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1 Introduction

This document aims to clarify all MPEG-I-Visual latest activities as briefly as possible (from outputs of previous meeting and inputs of the previous and the current meetings), such that future missing activities of MPEG-I-Visual can be identified. Updates of this document may be provided per meeting so that in one brief document all activities and future steps can be read.

2 Rationale and Current Activities

Following the informal descriptions of Table 1, MPEG-I Visual is an activity that addresses the specific requirements of Immersive Visual Media for six Degrees of Freedom virtual walkthroughs within a bounded volume, from 3DoF+ with slight body and head movements in a sitting position to 6DoF allowing some walking steps from a central position [N18344]. This includes the capture and rendering with dedicated cameras and displays, typically referred to as Light Field devices, targeting dense Light Field representations and their dedicated codecs [N18792].

As given in Table 1, a Light Field is a conceptual representation of light – i.e. the field of light that surrounds us – and many different devices may be used to capture and render a discretely sampled version of this Light Field. The goal of the MPEG-I Visual activities is to develop coding standards for such Light Field representations used in 6DoF Immersive applications.

The following sections give an overview of important documents over the past meetings, providing requirements, use cases, software tools, test material, exploration experiments, core experiments, subjective viewing results, demonstrations, recommendations and future activities related to Light Field representations used in Immersive Visual Media. The terminology used in this context is summarized in Table 1.

Exploration Experiments and Core Experiments use software tools and test material that are described further in this document.

A Call for Proposals on 3DoF+ Visual [N18145] has been issued in the 125th meeting in Marrakech January 2019, calling for simulcast HEVC based coding technology that conveys the camera views and their metadata (depth maps) in order to be able to synthesize virtual views at the receiver end, using RVS v3.1 reference software [N18068, N18145].

The responses to this call were reviewed in the 126th MPEG meeting in Geneva [N18353]. They all followed the same core idea: take several reference/base views (possible none) that gather most of the information of the scene from specific points of view, while supplementary information (e.g. disocclusions from other viewpoints) is collected into a mosaic of possibly non-rectangular patches, called an atlas. All methods use view synthesis to construct the base views and/or patches, in perspective, equirectangular or orthographic projection.

As a result, a Test Model called TMIV – Test Model for Immersive Video – has been defined in [N18470] using RVS 4.0 (extensions of RVS 3.1), view selection and the construction of atlases as core ingredients. These parts of the Test Model are further studied in the Immersive Video Core Experiments and were evaluated during the 127th MPEG meeting in Gothenburg [N18465-N18469], the 128th MPEG meeting in Geneva [N18705-N18707], the 129th meeting in Brussels [N18933-N18935], and the 130th meeting held as fully online meeting [N19215-N19217]. The current Core Experiments [N19485-N19487] study the sixth version of the Test Model [N19483]. Reference Software can be found on http://mpegx.int-evry.fr/software/MPEG/MIV/RS/TM1 and is available also publicly on https://gitlab.com/mpeg-i-visual/tmiv, while Core Experiments can be found on http://mpegx.int-evry.fr/software/MPEG/MIV/CE/. The Working Draft [N18464] has also been initiated in the 126th MPEG meeting in Geneva and after further development up to the fifth version [N19212], the first Committee Draft [N19482] was issued after the 131st meeting.

Due to considerable similarities, during the 128th MPEG meeting, the MPEG-I-Visual group decided to align the high-level syntax of the Working Draft with the Draft of International Standard of the Video-based Point Cloud Coding. This change is currently in the final stage, due to many valuable contributions on this topic presented in 129th and 130th MPEG meetings.

At the 130th MPEG meeting this alignment has been completed by restructuring Part 5 in a common specification *Visual Volumetric Video-based Coding* (V3C) and annex H *Video-based Point Cloud Compression* (V-PCC). V3C provides extension mechanisms for V-PCC and MIV.

Abbreviation	Informal Description
MPEG-I Visual	Covers the Visual technologies of Immersive media in MPEG-I
MIV	Metadata for Immersive Video
TMIV	Test Model for Immersive Video
360 video	Panoramic video texture projected onto a virtual shape (often a sphere) surrounding the user’s head, out of which he/she visualizes a portion for an immersive video experience.
ERP	An Equi-Rectangular Projection maps the texture of a sphere to a rectangle, similar to mapping the earth surface to a planar world map.
DoF	Degrees of Freedom
3DoF	3 Degrees of Freedom, i.e. allow movements along head rotation axes
3DoF+	3DoF with also small translational movements of the head within a restricted volume, typically a person sitting in a couch
6DoF	6 Degrees of Freedom, i.e. allow movements along 3 rotation axes and 3 translations. Without further specifications, 6DoF presumes that full freedom of movement through the scene is possible.
Omnidirectional 6DoF	A restricted form of 6DoF, or an extended form of 3DoF allowing – besides of unrestricted rotations – small translational movements of the body within a restricted volume, typically a person taking a few steps from a central position, with the ability to look all around (cf. omnidirectional).

Windowed 6DoF	A restricted form of 6DoF where the user virtually views the scene from behind a (virtual) window, with any position allowing to still see at least part of the scene.
FTV	Free viewpoint TeleVision
FN	Free Navigation, i.e. the capability to create all views required (cf. view synthesis) to create a smooth, virtual walkthrough between successive viewing positions
Epipolar Line	The line on which a feature point in a first camera view will necessarily lie in another camera view, as a consequence of a physical/optical relationship between cameras. Only parallel cameras have horizontal Epipolar Lines
EPI	Epipolar Plane Image, i.e. an image composed of corresponding Epipolar Line sections over all input camera views
EE	Exploration Experiment
Disparity	The displacement of a feature (typically all pixels) in the scene when viewed from one to another camera view. Disparity and Depth are inverse proportional to each other. Disparity is often used in the reference software, but a language abuse often wrongly refers to Depth instead of Disparity.
Depth Estimation	Estimation of depth for each visible point in the scene, by evaluating the Disparity between at least two adjacent camera views
View Synthesis	The process of synthesizing a virtual view from existing input camera views, typically by a disparity/depth-dependent interpolation process
DIBR	Depth Image-Based Rendering, where images are rendered based on depth information. It is the typical process used in image-based View Synthesis.
DERS	Depth Estimation Reference Software, estimating depth from camera views by methods similar to stereo matching
IVDE	Immersive Video Depth Estimation, software for inter-view consistent depth estimation using multiple perspective or/and omnidirectional views
PCR	Poznań Color Refinement, allows to enhance the inter-view and the temporal consistency of the multi-view input views
PDR	Poznań Depth Refinement, allows to enhance the inter-view consistency of the depth maps
VSRS	View Synthesis Reference Software, synthesizing a virtual view from two existing input camera views
RVS	The Reference View Synthesizer used in 3DoF+ with an unlimited number of input reference views in ERP and/or perspective camera format.
VVS	Versatile View Synthesizer used in Windowed-6DoF with a large number of input reference views in ERP and/or perspective camera format.
RLC	The Reference Lenslet Content Converter used to convert the lenslet data format into its corresponding Multiview format (also called subapertures).
HEVC	High Efficiency Video Coding
MV-HEVC	Multiview extension of HEVC, allowing the exploitation of redundancies over multiple views
3D-HEVC	3D extension of HEVC, i.e. Multiview + Depth, where depth information is compressed, and improves the texture compression as well.
HTM	3D-HEVC Test Model software.
HM	HEVC test Model software
MV	MultiView, i.e. multiple views of the scene, typically in the order of a dozen of views

MVD	MultiView+Depth, adding depth to MultiView content
Autostereoscopic Display	MultiView display, typically with a dozen of directional output views, providing a stereoscopic viewing experience without wearing 3D glasses.
SMV	Super-MultiView, i.e. MultiView with many captured and/or rendered views (several dozens to hundreds)
SMV display	An advanced Autostereoscopic Display device with several dozens to hundreds of directional output views, often restricted to providing horizontal parallax only stereoscopic viewing
Light Field	A conceptual representation of light, where in addition to luminance or color, also directional information is captured from each light ray emanating from a point in space. The concept of Light Field is often related to sampling of the Plenoptic function.
Plenoptic function	A mathematical description of the Light Field with up to 7 parameters (3 spatial position coordinates, 2 angular direction coordinates, the light wavelength/color, and time)
Sparse Light Field	A coarsely sampled Light Field, e.g. captured with a discrete set of cameras
Light Field Camera System	A camera device/system where each pixel captures luminance/color and directional light information from the Plenoptic function, e.g. with a discrete set of cameras, a Plenoptic Camera, etc.
Plenoptic Camera	Light Field Camera where in addition to the luminance/color, the directional light information of the Plenoptic function is obtained through an array of microlenses, correctly refracting light to the underlying pixels
Dense Light Field	A Light Field with light rays densely packed into the volume of interest (the so-called field of view), typically captured with Plenoptic Cameras, or synthesized/raytraced from 3D visual media representations
Light Field Display	An Autostereoscopic Display device, more advanced than SMV displays, to render a Dense Light Field, typically supporting full parallax and correct eye accommodation at very high light ray densities.
Stereo Sweeping View Sweeping	A method of sweeping from one view to the next (including virtual views) to evaluate the quality of the view synthesis
Perceptual metric	A quality metric incorporating the Human Visual System characteristics. This metric should correlate to subjective quality experiences
IV-PSNR	PSNR (adapted) for Immersive Video, objective quality metric for Immersive Video applications
WS-PSNR	Weighted to spherically uniform PSNR

Table 1: Abbreviations used throughout the document. The reader is referred to the latest version of the "Technical Report on Architectures for Immersive Media" for formal definitions.

3 Overviews

Documents that consist of overviews are:

- [N19488] Summary on MPEG-I Visual Activities
- [N19489] Overview of MPEG-I Visual Test Materials
- [N17933] MPEG-I Project Plan

4 Use cases

Documents that consist of use cases are:

- [N18355] MPEG-I Phase 2 Use Cases

5 Requirements

Documents that consist of requirements are:

- [N18127] Requirements for MPEG-I Phase 2
- [N18339] Requirements on Integration of Scene Description in MPEG-I

6 Test Materials

Documents that consist of test materials are:

- [N19489] Overview of MPEG-I Visual Test Materials
- [N18490] Call for MPEG-I Test Materials

7 Exploration Experiments

Documents that consist of Exploration Experiments are:

- [N19484] Common Test Conditions for Immersive Video
- [N19491] Exploration Experiments on Coding for Future MPEG Immersive Video
- [N19492] Exploration Experiments on Processing for Future MPEG Immersive Video
- [N19494] Exploration Experiments and Common Test Conditions for Dense Light Fields

8 Core Experiments

Documents that consist of Core Experiments are:

- [N19485] to [N19487] Description of Immersive Video Core Experiments 1 to 3

9 Reference software

The exploration and standardization activities in various groups related to MPEG-I was fruitful with the development and improvement of many software packages. Descriptions of these packages are spread over various MPEG documents, which sometimes describe only changes and differences between subsequent versions. This section gathers all the important information related to software developed and used in the MPEG-I visual exploration, with subsections providing respectively the current Reference Software, Depth Estimation and View Synthesis software updates, as well as Lenslet to Multiview data format converters.

9.1 *Current Reference Software*

- [N19483, m47998] The general structure of the TMIV. Reference software and Core Experiments can be found on:
  http://mpegx.int-evry.fr/software/MPEG/MIV
  while the reference software is also available publicly on:
  https://gitlab.com/mpeg-i-visual/tmiv
- [N18068] Reference View Synthesizer (RVS) 3.1 manual for 3DoF+; an updated version 4.0 of the software [m47998] can be found on the MPEG Git repository:
  http://mpegx.int-evry.fr/software/MPEG/Explorations/3DoFplus/RVS/tree/v4.0
- Versatile View Synthesizer (VVS) 2.0 for Windowed-6DoF with its manual [N18172] can be found on the MPEG Git repository:
  http://mpegx.intevry.fr/software/MPEG/Explorations/6DoF/VVS.git (tag v2.0).
- DERS9.0 with its manual [N19143] can be found on the MPEG Git repository
  http://mpegx.int-evry.fr/software/MPEG/Explorations/6DoF/DERS.git

- IVDE with its manual [N19224] can be found on the MPEG Git repository http://mpegx.int-evry.fr/software/MPEG/Explorations/6DoF/IVDE.git
- PDR with its manual [N18708] can be found on the MPEG Git repository: http://mpegx.int-evry.fr/software/MPEG/Explorations/6DoF/PDR
- PCR with its manual [N19141] can be found on the MPEG Git repository: http://mpegx.int-evry.fr/software/MPEG/Explorations/6DoF/PCR
- [N16730] describes the Depth map formats used within MPEG 3D technologies
- HTM [1] and HM [N17047]
- MV-HEVC [1] for parallel camera settings
- [N17133] Limitations of multi-view extensions of HEVC and fixes for MPEG-I Phase 2
- [N17459] Issues affecting the usage of HEVC reference software for experimental studies (this document was discussed during the 30th JCT-VC meeting and based mainly on issues mentioned in [N17133])
- [N19495] IV-PSNR Software Manual, cf. the software available on the MPEG Git repository:
  http://mpegx.int-evry.fr/software/MPEG/MIV/RS/IVPSNR
  and on:
  https://gitlab.com/mpeg-i-visual/ivpsnr
- [N18069] WS-PSNR Software Manual, cf. the software available on the MPEG Git repository:
  http://mpegx.int-evry.fr/software/MPEG/Explorations/3DoFplus/WS-PSNR
  and on:
  https://gitlab.com/mpeg-i-visual/wspsnr
- [N18793] Conversion method from lenslet image to multiview images: http://www.fujii.nuee.nagoya-u.ac.jp/multiview-data/

9.2 *Depth Estimation Software*

Throughout the years, MPEG has been developing Depth Estimation Reference Software (DERS) which has constantly been improved in order to provide state-of-the-art depth estimation results.

Currently, DERS can estimate depth maps based on arbitrary arranged input views. Depending on the configuration settings, up to 4 input views can be used. The depth is estimated with a graph cuts algorithm which finds optimal correspondences between the views on pixel-by-pixel basis. Therefore, the resolution of the generated depth is the same as the resolution of the input images. The output format of the depth maps is 4:2:0 YUV or 4:0:0 YUV (no chrominance) where the Y component contains normalized disparity of the center view. Additionally, DERS outputs two scaling values: zNear and zFar, which are used to normalize the disparity maps [N16730].

DERS has constantly improved starting from stereo depth estimation [m31518] with horizontal disparity only search, extended with epipolar line search [m31518], disparity ranges [m15377] and Z (depth) ranges [m32249]. The search precision [m15836] has also steadily improved to quarter-pel, also adding vertical upsampling [m31518]. The similarity metrics were first 3x3 block-based [m15837, m16390, m16092] with extensions to soft segmentation block matching [m17049, m16923] and enhancements thereof (Mean-shift algorithm, Pyramid segmentation, K-means clustering) [m16092, m16390]. For difficult cases, semi-automatic depth estimation was introduced using maps that mark edges and/or regions that do not change in time [m16923, m16605, m16411, m16391]. Time consistent enhancements [m16070, m16048] and 16 bits per depth sample were also introduced [m31518].

Currently, the new DERS 9.0 is based on the RDE software that includes all tools from DERS 8.0, but due to the refactorization of the code, its readability was highly improved [m52135].

With the aim of developing a DERS software tool that can effectively be used by anyone in the exploration experiments, UPM has become the software coordinator, cf. section 9.

During the development of the Test Model for Immersive Video, the group concluded that the quality of estimated depth maps is crucial for the efficiency of the proposed encoding technique. In order to enhance the quality of depth maps for natural content, the group decided to add a depth refinement software to current reference software tools. The current method (PDR) has been initially proposed in the Immersive Video CE-5 response [m48092] and allows to enhance the inter-view consistency of the depth maps.

During the 130th meeting, the group decided to add new depth estimation method as another reference software, as the Immersive Video Depth Estimation [N19224] handles also omnidirectional content and has similar objective results as DERS9 on perspective content. IVDE was designed by Poznań University of Technology and Electronics and Telecommunications Research Institute, the software is coordinated by PUT.

In IVDE, which is based on method [2], depth is estimated for segments instead of individual pixels, and thus the size of segments can be used to control the trade-off between the quality of depth maps and the processing time of estimation. Larger segments can be used to attain fast depth estimation, or finer segments can be used to attain higher quality. The estimation is performed for all views simultaneously and produces depths that are inter-view consistent because of the utilization of the new formulation of the cost function, developed for segment based estimation. No assumptions about the positioning of views are stated and any number of arbitrarily positioned cameras (both perspective and omnidirectional) can be used during the estimation.

In the used temporal consistency enhancement method, depth maps estimated in previous frames are utilized in the estimation of depth for the current frame, increasing the consistency of depth maps and simultaneously decreasing the processing time of estimation. The framework uses also a parallelization method that reduces the processing time of graph-based depth estimation.

9.3 *View Synthesis Software*

MPEG originally developed View Synthesis Reference Software (VSRS) that was recently replaced by the Reference View Synthesizer (RVS) for 3DoF+ [N18068, N18145] and the Versatile View Synthesizer (VVS) for 6DoF [N18172]. These tools synthesize a virtual view based on two or more input views and corresponding depth maps, stored in normalized disparity format [N16730]. Synthesized views can be positioned at any place in 3D space, but commonly they are positioned in-between the input views.

VSRS was originally designed using only two reference views (left and right), while RVS and VVS support a large number of reference views, achieving higher quality virtual views.

VSRS has always been used throughout the former FTV activities, preceding the MPEG-I Visual explorations, with the most recent improvements given below:

- View blending where each output pixel is a mixture of the content from the left and right views, depending on their depths [m37232]
- Inpainting where regions that do not exist in any of the input views (that are occluded) are filled with inpainted content [m40657]

RVS was designed under Philips/The Netherlands software coordination (cf. next section) using software that was originally developed by l'Université Libre de Bruxelles, Belgium, early 2018. This software could better handle step-in/out walkthrough scenarios using virtual triangles that connect any three adjacent pixels in the input images [2]. This automatically offers unlimited precision (half-pel, quarter-pel, etc.) for any virtual view position through shader rendering.

Philips provided extensions that now support ERP and/or perspective viewing input/output formats. The camera parameters follow the OMAF convention, using the JSON format documented in [N18068].

VVS was designed under Orange Labs software coordination (cf. next section) and replaced VSRS in Windowed-6DoF, late 2018. Its software architecture is described in Figure 1 of [N18172] with support for ERP and/or perspective viewing input/output formats as well. Currently, it supports up to 16 input views, but extensions to more input views can easily be added for future use.

9.4 *Lenslet Content Converter Software*

[m46374, N18567] describe a conversion method from lenslet images to multiview images, allowing to test the coding tools originally developed within MPEG-I Visual for conventional cameras, onto plenoptic cameras. Such tools are referred to as the Reference Lenslet Content Converter (RLC), with its current version being v0.3 [N18567].

10 Software coordinators

Julien Fleureau (InterDigital), Bart Kroon (Philips) and Vinod Kumar Malamal Vadakital (Nokia) are the software coordinators for the TMIV reference software [N19483].

Bart Kroon (Philips) is the software coordinator for RVS, Patrick Boissonade (Orange Labs) is the software coordinator for VVS, Eduardo Juárez (Universidad Politécnica de Madrid) is the software coordinator for DERS, Dawid Mieloch (Poznań University of Technology) is the software coordinator for IVDE, Mehrdad Teratani (l'Université Libre de Bruxelles) is software coordinator for RLC, and Adrian Dziembowski (Poznań University of Technology) is software coordinator for PDR and PCR.

References

[1] G. Tech and Y. Chen and K. Müller and J. R. Ohm and A. Vetro and Y. K. Wang, *Overview of the Multiview and 3D Extensions of High Efficiency Video Coding*, IEEE Transactions on Circuits and Systems for Video Technology, vol. 26, pp. 35–49, 2016.

[2] S. Fachada, D. Bonatto, A. Schenkel, G. Lafruit, "*Depth Image-Based View Synthesis with Multiple Reference Views for Virtual Reality*," 3DTV-CON, Stockholm-Helsinki, June 2018.

[3] D. Mieloch, O. Stankiewicz and M. Domański, "Depth Map Estimation for Free-Viewpoint Television and Virtual Navigation," IEEE Access, vol. 8, pp. 5760-5776, 2020.

[N16730] Depth map formats used with MPEG 3D technologies, ISO/IEC JTC1/SC29/WG11 MPEG2017/N16730, Geneva, January 2017.

[N17047] High Efficiency Video Coding (HEVC) Test Model 16 (HM 16) Encoder Description Update 9, ISO/IEC JTC1/SC29/WG11 MPEG2017/N17047, Torino, July 2017.

[N17133] Limitations of Multiview extensions of HEVC and fixes for MPEG-I Phase 2, ISO/IEC JTC1/SC29/WG11 MPEG2017/N17133, Macau, October 2017.

[N17459] Issues affecting the usage of HEVC reference software for experimental studies, ISO/IEC JTC1/SC29/WG11 MPEG2018/N17459, Gwangju, January 2018.

[N17933] MPEG-I Project Plan, ISO/IEC JTC1/SC29/WG11 MPEG2018/N17933, Macau SAR, CN, October 2018.

[N18068] Reference View Synthesizer (RVS) manual, ISO/IEC JTC1/SC29/WG11 MPEG2018/N18068, Macau SAR, CN, October 2018.

[N18069] WS-PSNR Software Manual, ISO/IEC JTC1/SC29/WG11 MPEG2018/N18069, Macau SAR, CN, October 2018.

[N18127] Requirements for MPEG-I Phase 2, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18127, Marrakech, January 2019.

[N18145] Call for Proposals on 3DoF+ Visual, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18145, Marrakech, January 2019.

[N18172] Versatile View Synthetizer (VVS) 2.0 manual, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18172, Marrakech, January 2019.

[N18339] Requirements on Integration of Scene Description in MPEG-I, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18339, Geneva, March 2019.

[N18344] MPEG-I Architectures, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18344, Geneva, March 2019.

[N18353] Vittorio Baroncini (EVATech) Giacomo Baroncini (GBTech), Evaluation Results of the Call for Proposals on 3DoF+ Visual, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18353, Geneva, March 2019.

[N18355] MPEG-I Phase 2 Use Cases, ISO/IEC JTC1/SC29/WG11 MPEG2018/N18355, Geneva, March 2019.

[N18464] Working Draft 1 of Metadata for Immersive Media (Video), ISO/IEC JTC1/SC29/WG11 MPEG2019/N18464, Geneva, March 2019.

[N18465] Description of Immersive Video Core Experiments 1, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18465, Geneva, March 2019.

[N18466] Description of Immersive Video Core Experiments 2, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18466, Geneva, March 2019.

[N18467] Description of Immersive Video Core Experiments 3, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18467, Geneva, March 2019.

[N18468] Description of Immersive Video Core Experiments 4, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18468, Geneva, March 2019.

[N18469] Description of Immersive Video Core Experiments 5, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18469, Geneva, March 2019.

[N18470] Test Model for Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18470, Geneva, March 2019.

[N18567] Manual of Reference Lenslet Content Convertor (RLC 0.3), ISO/IEC JTC1/SC29/WG11 MPEG2019/N18567, Geneva, October 2019.

[N18933] Description of Immersive Video Core Experiments 2: Pixel Pruning, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18933, Geneva, October 2019.

[N18934] Description of Immersive Video Core Experiments 3: Atlas Preparation, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18934, Geneva, October 2019.

[N18935] Description of Immersive Video Core Experiments 1: Metadata, ISO/IEC JTC1/SC29/WG11 MPEG2019/N18935, Geneva, October 2019.

[N19004] Description of Immersive Video Core Experiments 1: Metadata, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19004, Brussels, January 2020.

[N19005] Description of Immersive Video Core Experiments 2: Pruning and Synthesis, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19005, Brussels, January 2020.

[N19006] Description of Immersive Video Core Experiments 3: Atlas Preparation, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19006, Brussels, January 2020.

[N19143] Description of DERS, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19143, Brussels, January 2020.

[N19212] Working Draft 5 of Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19212, Online, April 2020.

[N19213] Test Model 5 for Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19213, Online, April 2020.

[N19215] Description of Immersive Video Core Experiments 1: Bitstream Adaptation, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19215, Online, April 2020.

[N19216] Description of Immersive Video Core Experiments 2: Pruning and Synthesis, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19216, Online, April 2020.

[N19217] Description of Immersive Video Core Experiments 3: Atlas Preparation, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19217, Online, April 2020.

[N19482] Text of ISO/IEC CD 23090-12 MPEG Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19482, Online, July 2020.

[N19483] Test Model 6 for MPEG Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19483, Online, July 2020.

[N19484] Common Test Conditions for MPEG Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19484, Online, July 2020.

[N19485] Description of MPEG Immersive Video Core Experiments 1, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19485, Online, July 2020.

[N19486] Description of MPEG Immersive Video Core Experiments 2, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19486, Online, July 2020.

[N19487] Description of MPEG Immersive Video Core Experiments 3, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19487, Online, July 2020.

[N19488] Summary on MPEG-I Visual Activities, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19488, Online, July 2020.

[N19489] Overview of MPEG-I Visual Test Materials, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19489, Online, July 2020.

[N19490] Call for MPEG-I Test Materials, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19490, Online, July 2020.

[N19491] Exploration Experiments on Coding for Future MPEG Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19491, Online, July 2020.

[N19492] Exploration Experiments on Processing for MPEG Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19492, Online, July 2020.

[N19494] Exploration Experiments and Common Test Conditions for Dense Light Fields, ISO/IEC JTC1/SC29/WG11 MPEG2020/N19494, Online, July 2020.

[N19495] Software manual of IV-PSNR for Immersive Video, ISO/IEC JTC1/SC29/WG11 MPEG2020/ N19495, Online, July 2020.

[m15377] Masayuki Tanimoto, Toshiaki Fujii, Kazuyoshi Suzuki, Norishige Fukushima, *Reference Softwares for Depth Estimation and View Synthesis*, ISO/IEC JTC1/SC29/WG11 MPEG2008/m15377, Archamps, April 2008.

[m15836] Masayuki Tanimoto, Toshiaki Fujii, Kazuyoshi Suzuki, *Reference Software of Depth Estimation and View Synthesis for FTV/3DV*, ISO/IEC JTC1/SC29/WG11 MPEG2008/ m15836, Busan, October 2008.

[m15837] Masayuki Tanimoto, Toshiaki Fujii, Kazuyoshi Suzuki, *Depth Estimation to improve boundary clarification*, ISO/IEC JTC1/SC29/WG11 MPEG2008/m15837, Busan, October 2008.

[m16048] Hui Yuan, Yilin Chang, Haitao Yang, Xiaoxian Liu, Sixin Lin, Lianhuan Xiong, *Depth Estimation Improvement for Depth Discontinuity Areas and Temporal Consistency Preserving*, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16048, Lausanne, February 2009.

[m16070] Gun Bang, Jaeho Lee, Namho Hur, Jinwoong Kim, *The consideration of the improved depth estimation algorithm*, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16070, Lausanne, February 2009.

[m16092] Masayuki Tanimoto, Toshiaki Fujii, Kazuyoshi Suzuki, *Depth Estimation Reference Software (DERS) with Image Segmentation and Block Matching*, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16092, Lausanne, February 2009.

[m16390] Masayuki Tanimoto, Toshiaki Fujii, Mehrdad Panahpour Tehrani, Kazuyoshi Suzuki, Menno Wildeboer, *Depth Estimation Reference Software (DERS) 3.0*, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16390, Maui, April 2009.

[m16391] Masayuki Tanimoto, Toshiaki Fujii, Mehrdad Panahpour Tehrani, Norishige Fukushima, Kazuyoshi Suzuki, Menno Wildeboer, *Semi-automatic Depth Estimation for FTV*, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16391, Maui, April 2009.

[m16411] Gun Bang, Jaeho Lee, Namho Hur, Jinwoong Kim, *Depth Estimation algorithm in SADERS1.0*, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16411, Maui, April 2009.

[m16605] Masayuki Tanimoto, Toshiaki Fujii, Mehrdad Panahpour Tehrani, Menno Wildeboer, Depth Estimation Reference Software (DERS) 4.0, ISO/IEC JTC1/SC29/WG11 MPEG2009/m16605, London, June 2009.

[m16923] Masayuki Tanimoto, Toshiaki Fujii, Mehrdad Panahpour Tehrani, Menno Wildeboer, *Depth Estimation Reference Software (DERS) 5.0*, ISO/IEC JTC1/SC29/WG11 MPEG2009/, Xian, October 2009.

[m17049] Olgierd Stankiewicz, Krzysztof Wegner, Menno Wildeboer, *A soft segmentation matching in Depth Estimation Reference Software (DERS) 5.0*, ISO/IEC JTC1/SC29/WG11 MPEG2009/, Xian, October 2009.

[m31518] Olgierd Stankiewicz, Krzysztof Wegner, Masayuki Tanimoto, Marek Domanski, *Enhanced Depth Estimation Reference Software (DERS) for Free-viewpoint Television*, ISO/IEC JTC1/SC29/WG11 MPEG2013/m31518, Geneva, October 2013.

[m31520] Krzysztof Wegner, Olgierd Stankiewicz, Masayuki Tanimoto, Marek Domanski, *Enhanced View Synthesis Reference Software (VSRS) for Free-viewpoint Television*, ISO/IEC JTC1/SC29/WG11 MPEG2013/m31520, Geneva, October 2013.

[m32249] Krzysztof Wegner, Olgierd Stankiewicz, *Z-distance-based search range in Depth Estimation Reference Software*, ISO/IEC JTC1/SC29/WG11 MPEG2014/m32249, San Jose, January 2014.

[m37232] Krzysztof Wegner, Olgierd Stankiewicz, Marek Domanski, *[FTV] Depth based view blending in VSRS*, ISO/IEC JTC1/SC29/WG11 MPEG2015/m37232, Geneva, October 2015.

[m40657] Takanori Senoh, Kenji Yamamoto, Nobuji Tetsutani, Hiroshi Yasuda, Krzysztof Wegner, *View Synthesis Reference Software (VSRS) 4.2 with improved inpainting and hole filling*, ISO/IEC JTC1/SC29/WG11 MPEG2017/m40657, Hobart, April 2017.

[m44788] P. Boissonade, J. Jung, P. Nikitin, *View synthesis algorithm for windowed-6DoF*, ISO/IEC JTC1/SC29/WG11 MPEG2017/m44788, Macau SAR, CN, October 2018.

[m46374] Kazuhiro Hara, Masahiro Kawakita, Tomoyuki Mishina, Mehrdad Teratani, *Conversion method from lenslet image to multiview images*, ISO/IEC JTC1/SC29/WG11 MPEG2019/m46374, Marrakech, January 2019.

[m47998] Bart Kroon, *Software coordination and general structure of 3DoF+ reference software*, ISO/IEC JTC1/SC29/WG11 MPEG2019/m47998, Geneva, March 2019.

[m48092] Dawid Mieloch, Adrian Dziembowski, Marek Domański, Gwangsoon Lee, *PUT/ETRI Response to Immersive Video CE-5: Depth and color refinement*, ISO/IEC JTC1/SC29/WG11 MPEG2019/m48092, Gothenburg, July 2019.

[m521375] Jaime Sancho, Takanori Senoh, Ségolène Rogge, Daniele Bonatto, Rubén Salvador, Eduardo Juárez, Adrian Munteanu, Gauthier Lafruit, *RDE Fine-tuning to achieve DERS 8.0 performance*, ISO/IEC JTC1/SC29/WG11 MPEG2019/m52135, Brussels, January 2020.