Recognition of Handwritten Mathematical Expression

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Preprocessing

- Normalize expressions to [0,200] in Y dimension, preserving aspect ratio.
- Smooth strokes
- For segmentation, normalize each *stroke* to 30 points.
- For classification, normalize each *symbol* to 30 points
- PCA on segmentation features

Segmentation

Heavily based on [1]

Simple AdaBoost classifier (50 decision stumps)

- Step through each stroke in expression
- Classifier says ‘MERGE’ or ‘SPLIT’

[1] Lei Hu;; Zanibbi, R., "Segmenting Handwritten Math Symbols Using AdaBoost and Multi-scale Shape Context Features," Document Analysis and Recognition (ICDAR), 2013 12th International Conference on , vol., no., pp.1180,1184, 25-28 Aug. 2013
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Segmentation Features

- 3 shape context features (stroke-pair, local, global), 60 bins each
- Current stroke features
    - E.g., Number of points, distance between first and last point
- Stroke pair features (Previous + Current & Current + Next)
    - Bounding box center distance, overlap, ratios
    - Minimum and Maximum distance between strokes
    - Writing slope (angle between last point of first stroke and first point of second stroke)
- 206 total features - PCA to 100

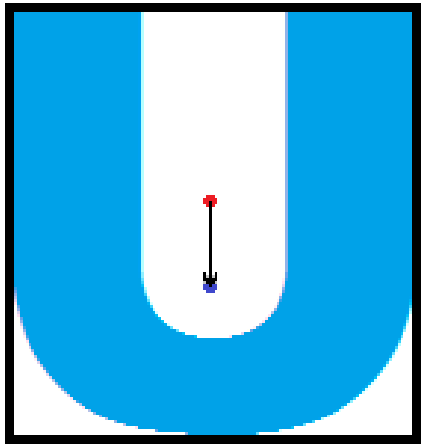
Classification

Random Forest classifier

- 100 Trees
- 15 maximum depth

Classification Features

- Shape context feature of whole symbol
- Internal angle (abs(cos), angle from horizontal)
- Number of strokes, cusps, intersections
- Number of points before normalization
- Vector from bounding box center to average center (normalized)



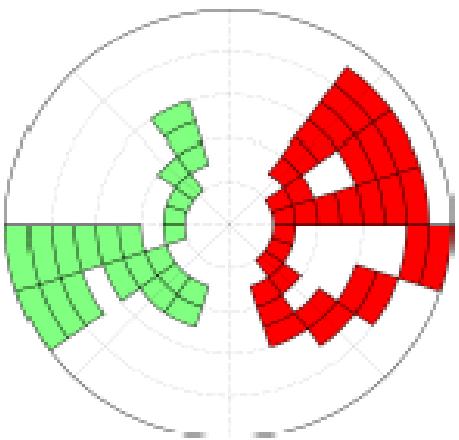
Results

Best Fold:

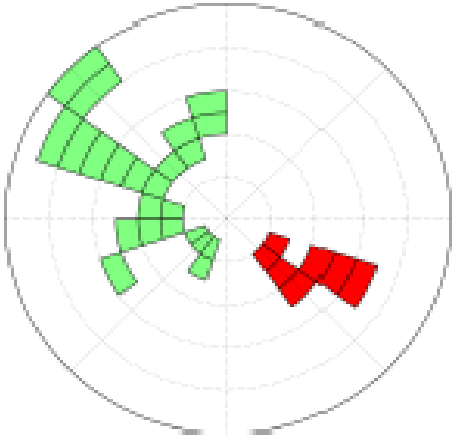
	Recall	Precision	F-Measure
Segmentation	80.91%	78.90%	79.8%
Segmentation+ Classification	63.67%	62.09%	62.8%

- Classification rate: ~78%

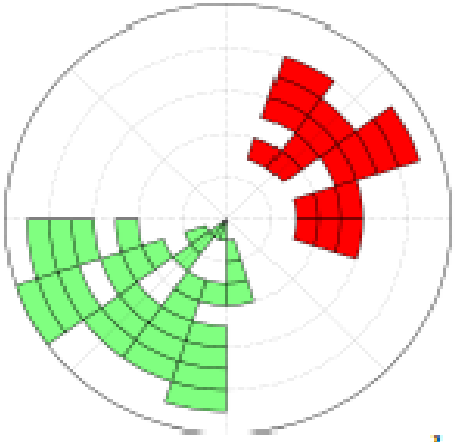
Parsing



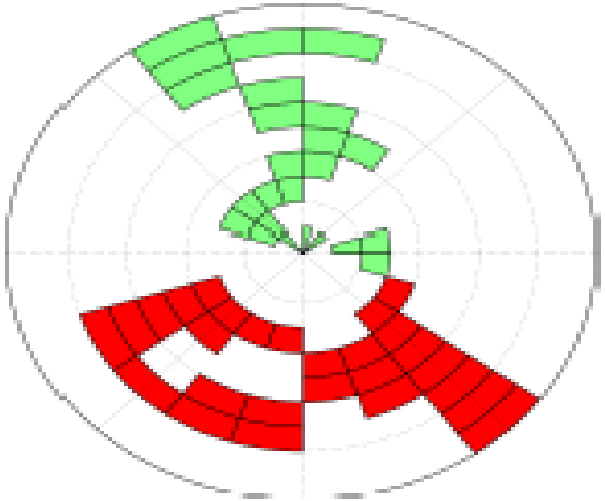
Horizontal: dB

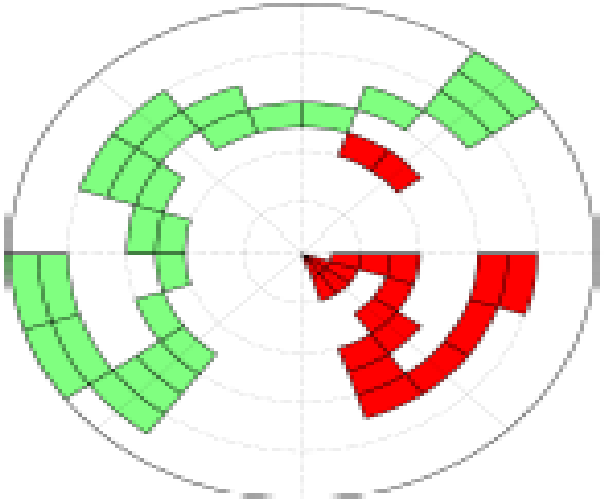


Subscript: X_u



Superscript: $\exp^{\frac{h}{d}}$





Below: $\sum_{C>h}$

Inside: $\sqrt{i}$

Polar Histogram

-Similar to Shape Context Features

- Horizontal,Superscript,Subscript,Below,Inside

-Cross validation, splitting the dataset randomly into 10 partitions

-M(i; j) = {-1,0,1}

-Support Vector Machine (SVM) classifier with a Gaussian kernel

Baseline Extraction

- The relationship between symbols is clear.

- Find the dominant baseline and use recursive baseline tree algorithm to create Layout Pass.

- We will have some result which would give us the final expression as output in LATEX format.

Motivation

Motivation to try this methodology:

- We have a visible final output rather than no output
- We found that we get much more information using MCSF.

References

[1] Lei Hu, Zanibbi, R., "Segmenting Handwritten Math Symbols Using AdaBoost and Multi-scale Shape Context Features," Document Analysis and Recognition (ICDAR), 2013 12th International Conference on , vol., no., pp.1180,1184, 25-28 Aug. 2013
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[2] F. Alvaro, J.A. Sanchez, and J.M. Bened. Recognition of on-line handwritten mathematical expressions using 2D stochastic context-free grammars and hidden Markov models. Pattern Recognition Letters, 2012.

[3] R.Zanibbi, D.Blostein and J.R.Cordy, "Recognizing mathematical expressions using tree transformation," IEEE Trans. PAMI, vol.24, no.11, pp.1455-1467, Nov. 2002

[4] Koschinski, M.; Winkler, H.-J.; Lang, M., "Segmentation and recognition of symbols within handwritten mathematical expressions," *Acoustics, Speech, and Signal Processing, 1995. ICASSP-95., 1995 International Conference on* , vol.4, no., pp.2439,2442 vol.4, 9-12 May 1995
doi: 10.1109/ICASSP.1995.47998