Compact Representation and Recognition for Handwritten Mathematical Characters

Stephen M. Watt
University of Western Ontario
London Ontario, Canada N6A 5B7
{oleg,watt}@csd.uwo.ca

This work presents recent results in the representation of digital ink and handwritten character recognition. We have been motivated by the problem of recognizing handwritten mathematical characters, where there are multiple similar characters using a small number of strokes and for which new techniques must be devised.

The usual representation of digital ink is as a stream of (x, y) points sampled along the ink trace curves, possibly with additional coordinates for pressure, pen angles and so on. To represent these ink traces more compactly they are often "resampled" to reduce the number of points. Recognition is typically performed using hidden Markov model or support vector machine techniques, based on features extracted from the coordinate curves. These methods require that the entire curve trace be written before recognition commences. This means that recognition on a pen-enabled device, such as a Tablet PC or PDA, typically proceeds in alternating phases of having the processor mostly idle while collecting input and having the user wait while characters are being recognized.

We take a different point of view and ask to what degree it is possbile to do useful computation as the digital ink is being written. The initial application is to the problem of mathematical handwriting recognition, where characters are typically written individually and segmentation is not an issue. Our approach is also applicable to other real-time problems such as recognition of other printed handwriting, recognition of entire cursively written words and other classification problems for curves.

Earlier work [1] has shown how coordinate curves $X(t)$, $Y(t)$ for handwritten characters can be modelled succinctly by truncated Chebyshev series and that the series coefficients can be used to classify characters and for recognition. Rather than describing a digital ink trace by a few hundred coordinate values, instead a visually indistinguishable curve can be modelled by twenty series coefficients. A secondary benefit of this representation is that the geometry of these curves can be analyzed by powerful analytic techniques rather than *ad hoc* numerical techniques.

The present work starts with a similar approach, but uses a different functional basis that allows computation as the curve data is received. The basic

idea is to integrate moments of the coordinate curves in real time as the stroke is written and then to construct the coefficients for a Legendre series representation of the size-normalized curves in constant time when the pen is lifted. We find that the Legendre series representation is just as suitable in practice for the representation and analysis of ink traces as the Chebyshev representation, but has the benefit that it can be computed in a small, fixed number of arithmetic operations at the end of a stroke. Additionally, the fixed number of arithmetic operations at each time step (to compute the moments) and on pen up (to normalize size and compute the series coefficients) makes this technique well suited to use on devices with limited computational capacity.

[1] B.W. Char and S. M. Watt. Representing and characterizing handwritten mathematical symbols through succinct functional approximation. In *Proc. International Conference on Document Analysis and Recognition (ICDAR)*, pp 1198–1202. IEEE Computer Society 2007.