AI for Computational Photography

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Note: This presentation contains a slide with flashing imagery.

What is computational photography?

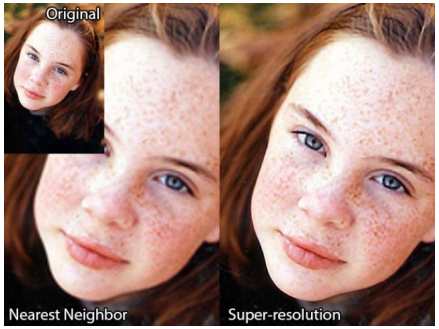
Computational photography refers to image capture and processing using digital computation (instead of optical processes). It's a core topic in "low level" computer vision.

Denoising

Inpainting

Automatic white balance

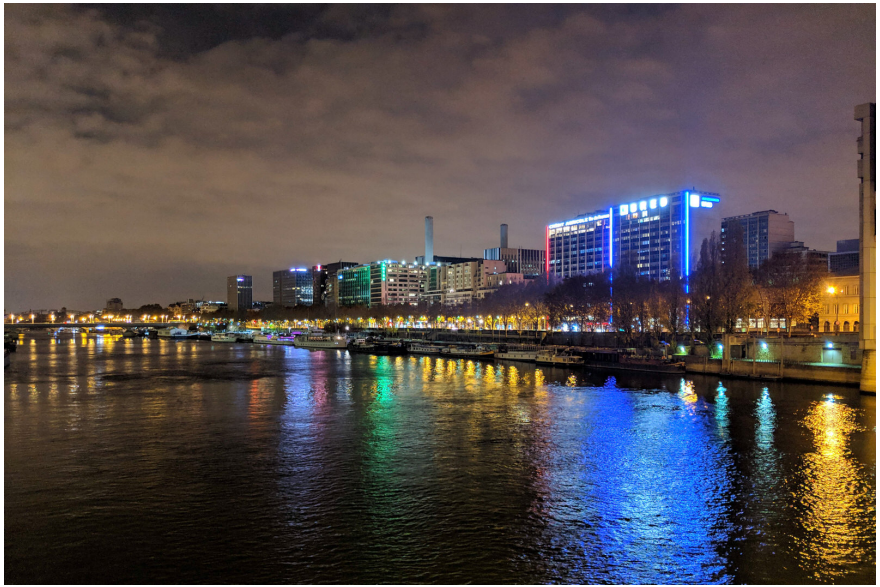
See in the dark



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…

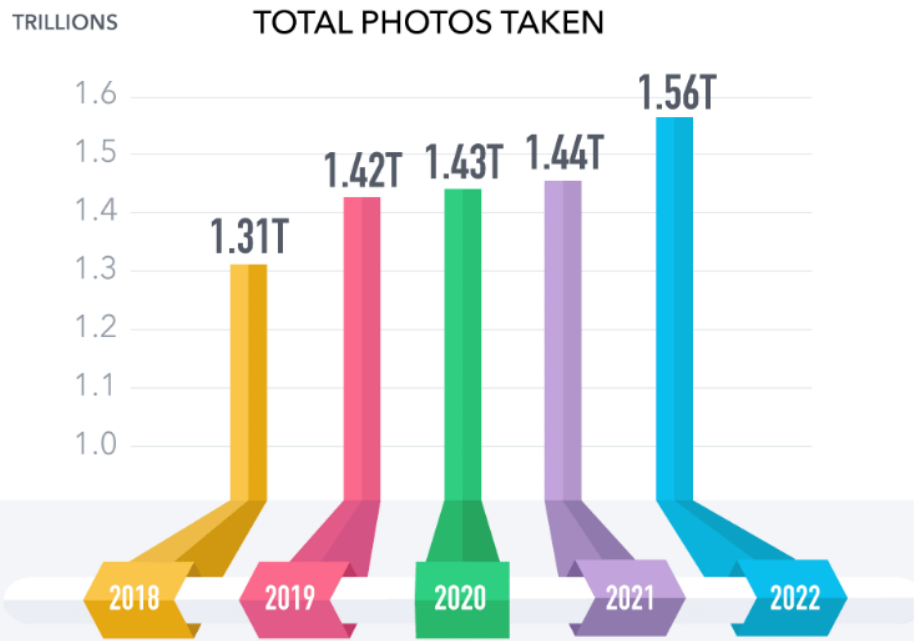
1.4 Trillion

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.

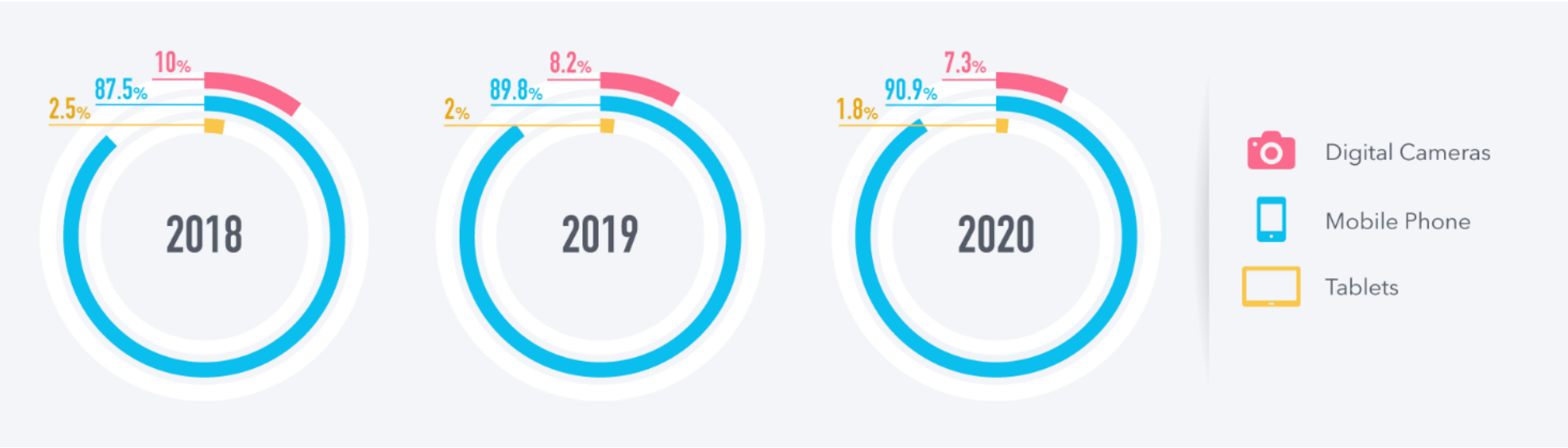
8.3%

Compound Annual Growth Rate



https://focus.mylio.com/tech-today/how-many-photos-will-be-taken-in-2020

…on our smartphones



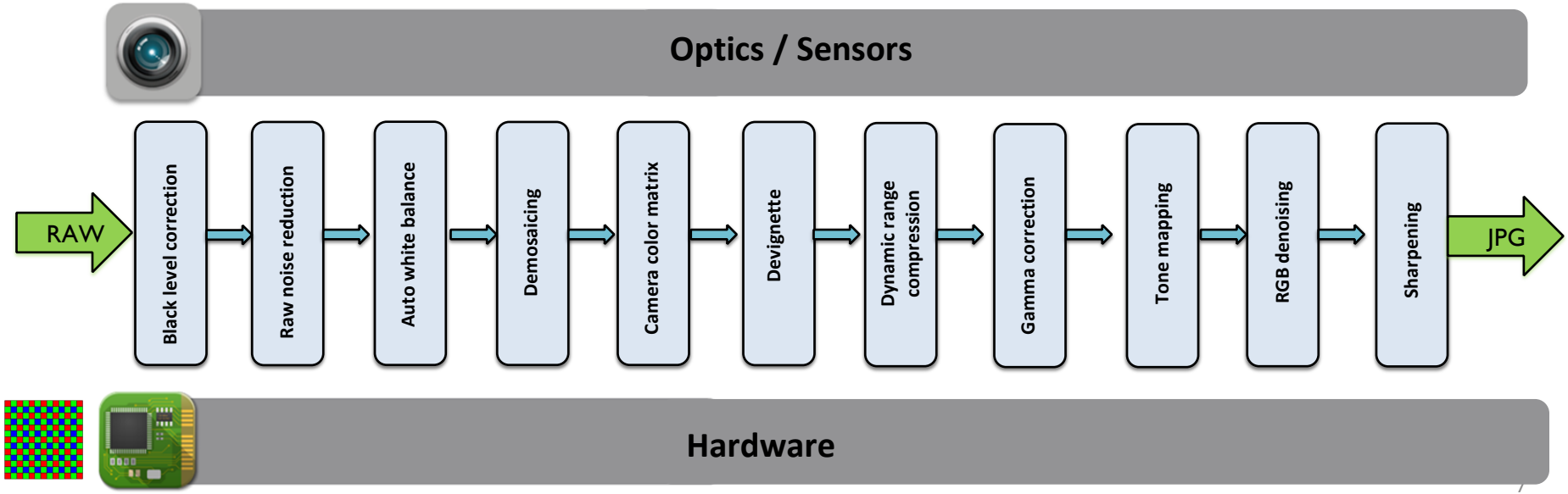
https://focus.mylio.com/tech-today/how-many-photos-will-be-taken-in-2020

But how to get more out of our photos?

https://www.clickinmoms.com/blog/reasons-deliberately-underexpose-photo/

Traditional ISP pipeline

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.



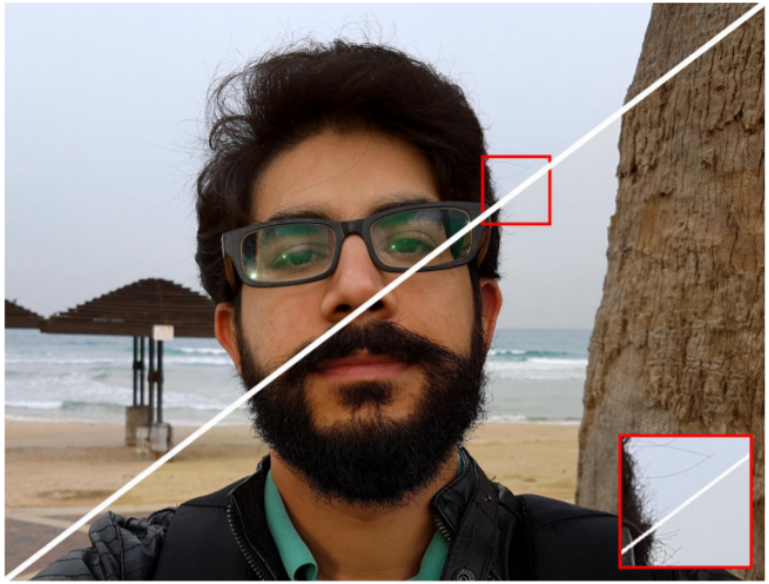
⇨ Can one use Deep Learning in the ISP?

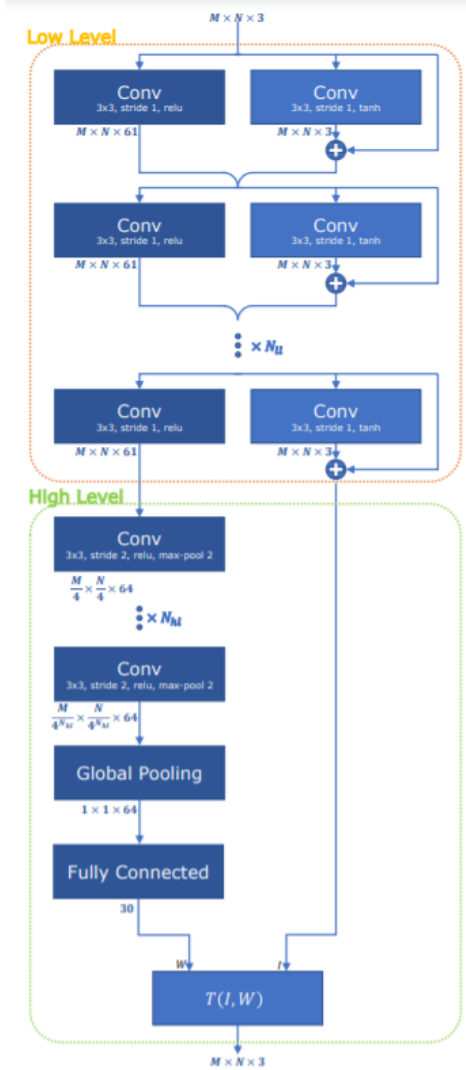
⇨ Can one *replace* the ISP with a neural network?

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



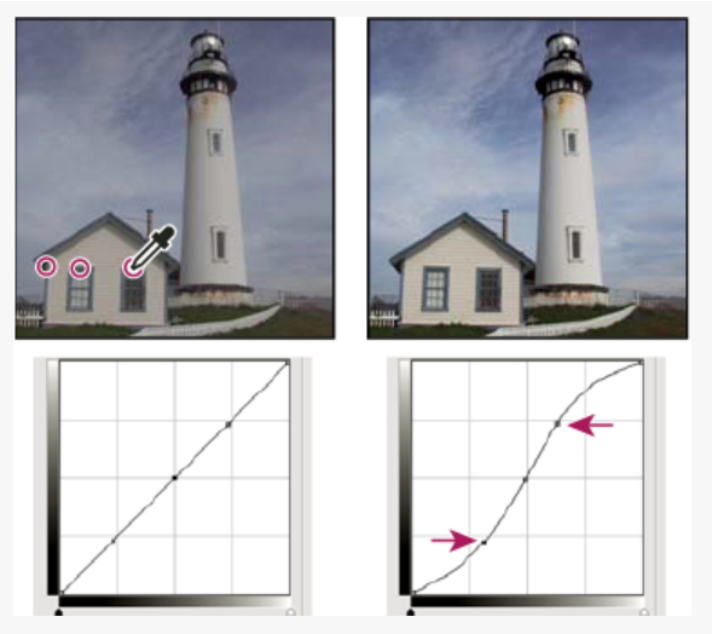


DeepISP: Toward Learning an End-to-End Image Processing Pipeline, Eli Schwartz, Raja Giryes, Alex M. Bronstein, IEEE Transactions on Image Processing, 28(2), 2019.

Image enhancement using curve layers

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

Example: adjusting brightness

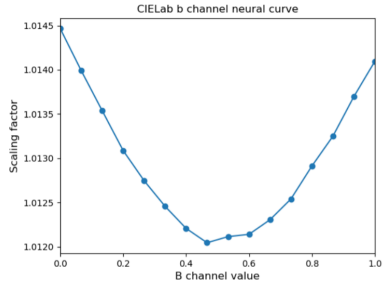


⇨ **Can we build a neural network perform these types of operations automatically**?

CURL

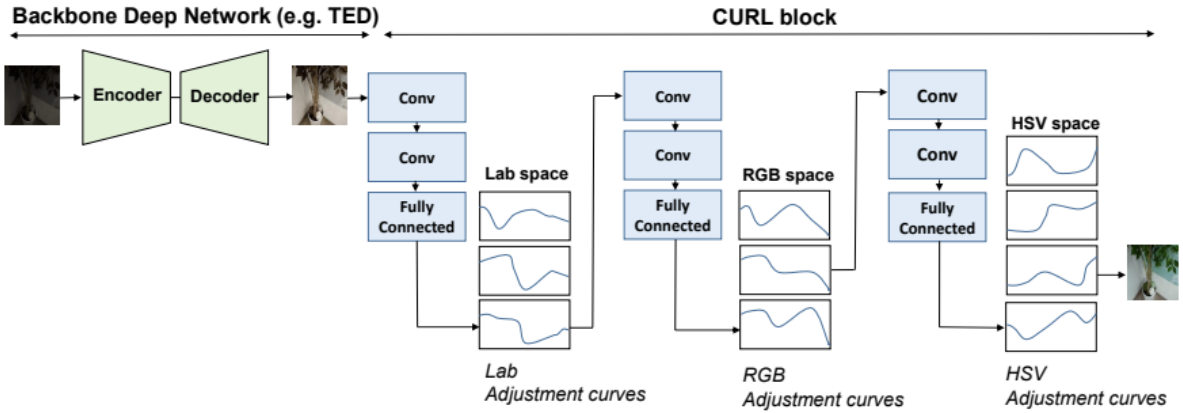
We recently introduced neural **CUR**ve **L**ayers (CURL) which learns and applies curve adjustments to an image. CURL has the following features:

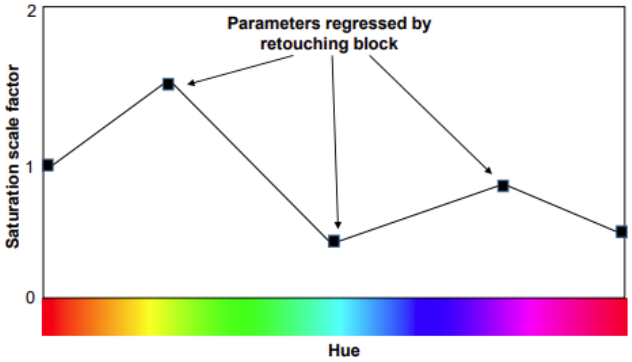
- Curves are piecewise linear
- Curves can flexibly adjust different image attributes (brightness, saturation, colour)
- Different colour spaces (RGB, HSV, LAB) supported
- Fully differentiable and trained end-to-end
- Predicted curves are intuitive and can be user adjusted
- State-of-the-art performance



CURL: Neural Curve Layers for Global Image Enhancement, Sean Moran, Steven McDonagh, Greg Slabaugh, to appear *ICPR 2020*

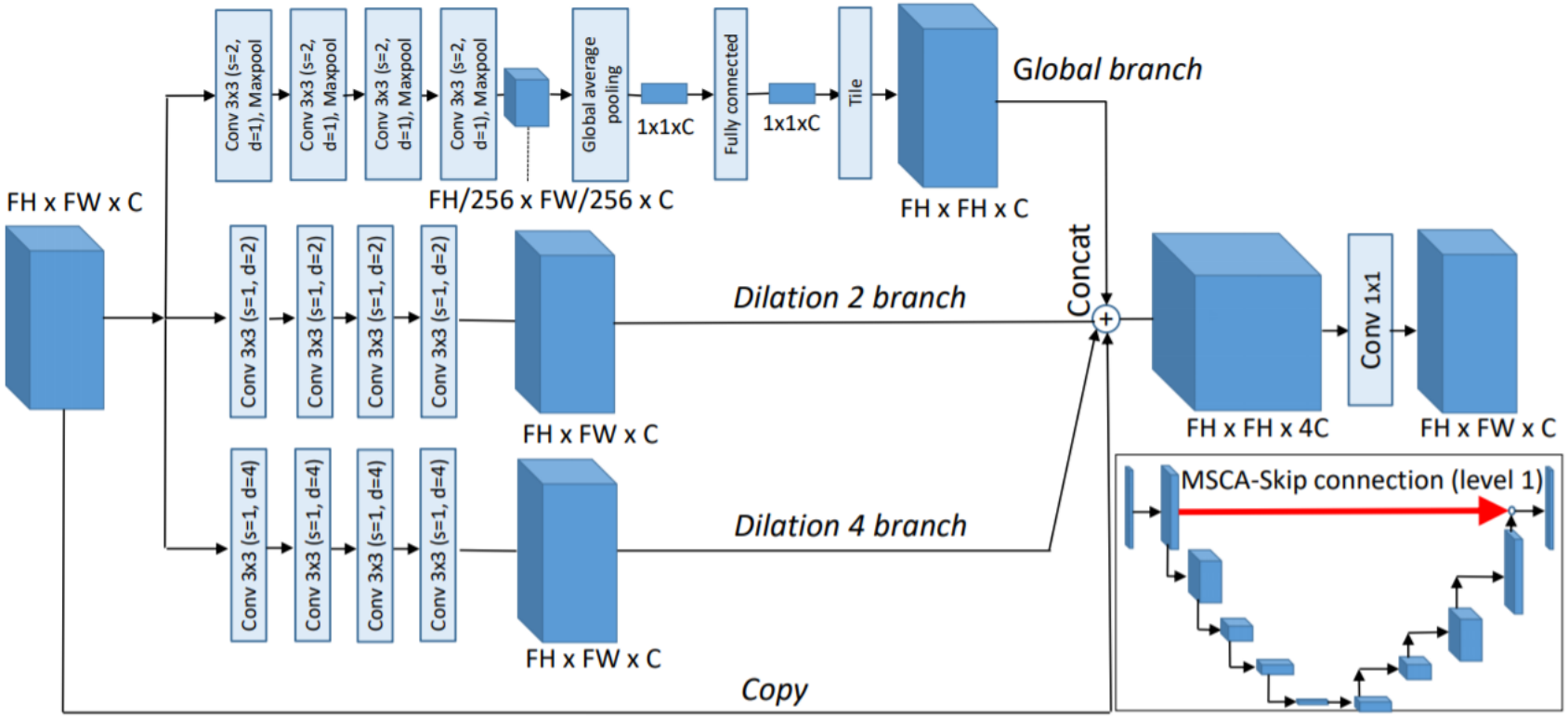
CURL architecture





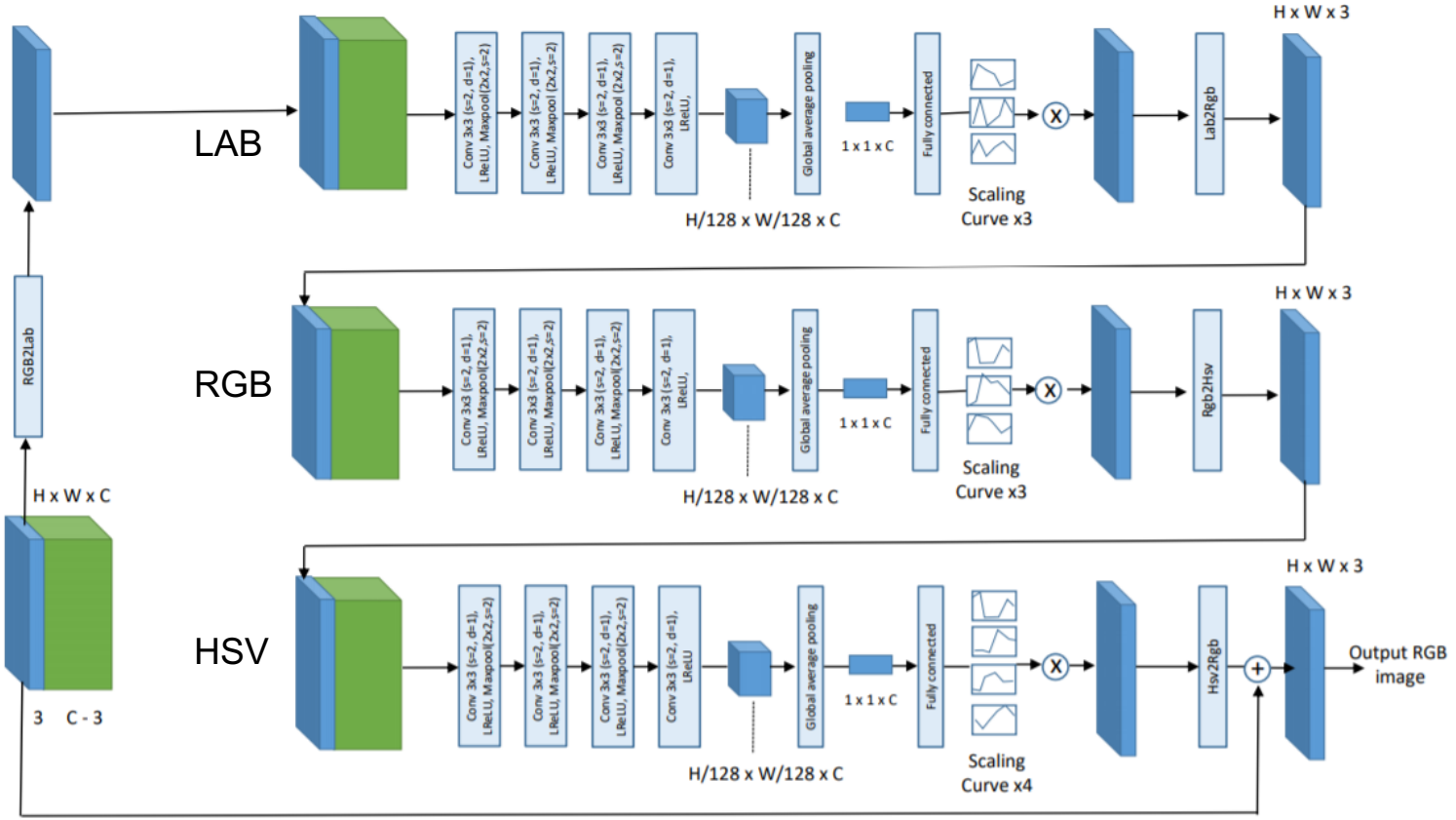
Transformed Encoder/Decoder (TED)

UNet style encoder/decoder but uses a multi-scale contextual awareness (MSCA) connection



CURL block

A CURL block is a multi-colour space neural retouching block that estimates enhancement curves



Loss and ablation studies

$$\mathcal{L} = \sum_{i=1}^{N} \mathcal{L}^i_{hsv} + \mathcal{L}^i_{lab} + \mathcal{L}^i_{rgb} + \mathcal{L}^i_{reg}$$

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	PSNR (test)↑
HSV→RGB→LAB	26.20
RGB→HSV→LAB	26.83
LAB→RGB→HSV	**27.09**
LAB→HSV→RGB	26.37
RGB→LAB→HSV	25.32
HSV→LAB→RGB	26.53

Ordering through colour spaces

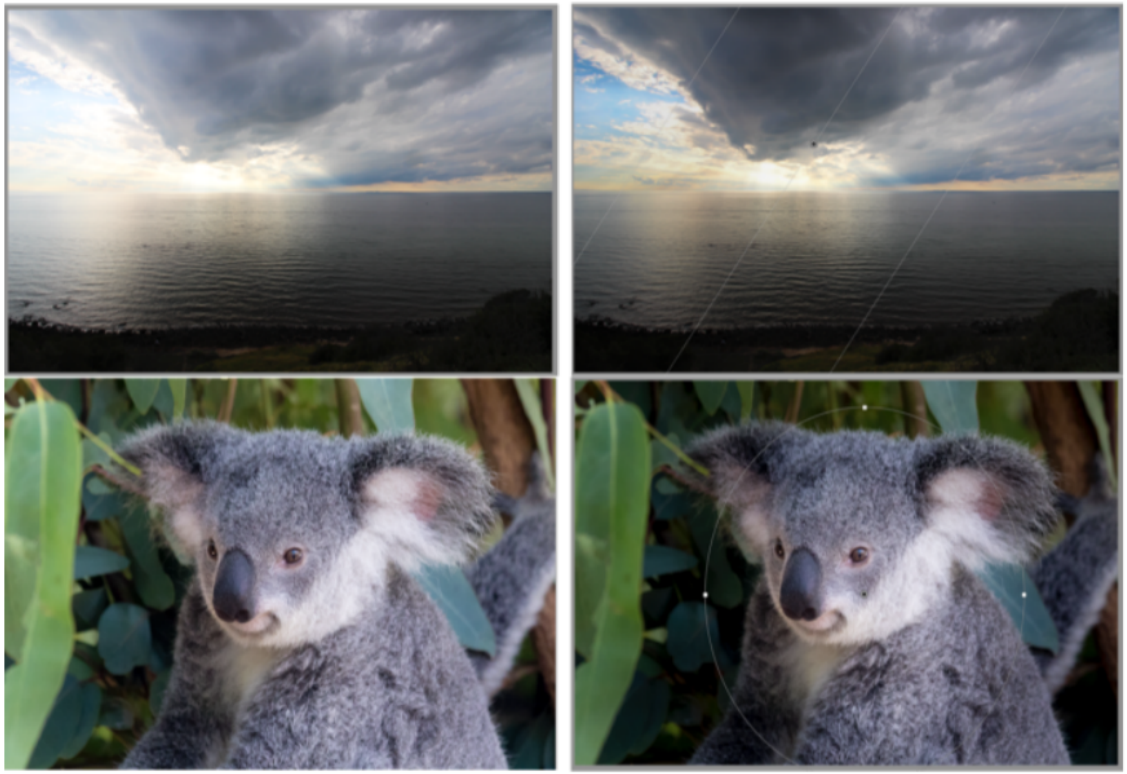
Architecture	PSNR↑
TED+ CURL	**27.04**
TED	26.56
U-Net [13]	25.90
DeepISP [8]	26.51

RAW to RGB

Architecture	PSNR↑
TED+CURL	**24.20**
HDRNet [15]	21.96
DPE [3]	22.15
White-Box [2]	18.57
Distort-and-Recover [24]	20.97
DeepUPE [1]	23.04

RGB to RGB

DeepLPF for local image enhancement



Graduated filters

Elliptical filters

DeepLPF: Deep Local Parametric Filters for Image Enhancement, Sean Moran, Pierre Marza, Steven McDonagh, Sarah Parisot, Gregory Slabaugh, CVPR 2020

Thank you