VISION-BASED EQUATION SOLVER

VISI-SOLVE

by Sebastian Ho, Matteo Negro, Andrea Paparella, Anup Raj & Dwij Shetty

Univerisity Of Illionis Chicago

LIST OF CONTENTS

PROBLEM

Recognizing mathematical equations from images: process, segment and recognize the digits to compute the final result.

Input

Images containing handwritten mathematical equations.

Ouput

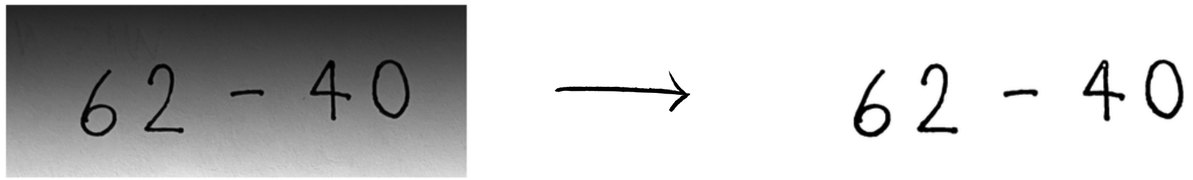
Result of the equation.

Challenges

Variability in handwriting, symbol complexity, and image quality.

IMAGE CLEANING

To accurately segment and predict symbols with a CNN, clear number display in images is crucial.



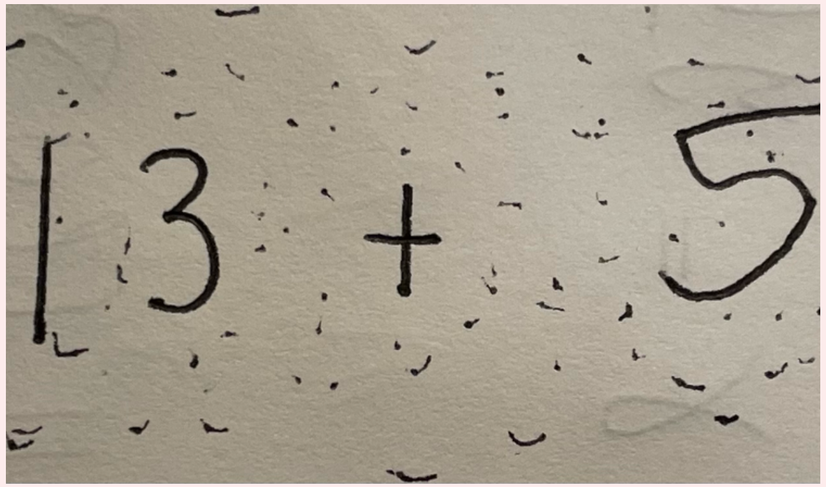
Noise Reduction

Brightness Adjustment

Histogram Equalization

NOISE REDUCTION

Removing noise from photos



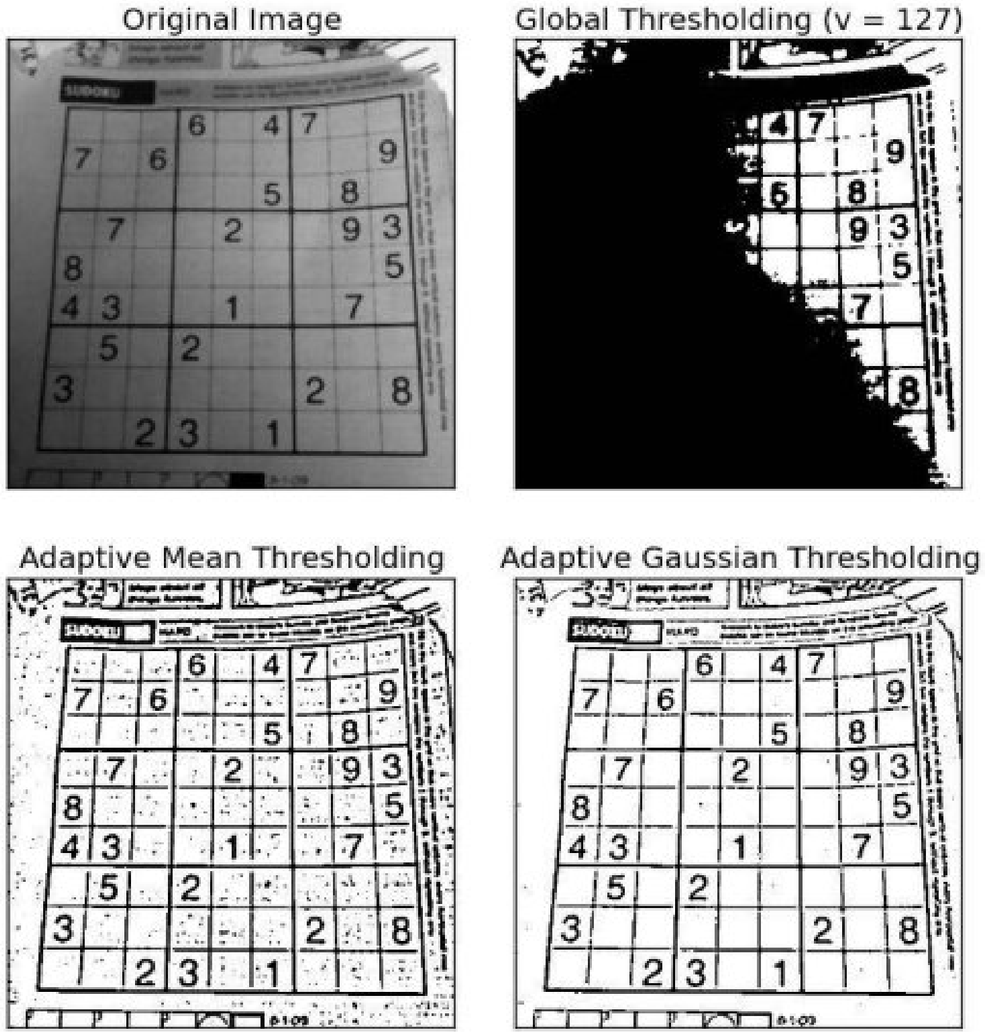
VERSION 1

- Thresholding
- Blurring

VERSION 2

- Shadow removal
- Erosion
- Adaptive thresholding

ADAPTIVE THRESHOLDING



ADAPTIVE MEAN

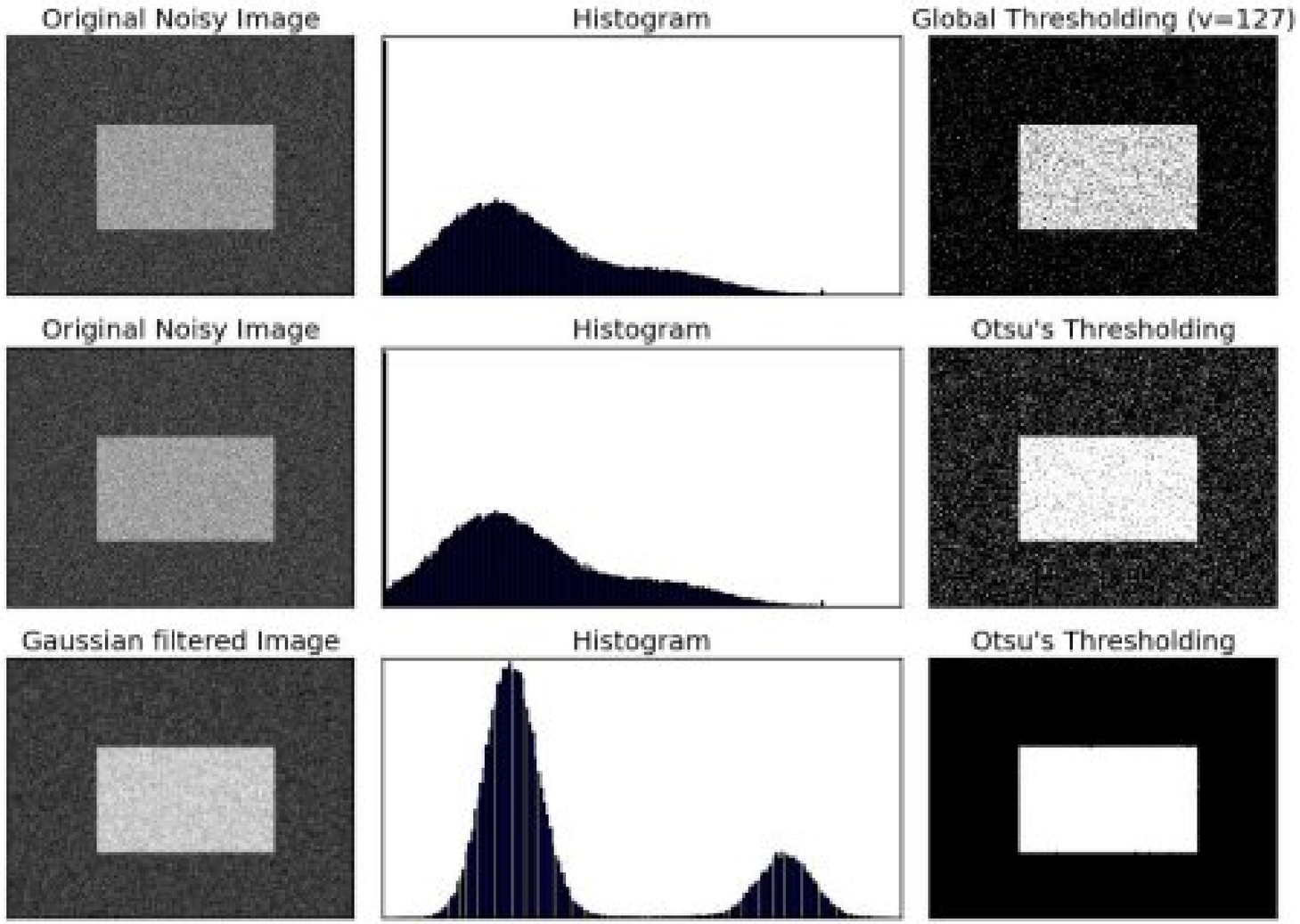
Thresholds areas based on the mean intensity of the neighborhood area

ADAPTIVE GAUSSIAN

Thresholds areas based on the Gaussian weighted sum of the neighborhood area. Weight each intensity by a Gaussian kernel, then take the sum of all elements.

https://docs.opencv.org/3.4/d7/d4d/tutorial_py_thresholding.html

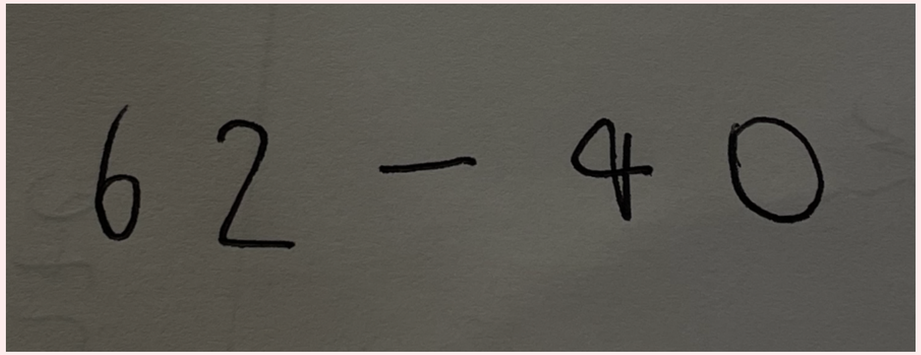
OTSU’S BINARIZATION



https://docs.opencv.org/3.4/d7/d4d/tutorial_py_thresholding.html

BRIGHTNESS ADJUSTMENT

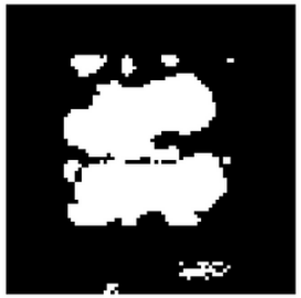
Adjusting the brightness in order to improve photo with low brightness to be recognized



ISSUES

- Makes the background more prominent than the text
- Complicates text-background contrast

Original Image

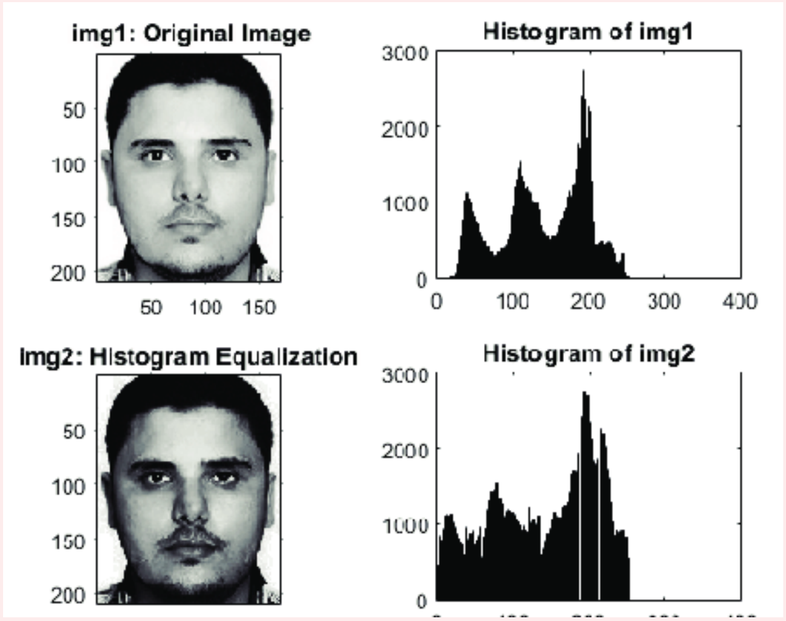


Threshold, Bright

Threshold, Original

HISTOGRAM EQUALIZATION

For adjusting image contrasts. To enhance low-contrast images, especially where symbols are faint or background lighting is poor.



ISSUES

- Amplification of background features.
- Unwanted enhancement of noise

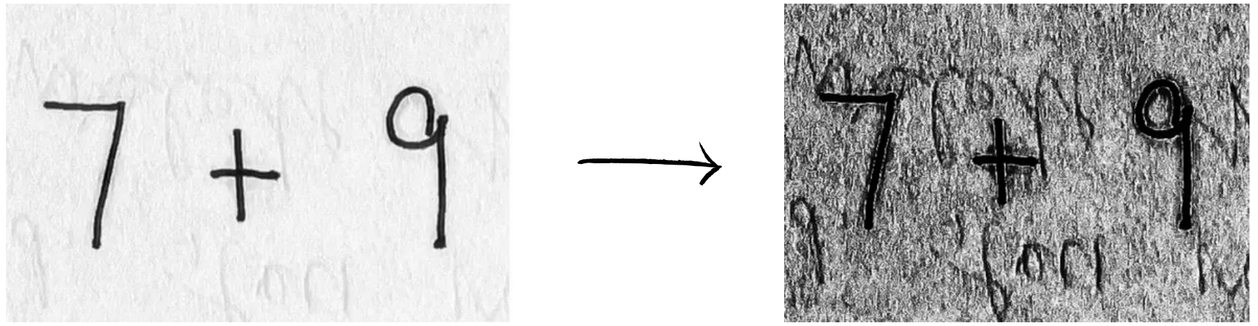


IMAGE SEGMENTATION

Photos of equations need to be separated into their constituent symbols so that each symbol can be fed as input to the neural network.

Countouring

Mean Shift Clustering

CONTOURING

Segmenting the images by contouring

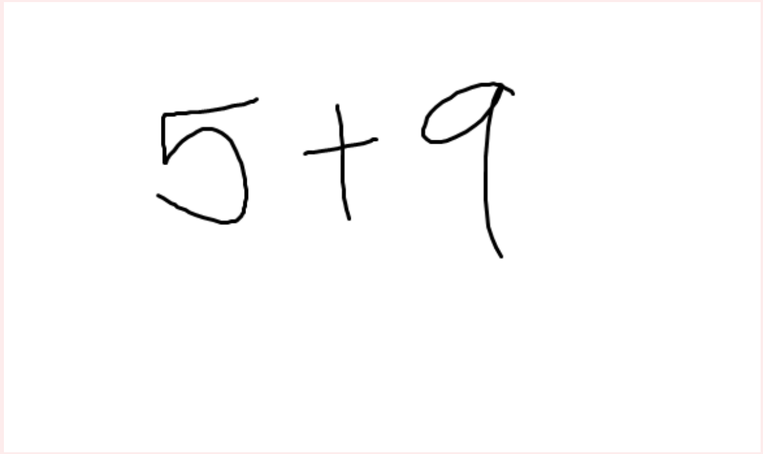
Contour Detection

Contour Processing

Bounding Rectangles

CONTOUR DETECTION

Identify the outlines of objects and shapes in an image



- cv2.findContours function used for detecting contours in an image.

- Analyzes a binary image and returns a list of contours found.

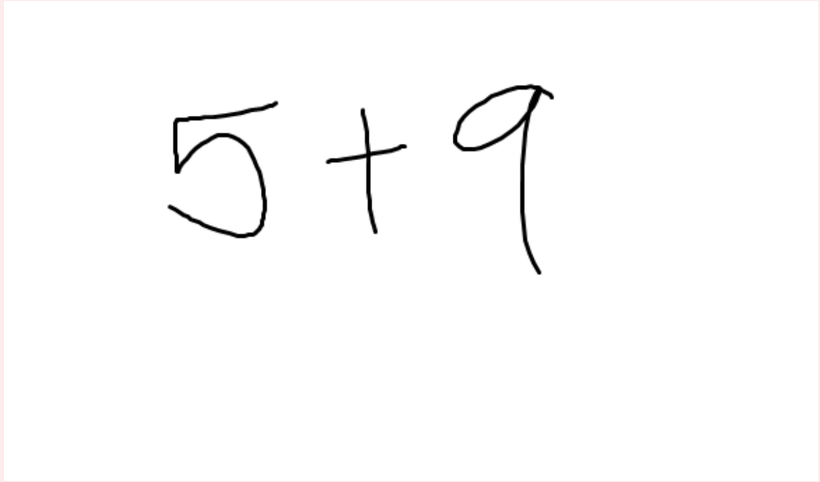
CONTOUR PROCESSING

Processing the contours identified in an image

- Sorting contours based on their x-coordinate
- Ignoring child contours

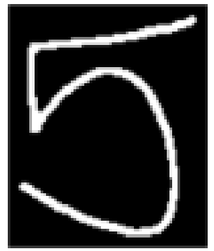
BOUNDING RECTANGLES

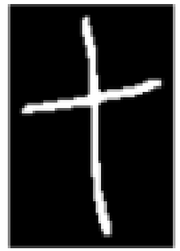
Encloses a contour and isolates individual symbols from the rest of the image.

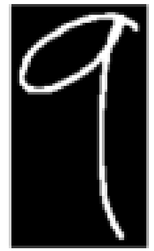


Original Image

- Isolates individual symbols from the rest of the image.
- The area within this rectangle is then cut out from the original binary image



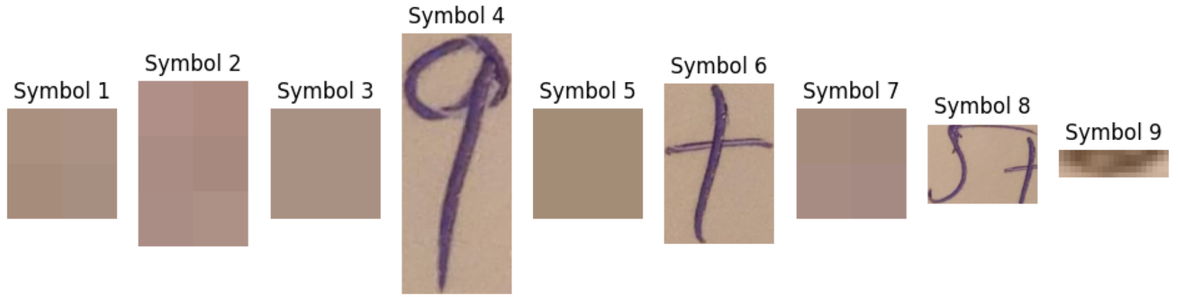


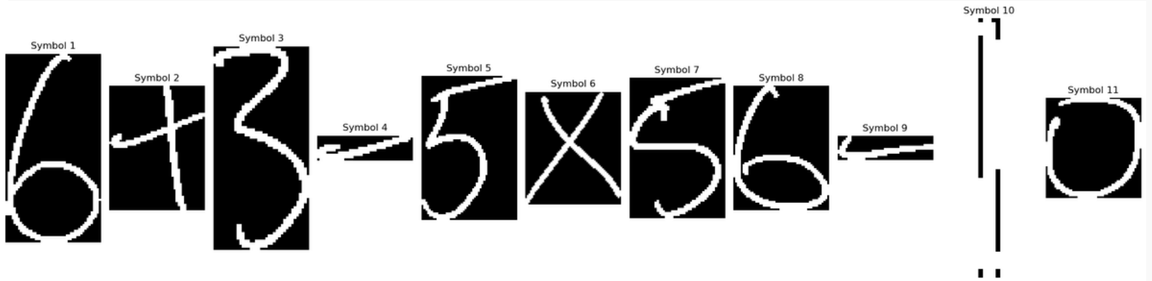


ISSUES

There are examples of what we needed to fix.

These issues usually revolve around the shape and nature of the symbol.





EXAMPLES

- Division symbol
- Equals sign

These numbers have a common theme

FIXING THE ISSUE

- We examine two separate contours.
- The edges are compared.
- Merging based on threshold.

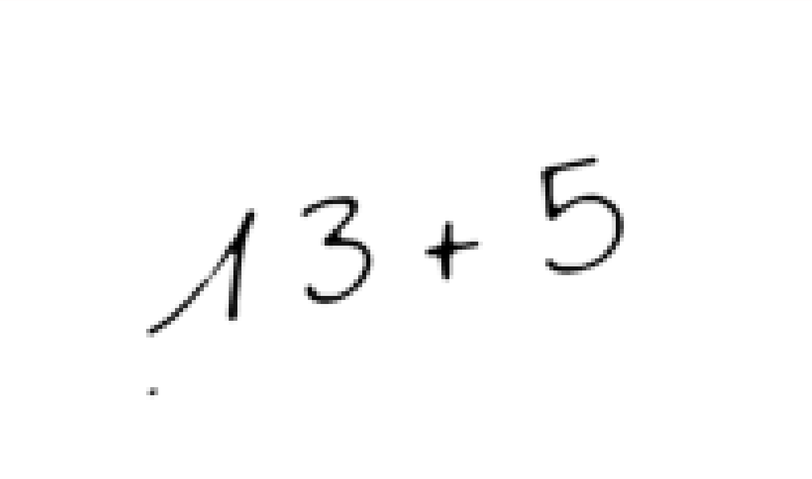
A visual example:

Contours with no merging

After merging contours to display a symbol

MEAN SHIFT FILTERING

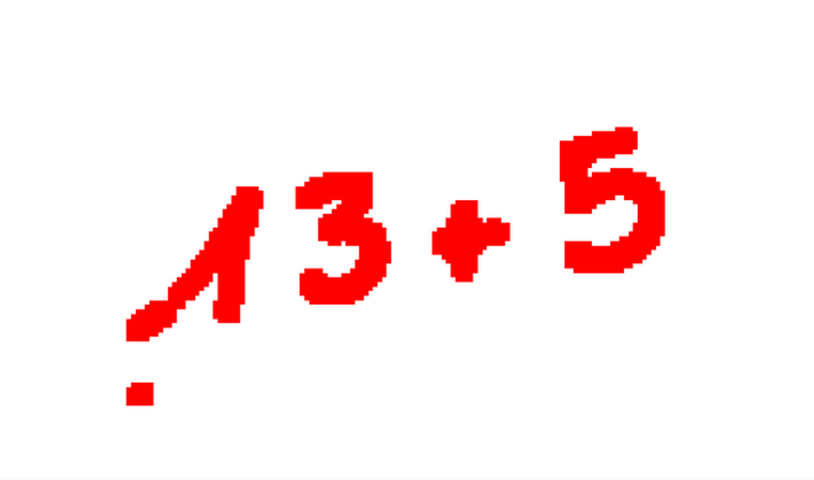
Decomposes an image into its
constituent symbols
based on the clustering of feature points.



- Harris corner detection
- Mean Shift Clustering groups feature points.
- Iterative processing of clusters to extract symbols.

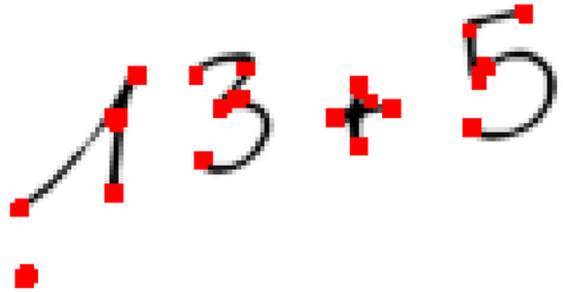
HARRIS CORNER DETECTION

Find special points in the image



ISSUES

- Noise
- Density

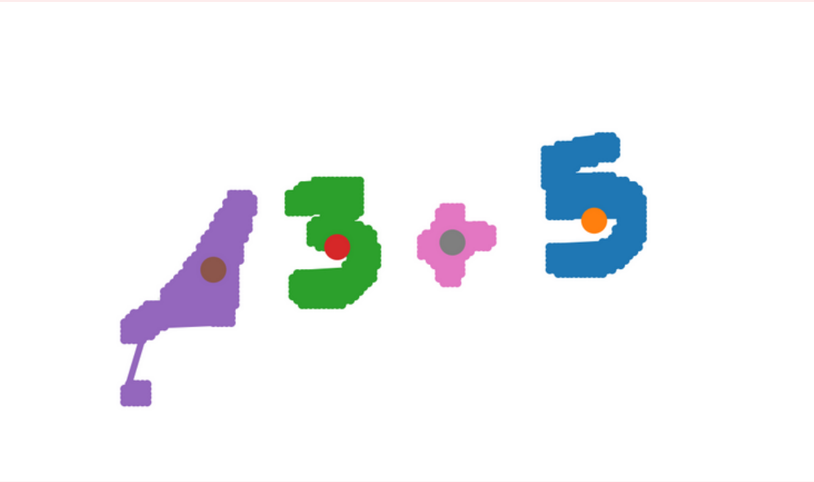


SOLUTION

- Hyper-parameters tuning

CLUSTERING

Find the groups of points that are close with **Mean Shift Algorithm**



ISSUES

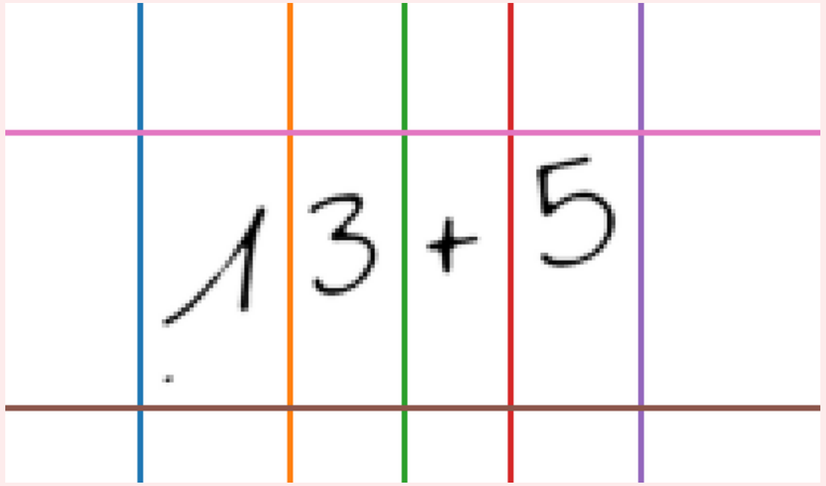
- Underfitting
- Overfitting
- Number of clusters

SOLUTION

- Hyper-parameters tuning
- Filtering

SYMBOLS EXTRACTING

Decompose the original image in smaller images with one digit each



RESULTS & ISSUES

- This method is scale sensible
- We are able to get good results in general

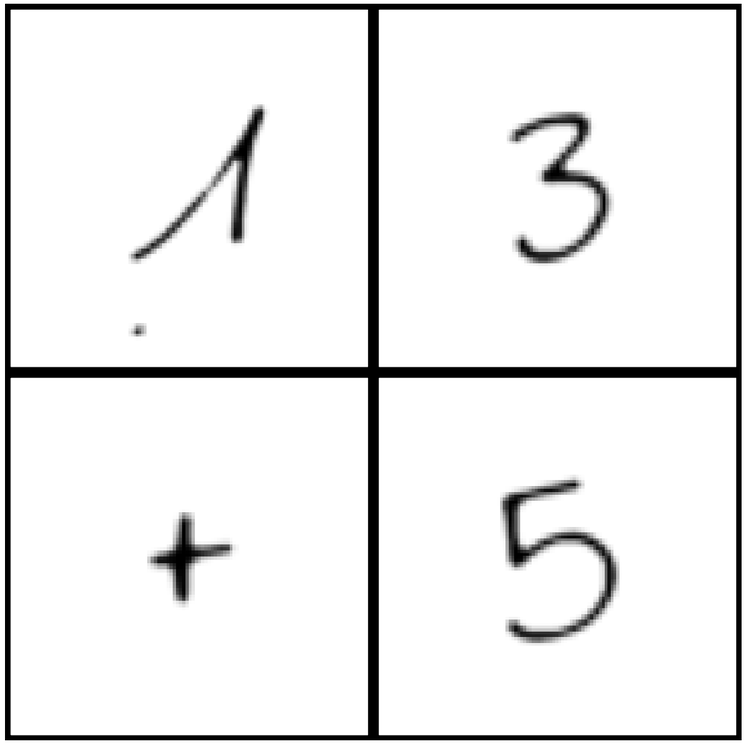


IMAGE RECOGNITION

Cleaned up and segmented images are now ready to be recognized.

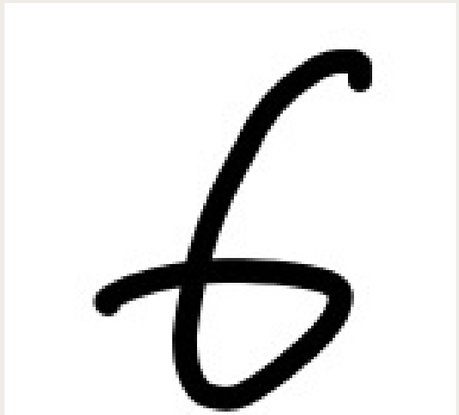
Dataset

Shallow, Deep MLP

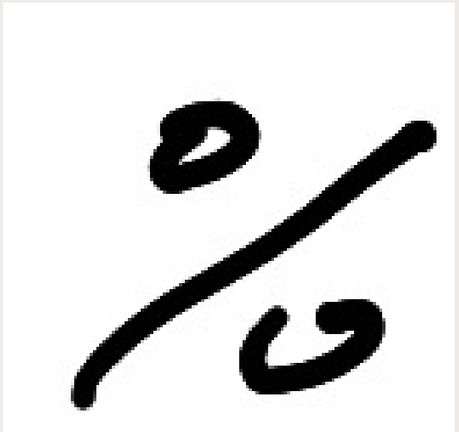
Shallow, Deep CNN

DATASET

- Handwritten
- No noise
- 554 images for each symbol
- Each image 155x135 pixels



Number 6

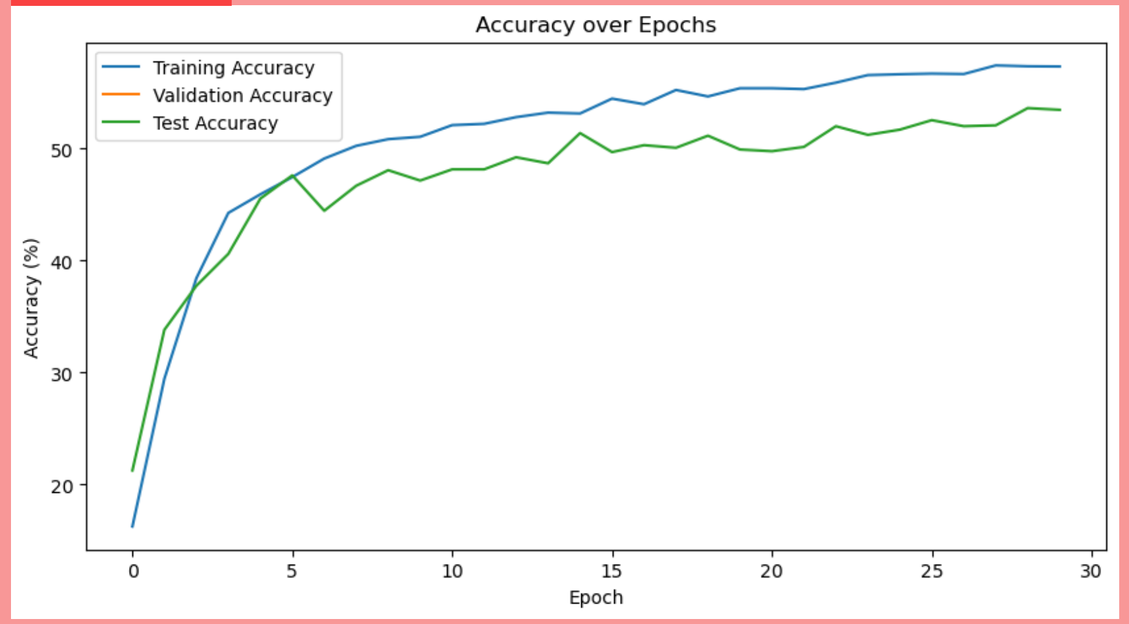


Division Operator

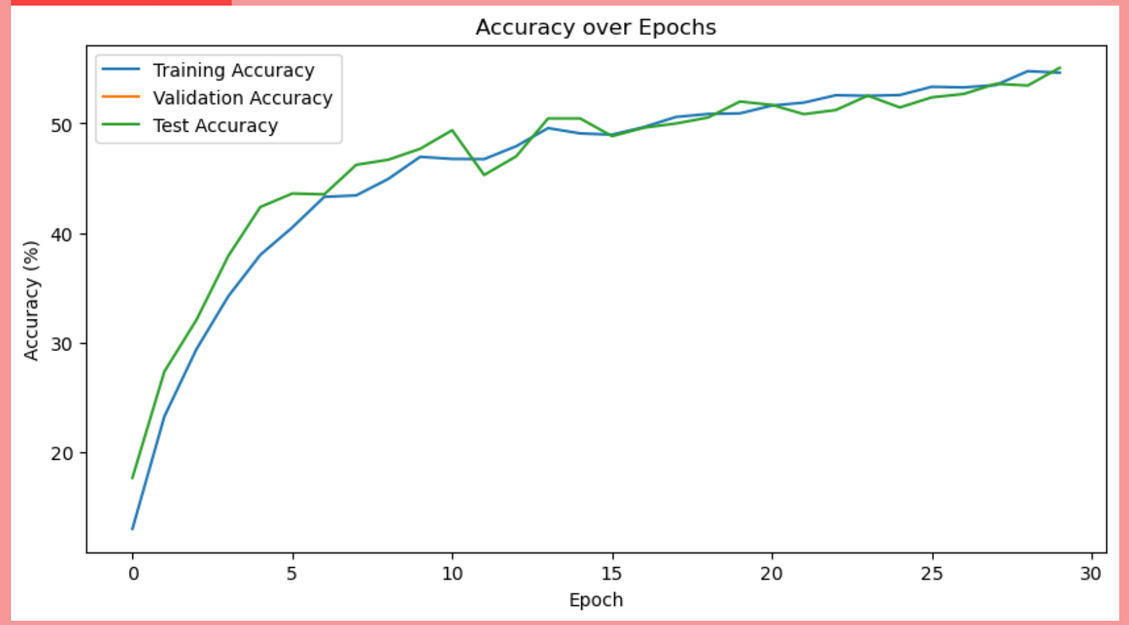
MLP

- Shallow and Deep MLP have low accuracy
- Not able learn the features

Shallow



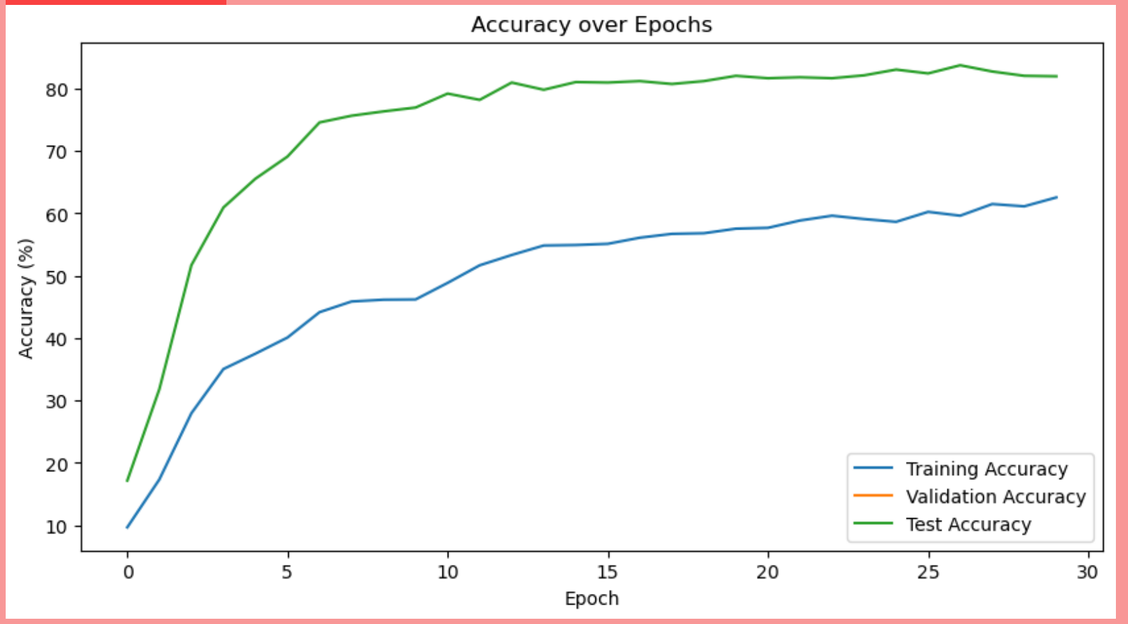
Deep



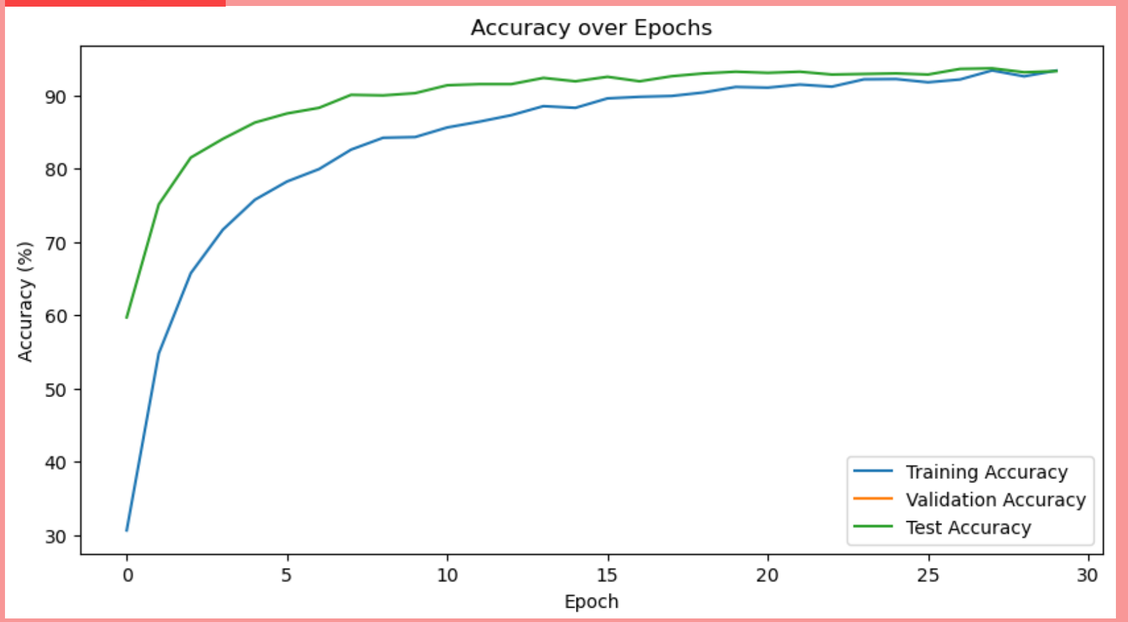
CNN

- CNNs perform better
- Shallow CNN is biased
- Deep CNN has very good accuracy and generalization capabilities

Shallow



Deep



OUR BEST MODEL

2 CONV

32 filters
Kernel size of 3

1 MAX-POOL

2 FULLY-CONNECTED

93.4%

Train Accuracy

0.18

Train Loss

93.3%

Test Accuracy

0.27

Test Loss

FUTURE WORK

Next steps to make a better product.

Scale invariant segmentation

Recognizing symbols at different angle

Larger dataset

LIVE DEMO

THANK YOU

University of Illinois Chicago

CONTRIBUTIONS

Sebastian

Led Image Cleaning

Matteo

Led Image Segmentation

Andrew

Led Image Recognition

Anup

Led Image Contouring

Dwij

Led Image Contouring