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| *Title:* | **On ERP equations for sample location remapping and sphere coverage signalling** | | |
| *Status:* | Input document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This contribution proposes to align the sample location remapping process for the equirectangular projection (ERP) and signalling of sphere coverage between the Omnidirectional MediA Format (OMAF) being developed by the MPEG Systems subgroup and the OMAF-related SEI messages being developed by JCT-VC.

The proposal includes the following two parts to the OMAF-related SEI messages:

1. Use a separate SEI message for signalling of sphere coverage information such that the same syntax could be used for any type of projection, and signal the sphere coverage information by specifying the center point of the coverage sphere region, the azimuth and elevation ranges, and the tilt angle of the sphere region. Consequently, remove the sphere coverage parameters from the ERP SEI message.
2. For ERP, if an applicable region-wise packing (RWP) SEI message is not present, the projection equations that involve the sphere coverage parameters apply; otherwise, the projection equations that do not involve the sphere coverage parameters apply. For both cases, the azimuth equation is changed a little bit such that the left side of a full coverage ERP picture corresponds to −180 degree instead of 180 degrees.

Text changes relative to JCTVC-AB1005-v1 are provided in this document (JCTVC-AC0024). The corresponding text changes to the draft OMAF specification for alignment are provided in the MPEG input document m41459.

It is claimed that the proposal and the corresponding OMAF text changes in the MPEG input document m41459 resolve issues #3, #4, #9, and #11 listed in JCTVC-AC0021.

# Introduction

The following alignment issues between OMAF-related SEI messages and OMAF were observed.

1. The ERP SEI message includes signalling of the sphere coverage information as part of the SEI message. However, the cubemap projection (CMP) SEI message does not include signalling of the sphere coverage information. In OMAF, the sphere coverage information is signalled in file format level using a separate structure than that for the projection, and that sphere coverage signalling applies to any projection type.
2. The ERP SEI message uses four parameters for signalling of the sphere coverage information: erp\_azimuth\_min, erp\_azimuth\_max, erp\_elevation\_min, and erp\_elevation\_max. To allow signalling of coverage sphere region that spans across the left and right boundaries of the projected picture, the values of erp\_aizmuth\_min and erp\_aizmuth\_max can be outside the range of −180 to 180 degrees, inclusive. Allowing the azimuth range to be greater than 360 degrees enables support of ERP padding.

In multiple places in OMAF and in the omnidirectional viewport SEI message, a sphere region (including a sphere coverage region) is signalled by indicating its center position and the azimuth and elevation ranges. In addition, a sphere region may be a tilted sphere region indicated by the tilt angle, which is missing in the current sphere coverage signalling in JCTVC-AB1005-v1.

1. Currently, the overall sample location mapping processes are aligned between JCTVC-AB1005-v1 and OMAF. However, there is one significant discrepancy in the mapping equations for the equirectangular projection. In JCTVC-AB1005-v1, the mapping equations for the equirectangular projection involve the sphere coverage parameters, while this is not the case in OMAF.

A basic assumption in OMAF of the overall sample location mapping processes, which involve RWP, is that the projected picture conceptually covers exactly the entire sphere. However, the current ERP equations in JCTVC-AB1005-v1 violates this assumption, but rather assumes that the projected picture covers exactly the indicated sphere coverage, which can be a subset of, the same as, or a subset of the entire sphere. When both the ERP SEI message the RWP SEI message are present, both of the two conflicting assumptions are in use in the sample location mapping processes, and the result would not be correct in this case.

On the other hand, in OMAF, the RWP signalling needs to be present even when the true RWP functionality like region resizing, repositioning, rotation, mirroring as well as advanced guard band are not needed, e.g., for support of sub-sphere coverage and simple ERP padding.

1. OMAF clauses 10.1.2.2 includes the following constraint:

"When the video does not provide full 360 coverage, for each picture, there shall be a region-wise packing SEI messages present in the bitstream that applies to the picture."

However, this constraint wouldn't be needed when the sphere coverage information is present, since for the equirectangular projection the coverage in sphere domain is identical to the coverage in 2D picture domain, which the region-wise packing box provides in this scenario.

In the context of the OMAF-related SEI messages, there were also requests, e.g., from Minhua Zhou of Broadcom, to make the design of the OMAF-related SEI messages work for sub-360 coverage scenarios without mandating the presence of the region-wise packing SEI message when not necessary (i.e., when the projection type is the equirectangular projection and the sphere coverage information is present).

The above issues correspond to issues #3, #4, #9, and #11, respectively, in JCTVC-AC0021.

# Proposal

## Introduction

The proposal includes the following two parts to the OMAF-related SEI messages:

1. Use a separate SEI message for signalling of sphere coverage information such that the same syntax could be used for any type of projection, and signal the sphere coverage information by specifying the center point of the coverage sphere region, the azimuth and elevation ranges, and the tilt angle of the sphere region. Consequently, remove the sphere coverage parameters from the ERP SEI message.
2. For ERP, if an applicable region-wise packing (RWP) SEI message is not present, the projection equations that involve the sphere coverage parameters apply; otherwise, the projection equations that do not involve the sphere coverage parameters apply. For both cases, the azimuth equation is changed a little bit such that the left side of a full coverage ERP picture corresponds to −180 degree instead of 180 degrees.

Except for the new SEI message named the sphere coverage SEI message, other changes relative to JCTVC-AB1005-v1 are marked. The corresponding text changes to the draft OMAF specification for alignment are provided in MPEG input document m41459.

## Sphere coverage SEI message syntax and semantics

|  |  |
| --- | --- |
| sphere\_coverage( payloadSize ) { | **Descriptor** |
| **sphere\_coverage\_cancel\_flag** | u(1) |
| if( !sphere\_coverage\_cancel\_flag ) { |  |
| **sphere\_coverage\_persistence\_flag** | u(1) |
| **sphere\_coverage\_reserved\_zero\_6bits** | u(6) |
| **sphere\_coverage\_shape\_type** | u(8) |
| **sphere\_coverage\_azimuth\_centre** | i(32) |
| **sphere\_coverage\_elevation\_centre** | i(32) |
| **sphere\_coverage\_tilt\_centre** | i(32) |
| **sphere\_coverage\_azimuth\_range** | u(32) |
| **sphere\_coverage\_elevation\_range** | u(32) |
| } |  |
| } |  |

The sphere coverage SEI message indicates the coverage sphere region, which is a sphere region that is covered by the cropped decoded picture. When the indicated coverage sphere region is less than the entire sphere, there may be sphere locations that are outside of the indicated coverage sphere region that are also be covered by the cropped decoded picture.

The coverage sphere region is specified relative to the global coordinate axes.

**sphere\_coverage\_cancel\_flag** equal to 1 indicates that the SEI message cancels the persistence of any previous sphere coverage SEI message in output order. sphere\_coverage\_cancel\_flag equal to 0 indicates that sphere coverage information follows.

**sphere\_coverage\_persistence\_flag** specifies the persistence of the sphere coverage SEI message for the current layer.

sphere\_coverage\_persistence\_flag equal to 0 specifies that the sphere coverage SEI message applies to the current decoded picture only.

Let picA be the current picture. sphere\_coverage\_persistence\_flag equal to 1 specifies that the sphere coverage SEI message persists for the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture picB in the current layer in an access unit containing a sphere coverage SEI message that is applicable to the current layer is output for which PicOrderCnt( picB ) is greater than PicOrderCnt( picA ), where PicOrderCnt( picB ) and PicOrderCnt( picA ) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for picture order count for picB.

When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 is not present in the CLVS and applicable to the current picture and precedes the sphere coverage SEI message in decoding order, a sphere coverage SEI message with sphere\_coverage\_cancel\_flag equal to 0 shall not be present in the CLVS and applicable to the current picture. Decoders shall ignore sphere coverage SEI messages with sphere\_coverage\_cancel\_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 in the CLVS and applicable to the current picture.

When a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 is not present in the CLVS and applicable to the current picture, a sphere coverage SEI message with sphere\_coverage\_cancel\_flag equal to 0 and either sphere\_coverage\_shape\_type not equal to 1 or sphere\_coverage\_tilt\_centre not equal to 0 shall not be present in the CLVS and applicable to the current picture.

**sphere\_coverage\_reserved\_zero\_6bits** shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for sphere\_coverage\_reserved\_zero\_6bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of sphere\_coverage\_reserved\_zero\_6bits.

**sphere\_coverage\_shape\_type** specifies the shape of the coverage sphere region. sphere\_coverage\_shape\_type equal to 0 specifies that the coverage sphere region is specified by four great circles. sphere\_coverage\_shape\_type equal to 1 specifies that the coverage sphere region is specified by two azimuth circles and two elevation circles. Values greater than 1 for sphere\_coverage\_shape\_type are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore sphere coverage SEI messages with sphere\_coverage\_shape\_type greater than 1.

**sphere\_coverage\_azimuth\_centre** and **sphere\_coverage\_elevation\_centre** specify the centre point of the coverage sphere region, in units of 2−16 degrees, relative to the global coordinate axes. The value of sphere\_coverage\_azimuth\_centre shall be in the range of −180 \*216 to 180 \*216 − 1, inclusive. The value of sphere\_coverage\_elevation\_centre shall be in the range of −90 \*216 to 90 \*216, inclusive.

**sphere\_coverage\_tilt\_centre** specifies the tilt angle of the coverage sphere region. The value of sphere\_coverage\_tilt\_centre shall be in the range of −180 \* 216 to 180 \* 216 − 1, inclusive.

**sphere\_coverage\_azimuth\_range** and **sphere\_coverage\_elevation\_range** specify the azimuth and elevation range, respectively, of the coverage sphere region, in units of 2−16 degrees. The value of sphere\_coverage\_azimuth\_range shall be in the range of 216 to 720 \* 216, inclusive. The value of sphere\_coverage\_elevation\_range shall be in the range of 216 to 180 \* 216, inclusive.

When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 is present in the CLVS and applicable to the current picture, and no sphere coverage SEI message with sphere\_coverage\_persistence\_flag equal to 0 is present in the CLVS and applicable to the current picture, the following applies:

– The value of sphere\_coverage\_shape\_type is inferred to be equal to 1.

– The values of sphere\_coverage\_azimuth\_centre, sphere\_coverage\_elevation\_centre, and sphere\_coverage\_tilt\_centre are all inferred to be equal to 0.

– The values of sphere\_coverage\_azimuth\_range and sphere\_coverage\_elevation\_range are inferred to be equal to 360 \* 216 and 180 \* 216, respectively.

The variables AzimuthMin, AzimuthMax, ElevationMin, and ElevationMax are derived as follows:

AzimuthMin = sphere\_coverage\_azimuth\_centre – sphere\_coverage\_azimuth\_range ÷ 2  
AzimuthMax = sphere\_coverage\_azimuth\_centre + sphere\_coverage\_azimuth\_range ÷ 2 (D‑XX)  
ElevationMin = sphere\_coverage\_elevation\_centre – sphere\_coverage\_elevation\_range ÷ 2  
ElevationMax = sphere\_coverage\_elevation\_centre + sphere\_coverage\_elevation\_range ÷ 2

Let sphLocA, sphlocB, sphlocC, and sphlocD be the four sphere locations with sphere coordinates (azimuth, elevation) equal to (AzimuthMin, ElevationMin), (AzimuthMin, ElevationMax), (AzimuthMax, ElevationMax), and (AzimuthMax, ElevationMin), respectively.

When sphere\_coverage\_tilt\_centre is equal to 0, the coverage sphere region is specified by four the great circles (when sphere\_coverage\_shape\_type is equal to 0) or the two azimuth circles and two elevation circles (when sphere\_coverage\_shape\_type is equal to 1) that each passes through at least one of the four pairs of sphere locations {sphlocA, sphlocB}, {sphlocB, sphlocC}, {sphlocC, sphlocD}, and {sphlocD, sphlocA}.

When sphere\_coverage\_tilt\_centre is not equal to 0, the coverage sphere region is the tilted result of the coverage sphere region as specified above when sphere\_coverage\_tilt\_centre is equal to 0. The tilting is performed by rotating the un-tilted coverage sphere region along the axis originating from the sphere origin passing through the centre point of the un-tilted coverage sphere region by sphere\_coverage\_tilt\_centre \* 2-16 degrees, clockwise when looking from the origin towards the positive end of the axis.

When a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 and cmp\_padding\_flag equal to 0 is present in the CLVS that applies to the current picture, a sphere coverage SEI message with sphere\_coverage\_cancel\_flag equal to 0 is present in the CLVS that applies to the current picture, and the indicated coverage sphere region is not exactly the entire sphere, there shall be a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 present in the CLVC that applies to the current picture. [Ed. (YK): This constraint, if agreed, should be moved to the semantics of the region-wise packing SEI message.]

When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 is present in the CLVS that applies to the current picture, a sphere rotation SEI message with sphere\_rotation\_cancel\_flag equal to 0 is present in the CLVS that applies to the current picture, and at least of one of the indicated yaw, pitch, and roll rotation angles is not equal to 0, there shall be a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 present in the CLVC that applies to the current picture. [Ed. (YK): See JCTVC-AC0022 for the specification of the sphere rotation SEI message. This constraint enables specifying the coverage sphere region to be relative to the global coordinate axes, same as in OMAF on file format level and on DASH MPD level. This is because of the ERP remapping equations that involve the coverage sphere region parameters would work only when the coverage sphere region is relative to the local coordinate axes. However, when all the rotation angles are 0, the global and local coordinate axes are the same. If agreed, the constraint should be moved to the semantics of the region-wise packing SEI message.]

## Changes to the ERP SEI message syntax and semantics

|  |  |
| --- | --- |
| equirectangular\_projection( payloadSize ) { | **Descriptor** |
| **erp\_cancel\_flag** | u(1) |
| if( !erp\_cancel\_flag ) { |  |
| **erp\_persistence\_flag** | u(1) |
| **erp\_rotation\_flag** | u(1) |
| **erp**\_**reserved\_zero\_5bits** | u(5) |
| if( erp\_rotation\_flag  = =  1 ) { |  |
| **erp\_yaw\_rotation** | i(32) |
| **erp\_pitch\_rotation** | i(32) |
| **erp\_roll\_rotation** | i(32) |
| } |  |
| } |  |
| } |  |

...

**erp\_rotation\_flag** equal to 1 indicates that a rotation for conversion between the global and local coordinate systems applies. erp\_rotation\_flag equal to 0 indicates that no rotation is applied and the global and local coordinate systems are identical.

**erp**\_**reserved\_zero\_5bits**, when present, shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for erp\_reserved\_zero\_5bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of erp\_reserved\_zero\_5bits.

**erp\_yaw\_rotation** specifies the value of the yaw rotation angle, in units of 2−16 degrees. The value of erp\_yaw\_rotation shall be in the range of −180 \* 216 (i.e., −11 796 480) to 180 \* 216 − 1 (i.e., 11 796 479), inclusive. When not present, the value of erp\_yaw\_rotation is inferred to be equal to 0.

**erp\_pitch\_rotation** specifies the value of the pitch rotation angle, in units of 2−16 degrees. The value of erp\_pitch\_rotation shall be in the range of −90 \* 216 (i.e., −5 898 240) to 90 \* 216 (i.e., 5 898 240), inclusive. When not present, the value of erp\_pitch\_rotation is inferred to be equal to 0.

**erp\_roll\_rotation** specifies the value of the roll rotation angle, in units of 2−16 degrees. The value of erp\_roll\_rotation shall be in the range of −180 \* 216 (i.e., −11 796 480) to 180 \* 216 − 1 (i.e., 11 796 479), inclusive. When not present, the value of erp\_roll\_rotation is inferred to be equal to 0.

## Changes to the sample location remapping process

***D.3.41.5.1 General***

To remap colour sample locations of a region-wise packed picture to a unit sphere, the following ordered steps are applied:

– A region-wise packed picture is obtained as the cropped output picture by decoding a coded picture. For purposes of interpretation of chroma samples, the input to the indicated remapping process is the set of decoded sample values after applying an (unspecified) upsampling conversion process to the 4:4:4 colour sampling format as necessary when chroma\_format\_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format). This (unspecified) upsampling process should account for the relative positioning relationship between the luma and chroma samples as indicated by chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field, when present.

– If region-wise packing is indicated, the sample locations of the region-wise packed picture are converted to sample locations of the respective projected picture as specified in clause D.3.41.5.4. Otherwise, the projected picture is identical to the region-wise packed picture.

– If frame packing is indicated, the sample locations of the projected picture are converted to sample locations of the respective constituent picture of the projected picture, as specified in clause D.3.41.5.6. Otherwise, the constituent picture of the projected picture is identical to the projected picture.

– The sample locations of a constituent picture the projected picture are converted to sphere coordinates relative to the local coordinate axes, as specified in clause D.3.41.5.2.

– If rotation is indicated, the sphere coordinates relative to the local coordinate axes are converted to sphere coordinates relative to the global coordinate axes, as specified in clause D.3.41.5.3. Otherwise, the global coordinate axes are identical to the local coordinate axes.

The overall process for mapping of luma sample locations within a region-wise packed picture to sphere coordinates relative to the global coordinate axes is normatively specified in clause D.3.41.5.5.

For each cropped decoded picture, the following applies:

– If an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 and erp\_rotation\_flag equal to 1 that applies to the picture is present, or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 and cmp\_rotation\_flag equal to 1 that applies to the picture is present, RotationFlag is set equal to 1, and the following applies.

– If equirectangular projection is indicated, RotationYaw, RotationPitch, and RotationRoll are set equal to erp\_yaw\_rotation ÷ 216, erp\_pitch\_rotation ÷ 216, and erp\_roll\_rotation ÷ 216, respectively.

– Otherwise, RotationYaw, RotationPitch, and RotationRoll are set equal to cmp\_yaw\_rotation ÷ 216, cmp\_pitch\_rotation ÷ 216, and cmp\_roll\_rotation ÷ 216, respectively.

– Otherwise, RotationFlag is set equal to 0.

– If a frame packing arrangement SEI message with frame\_packing\_arrangement\_cancel\_flag equal to 0 that applies to the picture is not present, StereoFlag, TopBottomFlag, and SideBySideFlag are all set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

– Otherwise, the following applies:

– StereoFlag is set equal to 1.

– If the value of frame\_packing\_arrangement\_type of the frame packing arrangement SEI message is equal to 3, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 1, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

– Otherwise, if the value of frame\_packing\_arrangement\_type of the frame packing arrangement SEI message is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 2.

– Otherwise, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

– If a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 that applies to the picture is not present, RegionWisePackingFlag is set equal to 0, and ConstituentPicWidth and ConstituentPicHeight are set to be equal to cropPicWidth / HorDiv1 and cropPicHeight / VerDiv1, respectively, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped output picture.

– Otherwise, RegionWisePackingFlag is set equal to 1, and ConstituentPicWidth and ConstituentPicHeight are set equal to proj\_picture\_width / HorDiv1 and proj\_picture\_height / VerDiv1, respectively.

***D.3.41.5.2 Projection for a sample location***

Inputs to this clause are:

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic luma picture, in luma samples, and

– the centre point of a sample location (i, j) along the horizontal and vertical axes, respectively.

Outputs of this clause are:

– sphere coordinates (φ, θ) for the sample location in degrees relative to the coordinate axes specified in clause D.3.41.5.1.

The projection for a sample location is derived as follows:

– If equirectangular projection is indicated and RegionWisePackingFlag is equal 0, the following applies:

φ = ( AzimuthMin + ( i ÷ pictureWidth − 0.5 ) \* ( AzimuthMax − AzimuthMin ) ) \* 2−16 (D‑XX)  
θ = ( ElevationMin + ( 0.5 − j ÷ pictureHeight ) \* ( ElevationMax − ElevationMin ) ) \* 2−16

– Otherwise, if equirectangular projection is indicated and RegionWisePackingFlag is equal 1, the following applies:

φ = ( i ÷ pictureWidth − 0.5 ) \* 360 (D‑XX)  
θ = ( 0.5 − j ÷ pictureHeight ) \* 180

– Otherwise (cubemap projection is indicated), it is a requirement of bitstream conformance that pictureWidth shall be a multiple of 3 and pictureHeight shall be a multiple of 2, and the following applies:

lw = pictureWidth / 3  
lh = pictureHeight / 2  
i′ = −( 2 \* ( i % lw ) ÷ lw ) + 1  
j′ = −( 2 \* ( j % lh ) ÷ lh ) + 1  
w = Floor( i ÷ lw )  
h = Floor( j ÷ lh )  
if( w = = 1 && h = = 0 ) { /\* front face \*/  
 x = 1.0  
 y = −i′  
 z = j′  
} else if( w = = 1 && h = = 1 ) { /\* back face \*/  
 x = −1.0  
 y = j′  
 z = −i′  
} else if( w = = 2 && h = = 1 ) { /\* top face \*/ (D‑XX)  
 x = −i′  
 y = j′  
 z = 1.0  
} else if( w = = 0 && h = = 1 ) { /\* bottom face \*/  
 x = i′  
 y = j′  
 z = −1.0′  
} else if( w = = 0 && h = = 0 ) { /\* right face \*/  
 x = −i′  
 y = −1.0  
 z = j′  
} else { /\* ( w = = 2 && h = = 0 ), left face \*/  
 x = i′  
 y = 1.0  
 z = j′  
}  
φ = Atan2( y, x ) \* 180 ÷ π  
θ =

***D.3.41.5.3 Conversion from the local coordinate axes to the global coordinate axes***

Inputs to this clause are:

– rotation\_yaw (α), rotation\_pitch (β), rotation\_roll (γ), all in units of degrees, and

– sphere coordinates (φ, θ) relative to the local coordinate axes.

Outputs of this clause are:

– sphere coordinates (φ′, θ′) relative to the global coordinate axes.

The outputs are derived as follows:

x1 = Cos( φ ) \* Cos( θ )  
y1 = Sin( φ ) \* Cos( θ )  
z1 = Sin( θ )  
x2 = Cos( β ) \* Cos ( γ ) \* x1 − Cos( β ) \* Sin( γ ) \* y1 + Sin( β ) \* z1  
y2 = ( Cos( α ) \* Sin( γ ) + Sin( α ) \* Sin( β ) \* Cos( γ ) ) \* x1 +  
 ( Cos( α ) \* Cos( γ ) − Sin( α ) \* Sin( β ) \* Sin( γ ) ) \* y1 −  
 Sin( α ) \* Cos( β ) \* z1 (D‑XX)  
z2 = ( Sin( α ) \* Sin( γ ) − Cos( α ) \* Sin( β ) \* Cos( γ ) ) \* x1 +  
 ( Sin( α ) \* Cos( γ ) + Cos( α ) \* Sin( β ) \* Sin( γ ) ) \* y1 +  
 Cos( α ) \* Cos( β ) \* z1  
φ′ = Atan2( y2, x2 ) \* 180 ÷ π  
θ′ = Asin( z2 ) \* 180 ÷ π

***D.3.41.5.4 Conversion of sample locations for rectangular region-wise packing***

Inputs to this clause are:

– sample location (x, y) within the packed region in integer luma sample units,

– the width and the height of the projected region in luma sample units (projRegWidth, projRegHeight),

– the width and the height of the packed region in sample units (packedRegWidth, packedRegHeight),

– transform type (transformType), and

– offset values for sampling position (offsetX, offsetY).

Outputs of this clause are:

– the centre point of the sample location (i, j) within the projected region in sample units.

The outputs are derived as follows:

if( transformType  = =  0  | |  transformType  = =  1  | |  transformType  = =  2  | |  transformType  = =  3 ) {  
 horRatio = projRegWidth ÷ packedRegWidth  
 verRatio = projRegHeight ÷ packedRegHeight  
} else if ( transformType  = =  4  | |  transformType  = =  5  | |  transformType  = =  6  | |  
 transformType  = =  7 ) {  
 horRatio = projRegWidth ÷ packedRegHeight  
 verRatio = projRegHeight ÷ packedRegWidth  
}  
if( transformType = = 0 ) {  
 i = horRatio \* ( x + offsetX )  
 j = verRatio \* ( y + offsetY )  
} else if ( transformType = = 1 ) {  
 i = horRatio \* ( packedRegWidth − x − offsetX )  
 j = verRatio \* ( y + offsetY )  
} else if ( transformType = = 2 ) {  
 i = horRatio \* ( packedRegWidth − x − offsetX )  
 j = verRatio \* ( packedRegHeight − y − offsetY ) (D‑XX)  
} else if ( transformType = = 3 ) {  
 i = horRatio \* ( x + offsetX )  
 j = verRatio \* ( packedRegHeight − y − offsetY )  
} else if ( transformType = = 4 ) {  
 i = horRatio \* ( y + offsetY )  
 j = verRatio \* ( x + offsetX )  
} else if ( transformType = = 5 ) {  
 i = horRatio \* ( y + offsetY )  
 j = verRatio \* ( packedRegWidth − x − offsetX )  
} else if ( transformType = = 6 ) {  
 i = horRatio \* ( packedRegHeight − y − offsetY )  
 j = verRatio \* ( packedRegWidth − x − offsetX )  
} else if ( transformType = = 7 ) {  
 i = horRatio \* ( packedRegHeight − y − offsetY )  
 j = verRatio \* ( x+ offsetX )  
}

***D.3.41.5.5 Mapping of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes***

This clause specifies the semantics of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes.

offsetX is set equal to 0.5 and offsetY is set equal to 0.5.

If RegionWisePackingFlag is equal to 1, the following applies for each packed region n in the range of 0 to num\_regions − 1, inclusive:

– For each sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region with packing\_type[ n ] equal to 0 (i.e., with rectangular region-wise packing), the following applies:

– The corresponding sample location (xProjPicture, yProjPicture) of the projected picture is derived as follows:

– x is set equal to xPackedPicture – packed\_region\_left[ n ].

– y is set equal to yPackedPicture – packed\_region\_top[ n ].

– Clause D.3.41.5.4 is invoked with x, y, packed\_region\_width[ n ], packed\_region\_height[ n ], proj\_region\_width[ n ], proj\_region\_height[ n ], transform\_type[ n ], offsetX and offsetY as inputs, and the output is assigned to sample location (i, j).

– xProjPicture is set equal to proj\_region\_left[ n ] + i.

– When StereoFlag is equal to 0 or TopBottomFlag is equal to 1, and when xProjPicture is greater than or equal to proj\_picture\_width, xProjPicture is set equal to xProjPicture − proj\_picture\_width.

– When SideBySideFlag is equal to 1, the following applies:

– When proj\_region\_left[ n ] is less than proj\_picture\_width / 2 and xProjPicture is greater than or equal to proj\_picture\_width / 2, xProjPicture is set equal to xProjPicture − proj\_picture\_width / 2.

– When proj\_region\_left[n] is greater than or equal to proj\_picture\_width / 2 and xProjPicture is greater than or equal to proj\_picture\_width, xProjPicture is set equal to xProjPicture − proj\_picture\_width / 2.

– yProjPicture is set equal to proj\_region\_top[ n ] + j.

– Clause D.3.41.5.6 is invoked with xProjPicture, yProjPicture, ConstituentPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the luma sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region in the cropped decoded picture.

Otherwise (RegionWisePackingFlag is equal to 0), the following applies for each sample location (x, y) within the cropped decoded picture:

– xPicture is set equal to x + offsetX.

– yPicture is set equal to y + offsetY.

– Clause D.3.41.5.6 is invoked with xPicture, yPicture, ConstituentPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the sample location (x, y) within the cropped decoded picture.

***D.3.41.5.6 Conversion from a sample location in a projected picture or a cropped decoded picture to sphere coordinates relative to the global coordinate axes***

Inputs to this clause are

– the centre point of a sample location (xPicture, yPicture) within a projected picture (when RegionWisePackingFlag is equal to 1) or a cropped decoded picture (when RegionWisePackingFlag is equal to 0), and

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture (when RegionWisePackingFlag is equal to 1) or a monoscopic cropped decoded picture (when RegionWisePackingFlag is equal to 0), in luma samples.

Outputs of this clause are:

– sphere coordinates (azimuthGlobal, elevationGlobal), in units of degrees relative to the global coordinate axes, and

– when StereoFlag is equal to 1, the index of the constituent picture (constituentPicture) equal to 0 or 1.

The outputs are derived with the following ordered steps:

– If xPicture is greater than or equal to pictureWidth or yPicture is greater than or equal to pictureHeight, the following applies:

– constituentPicture is set equal to 1.

– If xPicture is greater than or equal to pictureWidth, xPicture is set to xPicture − pictureWidth.

– If yPicture is greater than or equal to pictureHeight, yPicture is set to yPicture − pictureHeight.

– Otherwise, constituentPicture is set equal to 0.

– Clause D.3.41.5.2 is invoked with pictureWidth, pictureHeight, xPicture, and yPicture as inputs, and the output is assigned to azimuthLocal, elevationLocal.

– If RotationFlag is equal to 1, clause D.3.41.5.3 is invoked with azimuthLocal, elevantionLocal, RotationYaw, RotationPitch, and RotationRoll as inputs, and the output is assigned to azimuthGlobal and elevationGlobal.

– Otherwise, azimuthGlobal is set equal to azimuthLocal and elevationGlobal is set equal to elevationLocal.

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# Patent rights declaration(s)

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