine Dricot, Joel Junga, Marco Cagnazzo, Béatrice Pesquet, Frédéric Dufaux, Péter Tamás Kovács, Vamsi Kiran Adhikarl, Subjective evaluation of Super Multi-View compressed contents on high-end light-field 3D displays, Signal Processing: Image Communication, vol.39, pp. 369-385, Nov. 2015	*A. Dricot*	*7*	A. Dricot (STSM recipient, France), Marco Cagnazzo (WG member, France), Béatrice Pesquet (MC member, France), Frédéric Dufaux (MC substitute member, France), Péter Tamás Kovács (MC member, Hungary), Vamsi Kiran Adhikarl (WG member, Hungary)	*WG2, WG5, WG4*	*June, 2015*		*http://dx.doi.org/10.1016/j.image.2015.04.012*	*no*	*yes*	*no*	*no*	*yes*	*yes*	
3	S.M.M. Faria , J Debono , P. Nunes , Nuno M. M. Rodrigues, 3D Video Representation and Coding , Chapter in Novel 3D Media Technologies, Ahmet Kondoz and T. Dagiuklas , Springer , New York 2015	*S. Faria*	*4*	S. Faria (MC member, Portugal), C.J. Debono (MC member, Malta) P. Nunes (MC member, Portugal), Nuno M. M. Rodrigues (WG member, Portugal), Ahmet Kondoz (MC member, UK), T. Dagiuklas (MC member, Greece)	*WG2, WG3*	*November, 2014*		*www.springer.com/us/book/9781493920259*	*no*	*no*	*no*	*no*	*yes*	*yes*	
4	Dumić, Emil; Grgić, Sonja; Šakić, Krešimir; Rocha, Pedro Miguel Regalo; da Silva Cruz, Luis A., 3D video subjective quality: a new database and grade comparison study, Multimedia tools and applications, pp.1-23, 2016.	Dumić, Emil	*5*	Dumić, Emil (MC member, Croatia), Grgić Sonja (MC member, Croatia), da Silva Cruz, Luis A (WG member, Portugal)	*WG3, WG4*	*July, 2015.*		*http://dx.doi.org/10.1007/s11042-015-3172-6*	*no*	*no*	*no*	*no*	*yes*	yes	*1.35*
5	Luis F.R. Lucas, Krzysztof Wegner, Nuno M.M. Rodrigues, C.L.P. Pagliari, E. Silva, S.M.M. Faria, Intra Predictive Depth Map Coding using Flexible Block Partitioning, IEEE Transactions on Image Processing, Vol. 24, No. 11, November 2015, pp. 4055-4068.	*Luis F.R. Lucas*	*6*	Luis F.R. Lucas (STSM recipient, Portugal), Krzysztof Wegner (STSM recipient, Poland), S.M.M. Faria (MC Member, Portugal)	*WG2*	*January, 2015*		*http://dx.doi.org/10.1109/TIP.2015.2456509*	*no*	*no*	*no*	*no*	*yes*	*yes*	*3.625*
6	F. Battisti, E. Bosc, M. Carli, P. Le Callet, S. Perugia, "Objective image quality assessment of 3D synthesized views", Signal Processing: Image Communication, Signal Processing: Image Communication, vol. 30, pp. 78-88, Jan 2015	*F. Battisti*	*5*	*F. Battisti (WG member, Italy) E. Bosc (STSM recipient) M. Carli (MC substitute member, Italy) P. LeCallet (MC substitute member, France)*	*WG4*	*May, 2013*		*http://dx.doi.org/10.1016/j.image.2014.10.005*	*no*	*no*	*no*	*no*	*yes*	*yes*	*1.554*
7	D. Sandić-Stanković, D. Kukolj, P. Le Callet, Multi-scale synthesized view assessment based on morphological	Dragana Sandić-Stanković	3	Dragana Stankovic (WG member, Serbia), Dragan Kukolj (MC member,	WG4	*Sept. 2015*		*http://iris.elf.stuba.sk/JEEEC/data/pdf/1_116-01.pdf*	*Yes*	*Yes*	*no*	*no*	*Yes*	*Yes*	

[1] MC Member/ MC Substitute/ MC Observer/ WG Member/ Training School Trainee/ STSM Recipient/ Other Action Participant

[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

[3] H2020 Societal Challenges are “Health, demographic change and wellbeing”; “Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy”; “Secure, clean and efficient energy”; “Smart, green and integrated transport”; “Climate action, environment, resource efficiency and raw materials”; “Europe in a changing world - inclusive, innovative and reflective societies”; “Secure societies - protecting freedom and security of Europe and its citizens”

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	pyramid", IEE Journal of Electrical Engineering, Slovak University of Technology, 67 (1), 2016			Serbia), Patrick Le Callet (MC substitute member, France)											
8	Navarro, H. , Saavedra, G. , Martinez-Corral, M. , Sjöström, M. & Olsson, R. (2014). Depth-of-field enhancement in integral imaging by selective depth-deconvolution. IEEE/OSA Journal of Display Technology, vol. 10: 3, pp. 182-188.	*Navarro, H.*	*5*	Martinez-Corral, M. (Spain, WG1), Sjöström, M. (Sweden, WG6, MC) Olsson, R. (Sweden, WG1, MC)	*WG1, WG6*	*2013*		*http://dx.doi.org/10.1109/JDT.2013.2291110*	*no*	*no*	*no*	*no*	*yes*	*no*	*2.241*
9	*C.J. Debono, P. Assuncao, 3D video coding and transmission, Xjenza online – Journal of the Malta Chamber of Scientists, 3:183-188, 2015*	*C.J. Debono*	*2*	*C.J. Debono (MC member, Malta, P. Assuncao (MC Chair, Portugal)*	*WG2, WG3*	*September 2014*		*https://issuu.com/maltachamberofscientists/docs/xjenza_online__new_series__-_vol._3/1*	*yes*	*yes*	*no*	*no*	*yes*	*yes*	
10	*Bregović, R., Kovács, P. T., Gotchev, A., Optimization of light field display-camera configuration based on display properties in spectral domain, Optics Express, Vol. 24, No 3, Feb 2016.*	*R. Bregovic*	*3*	*R. Bregovic (MC substitute member, Finland), P. Kovacs (MC member, Hungary), A. Gotchev (MC Vice-Chair, Finland),*	*WG1, WG5*	*Feb, 2016*		*http://dx.doi.org/10.1364/OE.24.003067*	*yes*	*no*	*no*	*no*	*yes*	*yes*	*3.148*

FP7/ H2020 Proposals and projects

This table contains FP7/ H2020 proposals/ projects spinning off from Action activities and including in the proposing consortium at least three Action participants from at least three different countries participating in the Action.

NO.	Title	Name and country of main proposer	Number of proposers	Action participants listed among the proposers (Name, country, role[3] in the Action)	Funding agency submitted to	Date submitted	Date results expected	Result	Call identifier	Relevance to H2020 Societal Challenges[4]?	Was the added value of the Action Networking necessary for the proposal / project?
Projects											
1	EU Marie-Sklodowska-Curie European Training Network on Full Parallax Imaging	A. Gotchev, Fin	8	A. Gotchev, Fin (Vice chair) M. Sjöström, Swe (MC, WG6) M. Martinez-Corral, Es (WG1) F. Zilly, Ge (WG1) P. Kovac, Hu (WG5) Ch. Perwass, Ge (WG1)	EU Horizon 2020 Marie-Sklodowska-Curie	2015		Accepted	H2020-MSCA-ITN-2015	no	yes
2	Immersive 3D Video Communications with Application to 3D Telehealth	University of Southern Queensland, Australia (International Partner Country)	3	University of Southern Queensland, Australia, Chief Investigator The University of New South Wales, United Kingdom, Chief Investigator Holografika Kft, Hungary, Partner Investigator	Australian Research Council	4/03/2015		accepted	ARC Discovery	yes	yes
3	QoE-Net	University of Cagliari, Italy	8	University of Cagliari, Italy, Italy, coordinator Kingston University, United Kingdom, partner Norwegian University of Science and Technology, Norway, partner Holografika, Hungary, partner	European Commission	19/04/2014		accepted	H2020-MSCA-ITN-2014	no	yes
4	EICIS - Enhanced Inter-Connected Immersive Spaces	The Oulu Region Joint Authority for Education/ Oulu University of Applied Sciences, Finland	12	*Iris Galloso, Spain, MC Substitute* *Francisco P. Luque, Spain, researcher* *Peter Kovacs,, Hungary, MC Member*	European Commission	15/01/2013		Not funded	FP7-ICT-2013-10	yes	yes
5	Study on Virtual-view 3D Video Processing	Poznań University of Technology, Poland	4	Poznań University of Technology, Poland, coordinator	International Visegrad Fund	1/22/2013		not funded	International Visegrad Fund—National Science Council, Taiwan Joint	no	yes

				Czech Technical University in Prague, Czech Republic, partner Holografika Kft, Hungary, partner					Research Projects Program		
6	3D Telemedicine: A Novel Light Field Based Remote Healthcare Solution	University of Southern Queensland, Australia	4	University of Southern Queensland, Australia, Chief Investigator The University of New South Wales, United Kingdom, Chief Investigator Holografika Kft, Hungary, Partner Investigator	Australian Research Council	11/11/2015			ARC Linkage	yes	yes
7	3D Holoscopic content CREATIVITY for enhanced immersive experiences	ATOS Spain SA, Spain	11	Centre for Research and Technology Hellas, Greece, Partner Holografika, Hungary, Partner Instituto de Telecomunicações, Portugal, partner	European Commission	01/11/2013		not funded		no	yes
8	Multi-Modal, Multi-Image Interpolation, Compression and Aggregation from Directional Observations	Université Libre de Bruxelles, Belgium	8	Fraunhofer Institute for Integrated Circuits IIS, Germany, partner Poznan University of Technology, Poland, partner Holografika, Hungary, partner	European Commission	04/14/2015		not funded	H2020-ICT-2015	no	yes
9	Light Field Medical Imaging Systems with embedded Quality-Utility Perceptual Evaluations (LIFE-MEDIQUE)	Instituto de Telecomunicaçoes, Portugal	15	Pedro Assuncao (MC chair), Margrit Gelautz (MC member, Austria), Ladislav Polak (MC member Czech Rep.), Frederik Zilly (WG member, Germany), Filiberto Pla (WG member, Spain), (Chaminda Hewage, WG member, UK), Tibor Balogh, MC member, Hungary), Emil Dumic (MC member, croatia), Cristain Perra (MC substitute, Italy), Carl Debono (MC member, Malta), Antonio Liotta (MC member, Netherlands), Sergio Faria (MC member, Portugal), Marek Domanski (MC member Poland), Marten Sjostrom (MC member Sweden), Vladimir Zlokolica (MC member, Serbia)	EU Horizon 2020 - COST Association	25/04/2015		Under evaluation	Open call OC2016-1	yes	yes

I.C. Networking

Added value of the Networking

Please describe here the added value of the networking, highlighting in particular anything that would not have happened without the Action networking.

The Networking provided by the Action enabled different types of activities and results across participants of different countries. While some of them are regarded as a direct consequence of the implementation and use of COST instruments (e.g., joint papers produced as a result of STSMs), others are not so tangible neither visible in the short-term.

Joint publications would not have been possible to achieve with this COST Action and the collaborative work that originated this type of result is already added value for the researchers themselves, for their institutions and also a contribution for the European Research Area. The research network and personal contacts created by the Action also promoted cross-invitations for technical/scientific papers and book chapters (e.g., E-Letters: IEEE MMTC Communications - Frontiers, several chapters in the books “Novel 3D Media Technologies” and “Connected 3D Media in the Internet Era” by editors A. Kondoz and T. Dagiuklas, *Xjenza Online* - Journal of The Malta Chamber of Scientists). For some researchers and PhD students, the Action created the appropriate research environment that allowed them to publish joint papers for the first time with co-authors from other countries, which certainly contributed to improve their research capacity to develop collaborative work beyond the frontiers of their own countries.

Also as a result of Networking several project European projects proposals were submitted, having several Action participants from different countries in the consortium. This is also evidence about the added value of the Action because most of these proposals would not have been submitted without the Networking enabled by the Action. Without participation in the Action meetings to discuss synergies and complementary fields of research such proposals would not have been submitted. Even those that were not funded contributed to strengthen the links between different researchers and institutions, creating added value with potential impact in the future.

Another type of added value obtained from Networking is long-term links established between participants from different countries, which create a great potential for joint research activities, even beyond the Action lifetime. Different types of collaborations already happened and more are expected in the future. For instance, organisation of scientific events such as conferences, workshops and Training Schools would not have happened without the Networking provided by the Action. This also contributed to build the capacity for organising international scientific events in the future with increased visibility of European researchers.

The participation of a research-oriented SME (Holografika) as a partner in the Action, also resulted in added value for many participants and also for the company itself. The light field displays produced by Holografika are quite innovative technology, not affordable for many research labs funded by national projects. In this case, significant added value was created by the Action, by enabling many participants to use the light field displays in their research work, otherwise very unlikely accessible. On the other hand, the company also benefited from the Action, not only from some research results but also from being part of an enlarged network, which created additional research funding opportunities through European projects, jointly submitted with other participants.

Close cooperation between research groups from Univ. of Nantes (France) and Univ. of Novi Sad (Serbia) is established. All activities were focused on development new perceptual metrics for assessment of 3D video content. More precisely, a new quality measure was developed, which is applicable on 3D multi-view video quality evaluation based on quality assessment of images synthesized by depth image based rendering techniques. Also, modelling of perceived 3D video content by physiological and emotional states of human observers is initiated and still is in early stage. These were scientific results, which would not have been achieved without the networking support of the Action.

Collaboration between University of Novi Sad (Serbia), Czech Technical University Prague (Czech Republic), Vienna University of Technology (Austria) and University of Nantes (France) was established related to formation of 3D-ConTourNet datasets for research purposes and benchmarking. Within the 3D-ConTourNet datasets group activity, more advanced 3D data set description has been developed which has provided data set with higher potential for actually being used in processing and visual quality assessment.

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University of Novi Sad has provided significant 3D data set contribution in collaboration with local industrial partner 3Lateral (http://3lateral.com/), which provided their equipment for recording 3D data sets. The Action allowed sharing such data sets and equipment to develop joint and comparable research, benefiting from networking activities with special emphasis for STSMs and meetings. Additionally, during the COST Action a consortium has been made for another EU project application - CEEPUS, with “Emerging multimedia systems - content creation, representation and perception”, which included 5 partners from this project and other related partners. This is also an example of collaboration where the Action was necessary to make it happen.

The network of researchers created by the Action also promoted several joint PhD evaluation committees with members from different countries, which contributes to harmonization and recognition of the academic research work carried out across Europe.

The table below shows the extent to which it would have been possible to achieve each of the Action’s objectives without the Action networking.

MoU objective	Possibility of achievement without Action networking		
Define guidelines and expand current end-user based content production model, existing within game and virtual world communities, into the design for the near future interactive and collaborative services. Previous research on QoS and QoE issues has been mainly focusing on cases where streamed media is the key. This approach has not been able to solve the issues with interactive media consisting of soft real-time elements. The basic understanding and solid background about end user behaviour will be pursued with the aid of rich interaction models. This knowledge will be applied to service design and development in order to make sure the quality of end user experience is as high as possible. The concept of rich interaction relates to the possibilities of the multi-user game and virtual environment users to act and express themselves in flexible and non-predefined ways. The future application of this concept will consist of (i) multi-modality in terms of forms and media for effective utilisation of various senses; (ii) high level of interactivity in terms of range, frequency and impact of individual interaction forms; (iii) flexibility to select corresponding actions and reactions through simulations and interaction models (e.g., physics model)with limited number of pre-programmed solutions; (iv) automation to allow reduction of mundane tasks and to support simulation of sub-conscious actions; (v) abstraction to enable various levels of control in interaction processes.			Impossible
Develop harmonization mechanisms, providing an evolution and roadmap for 3D coding architectures and algorithms. The current 3D research results reveals a spread of technologies and diversity, such as MVC, Multiview Coding + Depth (MVD), Free Viewpoint Video(FVV), Video + Depth (V+D), Video + DELTA, Side-by-Side (SbS), Multiview Scalable Wavelets, and others, incompatible each other, and trammelling a quick deployment of 3Dtechnology on the marketplace. The Action has the objective of defining a new framework to facilitate a 3D video coding interoperability ecosystem. Within such framework, the objective of the Action is also to extend the current concept of 3D media compression-efficiency into amore sustainable concept of energy-efficiency coding, by developing and integrating concepts of green computing into novel 3D video coding architectures.			Impossible
Develop QoE-aware networking framework where novel adaptation and congestion control mechanisms are devised to optimise 3D multimedia delivery over future media networks in heterogeneous technological environments. Since QoE is not only influenced by dynamic networking conditions, but also by the quality and perceptual relevance of each			Impossible

element of the coded source stream (e.g., stereoscopic view, audio channel), cross-layer methods shall be used in order to make QoE metrics available to network control and adaptation mechanisms. This Action will provide an ecosystem in terms of transport protocols, seamless mobility and continuity in wireless systems, rate control and transcoding and end-to-end QoE-aware mechanisms. The Action also targets to organise quality assessment sessions in several centres across Europe along with the necessary service emulators or prototypes that will encompass multiple use contexts and ambiances for users. The joint analyses of the acquired subjective assessments will be reflected back to the researchers and standardization bodies in the field to consider them as reliable references			
Develop methodologies and procedures for subjective assessment of QoE using 3D multi- modal content, extending existing standards and knowledge for evaluation of the quality and comfort. To achieve this objective, the Action will seek for interdisciplinary expertise and methodologies by exploring measures of quality and comfort derived from psychophysical, psychophysiological and behavioural methods. Such exploratory research will include subjective evaluation of 3D audio because, despite the existence of standards for the subjective evaluation of audio tracks, the introduction of fully spatialised sound introduces some assessments factors of its own, as happened with the transition from 2D to 3D visual displays. The goal is to find out the best suited methodology to evaluate perceived quality and comfort of 3D audio and conjoined presentations of 3D video and audio, by taking into consideration the specific issues of 3D audio.			Impossible

Extent of the networking

Describe the extent of the networking among the participants in the Action. Were all participants integrated into the networking equally? Were those targeted by COST policies on Inclusiveness Target Countries (ITCs), Early Career Investigators (ECIs)/ Young Researchers, and gender balance fully integrated into the Action networking?

All participants were always given the opportunity to participate in the Action and its activities. Regular calls for participation were sent to the general mailing list, where more than one hundred participants were registered. Participation in WG meetings and STSMs were actively promoted in the Action meetings and also through the mailing lists. Fortunately, no restrictions were ever applied to any eligible participant as they were not necessary because it was possible to manage the budget in order to not deny participation to anyone. All participants willing to participate in the Action were always welcome and fully integrated in the network according to their scientific interests and common benefits identified in the scope of the WG and Task Forces.

The Action was successful in promoting STSMs among ECIs and ITCs. The STSMs were granted to either young researchers or PhD students and at least one ITC country was involved in 18 out of 35 STSMs (51%), either as a host or home institution. The great majority of participants were male, but the MC took active measures to promote women in its activities. For instance, 3 out of 7 Task Force Leaders were women.

I.D. Impacts

The impacts that have resulted, or might result from the Action are described in the following table.

Description of the impact	Type of impact[4]	Timing of impact[5]
Enter one impact per line, and specify the type and timing of the impact.		

[4] Scientific/ technological, Economic, Societal
[5] Achieved/ Foreseen within 2 years/ Foreseen 2-5 years/ Foreseen 5-10 years/ Foreseen 10+ years

Work and finalization of PhD thesis of three female and one male researchers: two at Univ. of Novi Sad (Dragana Sandic-Stankovic and Dragana Djordjevic) and one at ISCTE-IUL, Lisbon (Caroline Conti), Telecom Paris Tech (Antoine Dricot)	Scientific	Foreseen within 2-5 years
Joint PhD supervision involving researchers from Instituto de Telecomuncações (Portugal) and University of Loughborough (UK)	Scientific	Foreseen within 2-5 years
Organisation of the international conference 3DTV-CON 2014 and 2015	Scientific, Economic	Achieved
Journal and conference publications with results directly or indirectly impacted by participation in the Action, available in international databases, such as IEEExplore.	Scientific	Achieved
Participation in the Action had impact on the research work of several PhDs awarded during the Action lifetime: Iris Galloso (UPM, Spain, 2015), Sebastian Schwarz (MiUN, Sweden, 2013), Sylvain Marcelino (UTAD, Portugal, 2016), Luís Lucas (UFRJ, Brasil, 2016)	Scientific	Achieved
Each Training School attracted about 40 participants from more than 15 European countries. This quantity and diversity of participants and the networking opportunity provided by these Schools, will have impact some impact in increasing potential scientific collaborations across Europe.	Societal	Foreseen 5-10 years
Contribution in the creation of a qualified consortium capable of submitting high quality proposals to be funded by the EC (Optintegral, 3FLEX, Autopost: H2020)	Scientific/ Technological, Economic,	5 years
Three participants are active contributors to standardization bodies MPEG and VQEG. Some of their contributions have been partially influenced by the Action, which can have technological impact in the future.	Technological	Foreseen within 2-5 years

I.E Dissemination and exploitation of Action results

Describe the Action's dissemination and exploitation approach as well as all activities undertaken to ensure dissemination and exploitation of Action results and the effectiveness of these activities.

Add description here

Item/ activity	Target audience	Result	Hyperlink
Nem Summit 2012, Workshop on 3D Immersive and Interactive Content Creation, Coding and Transmission	European researchers and engineers from academia and industry	Presentation of the COST framework and its instruments. Dissemination of the Action, its objectives, WG structure and scientific scope.	http://nem-initiative.org/nem-summit-2012-istanbul/
ICC Workshop on IIMC-FI	International audience, including academic researchers and industry experts	Presentation and discussion of scientific results in the conference and dissemination of the Action	http://multicomm.diee.unica.it/
3DTV-CON 2104	International audience, academic researchers and from R&D Labs	Presentation and discussion of scientific results in the conference and dissemination of the Action	http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6869197

ICC Workshop QoE-FI	International audience, including academic researchers and industry experts	Presentation and discussion of scientific results in the conference and dissemination of the Action	http://qoe-fi.diee.unica.it/2016/
Plenoptics training school	Young researchers, PhD students	The Training School programme included a poster session, where most participants presented and discussed their work	http://www.3d-contournet.eu/plenoptics-2013/
Demonstration of HoloVizio 80WLT wide-angle light-field display	Poznan WG meeting participants	All participants gained hands-on experience with light-field displays	2013
ICIP 2014: conference and exhibition booth	International Conference participants	Presentation and discussion of scientific results in the conference and dissemination of the Action activities in exhibition booth	https://icip2014.wp.mines-telecom.fr/
3DMUX 2012	Young researchers, PhD students	The Training School programme included a poster session, where most participants presented and discussed their work	http://sp.cs.tut.fi/3dmux2012/
Interaction 2014	Young researchers, PhD students	The Training School programme included a poster session, where most participants presented and discussed their work	http://3d-contournet.eu/interaction2014/
3D-AVCom2015	Young researchers, PhD students	The Training School programme included a poster session, where most participants presented and discussed their work	http://www.3d-contournet.eu/cost-training-school-3d-avcom-2015/
3DTV-CON 2105	International audience, academic researchers and from R&D Labs	Presentation and discussion of scientific results in the conference and dissemination of the Action	http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=7166143
MELECOM 2016	International audience, researchers	Presentation of the Action	http://www.melecon2016.org/

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I.F Action success(es)

COST regularly communicates the successes of Actions. What aspect(s) (outcomes and/ or impacts, rather than activities) of this Action is/ are the most suitable for communication?

Among its participant institutions the Action had Holografika, a research-oriented SME from Hungary, with its core business focused on different types of light field displays. The participation of this SME in the Action is considered a success case for several different reasons. The light field displays produced by this SME are innovative technology, not available in the consumer market, which raises the relevance of having such company on board because other Action participants could have access to a very expensive technology without buying it. The 3D display technology is one of the most limiting factors in 3D visualization, naturally giving rise to a lot of different studies and investigations to deal with light field content, optimise the display performance and improve perceived quality. The potential for obtaining relevant research results is higher if innovative and emerging technology is used, so the company attracted and hosted several STSMs. The company was a partner in various EU-project proposals with other participants during the Action lifetime, because it was considered as an added value in different types of consortia. In summary, the inclusion of Holografika in this Action was definitely of great interest to many participants and opened new research lines in the emerging field of Light Field displays. The company itself also benefited from some research results and from the networking opportunities created by the Action to integrate other EU-project consortia/proposals.	Policy implementation (Industry involvement)
Joint PhDs are currently running between UK-Portugal and Czech Republic-France.	

II. Management Report

II.A. Overview of expenditure

The table below summarises the Action's expenditure throughout its four year life.

	Grant Period 1	Grant Period 2	Grant Period 3	Grant Period 4	TOTAL
GP start and end dates	(01/08/2012-31/07/2013)	01/08/2013-31/07/2014	(01/08/2014-31/07/2015)	(01/08/2015-30/04/2016)	
Grant Holder institution	Instituto de Telecomunicações	Instituto de Telecomunicações	Instituto de Telecomunicações	Instituto de Telecomunicações	
Meetings	75.275,92	69.784,14	70.926,12	79.925,61	295.911,79
Training Schools	58.284,73	37.450,28	51.836,38	0,00	147.571,39
STSMs	12.250,00	20.700,00	19.840,00	20.900,00	73.690,00
Dissemination	2.500,00	0,00	1.490,00	0,00	3.990,00
OERSA[1]	0,00	1.800,00	0,00	0,00	1.800,00
Total Scientific Expenditure	148.310,65	129.734,42	144.092,50	100.825,61	522.963,18
FSAC[2]	20.748,87	19.214,62	20.726,34	15.123,84	75.813,67
TOTAL	EUR 169.059,52	EUR 148.949,04	EUR 164.818,84	EUR 115.949,45	EUR 598.776,85

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[1] OERSA = Other Expenses Related to Scientific Expenditure (e.g. bank charges)
[2] FSAC = Amount received by Grant Holder for Financial Scientific and Administrative Coordination

II.B. Budget and Participation management

II.B.1 Budget spent in relation to individuals/ institutions outside participating COST countries

STSMs from or to institutions from countries other than Participating COST countries

The table below describes the added value STSMs to approved institutions in IPC or NNC or Specific Organisations and any STSMs from an approved institution in an NNC to a participating COST country.

Grantee		Host		Date	Topic and value added to the Action
Institution	Country	Institution	Country		
Instituto de Telecomunicacoes, Portugal		Federal University of Rio de Janeiro, Brazil		July 2013	The STSM addressed multiple description coding (MDC) methods for resilient 3D video transmission over multipath media networks. There was on-going work on MDC schemes for 2D video at the home institution, while the host institution had been involved in several coding schemes for 3D multiview video beyond the current standards. The STSM allowed to rapidly understand the research issues of common interest and how MDC (a non-standard method) could be applied to 3D multiview video. As a result, the following conference paper was jointly co-authored and published at 3DTV-CON 2014: P. Correia; S. Marcelino; P. Assuncao; S. Faria; S. Soares; C. Pagliari; E. da Silva, "*Enhancement method for multiple description decoding of depth maps subject to random loss*", which is one of the Action scientific outcomes. http://dx.doi.org/10.1109/3DTV.2014.6874725

Invited Speakers

The table below highlights the added value of Invited Speakers from COST countries that have not accepted the MoU and/ or non-participating NNC, IPC or Specific Organisations whose participation at a meeting or Training School was reimbursed by the Action.

Participant name	Institution	Country	Event date	Topic and added value to the Action
James Tam	Communications Research Center	Canada	12-16 Aug. 2012	The speaker was invited to participate in the first Training School organized by the Action. He is an expert on the theme of "*applying our knowledge of the human visual system in the design and development of advanced video systems*". The topic of his talk was about "Human perception and 3D video applicaions", which was particularly relevant for those participants involved

				in research based on user-driven factors
Aljosch Smolic	Disney Research Zurich	Switzerland	12-16 Aug. 2012	The speaker was invited to participate in the first Training School organized by the Action. He addressed the topic of "Content Creation for stereoscopic 3D and Beyond", which is perfectly aligned with the Action topics and thus of general interest for all participants.
Kenji Yamamoto	NIICT	Japan	12-16 Aug. 2012	The speaker was invited to participate in the first Training School organized by the Action. The topic of his talk was "3D holographic technologies", which was a relatively new topic for most participants and as such this talk introduced a related field with potential interest for participants.
Kari Pulli	nVidia	USA	Aug. 2012	The speaker was invited to participate in the first Training School organized by the Action. The topic of his talk was "*Computational platforms*". This was a specific topic of great interest to the Action due to the fact that the speaker came from a renowed company in the fast evolving field for 3D graphics cards.
Andrew Lumsdaine	Indiana University	USA	June 2013	The speaker was invited to participate in the 2nd Training School organized by the Action. The topic of his lecture was: "Plenoptic capture and GPU computing". The lecture focused the foundations of plenoptic capture, the technology used in the Lytro camera and also multimode capture capabilities of plenoptic cameras.
Marty Banks	University of California	USA	July 2014	The topic of his lecture was "*Human stereopsis and 3D visual perception*" He addressed the essentials of perception of 3D visual scenes in the context of current 3D displays.
Ivana Tošić,	Ricoh Innovations Corp.	USA	July 2014	The topic of her lecture was "Scene recovery from plenoptic data" The tutorial addressed recent advances in image formation models (based on geometric and wave optics) and advanced signal processing algorithms.
Gene Cheung	National Institute of Informatics	Japan	July 2015	The topic of his lecture was "*Depth image coding & processing*". This lecture addressed the most recent advances in depth processing and coding, which is a field of interest for the Action.
Sanghoon Lee	Yonsei University	South Korea	July 2015	The topic of his lecture was "*Quality of experience and visual communication with 3D content*". This is a topic of broad interest to the Action.

Dissemination meetings					
The table below highlights the added value of Dissemination Meetings financed from Action funds.					
Participant name	Role	Country	Date	Location	Topic and added value to the Action
Pedro Assuncao	MC Chair	Portugal	March 2015	Lisbon	Topic: My COST experience This event was mostly to present the Action activities and discuss the benefits for researchers.
Pedro Assuncao and other participants	MC Chair	Portugal	Oct. 2014	Paris	This was not a meeting but an exhibition booth at the IEEE International Conference on Image processing (ICIP'2014). Several contacts were made and many people visited the booth, which has posters with scientific results, a demo of a holoscopic display and also a stereo SVC encoder, leaflets and booklets about about the Action. Some contacts with researchers from Asian countries enabled further collaborations afterwards (e.g. invited speakers for the Training School in 2015).
Pedro Assuncao and other participants	MC Chair	Portugla	Oct. 2012	Istanbul	Topic: 3D-ConTourNet – 3D content creation, coding and transmission over future networks. This was a workshop organised by the Action in the NEM Summit 2012, which was partially used for dissemination of the Action to researchers from European countries.

II.C. Participants

Management Committee			
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Annex 1

Definitions:

COST Action Challenge (main aim)	"The research question addressed by the COST Action targeting scientific, technological, and / or socioeconomic problems"
COST Action Innovation	"The creation and / or development of new or improved concepts, products, processes, services, and / or technologies that are made available to markets, governments and society"
COST Action objectives	"COST Action objectives are the results that an Action needs to achieve in order to respond to meet its challenge. These are SMART (Specific, Measurable, Achievable, Relevant, Timely) and twofold: research coordination objectives and capacity building objectives."
COST Action research coordination objectives	"Achieving these objectives turns COST Actions from initially scattered teams into one transnational team and leverages the existing funded research. These objectives entail the distribution of tasks, sharing of knowledge and know-how, and the creation of synergies among Action participants to achieve specific outputs."
COST Action capacity building objectives	"Achieving these objectives entail building critical mass to drive scientific progress, thereby strengthening the European Research Area. They can be achieved by the delivery of specific outputs and / or through network features or types and levels of participation."
COST Action networking activities	"any activities organised by the COST Action (whether or not directly funded by COST) in order to achieve research coordination and capacity building objectives."
COST Action networking tools	"instruments through which eligible activities can be funded"
COST Action outputs	"direct results from the COST Action activities. These can be codified knowledge, tacit knowledge, technology, and societal applications."
COST Action impact	"the short- to long-term scientific, technological, and / or socioeconomic changes produced by a COST Action, directly or indirectly, intended or unintended."
COST Action deliverable	"a distinct, expected and tangible output of the Action, meaningful in terms of the Action's overall objectives such as a report, a document, a technical diagram, a software etc. Action deliverables are used to measure its progress and success."
COST Action milestones	"Control points in the Action that help to chart progress. They are also needed at intermediary points so that, if problems have arisen, corrective measures can be taken. A milestone may be a critical decision point in the Action where, for example, the MC must decide which of several technologies to adopt for further development (e.g. core group and MC meetings, mid-term reviews)"
Inclusiveness Target Country (ITC):	Current COST Member Countries targeted by the COST inclusiveness Policy ("Inclusiveness Target Countries" (ITC)): EU 13 (Bulgaria, Cyprus, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovenia, Slovakia), EU candidate countries (the former Yugoslav Republic of Macedonia, Montenegro, Republic of Serbia, Turkey) and potential EU candidate countries (Bosnia and Herzegovina). In addition, to comply with the EC criteria for 'Spreading Excellence and Widening Participation', Portugal and Luxemburg are included.

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