AI for Computational Photography

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Note: This presentation contains a slide with flashing imagery.
Computational photography refers to image capture and processing using digital computation (instead of optical processes). It’s a core topic in “low level” computer vision.

What is computational photography?

- Super-resolution
- Denoising
- Inpainting
- See in the dark
- Automatic white balance
- Super-resolution
Why is this interesting?

Sony a7R III

Google Pixel 3

https://www.dxomark.com/smartphones-vs-cameras-closing-the-gap-on-image-quality/
We’re taking a lot of photos…

1.4 Trillion photos will be taken in 2020

Proving the adage ‘you’ll never have fewer digital pictures than before’, the number of photos taken worldwide is expected to grow again in 2020.

...on our smartphones

But how to get more out of our photos?

https://www.clickinmoms.com/blog/reasons-deliberately-underexpose-photo/
A traditional Image Signal Processor (ISP) is a pipeline of image processing algorithms to transform the raw data acquired by the image sensor into a high quality JPG image.

Can one use Deep Learning in the ISP?

Can one replace the ISP with a neural network?
DeepISP

DeepISP is a convolutional neural network that maps from RAW sensor data to a high quality RGB image.

- Low level network: denoising, demosaicing
- High level network: transforms colours using a quadratic function

Image enhancement using curve layers

- Photoshop / Lightroom allows users to adjust global image properties through the use of curves.

Example: adjusting brightness

- Can we build a neural network to perform these types of operations automatically?
We recently introduced neural **CURve Layers (CURL)** which learns and applies curve adjustments to an image. CURL has the following features:

- Curves are piecewise linear
- Curves can flexibly adjust different image attributes (brightness, saturation, colour)
- Different colour spaces (RGB, HSV, LAB) supported
- Fully differentiable and trained end-to-end
- Predicted curves are intuitive and can be user adjusted
- State-of-the-art performance
CURL architecture
Transformed Encoder/Decoder (TED)

UNet style encoder/decoder but uses a multi-scale contextual awareness (MSCA) connection
A CURL block is a multi-colour space neural retouching block that estimates enhancement curves.
Loss and ablation studies

\[ \mathcal{L} = \sum_{i=1}^{N} \mathcal{L}_{hsv}^i + \mathcal{L}_{lab}^i + \mathcal{L}_{rgb}^i + \mathcal{L}_{reg}^i \]

Loss is designed to control each of the colour-space specific transformations in CURL.
Results

DeepISP (28.19 dB)  TED+ CURL (29.37 dB)  Groundtruth

DeepUPE (16.85 dB)  TED+ CURL (23.55 dB)  Groundtruth
### Tables

#### Ordering through colour spaces

<table>
<thead>
<tr>
<th>Ordering</th>
<th>PSNR (test)↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSV → RGB → LAB</td>
<td>26.20</td>
</tr>
<tr>
<td>RGB → HSV → LAB</td>
<td>26.83</td>
</tr>
<tr>
<td>LAB → RGB → HSV</td>
<td><strong>27.09</strong></td>
</tr>
<tr>
<td>LAB → HSV → RGB</td>
<td>26.37</td>
</tr>
<tr>
<td>RGB → LAB → HSV</td>
<td>25.32</td>
</tr>
<tr>
<td>HSV → LAB → RGB</td>
<td>26.53</td>
</tr>
</tbody>
</table>

#### RAW to RGB

<table>
<thead>
<tr>
<th>Architecture</th>
<th>PSNR↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>TED + CURL</td>
<td>27.04</td>
</tr>
<tr>
<td>TED</td>
<td>26.56</td>
</tr>
</tbody>
</table>

#### RGB to RGB

<table>
<thead>
<tr>
<th>Architecture</th>
<th>PSNR↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>TED+CURL</td>
<td><strong>24.20</strong></td>
</tr>
<tr>
<td>DPE [3]</td>
<td>22.15</td>
</tr>
<tr>
<td>White-Box [2]</td>
<td>18.57</td>
</tr>
<tr>
<td>DeepUPE [1]</td>
<td>23.04</td>
</tr>
</tbody>
</table>
DeepLPF for local image enhancement

Graduated filters

Elliptical filters
Thank you