MetaHDR: Model-Agnostic Meta-Learning for HDR Image Reconstruction

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Motivation

In Low Dynamic Range (LDR) to High Dynamic Range (HDR) conversion, there exists a nonlinear mapping between the scene radiance and the pixel values.

Existing deep learning models learn a single nonlinear mapping across all scenes, cameras, etc.

We propose the use of a meta-learning framework that learns an infinite set of nonlinear mappings by producing a set of meta-parameters which capture the common structure of LDR-to-HDR non-linear mapping.

At test time, given specific examples of LDR images in a scene, our model can quickly adapt to the optimal task-specific nonlinear mapping.

Approach & Model Architecture

A set of scene-exposures is interpreted as a task. For $i$ tasks in a batch, pass through the MAML\(^{[4]}\) model. The loss function\(^{[5]}\) incorporates similarity and L1 distance. One pass involves 3 steps:

1. Compute task-specific $\phi_i$ for the UNet by optimizing meta-params $\theta$ (i.e., weights).
2. Use $\phi_i$ to compute HDR for test LDR image.
3. Accumulate loss and adjust meta-params $\theta$.

Discussion

Conclusion: Our novel approach for HDR image reconstruction generates comparable results to state-of-the-art. Model performs well in the single-shot setting. Few-shot setting improves results.

Challenges: Color saturation was hard to maintain between input and output.

Limitations: While single-shot reconstruction works, the model performs better when given more LDR exposures per scene. Labels need to simulated at meta-test time for model adaptation.\(^{[3]}\)

Future Work: Incorporate loss functions that prioritize saturated pixels during reconstruction. Train with more exposures per scene, and a wider variety of scenes.

Quantitative Results

<table>
<thead>
<tr>
<th></th>
<th>SSIM (†)</th>
<th>PSNR (dB) (†)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR No Recon.</td>
<td>0.489</td>
<td>12.200</td>
</tr>
<tr>
<td>Single Shot</td>
<td>0.666</td>
<td>15.777</td>
</tr>
<tr>
<td>Adaptation with True HDR(^{[2]})</td>
<td>0.683</td>
<td>19.753</td>
</tr>
<tr>
<td>Adaptation with Simulated HDR(^{[3]})</td>
<td>0.687</td>
<td>19.728</td>
</tr>
</tbody>
</table>

\(^{†}\) Averaged over all meta test set images.

Note: Labels refer to labels used for task-specific adaptation in meta-training.

References

5. Marnnerides et. Al. Eurographics, Vol:37, 2018