

reference image sequence are zero and the x dependence has already been removed:

$$JND = \max_r \left\{ \sum_{k,n} |P_{kn}(t)|^2 \right\}^{1/2} \quad (57)$$

Actually, this JND value is a function of the input stimulus, which is parameterized by α, ω : $JND = JND(\alpha, \omega)$.

Finally, the objective function (equation 47) to be optimized is formed. Consistency with the data is achieved, when the data values M are inserted in the above model and produces the result of one JND of perceived difference as predicted by the model. Calibration is accomplished when this consistency is achieved.

The generic calibration procedure (calibration on data of various luminances) is similar to the isoluminant calibration procedure with two differences. First, the step of obtaining the discrete temporal impulse-response function is omitted and $J_m^{(1)}$ is set equal to the value "1" and $J_m^{(2)}$ is set equal to the value "0". Second, the quantities $\Gamma_{kn}(B)$ are found separately for several values of B , but with a and b fixed as determined by the calibration at $B=200$ trolands.

FIG. 11 illustrates a method 1100 for assessing the visibility of differences between two input image sequences for improving image fidelity and visual task applications. Method 1100 begins at step 1110 and proceeds to step 1115 where the method determines whether the input image sequences contain chrominance components. If the query is affirmatively answered, then method 1100 proceeds to step 1117 where the RGB values for each pixel are combined with known emission spectra of the phosphors to produce CIE coordinates.

If the query is negatively answered, method 1100 proceeds to step 1120 where the input image sequence is "time-resampled" to account for the limitation of the human eye to process high frame rate image sequences. However, resampling does not take place unless the original (input image) frame rate is 200 Hz or higher. In addition, the answer to the query of step 1115 can be selectively determined to ignore the presence of any chrominance components for the purpose of reducing the computational overhead of a specific application.

In step 1119, the CIE coordinates of step 1117 are transformed into cone responses which are then used to arrive at another color coordinates in step 1162 as described below. Method 1100 then proceeds to step 1120.

In step 1125, the input images are resampled to correlate the inter-pixel spacing, size of the pixels and viewing distance of the input images with the inter-receptor spacing and size of the receptor of the retina respectively. Method 1100 computes an angular subtend for each pixel as seen from a viewer in accordance with equation (1).

In step 1130, method 1100 inserts a fixed-width border to each input image to prevent boundary effects. Two types of borders, fixed value border and edge value controlled border, can be applied depending on the application.

In step 1135, method 1100 adjusts (smooth/interpolate) the input image sequences to account for the pixels-to-receptors ratio. Namely, if the number of pixels is greater than the number of receptors, method 1100 applies "down-sampling" to the input images. If the number of receptors is greater than the number of pixels in the input image, method 1100 applies "up-sampling" to the input images. The smoothing/interpolating operation is performed in accordance with equations (2-5) as described above.

In step 1140, the input image sequences are transformed to approximate the point spread by the optics of the human

eye. Method 1100 convolves the input images with the function of equation (6).

In step 1145, the method determines whether the fixation depth is equal to the image depth. If the query is affirmatively answered, then method 1100 proceeds to step 1150 where the input images are resampled to generate retinal images. If the query is negatively answered, method 1100 proceeds to step 1147 where a "blur circle" is calculated and convolved with the input images to account for changes in effective image resolution with changes in the difference between image depth and fixation depth.

In step 1150, method 1100 attempts to simulate the sampling process of the human eye. Effectively, each input image is sampled at a density of 120 pixels per degree of visual angle to generate a "retinal image" of 512x512 pixels for "foveal viewing". For "non-foveal viewing", step 1150 samples the input image at a density in accordance with equation (7).

In step 1160, the method 1100 again determines whether the input image sequences contain chrominance components. If the query is affirmatively answered, method 1100 proceeds to step 1162 where the cone responses from step 1119 are used to arrive at another three color coordinates in accordance with equations 28-29. If the query is negatively answered, method 1100 proceeds to step 1165. Again, the answer to the query of step 1160 can be selectively determined to ignore the presence of any chrominance components for the purpose of reducing the computational overhead of a specific application.

In step 1165, temporal filtering is applied to the retinal images to separate the luminance component of each input image into two temporal channels, a sustained channel and a transient channel. Optionally, the chrominance components of each input sequence of images are also separated into two different channels, thereby generating four temporal responses for each of the two input sequences. The functions of the two temporal filters are expressed in equations (9) and (10).

In step 1170, a contrast pyramid is generated by decomposing each image generated from step 1165 in accordance with equations (22-25) and FIG. 7 (and as modified for the chrominance component). Each contrast pyramid contains seven frequency channels or pyramid levels.

In step 1175, method 1100 determines whether orientation filtering is selected. If the query is negatively answered, method 1100 proceeds to step 1180. If the query is affirmatively answered, method 1100 proceeds to step 1177 where orientation filtering is applied.

In step 1177, spatially oriented filters are applied to each contrast pyramid where the output images are then transformed in step 1179 in accordance with equation (35) to simulate the conversion of linear response among simple cells to an energy response among complex cells in the mammalian visual cortex.

In step 1180, method 1100 normalizes each contrast pyramid with a set of weighing factors to account for the contrast sensitivity function of the human eye. The weighing factors are calculated by changing the value of the contrast normalization term Γ_{kn} (in accordance with Tables 1-3) for each pyramid level and temporal channel.

In step 1185, method 1100 applies cross-frequency and/or cross-orientation masking of visual threshold to the contrast pyramids. Namely, each contrast pyramid value (input pyramid value) is divided or normalized by a sum of some other contrast pyramid values to account for the desensitization of the human visual perception under certain spatial and/or temporal frequency. The resulting contrast pyramid value (output pyramid value) is calculated in accordance with equation (39).