Patch Decoder-Side Depth Estimation in MPEG Immersive Video

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Outline

1. MPEG Immersive Video
2. Test Model for Immersive Video
3. Proposed Method
4. Results
5. Discussion and Summary

Patch Decoder-Side Depth Estimation in MPEG Immersive Video, Marta Milovanović, July 2021
MPEG Immersive Video (MIV)

- ISO/IEC 23090-12 MPEG Immersive Video (MIV) specification
- Standard for streaming and storage of immersive content
- Aims to provide the 6 DoF (degrees of freedom) user experience
- MIV does not utilize specialized depth coding tools
- MIV constraints: bitrate, pixel rate, number of simultaneous 2D decoders
- Variety of use cases and devices: head mounted displays, light field displays, tablets, laptops...

https://mpeg-miv.org/
https://venturebeat.com/2019/05/05/how-virtual-reality-positional-tracking-works/
MPEG Immersive Video (MIV)

- Input format: Multiview video plus depth (MVD)
- 3D scene is captured by multiple real or virtual cameras
- Depth maps can be computer generated or natural
- Computer generated depth maps are obtained using mathematical models of a 3D scene
- Natural depth maps are obtained by a sensor or some depth estimation algorithm (not perfect)
- Output format: texture and depth atlases
- These video data streams are compressed by 2D video codecs

https://mpeg-miv.org/index.php/content-database-2/
Representing source views using patch atlases

Pruned view reconstruction

Basel Salahieh, Bart Kroon, Joel Jung, and Marek Domanski,
TMIV Encoder & Decoder

Encoder

- Source camera parameters list
- Source views (T+D+E)
- Transport views, basic view flags, view parameters, sequence parameters
- Components are: T: Texture (opt), D: Depth/occupancy, E: Entity (opt)
- View optimizer

Decoder

- HEVC bitstream
- Block to patch map decoder
- MIV decoder and parser
- Attribute component
- Geometry component
- PatchId map
- Atlas data AD & Patch parameter list
- V-PCS parameter set VPS & Adaptation parameter set APS
- Render controller (incl. viewing space & depth/occupancy handling)
- Geometry scaler
- Culler
- Synthesizer
- Inpainter

The pruning process removes the inter-view redundancy

The pruner uses three criteria to determine if a pixel may be pruned:
- The pixel should be synthesized from the views higher up in the hierarchy
- The difference between synthesized and source geometry should be less than a threshold
- The minimum difference between luma of a synthesized pixel and luma of all pixels within a collocated source 3×3 block should be less than a pruning luma threshold

Second-pass pruning: identifying the pixels that are not to be pruned among the pixels that were initially determined to be pruned (global color component differences)

Temporal consistency: the pruning masks are aggregated frame-by-frame and reset at the beginning of each intra period

The pruning graph is created:
Proposed Method

• Goal:
  • Reduce the transmission of the depth data in the context of TMIV

• Motivation:
  • MIV constraints (bitrate, pixel rate, number of 2D decoders)
  • Decoder-Side Depth Estimation: transmission of the depth maps is not needed

• The main idea:
  • Omit the depth component of some patches that belong to pruned views

Proposed Method

- Use the information available at the decoder side:
- Recover the pruned views: take the patches from atlases and put them to the correct positions in corresponding views using the metadata information
- Estimate the patch-depth using all textures from available basic views and the corresponding pruned view
Proposed Method

Process diagram for anchor (switch = 1) and proposed method (switch = 0) in TMIV framework
Outline

MPEG Immersive Video
Test Model for Immersive Video
Proposed Method
Results
Discussion and Summary
Synthesis Results

<table>
<thead>
<tr>
<th>Sequence</th>
<th>CTC - High bitrate</th>
<th>CTC - Medium bitrate</th>
<th>Low bitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaman (CG)</td>
<td>26.34</td>
<td>8.99</td>
<td>0.73</td>
</tr>
<tr>
<td>Kitchen (CG)</td>
<td>66.95</td>
<td>30.33</td>
<td>10.72</td>
</tr>
<tr>
<td>Painter (NC)</td>
<td>2.75</td>
<td>-7.81</td>
<td>-12.86</td>
</tr>
<tr>
<td>Frog (NC)</td>
<td>3.57</td>
<td>-3.49</td>
<td>-8.01</td>
</tr>
<tr>
<td>Fencing (NC)</td>
<td>-12.33</td>
<td>-16.02</td>
<td>-18.35</td>
</tr>
<tr>
<td>Carpark (NC)</td>
<td>0.26</td>
<td>-8.33</td>
<td>-12.63</td>
</tr>
<tr>
<td>Street (NC)</td>
<td>-6.10</td>
<td>-8.67</td>
<td>-10.65</td>
</tr>
<tr>
<td>Hall (NC)</td>
<td>-8.53</td>
<td>-9.48</td>
<td>-10.17</td>
</tr>
<tr>
<td>Average (all)</td>
<td>9.11</td>
<td>-1.81</td>
<td>-7.65</td>
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<tr>
<td>Average (NC)</td>
<td>-3.40</td>
<td>-8.97</td>
<td>-12.11</td>
</tr>
</tbody>
</table>

Table 1. BD-rate results per test sequence, in terms of Y-PSNR of synthesized texture [%]. Negative values indicate gains.

+ pixel rate reduction of 8.3% per sequence

<table>
<thead>
<tr>
<th>Sequence</th>
<th>High VMAF</th>
<th>Med VMAF</th>
<th>Low VMAF</th>
<th>High MS-SSIM</th>
<th>Med MS-SSIM</th>
<th>Low MS-SSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaman (CG)</td>
<td>3.44</td>
<td>-6.69</td>
<td>-11.53</td>
<td>20.60</td>
<td>1.54</td>
<td>-6.33</td>
</tr>
<tr>
<td>Kitchen (CG)</td>
<td>46.96</td>
<td>12.77</td>
<td>-0.28</td>
<td>20.14</td>
<td>5.08</td>
<td>-3.38</td>
</tr>
<tr>
<td>Frog (NC)</td>
<td>-3.57</td>
<td>-8.57</td>
<td>-11.13</td>
<td>6.19</td>
<td>-5.49</td>
<td>-10.07</td>
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<tr>
<td>Fencing (NC)</td>
<td>-12.91</td>
<td>-16.87</td>
<td>-19.60</td>
<td>-3.74</td>
<td>-13.29</td>
<td>-17.03</td>
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<tr>
<td>Carpark (NC)</td>
<td>-5.53</td>
<td>-13.14</td>
<td>-16.52</td>
<td>-1.70</td>
<td>-12.27</td>
<td>-16.15</td>
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<tr>
<td>Street (NC)</td>
<td>-7.00</td>
<td>-9.52</td>
<td>-11.32</td>
<td>-6.54</td>
<td>-9.31</td>
<td>-11.29</td>
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<tr>
<td>Hall (NC)</td>
<td>-10.84</td>
<td>-13.35</td>
<td>-15.09</td>
<td>3.93</td>
<td>-5.73</td>
<td>-10.22</td>
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<tr>
<td>Average (all)</td>
<td>-0.31</td>
<td>-9.25</td>
<td>-13.35</td>
<td>4.33</td>
<td>-6.68</td>
<td>-11.59</td>
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<tr>
<td>Average (NC)</td>
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<td>-13.34</td>
<td>-15.83</td>
<td>-1.01</td>
<td>-10.01</td>
<td>-13.83</td>
</tr>
</tbody>
</table>

Table 2. BD-rate results per test sequence, in terms of VMAF and MS-SSIM metrics [%]. Negative values indicate gains.
Synthesis Results

**Fencing**

- Anchor
- Proposed method

**Hall**

- Anchor
- Proposed method

**Street**

- Anchor
- Proposed method

**Carpark**

- Anchor
- Proposed method
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Discussion and Summary

• We demonstrate:
  • Gains measured with objective metrics for natural content:
    • 3.4%, 9.0%, 12.1% Y-PSNR BD-rate gains on high, medium, and low bitrate, respectively
    • Preserved perceptual quality as measured with MS-SSIM and VMAF
    • Pixel rate reduction of 8.3% per sequence
  • For CG content, comparison is done with the Blender ground-truth depths!

• Limitations:
  • Pruning strategy
  • Local depth estimation on very small patch areas
  • Depth estimation from compressed textures
Discussion and Summary

Future work:

• Adapt the pruning strategy to ensure a reliable patch depth estimation at the decoder side
• Current tests involve patch level decisions based on depth estimation quality
• This approach gives new possibilities, e.g. sending more textures, instead of depths

Thank you for your attention!
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