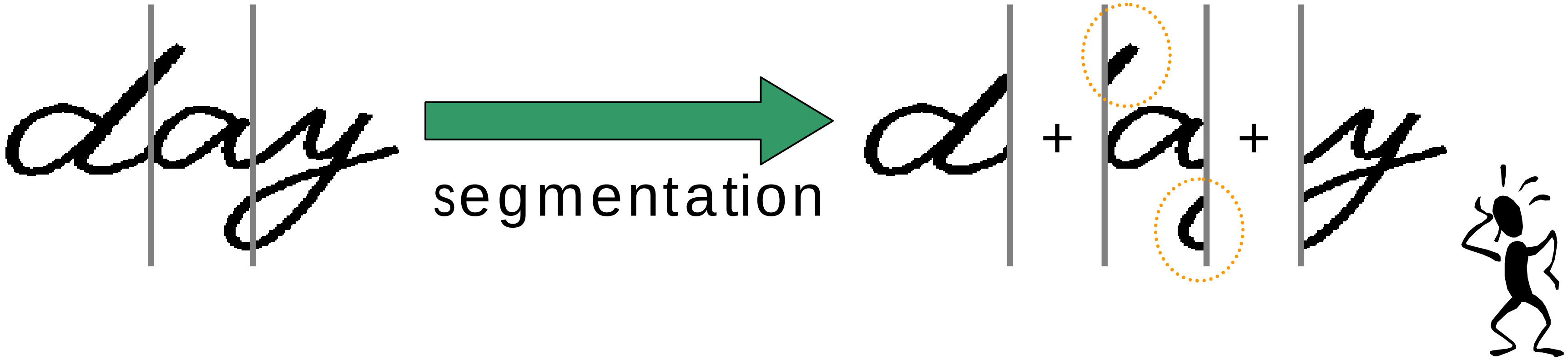
Non-uniform Slant Correction Using Dynamic Programming

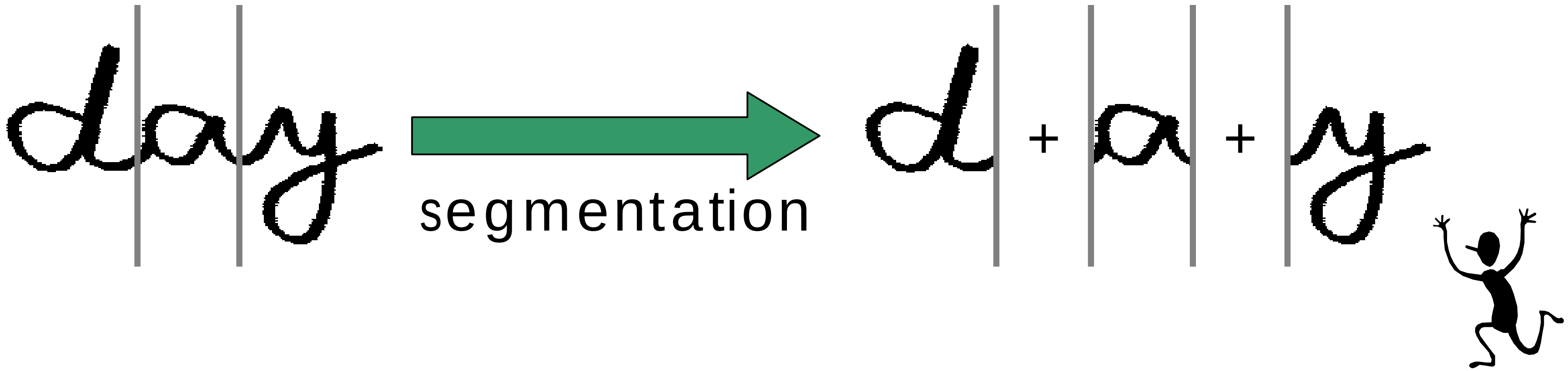
S. Uchida, E. Taira, and H. Sakoe
Kyushu University, Japan

Slant correction of handwritten word

Handwritten word

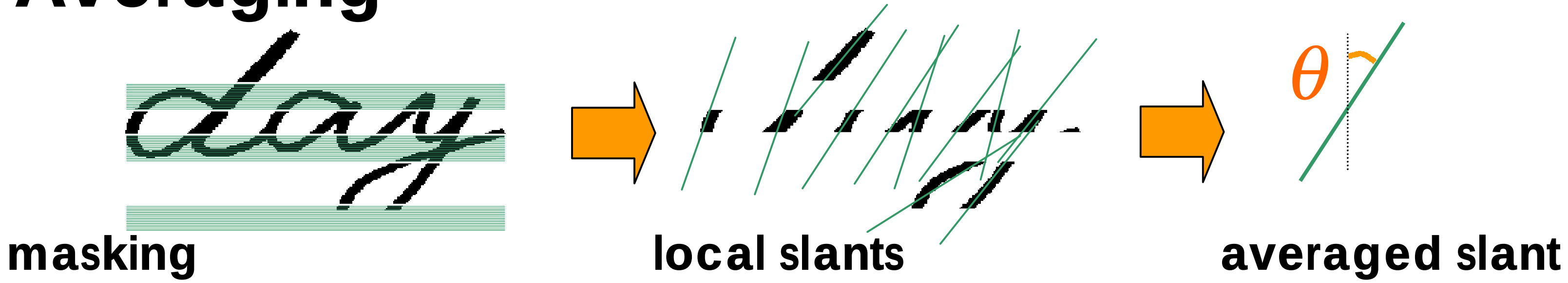


Slant-corrected word



Conventional techniques

■ Averaging



■ Projection histograms

■ Statistics of chain-coded stroke contours

$$\theta = \tan^{-1}\left(\frac{n_1 + n_2 + n_3}{n_1 - n_3}\right)$$

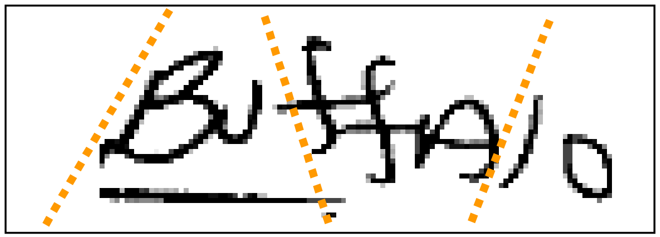
Conventional techniques : the problem

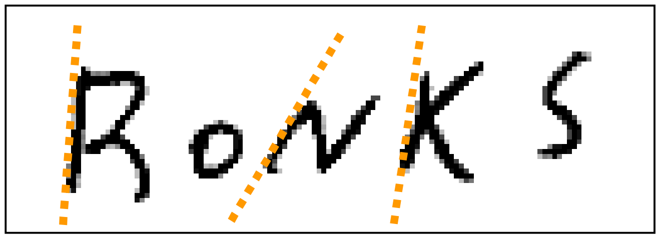
Assumption in all conventional techniques :

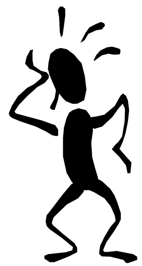
Slant is uniform in a word

But…. sometimes, slant is non-uniform

(with a probability of 5 to10%)

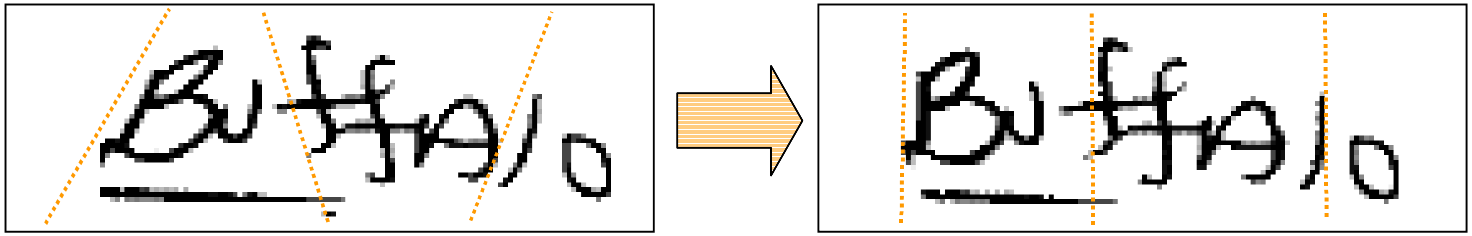


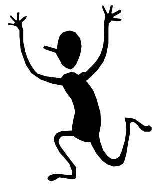




Overview of the present technique

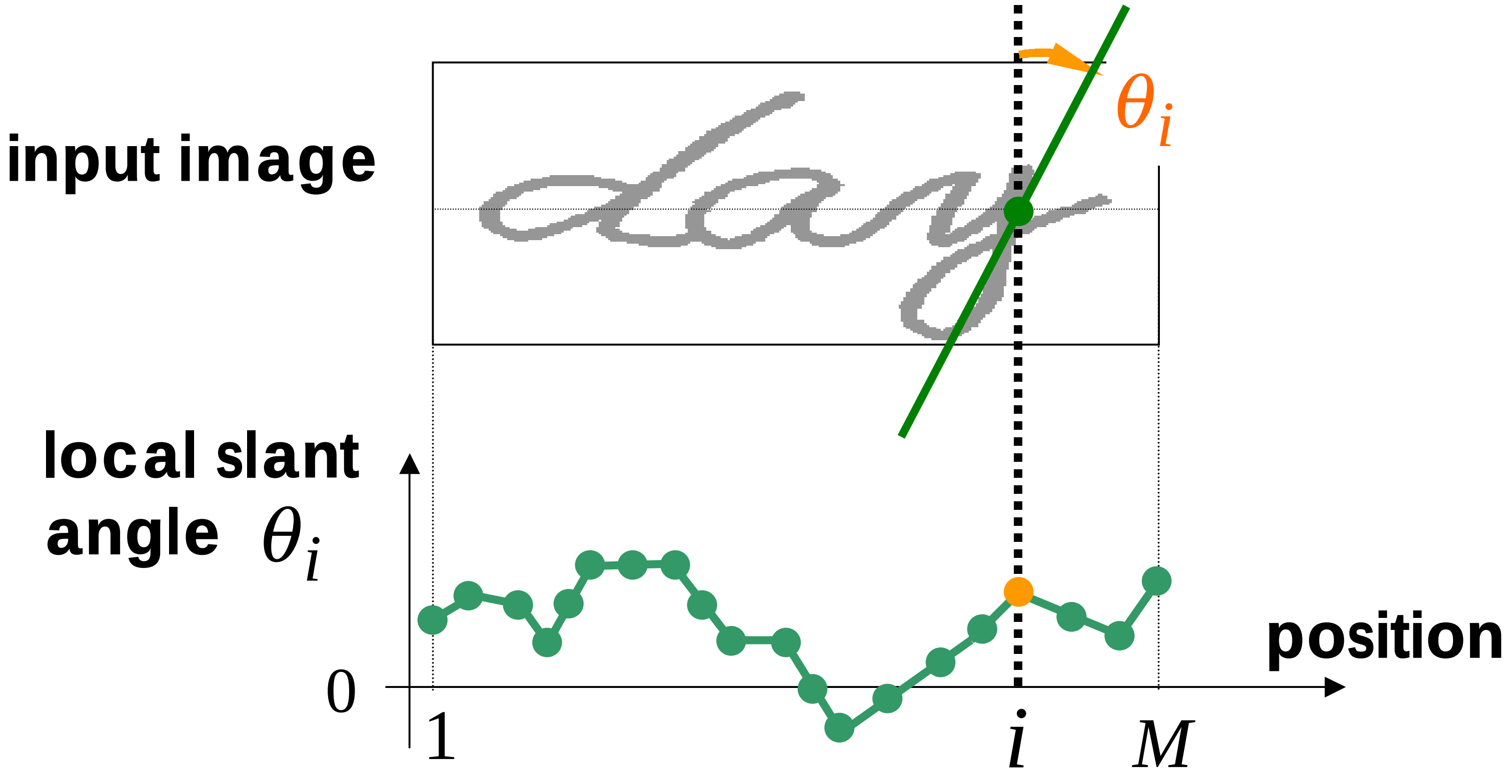
- Estimation and correction of **non-uniform slant** in an optimization framework





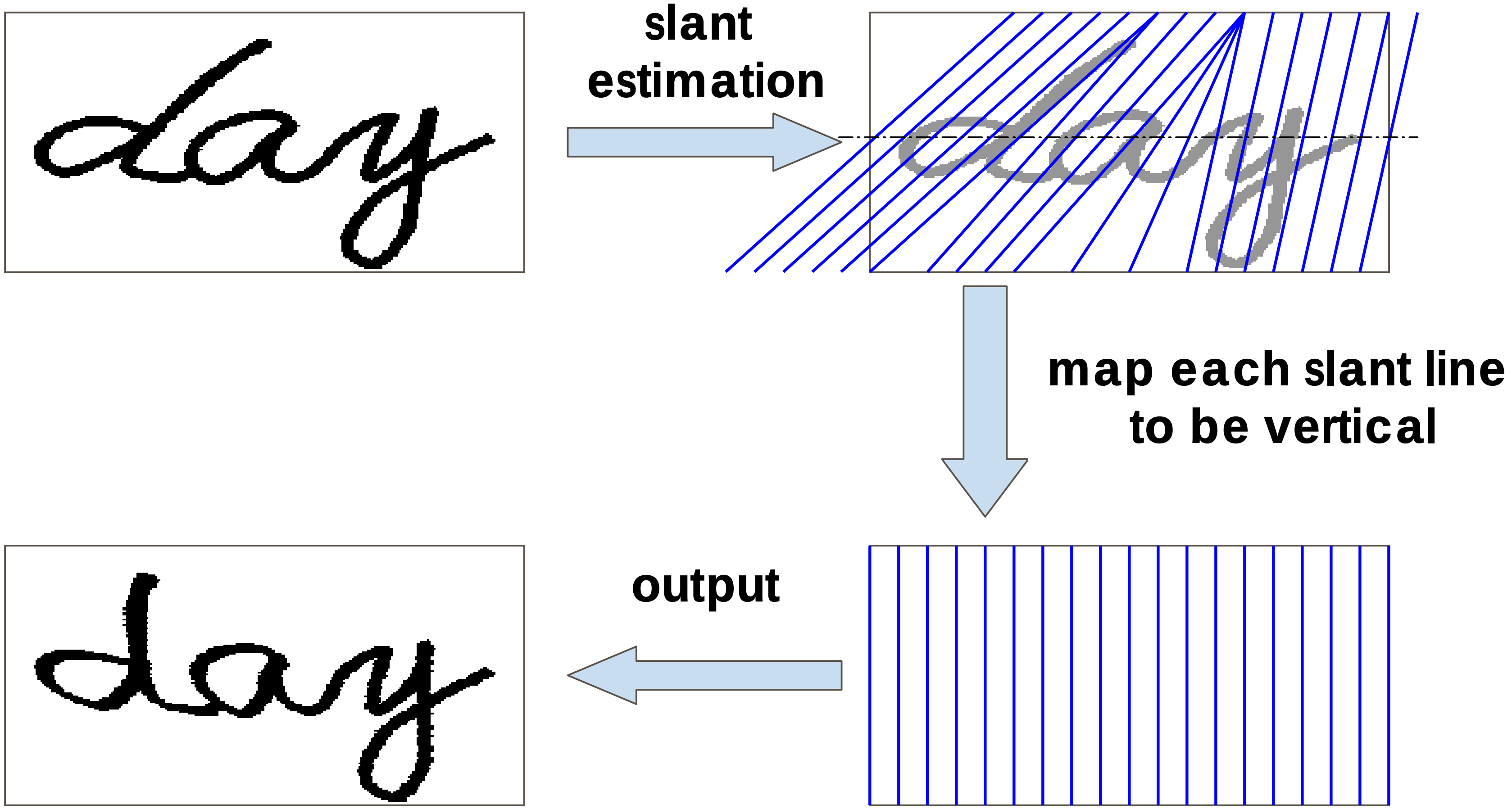
- Simple and fast algorithm based on **dynamic programming (DP)**

Non-uniform slant correction as an optimal estimation problem



non-uniform slant correction
= optimal estimation of $\theta_1, \ldots, \theta_i, \ldots \theta_M$

Create slant-corrected image using estimated slant



Directions on designing the criterion for the optimal estimation

Detect long vertical strokes

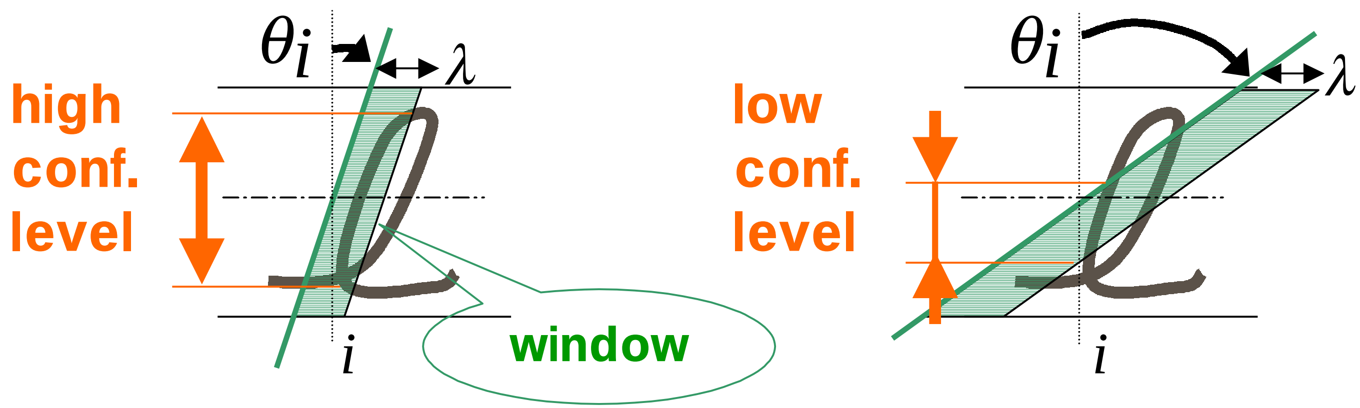
and

Propagate their slant angles
to their neighborhood smoothly

Our criterion

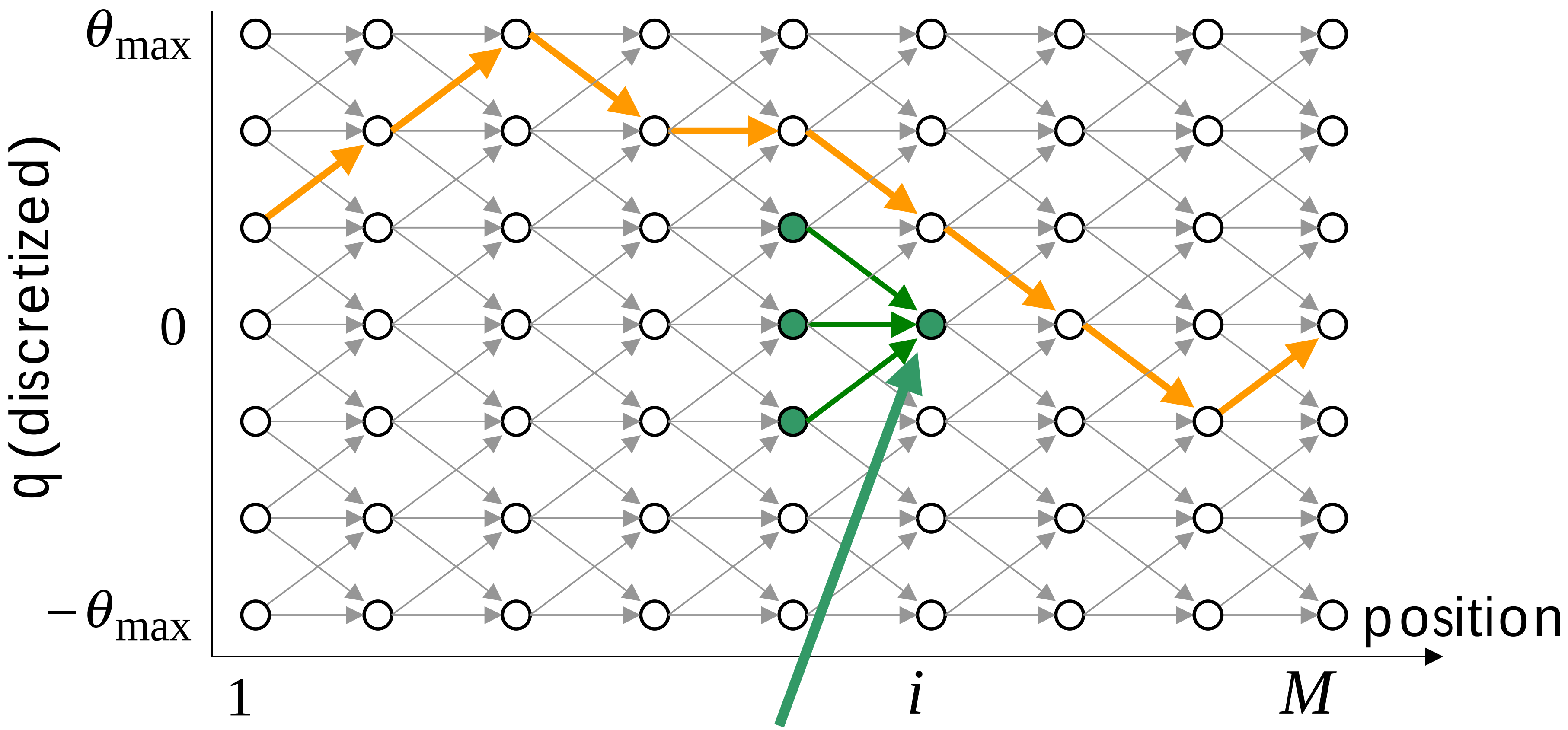
$$\text{maximize} \quad \sum_{i=1}^{M} \left[s_i(\theta_i) + \rho(\theta_i \mid \theta_{i-1}) \right]$$

- $s_i(\theta_i)$: **confidence level of θ_i at position i**



- $\rho(\theta_i \mid \theta_{i-1})$: **continuity between θ_i and θ_{i-1}**

Algorithm based on dynamic programming



DP recursion

$$g_i(\theta_i) = s_i(\theta_i) + \max_{\theta_{i-1}} \left[g_{i-1}(\theta_{i-1}) + \rho(\theta_i \mid \theta_{i-1}) \right]$$

Computational Complexity

- **Theoretical :**

  $O(MNW)$

  where M=**width**, N=**height**, **and** W=**max slant**

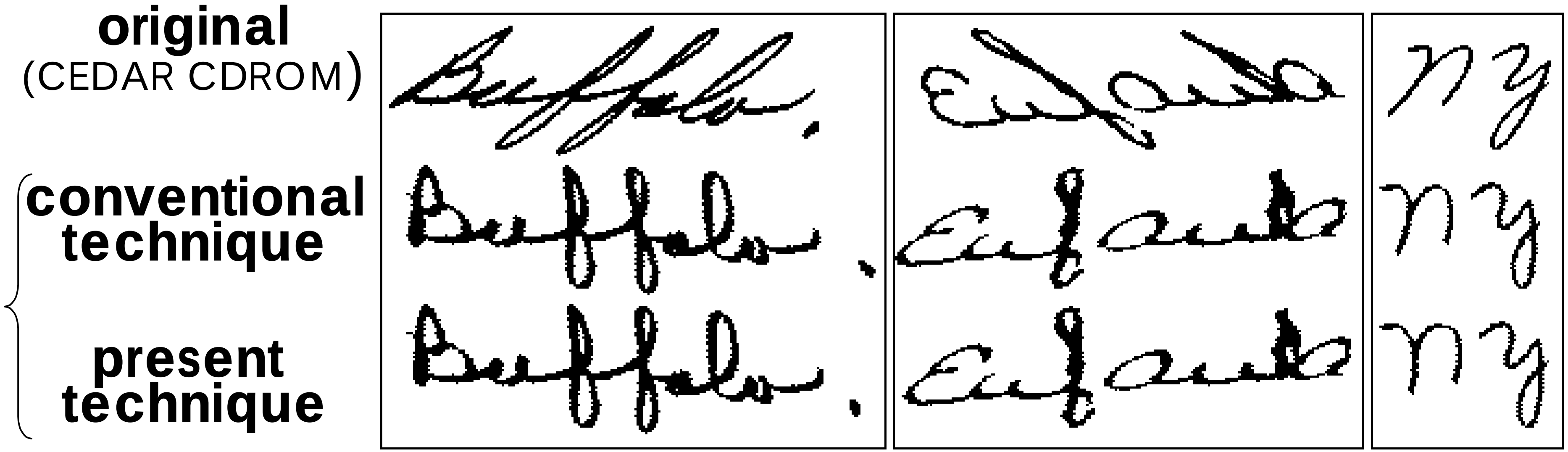
- **Practical :**

  140 ms (latest result)

  for M=256, N=64, **and** W=60(degrees)

  at PC with Pentium III, 500MHz

Results (1) :
Correction of uniform slant

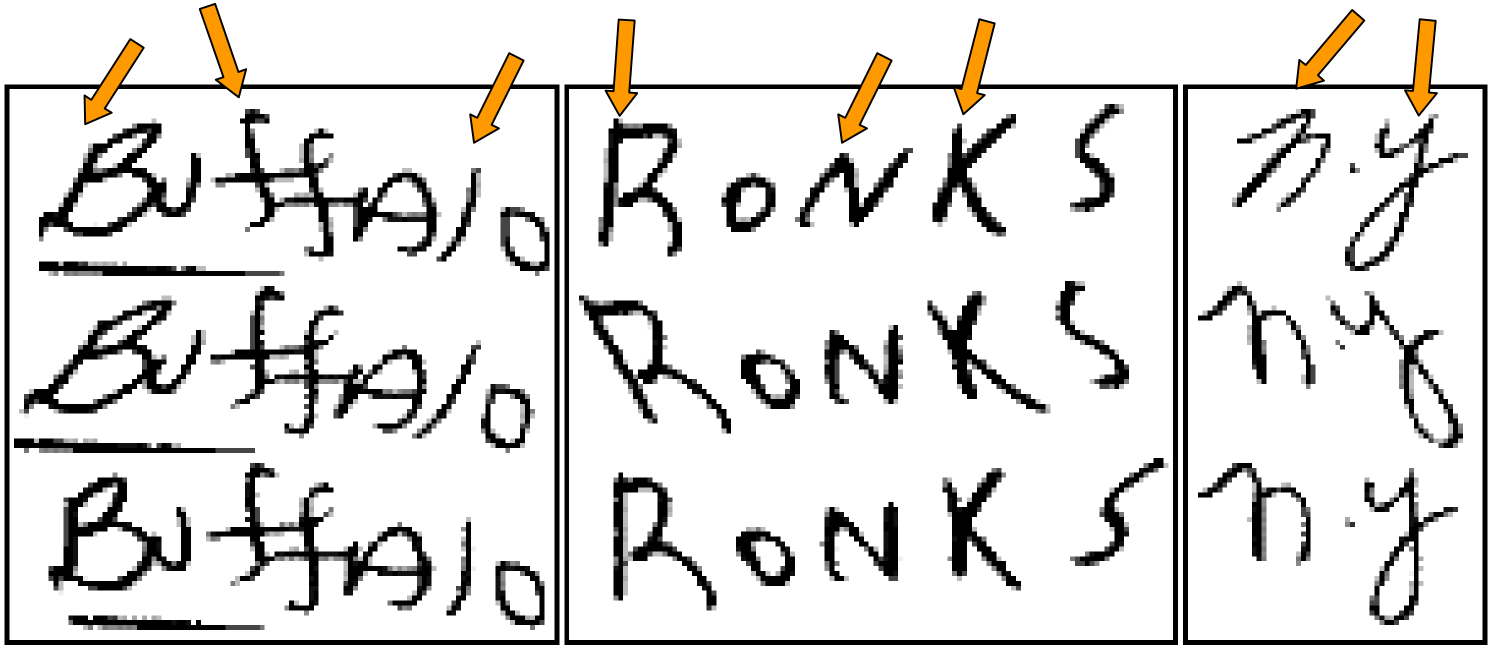


Results (2) : Correction of non-uniform slant

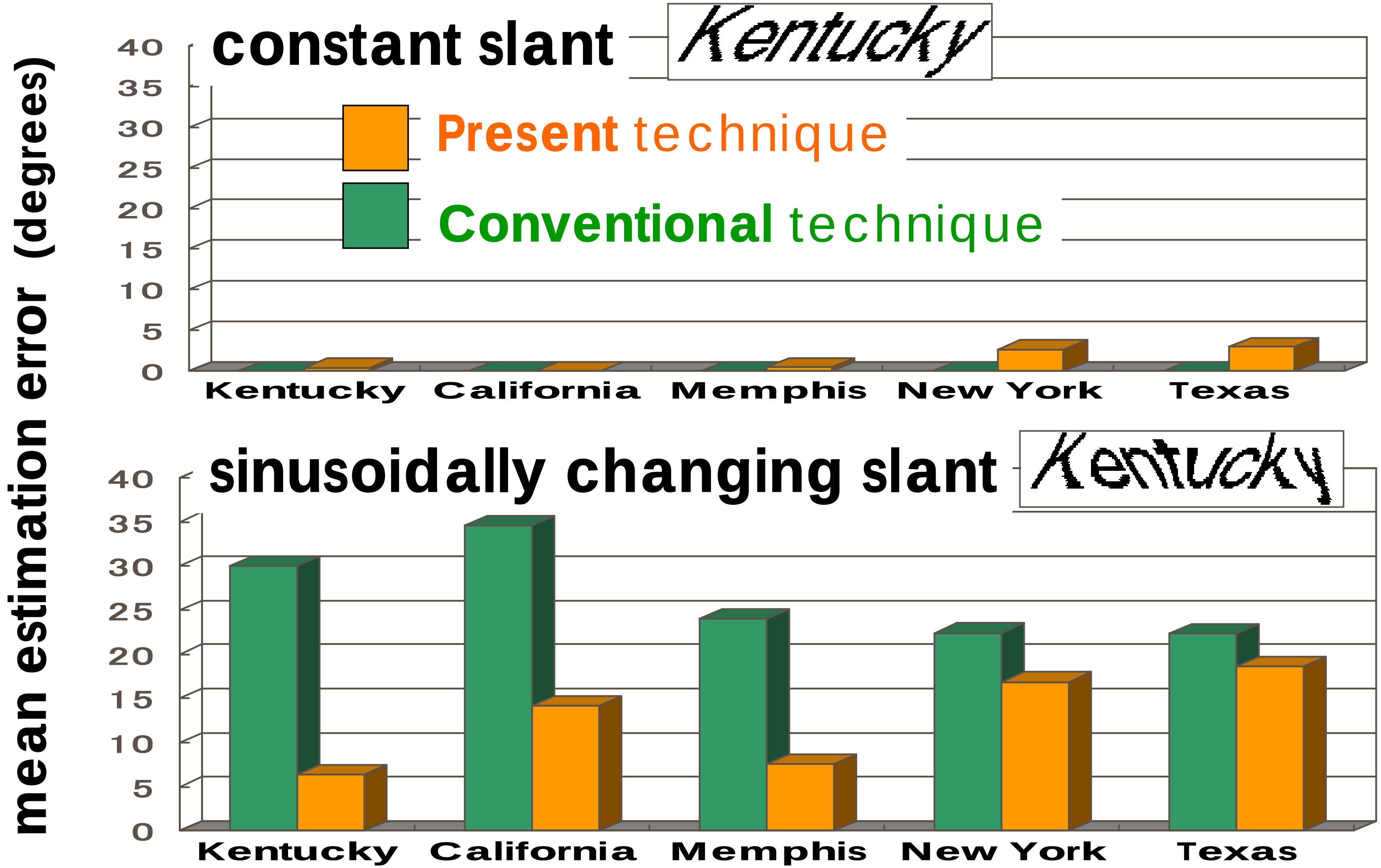
original
(CEDAR CDROM)

conventional technique

present technique



Quantitative evaluation

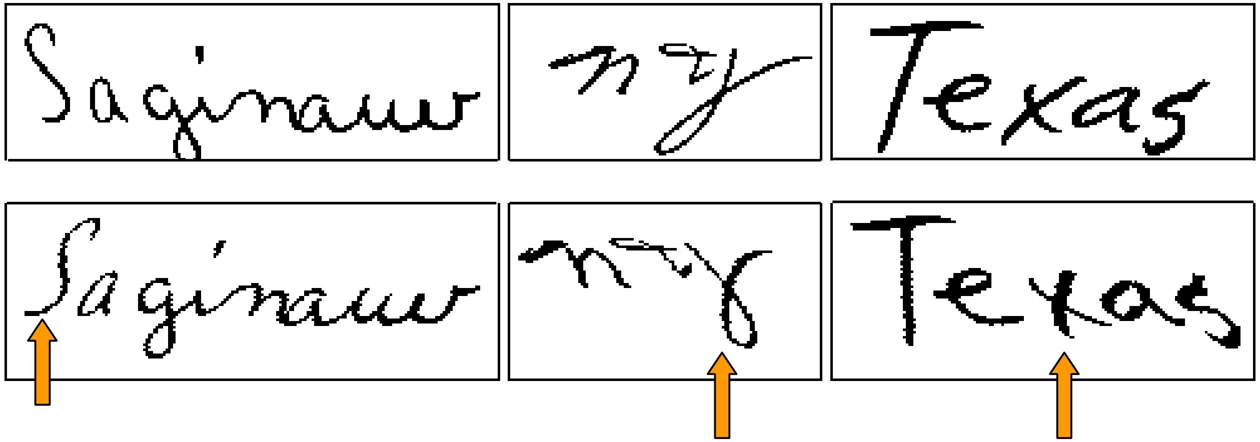


Future work : Suppression of over-correction

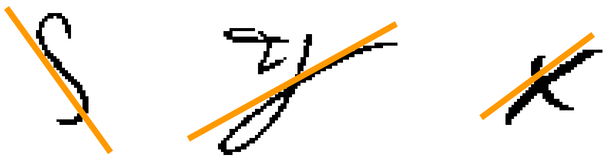
- **Examples**

original

present technique



- **Cause : originally slanted parts**



Conclusion

- Formulate the non-uniform slant correction problem as an optimization problem
- Provide a simple and fast algorithm based on dynamic programming
- Indicate superiority over conventional techniques through experiments

Future work

- Suppression of over-correction
- Evaluation of the present technique on segmentation performance
- Embedding slant correction into recognition process
  (slant-correction-and-segmentation by recognition)

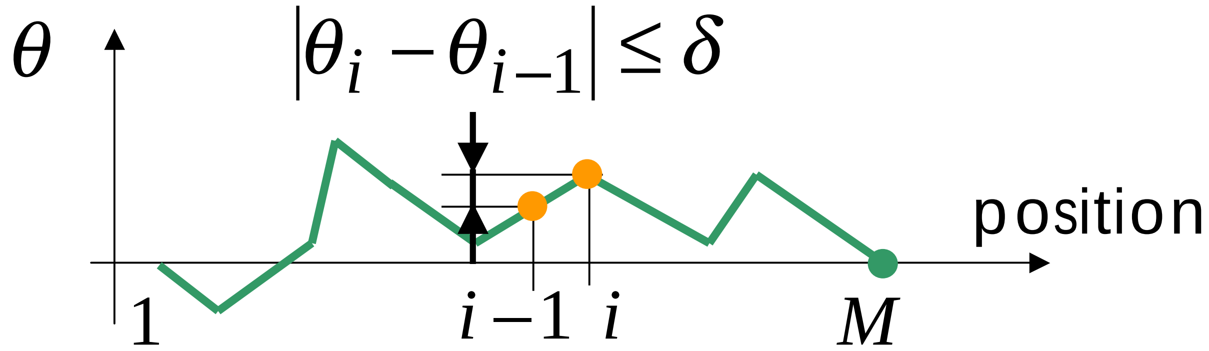
Possible remedies to suppress over-correction

- 1st steps
  - Suppression of the large difference from globally and/or locally averaged slant
  - Utilization of background region

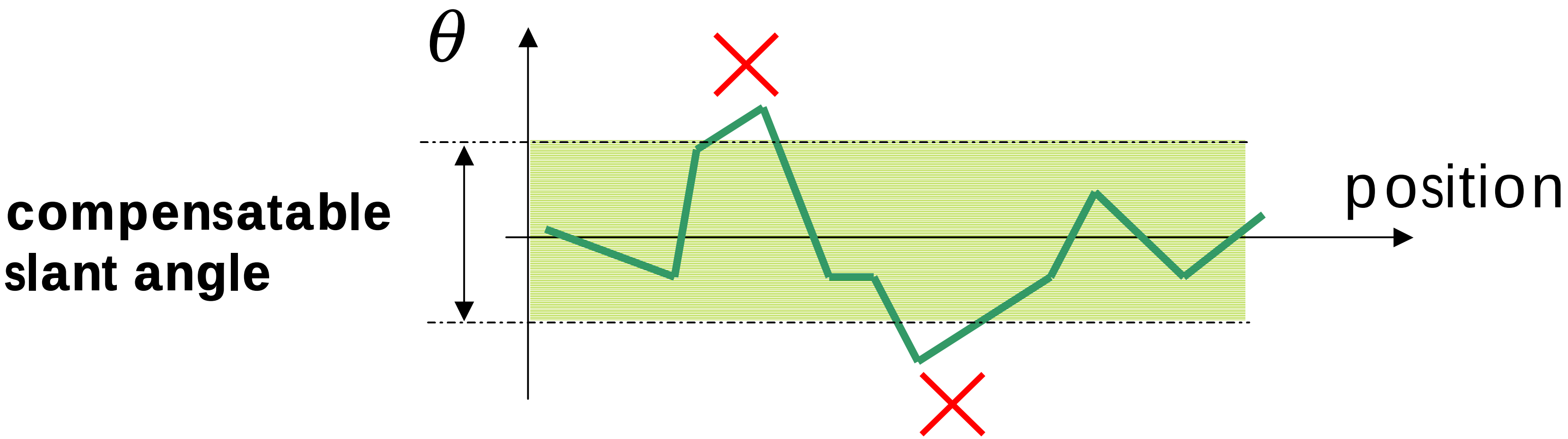
- … and a further step
  - Embedding slant correction into recognition process

Constraints

- **Continuity**



- **Range limitation**



Quantitative evaluation (1)

- **Evaluate accuracy by mean error between estimated and true slant angles**
- **5 city name words were subjected**
  (Kentucky, California, Memphis, New York, Texas)
- **Artificially slanted according to two rules**
  (i.e., true slant angle is known)

constant

sinusoidal

Quantitative evaluation (2)