ISO/IEC JTC 1/SC 29/WG1 **N88015**

88th Meeting – Online(Geneva), 7-10 July 2020

INTERNATIONAL ORGANISATION FOR STANDARDISATION
ORGANISATION INTERNATIONALE DE NORMALISATION

ISO/IEC JTC 1/SC 29/WG1
(ITU-T SG16)

Coding of Still Pictures

JBIG	**JPEG**
Joint Bi-level Image Experts Group	Joint Photographic Experts Group

TITLE: JPEG Pleno Holography Uses Cases and Requirements

SOURCE: Kwan-Jung Oh (ETRI) and Peter Schelkens (VUB-imec) as editors

PROJECT: JPEG Pleno

STATUS: Informative

REQUESTED ACTION: For review by WG1 and JPEG Requirement Subgroup

DISTRIBUTION: WG1

Contact:

ISO/IEC JTC 1/SC 29/WG 1 Convener – Prof. Touradj Ebrahimi
EPFL/STI/IEL/GR-EB, Station 11, CH-1015 Lausanne, Switzerland
Tel: +41 21 693 2606, Fax: +41 21 693 7600, E-mail: Touradj.Ebrahimi@epfl.ch

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1. Introduction

JPEG Pleno aims to provide a standard framework for representing new imaging modalities, such as texture-plus-depth, light field, point cloud, and holographic imaging. Such imaging should be understood as light representations inspired by the plenoptic function, regardless of which model captured or created all or part of the content. JPEG Pleno standard tools will be designed together to consider their synergies and dependencies for the whole to be effectively greater than the sum of its parts. To fully exploit this holistic approach, JPEG Pleno is not just a set of efficient coding tools addressing compression efficiency. It is a representation framework understood as a fully integrated system for providing advanced functionality support for image manipulation, metadata, random access and interaction, and various file formats. In addition, it should offer privacy protection, ownership rights, and security. This document describes a number of use cases for the coding of holograms and derives relevant requirements.

2. Use Cases

This section introduces the main use cases of JPEG Pleno holography.

2.1 Holographic Microscopy

Holographic microscopy [1] records the light wavefront originating from an object instead of the projected image of the object recorded in common microscopy. The viewable image of the recorded hologram is created using a numerical reconstruction algorithm. Holographic microscopy supports a large depth of field and it enables the visualization of transmissive objects. Examples of life science applications also include monitoring the viability of cell cultures in suspensions, automating multi-well plate screening devices to measure cell density and cell coverage of adherent cell cultures, and supporting simultaneous fluorescent and holographic cell imaging.

2.2 Holographic Tomography

Holographic tomography is the technology that makes a tomogram with the R I(refractive index) and the 3-dimensional location which can be obtained by calculating phase shift in hologram taken around the specimen 360°. When light pass through the object, the diffraction happens according to the object’s own RI (refractive index) and some properties of light including wavelength and phase shift, etc. also change. If the light that passes through the object is mixed up with the original light (reference), we can observe brightness changes in images according to the change of phase shift. This is a fundamental theory of phase contrast microscopy and holographic tomography is an extension of holographic microscopy.

2.3 Holographic Interferometry

Holographic interferometry [2] is a full-field optical metrology tool that allows for a quantitative comparison of two states of an arbitrary scattering, reflective, or transmissive object subject to some change. It visually reveals temporal changes (eg, deformations, displacements, and modifications of the refractive index) without damage. The underlying principle is that incident light is reflected by the material at different angles before and after the change under consideration. Thus, holographic interferometry is widely used for non-destructive testing. It is also used in special digital cameras such as those in space and nuclear power station related applications, deep ocean exploration, and holographic endoscopes.

2.4 Holographic Display

Holographic displays can realize autostereoscopic rendering without vergence-accommodation conflict (VAC) [3]; this is because all the 3D depth cues perceived by humans in the real world are embedded in the holographic signal. The holographic display can be implemented in a variety of ways, including holographic TVs, table-top holographic displays, holographic projection systems, and holographic head-mounted displays (HMDs). The quality of holographic displays is associated with the so-called space-bandwidth product (SBP), which is a measure of the data capacity of electro-optical devices such as spatial light modulators (SLMs) [4, 5]. In this context, overcoming the SBP constraints and limitations is regarded as a critical factor to realize a practical holographic display to reconstruct objects with both reasonable size and field of view (FOV). The pixel pitch of the top panels currently used in current TVs is close to 100μm. For holographic displays, a pixel pitch of approximately 1μm is required to provide a viewing angle of approximately 30° [6]. Therefore, a holographic display with the same size of a current TV would require approximately 10,000 (100×100) times more data, which means highly effective compression mechanisms are required. Consequently, it is to be expected that the first products to be released will have humble SBPs. Hence, early products are to be expected to first be in HMD and automotive windshield project system markets.

2.5 Holographic Printing

Holographic printing simultaneously offers the texture quality and spatial resolution of existing pictures and the 3D characteristics of holograms [7]. The latter enables depth cues and parallax to be provided, unlike in pictures. Holographic printing uses a laser to record captured discrete viewpoint images (holographic stereogram printing) or wavefront (wavefront printing) in holographic material. The holographic stereogram can be best represented and compressed as a light field [8]. Holographic optical elements (HOEs) are used to perform the same functions as lenses, mirrors, gratings, diffusers, etc. and are a good example of holographic printing; they can also combine several functions together, which is not possible with conventional optical elements; hence, they hold the promise for extreme miniaturization of certain complex optical or digital image processing steps.

3. Royalty-free Goal

The royalty-free patent licensing commitments made by contributors to previous standards, e.g. JPEG 2000 Part 1, have arguably been instrumental to their success. JPEG expects that similar commitments would be helpful for the adoption of a JPEG Pleno hologram coding standard.

4. Requirements

This section presents the overall set of requirements that have been extracted from the above described use cases [9].

4.1 Representation

4.1.1 Hologram Types

Shall support the following hologram types:

- amplitude modulation hologram;
- phase modulation hologram;
- complex modulation holograms.

4.1.2 Representation format

Shall support one or more of the following representation formats for the supported hologram types: amplitude-only, phase-only, amplitude-phase and real-imaginary.

4.1.3 Spatial resolution

Shall support large spatial resolution of the hologram to enable large space-bandwidth product holograms that are offering a large Field of View (FoV) and a large viewing angle support (i.e. small pixel pitch).

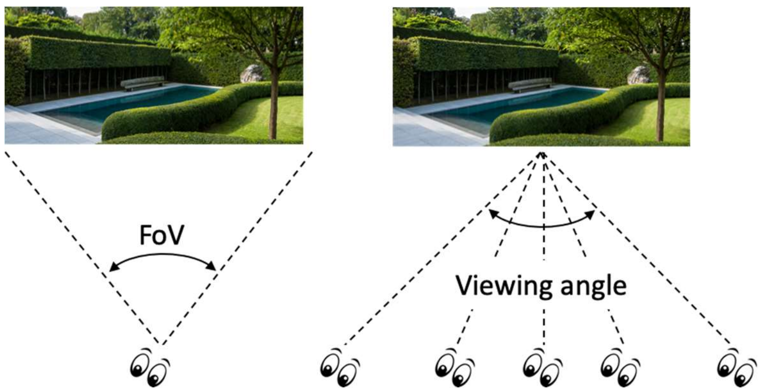

Figure 1 - Field of View (FoV) and viewing angle

4.1.4 Bit depth

Shall support holographic data with bit depths ranging from bi-level up to 16-bit integer precision.

4.1.5 Floating point

Should support at least 32-bit IEEE 754 floating point representation format.

4.1.6 Colour space

Shall support multiple components, including RGB.

4.1.7 Hologram sequences

Should support hologram sequences both in time and space.

4.2 Coding

4.2.1 Coding types

The following coding types shall be supported:

- near-lossless and lossy coding up to high quality.

The following coding types should be supported:

- lossless coding.
- perceptual lossless coding. Perceptually lossless means here that reconstructed holograms are visually indistinguishable from the original reconstructed holograms.

4.2.2 Compression efficiency

Shall support high compression efficiency considering the state-of-the-art.

4.2.3 Quality control

Shall support quality control, notably for machine vision analysis in the context of interferometry and holographic microscopy/tomography.

4.2.4 Perceptual coding

Should support coding tools that exploit the human visual system properties to achieve maximal visual quality for reconstructed holograms.

4.2.5 Random access

Shall allow decoding of subsets of the complete codestream to enable selecting an aperture window in space-frequency domain of the hologram.

4.2.6 Scalability

Should support the decoding of different levels of quality (SNR), spatial resolution, depth resolution, temporal resolution, spectral resolution and FoV from a subset of the codestream.

4.2.7 Error resilience

Should be resilient against bit errors and packet losses.

4.3 Algorithmic complexity

4.3.1 Computational and memory complexity

Should remain within reasonable bounds with respect to near-future computing and memory capabilities.

4.3.2 Parallel and distributed processing

Shall facilitate efficient implementation on GPU and multi-core architectures.

4.3.3 Hierarchical data decoding

Should allow for staged processing to reduce the internal decoder bandwidth consumption.

4.3.4 Hardware implementation

Shall facilitate efficient implementation in hardware platforms.

4.4 Additional functionality

4.4.1 JPEG Pleno framework architecture

Shall be compliant with the JPEG Pleno framework architecture as defined in Part 1 (ISO/IEC 21794).

4.4.2 Metadata

Shall enable signaling relevant metadata such as capture parameters, calibration data (e.g. geometrical setup), half/full parallax, wavelengths, image sensor (CCD/CMOS) information, horizontal and vertical pixel pitch, pixel shape, microscope configuration, spectral channel information, display and rendering parameters, and information about additional processing steps.

4.4.3 Privacy and security

Shall provide support for JPEG Privacy and Security tools.

4.4.4 Editing and manipulation

Should support efficient change of depth of field or viewpoint, refocusing, relighting, navigation, rotation, and enhanced analysis of objects without transcoding of content.

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