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Abstract

This document presents an overview of the High Efficiency Image File Format (HEIF, ISO/IEC 23008-12). HEIF specifies the storage of individual images as well as image sequences into a container file. HEIF includes the storage specification of HEVC intra images and HEVC image sequences in which inter prediction is applied in a constrained manner. HEIF files are compatible with the ISO Base Media File Format (ISO/IEC 14496-12) and can also include other media streams, such as timed text and audio.

This contribution updates the overview provided in JCTVC-U0039 to be aligned with the decisions made in MPEG meeting #112 (June 2015) and hence with the final technical design of HEIF.

1 Introduction

The High Efficiency Image File Format (HEIF, ISO/IEC 23008-12) enables encapsulation of images and image sequences, as well as their associated metadata into a container file. HEIF is compatible with the ISO Base Media File Format (ISOBMFF, ISO/IEC 14496-12). Use cases supported by HEIF include:

- Storage of burst photos.
- Support for simultaneous capture of video and still images, i.e. storing still images and timed image sequences into the same file.
- Efficient representation of animations and cinemagraphs.
- Storage of focal and exposure stacks into the same container file.
- Storage of images derived from other images of the file, either as derived images represented by non-destructive image editing operations or as pre-computed derived images.
- Support for storing other media, such as audio and timed text, into the same container file with timed image sequences and synchronizing their playback.

HEIF specifies a structural format, from which codec-specific image formats can be derived. HEIF also includes the specification for encapsulating images and image sequences conforming to the High Efficiency Video Coding (HEVC, ISO/IEC 23008-2 | ITU-T Rec. H.265).

In ISOBMFF, a continuous or timed media or metadata stream forms a track, whereas static media or metadata is stored as items. Consequently, HEIF has the following basic design:

1. Still images are stored as items. All image items are independently coded and do not depend on any other item in their decoding. Any number of image items can be included in the same file.

2. Image sequences are stored as tracks. An image sequence track can be indicated to be displayed either as a timed sequence or in a non-timed manner, such as a gallery of images. An image sequence track needs to be used instead of image items when there is coding dependency between images.

A file may contain both image items and image sequence tracks along with other media. For example, it is possible to create a file that includes image items or image sequence tracks conforming to HEIF, along with video, audio and timed text tracks conforming to any derivative format of the ISOBMFF.

Files conforming to ISOBMFF consist of a sequence of data structures called boxes, each containing a four-character code (4CC) indicating the type of the box, the size of the box in terms of bytes, and the payload of the box. Boxes may be nested, i.e. a box may contain other boxes. ISOBMFF and HEIF specify constraints on the allowed box order and hierarchy.

References of this document include an overview paper [1] by the same authors, a publicly available draft standard [2] (March 2015) and the technically frozen standard [3] (August 2015). The standard [3] will still undergo a final approval ballot, in which no technical changes are made. This document provides a summary of the features of HEIF, whereas the overview paper [1] gives a tutorial with examples, a history of the development, and a shallower feature overview. Some parts are shared between the two documents – particularly, Section 2 and Annex B of this document originate from [1] with minor changes.

The document is organized as follows:

- Section 2 presents how HEIF files are profiled and signalled.
- Section 3 sums up the features related to image items.
- Section 4 describes the features of image sequence tracks.
- Section 5 provides a summary how the HEVC image file format is derived from HEIF.
- Annex A includes a feature comparison of HEIF to some other image formats.
- Annex B provides some compression performance results of HEVC image and image sequence coding.
- Annex C provides a summary of changes between the publicly available draft standard [2] and the technically frozen standard [3].

2 Brands and MIME type definitions

Files conforming to HEIF start with a `FileTypeBox`, which contains a list of brands the file complies with. Each brand is identified by its unique four-character code. The specification of a brand can include requirements and constraints for files of the brand and for file players supporting the brand. A brand included in the `FileTypeBox` permits a player that supports the requirements of the brand to play the file.

The brands specified in the HEIF standard are presented in Table I. The HEIF standard specifies the `'mif1'` and `'msf1'` structural brands, where requirements on file structures present in the file and to be supported by players, are given, but any image coding format can be used. Additionally, HEVC-specific brands are specified as listed in Table I. Further information on the HEVC-specific brands is provided in Section 5.3. As the File Type box is located at the start of the file, it provides easily accessible indications of the file contents to file players. It can be expected that the Main profile of HEVC will be most widely implemented out of all the HEVC profiles. The dedicated brand names, `'heic'` and `'hevc'`, for the Main profile compatible image files allows players that support only the Main profile to determine whether the playback of the file is possible by inspecting the `FileTypeBox`.

Table I. Brands, MIME subtypes, and file extensions for HEIF.

Brand	Coding format	Image or sequence?	MIME type	MIME subtype	File extension
`mif1`	any	image	`image`	`heif`	`.heif`
`msf1`	any	sequence	`image`	`heif-sequence`	`.heif`
`heic`	HEVC (Main or Main Still Picture profile)	image	`image`	`heic`	`.heic`
`heix`	HEVC (Main 10 or format range extensions profile)	image	`image`	`heic`	`.heic`
`hevc`	HEVC (Main or Main Still Picture profile)	sequence	`image`	`heic-sequence`	`.heic`
`hevx`	HEVC	sequence	`image`	`heic-sequence`	`.heic`

	(Main 10 or format range extensions profile)				

Internet media types, also known as MIME (Multipurpose Internet Mail Extensions) types, are used by various applications to identify the type of a resource or a file. MIME types consist of a media type (`'image'` in the case of HEIF files), a subtype, and zero or more optional parameters. For multi-purpose files, the selection of the subtype can be made on the basis of the primary use of the file.

An optional `codecs` MIME parameter can be present to indicate the used coding formats of the tracks of the file. Similarly, an optional `itemtypes` MIME parameter can be present to indicate the used coding format or the type of the derived image item (see section 3.3) as well as the essential properties (see section 3.2) of each image item present in the file. The `codecs` and `itemtypes` MIME parameters also include the profile-tier-level value to which an HEVC-coded image sequence track or image item, respectively, conforms.

3 Image items

3.1 Roles of images

As multiple images can be stored in the file, it can be useful to differentiate between them by assigning certain roles. The roles specified in HEIF are listed and described in Table II. Note that a single image can be associated with more than one role.

Table II. Roles of images.

Role	Description
coded image	A coded representation of an image.
derived image	An image that is represented in a file by an indicated operation to indicated input images and can be obtained by performing the operation to the input images. See also section 3.3.
cover image (a.k.a. primary item)	A representative image of the image items and image sequence tracks of the file. The cover image should be displayed when no other information is available on the preference to display the image items of the file. The file can have only one cover image.
thumbnail image	A smaller-resolution representation of a master image. A master image can have multiple thumbnail images (e.g. different resolutions).
auxiliary image	An image that complements a master image. For example, an alpha plane or a depth map. Can assist in displaying the master image but is not typically displayed as such.
master image	An image that is not a thumbnail image or an auxiliary image. Typically represents a full-resolution displayable image.
hidden image	An image that should never be displayed. Can be present in the file for example as an input image for a derived image.
pre-derived coded image	A coded image that has been derived from other images. For example, a high dynamic range image derived from an exposure-bracketed set of images. The input images used for derivation are linked to the final pre-derived coded image by referencing. No derivation operation is defined.

3.2 Image properties

Images can be indicated to have properties that are either descriptive (i.e. not imposing a modification on the image item) or transformative (i.e. modifying the image). Properties can be marked as essential imposing mandatory parsing by the file player. The currently defined image properties are listed in Table III.

Table III. Image properties.

Property	Descriptive/ transformative	4CC Code	Description
Decoder	descriptive	Specific to the	The information needed to initialize the decoder. The

configuration and initialization		image coding format.	structure of this information is usually defined in the related image coding format specification.
Image spatial extents	descriptive	'ispe'	The width and height of the image item
Pixel aspect ratio	descriptive	'pasp'	Pixel aspect ratio
Colour information	descriptive	'colr'	Colour conversion information, such as ICC profile
Pixel Information	descriptive	'pixi'	The number and bit depth of colour components in the image item.
Relative Location	descriptive	'rloc'	The horizontal and vertical position of the reconstructed image of the associated image item relative to a referenced image item.
Image properties for auxiliary images	descriptive	'auxC'	The type of an associated auxiliary image. Depending on the type, other related information may also be provided within this property.
Clean aperture	transformative	'clap'	Rectangular cropping of the image.
Image Rotation	transformative	'irot'	Rotation on the image in units of 90 degrees.

In addition to descriptive image properties, image items can optionally be characterized with metadata items, the format of which follows Exif, XMP, or MPEG-7 metadata.

3.3 Derived images

Derived images enable non-destructive image editing, where the original coded images are kept in the file, while new images, called derived images, can be introduced by specifying a transformation operation that is applied to one or more input images. HEIF specifies the generic structures used for storing derived images as items as well as a few specific types of derived images. The item type of a derived image item indicates the transformation operation, while the item payload contains the input parameters to the operation. Item references of type 'dimg' specify the input image(s) of the derived image. The input images can be coded images or derived images. The derived image types specified in the HEIF standard are listed in Table IV. Other types may be specified in other documents or later versions of the HEIF standard.

Table IV. Derived image types.

Name	Item 4CC	Description
Identity transformation	iden	Cropping and/or rotation by 90, 180, or 270 degrees, imposed through the respective transformative properties.
Image overlay	iovl	Overlaying any number of input images in indicated order and locations onto the canvas of the output image.
Image grid	grid	Reconstructing a grid of input images of the same width and height.

3.4 Processing of image items by file players

Figure 1 illustrates how a file player processes the coded images and the derived images included in a file. The file player decodes a coded image into a reconstructed image. Similarly, the file player applies the operation of the derived image to the indicated one or more input images to obtain the respective reconstructed image. The descriptive image properties generally describe the reconstructed image, with the exception of the decoder configuration and initialization information, which is associated with the coded image. The transformative image properties, if any, are applied to the reconstructed image to obtain an output image. The output image can be displayed, when the coded image or the derived image is not a hidden image. The output image can also act as an input image to derived images.

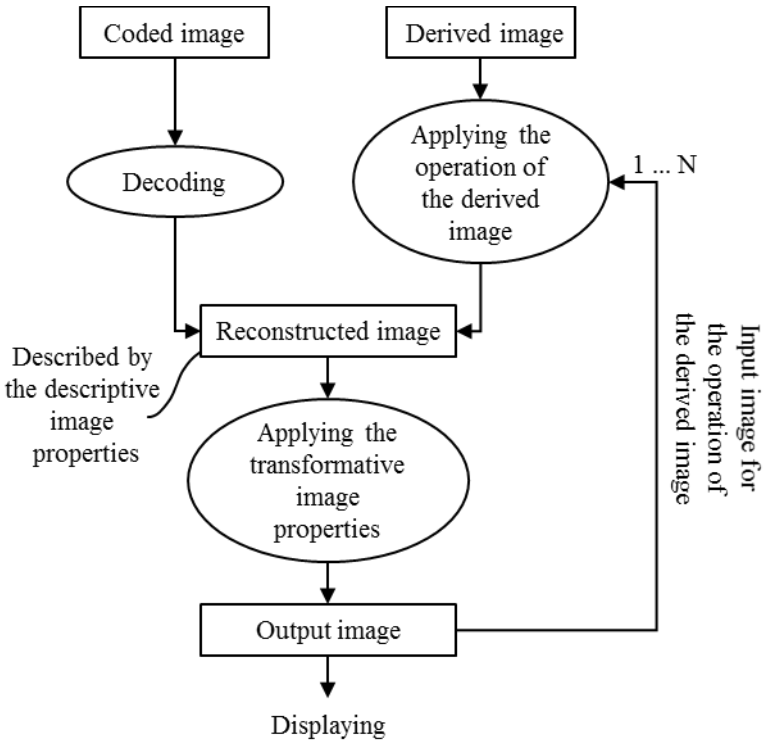

Figure 1. Operations performed by file players

3.5 Indicating alternatives

An HEIF file can contain several image items representing the same image content. A desired file player operation is to select one of the alternative representations of the same image content for displaying. A mechanism, known as entity grouping, is used for indicating alternate groups, which can contain both image items and tracks. Examples where alternate groups can be used include the following:

- The same original image is coded into two or more image items with different properties, such as spatial resolution, bit-depth, or color gamut.
- The same original image is coded into two or more image items with a different coding format or profile.
- A timed image sequence, such as a cinemagraph, is an alternative to an image item.

4 Image sequence tracks

4.1 Introduction

In the ISOBMFF terminology tracks comprise *samples*, such as coded pictures. Each track has a type, identified by a four-character handler code. A sample entry of a track includes decoder initialization information for the linked samples.

HEIF specifies a new handler type `'pict'` for image sequences. An image sequence track inherits the properties and features of a video track except in the following cases:

- A key difference between an image sequence track and a video track lies in the interpretation of the timing information given for the track: While the timing information given for a video track adheres the decoding and output timing of the contained video bitstream, the timing information of an image sequence track can represent the capture times (e.g. for separate images of an exposure stack) or the suggested display timing (e.g. for a slide

show). It can be indicated whether an image sequence track should be played as a timed sequence or by some non-timed means, such as an image gallery.

- The sample entries of image sequence tracks are required to include `CodingConstraintsBox` for indicating the applied prediction constraints and hence assisting players in accessing individual images of the image sequence track. See Section 4.4 for further details on `CodingConstraintsBox`.

4.2 Roles of image sequence tracks

Roles can be indicated for image sequence tracks similarly to image items. Table V lists the roles of the image sequence tracks.

Table V. Roles of image sequence tracks.

Role	Description
thumbnail image sequence	A smaller-resolution representation of a master image sequence.
auxiliary image sequence	An image sequence that complements a master image sequence. For example, a sequence of alpha plane or depth map images. Can assist in displaying the master image sequence but is not typically displayed as such.
master image sequence	An image sequence that is not a thumbnail image sequence or an auxiliary image sequence. Typically contains full-resolution displayable images.

4.3 Controlling the playback

The most important features that enable controlling the playback of an HEIF file are listed in Table VI. As indicated in the table, some features were introduced in the ISOBMFF or ISO/IEC 14496-15 and are explicitly inherited by HEIF, while other features were specifically designed for the HEIF standard.

Table VI. Features controlling image sequence playback.

Feature	First appeared in	Description
non-displayable sample	ISO/IEC 14496-15	Is never displayed, but can be used as a reference for predicting other images in the track.
timed vs. non-timed playback	HEIF	In timed playback, the image sequence is played as video, whereas in non-timed playback the samples of the track are displayed by other means, such as an image gallery. Non-timed playback may be indicated e.g. when a track is used for achieving a better compression efficiency for an exposure stack.
edit list	ISOBMFF	A list of ranges of the image sequence track in their playback order. Enables modifying the playback order and pace of samples.
looping	HEIF	HEIF allows indicating edit list repetition e.g. for looping animations. The repetition can be indicated to last for a certain duration or be infinite.
cropping and rotation	ISOBMFF	Rectangular cropping and rotation by 90, 180, 270 degrees can be specified.

4.4 Inter-picture prediction and random access

HEIF allows the use of inter-picture prediction (a.k.a. inter coding), which can provide significant coding efficiency improvement to image sequences when images are correlated. Such correlation is especially evident in content like image bursts or animation clips.

A conventional operation for playing a video track is to decode samples of the track sequentially in their decoding order. If the user seeks to a position within the track, the file player first finds the preceding randomly accessible sample (an intra-coded image) and then sequentially decodes samples of the track until the seek position is reached. While such operation is fine for typical video use cases, image sequence use cases may require faster access to individual images and the ability to edit individual images without affecting any other images. HEIF therefore includes the following two features:

1. `CodingConstraintsBox` to indicate prediction constraints applying to all the linked samples. For example, it can be indicated that all reference images used for inter-picture prediction are intra-coded images.
2. Sample-wise listing of referenced samples using the sample grouping mechanism of ISOBMFF. This feature enables decoding of only those samples that are needed for accessing a particular sample and avoids the need of sequential decoding of each sample starting from the previous intra-coded image.

4.5 Information linked to image sequence tracks

Table VII presents a summary of the information that that must or may complement an image sequence track. By comparing Table III, Error: Reference source not found and Table VII, it can be seen that similar information is provided both for image items and image sequence tracks.

Table VII. Information associated with image sequence tracks
(M = mandatory in HEIF files, O = optionally present in HEIF files).

Name		**Description**
Sample entry	M	One or more sample entries are included in the `SampleDescriptionBox`. The coding format is identified with the 4CC of the sample entry (e.g. `'hvc1'` for HEVC). A visual sample entry contains: - the width and the height of the coded images - the initialization data for the decoder A visual sample entry may also contain - cropping information - pixel aspect ratio - color information, such as the ICC profile or color primaries
Track metadata	M	The track-specific metadata is contained in the `TrackHeaderBox` and some of its child boxes. For example the following information can be specified: - transformation matrix, e.g. for rotation - duration
Externally specified metadata	O	Timed metadata track(s) can be used to convey Exif, XMP, and MPEG-7 metadata applying to time-parallel samples of the linked image sequence track.

5 HEVC image file format

5.1 Introduction

The HEIF standard includes the specification of encapsulating HEVC-coded images and image sequences into HEIF-compliant files. The specification includes the following aspects:

- The sample entry format and the sample format of HEVC image sequence tracks are identical to those of the HEVC video tracks specified in ISO/IEC 14496-15. For compatibility with HEVC-capable video players, it is therefore advisable to create both an HEVC image sequence track and an HEVC video track that refer to the same coded images.
- The format of the decoder configuration information in the image entry item is identical to that in the sample entry format. Likewise, the item format is identical to the sample format of HEVC video and image sequence tracks. This enables having the same intra-coded image as an image item and as a sample in an HEVC image sequence or video track.
- The configuration information of alpha planes and depth maps follows the respective supplemental enhancement information of HEVC.

5.2 Additional features

Like many other video coding standards, HEVC supports slices that can be regarded as basic units for transmission and may also be used for parallel processing. In addition, HEVC includes parallelization tools, known as tiles and wavefronts, which can be used in encoding and in a limited fashion also in decoding.

The `SubSampleInformationBox` of the ISOBMFF enables indicating byte ranges within a sample and indicate properties for those byte ranges. Sub-sample partitioning based on slices, tiles, and wavefronts (i.e., coding tree unit rows) is specified for HEVC video tracks. The same sub-sample partitioning also inherited by HEVC image items and HEVC image sequence tracks. This signalling can be used for decoding a subset tiles of an image, for example. HEIF also enables grouping of a rectangular set of tiles into an HEVC tile item, which can simplify the operation of a file player when decoding a partial image.

5.3 Constraints for files and requirements for players

Table VIII describes the additional constraints that all HEVC image files have to follow and the additional requirements for HEVC image file players. A primary alternate group is defined for Table VIII to be the alternate group including the cover image. Some of the motivations for including these constraints and requirements in the HEIF standard are provided below the Table VIII.

Table VIII. Constraints for HEVC image files and requirements for HEVC image file players

	Brand	**Constraint or option for files**	**Requirement for players**
Primary alternate group	`heic`, `heix`	Files shall include an image item with a coding format inferred by the brand in the primary alternate group.	Player shall display any image item that has a supported coding format and is in the primary alternate group.
Cropping and rotation	`heic`, `heix`, `hevc`, `hevx`	-	Player shall support clean aperture and rotation by 90, 180, and 270 degrees.
Constraint on inter-picture prediction	`hevc`, `hevx`	Samples in image sequence tracks shall be either intra-coded images or inter-picture predicted images with reference to only intra-coded images.	-

The required support for primary alternate group guarantees proper playback of multi-branded files, where for example the same original image is represented by two alternative images in the file, one coded with HEVC Main profile at 1920x1080 resolution and another coded with HEVC Main 10 profile at 3840x2160 resolution, and both `'heic'` and `'heix'` brands are included in the `FileTypeBox`.

The primary use case for the mandatory support for rotation by 90 degrees is for the photo shooting situations in which the camera orientation is incorrectly detected or concluded. This requirement makes it possible to manually adjust the image or image sequence orientation afterwards without the need for re-encoding the image or image sequence. Similarly, cropping may be useful to enable post-shooting zoom without the need for re-encoding. As rotation by 90, 180, or 270 degrees as well as cropping are mandatory for all HEVC image file players, it is guaranteed that re-encoding is not required to carry out these operations.

The constraints of inter-picture prediction reduce the decoding latency for accessing any particular image within an HEVC image sequence track.

Annex A: comparison to other image formats

Table IX provides a comparison of the features of HEIF to other selected image formats. It can be observed that HEIF is more extensible and comprehensive than the other compared file formats. Particularly the possibility to include other media types, the advanced multi-picture features, and the support for non-destructive editing make HEIF more advanced than the other formats. The rich set of features make HEIF suitable for a broad range of devices and applications, including for example burst photography.

It is acknowledged that a summary such as that in Table IX might be somewhat inaccurate when it comes to features of different formats. For example, the table does not cover some of the extensions of JPEG. The authors welcome feedback and corrections to the table.

The references used to conclude the information in Table IX are included in Table X.

Table IX. Comparison of the features of some image file formats.

	.heic	JPEG/Exif	PNG	GIF (89a)	WebP	JPEG-XR / TIFF	JPEG-XR / JPX	BPG
Formats and extensibility								
Base container file format	ISOBMFF	TIFF	-	-	RIFF	TIFF	-[4]	-
Lossy compression	Yes (HEVC)	Yes (JPEG)	No	No	Yes (VP8)	Yes	Yes	Yes (HEVC[10])
Lossless compression	Yes (HEVC)	Yes (TIFF Rev 6.0)	Yes (PNG)[1]	Yes (GIF)[1]	Yes (VP8L)	Yes	Yes	Yes (HEVC[10])
Extensible to other coding formats	Yes	Yes[8]	No	No	No	Yes[8]	Yes[5]	No
Metadata format (on top of internal)	Exif, XMP, MPEG-7	Exif	-	-	Exif, XMP	Exif, XMP	JPX, (XMP)[6]	Exif, XMP
Extensible to other metadata formats	Yes	No	No	No	No	No	Yes (XML-based)	Yes
Other media types (audio, text, etc.)	Yes	Audio[2]	No	No	No	No	Yes[7]	No
Multi-picture features								
Multiple images in the same file	Yes	No[11]	No	Yes[3]	Yes[3]	No	Yes	Yes[9]
Image sequences / animations	Yes	No	No	Yes	Yes	No	Yes	Yes
Inter coding	Yes	No	No	No	No	No	No	Yes
Derived images								
Multiple-of-90-degree rotations	Yes	Yes	No	No	No	Yes	Yes	No
Cropping	Yes	No	No	No	No	No	Yes	No
Tiling/overlaying	Yes	No	No	No	Yes	No	Yes	No
Extensible to other editing operations	Yes	No	No	No	No	No	No	No
Auxiliary picture information								
Transparency (alpha plane)	Yes	No	Yes	No[12]	Yes	Yes	Yes	Yes
Thumbnail image	Yes	Yes	No	No	No	Yes	Yes	Yes

[1] In GIF and indexed color PNG encoding, lossy color quantization is applied while the color-quantized image is losslessly compressed.
[2] PCM, μ-Law PCM and ADPCM encapsulated in RIFF WAV
[3] Only for animations and tiling/overlaying
[4] JPX is a box-structured format compatible with ISOBMFF. However, only the File Type box is common in JPX and ISOBMFF.
[5] Encapsulation of JPEG-2000 and JPEG-XR have been specified for JPX container. Mappings for other codecs could be similarly specified.
[6] JPX (ITU-T T.800 and T.801) specifies an own metadata schema, but is capable of carrying an XML formatted metadata, such as XMP.
[7] JPX can contain media complying with ISOBMFF (or derivatives thereof). No accurate synchronization between JPX animations and other media.
[8] TIFF as a container format facilitates extensions to other coding formats.
[9] Only for animations, thumbnails, and alpha planes. Non-timed image collections not supported.
[10] HEVC Main 4:4:4 16 Still Picture profile, Level 8.5, with additional constraints
[11] Can be enabled through the MP extension
[12] A palette index for fully transparency can be specified

Table X. References for the compared image file formats

Image format	Version or date	Reference and/or URL
HEIF (.heic)	03/2015	ISO/IEC 23008-12 http://mpeg.chiariglione.org/standards/mpeg-h/image-file-format/draft-text-isoiec-fdis-23008-12-carriage-still-image-and-image
JPEG		ISO/IEC 10918-1 | ITU-T Rec. T.81 http://www.w3.org/Graphics/JPEG/itu-t81.pdf
Exif		http://www.cipa.jp/std/documents/e/DC-008-2012_E.pdf
PNG		http://www.w3.org/TR/PNG/
GIF	89a	http://www.w3.org/Graphics/GIF/spec-gif89a.txt
WebP		https://developers.google.com/speed/webp/docs/riff_container VP8L: https://developers.google.com/speed/webp/docs/webp_lossless_bitstream_specification
JPEG-XR		ISO/IEC 29199-2 | ITU-T Rec. T.832 ISO/IEC 15444-2 | ITU-T Rec. T.801 (for JPX)
BPG	0.9.5	http://bellard.org/bpg/bpg_spec.txt

Annex B: compression performance

In order to assess coding efficiency of the HEVC intra picture coding we carried out a set of experiments using the JCT-VC common test conditions [4]. The resulting picture quality varied typically in the range of 34 dB to 44 dB (in luma peak signal-to-noise ratio) illustrating wide range of quality levels varying from typical web usage to visually lossless levels. More information on the experiment setup is available in [5].

Table XI illustrates coding efficiency of HEVC intra coding with respect to well-known still picture codecs. The results indicate that JPEG would require on average 139 % higher bitrate than HEVC (i.e. 2.39 times the file size) in order to achieve the same objective picture quality. For JPEG-XR and JPEG-2000 the average increase in bitrates are 66 % and 44 %, respectively.

Table XI. HEVC intra coding performance with respect to legacy formats. Bitrate increase required to achieve the objective quality provided by HEVC intra coding is reported for each test category.

Class	Resolution	Characteristics	JPEG	JPEG XR	JPEG 2000
Class A	2560x1600	Cropped 4Kx2K sequences for Ultra HDTV services	87 %	44 %	48 %
Class B	1920x1080	High resolution sequences for streaming and broadcast services	124 %	62 %	15 %
Class C	832x480	Medium resolution sequences for Internet/mobile video services	122 %	53 %	50 %
Class D	416x240	Low resolution sequences for services to resource constrained devices	110 %	47 %	43 %
Class E	1280x720	720p sequences for video conferencing applications	170 %	73 %	23 %
Class F	1024x768, 1280x720	Computer screen content and computer generated content	223 %	118 %	87 %
Average			**139 %**	**66 %**	**44 %**

Subjective testing performed for different test sets appear to verify the results also when it comes to the perceived quality of material coded with different codecs. For instance, [6] reports that typically subjective quality of HEVC intra coded pictures are comparable to that of JPEG coded pictures using twice, or sometimes even four times the bitrate of HEVC.

In order to measure coding efficiency of low latency HEVC encoding structures for different use cases the following experiments were performed. Firstly, the JCT-VC test set [4] was used to mimic image bursts. Eight first frames of each sequence was coded using the fourth picture in each clip as a reference picture for inter coding. Secondly, additional use cases with exposure stack, focal stack and cinemagraph content were simulated by coding a representable sequence in each category. For an exposure stack a well-known "Memorial" sequence with 16

different exposures was used. In the focal stack case a "Mersu" sequence with 13 different focus distances was selected and finally a "Car&Tractor" cinemagraph was used to represent an animated clip where majority of the picture is frozen and certain area of the scene is undergoing motion. The results reported in Table XII indicate that one can expect that for natural content the restricted inter coding can typically provide two to three times better compression than intra picture coding. In special cases like animations where majority of the scene is static the compression efficiency can significantly exceed those levels and be tens of times more efficient than intra coding. More information on the experiment is available in [5].

Table XII. Coding efficiency improvements provided by low latency predictive coding of the HEVC Image File Format. Bitrate impact and coding gain are reported with respect to HEVC intra coding.

Content	Type	Frames	Bitrate change	Coding gain
Class A	Image burst	8	-46 %	1.9
Class B	Image burst	8	-51 %	2.0
Class C	Image burst	8	-60 %	2.5
Class D	Image burst	8	-63 %	2.7
Class E	Image burst	8	-79 %	4.8
Class F	Image burst	8	-55 %	2.2
Memorial	Exposure stack	16	-29 %	1.4
Mersu	Focal stack	13	-25 %	1.3
Car&Tractor	Cinemagraph	48	-97 %	33.3

Annex C: summary of specification changes since the publicly available draft

This Annex summarizes the technical changes between the publicly available draft [2] and the technically frozen HEIF standard [3]. The intent of the Annex is to help readers to get an understanding how the publicly available draft [2] evolved prior to completing the technical standardization. The changes can clustered in the following categories:

1. The image properties (see 3.2) were introduced. The decoder configuration and initialization property replaced the image entry items in [2] and the other descriptive image properties substituted the items of ISOBMFF-derived metadata in [2]. The transformative properties for clean aperture and rotation replaced the respective derived image types in [2]. These changes were carried out mainly to reduce the number of items and item references in the file and consequently to simplify the file structure.

2. The `itemtypes` optional MIME parameter was introduced to carry information for items, whereas previously the `codecs` MIME parameter described both tracks and items.

3. The term pre-derived coded image replaced the term pre-computed derived image, since the term is used as a role for a coded image.

Abbreviations

4CC	four-character code
Exif	Exchangeable image file format
HEIF	High Efficiency Image File Format
HEVC	High Efficiency Video Coding
ICC	International Color Consortium
ISOBMFF	ISO base media file format
MIME	Multi-purpose Internet Mail Extensions
URN	Uniform Resource Name
XMP	Extensible Metadata Platform

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