Lab 2
Energy efficient image processing

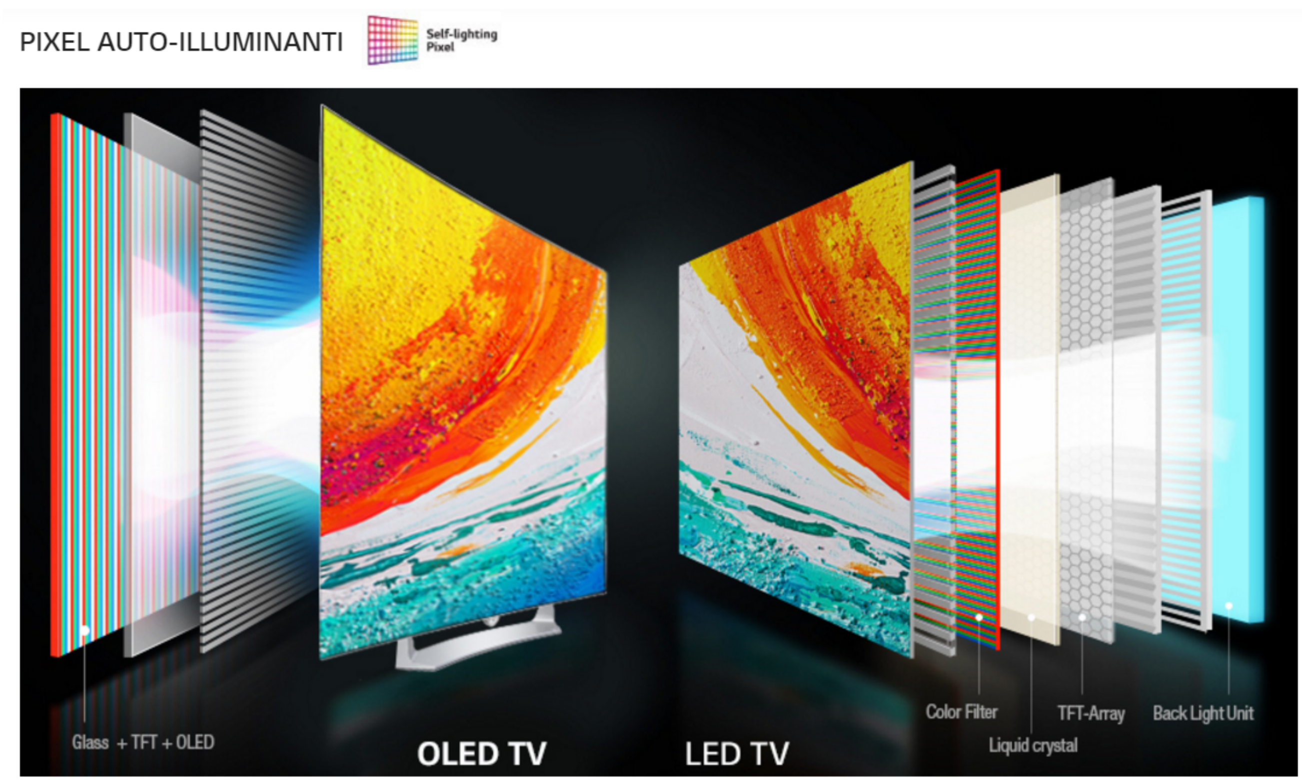
Objective and organization

- Demonstrates how manipulation of an image can be used to tradeoff image quality to save power in emissive displays
  - 1 report – 2 days
  - Matlab

- Organize all implemented methods in functions and scripts to **automatically** test and evaluate all images and all techniques

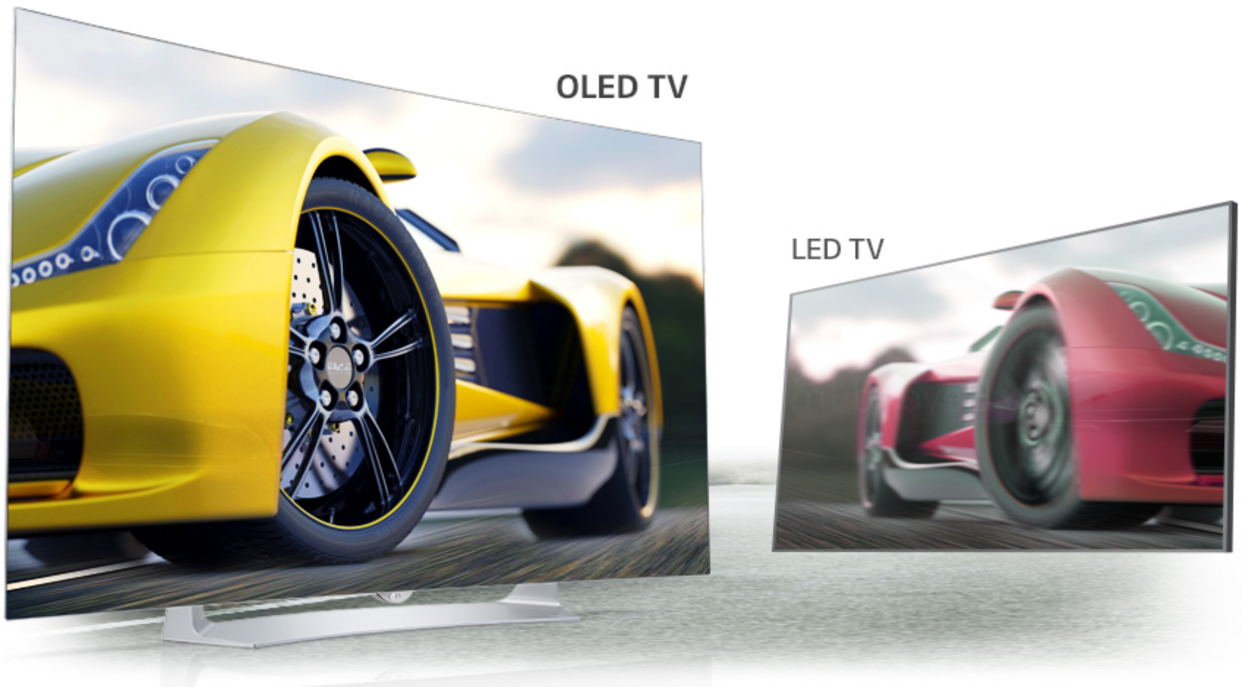
OLED vs LED

- OLED TVs
  - Do not require external lighting
    - Better black levels



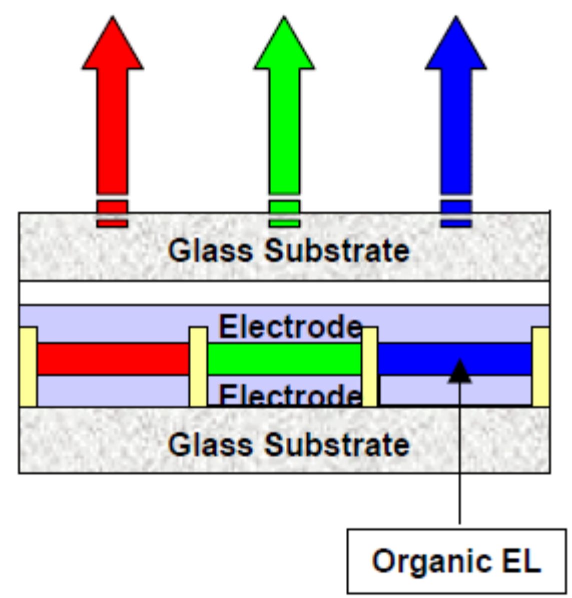
OLED vs LED

- OLED TVs
  - Pixels are independent from each other
    - More sense of depth
    - Higher contrast makes images more realistic



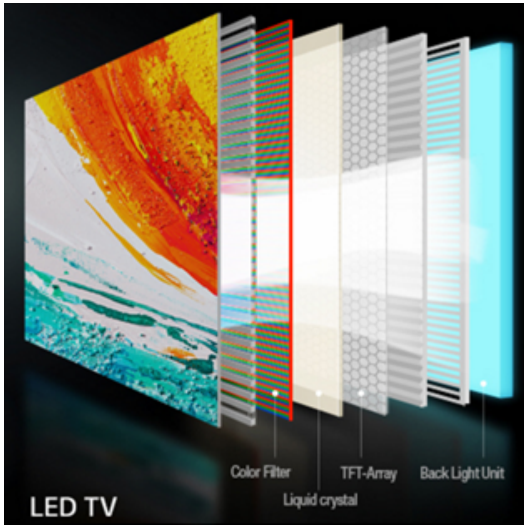
OLED

- Interesting case study from our perspective…
- Organic light-emitting diode (OLED)
  - Do not require external lighting
  - Pixels are emissive
    - Emissive layer is a film of organic compound which *emits light in response to an electric current*
  - Each pixel is made of three devices corresponding to red, green and blue components



OLED

- In LCDs, backlight dominates power consumption and color has only negligible power impact
- With OLED displays, the color of a pixel impacts on power consumption
  - E.g., hungry blue
  - Different luminance efficacies
  - Different images imply different power consumption



Lab 2
Energy efficient image processing

Dynamic Voltage Scaling of OLEDs

- Power consumption of OLEDs depends only on pixels…
  - No back light
  - Pixels are emissive, i.e., emits light in response to an electric current

- … and pixels power consumption depends on:
  - Displayed colors
    - Hungry blue / low power green
  - Input current

DVS for OLEDs

- Supply voltage is set to maximum to support full luminance of pixel
  - But maximum luminance may not be necessary

- Dynamic Voltage Scaling
  - Scale the supply voltage
    - Decreases current of all pixels
    - Saves power
  - Note that reducing current implies changing the RGB color of pixels!
    - Sacrifice image quality for power saving

DVS for OLEDs

- Effects of DVS
  - Reducing current implies changing the RGB color of pixels!
    - Emitted color strictly depends on input current
    - Reduced voltage → reduced current through pixels

ORIGINAL IMAGE

SIMULATED VOLTAGE SCALING

DVS for OLEDs

- Effects of DVS
  - Sacrifice image quality for power saving
    - Reduced color luminance
    - Color distortion in displayed images
  - Saved power

DVS for OLEDs

- Can compensate the image distortion by applying an image compensation
  - E.g., working on image luminance

Original image

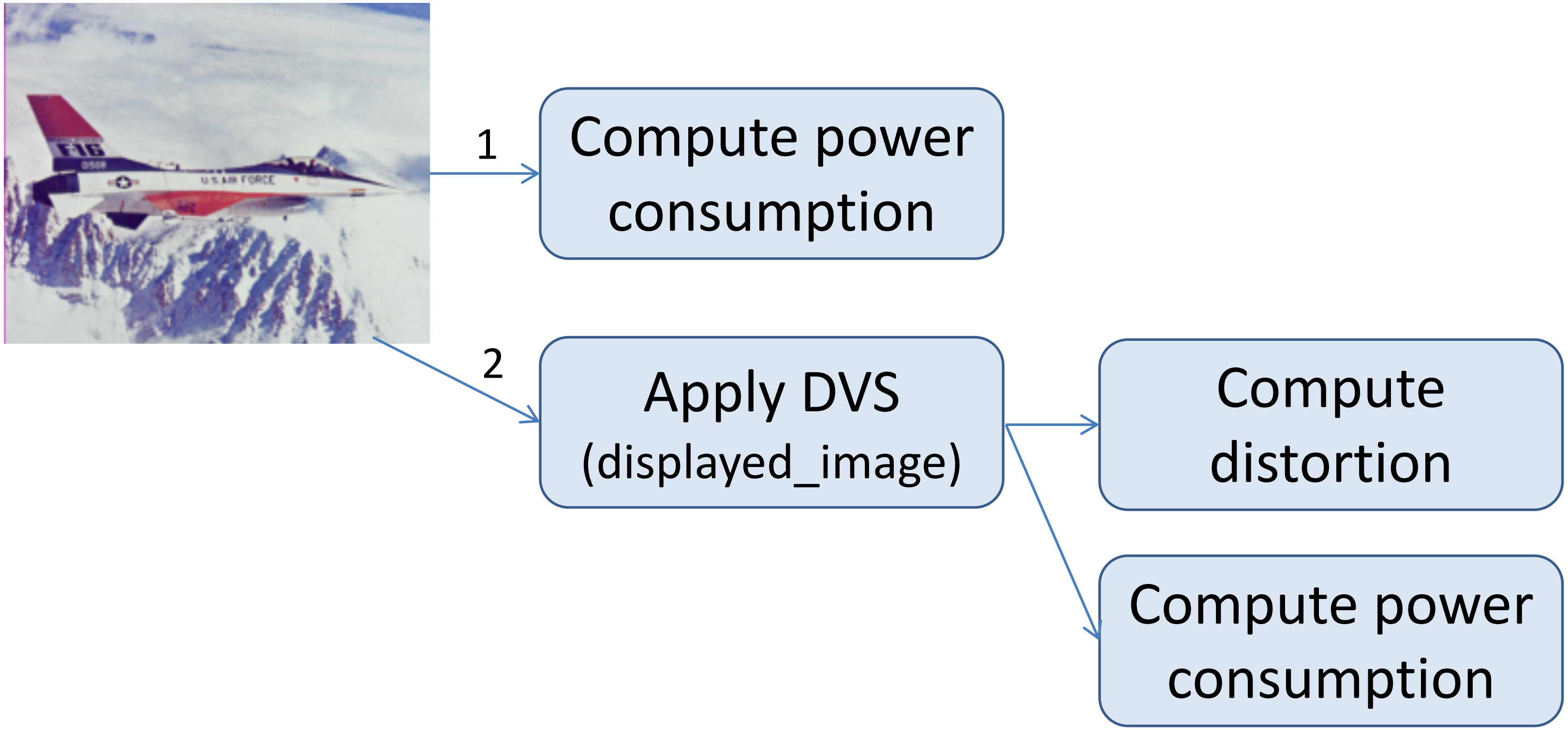
Effect of voltage scaling

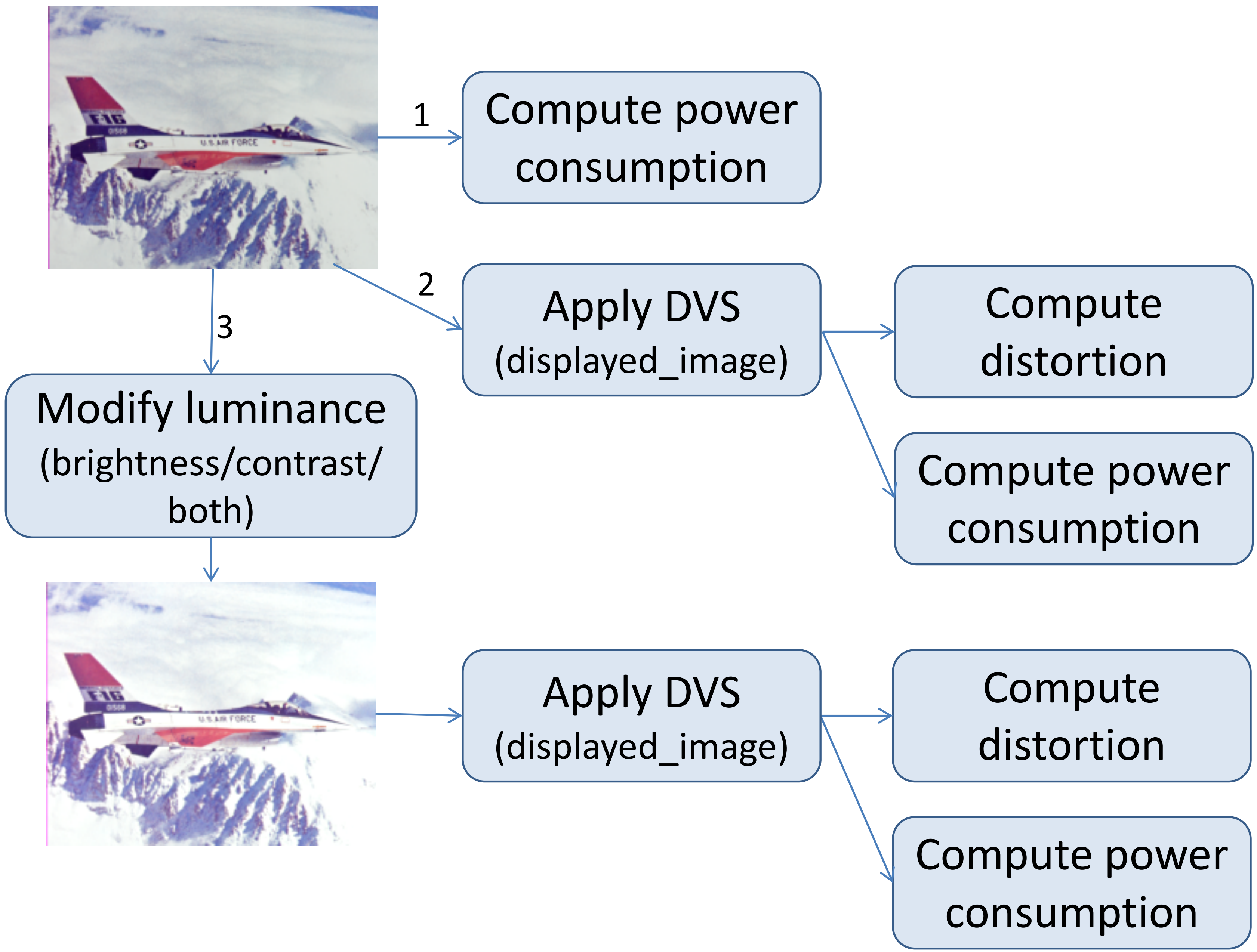
Effect of voltage scaling + image compensation

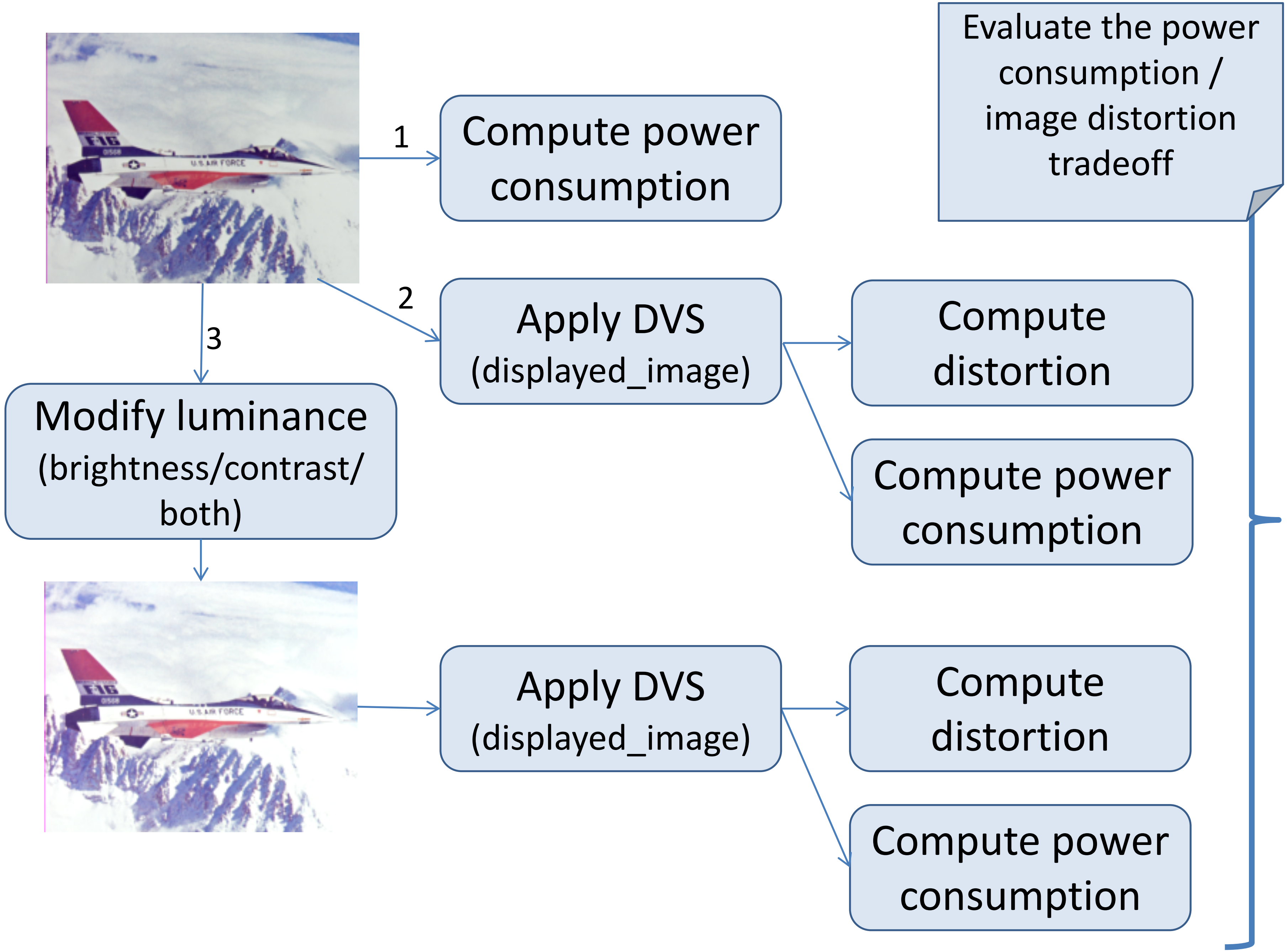
Assignment 2

1

Compute power consumption


1
Compute power consumption
2
Apply DVS
(displayed_image)
Compute distortion
Compute power consumption


1
Compute power consumption
2
Apply DVS (displayed_image)
Compute distortion
Compute power consumption
3
Modify luminance (brightness/contrast/ both)
Apply DVS (displayed_image)
Compute distortion
Compute power consumption


Evaluate the power consumption / image distortion tradeoff
1
Compute power consumption
2
Apply DVS (displayed_image)
Compute distortion
Compute power consumption
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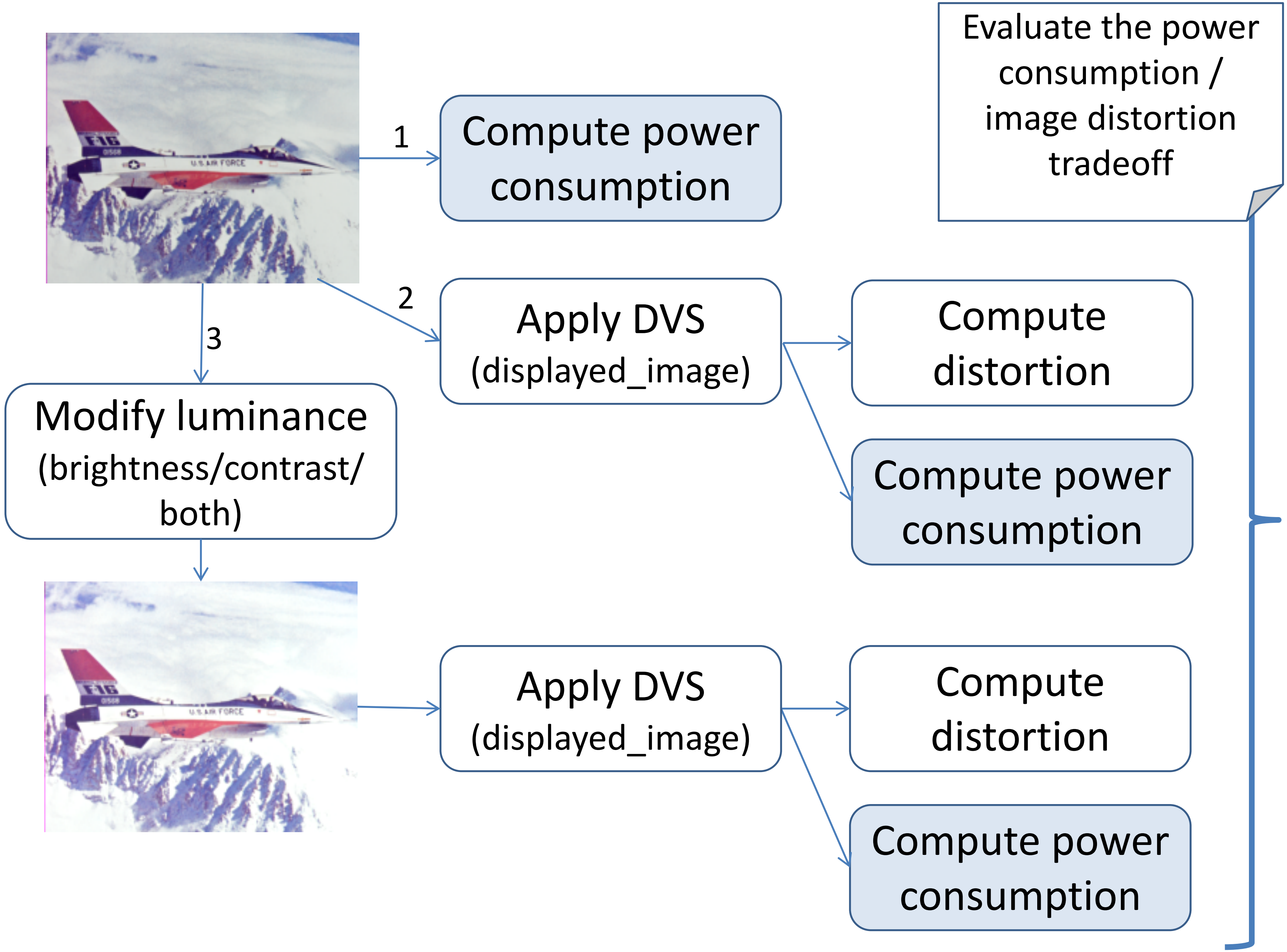
Compute power consumption

Assignment 2: how to



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1. Cell current calculation and evaluation of power consumption

- Given the RGB color of each pixel, determine current flowing through the cell

$$I_{cell} = \frac{p_1 \, V_{dd} \, D_{RGB}}{255} + \frac{p_2 \, D_{RGB}}{255} + \ p_3 \qquad [mA]$$

D_{RGB} is the RGB color value of current pixel

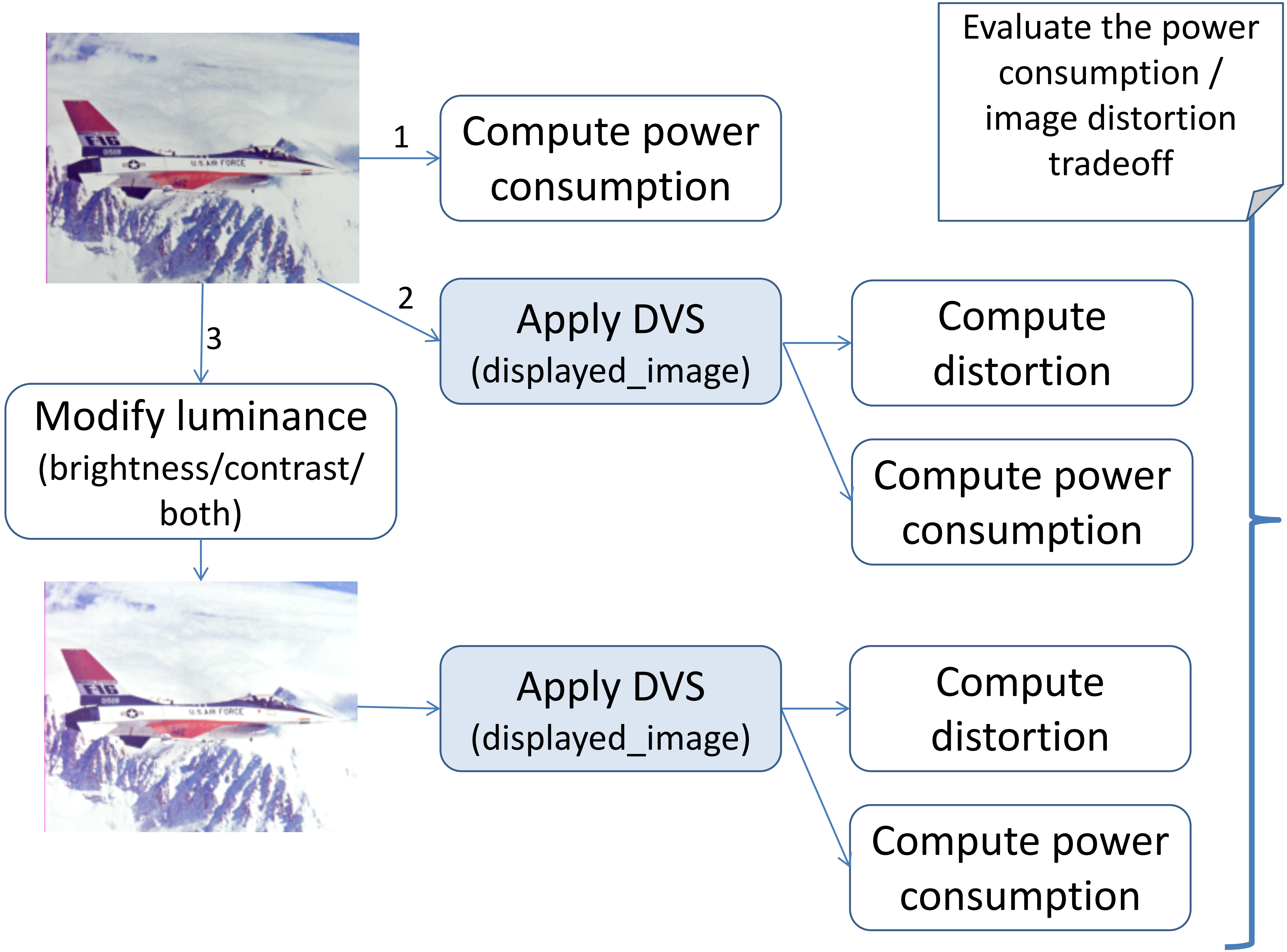
- Determine power consumption
  - Different (less accurate model) but expressing dependency from DVS
  - $P_{panel} = \ V_{dd} \ \sum_{i=1}^{W} \sum_{j=1}^{H} I_{cell(i,j)} \qquad [mW]$

1. Cell current calculation and evaluation of power consumption

- Determine current flowing through a cell given the RGB color of the pixel

$$- I_{cell} = \left(\frac{p_1 \, V_{dd} \, D_{RGB}}{255}\right) + \left(\frac{p_2 \, D_{RGB}}{255}\right) + p_3 \qquad [mA]$$

  - p_1 = +4.251e-05
  - p_2 = -3.029e-4
  - p_3 = +3.024e-5
  - Default V_{dd} = 15V



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2. Application of voltage scaling

- Voltage supply determines the maximum current that can flow in the OLED
  - Current value → pixel color

- Effect simulated by the function

  displayed_image(I_{cell}, V_{dd}, *mode*)

  - Given an image as the matrix of currents corresponding to pixels
  - Applies voltage scaling with the specified V_{dd}
  - Try example.m in the test code

2. Application of voltage scaling

- Effect simulated by the *displayed_image()* function
  - Computes the maximum current that can flow with the new V_{dd}
  - Determines the corresponding maximum RGB value RGB_{max}
  - Any RGB value higher than RGB_{max} is saturated to RGB_{max}

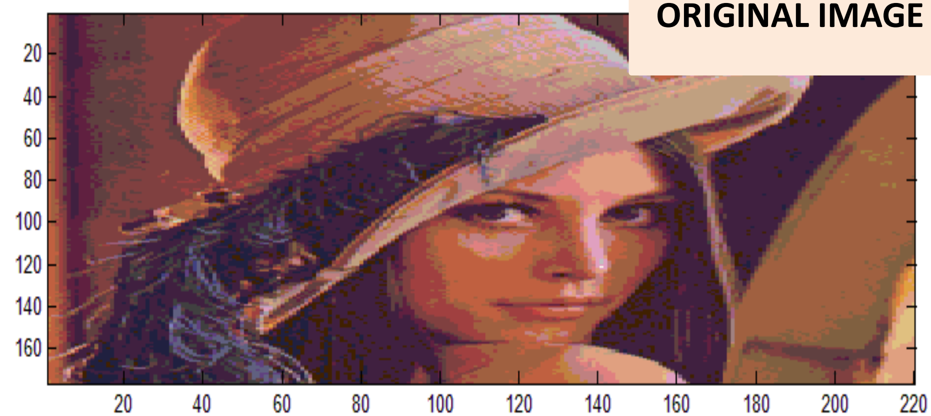
2. Application of voltage scaling

- Given
  - $I_{cell} = \left(\frac{p_1 \, V_{dd} \, D_{RGB}}{255}\right) + \left(\frac{p_2 \, D_{RGB}}{255}\right) + p_3$
- The maximum current given V_{dd} is:
  - $I_{max} = \left(\frac{p_1 \, V_{dd} \, [255\ 255\ 255]}{255}\right) + \left(\frac{p_2 [255\ 255\ 255]}{255}\right) + p_3$
- …and the maximum RGB:
  - $RGB_{max} = \frac{(I_{max} - p_3)\, 255}{p_1 V_{dd} + p_2}$
    - Whenever $I_{cell} > I_{max}$ the pixel is assigned RGB value RGB_{max}
    - Saturate to the maximum RGB value that can be generated given V_{dd}

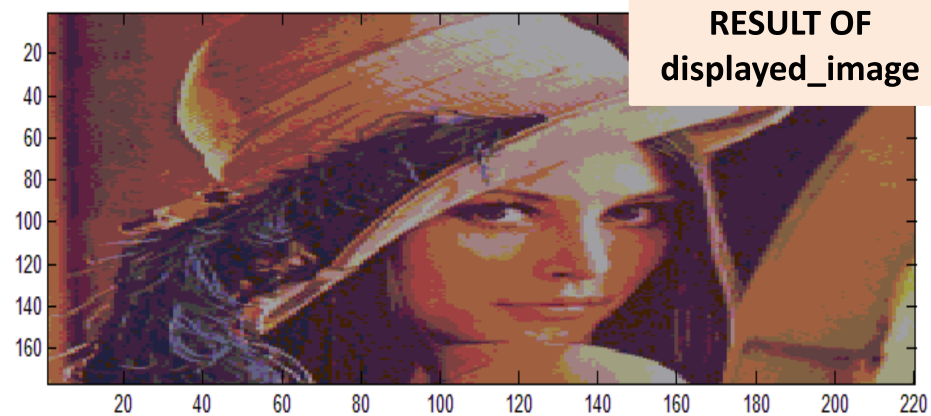
2. Application of voltage scaling

- Note: the image does not change!
  - What changes is the effect on the display
  - *displayed_image()* function simulates this effect

ORIGINAL IMAGE



RESULT OF displayed_image



2. Image after voltage scaling

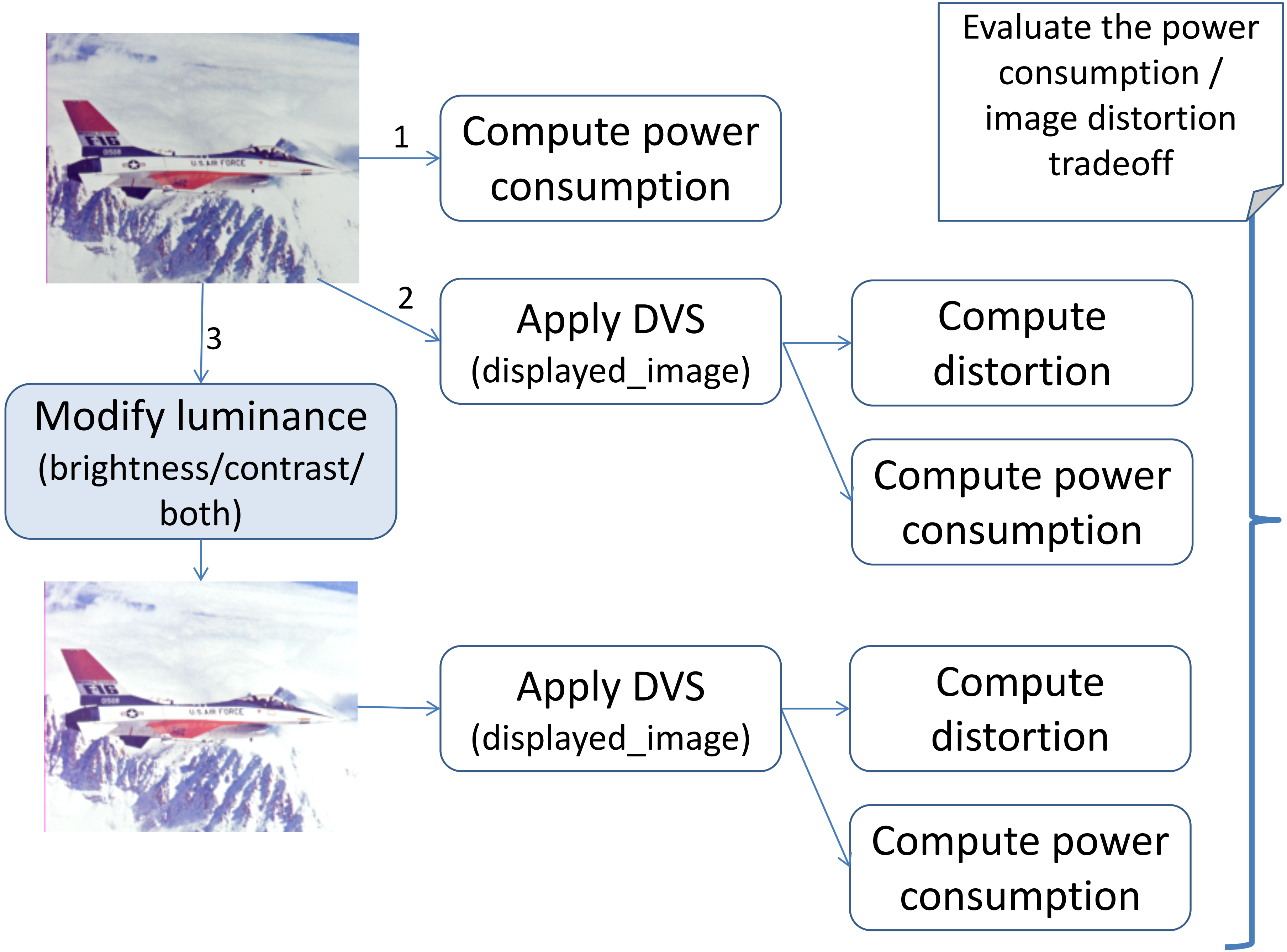
```
function out = displayed_image(I_cell, Vdd, mode)

SATURATED = 1;
DISTORTED = 2;

p1 =  4.251e-05;
p2 = -3.029e-04;
p3 =  3.024e-05;
Vdd_org = 15;

I_cell_max = (p1 * Vdd * 1) + (p2 * 1) + p3;
image_RGB_max = (I_cell_max - p3)/(p1*Vdd_org+p2) * 255;
out = round((I_cell - p3)/(p1*Vdd_org+p2) * 255);

if (mode == SATURATED)
   out(find(I_cell > I_cell_max)) = image_RGB_max;

else if (mode == DISTORTED)
      out(find(I_cell > I_cell_max)) = round(255 - out(find(I_cell > I_cell_max)));
   end
end
end
```

Maximum current that can flow with reduced voltage

Maximum RGB value that can be represented (lower than 255)

Matrix of RGB values of the original image (given the currents)

Saturates to max RGB value (Focus on this mode!)



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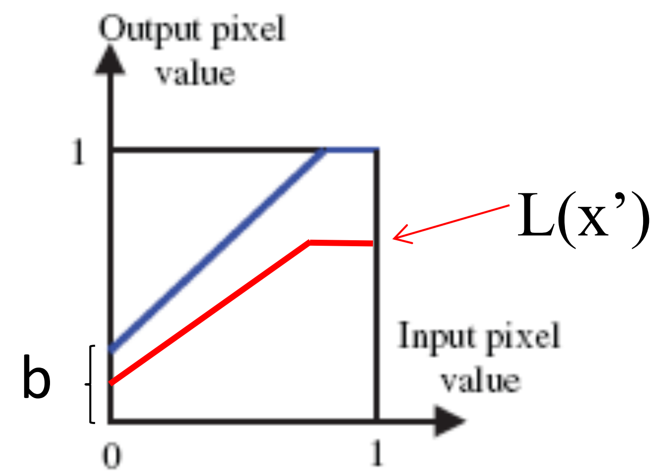
3. Apply image compensation

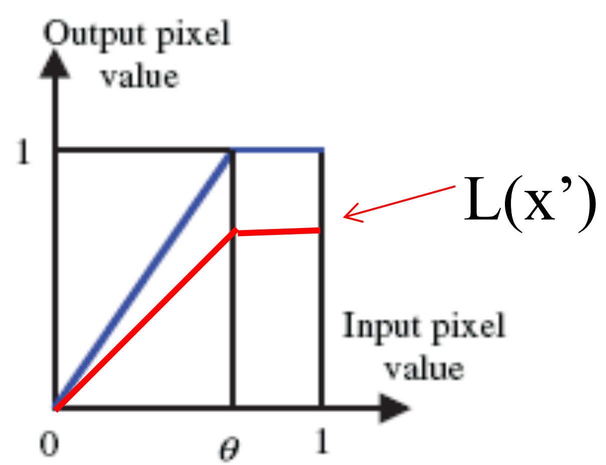
- Want to improve quality of resulting image
  - Apply some techniques **prior than** DVS
  - Enhance brightness/contrast of image

- Goal is to have lower distortion and higher power saving

3. Apply image compensation

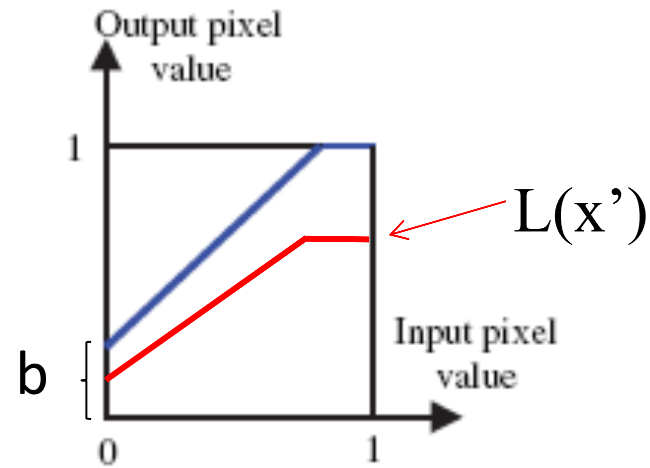
- Brightness scaling
  - Increase the pixel values by a certain constant b
    - E.g., b equal to luminance loss
    - V' = v + b
- Contrast enhancement
  - Amplification of contrast
    - V' = V * b
  - Multiply pixel values by a certain constant factor
    - Depends on variation of V_{dd}

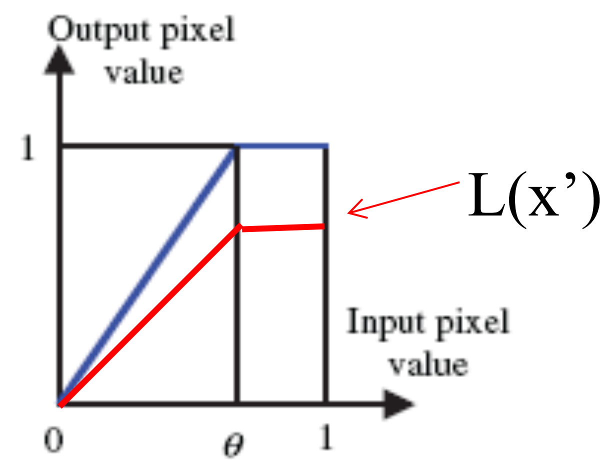


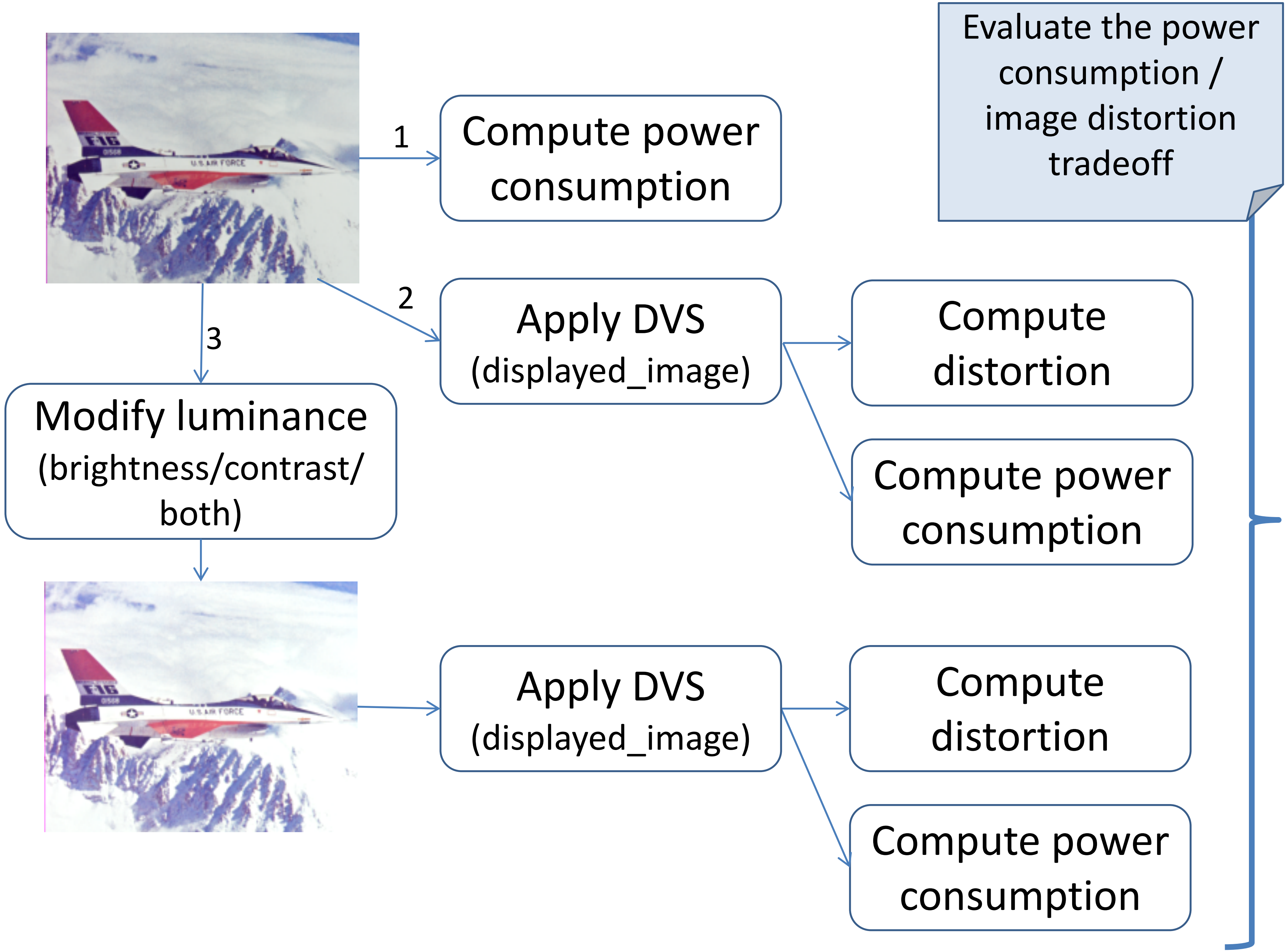


3. Apply image compensation

- Implemented in the HSV space
- Must determine the factor b as dependent from original V_{dd} and new V_{dd}
  - Brightness compensation
    - V' = V + b
    - b($V_{dd}\ original, V_{dd}\ new$)
  - Contrast enhancement
    - V' = V * b
    - b($V_{dd}\ original, V_{dd}\ new$)
  - Application of both







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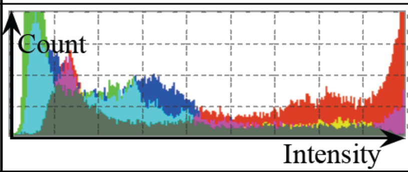
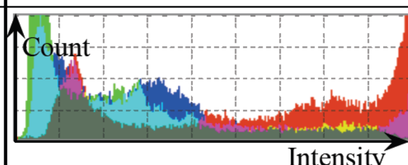
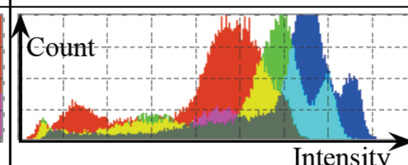
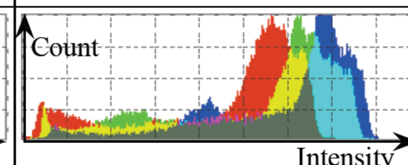
4. Analysis

- Find optimal supply voltage and compensated image to:
  - Minimize power consumption
  - Reach an average distortion distortion value of
    - 1%, 5%, 10%
- Apply the overall flow to all 15 images!

4. Analysis

t_{image}	Original image	10	Original image	300
Viewed image				
Color histogram				
V_{DD} (V)	15.0	8.7	15.0	12.0
Power (mW)	399.9	189.8	731.7	572.5
Saving (%)	-	52.5	-	21.8

LOW DISTORTION
COLOR DISTRIBUTION
ALMOST THE SAME

HIGH SAVING
OVER 50%

HIGHER DISTORTION
ORIGINAL IMAGE IS VERY
BRIGHT

LOWER SAVING
AROUND 20%