Ink Segmentation

Lecture #7: Ink Segmentation
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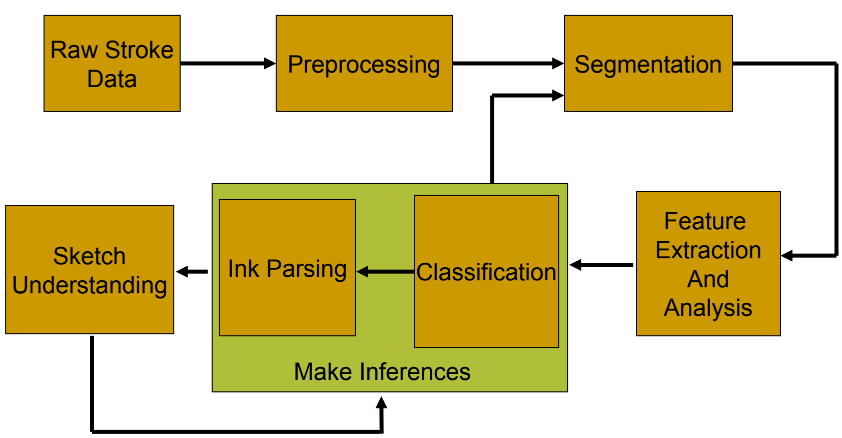
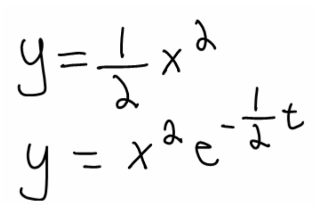
Recall Pen-Based Interface Dataflow



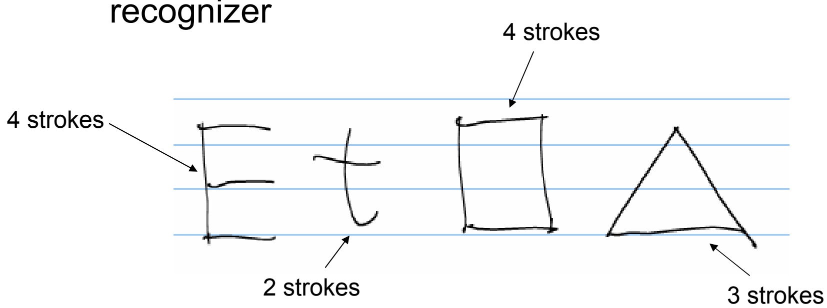
Segmentation

- Determine which strokes go together
- Determine which strokes should be apart
- Can be done in real-time or in batch
- Often uses proximity and timing information



Grouping Strokes Together

- Why? – Multiple strokes can form one symbol
  - math symbols, shapes, etc…
  - want to pass all strokes that make up a symbol to recognizer

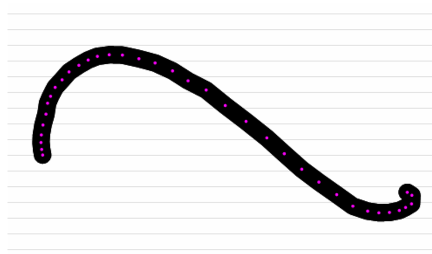


Grouping Strokes Together – Basic Approach

- Check to see if two or more strokes intersect
  - if they do then group them together
- Can use simple line segment intersection tests
- Problems
  - ink strokes – ink ≠ polyline
  - what if two strokes do not intersect but should be grouped together?
  - what if two strokes intersect but should not be grouped together?

Ink Strokes and Polylines

- Polylines are internal representation
- Ink has width
  - need requires more robust intersection
- One approach
  - find silhouettes
  - do intersection testing on them



Robust Stroke Intersection (Part 1)

Input: Stroke s_i, a set of candidate strokes $CS = \{s_1, s_2, \ldots, s_n\}$.
Output: True or false
RobustIntersection(s_i,CS)

(1) $P \leftarrow Points(s_i)$
(2) $cs_1 \leftarrow Circle(P_1, \frac{PenInkWidth()}{2})$
(3) $cs_2 \leftarrow Circle(P_n, \frac{PenInkWidth()}{2})$
(4) $sil_1 \leftarrow Polygon(ComputeStrokeEdges(s_i))$
(5) **foreach** Stroke $stk \in CS$
(6) $\quad Q \leftarrow Points(stk)$
(7) $\quad cstk_1 \leftarrow Circle(Q_1, \frac{PenInkWidth()}{2})$
(8) $\quad cstk_2 \leftarrow Circle(Q_n, \frac{PenInkWidth()}{2})$
(9) $\quad sil_2 \leftarrow Polygon(ComputeStrokeEdges(stk))$
(10) $\quad$ **if** $cs_1 \cap cstk_1$ **or** $cs_1 \cap cstk_2$ **or** $cs_1 \cap sil_2$ **or** $cs_2 \cap cstk_1$ **or** $cs_2 \cap cstk_2$ **or** $cs_2 \cap sil_2$ **or** $sil_1 \cap cstk_1$ **or** $sil_1 \cap cstk_2$ **or** $sil_1 \cap sil_2$
(11) $\quad\quad$ **return** true
(12) **return** false

Robust Stroke Intersection (Part 2)

Input: Stroke s_i
Output: A list of silhouette points
ComputeStrokeEdges(s_i.)

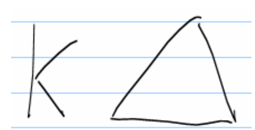
(1) $P \leftarrow Points(s_i)$
(2) $pen_w \leftarrow \frac{PenInkWidth()}{2}$
(3) **if** $n < 3$
(4) $\quad$ **return** P
(5) **for** $i = 1$ **to** $n - 1$
(6) $\quad \vec{v_1} \leftarrow Vector(Y(P_{i+1}) - Y(P_i), -(X(P_{i+1}) - X(P_i)))$
(7) $\quad \vec{v_2} \leftarrow Vector(-(Y(P_{i+1}) - Y(P_i)), X(P_{i+1}) - X(P_i))$
(8) $\quad Ppts1_i \leftarrow P_i + pen_w \frac{\vec{v_1}}{\|\vec{v_1}\|}$
(9) $\quad Ppts2_i \leftarrow P_i + pen_w \frac{\vec{v_2}}{\|\vec{v_2}\|}$
(10) $\quad$ **if** $i = n - 1$
(11) $\quad\quad Ppts1_i \leftarrow P_{i+1} + pen_w \frac{\vec{v_1}}{\|\vec{v_1}\|}$
(12) $\quad\quad Ppts2_i \leftarrow P_{i+1} + pen_w \frac{\vec{v_2}}{\|\vec{v_2}\|}$

Robust Intersection (Part 2) –cont'd

```
for i = 1 to n − 1
    if i = 1
        Silpts1_i = Ppts1_i
        Silpts2_i = Ppts2_i
        continue
    if i = n − 1
        Silpts1_{i+1} = Ppts1_{i+1}
        Silpts2_{i+1} = Ppts2_{i+1}
        continue
    v3 ← Vector(X(Ppts1_{i−1})−X(Ppts1_i), Y(Ppts1_{i−1})−Y(Ppts1_i))
    v4 ← Vector(X(Ppts1_i)−X(Ppts1_{i+1}), Y(Ppts1_i)−Y(Ppts1_{i+1}))
    intpt ← LineIntersection(Ppts1_i, v3/||v3||, Ppts1_{i+1}, v4/||v4||)
    if intpt = ∅
        Silpts1_i = Ppts1_i
    else
        Silpts1_i = intpt
    v5 ← Vector(X(Ppts2_{i−1})−X(Ppts2_i), Y(Ppts2_{i−1})−Y(Ppts2_i))
    v6 ← Vector(X(Ppts2_i)−X(Ppts2_{i+1}), Y(Ppts2_i)−Y(Ppts2_{i+1}))
    intpt ← LineIntersection(Ppts2_i, v5/||v5||, Ppts2_{i+1} v6/||v6||, )
    if intpt = ∅
        Silpts2_i = Ppts2_i
    else
        Silpts2_i = intpt
return CreatePointList(Silpts1, Silpts2, Silpts1_0)
```


Grouping Strokes Together – Extending Basic Approach

- What if two or more strokes should be grouped together but do not intersect?
- Need other information
  - timing info
  - spatial info



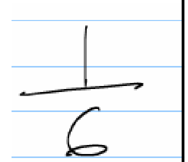
- If two strokes are close together and they have been drawn consecutively then there is a good chance they should be grouped together
  - still has problems

Grouping Strokes Together – Using Recognition

- To help with segmentation – use recognizer (Smithies et. al 1999)
- For each stroke
  - take last k strokes and send to recognizer
  - look for symbol recognitions with highest confidence level
  - group based on highest confidence level
- When all else fails
  - use domain knowledge
  - easy to use UI correction techniques

Inadvertent Stroke Grouping

- What if strokes are intersecting but should not be grouped together?
- Must look at context
  - would such a symbol make sense in its surroundings?
  - example – perpendicular symbol over 6 does not make sense (so ungroup to make 1 and division line)
- UI correction also important (tools for breaking strokes apart)

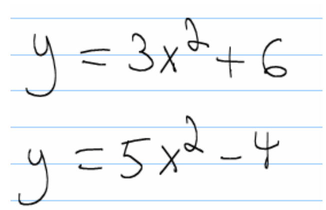


Breaking Strokes Apart

- Why? – Want to break symbols (groups of strokes) into logical blocks
  - Examples include mathematical expressions on a page, multiple diagrams or drawings
- Starts moving into sketch understanding and sketch parsing
- As with grouping, using recognition engine can help
- Domain knowledge also important

Breaking Strokes Apart – Basic Approach

- Lines of math
- Do a horizontal line sweep, if white space is found, break up strokes into expressions
  - a threshold could be used just in case of a few pixels found in sweep
- Another approach
  - Look at histogram of points
    - rotate ink 90 degrees
    - project onto x-axis
    - find minima



Strategy Summary

- Can go a long way with speed data, proximity info, and intersection testing
  - does not work every time
- Use recognizer to help find segmentations that make sense
- Make use of domain knowledge
- Have easy to use UI techniques for corrections
- More on this when we get to sketch understanding

Readings

- Gennari, L., L. Kara, and T. Stahovich. Combining geometry and domain knowledge to interpret hand drawn diagrams, Computers and Graphics, 29(4):547-562, 2005.
- Smithies, Steve, Kevin Novins, and James Arvo. A Handwriting-Based Equation Editor. In Proceedings of Graphics Interface'99, 84-91, 1999.
- Lehmberg, Stefan, Hans-Jurgen Winkler, and Manfred Lang. A Soft-Design Approach for Symbol Segmentation Within Handwritten Mathematical Expressions. In 1996 International Conference on Acoustics, Speech, and Signal Processing, 3434-3437, 1996.
- Pearce, Stephen, and Ahmed Maher. An Evolutionary Algorithm for General Symbol Segmentation, Seventh International Conference on Document Analysis and Recognition (ICDAR'03), 726-731, 2003.

