A. Naturalness value distribution

For a given image \( I \in \mathbb{R}^{3 \times H \times W} \) and spatial indices \( i \in \{1, \ldots, H\}, \ j \in \{1, \ldots, W\} \), the naturalness value of an image pixel \( I(i, j) \) is defined as

\[
N(i, j) = \frac{I(i, j) - \mu(i, j)}{\sigma(i, j) + 1}.
\] (1)

The local mean \( \mu(i, j) \) and deviation \( \sigma(i, j) \) are calculated as follow:

\[
\mu(i, j) = \sum_{k=-K}^{K} \sum_{l=-L}^{L} \omega_{k,l} I(i+k, j+l),
\] (2)

\[
\sigma(i, j) = \sqrt{\sum_{k=-K}^{K} \sum_{l=-L}^{L} \omega_{k,l} [I(i+k, j+l) - \mu(i, j)]^2},
\] (3)

where \( \omega_{k,l} \) denotes a 2D isotropic Gaussian weight function:

\[
\omega_{k,l} = \frac{1}{2\pi \sigma^2} e^{-\frac{k^2 + l^2}{2\sigma^2}}.
\] (4)

The distribution of naturalness value \( N(i, j) \) follows a Gaussian distribution when the naturalness of image \( I \) is high. In other words, the distribution is violated if the image is derived from an unnatural source (computer-rendered content). As shown in Fig. 1, for screen content images, there are several fluctuations, whereas for natural images, the distributions follow a Gaussian distribution. From this comparison, we can demonstrate that computer-rendered contents decrease the naturalness of the image, which completely transforms the statistical property of the image.

![Comparison on naturalness value distribution between screen content images and natural images.](image-url)
B. B-spline basis function

The B-spline basis function $\beta^n$ is a piece wise function, where $n$ is its polynomial degree, and is set to the $n^{th}$ convolution between $\beta^0(x)$, itself. The $\beta^0(x)$ is defined as 1 if $|x| < 0.5$ and 0 for otherwise. We utilize $\beta^3(x)$ for our BTC. Additionally, we retrain BTC($\beta^2$) and BTC($\beta^4$) in Sec. 5.3. $\beta^2(x)$ and $\beta^4(x)$ are as follows:

$$\beta^2(x) = \begin{cases} 
\frac{1}{2}(1.5 + x)^2 & \text{if } -1.5 < x \leq -0.5; \\
\frac{1}{2}(1.5 - 2x^2) & \text{if } -0.5 < x \leq 0.5; \\
\frac{1}{2}(1.5 - x)^2 & \text{if } 0.5 < x < 1.5; \\
0 & \text{otherwise,}
\end{cases}$$

$$\beta^4(x) = \begin{cases} 
\frac{1}{24} (39.0625 + 62.5x + 37.5x^2 + 10x^3 + x^4) & \text{if } -2.5 < x \leq -1.5; \\
\frac{1}{24} (13.75 - 5x - 30x^2 - 20x^3 - 4x^4) & \text{if } -1.5 < x \leq -0.5; \\
\frac{1}{24} (14.375 - 15x^2 + 6x^4) & \text{if } -0.5 < x \leq 0.5; \\
\frac{1}{24} (13.75 + 5x - 30x^2 + 20x^3 - 4x^4) & \text{if } 0.5 < x < 1.5; \\
\frac{1}{24} (39.0625 - 62.5x + 37.5x^2 - 10x^3 + x^4) & \text{if } 1.5 < x < 2.5; \\
0 & \text{otherwise.}
\end{cases}$$