MICRO-428: METROLOGY

WEEK EIGHT: OPTICAL IMAGE SENSORS

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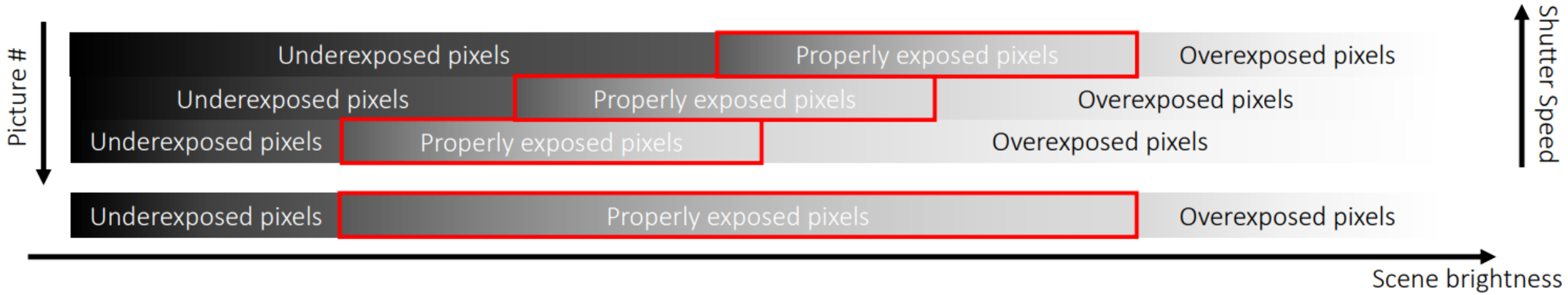
Exercise: High Dynamic Range

- Cameras have a limited amount of dynamic range, given by the ratio of the maximum well capacitance and the noise floor:

$$DR = 20log\frac{N_{SAT}}{N_{noise}}$$

- Usually cameras have a dynamic range in the order of 40-70 dB. However, modern cameras have the option of stacking multiple exposed pictures of the same scene to create a HDR (High Dynamic Range) image.



Exercise: High Dynamic Range

- In order to build an HDR image algorithm follows these steps:
  - Find (if not given) the ratio of exposure between the several pictures `w`, which is going to work as weight of the average in order to have consistent brightness values. (It can be the exposure time ratios, the ISO ratios, or the combination of the two)
    - Example: for exposure times of 1/60s, 1/120s and 1/240s, the weights would be 1, 2 and 4 respectively.
  - Load each image and transform it in workable matrices. For an 8-bit image, the matrix will be a 3D array, of dimensions `(x,y,3)`, where `x,y` is the image size and `3` stands for the three colors (RGB). The values of each point will range between `0` and `255`.
  - Then, for each image:
    - Set the pixels underexposed and overexposed thresholds (e.g. values lower than `5` and higher than `250`).
    - Find the properly exposed pixels (not overexposed nor underexposed).
    - Add their positions on a `properlyExposedCounts` matrix.
    - Calculate the weighted sum to get the final HDR matrix.

Exercise: High Dynamic Range

- After the last image, if a pixel has been counted more than once (as it was properly exposed more than once) it needs to be averaged dividing the value with the number of appearances in the `properlyExposedCounts` matrix.

- The built image is going to have a maximum value of properly exposed pixel brightness higher than `255` so rescaling is necessary. In order to save the image as an 8-bit image, we will rescale the pixel values.

- Finally:
  - if we had overexposed pixels in the lowest exposure picture, we will write them in the HDR matrix as the bright pixels (without weights).
  - if we had underexposed pixels in the highest exposure picture, we will write them in the HDR matrix as the dark pixels (without weights).

Exercise: High Dynamic Range

- We can perform these changes starting from any of the color spaces. RGB (Red, Green, Blue) is the default color space; however, good HDR algorithms are quite tricky, to control saturation and brightness at the same time while working on three different colors at the same time. We will perform out HDR stacking in the HSL (Hue, Saturation, Lightness) space, which sets the color with the H and S values: we will have to work only on the L value while the color will be preserved.