



CREATING THE LIVING NETWORK™

JVET-L0231

CE13: PERP with horizontal geometry
padding of reference pictures (Test 3.3)

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Geometry Padding

- Extends the reference picture boundaries by considering the 3D geometry
- Pads each face with meaningful neighboring samples in the spherical domain
- Geometry padding for ERP is straightforward

Repetitive padding



Geometry padding



X. Ma, H. Yang, Z. Zhao, L. Li, H. Li, “Co-projection-plane based motion compensated prediction for cubic format VR content”, JVET-D0061

J. Sauer, M. Wien, “Geometry correction for motion compensation of planar-projected 360VR video”, JVET-D0067

Y. He, Y. Ye, P. Hanhart, X. Xiu “AHG8: Geometry padding for 360 video coding”, JVET-D0075

C.-H. Shih, H.-C. Lin, J.-L. Lin, S.-K. Chang, “AHG8: Face-based padding for cube projection”, JVET-E0057

Seam Artifact in ERP

- The padded ERP (PERP) format was shown to effectively reduce the seam artifact and was selected as the format used for the 360° CfP anchors
- However, padding and blending may not be sufficient to completely resolve the seam issue, as a seam artifact is still visible in Chairlift
- It was shown that geometry padding of the reference pictures can significantly reduce the remaining seam artifact in PERP

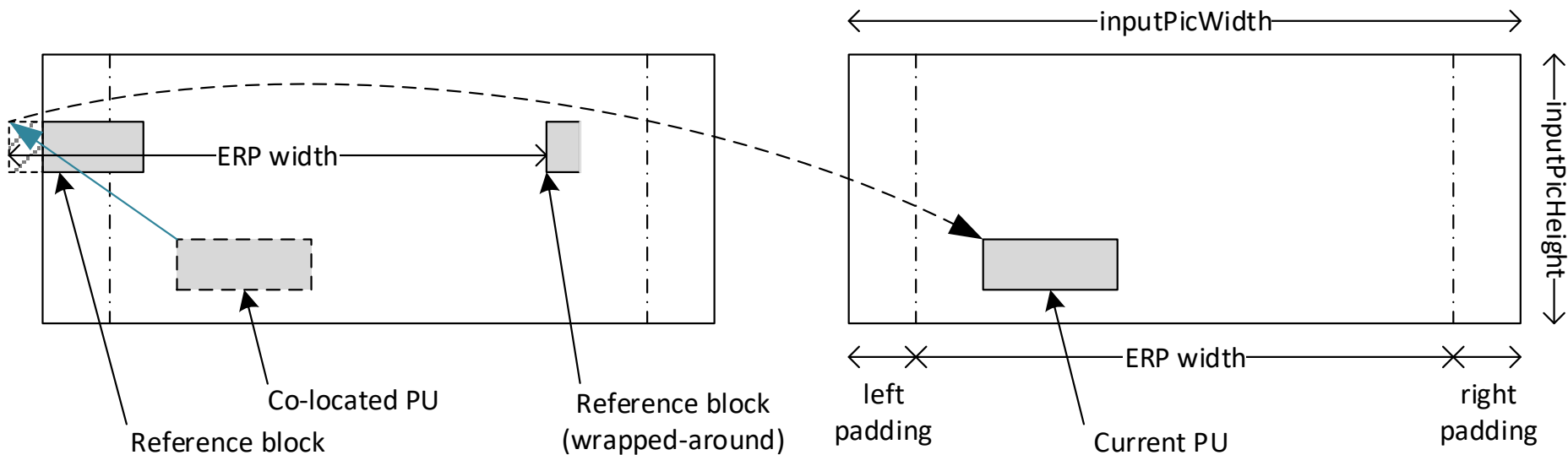
P. Hanhart, Y. He, Y. Ye, “AHG8: Geometry padding for PERP”, JVET-J0044

P. Hanhart, Y. He, Y. Ye, “AHG8: Horizontal geometry padding for PERP”, JVET-K0333

Horizontal Geometry Padding for MCP in PERP

Reference picture

Current picture



M. Zhou, "AHG8: Unrestricted Motion Compensation for 360 Video in ERP Format", JVET-E0065

Simulation Results

| | VTM | | |
|-----------------|------------|------------|------------|
| | BD-rate(Y) | BD-rate(U) | BD-rate(V) |
| SkateboardInLot | -0.53% | -1.11% | -1.18% |
| ChairLift | -0.73% | -0.95% | -0.85% |
| KiteFlite | -0.02% | 0.03% | 0.03% |
| Harbor | -0.03% | -0.05% | -0.10% |
| Trolley | -0.12% | -0.13% | -0.18% |
| GasLamp | -0.01% | 0.02% | 0.01% |
| Balboa | -0.04% | 0.17% | 0.10% |
| Broadway | -0.04% | 0.05% | 0.02% |
| Landing2 | -0.14% | -0.26% | -0.81% |
| BranCastle2 | -0.52% | -0.70% | -0.81% |
| Average | -0.22% | -0.29% | -0.38% |
| Enc Time [%] | 101% | | |
| Dec Time [%] | 98% | | |

Average for moving camera sequences: -0.33%

Subjective Quality Evaluation

- PERP
 - Seam artifact is clearly visible for Chairlift
 - Less visible on still images, but particularly objectionable during video playback
- PERP + horizontal geometry padding
 - Seam artifact in Chairlift is barely noticeable to expert viewers
 - Horizontal geometry padding can significantly reduce the seam artifact for cases where PERP alone is not sufficient

Syntax

| | |
|--|-------------------|
| seq_parameter_set_rbsp() { | Descriptor |
| ... | |
| sps_360_video_flag | u(1) |
| if(sps_360_video_flag) | |
| sps_projection_geometry | ue(v) |
| if(sps_projection_geometry == 0) | |
| sps_geometry_padding_enabled_flag | u(1) |
| if(sps_geometry_padding_enabled_flag) | |
| guard_bands_width_in_luma_samples | ue(v) |
| ... | |
| } | |

| | |
|--------------------------------|----------------------------|
| sps_projection_geometry | Projection geometry |
| 0 | Equirectangular |
| 1 | Cubemap |

Specification – Current

- Luma/chroma sample interpolation process with repetitive padding

$$xInt_L = xPb + x_L + (mvLX[0] \gg 2)$$

$$yInt_L = yPb + y_L + (mvLX[1] \gg 2)$$

$$xA_{i,j} = \text{Clip3}(0, \text{pic_width} - 1, xInt_L + i)$$

$$yA_{i,j} = \text{Clip3}(0, \text{pic_height} - 1, yInt_L + j)$$

$$\text{Clip3}(x, y, z) = \begin{cases} x & ; z < x \\ y & ; z > y \\ z & ; \text{otherwise} \end{cases}$$

| | | | | | | | | | | | | |
|--------------------|--|--|--|-------------------|-------------------|-------------------|-------------------|-------------------|--|--|--|-------------------|
| A _{-1,-1} | | | | A _{0,-1} | a _{0,-1} | b _{0,-1} | c _{0,-1} | A _{1,-1} | | | | A _{2,-1} |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| A _{-1,0} | | | | A _{0,0} | a _{0,0} | b _{0,0} | c _{0,0} | A _{1,0} | | | | A _{2,0} |
| d _{-1,0} | | | | d _{0,0} | e _{0,0} | f _{0,0} | g _{0,0} | d _{1,0} | | | | d _{2,0} |
| h _{-1,0} | | | | h _{0,0} | i _{0,0} | j _{0,0} | k _{0,0} | h _{1,0} | | | | h _{2,0} |
| n _{-1,0} | | | | n _{0,0} | p _{0,0} | q _{0,0} | r _{0,0} | n _{1,0} | | | | n _{2,0} |
| A _{-1,1} | | | | A _{0,1} | a _{0,1} | b _{0,1} | c _{0,1} | A _{1,1} | | | | A _{2,1} |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| A _{-1,2} | | | | A _{0,2} | a _{0,2} | b _{0,2} | c _{0,2} | A _{1,2} | | | | A _{2,2} |

Specification – Modified

- Luma/chroma sample interpolation process with horizontal geometry padding for ERP

$$xInt_L = xPb + x_L + (mvLX[0] \gg 2)$$

$$yInt_L = yPb + y_L + (mvLX[1] \gg 2)$$

$$xA_{i,j} = \text{ClipH}(\text{pic_width}, \text{face_width}, xInt_L + i)$$

$$yA_{i,j} = \text{Clip3}(0, \text{pic_height} - 1, yInt_L + j)$$

$$\text{ClipH}(P, F, x) = \begin{cases} x + F & ; x < 0 \\ x - F & ; x > P - 1 \\ x & ; \text{otherwise} \end{cases}$$

| | | | | | | | | | | | | |
|--------------------|--|--|--|-------------------|-------------------|-------------------|-------------------|-------------------|--|--|--|-------------------|
| A _{-1,-1} | | | | A _{0,-1} | a _{0,-1} | b _{0,-1} | c _{0,-1} | A _{1,-1} | | | | A _{2,-1} |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| A _{-1,0} | | | | A _{0,0} | a _{0,0} | b _{0,0} | c _{0,0} | A _{1,0} | | | | A _{2,0} |
| d _{-1,0} | | | | d _{0,0} | e _{0,0} | f _{0,0} | g _{0,0} | d _{1,0} | | | | d _{2,0} |
| h _{-1,0} | | | | h _{0,0} | i _{0,0} | j _{0,0} | k _{0,0} | h _{1,0} | | | | h _{2,0} |
| n _{-1,0} | | | | n _{0,0} | p _{0,0} | q _{0,0} | r _{0,0} | n _{1,0} | | | | n _{2,0} |
| A _{-1,1} | | | | A _{0,1} | a _{0,1} | b _{0,1} | c _{0,1} | A _{1,1} | | | | A _{2,1} |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| A _{-1,2} | | | | A _{0,2} | a _{0,2} | b _{0,2} | c _{0,2} | A _{1,2} | | | | A _{2,2} |

Conclusion

- Horizontal geometry padding for (P)ERP is the simplest case of geometry padding
 - Same complexity as repetitive padding
 - Same worst-case as repetitive padding
 - Same memory bandwidth as repetitive padding
- Advantages
 - Can be applied to other projection formats, e.g., Lambert cylindrical equal-area projection
 - Can significantly reduce the seam artifact for cases where PERP alone is not sufficient
- Recommending it for adoption allows us to
 - Probe the water in the main track
 - Pave the way for more complex 360° video coding tools if adopted

THANK YOU!

