Recognition & Retrieval of Handwritten Mathematical Expressions Lei Hu Advisor: Richard Zanibbi

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Project Description

Math expressions are an indispensable component of scientific and technical literatures. It will be very exciting if math expression can be recognized and located in document databases automatically. But recognition and retrieval of math expressions are in comparatively early stages of research [1].







Three goals for the project:

(1) develop an effective algorithm for the recognition and retrieval of handwritten math expressions.

(2) improve and combine different recognition algorithms to allow multiple input modalities (finger, pen, mouse, image).

(3) improve math retrieval by searching for expressions based on a combination of appearance, symbol layout and semantics is also desirable.

Current Research

We build a recognition system based on HMM for isolated online handwritten math symbols [2]. We design a continuous left to right HMM for each symbol class and use four online local features, including a new feature: normalized distance to stroke edge. A variant segmental K-means is used to get initialization of the GMM's parameters. Figure 1. DPRL Math Entry Prototype: a portion of system used in Competition on Recognition of Online Handwritten Mathematical Expressions (CROHME 2011)

Interface URL: <u>http://saskatoon.cs.rit.edu/pen_entry</u>

Flow Chart of Symbol Recognition



Modified Pen-up/down Feature



$$NDTSE(s,t) = \begin{cases} 1 - \frac{|d_e - d_b|}{l_s}, \text{ for actual stroke} \\ -(1 - \frac{|d_e - d_b|}{l_s}), \text{ for interpolated stroke} \end{cases}$$

distance to beginning d_b

Experiment Result

The dataset is from a new publicly available, groundtruthed corpus of handwritten math expressions. MacLean et al. [3] applied dynamic time warping algorithm on all the single-stroke symbols. Their top-1 recognition rate is 85.8%, and top-5 is 97.0%. Our system gets top-1 of 85.5% and top-5 of 99.1%.

Comparison of average recognition rate and standard deviation between using NDTSE and Pen-up/down



Figure 2. New feature: NDTSE, containing the penup/down information and the location information of the current point



top 1 all top 1 multi top 1 single top 5 all top 5 multi top 5 single

[1] R. Zanibbi and D. Blostein, "Recognition and Retrieval of Mathematical Expressions," International Journal on Document Analysis and Recognition, to appear.
[2] L. Hu and R. Zanibbi, "HMM-Based Recognition of Online Handwritten Mathematical Symbols Using Segmental K-means Initialization and a Modified Pen-up/down Feature," Int'l. Conf. Document Analysis and Recognition, Beijing, China, September 2011(to appear).

[3] S. MacLean and G. Labahn, "Elastic Matching in Linear Time and Constant Space," Int'l. Workshop on Document Analysis Systems. ACM, 2010, pp. 551-554.



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