[0008a] According to the first aspect of the present invention, there is provided a method comprising:

accessing an input image in a first color space with a first dynamic range;

applying a color transformation step to the input image to determine a first output image in a perceptually-quantized IPT (IPT-PQ) color space, the first output image comprising intensity pixel values and chroma components pixel values, wherein the color transformation step comprises applying a non-linear perceptual quantizer function to a function of the input image;

applying a color-volume mapping function to the first output image to generate a tone-mapped output image, the tone-mapped output image comprising intensity pixel values and chroma components pixel values,

wherein the color-volume mapping function comprises a tone mapping function, a saturation mapping function, and a pixel saturation estimate function,

wherein the tone mapping function generates the intensity pixel values of the tone-mapped output image by applying a non-linear mapping to the intensity pixel values of the first output image,

wherein the saturation mapping function generates the chroma components pixel values of the tone-mapped output image by adjusting the intensity pixel values of the first output image based on changes in intensity,

wherein the pixel saturation estimate function computes a saturation metric (S) as the sum of squares of the chroma components pixel values of the first output image, wherein the saturation metric is applied to the tone-mapped output image to darken the intensity pixel values and to desaturate the chroma components pixel values; and

applying a detail preservation function to the intensity pixel values of the tone-mapped output image to generate intensity pixel values of a filtered tone-mapped output image, the filtered tone-mapped output image comprising the chroma components pixel values of the tone-mapped output image, wherein the detail preservation function comprises a blur filter and horizontal and vertical edge-detection

filters coupled to the blur filter, and wherein the tone-mapped output image has a dynamic range being lower than the input image.

[0008b] There is also provided an apparatus comprising a processor and configured to perform the method as defined in the first aspect.

[0008c] There is also provided a non-transitory computer-readable medium having stored thereon computer-executable instruction for executing a method as defined in the first aspect.

CLAIMS

1. A method comprising:

accessing an input image in a first color space with a first dynamic range;

applying a color transformation step to the input image to determine a first output image in a perceptually-quantized IPT (IPT-PQ) color space, the first output image comprising intensity pixel values and chroma components pixel values, wherein the color transformation step comprises applying a non-linear perceptual quantizer function to a function of the input image;

applying a color-volume mapping function to the first output image to generate a tone-mapped output image, the tone-mapped output image comprising intensity pixel values and chroma components pixel values,

wherein the color-volume mapping function comprises a tone mapping function, a saturation mapping function, and a pixel saturation estimate function,

wherein the tone mapping function generates the intensity pixel values of the tone-mapped output image by applying a non-linear mapping to the intensity pixel values of the first output image,

wherein the saturation mapping function generates the chroma components pixel values of the tone-mapped output image by adjusting the intensity pixel values of the first output image based on changes in intensity,

wherein the pixel saturation estimate function computes a saturation metric (S) as the sum of squares of the chroma components pixel values of the first output image, wherein the saturation metric is applied to the tone-mapped output image to darken the intensity pixel values and to desaturate the chroma components pixel values; and

applying a detail preservation function to the intensity pixel values of the tone-mapped output image to generate intensity pixel values of a filtered tone-mapped output image, the filtered tone-mapped output image comprising the chroma components pixel values of the tone-mapped output image, wherein the detail preservation function comprises a blur filter and horizontal and vertical edge-detection

filters coupled to the blur filter, and wherein the tone-mapped output image has a dynamic range being lower than the input image.

2. The method of claim 1, wherein applying the color transformation step further comprises:

removing any non-linear encoding from the input image to generate a linear image;

converting the linear image into an LMS color image; and

applying the non-linear perceptual quantizer (PQ) function to the LMS color image to generate the first output image.

3. The method of claim 2, wherein the non-linear perceptual quantizer function comprises the SMPTE ST 2084 mapping function.

4. The method of any of claims 1-3, wherein the tone-mapping function is expressed as a parameterized sigmoidal tone curve function, wherein parameters of the function are determined based on characteristics of a source display and a target display.

5. The method of claim 4 wherein the characteristics of the source display comprise a minimum brightness value and a maximum brightness value for the source display.

6. The method of claim 4 or claim 5, wherein the characteristics of the target display comprise a minimum brightness value and a maximum brightness value for the target display.

7. The method of any of claims 4-6, wherein the characteristics of the source display are accessed through received source display metadata.

8. The method of any of claims 4-7, wherein the sigmoidal tone function is expressed as

$$I_m = \left(\frac{C_1 + C_2 I_o^{Slope}}{1 + C_3 I_o^{Slope}}\right)^{Rolloff}$$

wherein C_1, C_2, C_3, *Slope*, and *Rolloff* are constants defining the parameters of the tone-mapping function, and for an input I_o, represented by an intensity pixel value of

the first output image, I_m is a corresponding output value, represented by the corresponding intensity pixel value of the tone-mapped output image.

9. The method of any of claims 4-8, wherein parameters of the tone-mapping function are further determined based on a *Brightness* value and a *Contrast* value to adjust overall brightness and contrast of the tone-mapped output image.

10. The method of any of claims 1-9, wherein the saturation mapping function is expressed as

$$f_{SM}(I_o) = I_m - I_o + 1$$

wherein $I_m$denotes the output of the tone-mapping function, and I_o denotes the intensity pixel values of the first output image, and

wherein applying the color-volume mapping function comprises computing:

$I_m = f_T(I_o) * (1 - S * \alpha)$,

$P_m = P * f_{SM}(I_o) * (1 - S * \beta)$,

$T_m = T * f_{SM}(I_o) * (1 - S * \beta)$,

where S denotes the saturation metric generated by the pixel saturation estimation function, α and β denote input weights, $f_T(I_o)$ denotes the tone-mapping function, $f_{SM}(I_o)$ denotes the saturation mapping function, I_o denotes the intensity pixel values of the first output image, P and T denote the chroma components pixel values of the first output image, I_m denotes the pixel values of the tone-mapped output image, and P_m and T_m denote the color components pixel values of the tone-mapped output image.

11. The method of claim 10, wherein the values of $(1 - S * \alpha)$ and $(1 - S * \beta)$ are clamped to always be larger than zero.

12. The method of any of claims 1-11, wherein applying the detail preservation function further comprises computing:

$D = I_o - I_m$,

$B = F(D, H)$,

$Ex = F(B, Hx)$,

$Ey = F(B, Hy)$,

$E = (|Ex| + |Ey|) * W_{MSE} + (1 - W_{MS})$,

$$I_{mf} = I_o - B - E * (D - B)$$

where *F(D,H)* denotes applying to image *D* a filter with kernel *H*, I_o denotes intensity pixel values of the first output image, I_m denotes the intensity pixel values of the tone-mapped output image, I_{mf} denotes the intensity pixel values of the filtered tone-mapped output image, *B* denotes the output of the blur filter, Ex denotes the output of the horizontal edge-detection filter, Ey denotes the output of the vertical edge-detection filter, and W_{MSE} and W_{MS} are weights.

13. The method of claim 12, wherein the *E* output value is further clamped to be between 0 and 1.

14. The method of claim 12 or claim 13 wherein the kernel *H* comprises a 5x11 Gaussian filter with standard deviation equal to 2.

15. The method of any of claims 12-14 wherein the kernel *H* comprises a low-pass filter.

16. An apparatus comprising a processor and configured to perform any one of the methods recited in claims 1-15.

17. A non-transitory computer-readable storage medium having stored thereon computer-executable instruction for executing a method in accordance with any of claims 1-15.