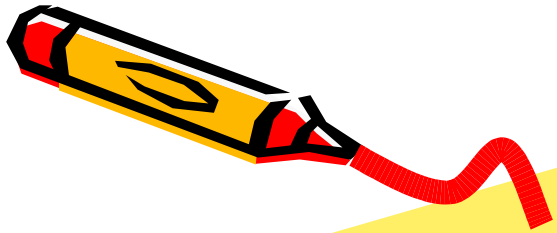

Ink Segmentation

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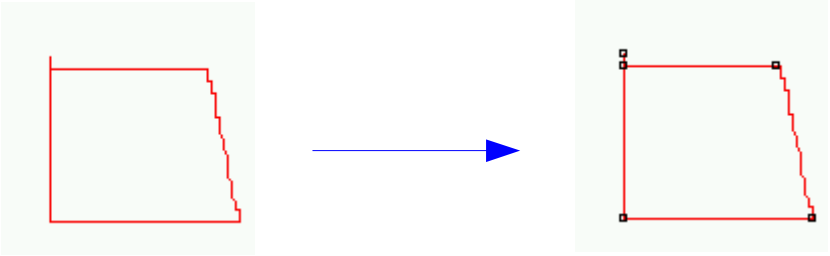
Apr 5, 2005

Outline

- Motivation
- Contribution
- Background
- How It Works
- Conclusion
- References

Motivation

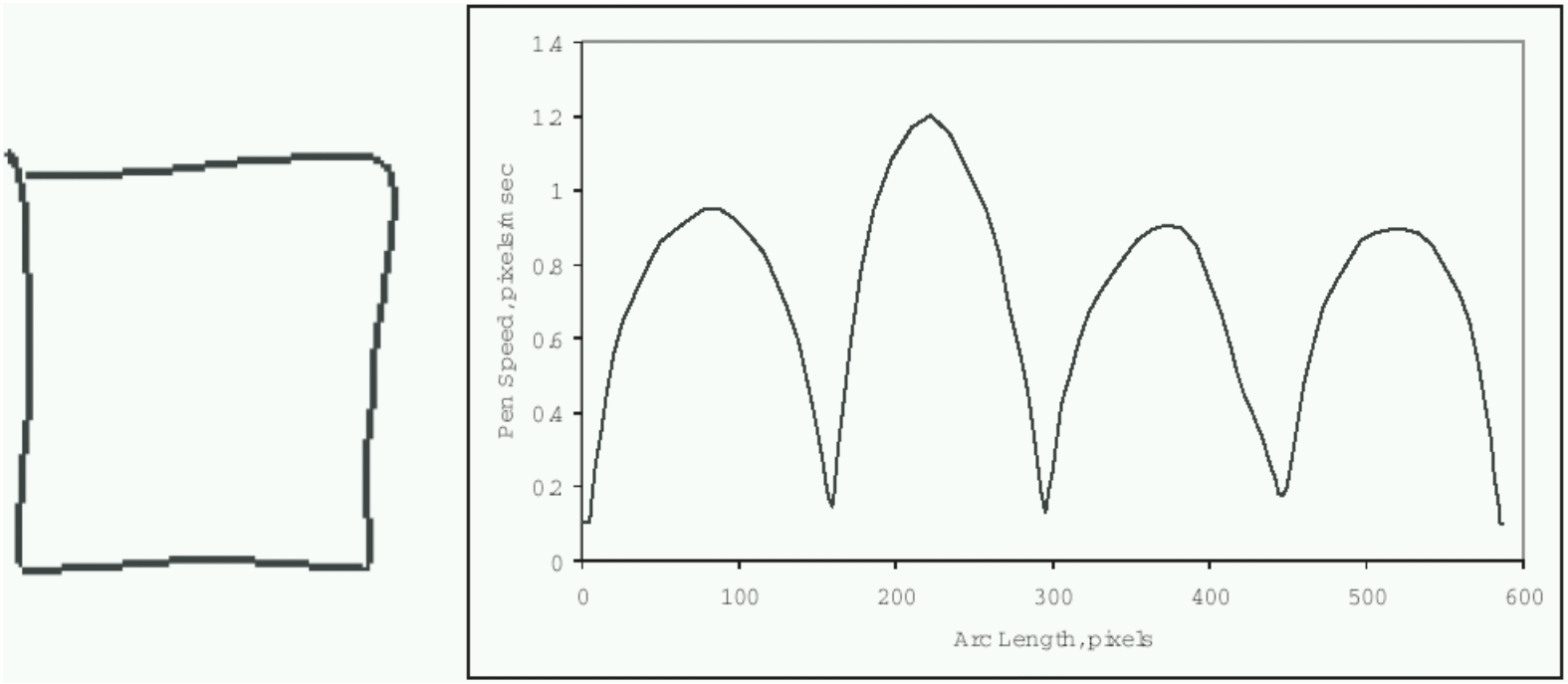
- Segment pen strokes automatically into the intended lines and arcs



  - The outcome will be the input of higher level sketch parser and symbol recognizer
- Determine which bumps and bends are intended, and which are accidents
- Match the drawer's intent not the ink

Motivation (cont)

- Consider the shape alone is not enough
- Slow the pen when making intentional discontinuities in a shape



Contribution

- Use pen speed and curvature to figure out the segments
- Accuracy between 92% to 96%

Background – Pen Speed

- Arc length of each coordinate point

$$d_i = \sum_{j=1}^{i} \left| \vec{P}_j - \vec{P}_{j-1} \right|$$

- Speed

$$s_i = \frac{d_{i+1} - d_{i-1}}{t_{i+1} - t_{i-1}}$$

- Smooth

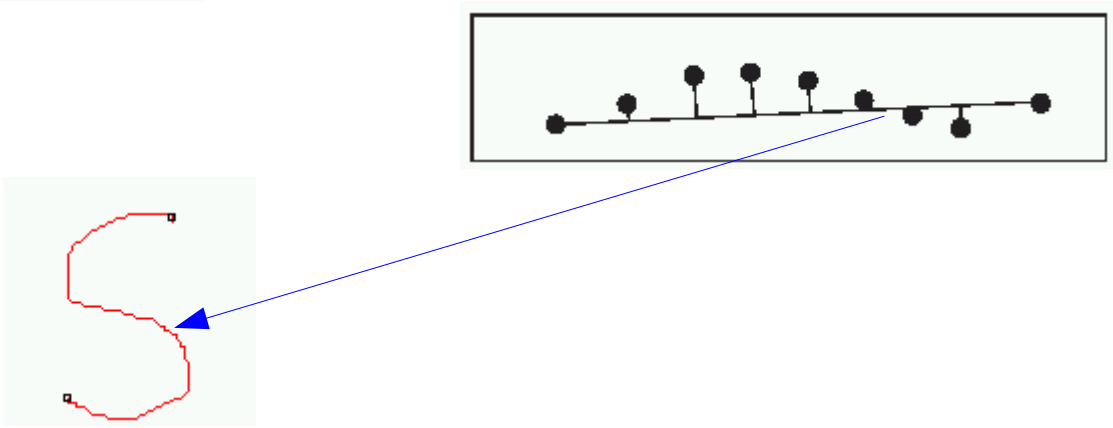
$S_i = (S_{i-1} + S_i + S_{i+1}) / 3$

http://www.cs.ucr.edu/~weesan/smart_tools/ink_segmentation.pdf

Background – Curvature

- Derivative of the tangent angle with respect to arc length

$$C = \frac{\partial \theta}{\partial s}$$



Background – Least Squares Line Fit

- y = Ax + B
- Regression equation

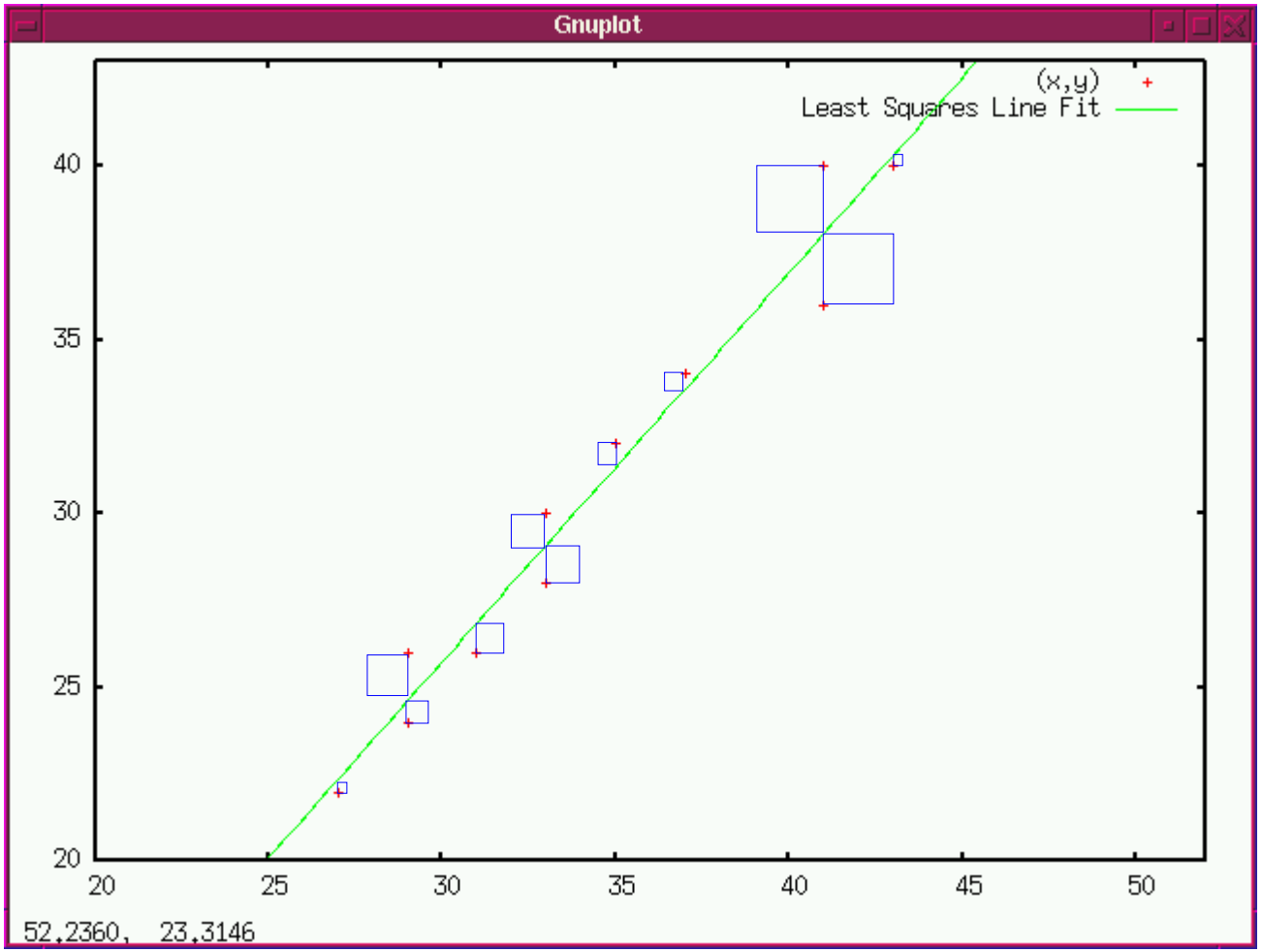
$$\begin{bmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{bmatrix} \begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \end{bmatrix}$$

- Total Square Error/Error of Fit

$$\sum_{i=1}^{n} (Ax_i + B - y_i)^2$$

http://www.cs.ucr.edu/~weesan/smart_tools/ink_segmentation.pdf

Background – Least Squares Line Fit (Cont)



Background – Least Squares Circle Fit

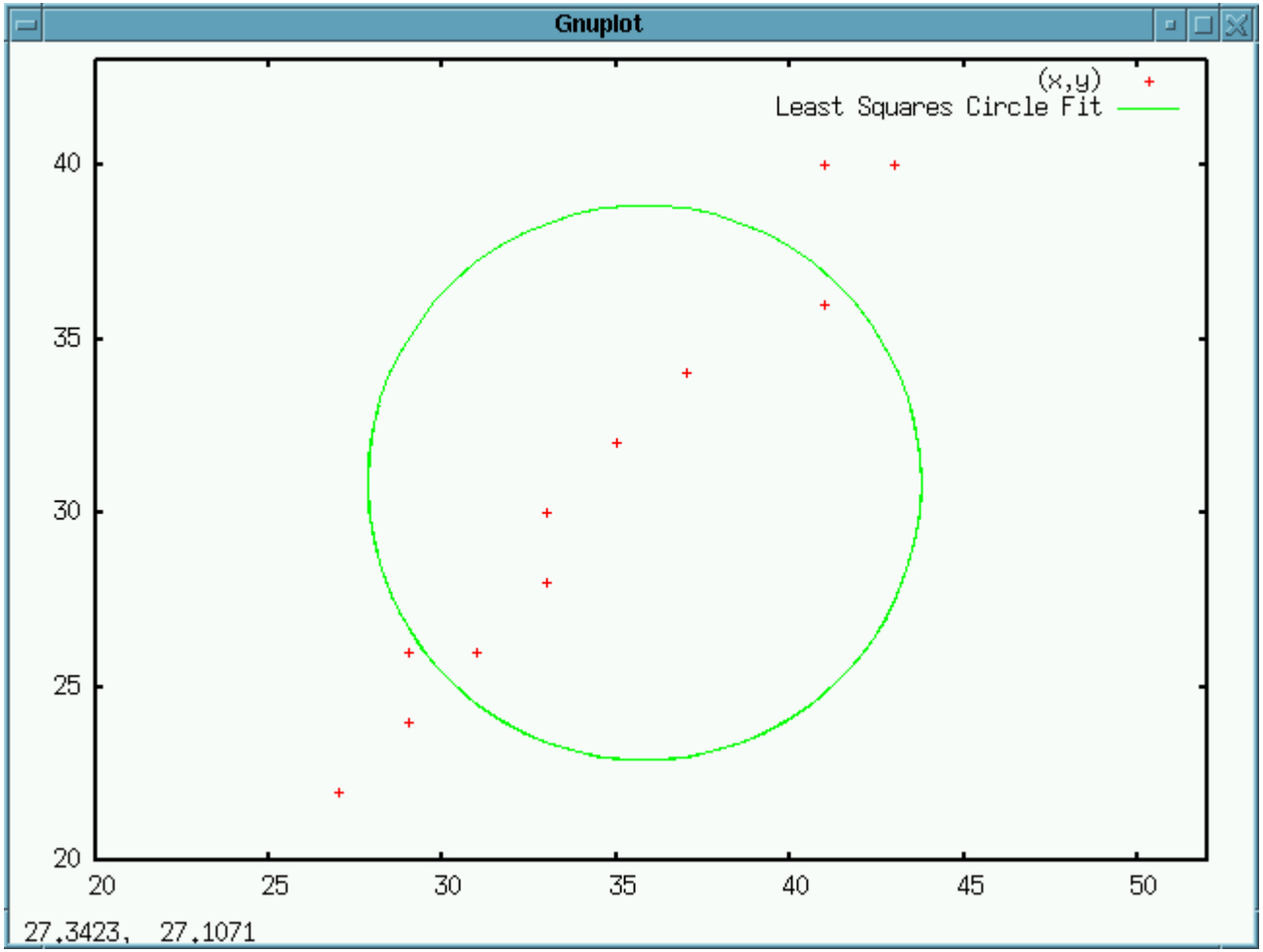
- $X^2 + y^2 + 2ax + 2by + c = 0$
- $r = \sqrt{a^2 + b^2 - c}$
- Regression equation

$$\begin{bmatrix} 2\sum x_i^2 & 2\sum x_i y_i & \sum x_i \\ 2\sum x_i y_i & 2\sum y_i^2 & \sum y_i \\ 2\sum x_i & 2\sum y_i & n \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} \sum -(x_i^2 + y_i^2)x_i \\ \sum -(x_i^2 + y_i^2)y_i \\ \sum -(x_i^2 + y_i^2) \end{bmatrix}$$

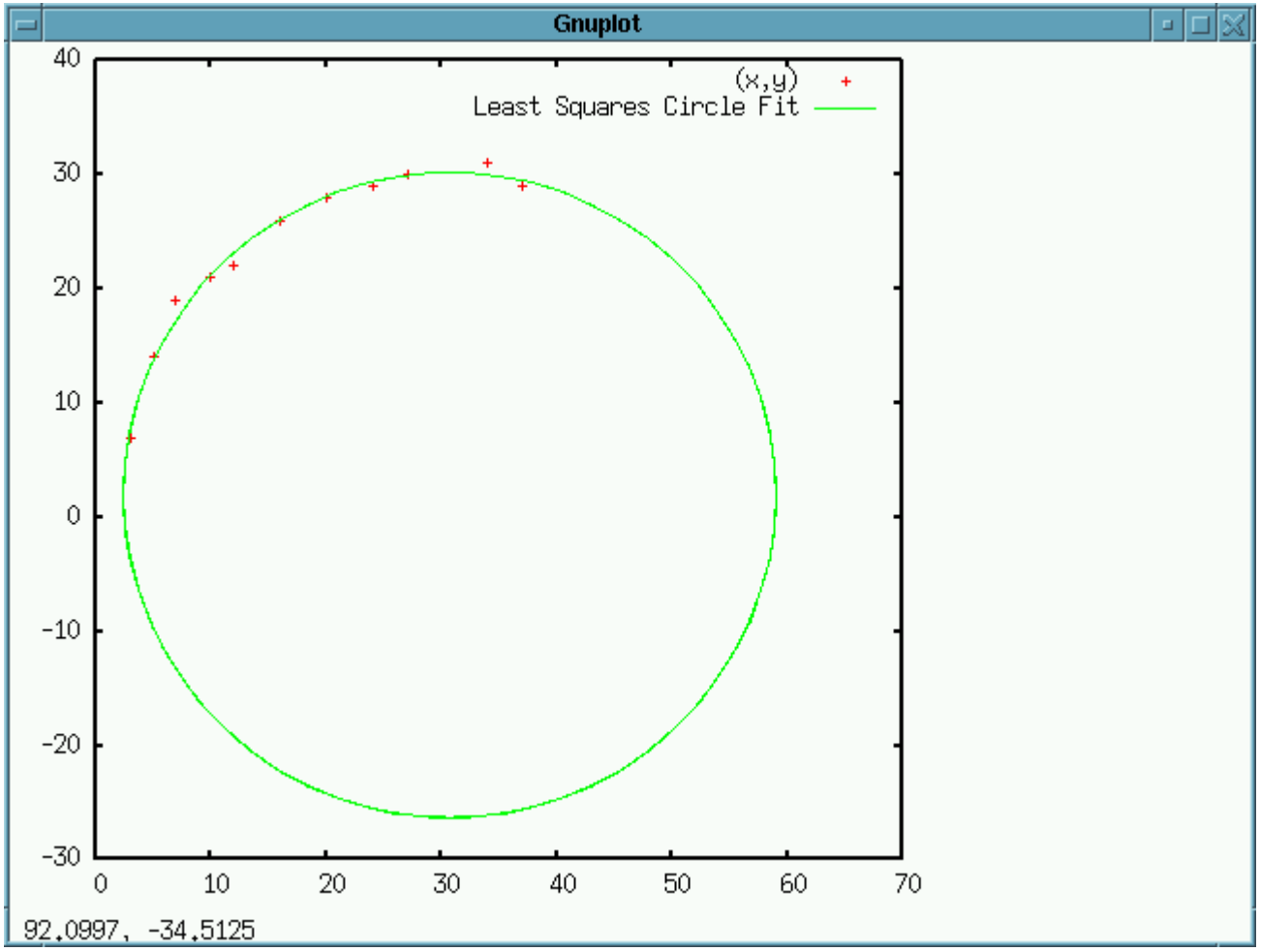
- Total Square Error/Error of Fit

$$\sum_{i=1}^{n} (x_i^2 + y_i^2 + 2ax_i + 2by_i + c)^2$$

Background – Least Squares Circle Fit (cont)



Background – Least Squares Circle Fit (cont)



How It Works

- Compute Pen Speed and Curvature
- Select candidate/initial segment points
  - Points that are both a minima of speed (< 25% of average speed) and maxima of curvature
  - Discard the point
    - If it is within 7 data points of a subsequent segment point
    - If the first segment contains < 15 data points
    - If the first or last segment is much shorter than its immediate neighbors

How It Works (cont)

- Fit primitives to the segments
  - Construct both line and circle fit for the segment between each pair of consecutive segment points
  - Pick one with the smallest Error of Fit
  - If the fit is an arc, it also has to be at least one tenth of a circle (36°)

How It Works (cont)

- Merge
  - If a segment is shorter than 20% of the length of its adjacent segment, or, if adjacent segments are of the same type, the program tries to merge them
  - If error of fit of new segment is < 10% of the sum of fit errors of the original 2 segments, new segment is used

How It Works (cont)

- Split
  - If neither line nor arc fits the ink, the program tries to split them by including a segment point based on a change in the sign of the curvature
    - All points of curvature sign changing in a segment are considered, the minimum that is < 65% of the original fit error will be retained
  - If there is no point whose curvature changing sign, it will try to include the points whose speed are less then 130% of the average speed

How It Works (cont)

- Summary
  - Determine initial set of segment points
  - Fit line/arc to the segments
  - Filter noise at the start and end segments
  - Merge segments
  - Split segments
  - Merge segments again

Conclusion

- Use pen speed to segment pen stroke into lines and arcs
- Work better with curvature
- Achieve accuracy of 92% - 96%

Reference

- Thomas F. Stahovich. Segmenting Hand Drawn Curves Using Pen Speed. 2005
- Thomas F. Stahovich. Segmentation of Pen Strokes Using Pen Speed. 2004
- Chris Calhoun, Thomas F. Stahovich, Tolga Kurtoglu, Levent Burak Kara. Recognizing Multi-Stroke Symbols