Ink Preprocessing and Preparation

Lecture #5: Preparing Ink
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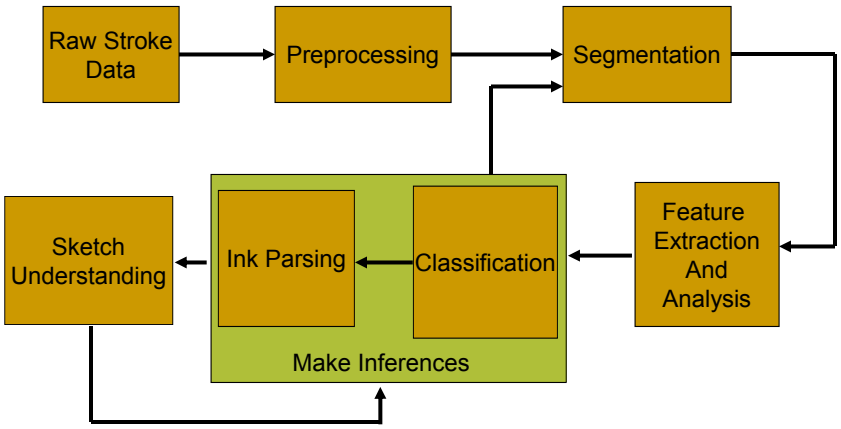
Recall Pen-Based Interface Dataflow



Representing Data

- Points and strokes

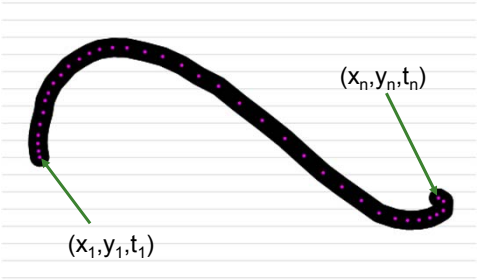
$$s = p_1 p_2 \ldots p_n$$

where

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

$$S = s_1 s_2 \ldots s_m$$

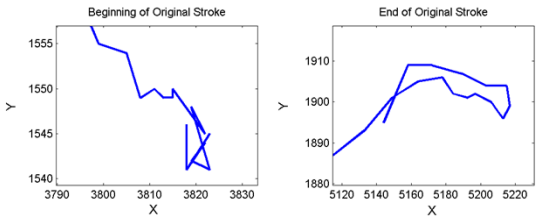
- Image
  - pixel matrix
  - not as popular



Preprocessing

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

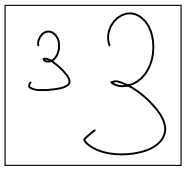
Normal view of stroke



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

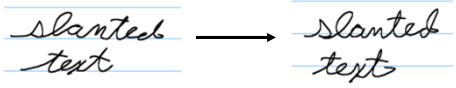
- Why? – want to ensure stroke has canonical representation so its *position* makes no difference in recognition
- Approach
  - translate stroke to origin
  - use stroke bounding box
  - possible translation points
    - top left point
    - center point

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

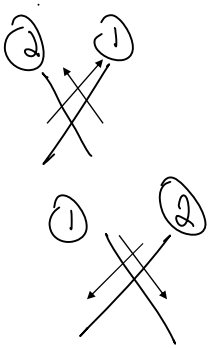
Slant/Skew Invariance

- 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



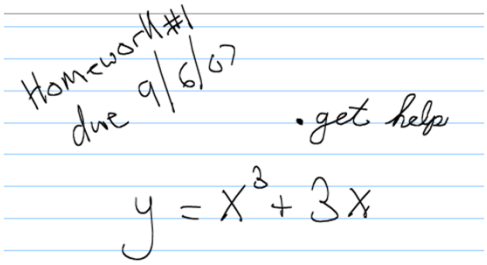
Stroke Direction and Ordering Invariance

- 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)
(1)   P ← Points(s_i)
(2)   cur_pt ← P_1
(3)   for i = 2 to n
(4)      if cur_pt = P_i
(5)         BadPts ← P_i
(6)      else
(7)         cur_pt = P_i
(8)   RemovePointsFromPointList(BadPts, P)
(9)   SelfInts ← SelfIntersectionLocations(P)
(10)  prev ← −1
(11)  for i = 1 to ||P||
(12)     if prev ≠ −1 and SelfInts_i − prev > α
(13)        for j = prev to SelfInts_i
(14)           BadPts ← P_j
(15)     prev ← SelfInts_i
(16)  RemovePointsFromPointList(BadPts, P)
(17)  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})

```
(1)   P ← Points(s_i)
(2)   maxdist ← 0
(3)   for i = 2 to min(hook_min, P_n − hook_max)
(4)     dist ← ||P_i − P_1||
(5)     if dist > ε_hook
(6)       break
(7)     if dist ≥ maxdist
(8)       maxdist = dist
(9)     else
(10)      for j = 1 to i
(11)        BadPts ← P_j
(12)      break
(13)    maxdist ← 0
```

Dehooking Algorithm Cont'd

```
(14)  for i = P_{n-1} down to max(hook_max, P_n − hook_min)
(15)    dist ← ‖P_n − P_i‖
(16)    if dist > ε_hook
(17)      break
(18)    if dist ≥ maxdist
(19)      maxdist = dist
(20)    else
(21)      for j = n down to i
(22)        BadPts ← P_j
(23)      break
(24)  RemovePointsFromPointList(BadPts, P)
(25)  return P
```


Next Class – Discussion

- Assignment 1 – out
- Readings
  - Wolin, A., Eoff, B., and Hammond, T. ShortStraw: A Simple and Effective Corner Finder for Polylines. Eurographics 5th Annual Workshop on Sketch-Based Interfaces and Modeling, Annecy, France, June, 2008, pp. 33-40.
  - Xiong, Y. and LaViola, J. "Revisiting ShortStraw – Improving Corner Finding in Sketch-Based Interfaces", Proceedings of the Sixth Eurographics/ACM Symposium on Sketch-Based Interfaces and Modeling 2009, 101-108, August 2009.
  - Herold, J. and Stahovich, T. SpeedSeg: A Technique for Segmenting Pen Strokes Using Pen Speed Computers and Graphics, Volume 35, Issue 2, 2011, pp. 250-264