Ink Preprocessing and Preparation

Lecture #5: Preparing Ink

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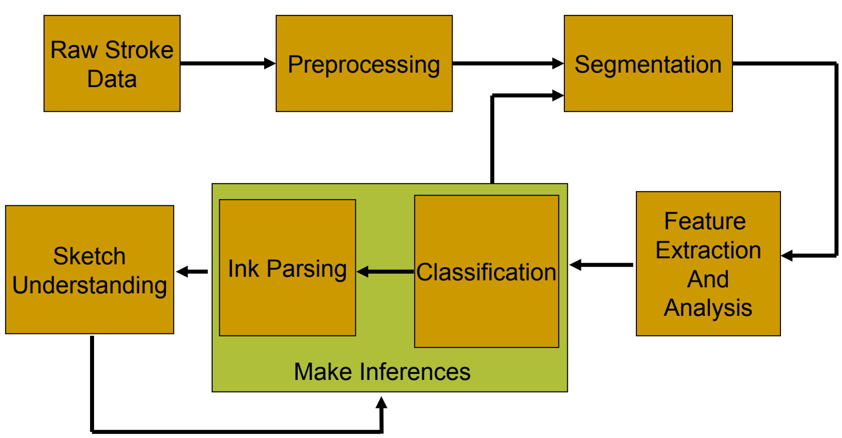
Recall Pen-Based Interface Dataflow



Representing Data

- Points and strokes

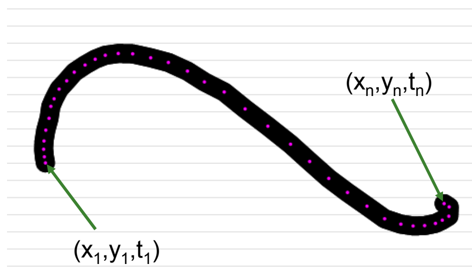
$$s = p_1 p_2 \ldots p_n$$

where

$$p_i = (x_i, y_i, t_i),\ 1 \le i \le n$$

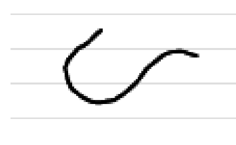
$$S = s_1 s_2 \ldots s_m$$

- Image
  - pixel matrix
  - not as popular

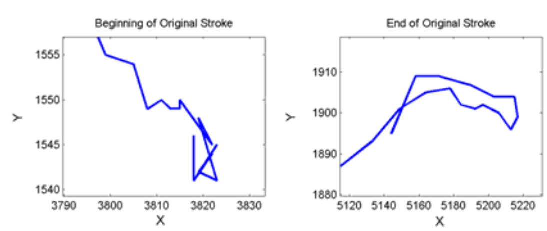


Preprocessing

- Often required to clean raw data
- Stroke Invariance
  - scale
  - position
  - orientation
  - slant/skew
  - order/direction
- Filtering and Smoothing
- Dehooking



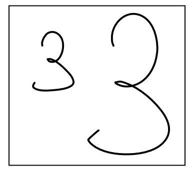
Normal view of stroke



Zoomed in view of stroke showing unwanted cusps and self-intersections

Scale Invariance

- Why? – want to ensure stroke has a canonical representation so its *size* makes no difference in recognition
- Approach
  - define constant width or height
  - scale stroke maintaining aspect ratio
  - choose constant width or height based on stroke

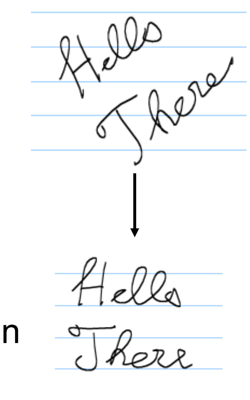


Translation Invariance

- Why? – want to ensure stroke has canonical representation so its *position* makes no difference in recognition
- Approach
  - translate stroke to origin
  - use stroke bounding box
  - possible translation points
    - top left point
    - center point

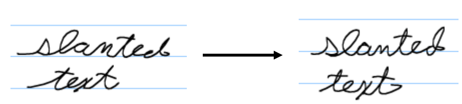
Rotation Invariance

- Primarily used when for handwriting (sometimes for shapes)
- Why? – want to remove baseline drift which could affect recognition
- Baseline drift – deviation between baseline and horizontal axis
- Difficult problem to deal with
  - ambiguous baseline locations
- One approach (Guerfali and Plamondon 1993)
  - uses center of mass of word regions
  - least squares for baseline construction



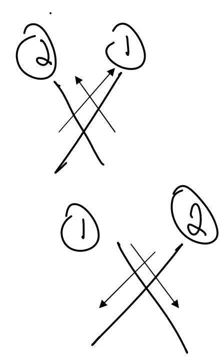
Slant/Skew Invariance

- Important in handwriting recognition
- Handwriting slant – deviation between the principal axis of strokes and vertical axis
  - Often referred to as *deskewing process*
- Why? – can be important for segmentation
- Difficult problem – very subjective
- One approach (Guerfali and Plamondon 1993)
  - zone extraction
  - observation windows
  - local and global slants



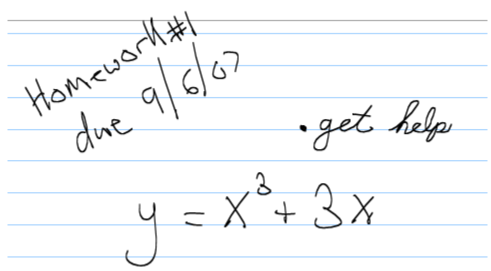
Stroke Direction and Ordering Invariance

- Can be large variation in ways a symbol is drawn
  - order of strokes
  - direction of strokes
- Possible approach is to model each possible combination
  - combinatorially expensive
  - could hurt recognition accuracy
- Want to assign canonical ordering and direction
  - see Matsakis (1999)



Stroke Invariance Summary

- Want to have canonical representation
- Makes calculating features easier
- Makes recognition easier



Resampling

- Why? – sometimes we want to have all strokes have the same number of points
  - helps deal with some recognition algorithms
- Approach
  - linear interpolation between points

Filtering and Smoothing

- Remove duplicate points
- Remove unwanted cusps and self-intersections
- Thinning – reduce points
- Dot reduction – reduce dots to single point
- Stroke connection- deal with extraneous pen lifts (e.g., stroke segmentation)

Gaussian Smoothing

$$p_i^{filt} = \sum_{j=-3\sigma}^{3\sigma} w_j \, p_{j+i}$$

$$w_j = \frac{e^{-\frac{j^2}{2\sigma^2}}}{\sum_{k=-3\sigma}^{3\sigma} e^{-\frac{k^2}{2\sigma^2}}}$$

σ is a scaling parameter

Should try to maintain cusps when filtering

A Filtering Algorithm

Input: Stroke s_i and a self-intersection threshold α.
Output: A filtered list of points
FilterStroke(s_i,α)

$P \leftarrow Points(s_i)$
$cur_{pt} \leftarrow P_1$
for $i = 2$ **to** n
    if $cur_{pt} = P_i$
        $BadPts \leftarrow P_i$
    else
        $cur_{pt} = P_i$
$RemovePointsFromPointList(BadPts, P)$
$SelfInts \leftarrow SelfIntersectionLocations(P)$
$prev \leftarrow -1$
for $i = 1$ **to** $\|P\|$
    if $prev \neq -1$ **and** $SelfInts_i - prev > \alpha$
        for $j = prev$ **to** $SelfInts_i$
            $BadPts \leftarrow P_j$
    $prev \leftarrow SelfInts_i$
$RemovePointsFromPointList(BadPts, P)$
return P

Dehooking

- Want to eliminate hooks that can occur at the end of strokes (sometimes at the beginning)
- Hooks come from
  - inaccuracies in pen-down detection
  - rapid and erratic stylus motion
- Hooks vary depending on user and on stroke

A Dehooking Algorithm

Input: Stroke s_i, minimum and maximum hook threshold $hook_{min}$ and $hook_{max}$, and a dehooking distance threshold ϵ_{hook}.

Output: A dehooked list of points

DeHook(s_i,$hook_{min}$,$hook_{max}$,ϵ_{hook})

$P \leftarrow Points(s_i)$
$maxdist \leftarrow 0$
for $i = 2$ **to** $\min(hook_{min}, P_n - hook_{max})$
    $dist \leftarrow \|P_i - P_1\|$
    if $dist > \epsilon_{hook}$
        break
    if $dist \geq maxdist$
        $maxdist = dist$
    else
        for $j = 1$ **to** i
            $BadPts \leftarrow P_j$
        break
    $maxdist \leftarrow 0$

Dehooking Algorithm Cont'd

```
for i = P_{n-1}  down to max(hook_max, P_n - hook_min)
    dist <- ||P_n - P_i||
    if dist > ε_hook
        break
    if dist >= maxdist
        maxdist = dist
    else
        for j = n  down to i
            BadPts <- P_j
        break
RemovePointsFromPointList(BadPts, P)
return P
```


Next Class – Discussion

- Assignment 1 – out
- Readings
  - Guerfali, Wacef and R´ejean Plamondon. Normalizing and Restoring On-Line Handwriting. Pattern Recognition, 26(3):419-431, March 1993.
  - Tevfik Metin Sezgin, Thomas Stahovich, and Randall Davis. Sketch Based Interfaces: Early Processing for Sketch Understanding**.** *Workshop on Perceptive User Interfaces*, Orlando FL . 2001.
  - Matsakis, Nicholas, Recognition of Mathematical Expressions, Master's thesis, MIT, page 21-28. 1999.