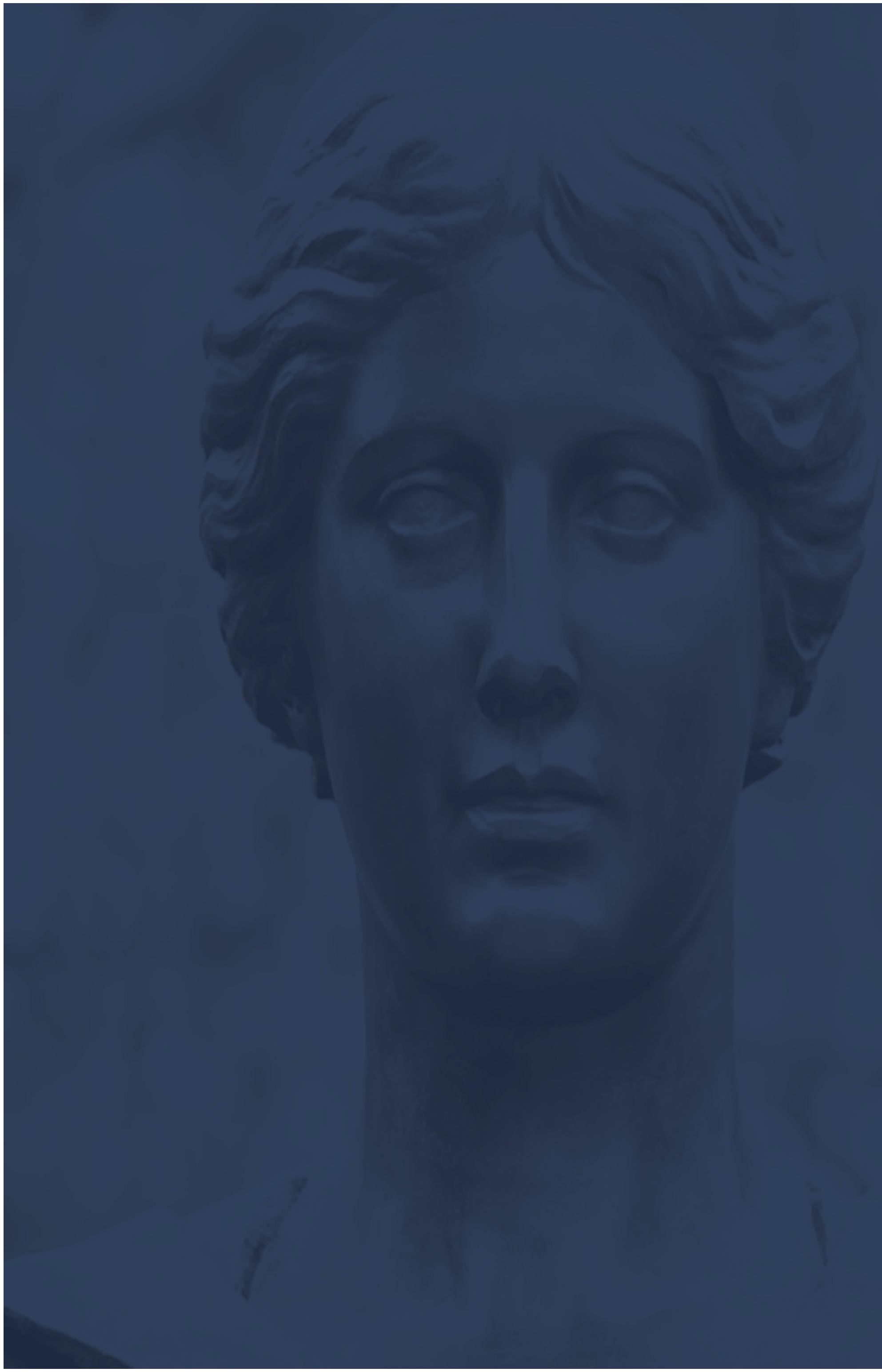

Unsupervised clustering methods for image segmentation: application to scanning electron microscopy images of graphene

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Graphene: Microscopy Images

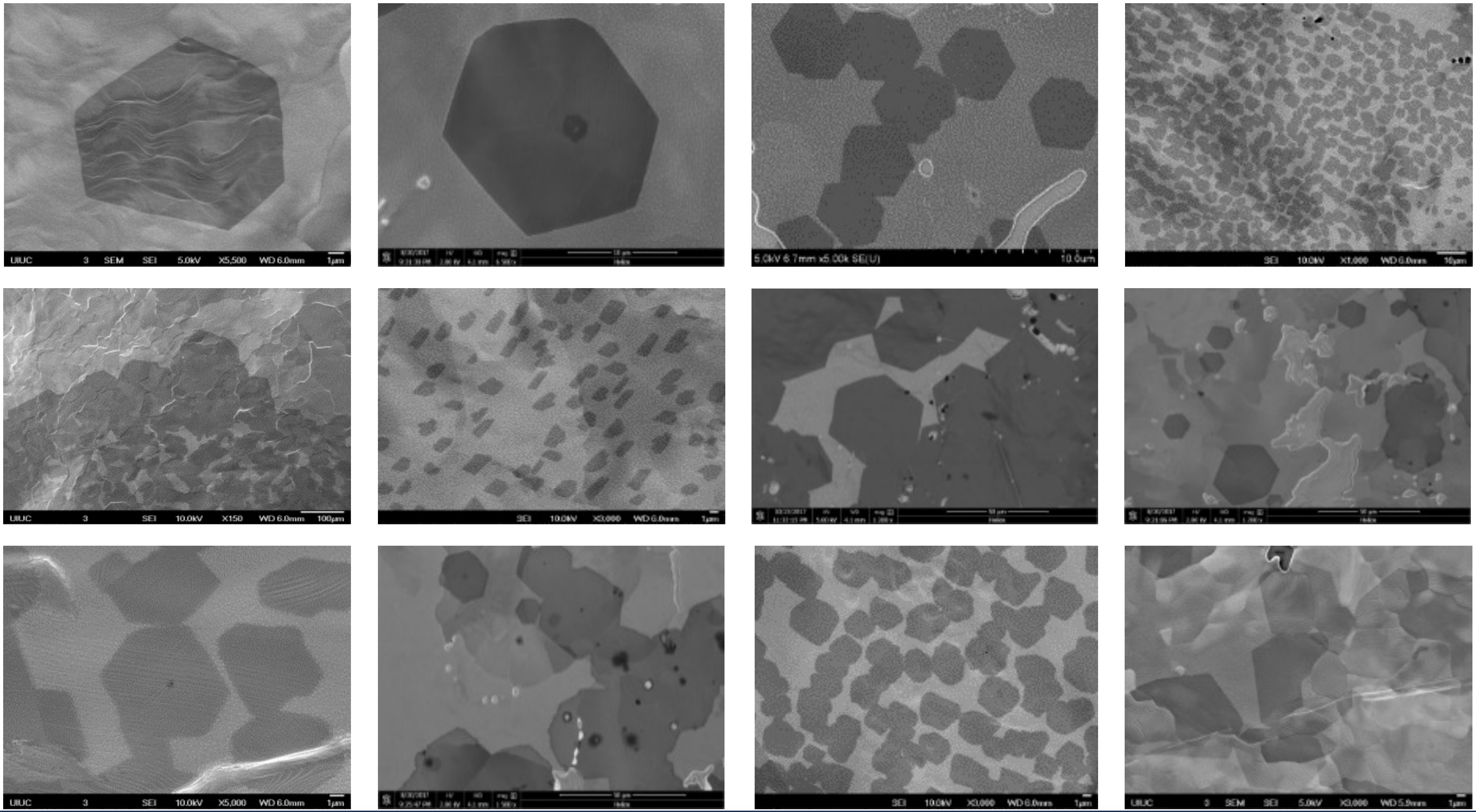
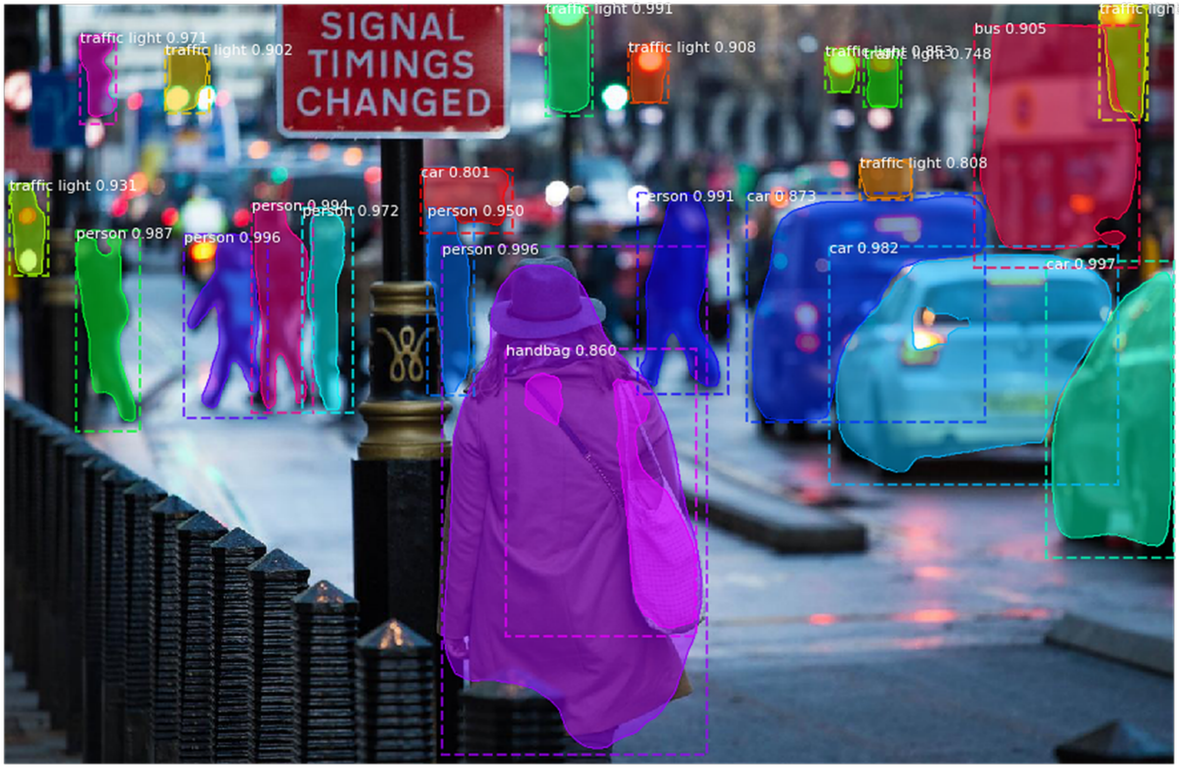


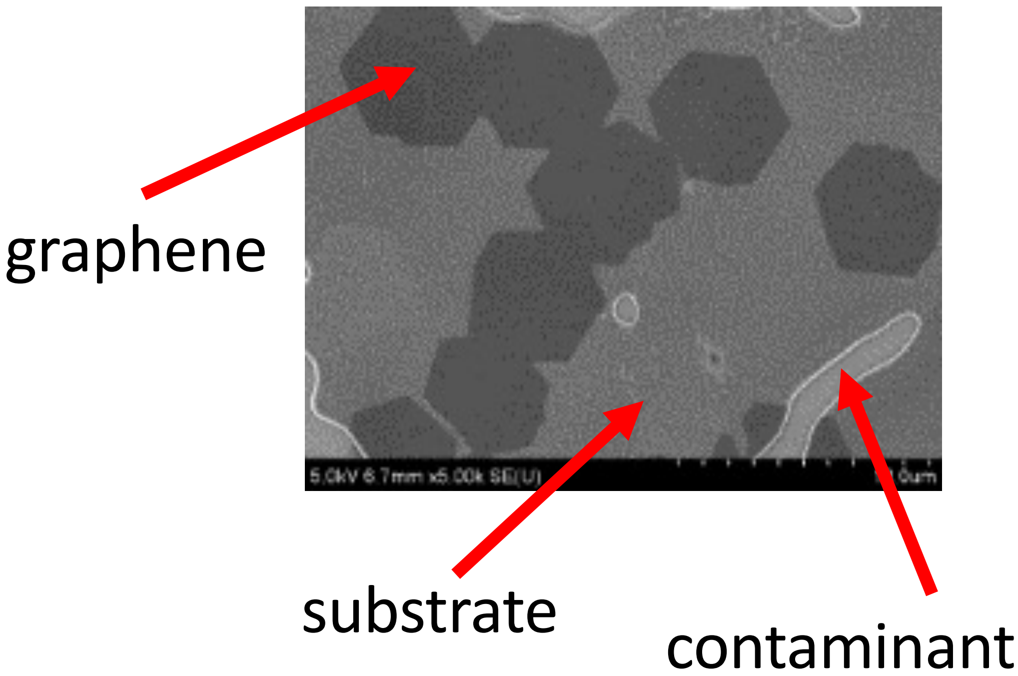
Image Segmentation in General

- Image segmentation is a way of separating an image into regions containing shared attributes.
- In our case, we will separate graphene from the substrate



towardsdatascience.com

Automated Segmentation



- Goal: given an image, analyze each pixel to determine whether it corresponds to graphene or something else.
- Humans can usually recognize graphene after seeing one or two images (e.g. contrast, hexagonal edges) but quantifying many hundreds of images takes time
- Automated segmentation can help identify important characteristics such as
  - Percent area covered
  - Crystalline Quality (hexagons)

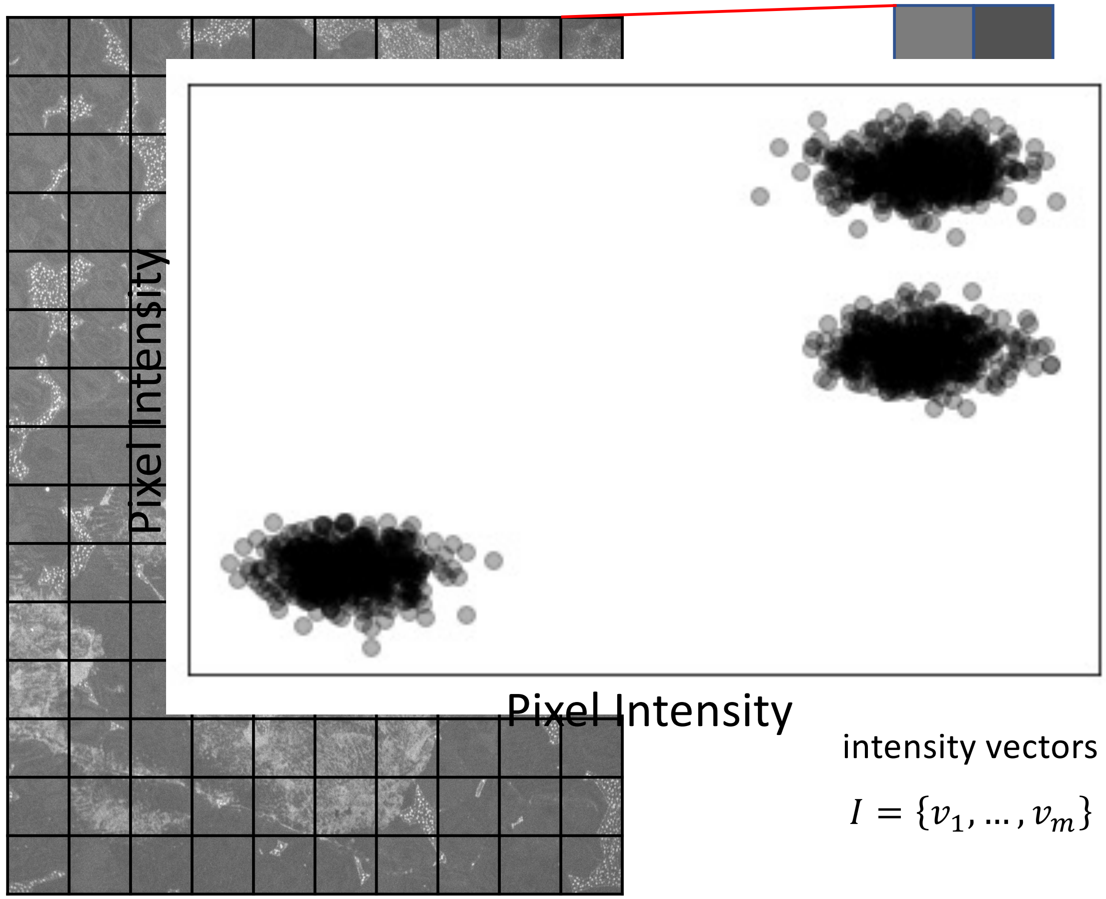
Today's topics: two approaches to image segmentation

- Template matching
- K-means

Both of these require pre-processing the image in the same way.

Pre-processing

- Divide an image into windows
- Each window represents a vector of pixel intensities
- Plot the pixel intensities
- They generally form clusters

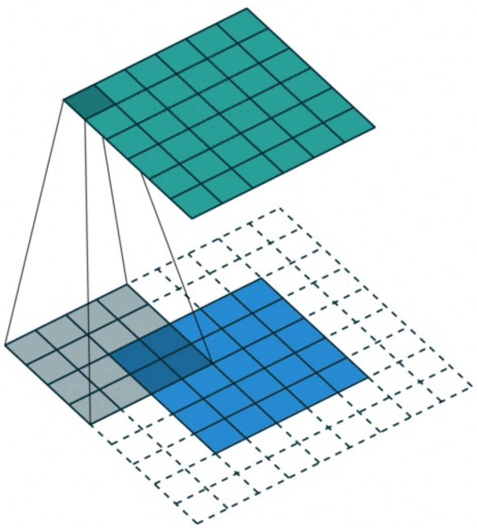


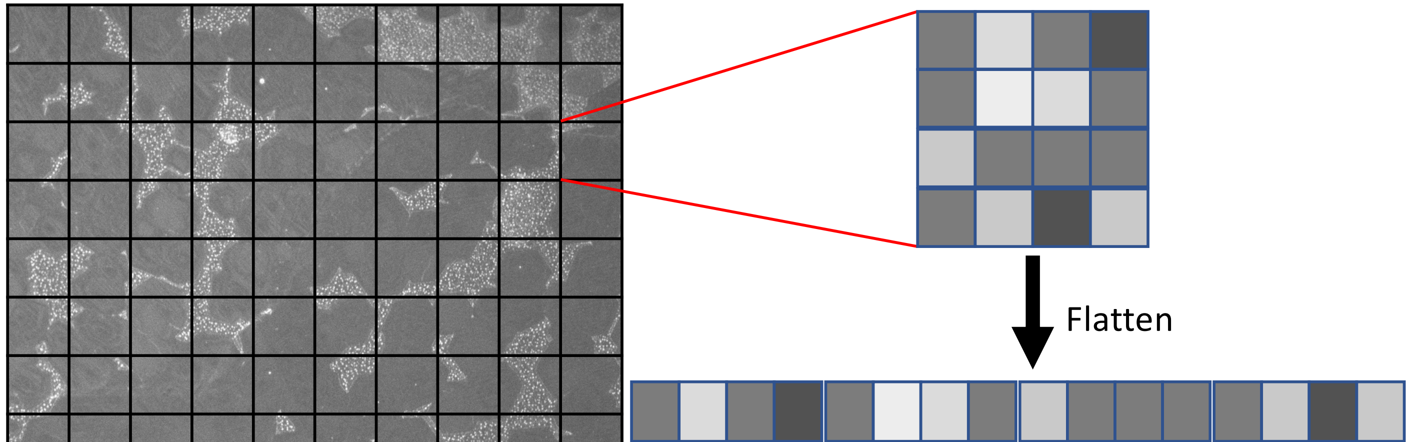
intensity vectors

$I = \{v_1, \ldots, v_m\}$

Pre-processing

- In reality, we have a 2D window of $n \times n$ pixels
- We flatten them out to make the vector





$v = \langle p_1, \ldots, p_{n^2} \rangle$

Set of all intensity vectors

$I = \{v_1, \ldots, v_m\}$

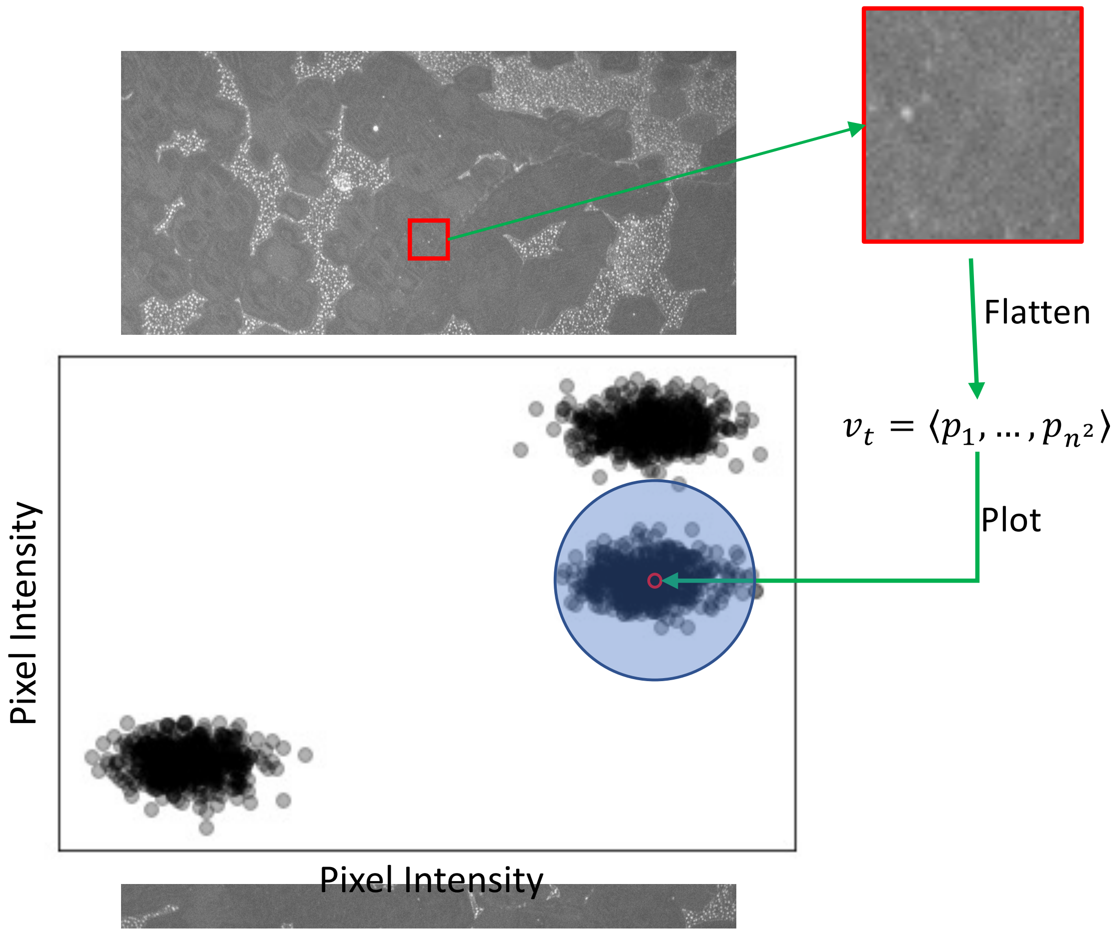
Template Matching

Idea: select area that looks like graphene and screen for similar looking areas

- Step 1: Select the “template” , flatten and vectorize it.
- Step 2: Plot it on the intensity vector plot
- Step 3: For all other parts of the image, measure how close they are to the template on the intensity vector plot
- Step 4: If the distance is within a threshold, classify as “graphene”. If not, then “not graphene”.

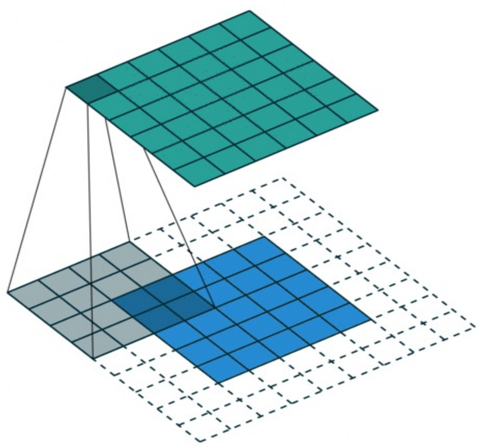
Parameters:

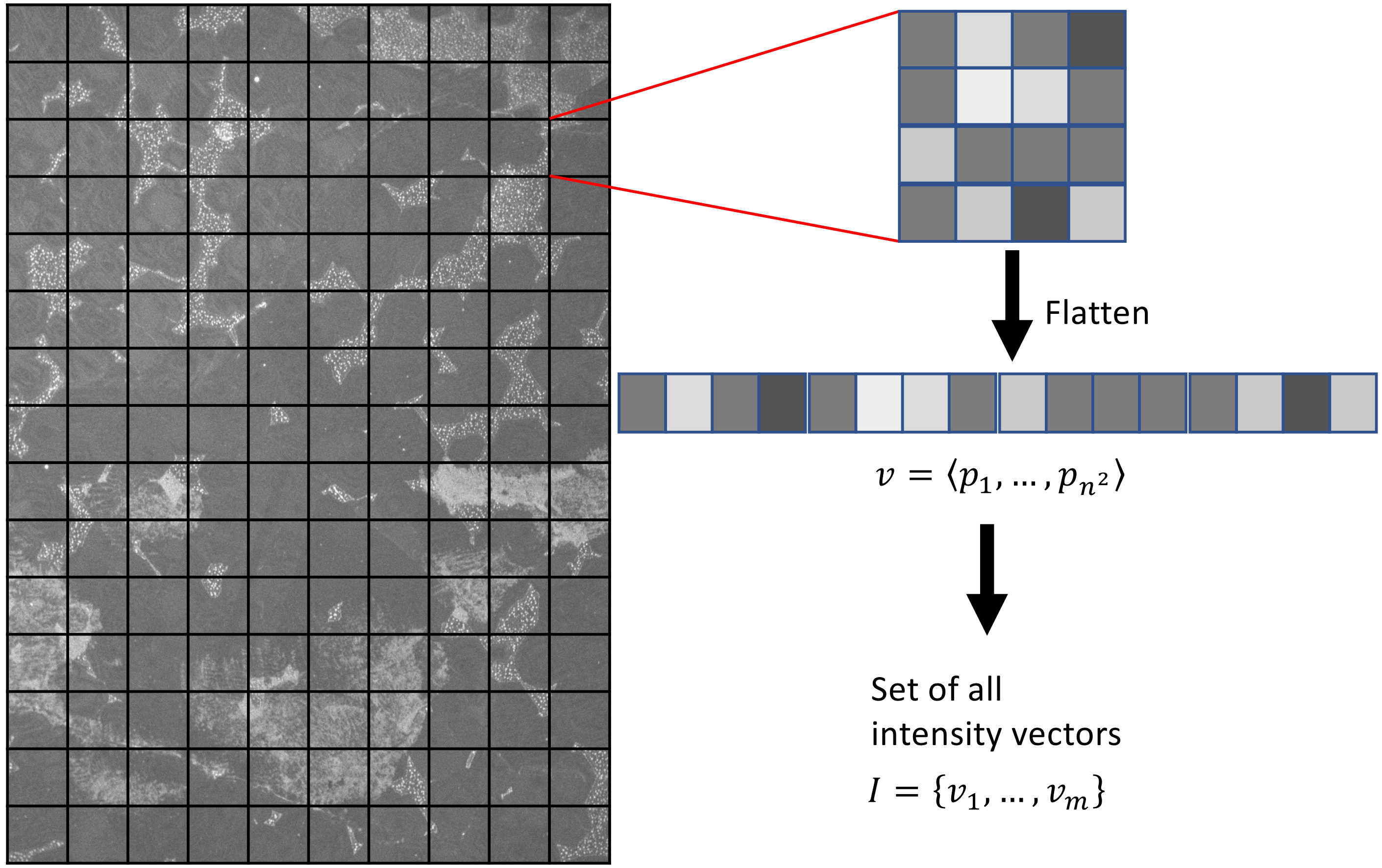
- Template position
- Template size
- Threshold (or distance)



K-Means: Pre-processing

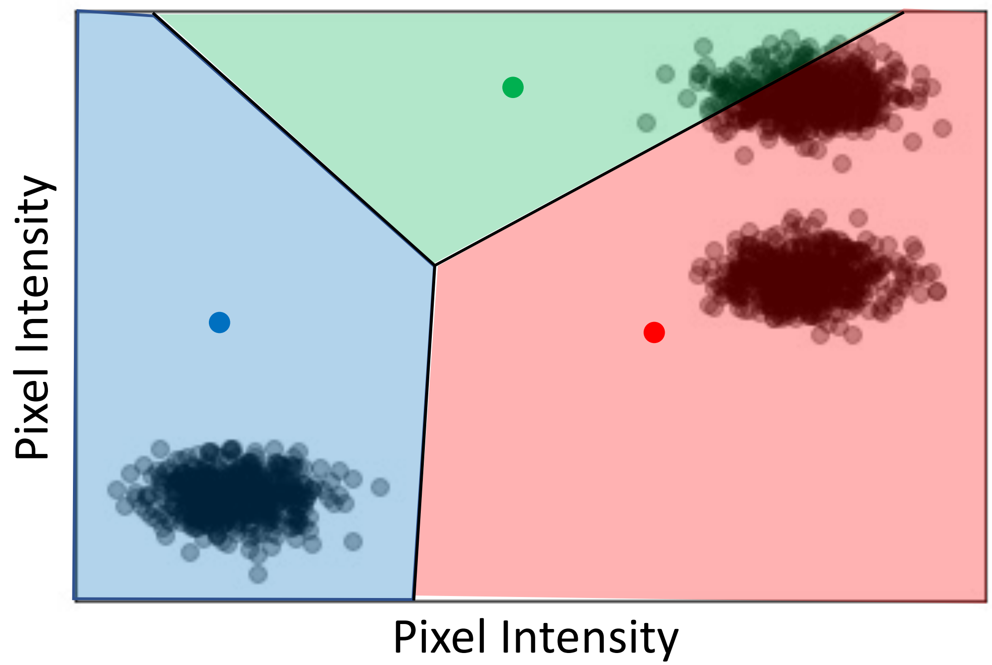
- Recall preprocessing: We divide the image into windows, flatten them to make pixel intensity vectors and plot the vectors on high dimensional graph
- In k-means, we also control the number of pixels moved between two tiles (stride length)





K-Means (unsupervised clustering method)

- Main idea: divide the pixels into clusters by partitioning the pixel intensity plot using Voronoi polyhedra
- Algorithm
  - Start with map of pixel intensities from before
  - Initialize centroids
  - Step 1: construct Voronoi polyhedral around centroids
  - Step 2: calculate new centroids by averaging all points within a centroid's Voronoi polyhedron
  - Repeat steps 1 and 2 until polyhedral are optimally selected.
  - For each cluster, assign it a label: graphene or not graphene



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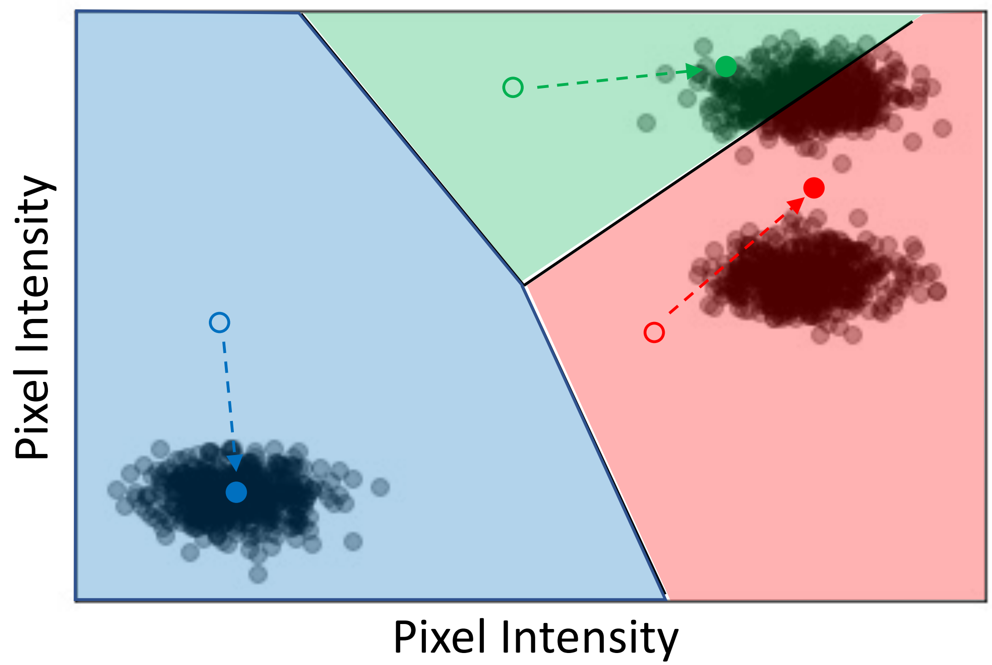
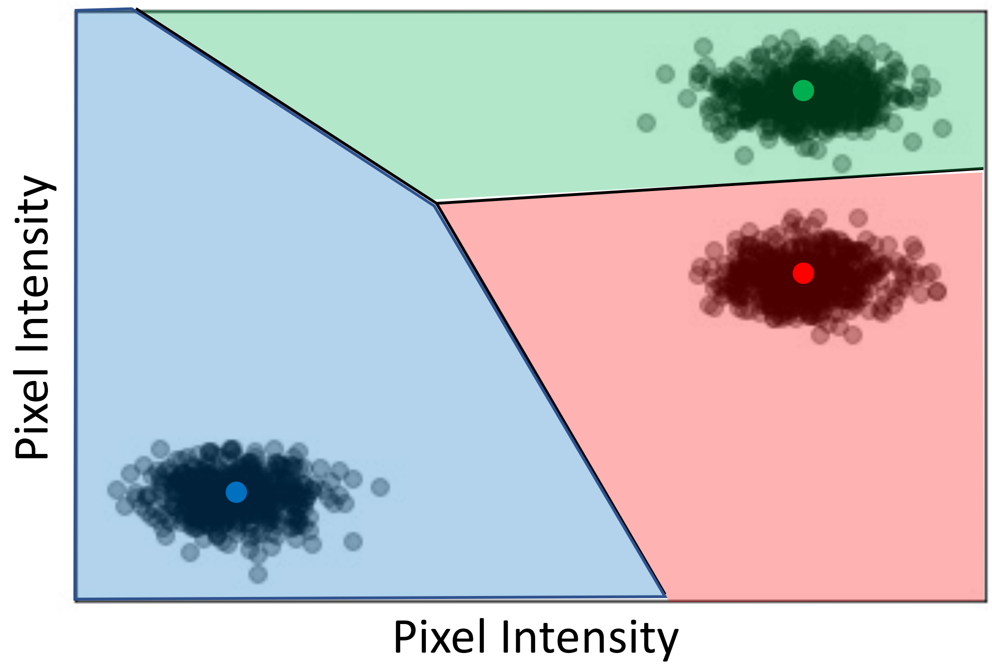


K-Means (unsupervised clustering method)

- Algorithm
  - Initialize centroids
  - Step 1: construct Voronoi polyhedral around centroids
  - Step 2: calculate new centroids by averaging all points within a centroid's Voronoi polyhedron
  - Repeat steps 1,2.
  - Assign labels to the clusters

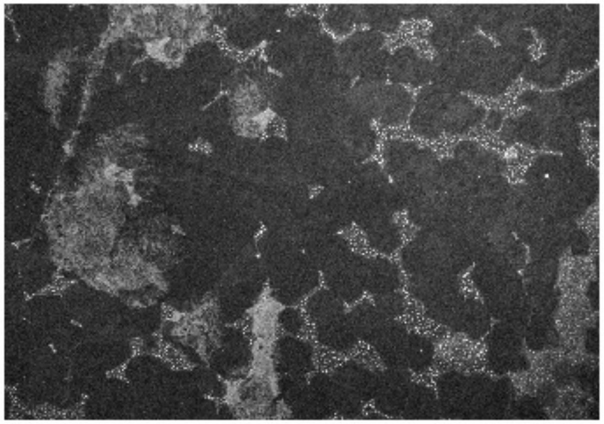


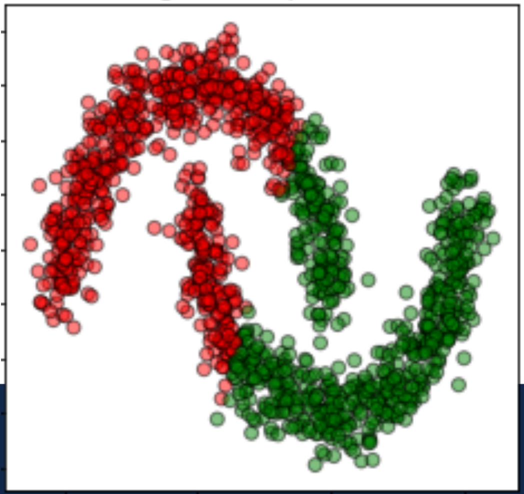
Parameters:

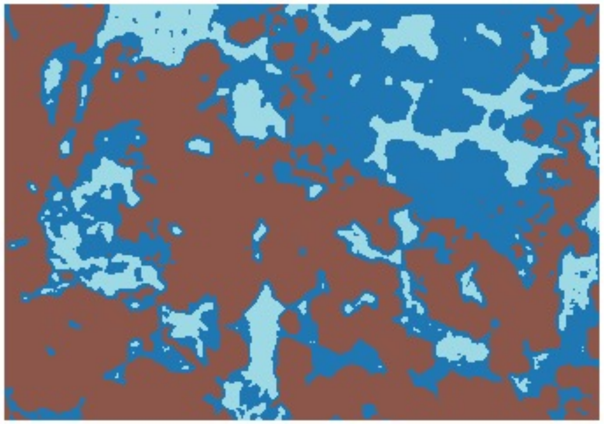
- Number of clusters
- Tile size
- Stride length

K-Means (unsupervised clustering method)

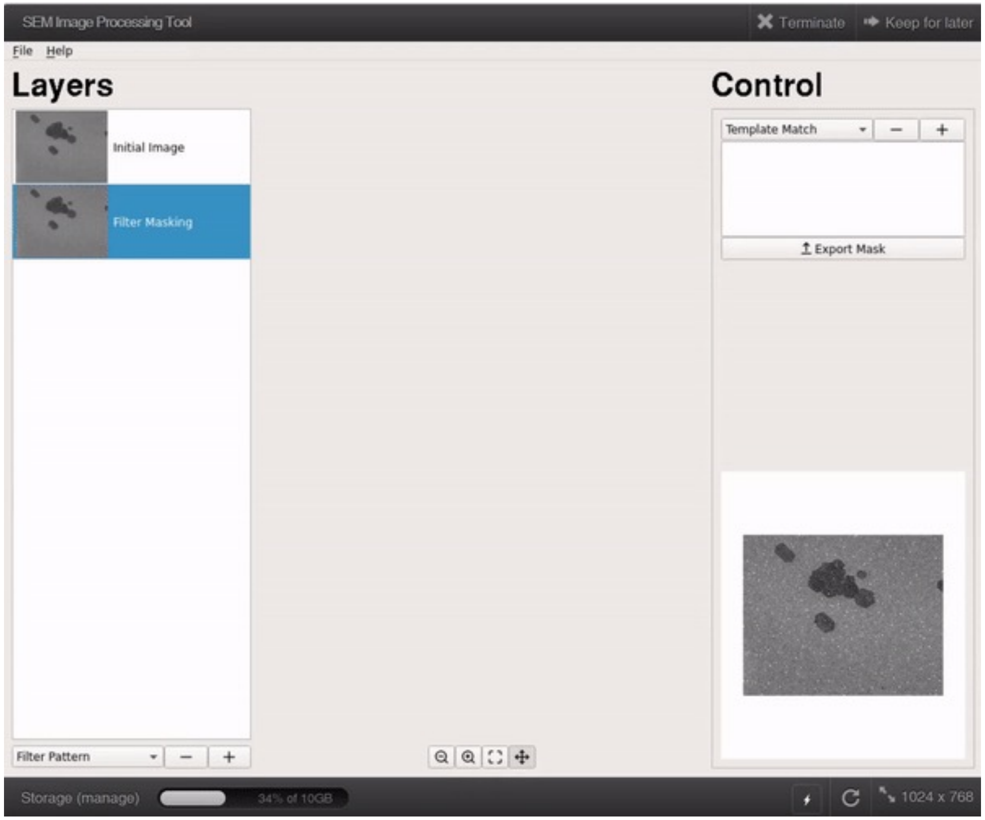
- Advantages:
  - No need to select template or threshold
  - Fast, memory efficient
- Drawbacks:
  - Need to select number of centroids (clusters)
  - Can suffer from concave shaped blobs







SEM Image Processing Tool



Visit https://nanohub.org/tools/gsaimage

Or

Look for “SEM Image Processing Tool” on nanoHUB.

Exercise

Open the following notebooks on Google Colab:

https://github.com/ertekin-research-group/image-segment/blob/master/bin/Template_Matching.ipynb

https://github.com/ertekin-research-group/image-segment/blob/master/bin/K-Means.ipynb

!git clone https://github.com/nanoMFG/nanohub_workshop_2021.git