Rendering Handwritten Equations

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Capstone Project Presentation
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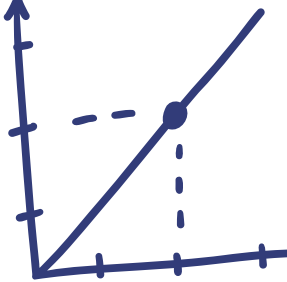


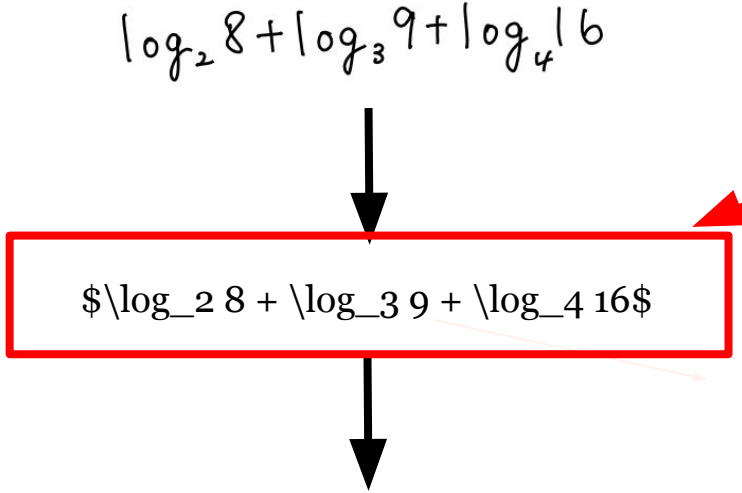
Problem Statement

Develop a tool that can render handwritten equations in digital format.

Input: an image containing an equation

Output: the equation in digital format, using LaTeX math notation

For example..

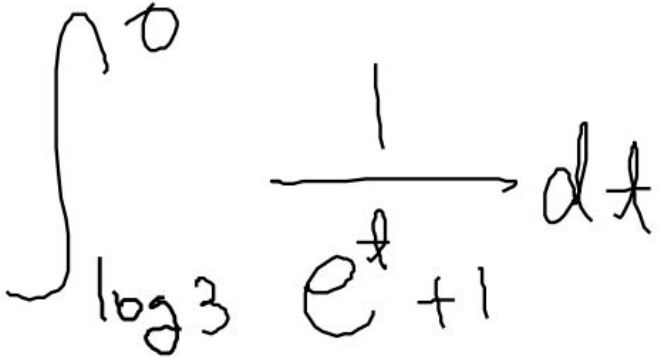


How we evaluate performance

$$\log_2 8 + \log_3 9 + \log_4 16$$

Why is this complicated?

Symbols are not just read left-to-right

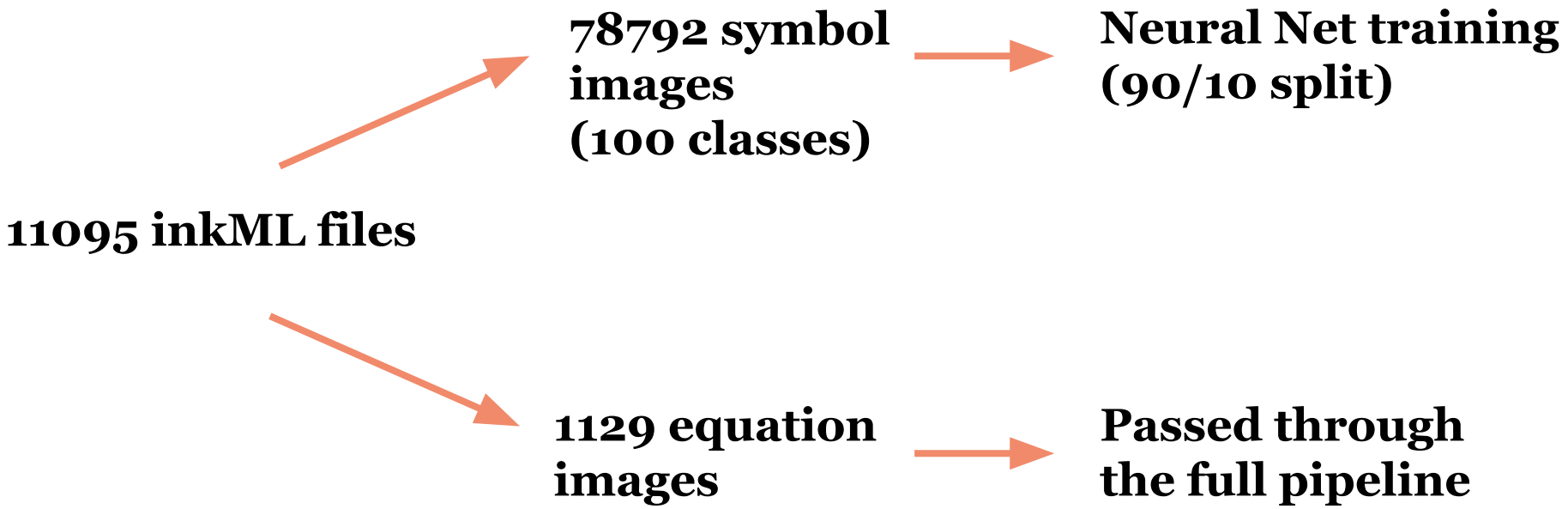


Data

- **CROHME**
- **‘inkML’ format**
- **Full equation label**
- **Labels for each symbol**
- **100 different symbols**

https://www.isical.ac.in/~crohme/CROHME_data.html

Data Processing



Pipeline Overview

1. Image tresholding

Change image into black/white values

2. Resolving Symbols

Figure out the symbol on the image and their order

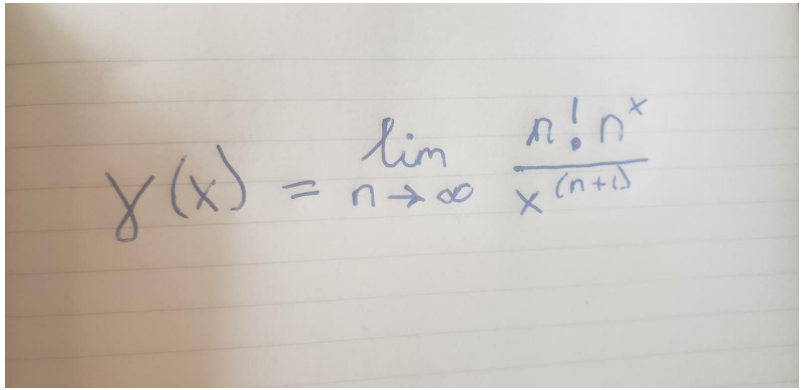
3. Model Prediction

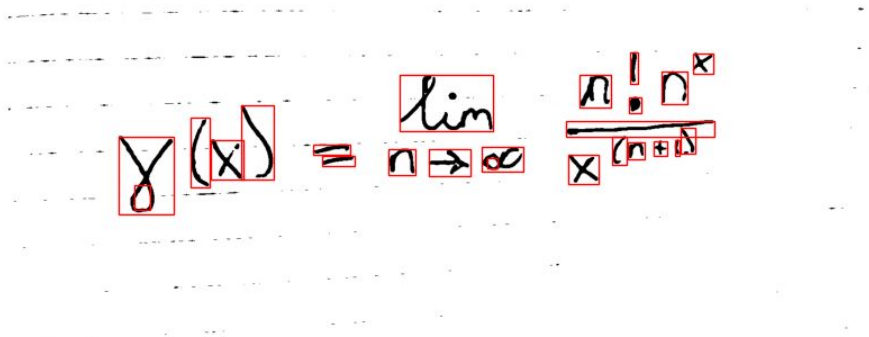
Use an EfficientNetB0 CNN to predict labels

4. Rendering the equation

Stitch the predictions together into an equation

1) Image Tresholding

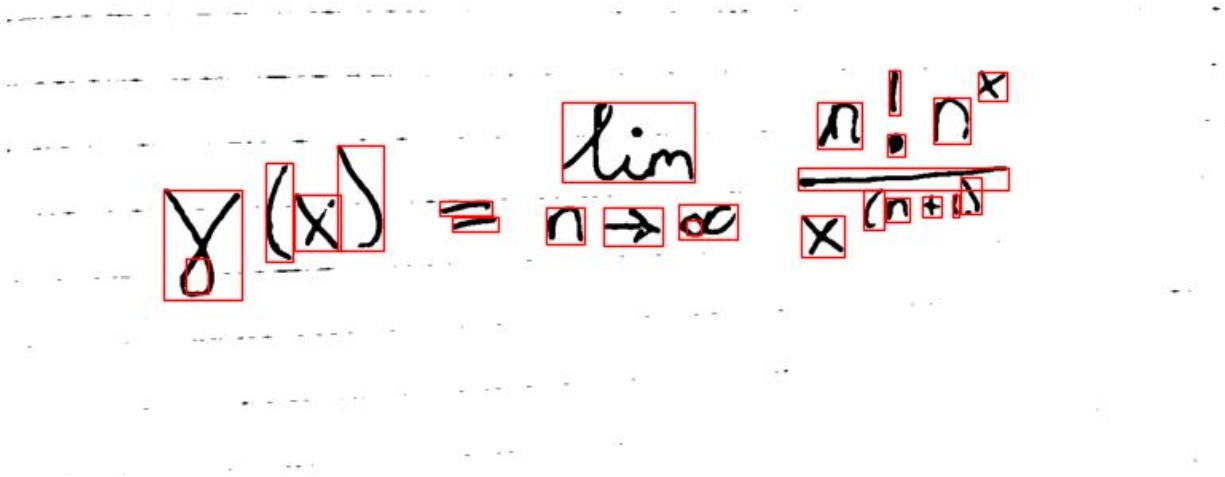




Adaptive Gaussian Tresholding

2) Resolving Symbols

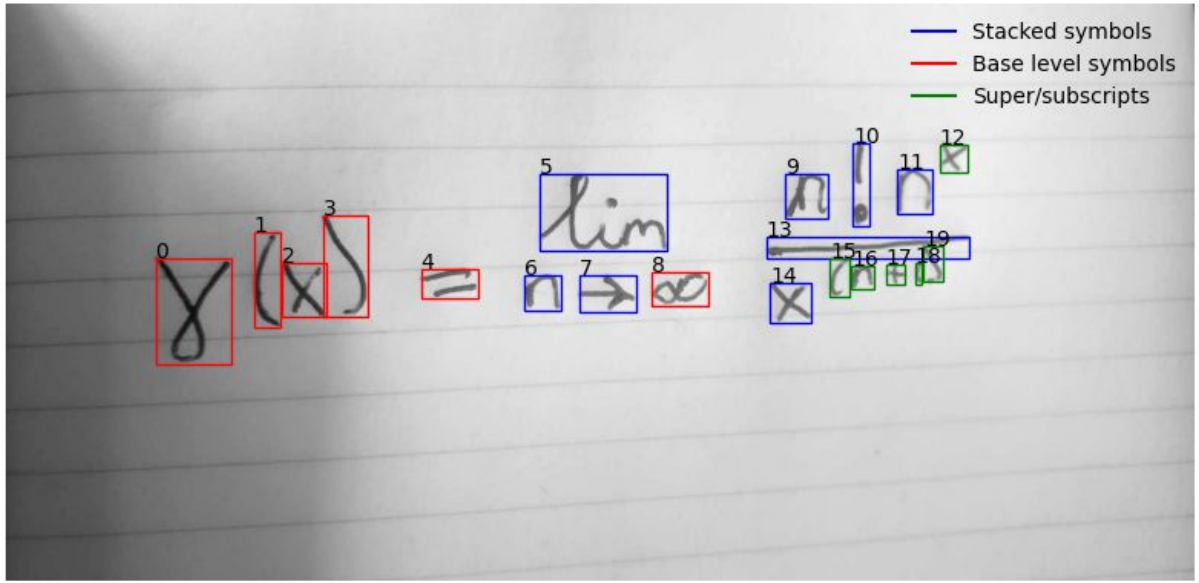
Find Contours and Bounding Boxes



i) Remove Inner Contours
ii) Merge Boxes

iii) Determine Symbol order
iv) Determine Script level

2) Resolving Symbols



i) Remove Inner Contours
ii) Merge Boxes

iii) Determine Symbol order
iv) Determine Script level

3) Model Predictions

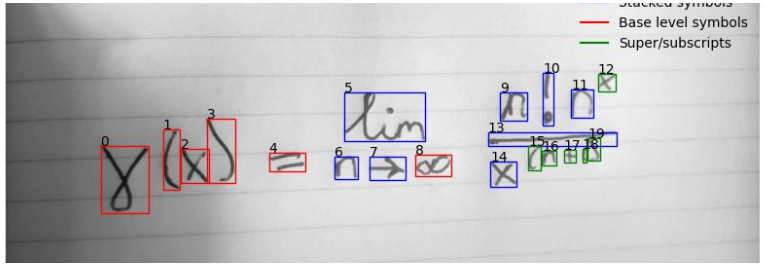
Model: EfficientNetB0 CNN

95% accuracy on validation data
(*individual symbol images)*

Prediction Step:

Symbol Images ->
List of class labels

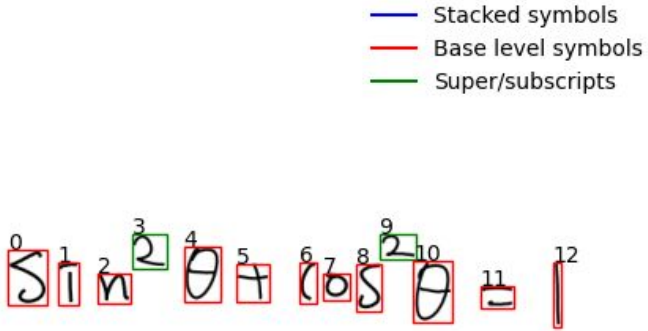
4) Render the Equation



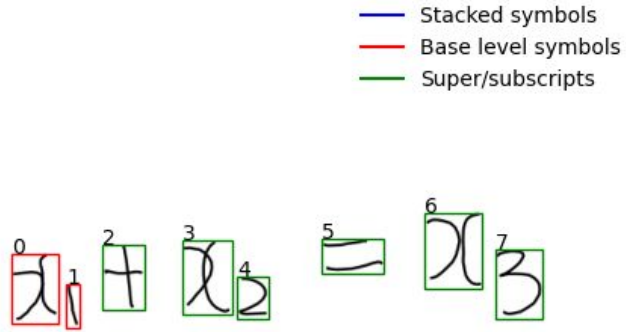
$\\gamma(X)=\\lim_{n-}\\infty\\frac{n!n^{k}}{\\times^{(n+1\\prime}}$

$$\gamma(X) = \lim_{n-} \infty \frac{n!n^k}{\times^{(n+1\prime}}$$

Two more examples



Prediction: $\sin^2\theta + \cos^2\theta = 1$



Prediction: $x1^{+x2=x3}$

Overall Pipeline Performance

Damerau-Levenshtein distance

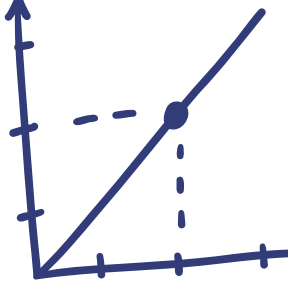
Actual: 'x_{i}-x_{i+1}+x_{i+2}'
Predicted: '**1**x_{**1**}-x_{**1**+1}+x_{**1**+2}'

1 deletion, 3 substitutions

Normalize by actual string length:
Distance = 4/21 ≈ 0.477

DL distance	% of equations
0	**15.7%**
< 0.10	**20.9%**
< 0.50	**65.9%**

Final thoughts..



This is a difficult problem to solve!

Errors compound through the 4 pipeline steps

Different linewidths seem to make the predictions less accurate than the 95% accuracy in NN

Multiple Object Detection algorithms