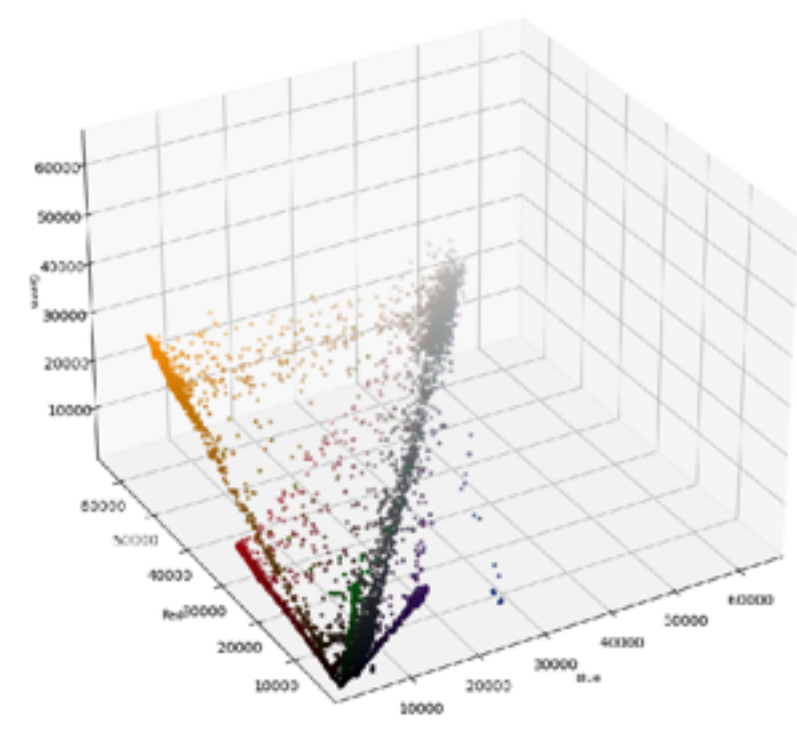


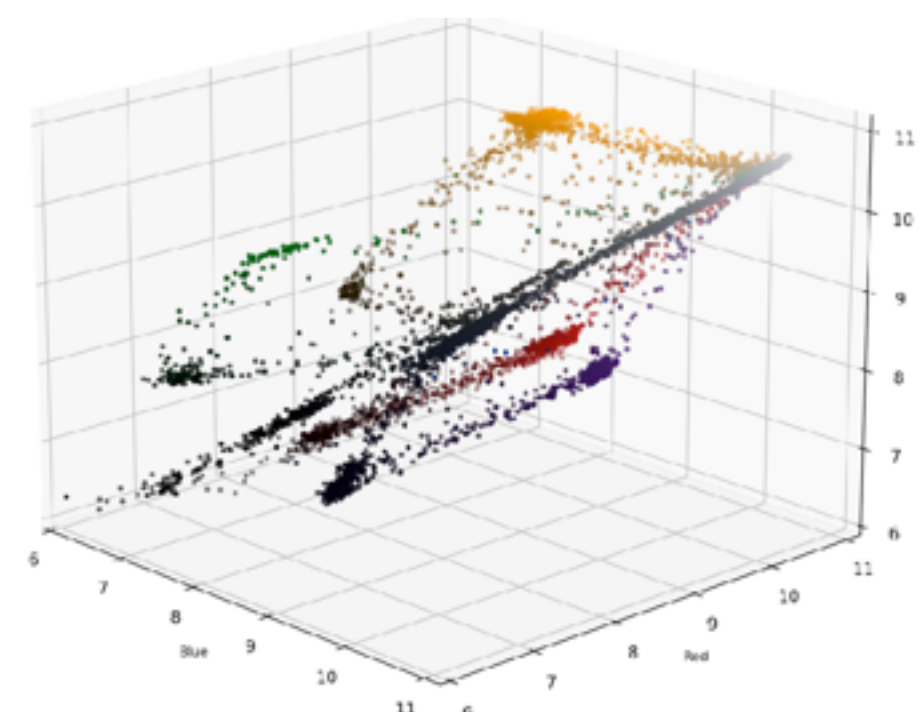
Log RGB Images Provide Invariance to Intensity and Color Balance Variation for Convolutional Networks

Bruce A. Maxwell, Sumegha Singhanian, Heather Fryling, Haonan Sun
Northeastern University

Reflection follows the laws of physics

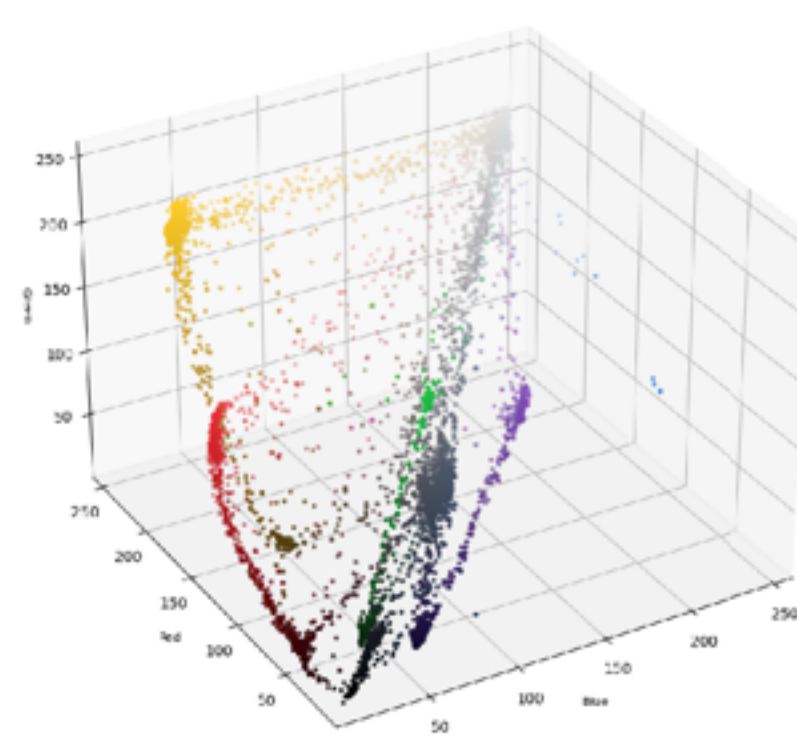


Linear RGB histogram

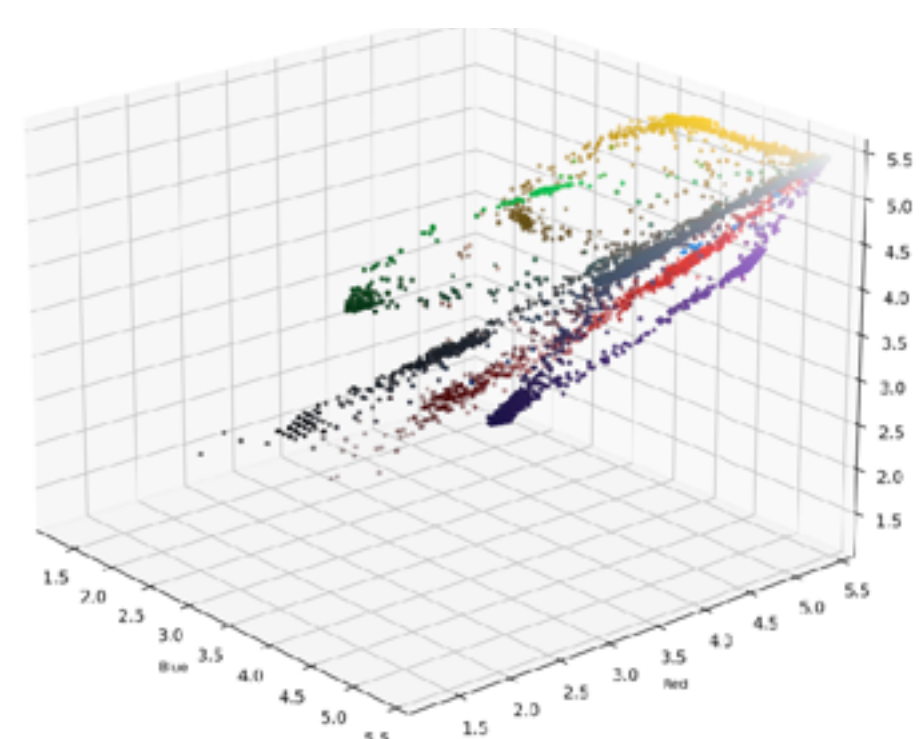


Log RGB histogram
Note consistent lines with clear separation for each material

Standard processing for human viewing breaks the physical laws

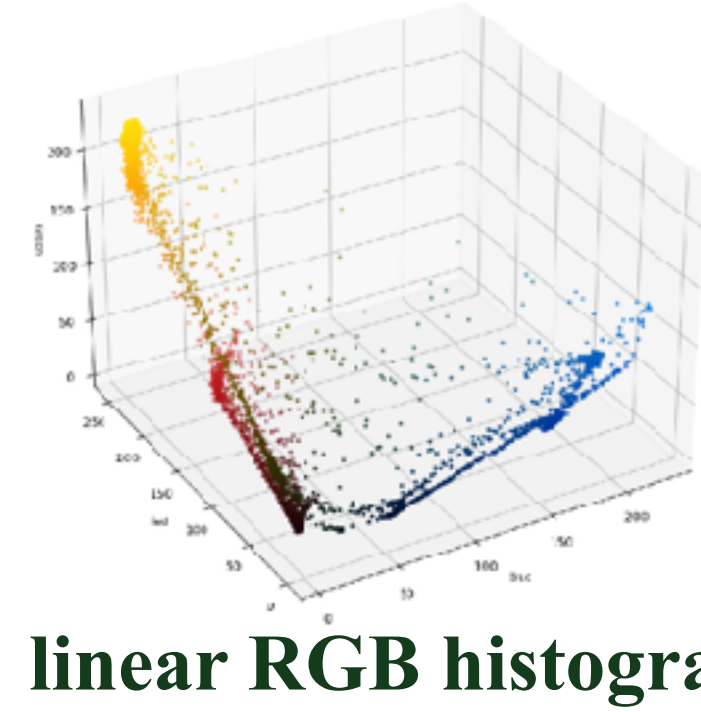
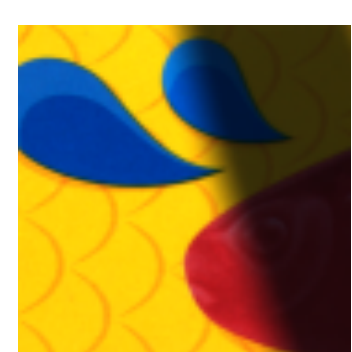
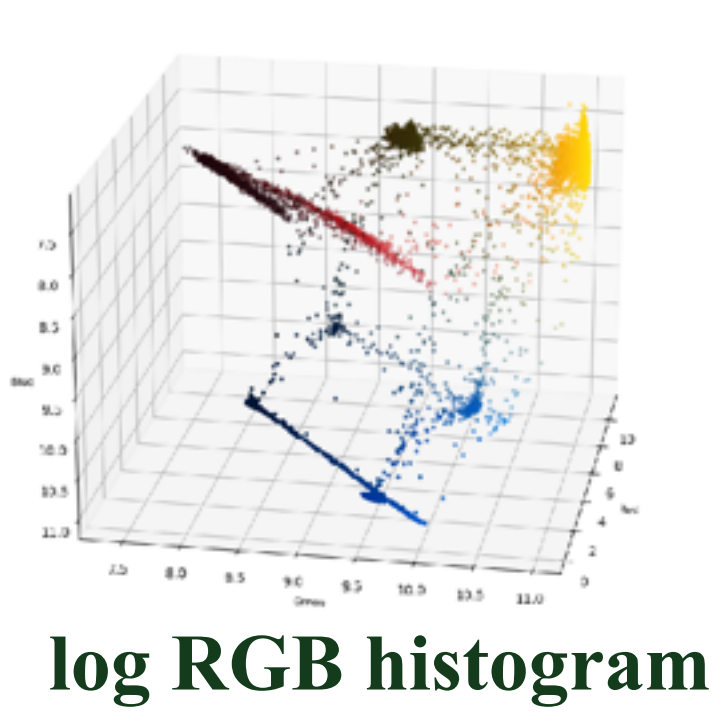


sRGB histogram

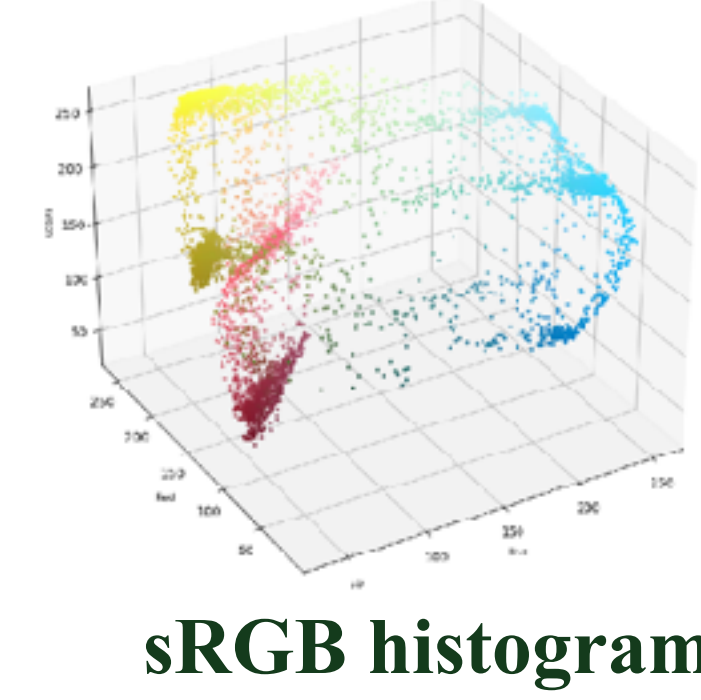
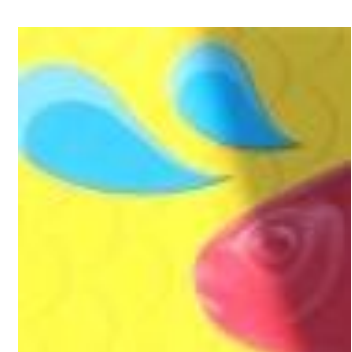
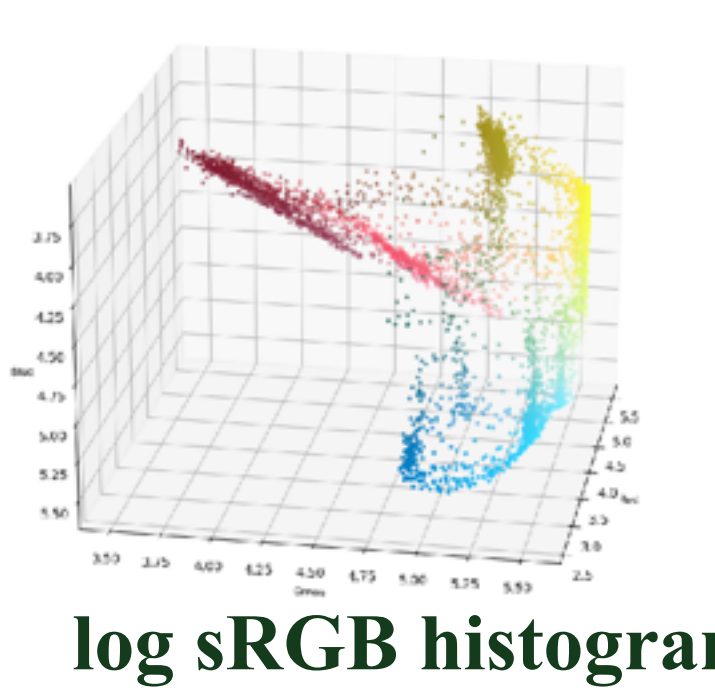


Log sRGB histogram
Note curving of the body reflection lines in both graphs

Clean relationships between pixels become color and image-specific



linear RGB histogram



sRGB histogram

Network

Network designed to be simple and trainable from scratch without memorization

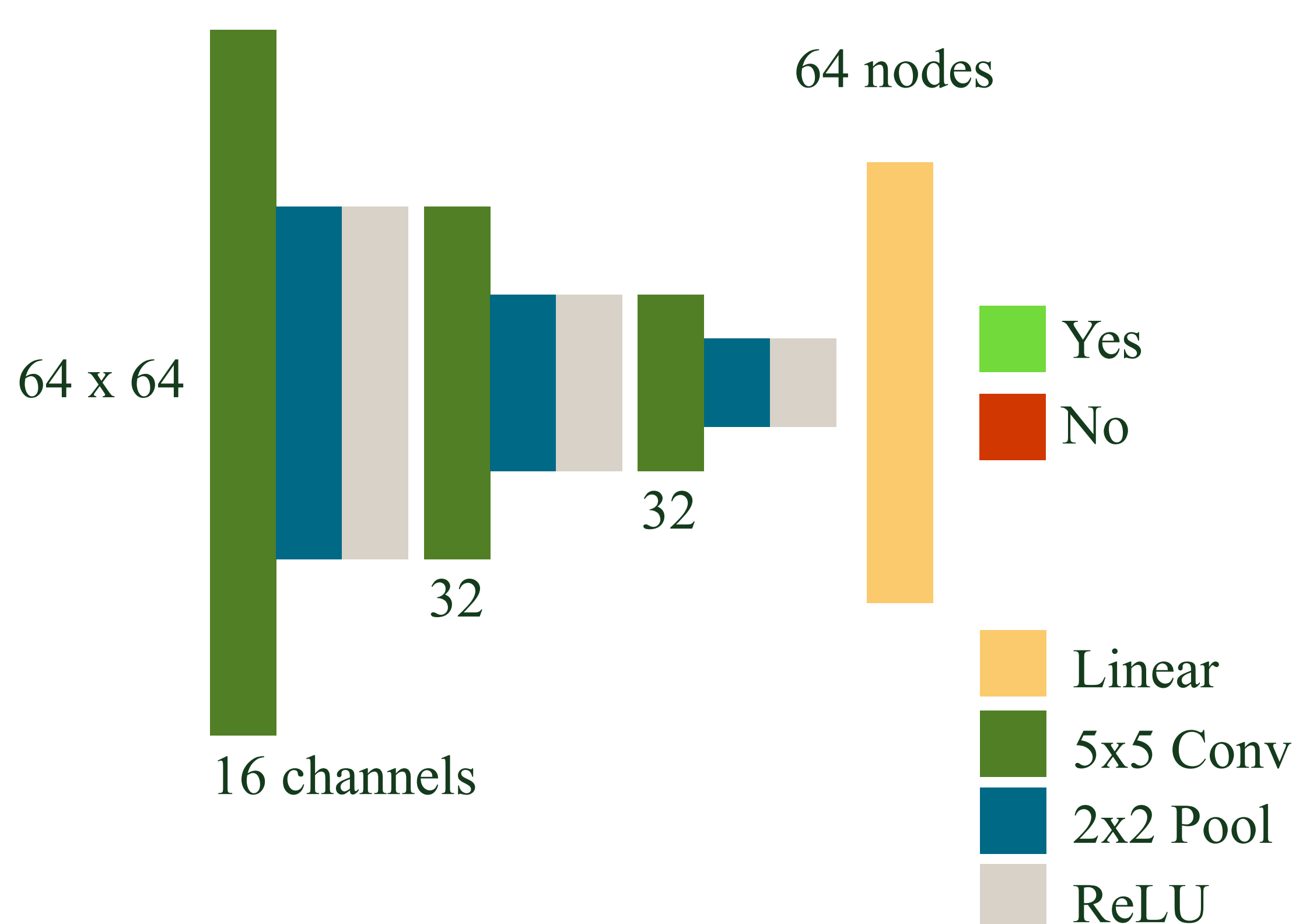


Image Model:

$I = \text{Image}$

$A = \text{Ambient Illuminant}$

$R = \text{Body Reflectance}$

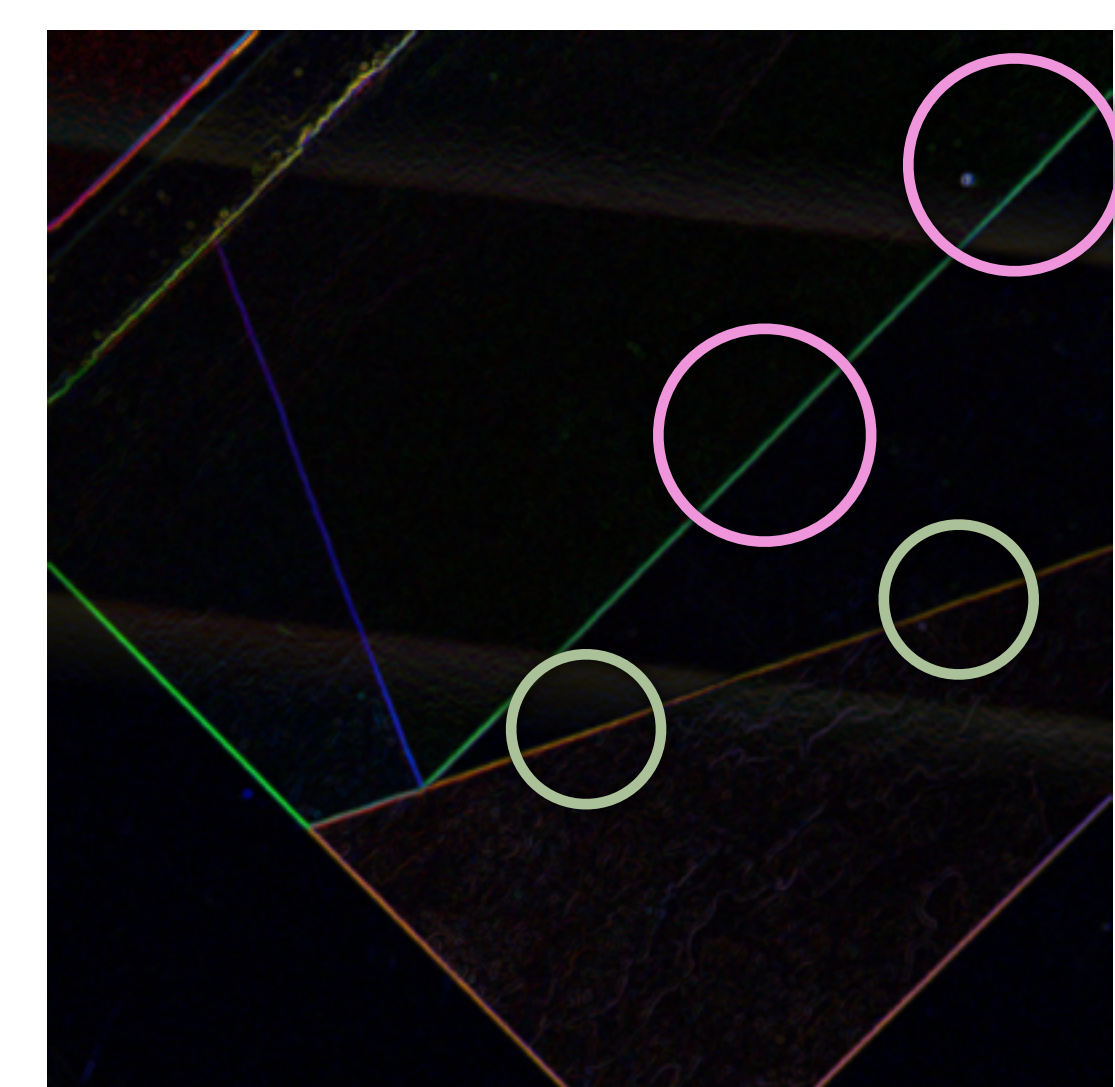
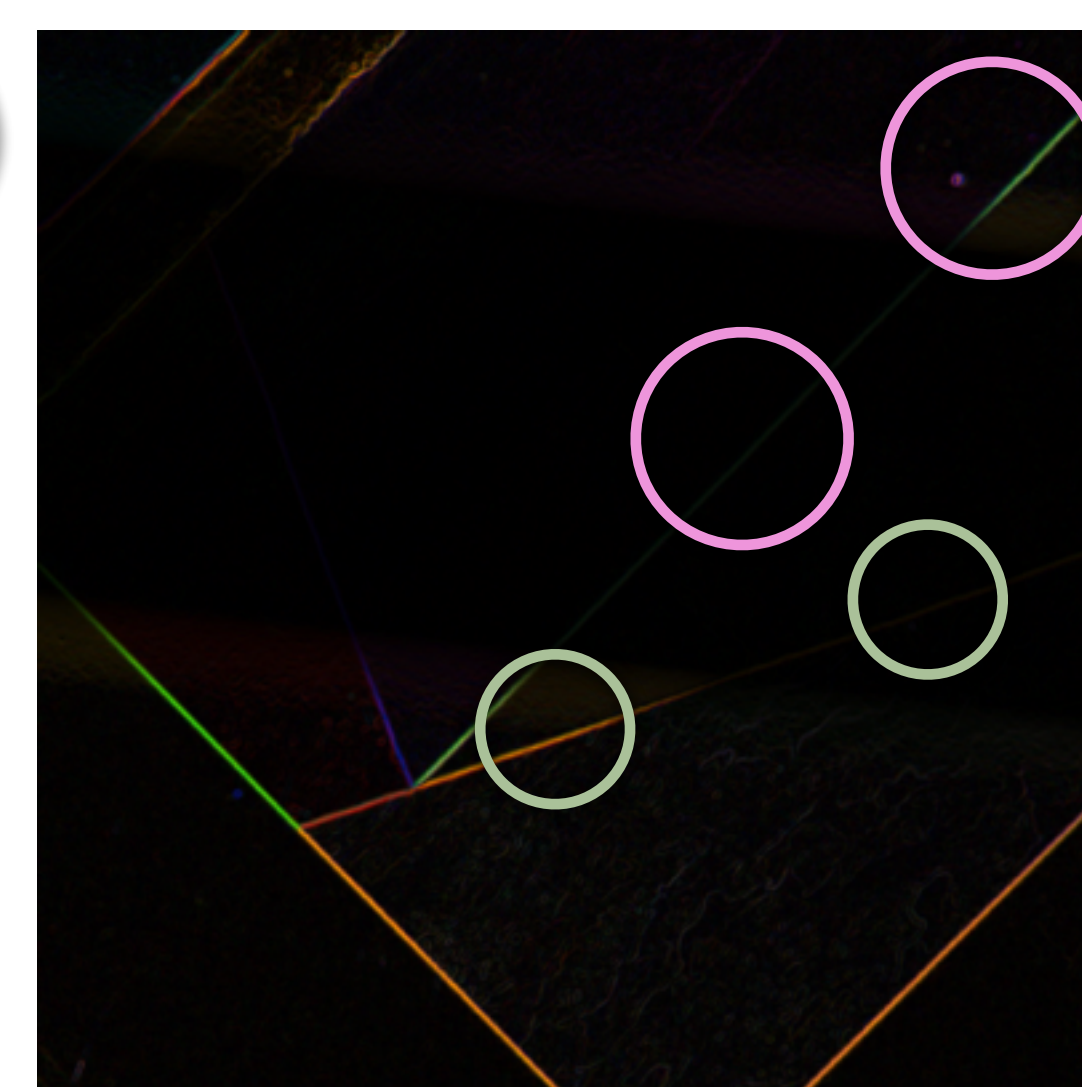
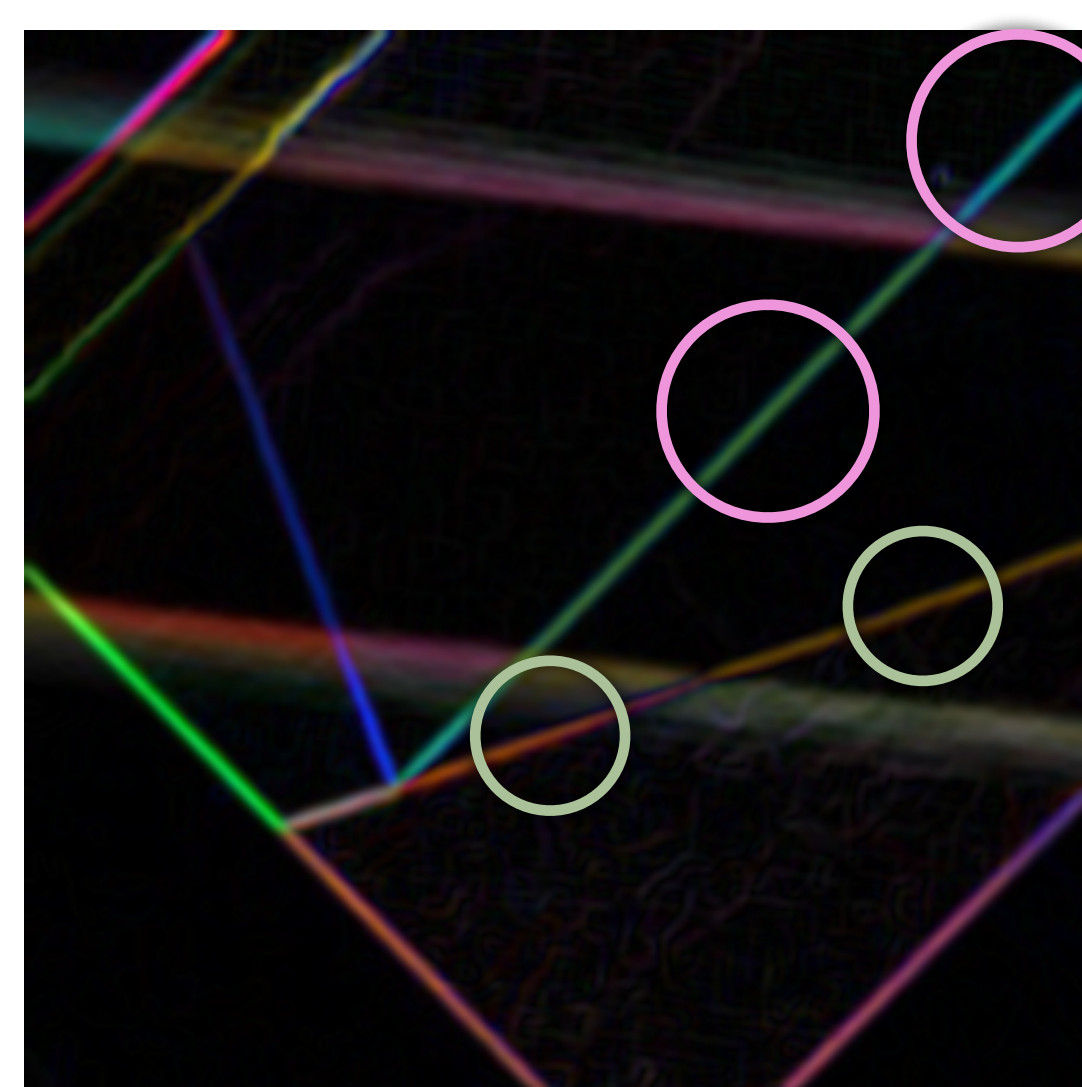
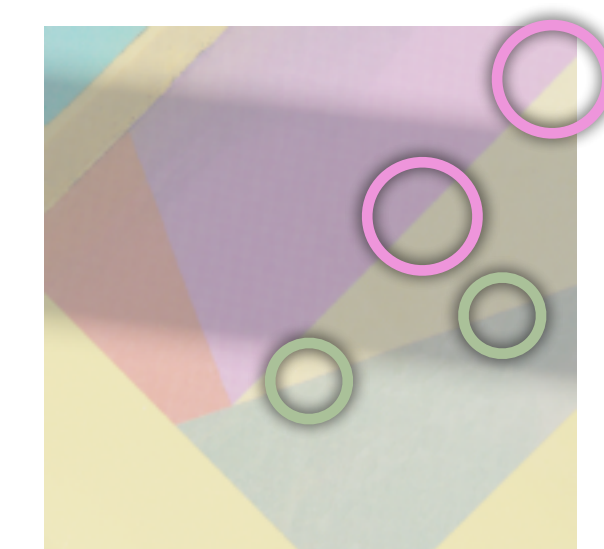
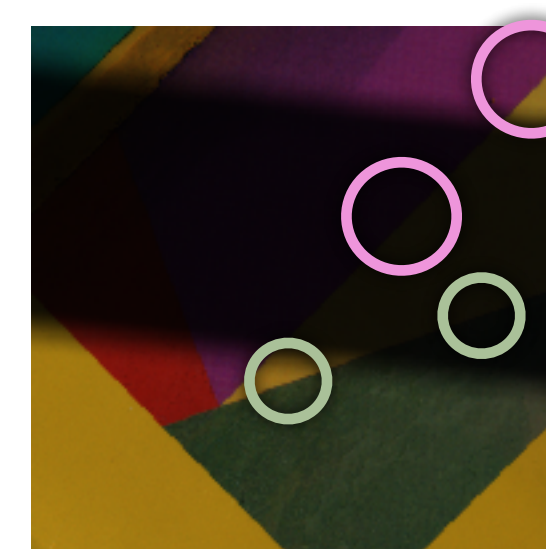
$L = \text{Direct Illuminant}$

$\gamma = \text{Strength of } L \in [0, 1]$

$$I = AR + \gamma LR = R(A + \gamma L)$$

$$\log I = \log [R(A + \gamma L)] = \log R + \log(A + \gamma L)$$

Differences in log space measure ratios instead of differences, making them consistent features across illumination conditions



sRGB Edges

Linear Edges

Log RGB Edges

Databases:

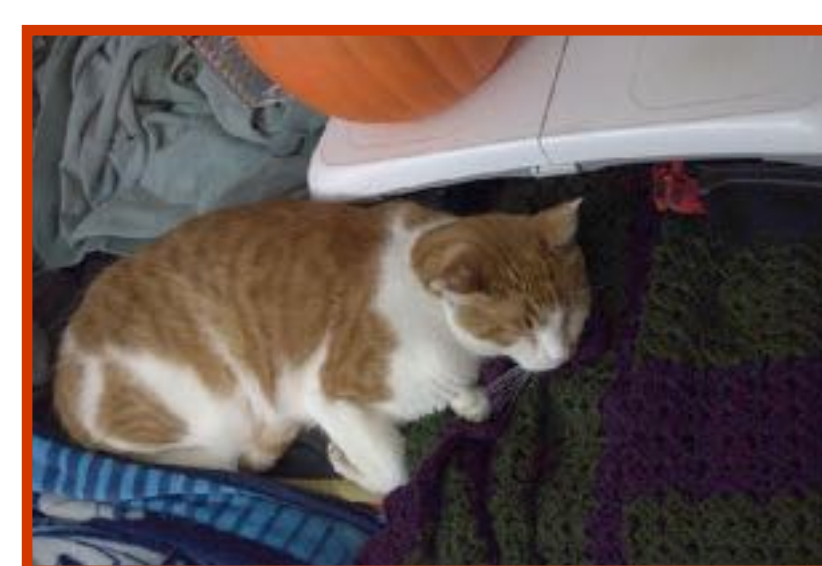
1118 Images captured in RAW format, 561 with a Swedish Fish® box

All images processed using rawPy library into linear RGB data and resized to min edge = 64

JPG/sRGB Database: sRGB transformation, saved as JPG images using OpenCV defaults

Linear Database: saved as 16-bit TIFF images

Log Database: natural log transformation, saved as 32-bit EXR images



Results

(1) Unmodified Train Set	JPEG	Linear RGB	Log RGB
Original Test Set	89.0% / 0.292	90% / 0.455	91% / 0.272
Random Color Balance	62% / 0.815	75% / 1.163	89% / 0.318
Random Intensity	73% / 0.669	82% / 0.748	94% / 0.247
Both	69% / 0.750	74% / 1.400	89% / 0.292
Validation	88.7% / 0.312	93.6% / 0.263	87.7% / 0.321
(2) Fixed Modified Train Set	JPEG	Linear RGB	Log RGB
Original Test Set	65% / 0.683	87% / 0.514	90% / 0.285
Random Color Balance	78% / 0.455	85% / 0.782	92% / 0.216
Random Intensity	71% / 0.681	92% / 0.392	93% / 0.192
Both	78% / 0.444	88% / 0.684	93% / 0.193
Validation	89.0% / 0.283	95.6% / 0.156	95.0% / 0.179
(3) Dynamic Train Set	JPEG	Linear RGB	Log RGB
Original Test Set	82% / 0.527	87% / 0.320	94% / 0.197
Random Color Balance	56% / 1.090	84% / 0.339	92% / 0.227
Random Intensity	55% / 1.119	85% / 0.357	92% / 0.210
Both	55% / 1.122	85% / 0.324	92% / 0.213
Validation	90% / 0.361	91.7% / 0.313	87.3% / 0.344