Classifying Colon Cancer Colonoscopy Images Using Edge Histograms

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January 19, 2017

Content

Task - Overview

Task - Overview

What?

- Colon cancer colonoscopy images
- Edge histograms
- KNN: K Nearest Neighbors - Classification

Task - Overview

How?

1. Preprocess images
2. Perform edge detection
3. Extract features (e.g. edge lengths)
4. Compute Edge Histogram
5. Classify with KNN
6. Analyze the results

Edge Detection

Overview

- What are Edges
- Edge Detection
- First Derivative
- Second Derivative
- Canny Edge Detection

Edges:

Edges are pixels, in which the image intensity function changes its magnitude

(a) Original Image (b) Image after Edge Detection

Figure: Edge Detection using Canny

Edge Detection:

Almost every Edge Detector uses either the first derivative or the second derivative of the intensity function.

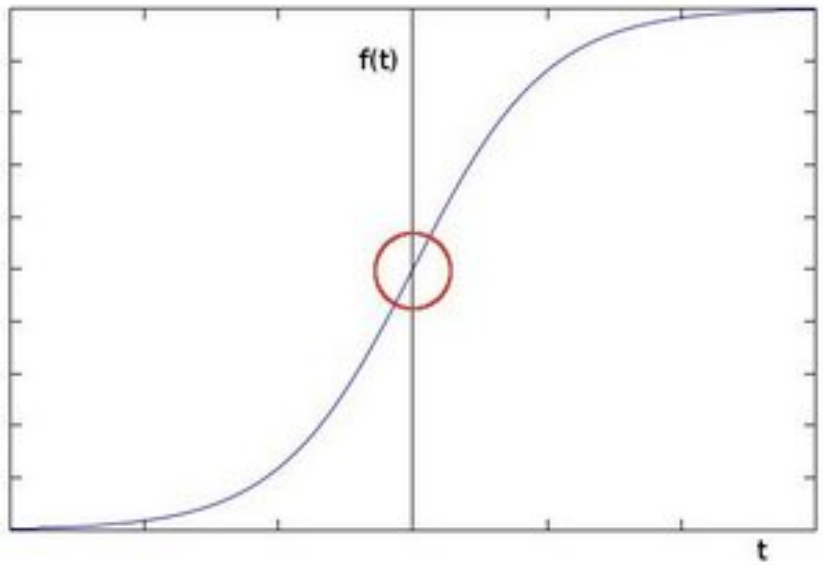


Figure: Intensity function

First Derivative:

Sobel-, Roberts-, Robinson-, Kirsch-Operator

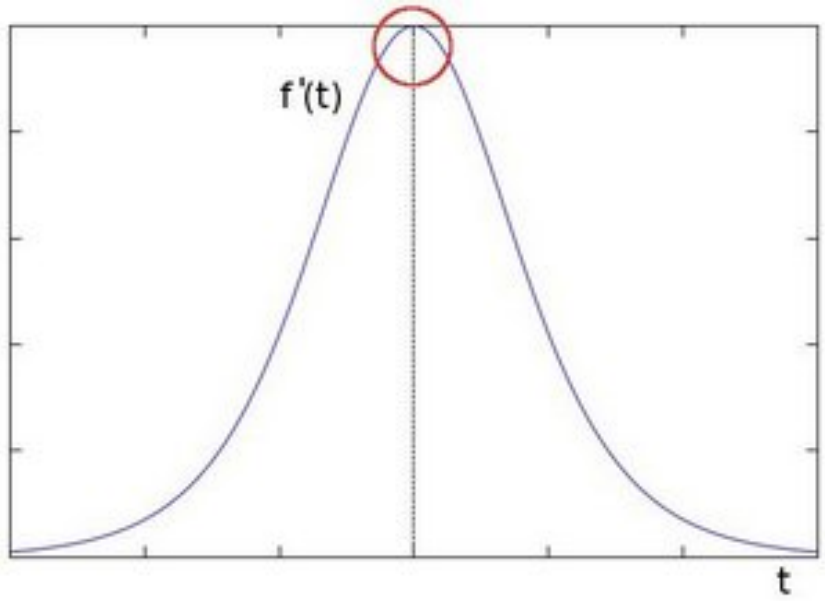


Figure: Intensity function - First derivative

Second Derivative:

Laplace-, Mexican-Hat-Operator

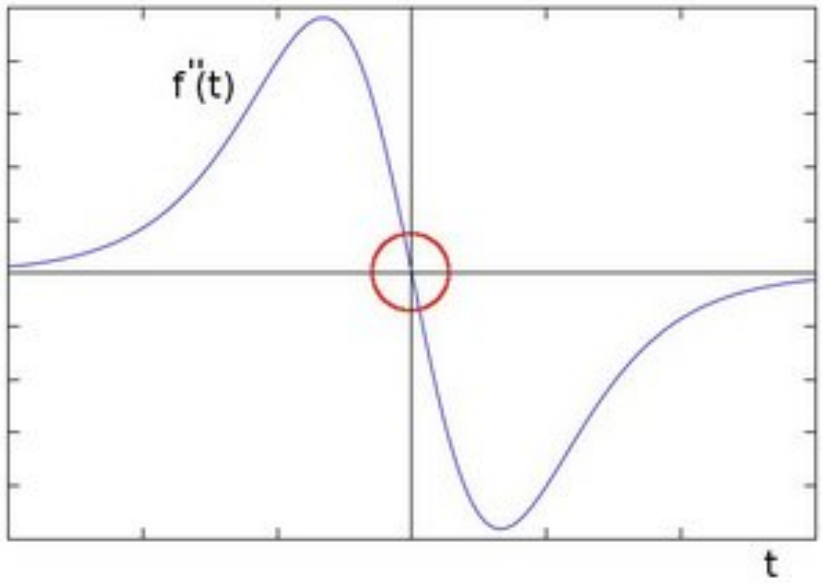


Figure: Intensity function - Second derivative

Canny Edge Detection:

- Low error rate
- Good localization
- Minimal response

Steps:

1. Filter out noise using Gaussian filter
2. Find the intensity gradient using Sobel-Operator
   $G = \sqrt{G_x^2 + G_y^2}$ or $G = |G_x| + |G_y|$
3. Non-maximum suppression
4. Hysteresis

Implementation

Overview

- Development and Frameworks
- Image Enhancement
- Edge Detection
- Edge Histograms
- Edge Lengths
- Edge Orientation
- Image Classification

Development and Frameworks

Developed using:

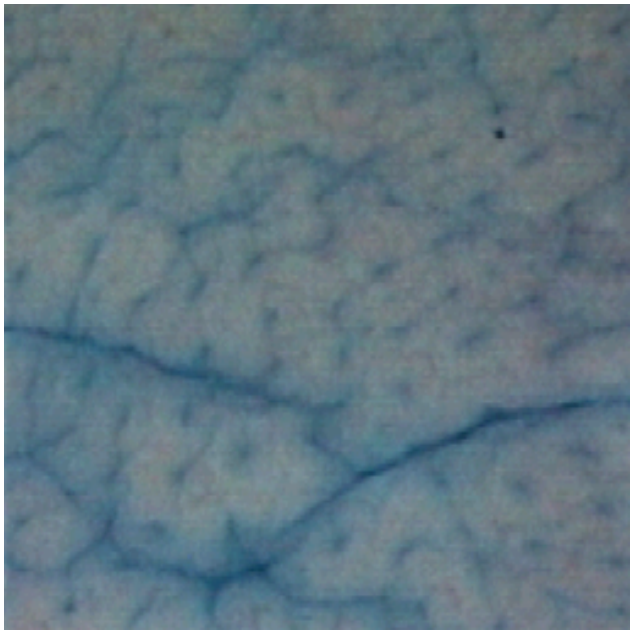
- Java 8
- OpenCV for Java
- Eclipse Neon

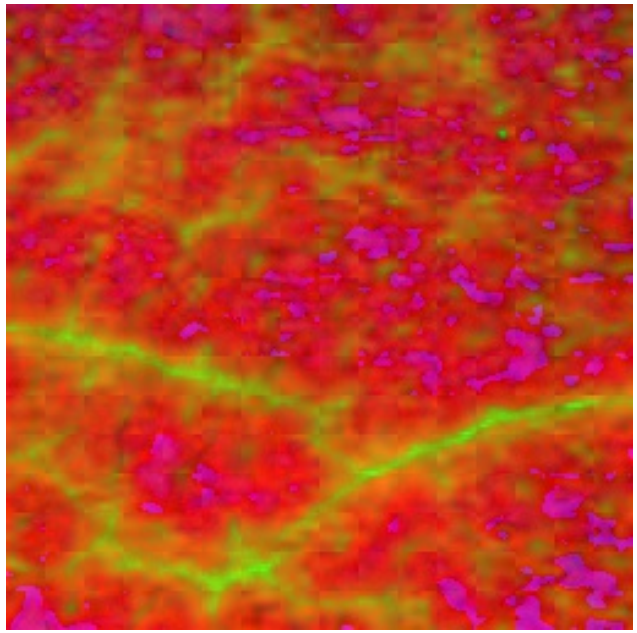
Image Enhancement and Conversion

- Color Space Conversion
- Normalization
- CLAHE
- All part of OpenCV

Image Enhancement and Conversion

RGB to HSV





```
Imgproc.cvtColor(srcMatrix, dstMatrix, colorSpace)
colorSpace: e.g. Imgproc.COLOR_RGB2HSV
```

Image Enhancement and Conversion

Normalization:

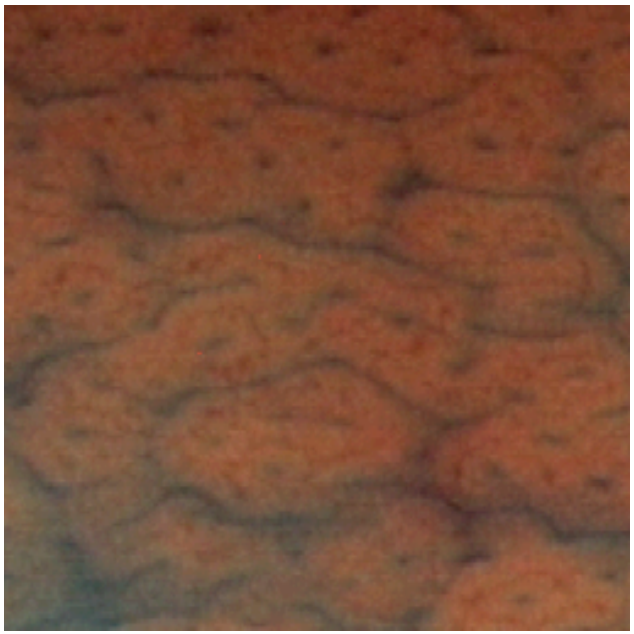
```
Core.normalize(srcMatrix, dstMatrix, 255, 0,
 Core.NORM_MINMAX);
```

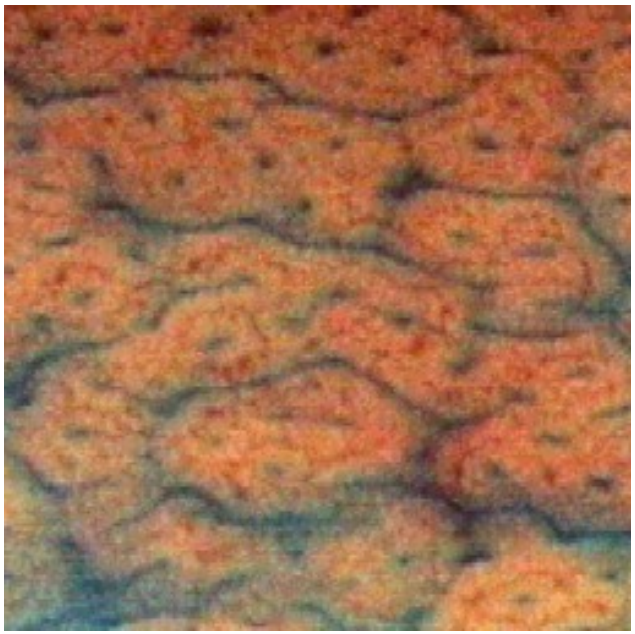
CLAHE:

```
Mat channel = new Mat();
Core.extractChannel(matrix, channel, i);
CLAHE clahe = Imgproc.createCLAHE();
clahe.apply(channel, channel);
Core.insertChannel(channel, matrix, i);
```

Image Enhancement and Conversion

Image Enhancement and Conversion

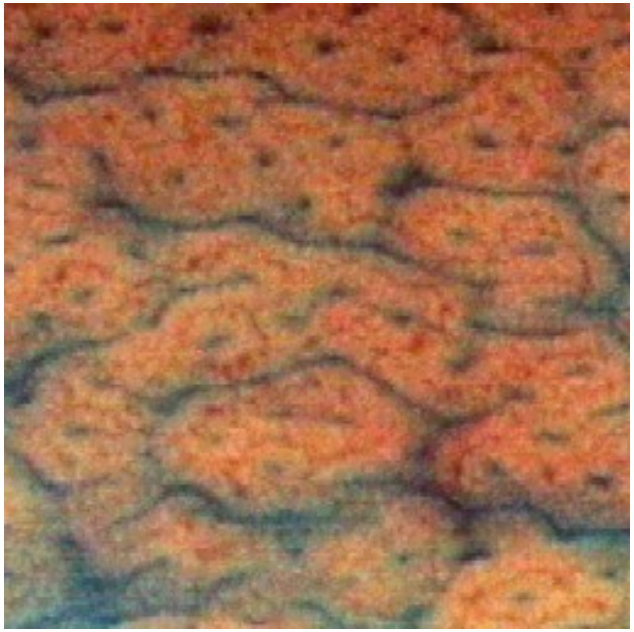


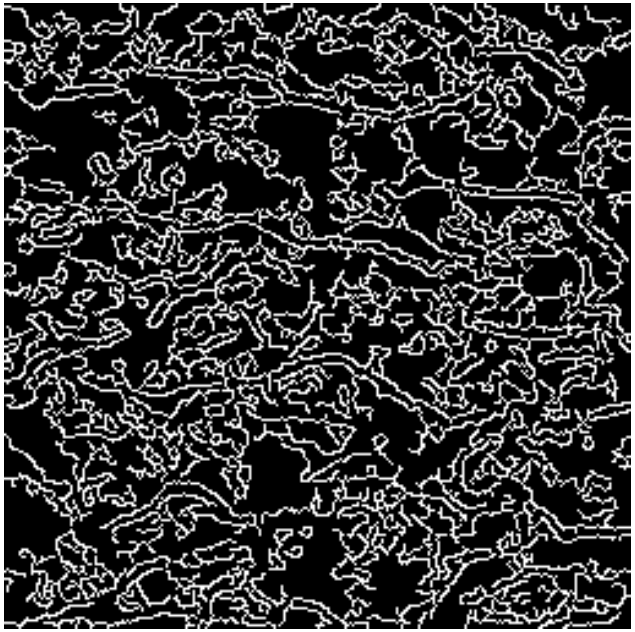


Edge Detection

- Grayscale Conversion
- Canny Edge Detector

Edge Detection





```
Imgproc.Canny(srcMatrix, dstMatrix,
 lowThresh, highThresh);
```

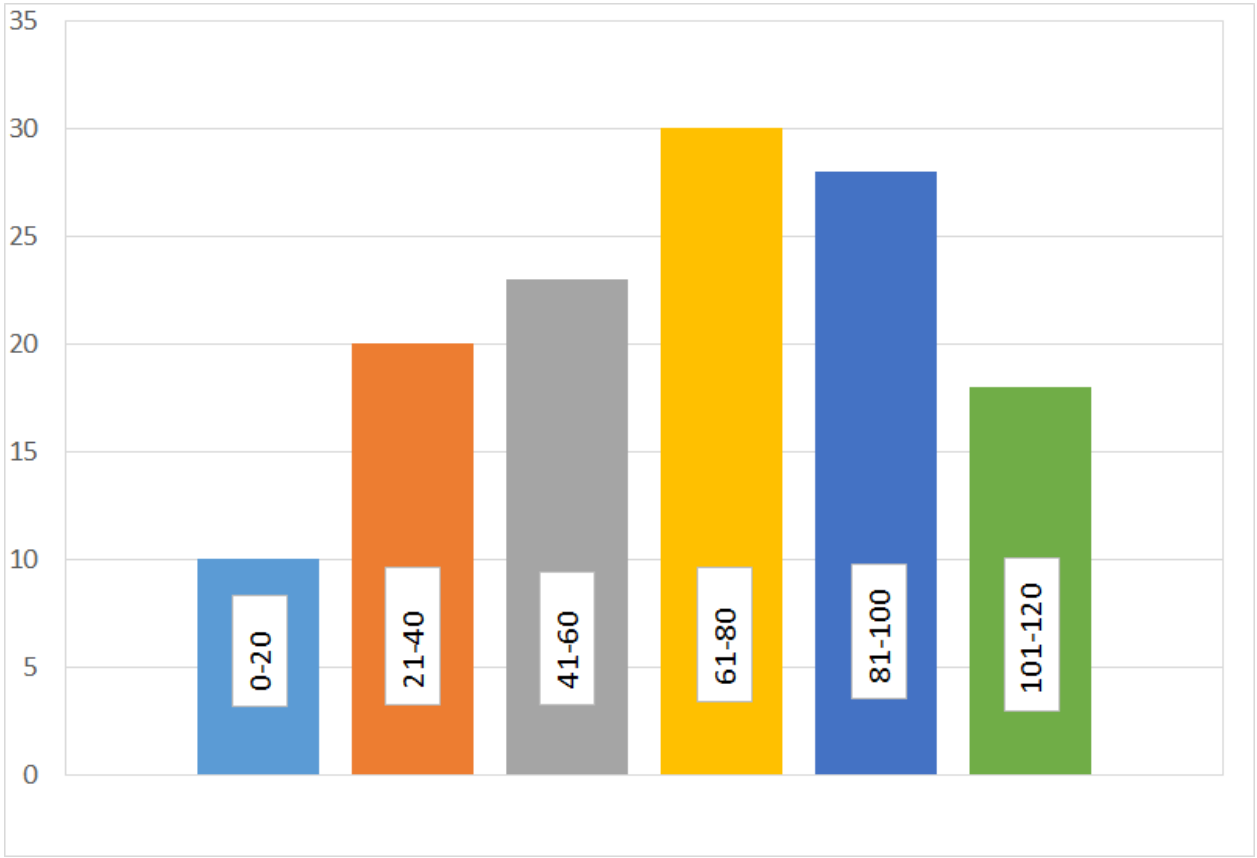
Edge Histograms

Definition

- Characteristics of an image e.g. edge lengths
- Partition characteristic attributes into bins
- In our case: edge lengths & orientations
- Length: image has
  5 edges of length 0 - 20 pixels
  20 edges of length 100 - 120 pixels

Edge Histograms

Simple Example:
10.0, 20.0, 23.0, 30.0, 28.0, 18.0, 1



Edge Histograms

- Histogram data for each example image collected in a hist-file.
- Specify Category. Here: Cancer stage
- Example:

```
210.0,3.0,170.0,142.0,126.0,93.0,32.0,16.0,1
192.0,2.0,181.0,139.0,119.0,87.0,32.0,17.0,2
143.0,1.0,172.0,147.0,128.0,91.0,30.0,16.0,3
```

Edge Lengths

Prequisites

- Image with detected edges
- Edges white
- Rest black
- Not entirely given $\rightarrow$ threshold set at grayscale 200

Edge Lengths

Algorithm

Iterate over all pixels

1. Check if pixel is white $\rightarrow$ new edge found
2. Check immediate neighbours: if white $\rightarrow$ add pixel to edge
3. Follow white path until no more connected white pixels
4. Add all passed pixels to collection of used pixels
5. Add 1 to bin with detected length
6. Continue iterating and start at 1

Edge Lengths

Algorithm

```
function measureEdge(pixel) {
    length = 1
    for each surrounding pixel p:
        if p == white
            length += measureEdge(p)

    return length
}
```

Edge Orientation

- Requires edge detected image
- Use sobel operator to detect edges
- Extract edge orientations from image (OpenCV)
- Partition edges into bins
- Bin content: pixels part of edge with certain orientation
- Bin: range of angles

Image Classification

1. Classify all example images $\rightarrow$ create file with histograms
2. Create list of feature vectors
3. Enhance image to be classified
4. Create feature vector
5. KNN: Compare new vector all vectors in list
   $\rightarrow$ euclidean distance
6. Select K vectors with smallest distance
7. Classification: category found most often

Paramter Optimization

Difference between a good and barely functional program

- Selection of input images
- Thresholds for edge detection
- Edge Lengths: number of bins, range of lengths in bins
- Weights of features: all equally significant
  Lengths: per edge
  Orientation: per pixel

Results

Evaluation

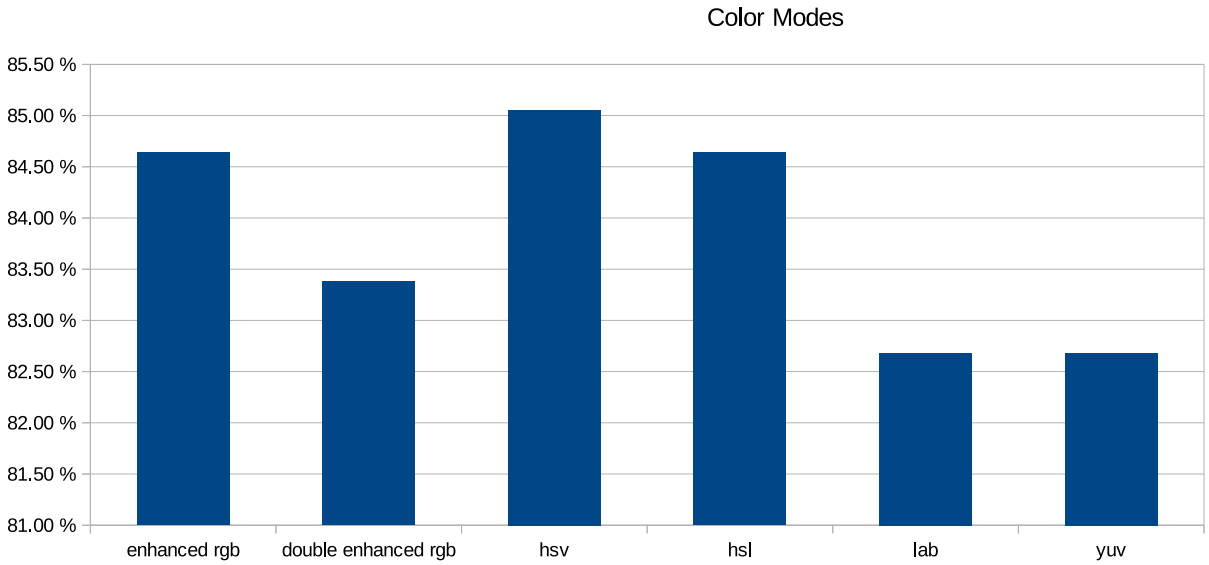
Normalizing

- Two features: Length, Orientation
- Histograms results are normalized
- from 0.0 to 1.0
- 0.0 is the lowest occuring value (usually 0.0 anyway)
- 1.0 is the highest occuring value

Results

- Total % of correct classified images
- Class 2 weights stronger than class 3 (fewer images)

Colormodes



Edge Length: 100 - 1000

Low Threshold: 33

High Threshold: 100

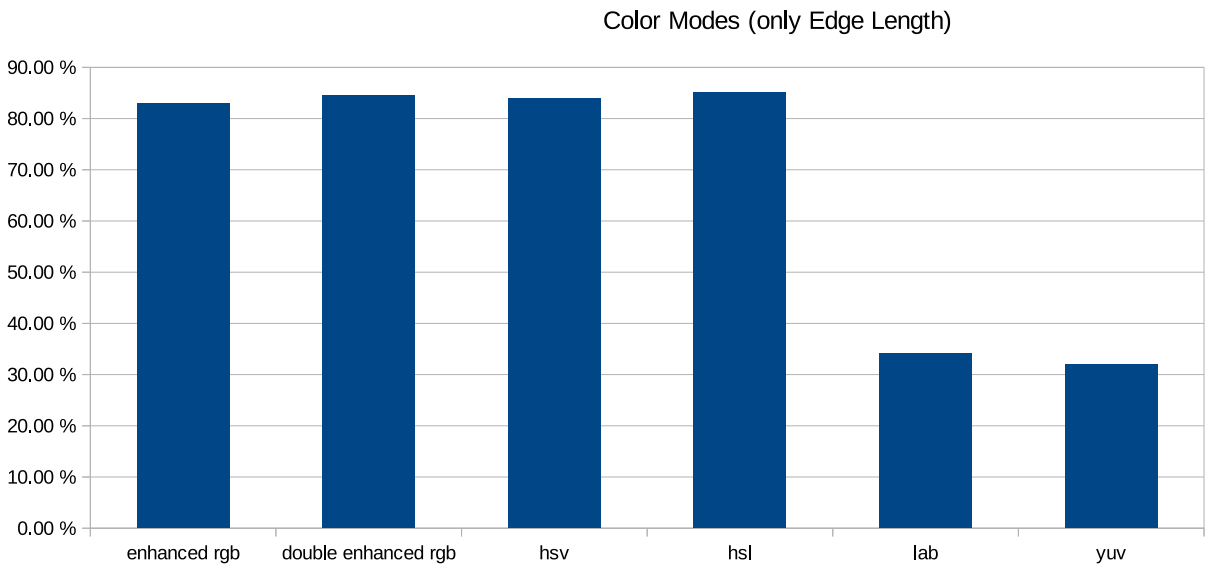
Max Edge Length 1000 px

Bin Size (Length): 50

Bin Size (Orientation): 20

k: 5

Colormodes (without Edge Orientation)



Edge Length: 100 - 1000

Low Threshold: 33

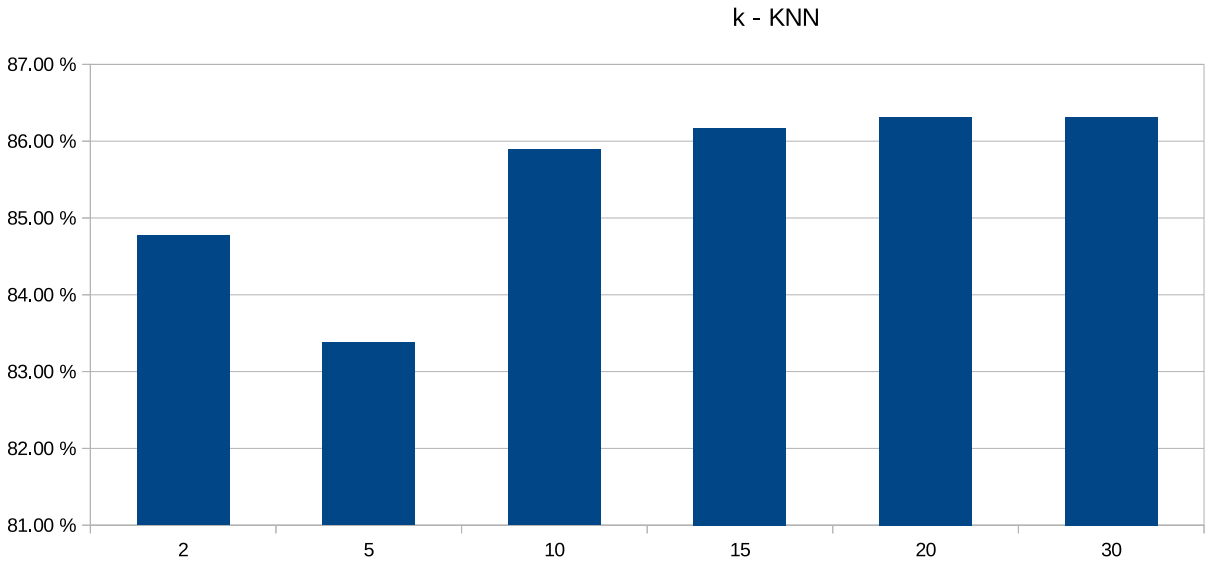
High Threshold: 100

Max Edge Length 1000 px

Bin Size: 50

k: 5

k - KNN



Color Mode:
double enhanced rgb

Edge Length: 100 - 1000

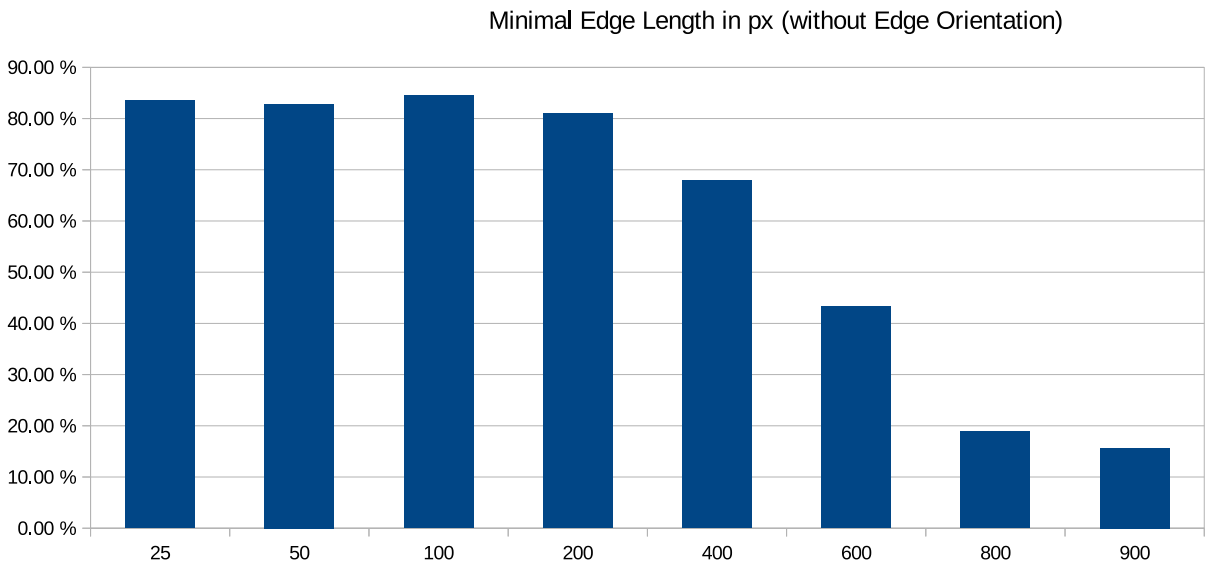
Low Threshold: 33

High Threshold: 100

Max Edge Length 1000 px

Bin Size: 50

Edge Length (without Edge Orientation)



Color Mode:
double enhanced rgb

Low Threshold: 33

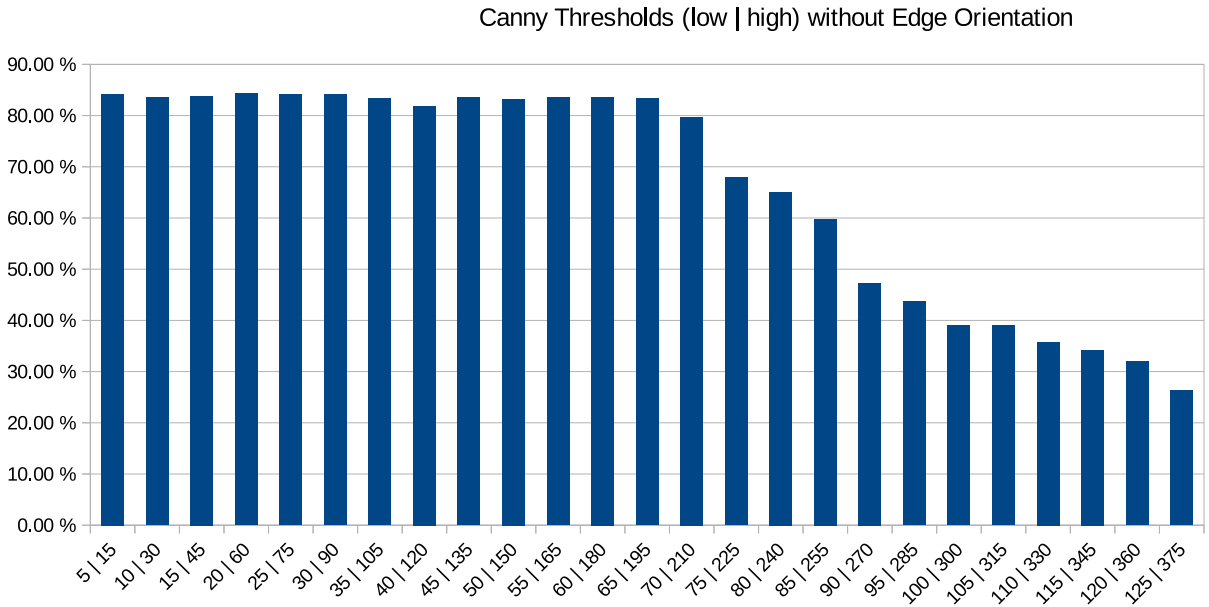
High Threshold: 100

Max Edge Length 1000 px

Bin Size: 50

k (KNN): 5

Canny Thresholds (without Edge Orientation)



Color Mode:
double enhanced rgb

Edge Length: 100-1000 px

Bin Size: 50

k (KNN): 5

Problems

Encountered Problems

- Fine tuning of parameters (unlimited combinations)
- Understanding how to use CLAHE in OpenCV
- Different parameter sets for different images
- Normalizing features to weight equally
- Can get over 80% correctness without recognizing class 3

Thank You!