TU-Delft Image Processing course

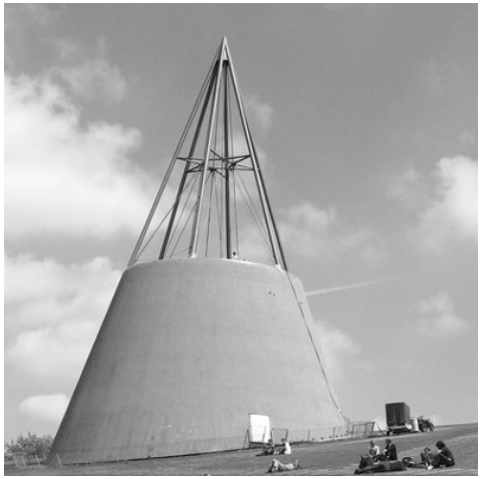
Histograms

Lecturer: Jan van Gemert

Histograms: Learning objectives

- Intuitive understanding of image histograms
- Contrast stretching
- Histogram equalization

Q: Which histogram to which image?



A



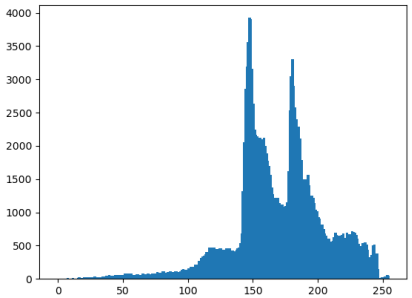
B



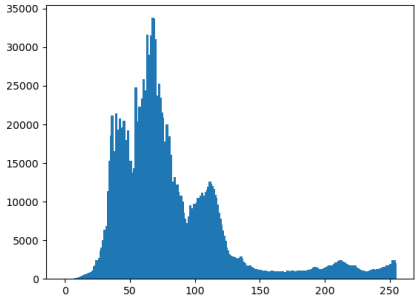
C



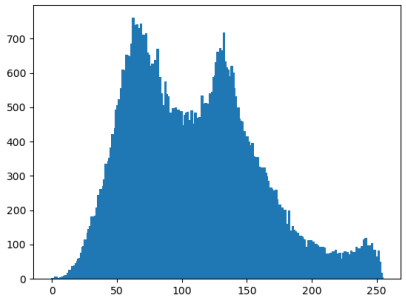
D



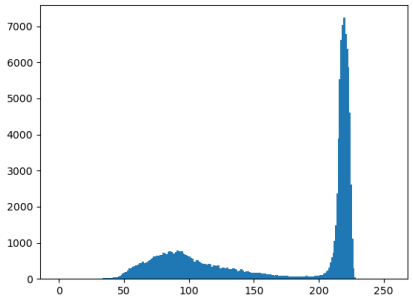
1



2

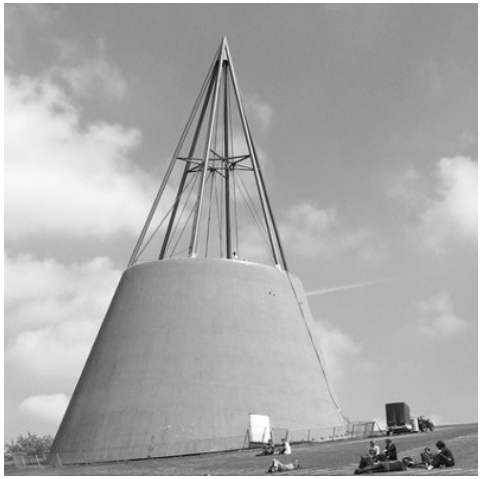


3



4

Q: Which histogram to which image?



A



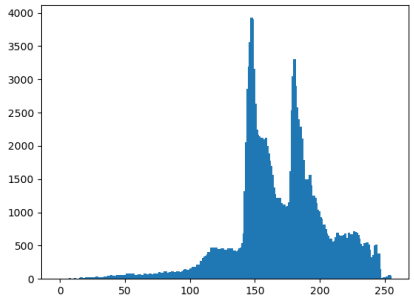
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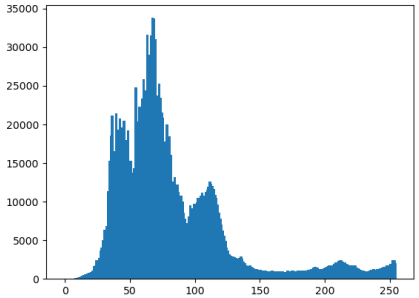
C



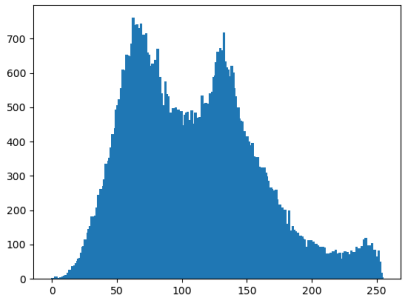
D



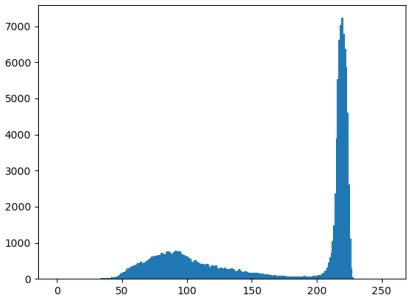
1



2



3



4

Answer: A1 B3 C4 D2

Question to you

Q: Given a histogram, can you reconstruct the image?

1. Never;
2. Only in special cases;
3. Always;
4. Always, if image width and image height are known.

Question to you

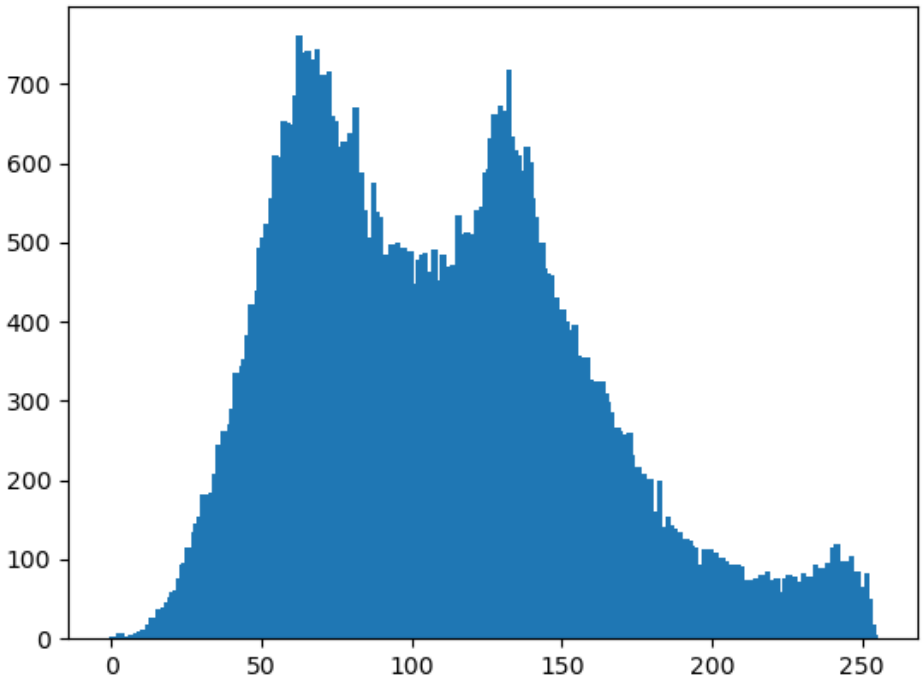
Q: Given a histogram, can you reconstruct the image?

1. Never;
2. Only in special cases;
3. Always;
4. Always, if image width and image height are known.

Answer: 2

Question to you

Given a 256 x 256 image, with the following histogram



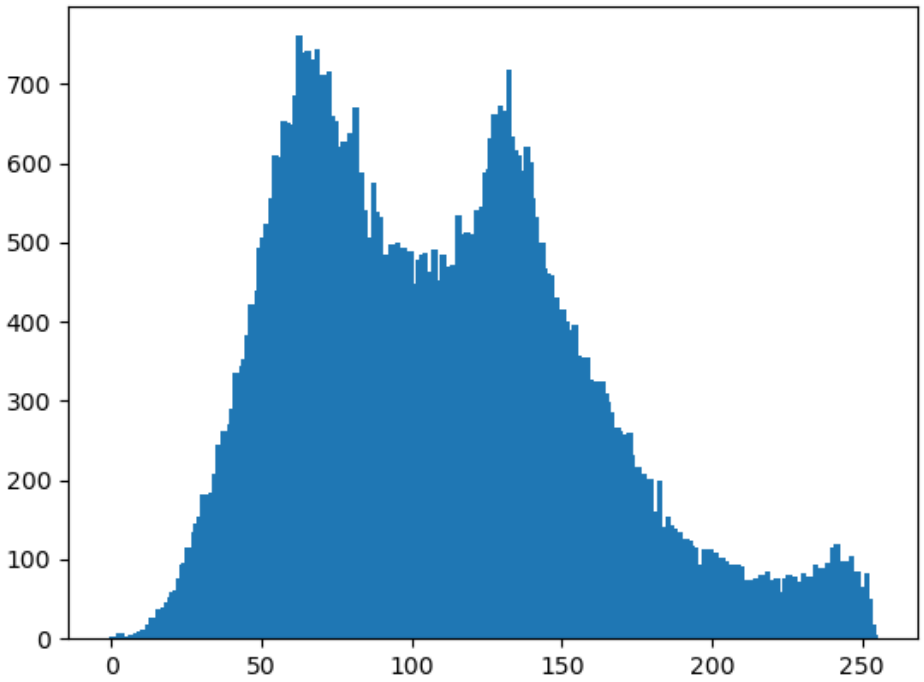
Q: What is the probability of the most frequent intensity value?

(choose best single answer)

1. $\approx \frac{1}{30}$
2. $\approx \frac{1}{60}$
3. $\approx \frac{1}{90}$
4. $\approx \frac{1}{120}$
5. $\approx \frac{1}{256}$
6. $\approx \frac{1}{750}$

Question to you

Given a 256 x 256 image, with the following histogram



Q: What is the probability of the most frequent intensity value?

(choose best single answer)

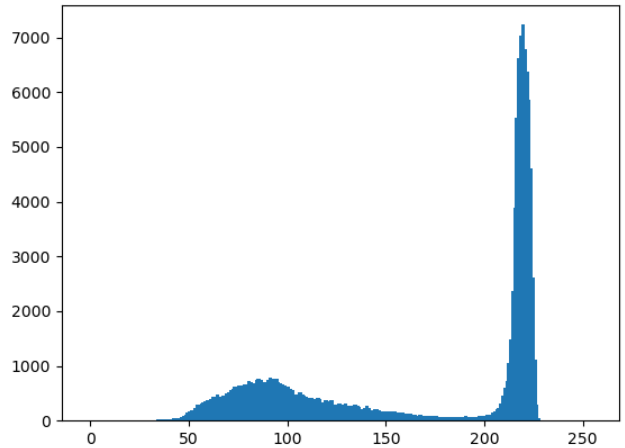
1. $\approx \frac{1}{30}$
2. $\approx \frac{1}{60}$
3. $\approx \frac{1}{90}$
4. $\approx \frac{1}{120}$
5. $\approx \frac{1}{256}$
6. $\approx \frac{1}{750}$

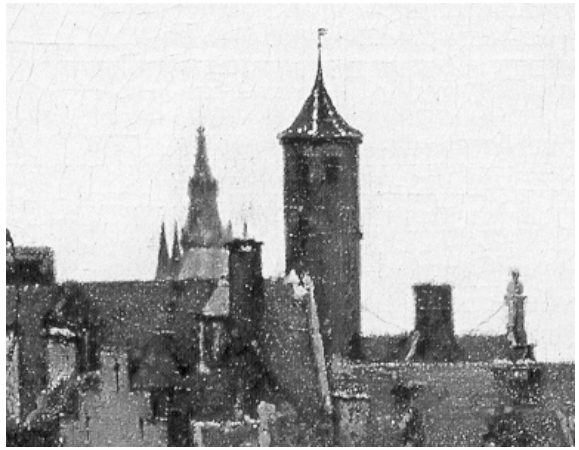
A: $\frac{750}{256 \times 256} \approx \frac{1}{90}$

Contrast stretching

For an intensity (gray value) given by i, use a function f to do a linear transform for using the full gray level range: $f(i) = a(i + b)$







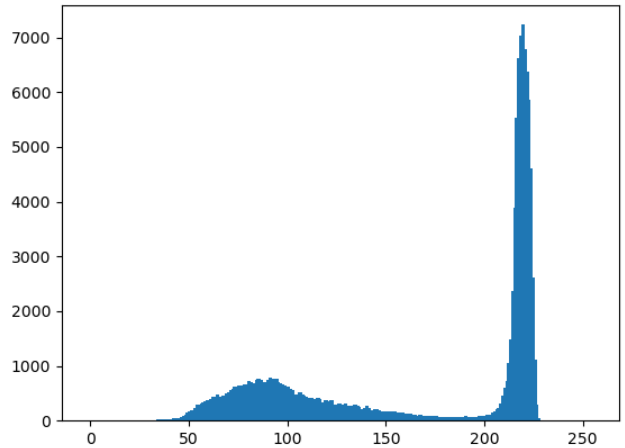
Q: What is a and b for this image?

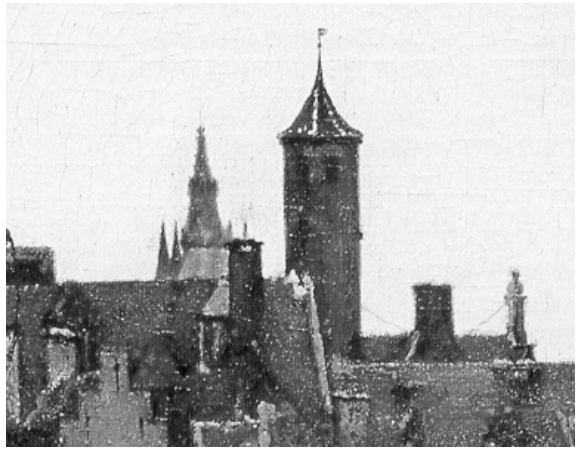
1. $a = 225,\ b = -50$
2. $a = 225,\ b = 25$
3. $a = \frac{255}{175},\ b = -50$
4. $a = \frac{255}{175},\ b = 25$

Contrast stretching

For an intensity (gray value) given by i, use a function f to do a linear transform for using the full gray level range: $f(i) = a(i + b)$







Q: What is a and b for this image?

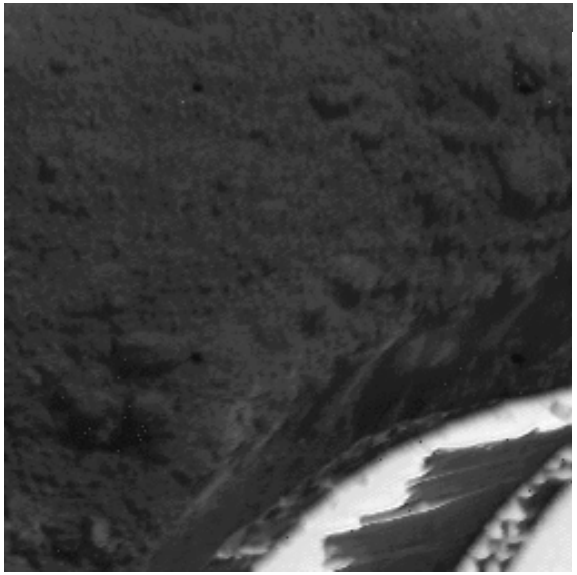
1. $a = 225,\ b = -50$
2. $a = 225,\ b = 25$
3. $a = \frac{255}{175},\ b = -50$
4. $a = \frac{255}{175},\ b = 25$

Answer: 3

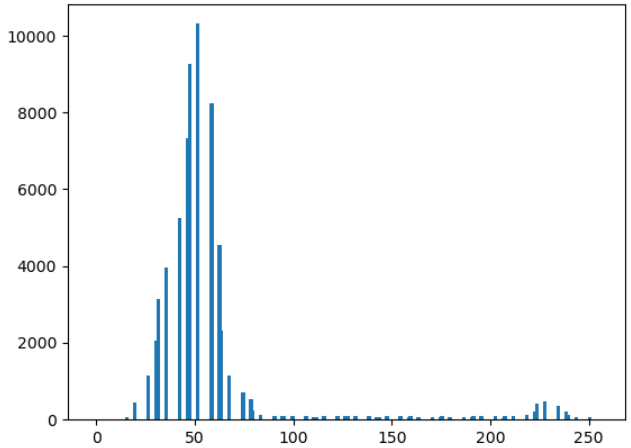
Questions?

Contrast stretch 2

Image



Histogram

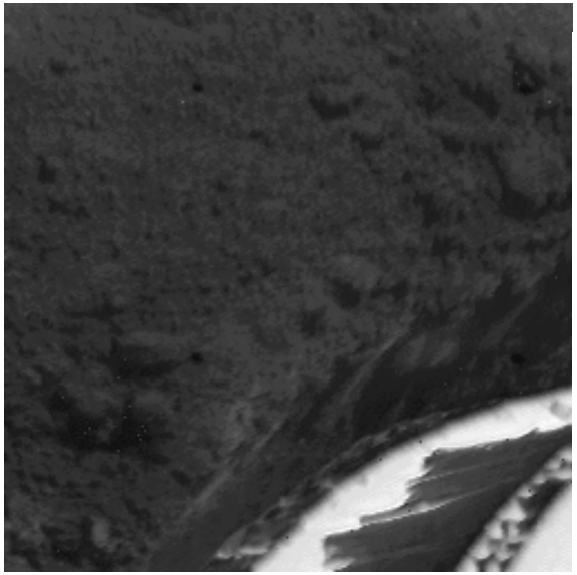


Contrast stretched image

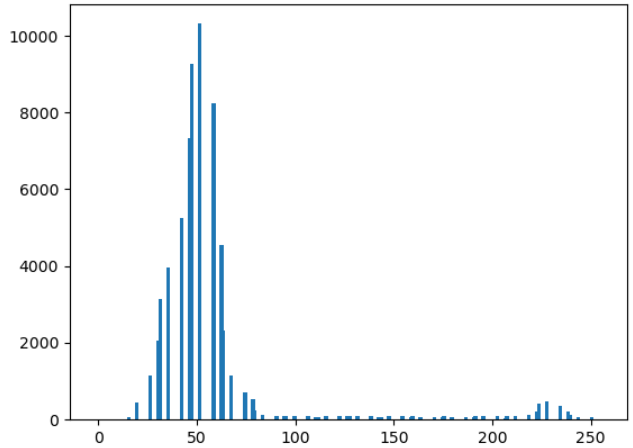
Q: How many groups do you see in the image/histogram?

Contrast stretch 2

Image



Histogram

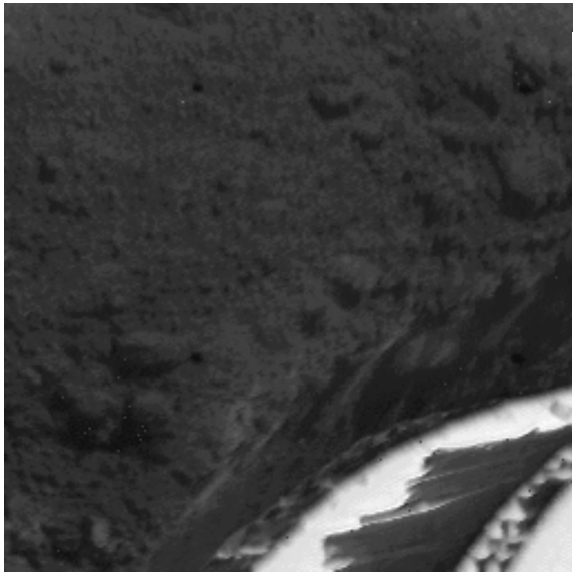


Contrast stretched image

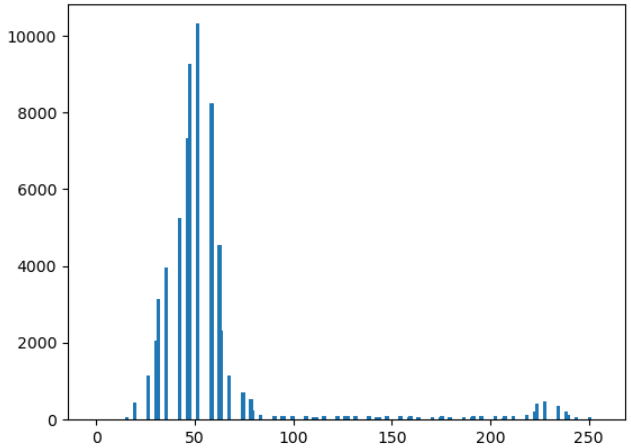
Q: How many groups do you see in the image/histogram?
A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)

Contrast stretch 2

Image



Histogram

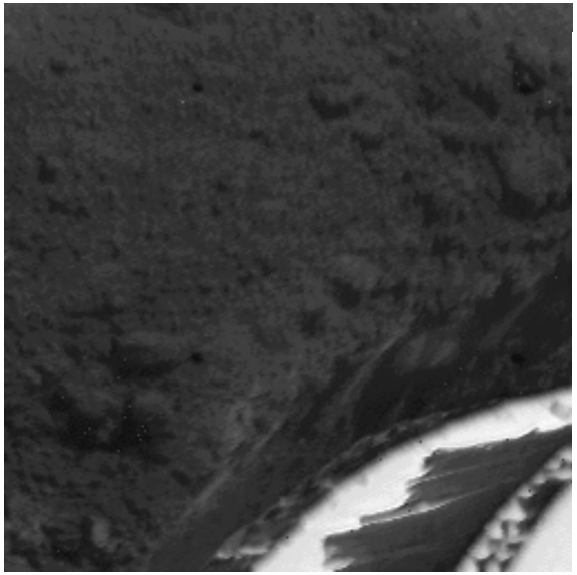


Contrast stretched image

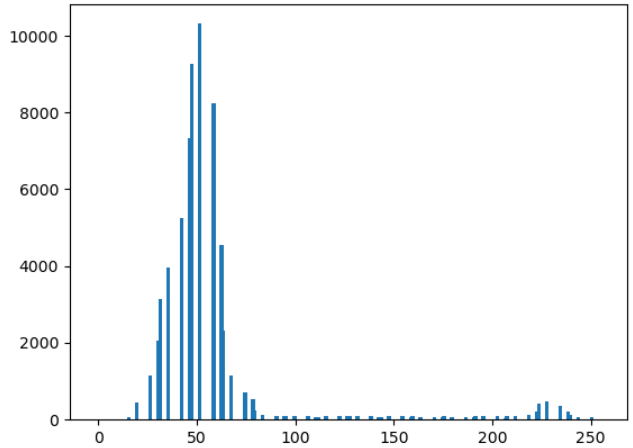
Q: How many groups do you see in the image/histogram?
A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)
Q: For each peak, what is it's range? (ie: how many bins)

Contrast stretch 2

Image



Histogram

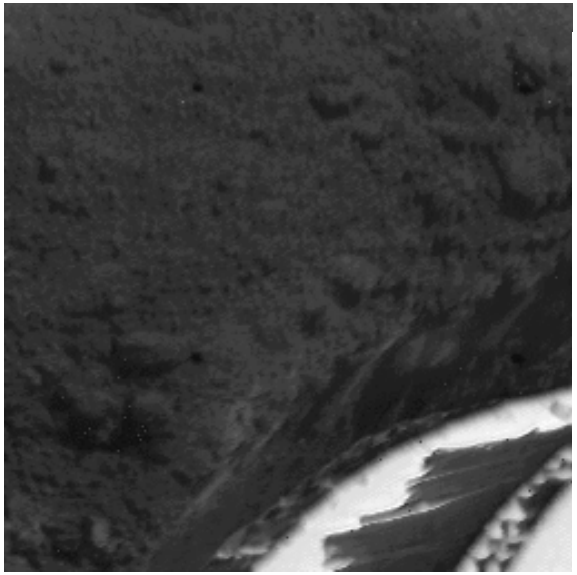


Contrast stretched image

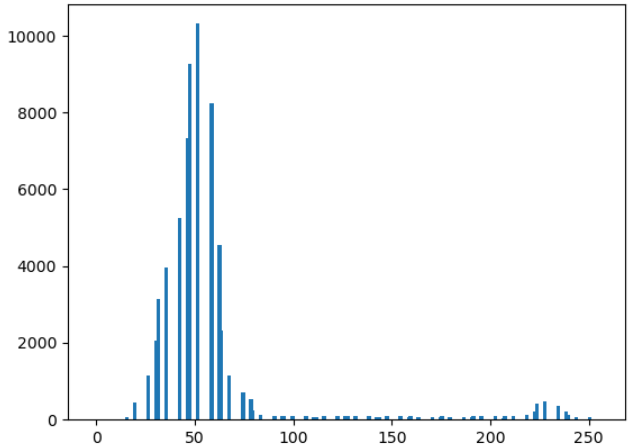
Q: How many groups do you see in the image/histogram?
A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)
Q: For each peak, what is it's range? (ie: how many bins)
A: Low-gray value peak: ≈ 50 bins; High-grey value peak: ≈ 25 bins.

Contrast stretch 2

Image



Histogram

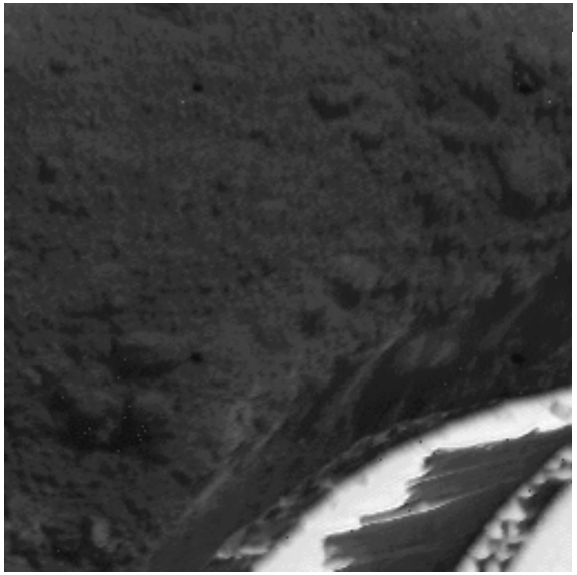


Contrast stretched image

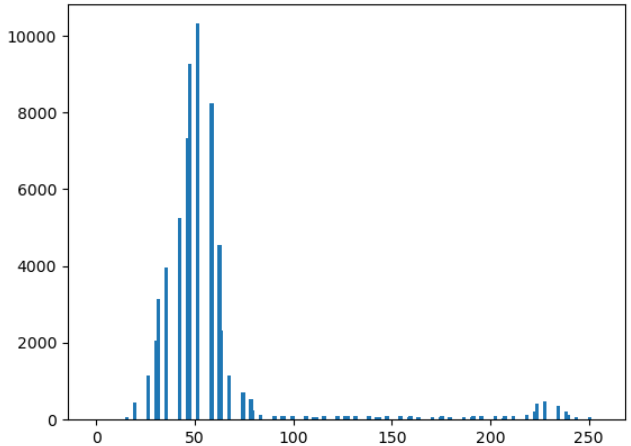
Q: How many groups do you see in the image/histogram?
A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)
Q: For each peak, what is it's range? (ie: how many bins)
A: Low-gray value peak: ≈ 50 bins; High-grey value peak: ≈ 25 bins.
Q: What would happen when contrast stretching?

Contrast stretch 2

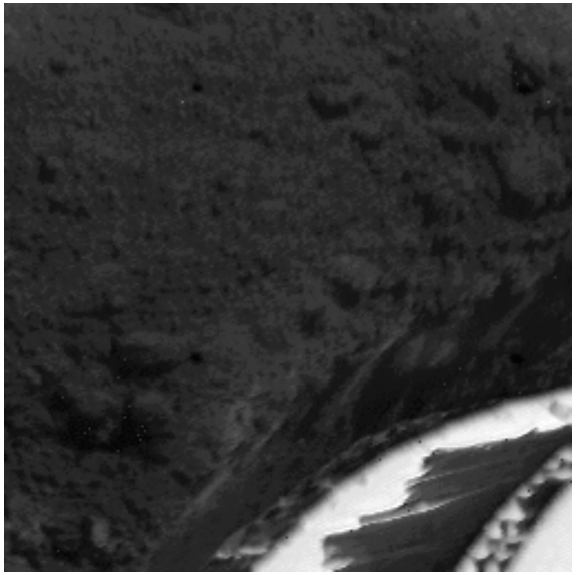
Image



Histogram



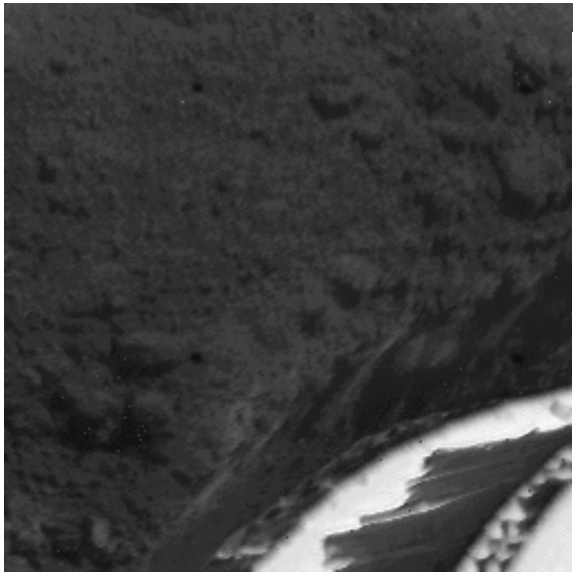
Contrast stretched image



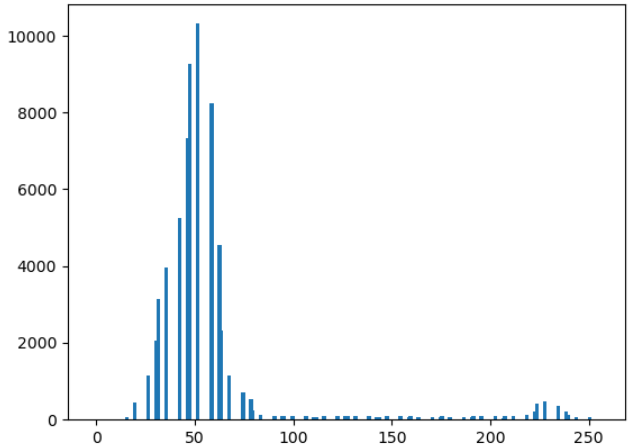
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A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)
Q: For each peak, what is it's range? (ie: how many bins)
A: Low-gray value peak: ≈ 50 bins; High-grey value peak: ≈ 25 bins.
Q: What would happen when contrast stretching?
A: Only a small change in the stretched image.

Contrast stretch 2

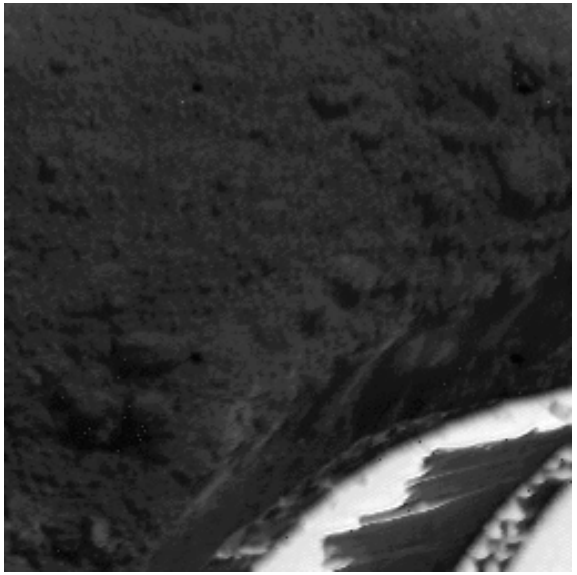
Image



Histogram



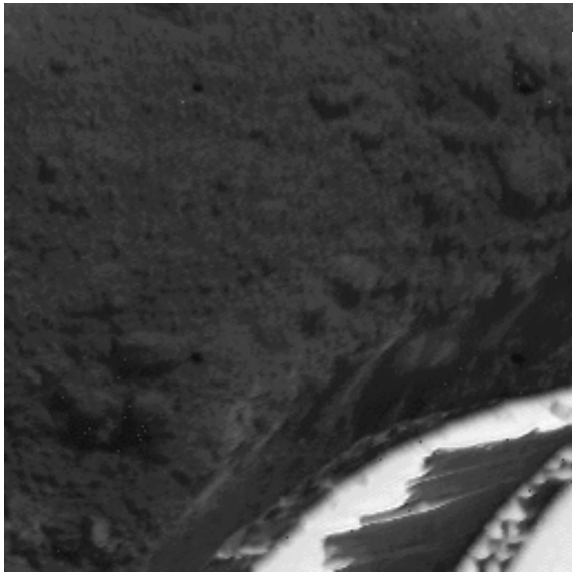
Contrast stretched image



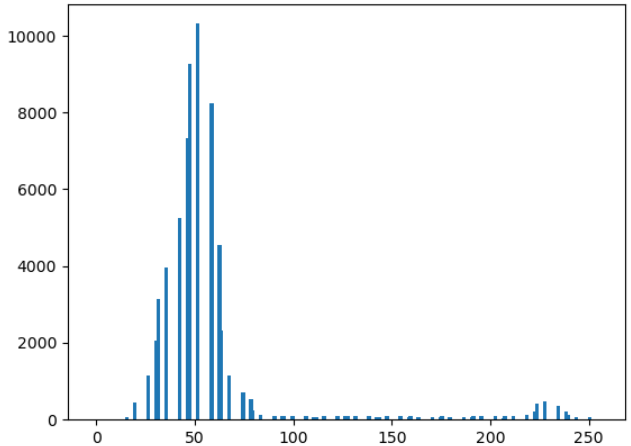
Q: How many groups do you see in the image/histogram?
A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)
Q: For each peak, what is it's range? (ie: how many bins)
A: Low-gray value peak: ≈ 50 bins; High-grey value peak: ≈ 25 bins.
Q: What would happen when contrast stretching?
A: Only a small change in the stretched image.
Q: Why?

Contrast stretch 2

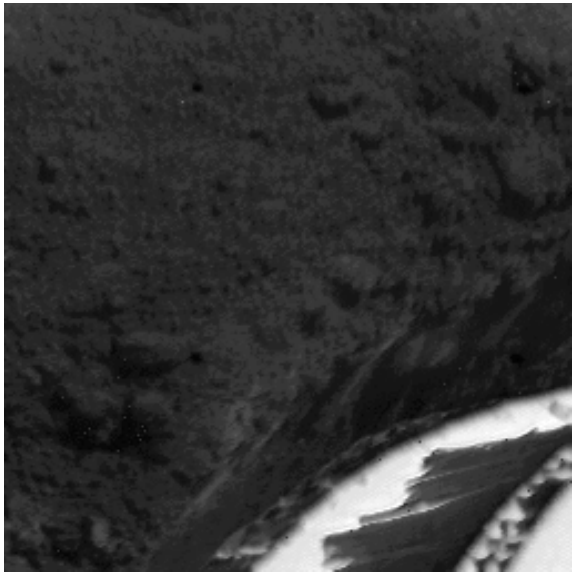
Image



Histogram

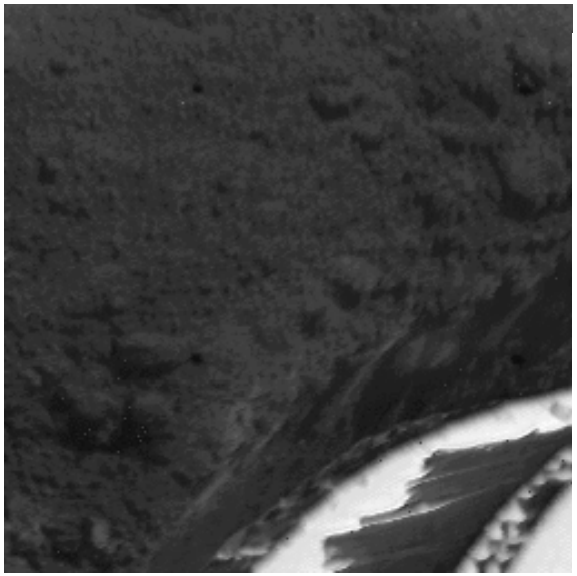


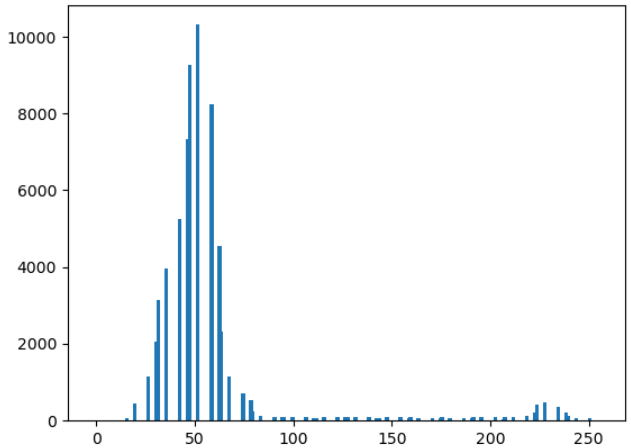
Contrast stretched image



Q: How many groups do you see in the image/histogram?
A: 2 groups (a larger low-gray value peak and smaller high-grey value peak)
Q: For each peak, what is it's range? (ie: how many bins)
A: Low-gray value peak: ≈ 50 bins; High-grey value peak: ≈ 25 bins.
Q: What would happen when contrast stretching?
A: Only a small change in the stretched image.
Q: Why? A: No much room to 'stretch'.

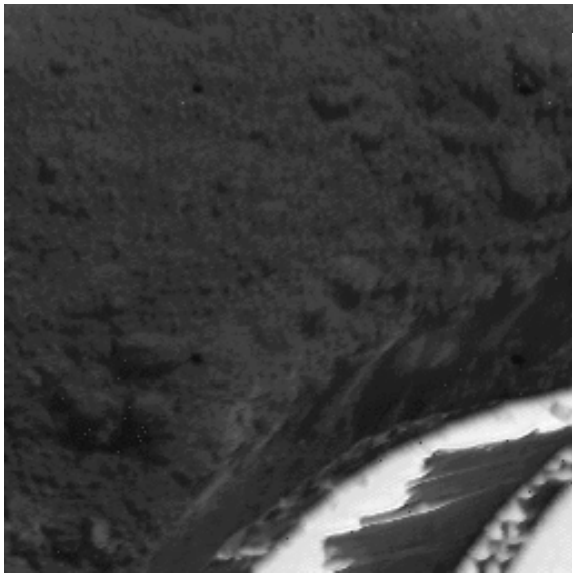
Histogram equalization: Motivation

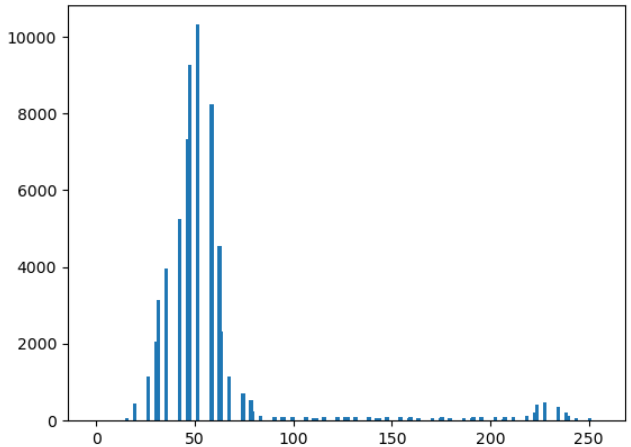


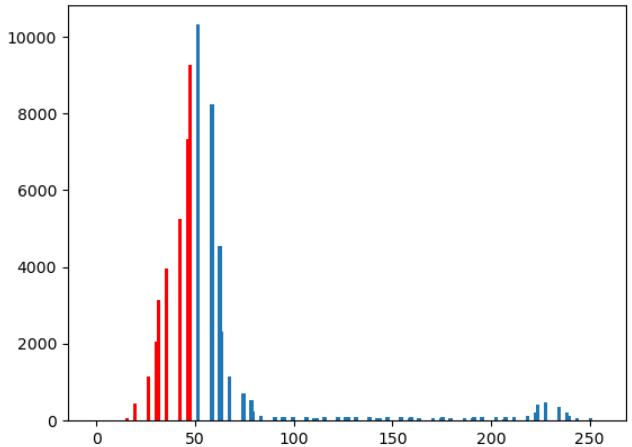


Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?

Histogram equalization: Motivation

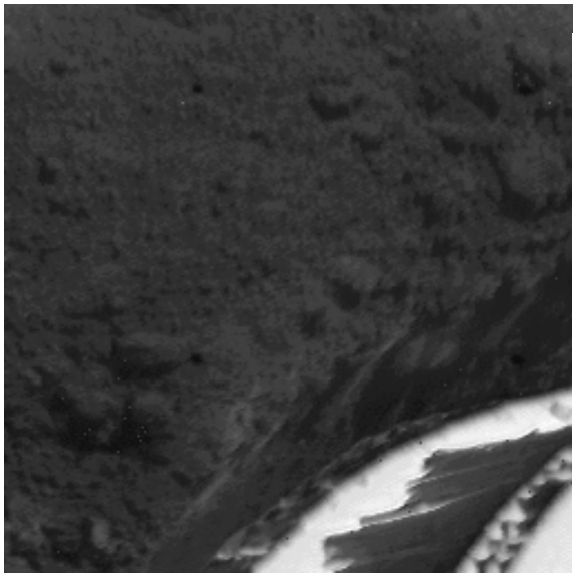


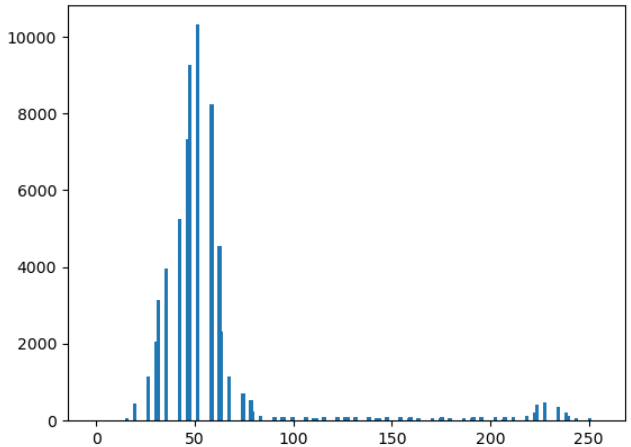


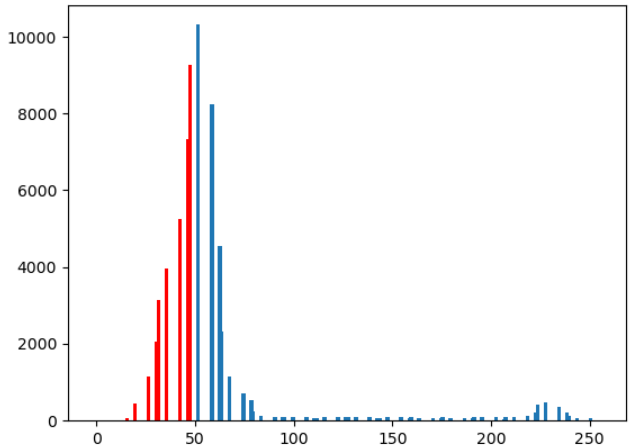


Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?
A: Around 50 bins. (See right image, in red)

Histogram equalization: Motivation

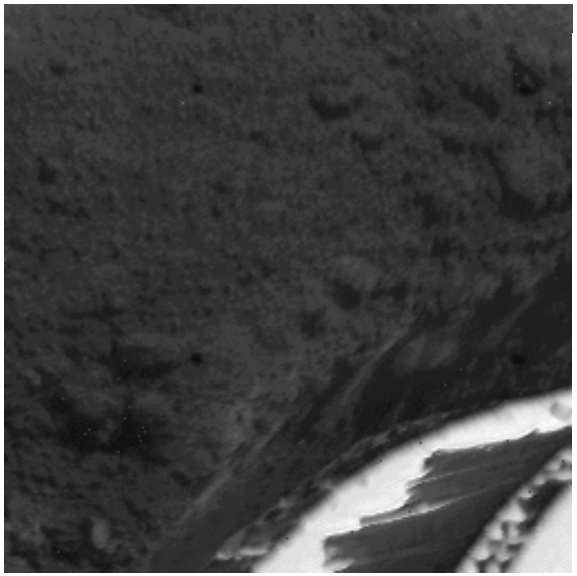


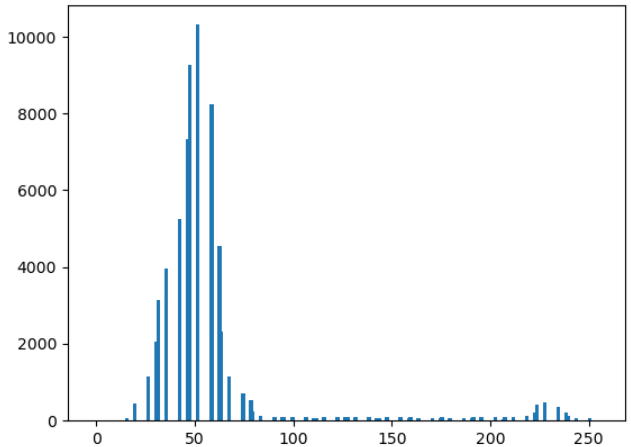


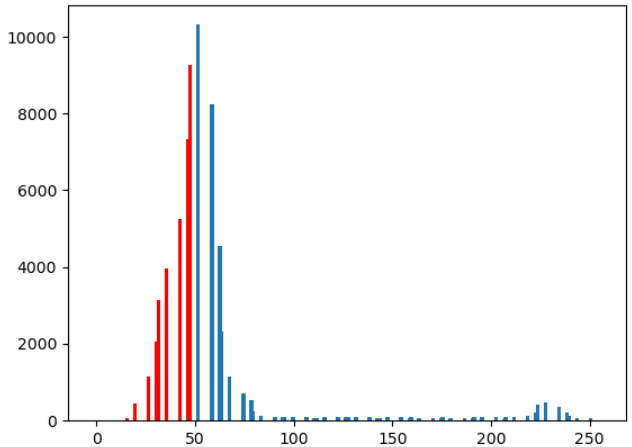


Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?
A: Around 50 bins. (See right image, in red)
Q: What is the fraction (%) of bins used by $\sim 60\%$ of the nr of pixels?

Histogram equalization: Motivation

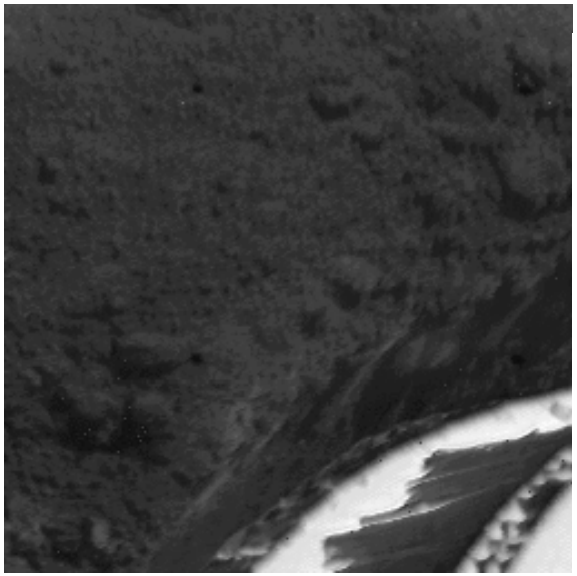


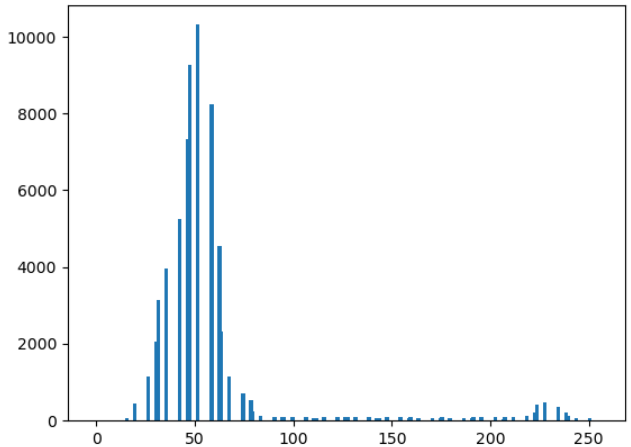


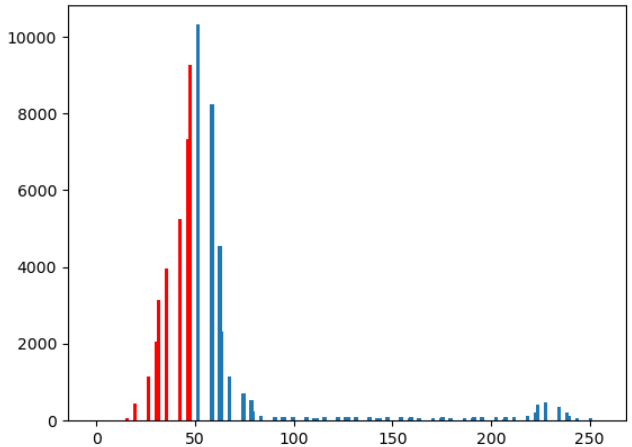


Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?
A: Around 50 bins. (See right image, in red)
Q: What is the fraction (%) of bins used by $\sim 60\%$ of the nr of pixels?
A: 50 bins $\approx 20\%$ out of 256 bins in total;

Histogram equalization: Motivation



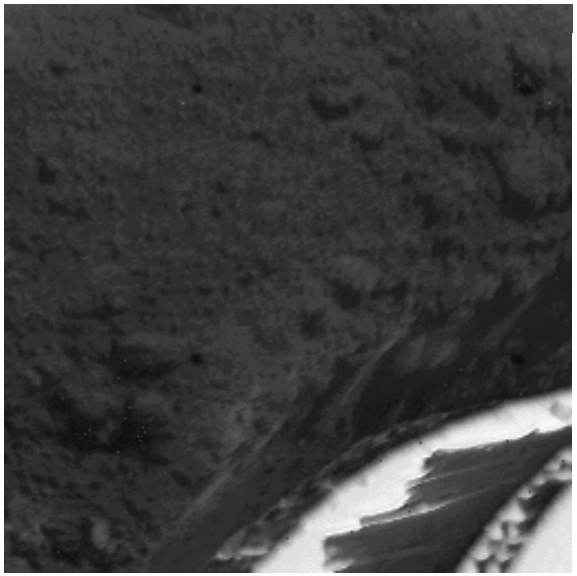


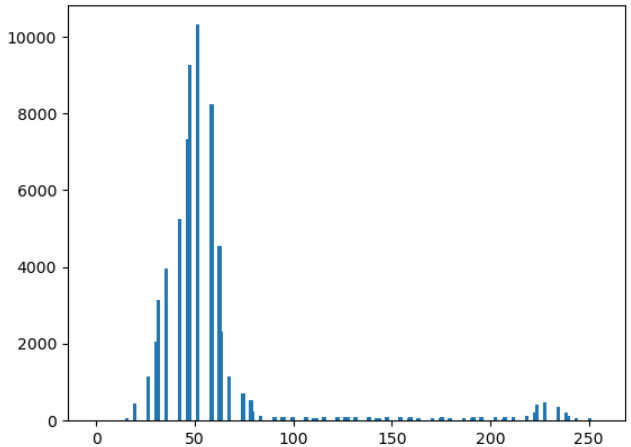


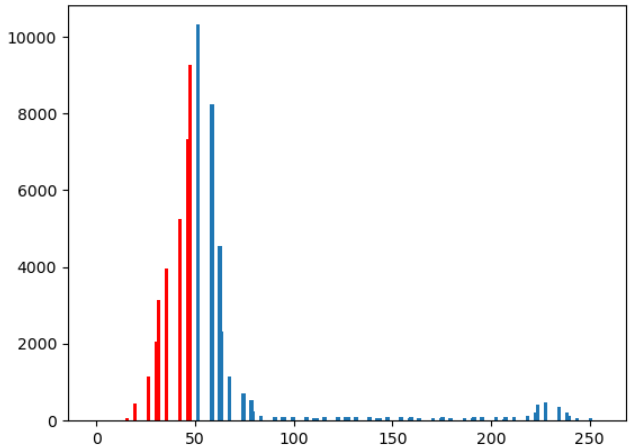
Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?
A: Around 50 bins. (See right image, in red)
Q: What is the fraction (%) of bins used by $\sim 60\%$ of the nr of pixels?
A: 50 bins $\approx 20\%$ out of 256 bins in total;

so... 60% of pixels is in only 20% of the bins.

Histogram equalization: Motivation





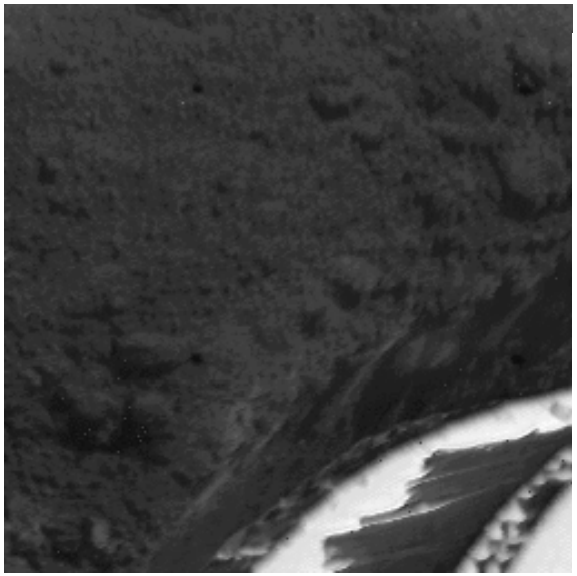


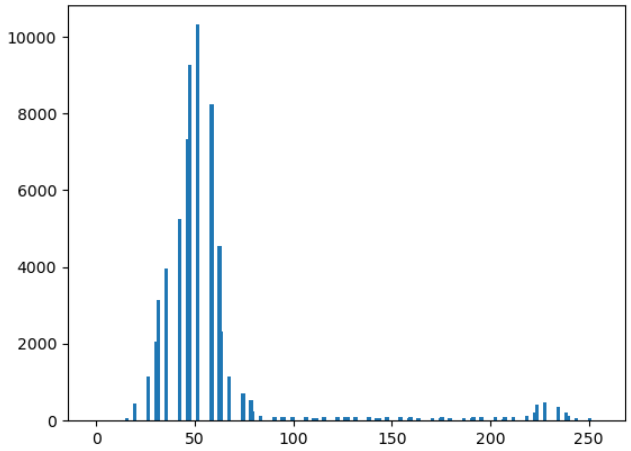
Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?
A: Around 50 bins. (See right image, in red)
Q: What is the fraction (%) of bins used by $\sim 60\%$ of the nr of pixels?
A: 50 bins $\approx 20\%$ out of 256 bins in total;

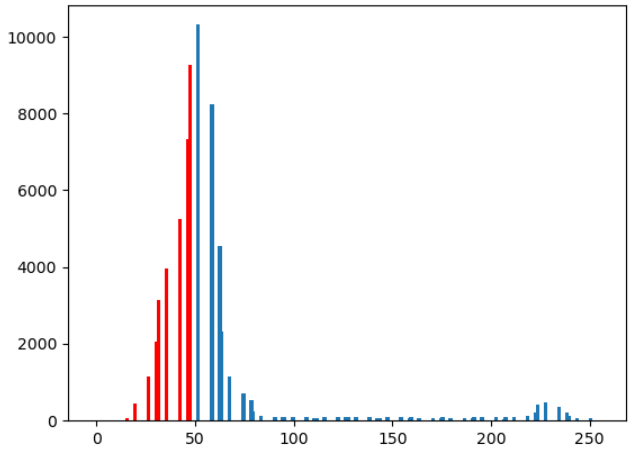
so... 60% of pixels is in only 20% of the bins.

Q: How to spread the contrast more fairly over the number of pixels?

Histogram equalization: Motivation





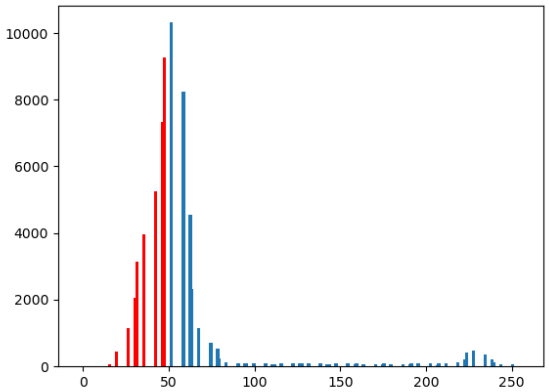


Q: Starting from bin 0, how many bins needed for $\sim 60\%$ of the nr of pixels?
A: Around 50 bins. (See right image, in red)
Q: What is the fraction (%) of bins used by $\sim 60\%$ of the nr of pixels?
A: 50 bins $\approx 20\%$ out of 256 bins in total;

so... 60% of pixels is in only 20% of the bins.

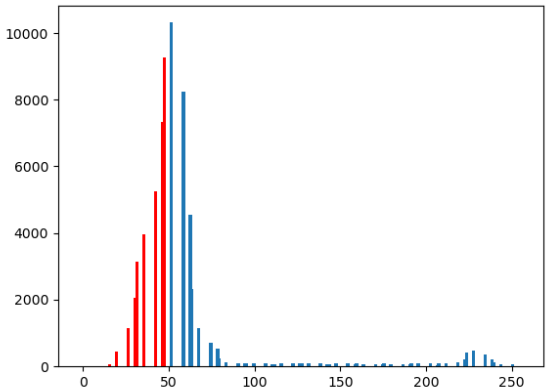
Q: How to spread the contrast more fairly over the number of pixels?
A: Spread number of pixels uniformly over nr of bins (histogram equalization)

Histogram equalization: How to compute



Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

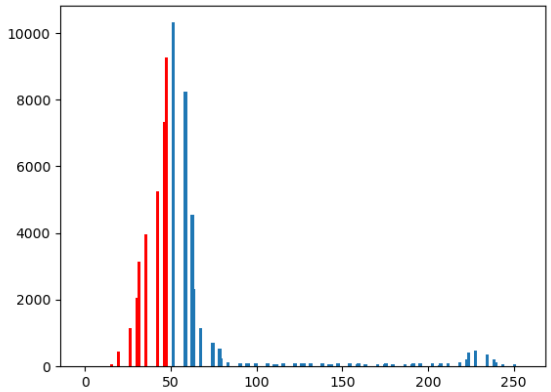
Histogram equalization: How to compute



Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

Q: For the histogram above, and gray-value (bin) $i = 50$, what would $f(50)$ be?

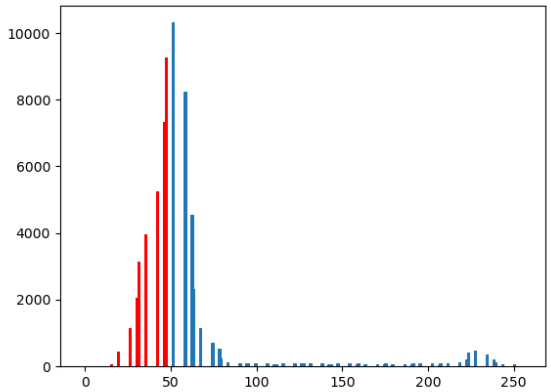
Histogram equalization: How to compute



Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

Q: For the histogram above, and gray-value (bin) $i = 50$, what would $f(50)$ be?
A: $i = 50 \approx 60\%$ of the pixels; 60% of the 256 bins is around 150; so $f(50) \approx 150$.

Histogram equalization: How to compute

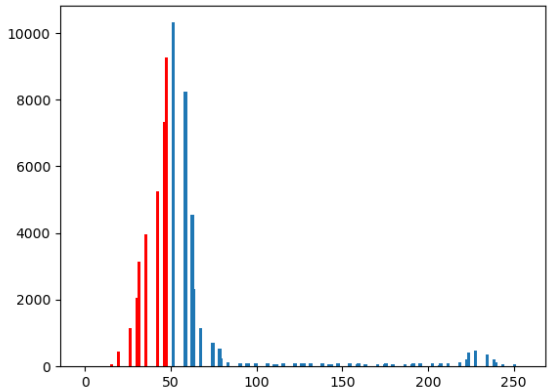


Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

Q: For the histogram above, and gray-value (bin) $i = 50$, what would $f(50)$ be?
A: $i = 50 \approx 60\%$ of the pixels; 60% of the 256 bins is around 150; so $f(50) \approx 150$.
Q: How to compute the mapping function $f(i)$?

A: $f(i) =$

Histogram equalization: How to compute



Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

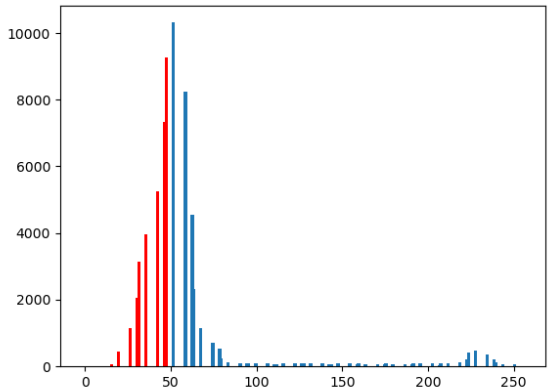
Q: For the histogram above, and gray-value (bin) $i = 50$, what would $f(50)$ be?

A: $i = 50 \approx 60\%$ of the pixels; 60% of the 256 bins is around 150; so $f(50) \approx 150$.

Q: How to compute the mapping function $f(i)$?

A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

Histogram equalization: How to compute



Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

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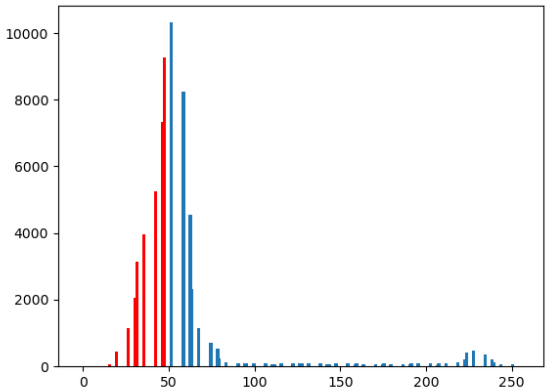
A: $i = 50 \approx 60\%$ of the pixels; 60% of the 256 bins is around 150; so $f(50) \approx 150$.

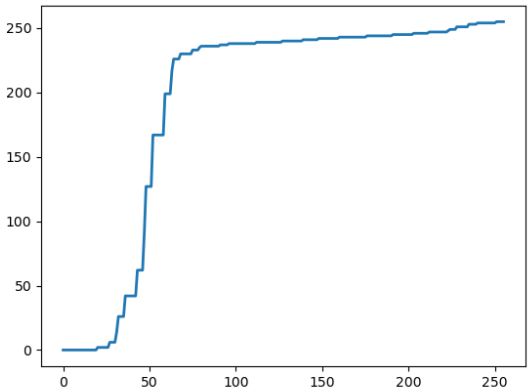
Q: How to compute the mapping function $f(i)$?

A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

Q: What would a plot of f for this image look like? (x-axis: i, y-axis: $f(i)$)

Histogram equalization: How to compute





Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

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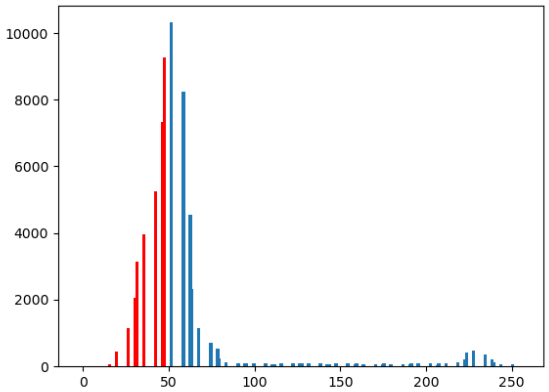
A: $i = 50 \approx 60\%$ of the pixels; 60% of the 256 bins is around 150; so $f(50) \approx 150$.

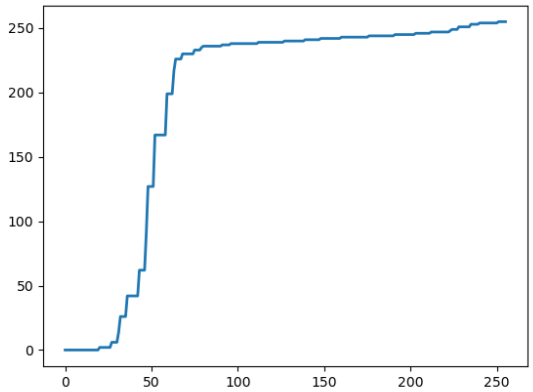
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A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

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Histogram equalization: How to compute





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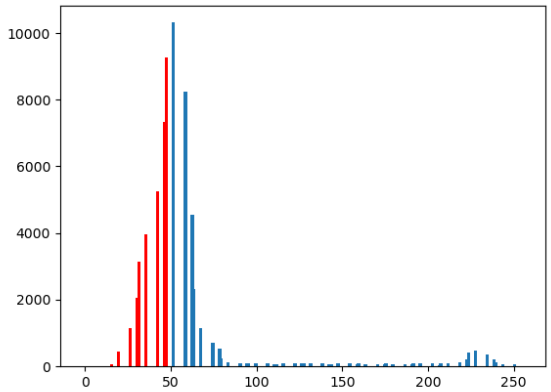
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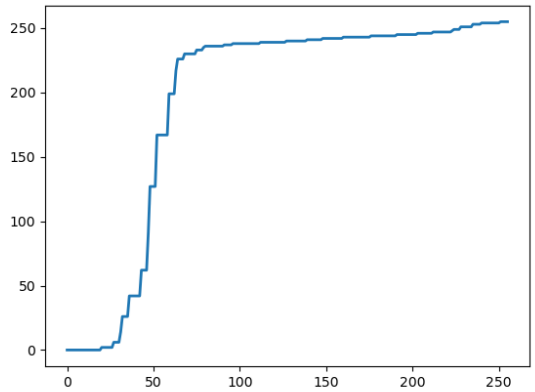
A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

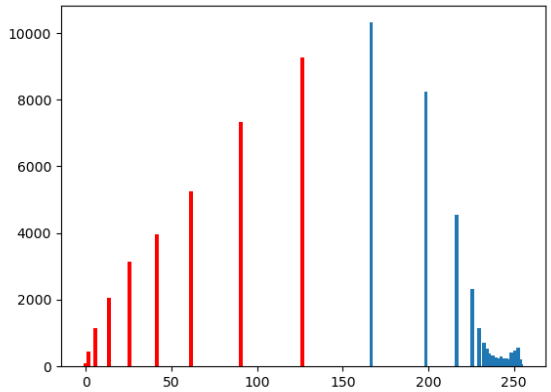
Q: What would a plot of f for this image look like? (x-axis: i, y-axis: $f(i)$)

Q: What would the new histogram look like?

Histogram equalization: How to compute







Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

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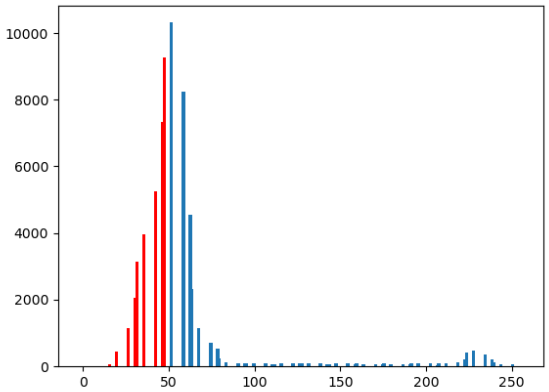
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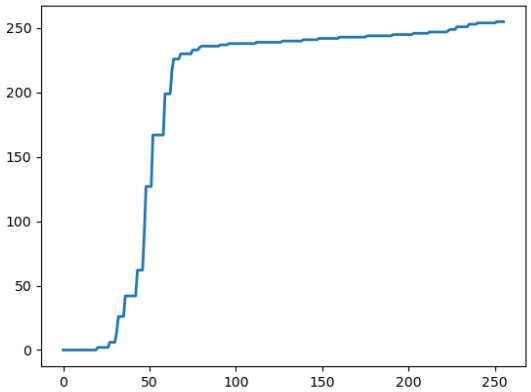
A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

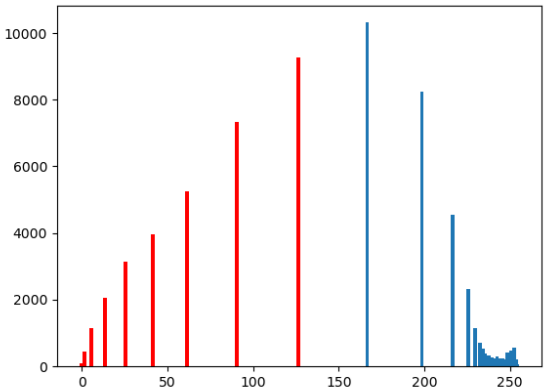
Q: What would a plot of f for this image look like? (x-axis: i, y-axis: $f(i)$)

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Histogram equalization: How to compute







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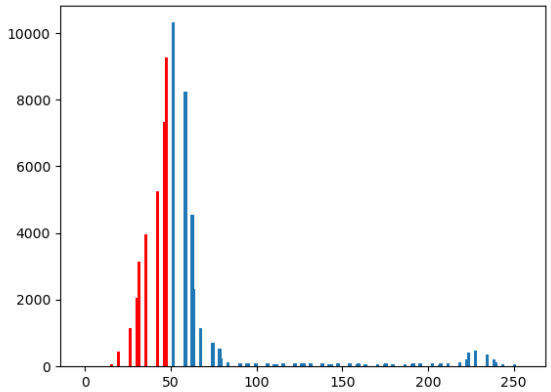
A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

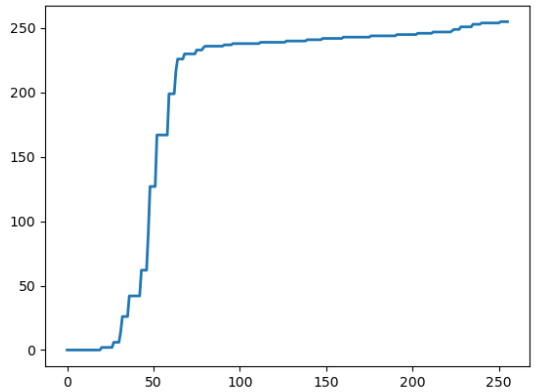
Q: What would a plot of f for this image look like? (x-axis: i, y-axis: $f(i)$)

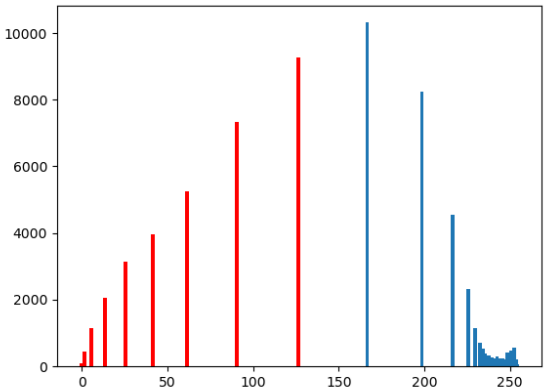
Q: What would the new histogram look like?

Q: Why are the red bins not closer to 150?

Histogram equalization: How to compute







Data-driven function f to map input gray-value (bin) i to new value (bin) $f(i)$.

Q: For the histogram above, and gray-value (bin) $i = 50$, what would $f(50)$ be?
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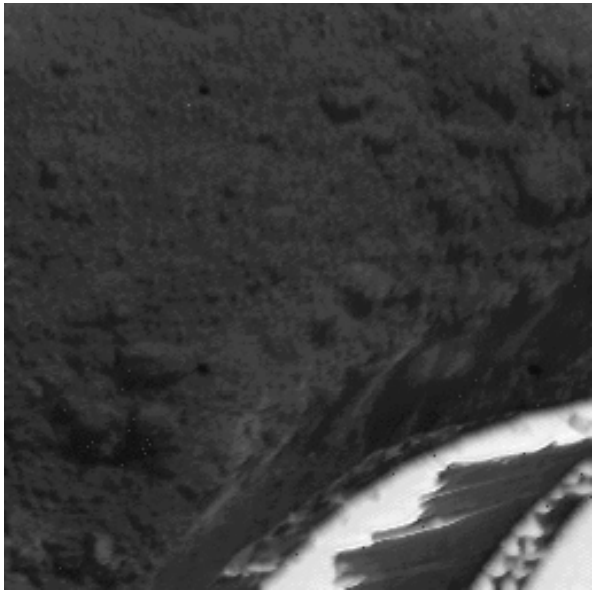
A: $f(i) = \frac{\text{nr bins}-1}{\text{nr pixels}} \sum_{j=0}^{i} \text{histogram}(j)$

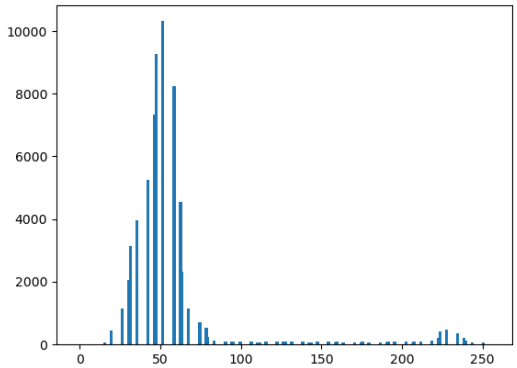
Q: What would a plot of f for this image look like? (x-axis: i, y-axis: $f(i)$)
Q: What would the new histogram look like?
Q: Why are the red bins not closer to 150?
A: Discretization artifacts (f can only 'move' bins around; actually $i = 50$ is around 50% of the pixels, but $i = 51$ is $> 60\%$ of the pixels)

Questions?

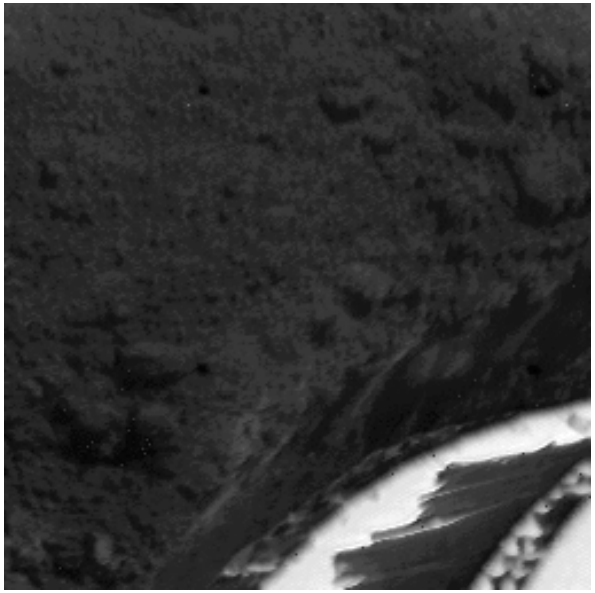
Examples: Moon

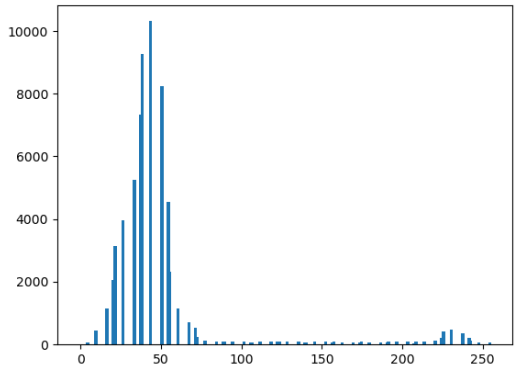
Original





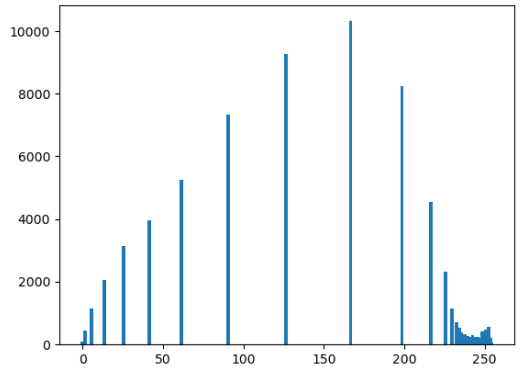
Stretched





Equalized

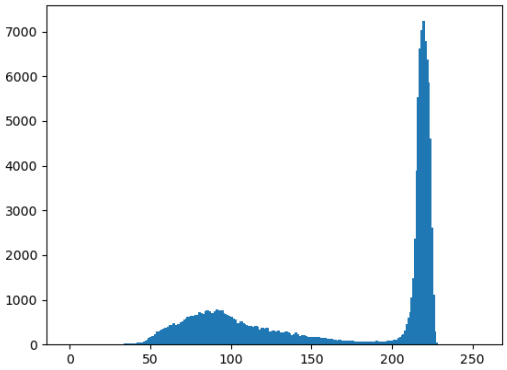




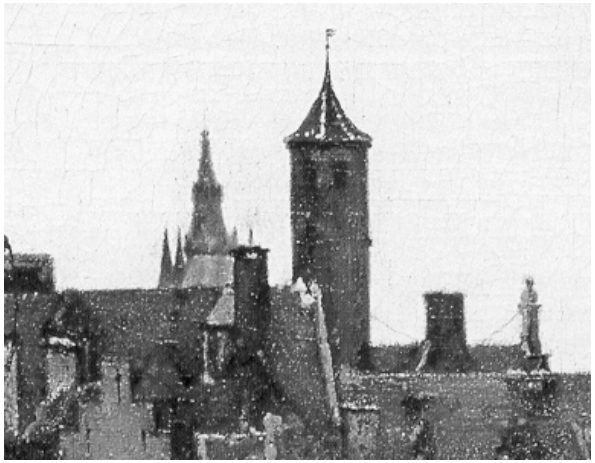
Examples: Oude kerk

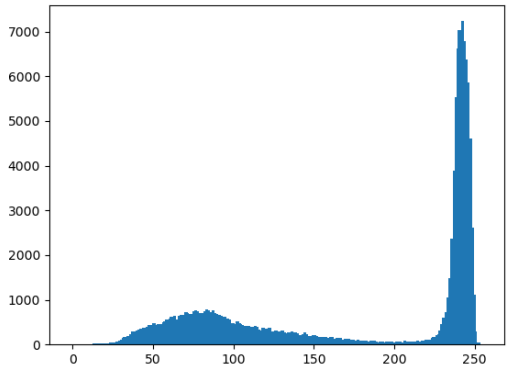
Original



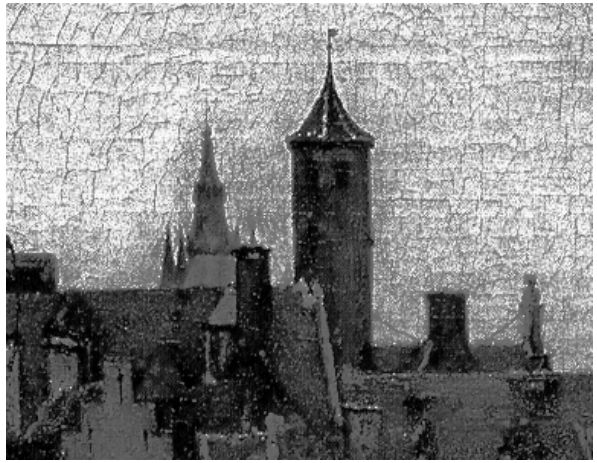


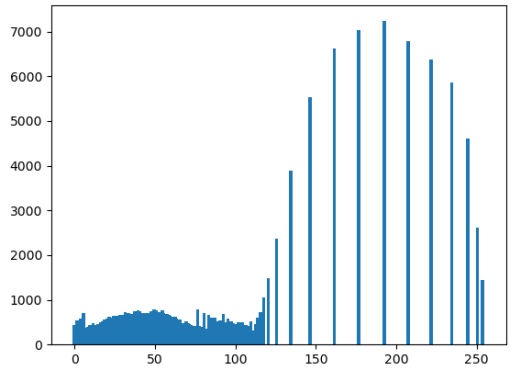
Stretched





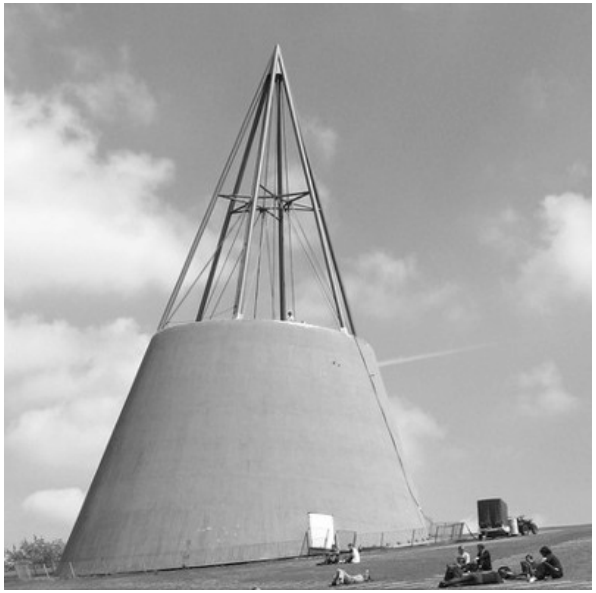
Equalized

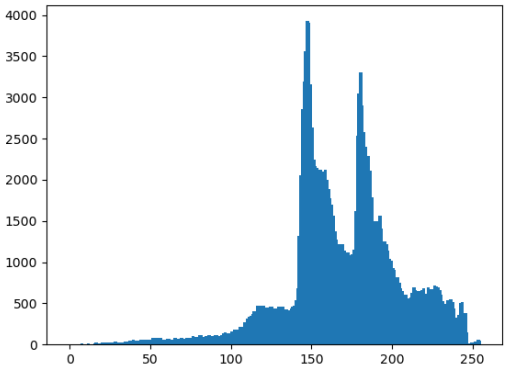




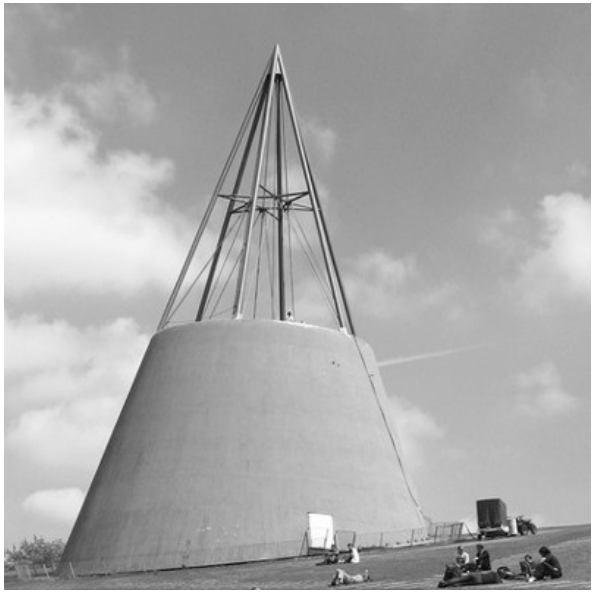
Examples: Library

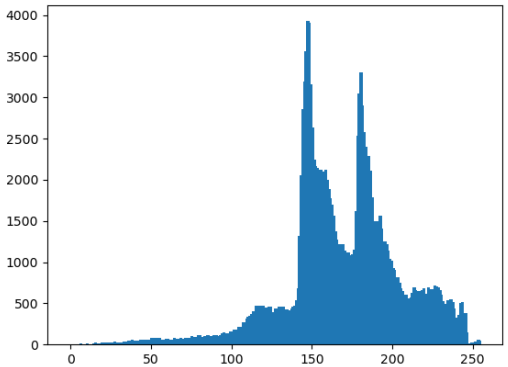
Original



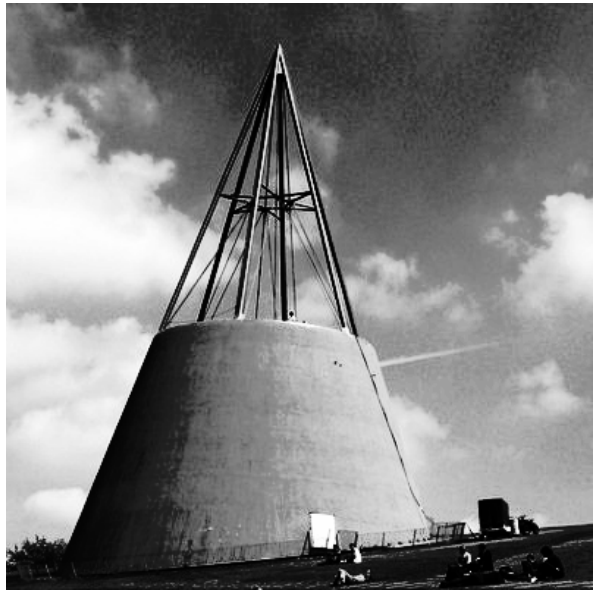


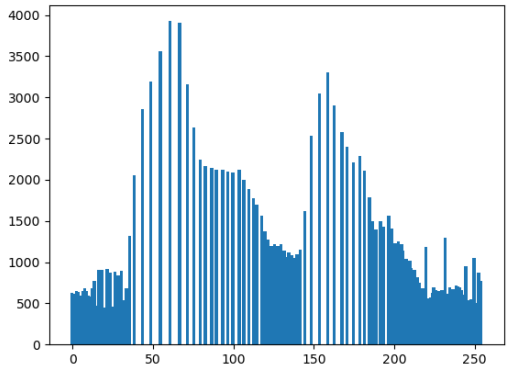
Stretched





Equalized





Questions?