Evaluating Growth in Coral Spawn Using Image Segmentation

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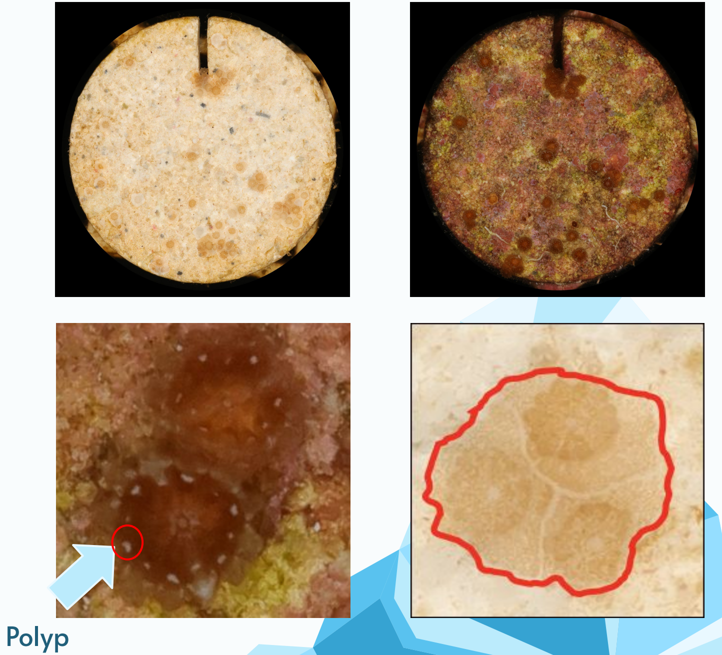
Introduction to Computer Vision, CS 136 Sec 01, Nada Attar

Introduction

Sample Info

- We are given 3 pairs of images of coral growth.
- The images are taken at 10 different timepoints, but we only get **timepoints 0 and 1.**
- Each sample is given a **different diet** .
- The samples contain groups of coral spawn, each with little polyps in them.
- Prof. Heller has an **AI model that is capable of circling the colonies of spawn** .



Main Goal

Increase the **contrast** between the **coral spawn and their background** so that the spawn can be **counted** as a **measure of best diet**.

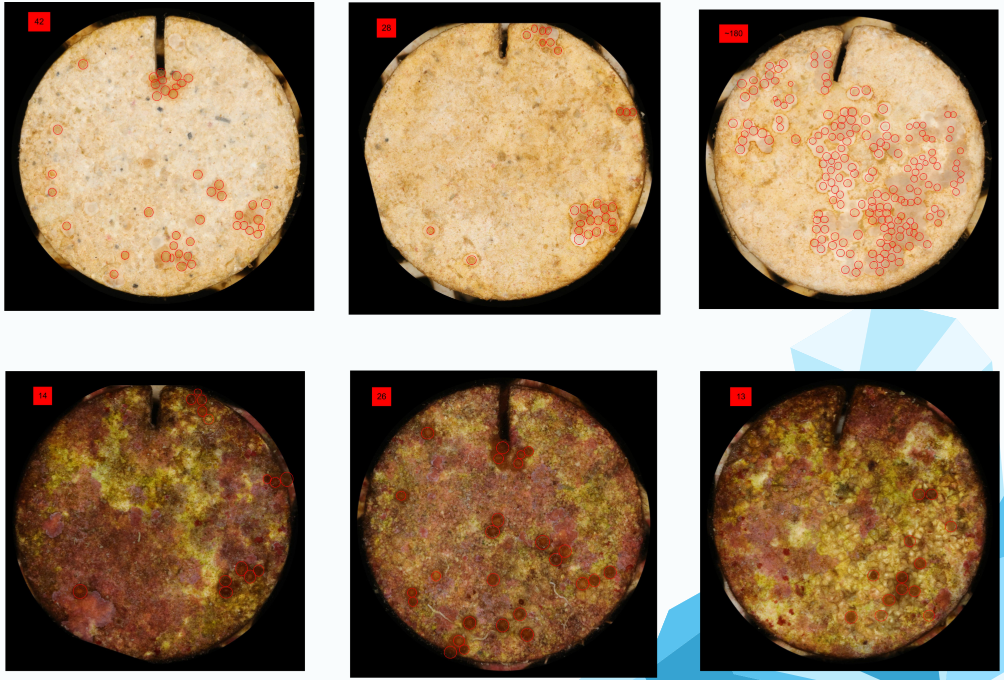
Our Approach

- We tried an iterative approach (using OpenCV):

1. Apply **contrasting algorithm(s)** to the spawn
2. Apply **smoothing, edge detection, feature detection, and segmentation** algos to **evaluate** the effectiveness of the **contrasting** algorithms.
3. **Observe** the result and **discuss** what works or what could be improved next iteration.

Our Baseline

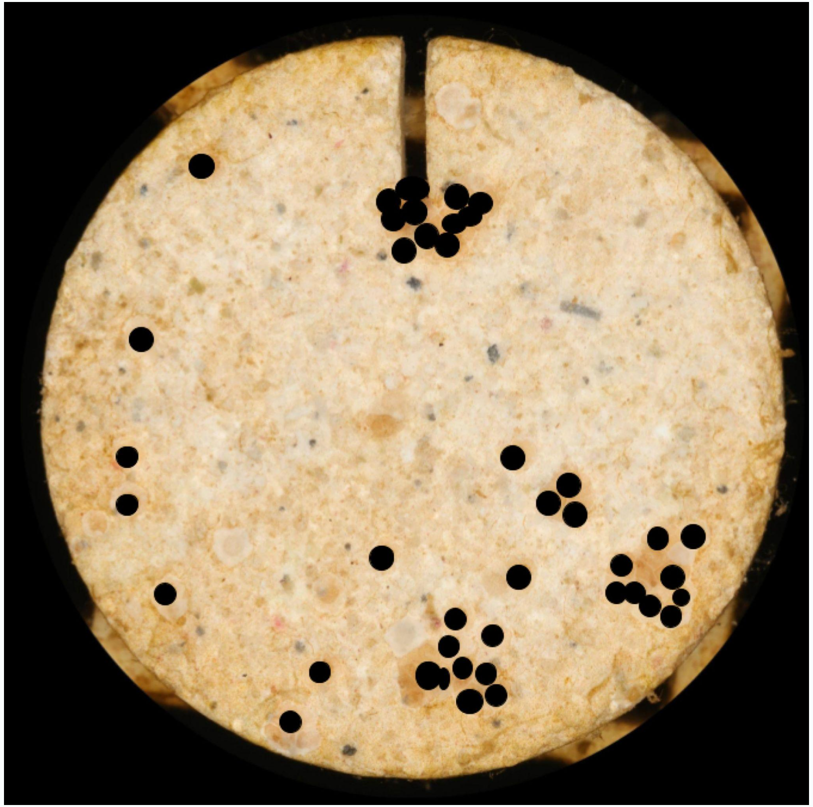
- As a way to evaluate performance, we manually counted the number of coral spawn in each sample.



Histogram Analysis

Histogram Analysis (Goal)

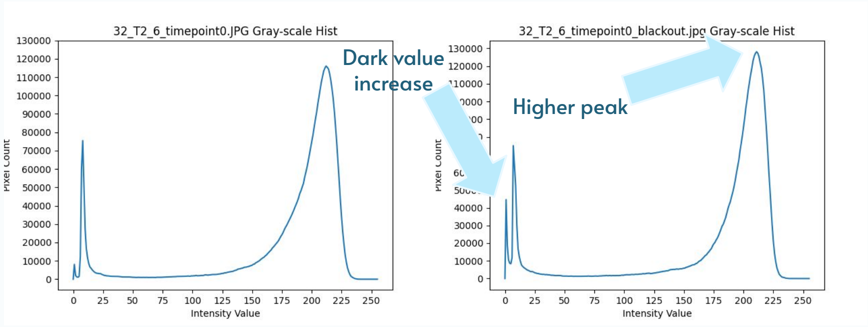
- **Goal**
  - Find a **value or unique range** to the coral spawn that can be **intensified or extracted** .
- **Preprocessing**
  - **Blackout** the coral spawn
  - Export at 2500 x 2500 from google drawings
  - Resize original to 2500 x 2500 and generate a histogram of both
  - **0** values **removed** from histograms

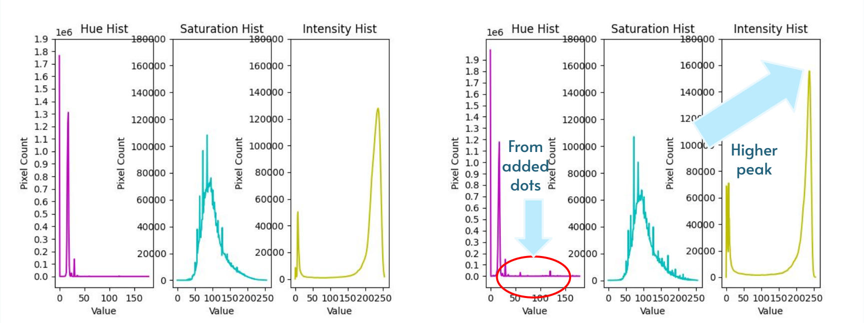


Histogram Analysis (Goal)

- The general trend between all the histograms was:
  - the intensity peak was higher in blackout, likely due to google drawing compression.
  - Dark values, or some hues increased due to the added black dots.
- **Conclusion** : We found **no value range** in the original images that can be increased to bring out the spawn.

Gray-scale





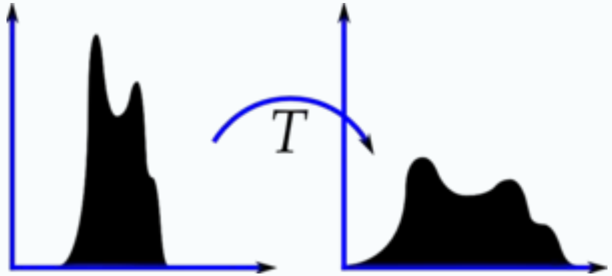
HSI

Contrasting Algorithms

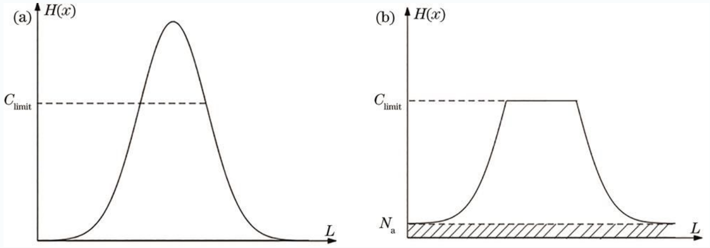
Histogram Equalization and CLAHE

- **Histogram Equalization** :
  - Normalizes an image's histogram so that it encompasses a larger range of intensities.
- **CLAHE** :
  - Reduces the impact of noise by:
    - Equalizing histograms in **small tiles** around the image
    - **Distributing** values **above a threshold** to the **rest** of the histogram

HE

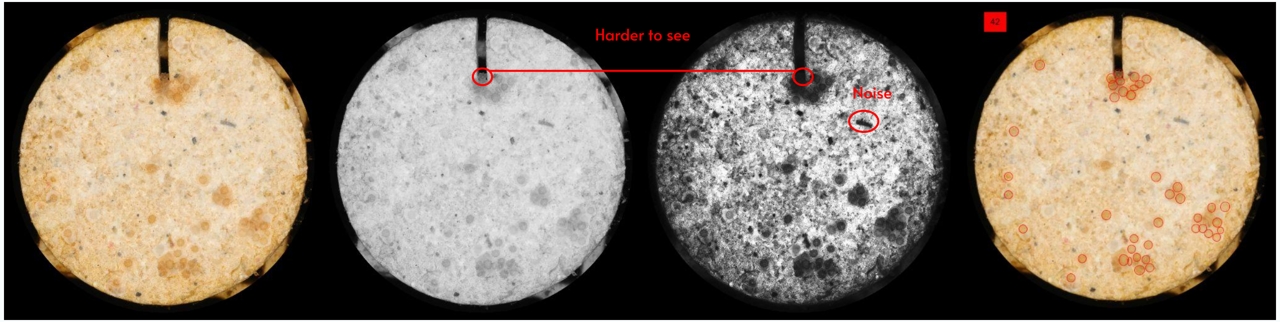


CLAHE



Histogram Equalization

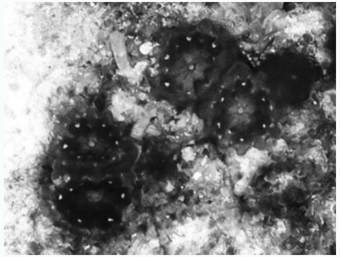
Timepoint 0



original | gray-scale | HE | Labeled

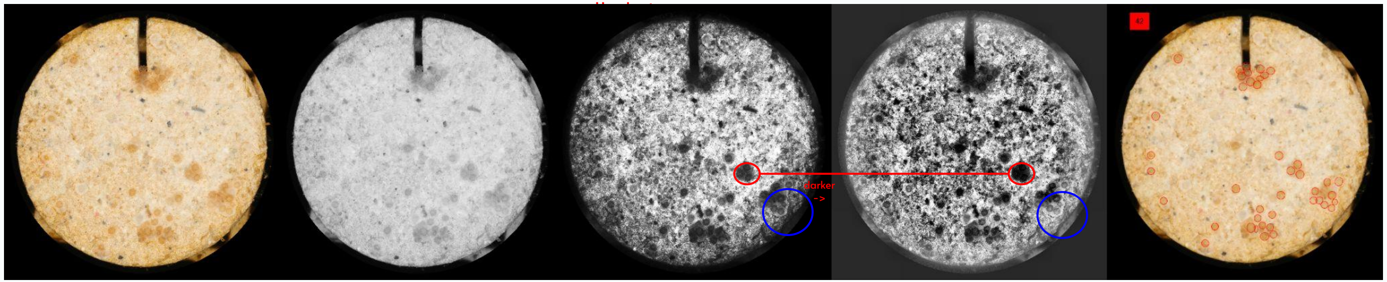
- **General Observations :**
  - Does make the spawn more visible, but:
    - A spawn with a black background is harder to see.
    - The noise is also increased
  - The polyps at timepoint 1 are more visible.

Timepoint 1



CLAHE (Contrast Limited Adaptive Histogram Equalization)

Timepoint 0



original gray-scale HE CLAHE Labeled

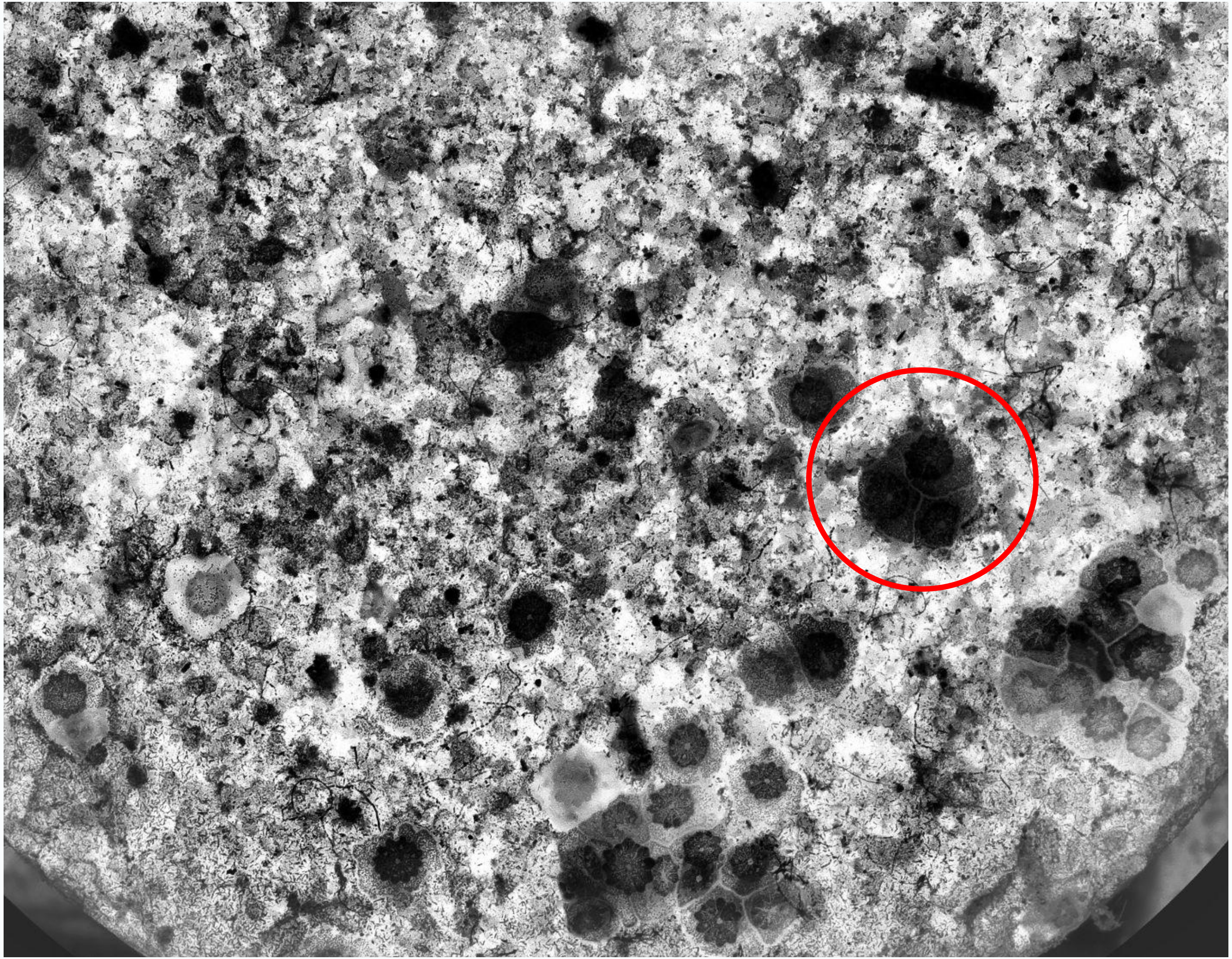
- **General Observations** :
  - Params:
    - TileGridSize: 8 x 8
    - clipLimit: 40
  - Red: Does seem to make most spawn **darker than HE** .
  - Blue: Seems to be weaker around the edges due to out dark background being over the clipLimit..
    - Perhaps tile size could be smaller, or clipSize larger

Smoothing Filters

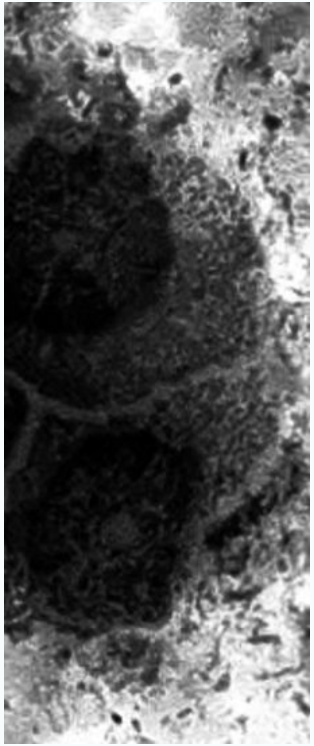
Smoothing Filters

- Goal: Increase contrast between “voids” corresponding to coral babies and the background as much as possible
- Reduce positive noise in voids
- Reduce negative noise within the background

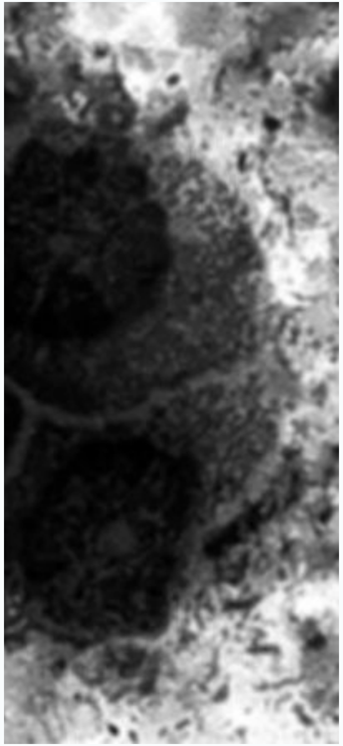
→ Reduced detection of false edges, noise



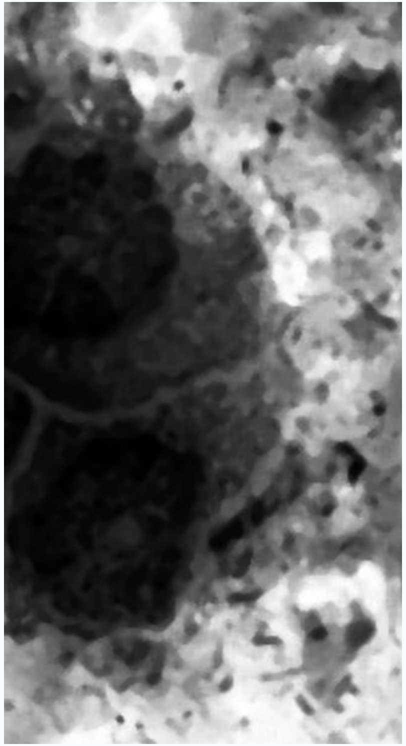
CLAHE



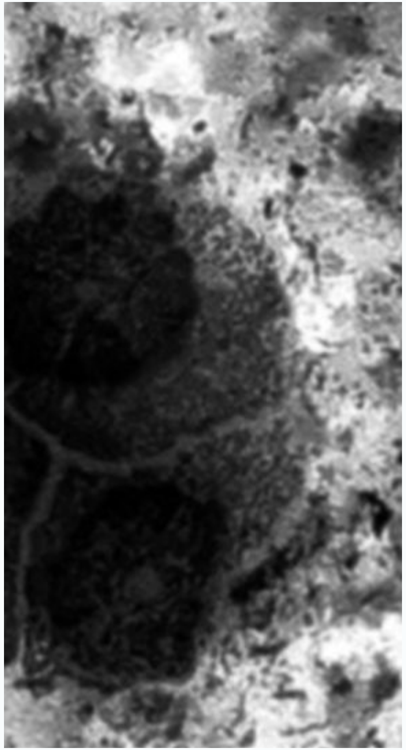
Mean (3x3)



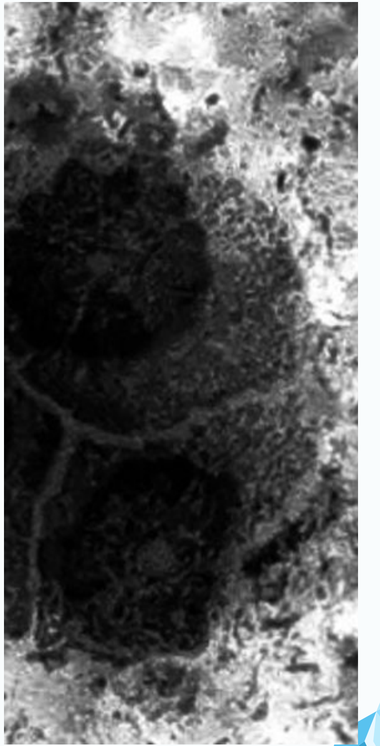
Median (5x5)



Gaussian (3x3)



Bilateral(4x4)



Mean Smoothing

- Mean: Uniform convolution filter applied
- Used a 3x3 filter
- Larger than 3x3 → noticeable bleed from background into void, would likely eat into the area occupied by voids (and therefore, area detector)
- Result is that the overall contrast decreases, more pixels in the middle ground between void and background, not good!

Median Smoothing

- Median: Median pixel taken from filter
- Used a 5x5 filter
- Can afford to use larger than 3x3 because bleed less apparent (13 pixels void & 12 pixels background → void), but beyond 5x5, bleeding becomes more apparent
- Somewhat promising!

Gaussian Smoothing

- Gaussian: Non-uniform convolution filter, higher weight for center pixels
- Used a 3x3 filter
- Could probably go larger than 3x3, but unsure about sensitivity of edge tolerance
- Eliminates slightly less noise than median filtering, in exchange for sacrificing less visual fidelity
- Trend regarding noise: Will shrink noise and make it less apparent, but removing it will require multiple passes

Bilateral Smoothing

- Bilateral: Gaussian smoothing, but applied selectively in order to smooth out textures but conserve edges
- Conserves the most detail and visual fidelity, but this is because it barely applies any smoothing at all
- The majority of the image is noisy enough that the bilateral smoothing filter has trouble determining what comprises texture, and what comprises edges

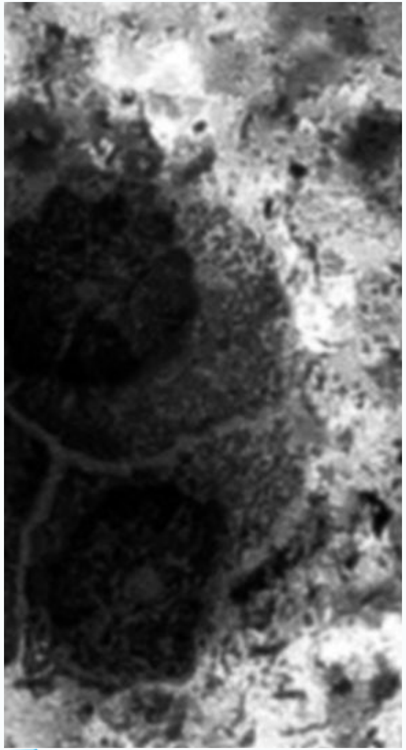
Edge Detection

Edge Detection

- Goal: Create a contiguous demarcation between the voids / coral babies and the background
- Remove / reduce noise from both the voids and the background

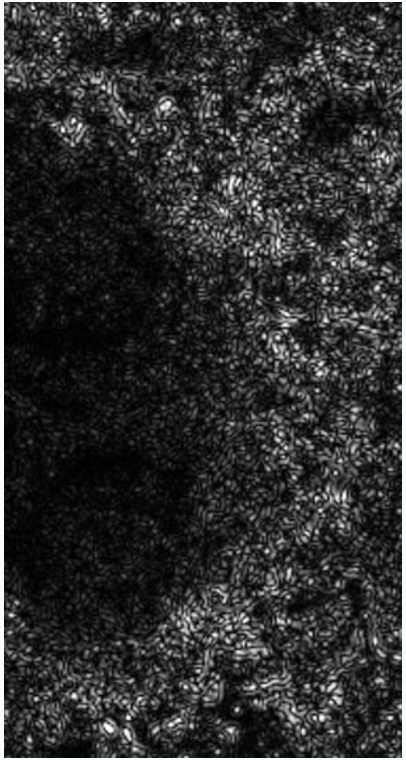
→ Allows for the location of corals to be demarcated, what areas should the AI model take into consideration?

Gaussian (3x3)

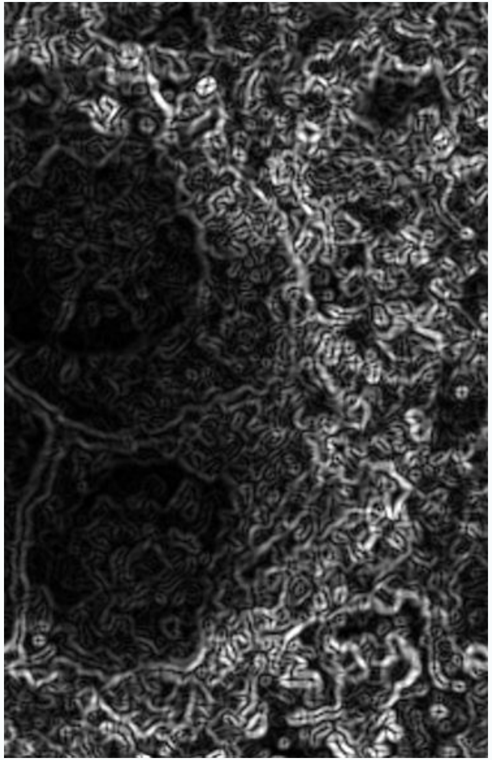


Canny

Laplacian



Sobel



Canny Edge Detection

- Contours of the coral babies are marked, but not very well connected.
    - A simple flood fill would bleed significantly into the background
- Noticeable gradient in the strength of edges
- Promising in the determination of area colonized, not so much in the # of coral babies present

Laplacian Edge Detection

- Significant spotting noise within the void
- Very few lines, features are often represented as mottled collections of points
- Probably not of very much use

Sobel Edge Detection

- Unlike Canny, the three separate bodies that make up the void are clearly detected, which would be useful in finding the # of coral babies
- Lines are noticeably continuous than Canny
- Gradient of edges carries much further into the void
- Results in the most noise within the void of the three edge detection algorithms

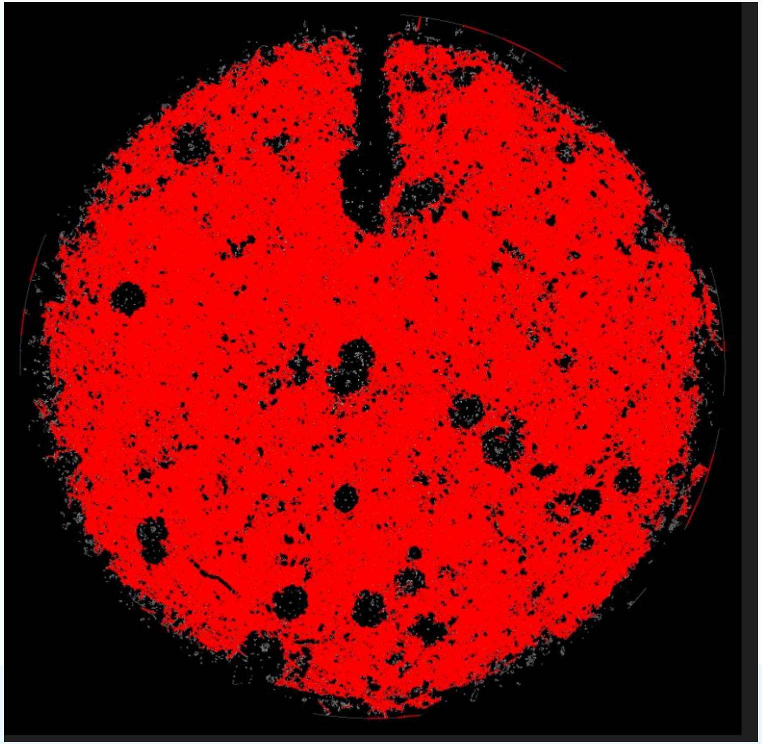
Feature Detection

Feature Detection

- Goal: Identify features that may be helpful in the segmentation of the image between corals / background
  - Features that can be excluded
  - Features that can be included
- Goal2: Count the spawn

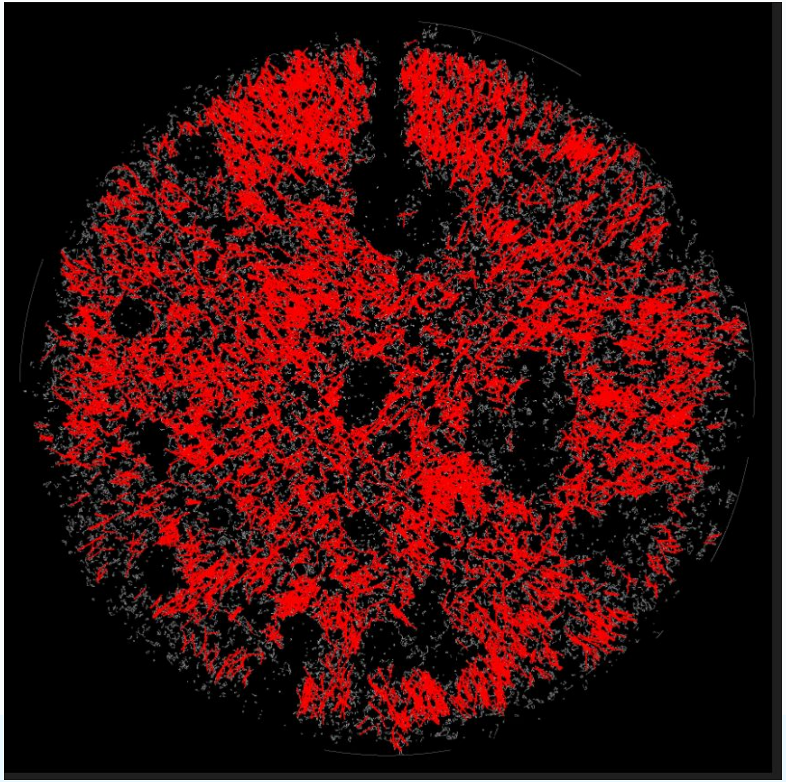
→ Allows us to be more specific about our segmentation algorithms

Hough Line Transform



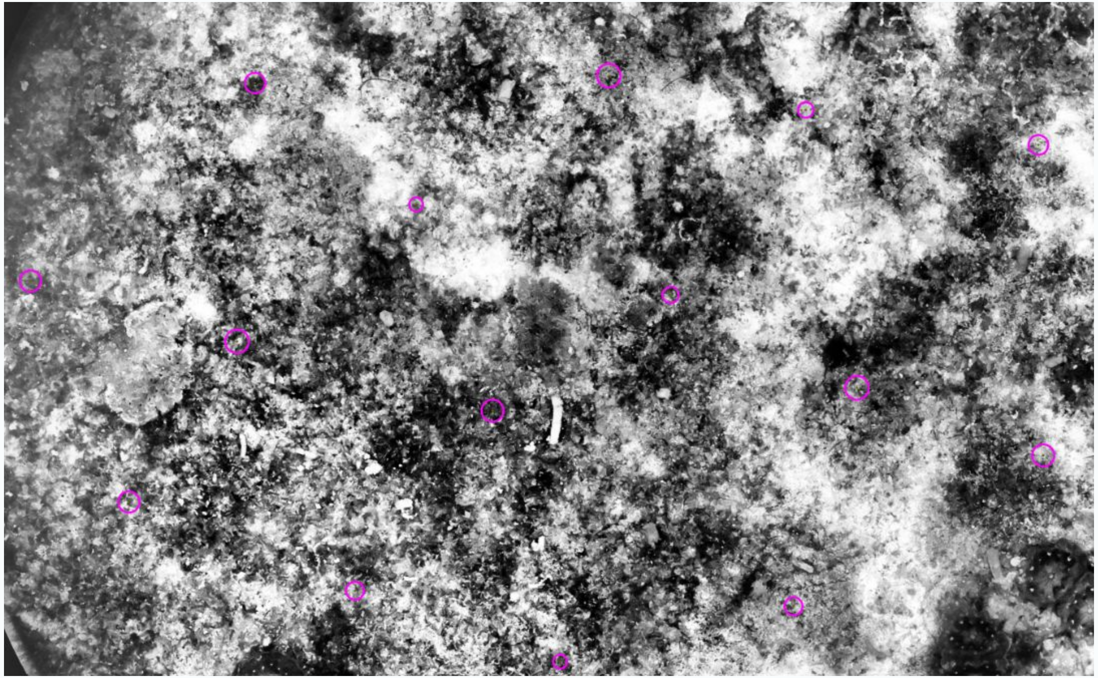
- The Hough Line Transform does appear to highlight the voids
- High rate of false negatives, many voids / coral babies, especially smaller ones, are suffocated by the lines

Hough Line Transform



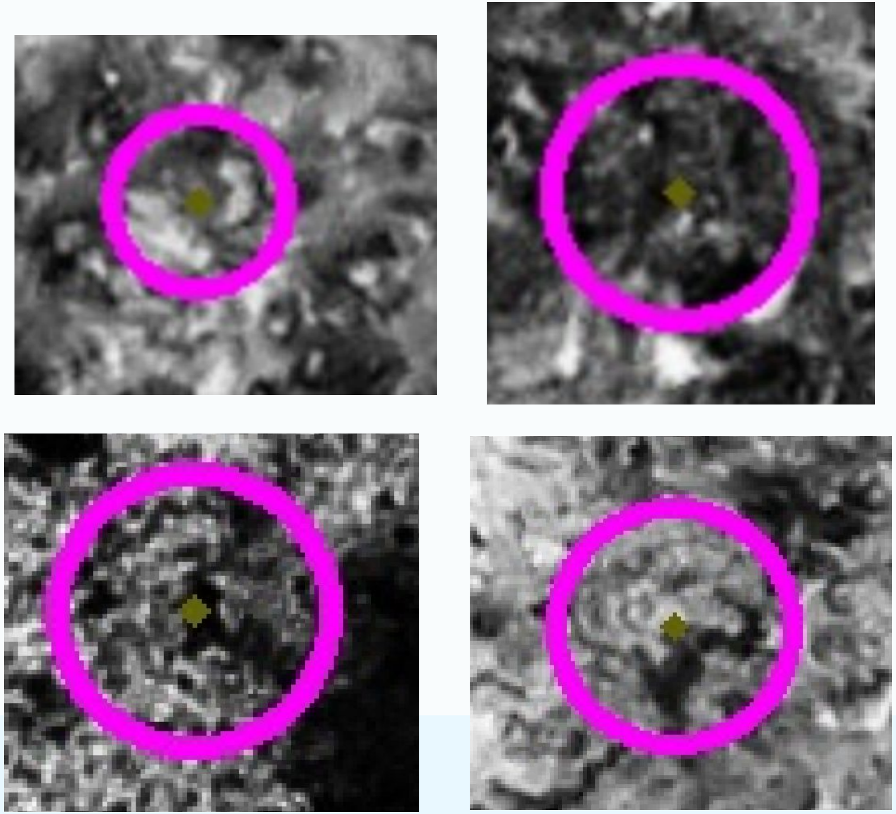
- Applying the Hough Line Transform on a non-histogram equalized input results in less false negatives, in exchange for a lesser recognition of the background

Hough Circle Transform



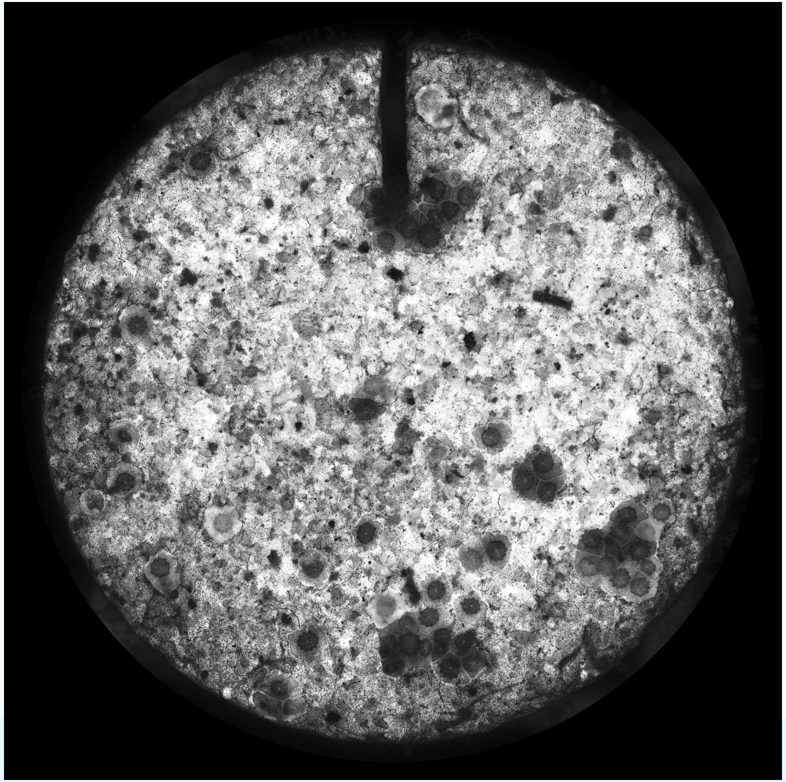
- The Hough Circle Transform doesn't seem to be good for much...

Hough Circle Transform



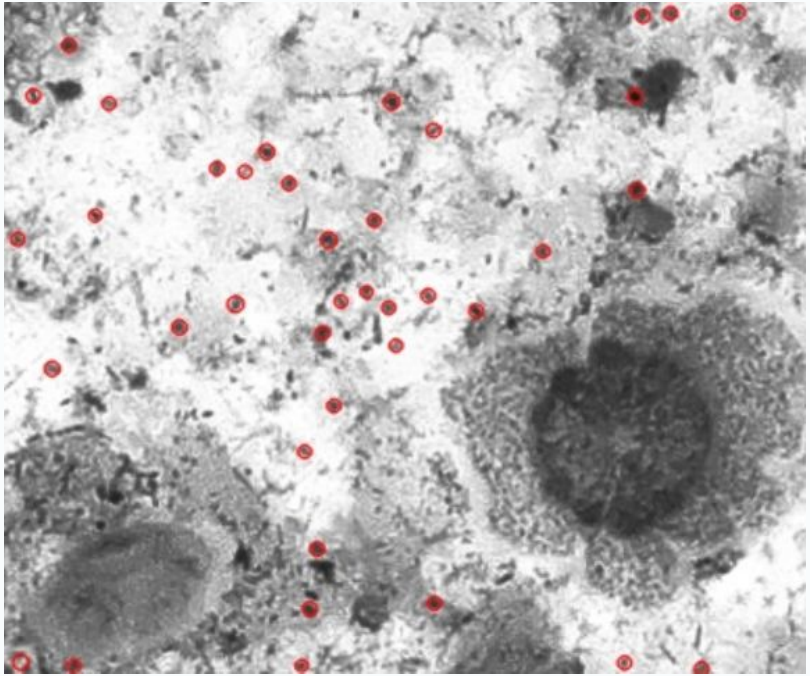
- Besides detecting where the diamond overlays associated with the image are
- The Hough circle transform appears to perform quite well with uniform or nearly uniform shapes, such as circles or diamonds, but it falls flat, particularly when dealing with the irregular textures associated with CLAHE

Blob Detector



- **Algorithm**:
    - Convert to binary
    - Group white-white and black-black
    - Merge close blobs
    - Find center and radius of blobs
- **Our Parms**:
    - MinCircularity = 0.2
        - **Very deformed**
    - minInertiaRatio = 0.2
        - **Very elliptical**
    - MinArea and MaxArea set to max of min area of coral spawn
- **Result**:
    - **Zero detections**

Blob Detector



- If we **remove area** constraints, it only detects blobs far below out minArea.
- Seems that the spawn are far too morphed into the white background to be detected
- **Might work if** we do an expand or use a blur.

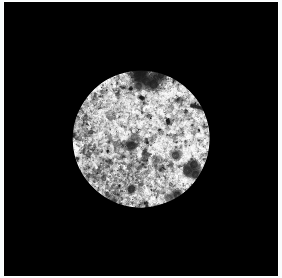
Segmentation

Segmentation

- Applied
  - Active Contour
  - Graph Cut
  - Mean Shift
  - Region Based

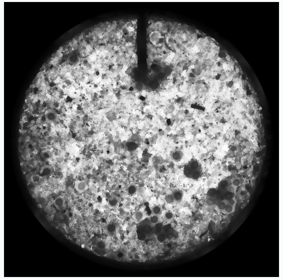
Segmentation

Active Contour



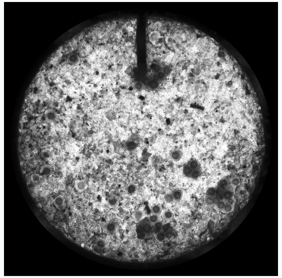
- Just cut out a center circle

Mean Shift



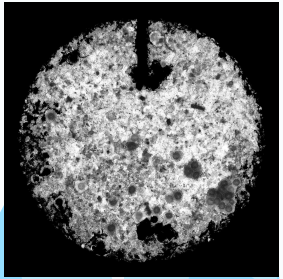
- Grouped like intenties, but not very useful, just changed the style, **maybe convert to binary lst ?**

Graph Cut



- **Couldn't distinguish** between background and foreground

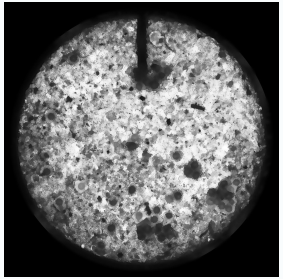
Region Based



- **Not useful** , just cut out some of the spawn we needed.

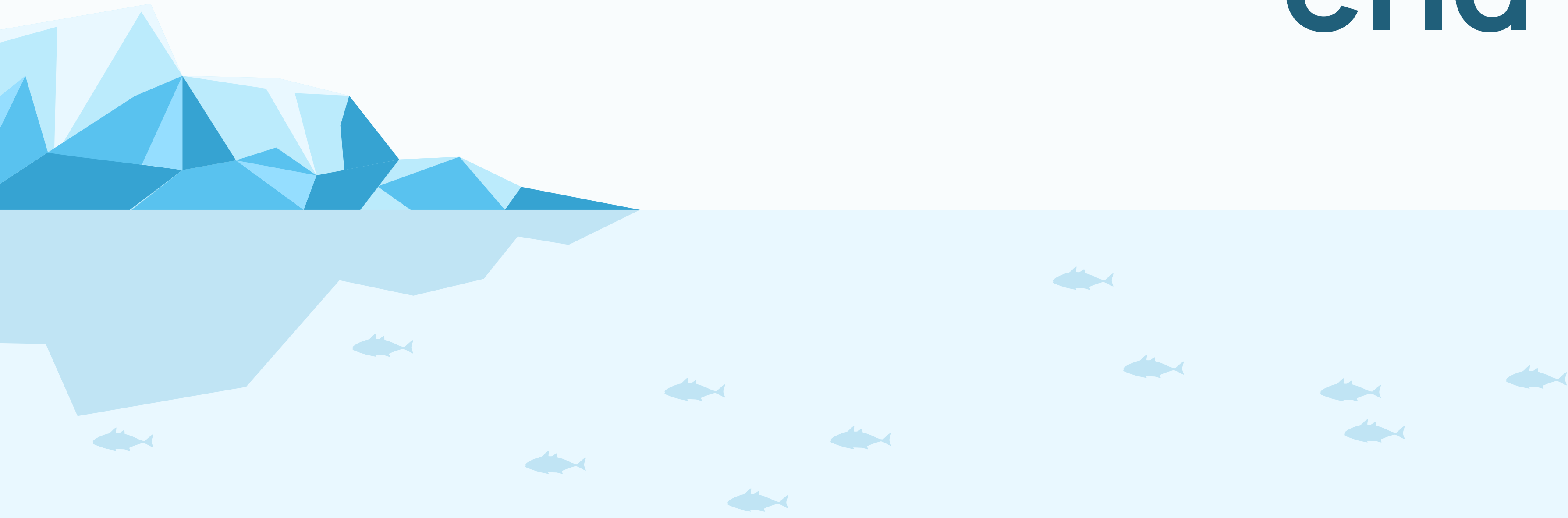
Segmentation

Mean Shift



- Most interesting, might be useful if we convert the image to binary first

Iteration 1 end

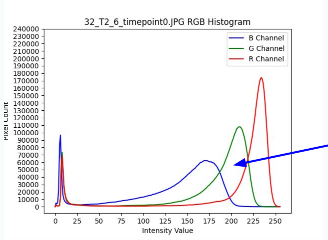


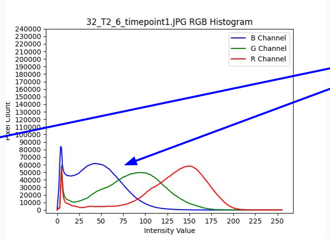
Iteration 1 Reflection

- Let’s take what worked from iteration I and use those combinations in iteration 2.
- Median filtering reduce positive noise, which was a problem with blob detection, so
  - **Median smoothing + blob**
- Also should try **binary + Mean Shift**
- Try **tuning Hough Circles** .
- Furthermore, let’s try one more contrasting algorithm.
- According to Prof. Heller, his **AI** is able to **represent the colonies** as . . .
  - As a collection of (x,y) coordinates of all pixels in the colony, in arbitrary order.
- **Problem** : We don’t have these pixel locations
  - But we can make them ourselves

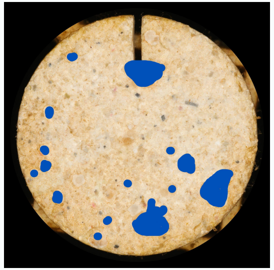
Iteration 2

Colony Map

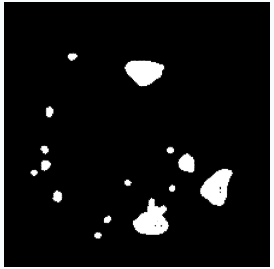




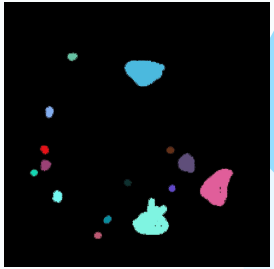
Blue at higher values is uncommon in the samples



Color over colonies with blue (0, 81, 186)

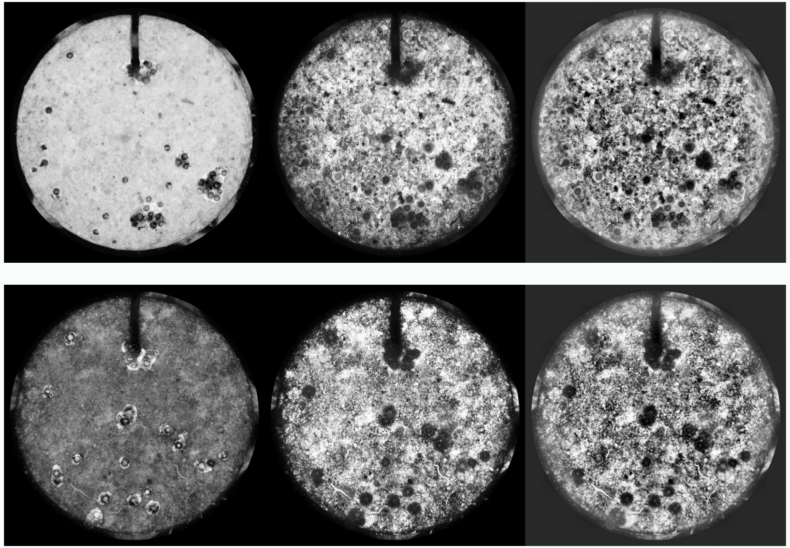


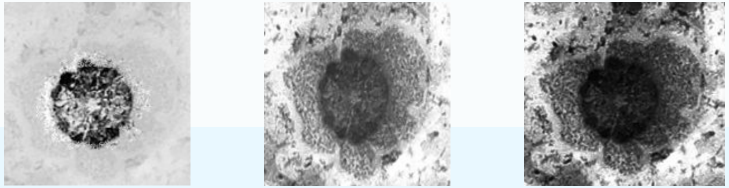
Convert blue to white and other to black



Find connected components

TAHE (Targeted Adaptive Histogram Equalization)



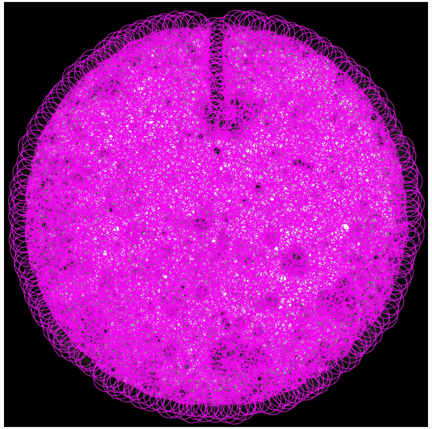


- Perform HE on only the individual colonies.
- With TAHE, the **background noise** is **less intensified**.
- But, as below, there is more **white noise within the spawn** themselves.
- But, the **change in intensities** between the spawn and their background might be enough for a less noisy sobel or canny.
- Let try to apply **canny**, then use **hough circles**.

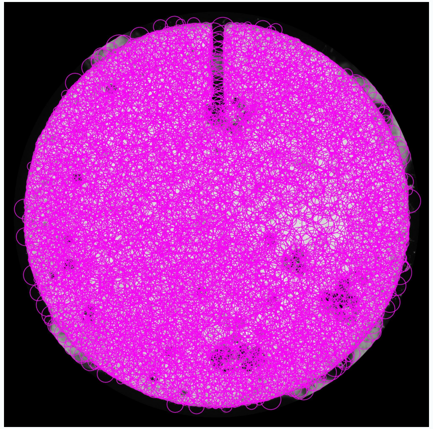
Hough Circles (tuned)

- Our previous hough circles was not tuned to the min and max sizes of the spawn, so we use
    - minRadius = 20
    - maxRadius = 112

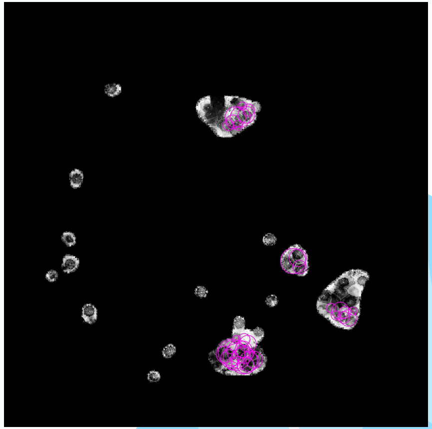
Hough Circles (tuned)



- **Sample** : HE
- Params:
  - Votes needed: 30
  - Canny thresh: 50

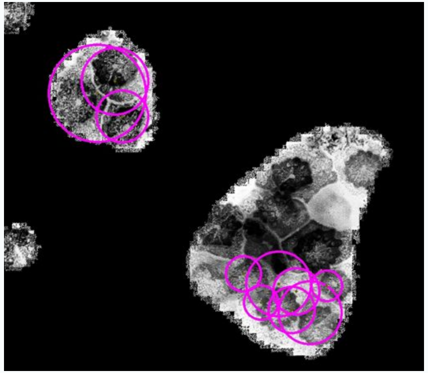


- **Sample** : TAHE
- Params:
  - Votes needed: 50
  - Canny thresh: 50



- **Sample** : TAHE (no background)
- Params:
  - Votes needed: 80
  - Canny thresh: 150

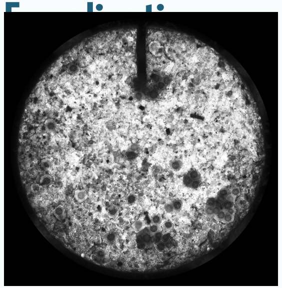
Hough Circles (tuned)



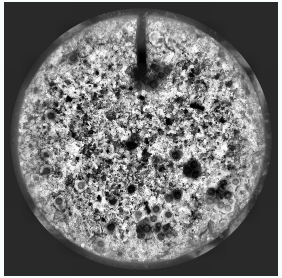
- **Sample** : TAHE (no background)
  - A few circles did seem around the spawn, but still **too many false positives**

Median + Blob

Histogram



CLAHE



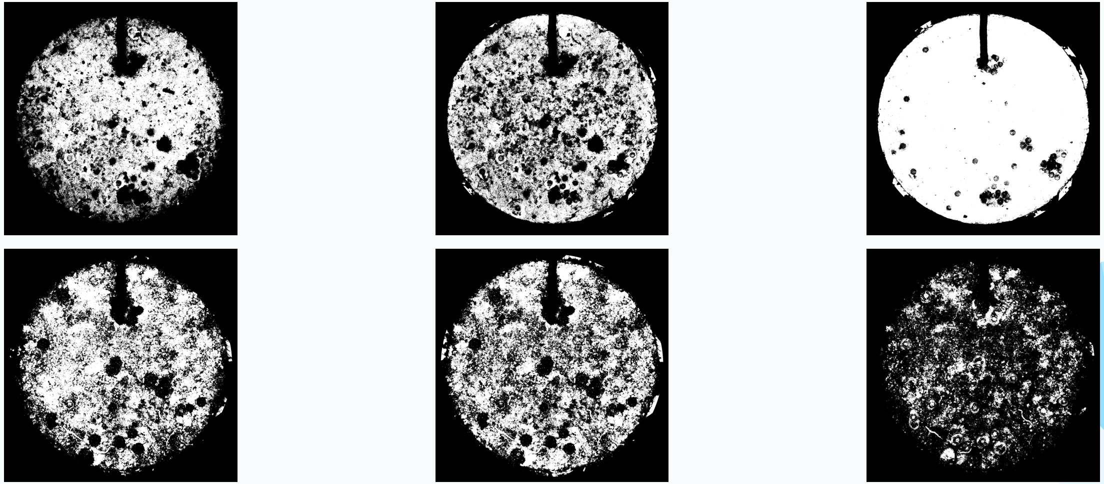
- Still 0 detections

Binary Mean Shift

HE CLAHE TAHE

Time Point 0

Time Point 1



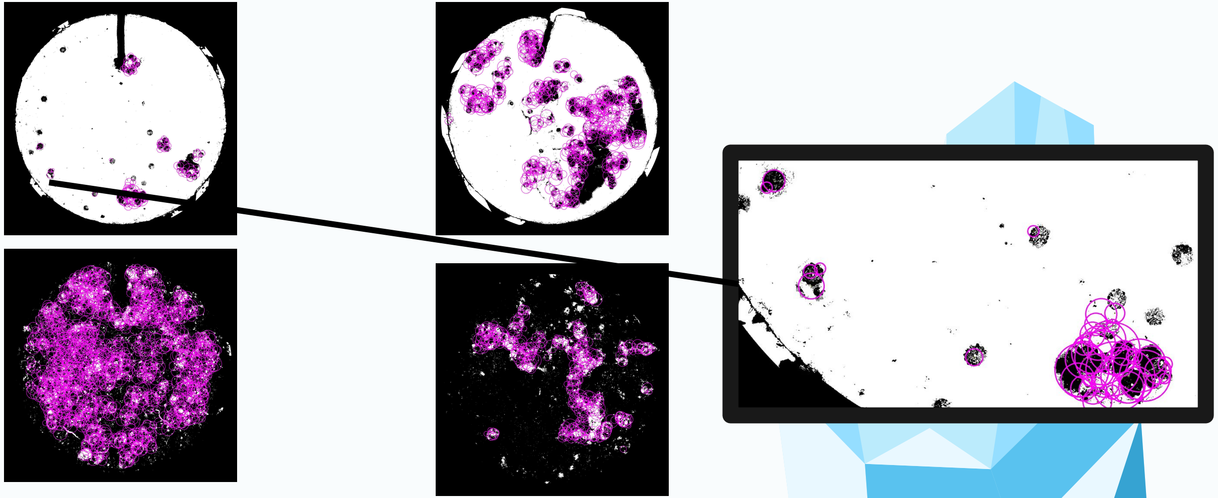
- Does distinguish between spawn and background, but noisy
- More dark noise than HE.
- **Best** separation for **T0**, but **worst** for **T1**.

Binary Mean Shift (TAHE) > HoughC

- Params:
  - CannyThresh: 50
  - votesNeeded: 30

Time Point 0

Time Point 1



- Performs poorly with timepoint 1 and large clusters of spawn.
- Performs when spawn aren't clustered such as the top-right, but parameters can still be tuned, many false positives.

Discussion/Conclusion

- We got some interesting results, but more work must be done to reach our end goal.
- In the future perhaps we can look more into:
  - Applying a gamma transform to the non-colony TAHE binary mean-shift pixels at timepoint 1
  - More experiments with expand and shrink with the TAHE binary mean shift images
  - Experiment with texture segmentation and further tuning Hough Circles.
  - Apply the forms of HE and AHE to all RGB or HSI channels

Our source code can be found at: https://github.com/rKim19300/CS136-TermProject-CoralBabies