

A Handwritten Character Recognition Method Based on Unconstrained Elastic Matching and Eigen-Deformations

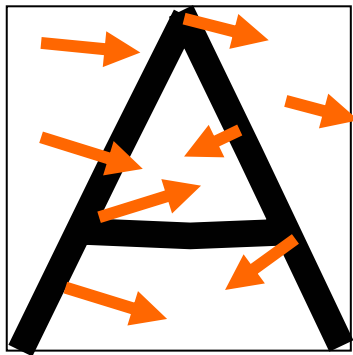
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Fukuoka, Japan

Elastic Matching (EM)

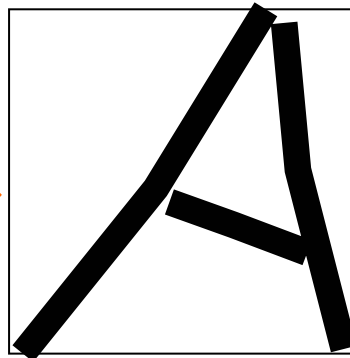
*displacement
field*



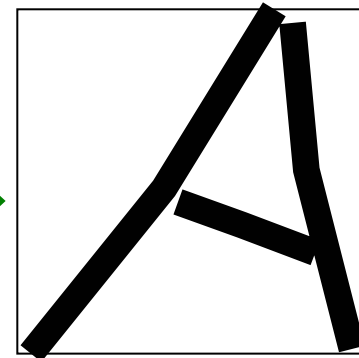
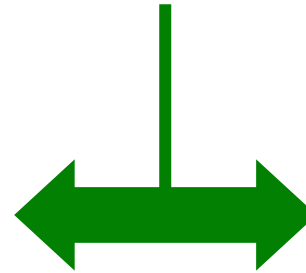
reference



*deformation-invariant
distance*



warped
reference



input

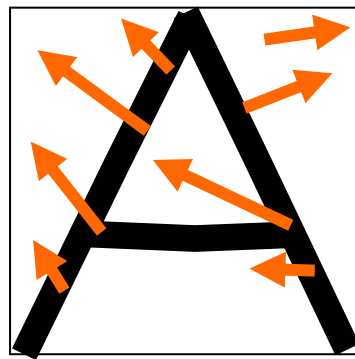
Unconstrained EM

- A classical EM method
- Based on **individual & local** optimization of the displacement at each pixel
- High speed & high flexibility !

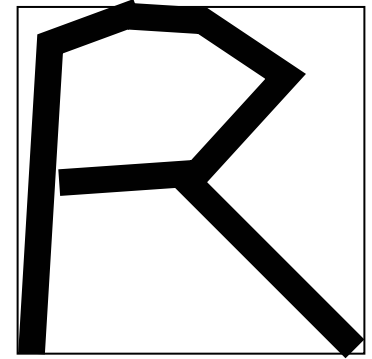
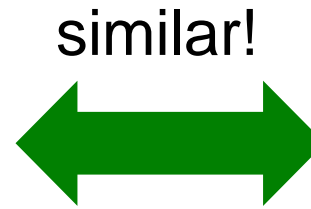
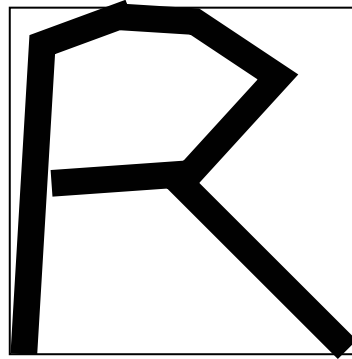
- ... but, rarely employed !
(slower and less flexible **constrained EMs** are often employed).



Overfitting by Unconstrained EM

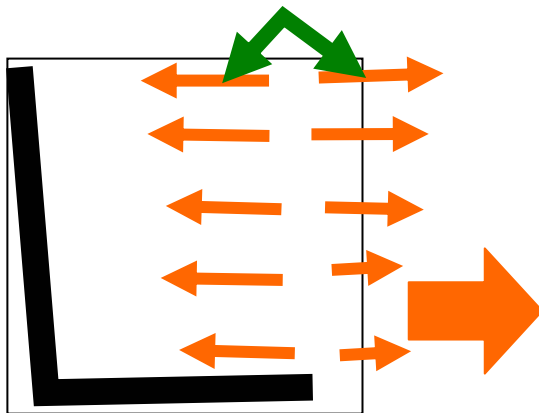


reference



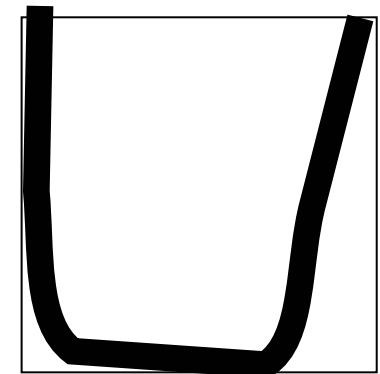
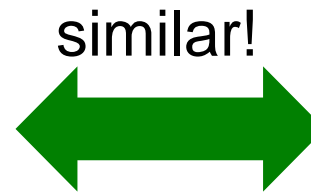
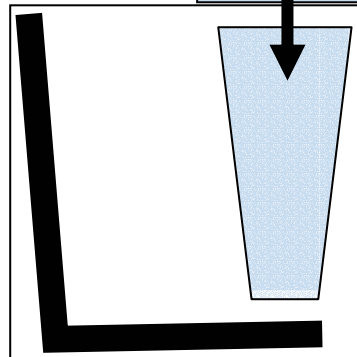
input

discontinuity



reference

"gap"
(neglected in evaluation)



input

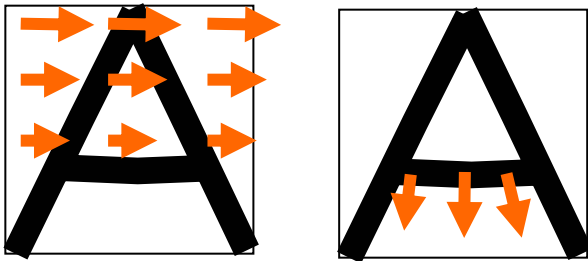
Purpose and Key Idea

■ Purpose

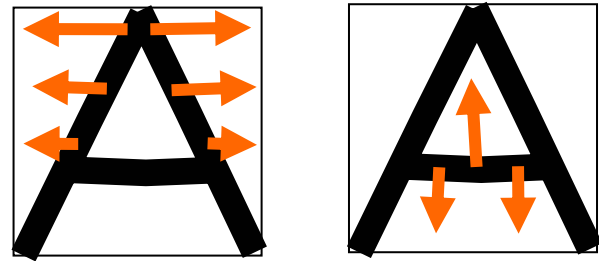
Revive unconstrained EM
by relaxing the overfitting problem

■ Key Idea

Detect overfitting as the deviation
from *eigen-deformations*



eigen-deform.



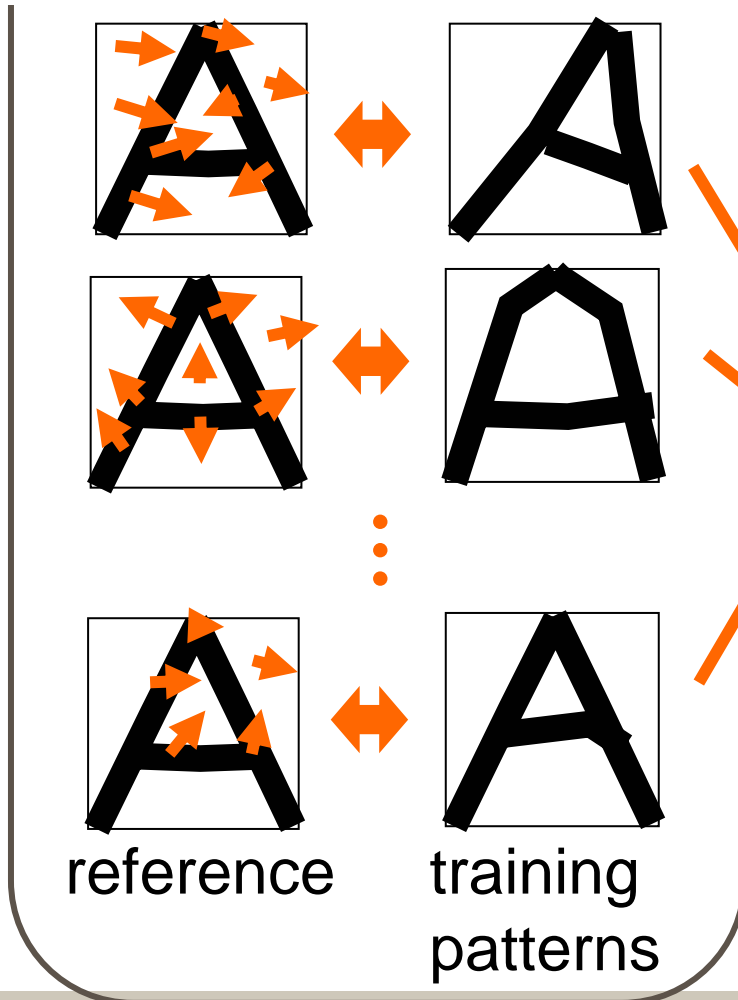
not eigen-deform.

Two Tasks

- **How to estimate** eigen-deformations ?
- **How to use** the eigen-deformations in recognition process to detect overfitting ?

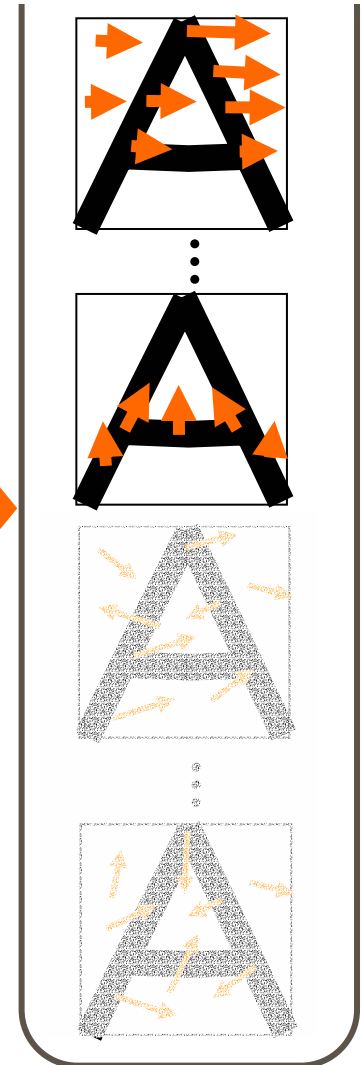
Estimation of Eigen-Deformations

collection of displacement fields
using unconstrained EM

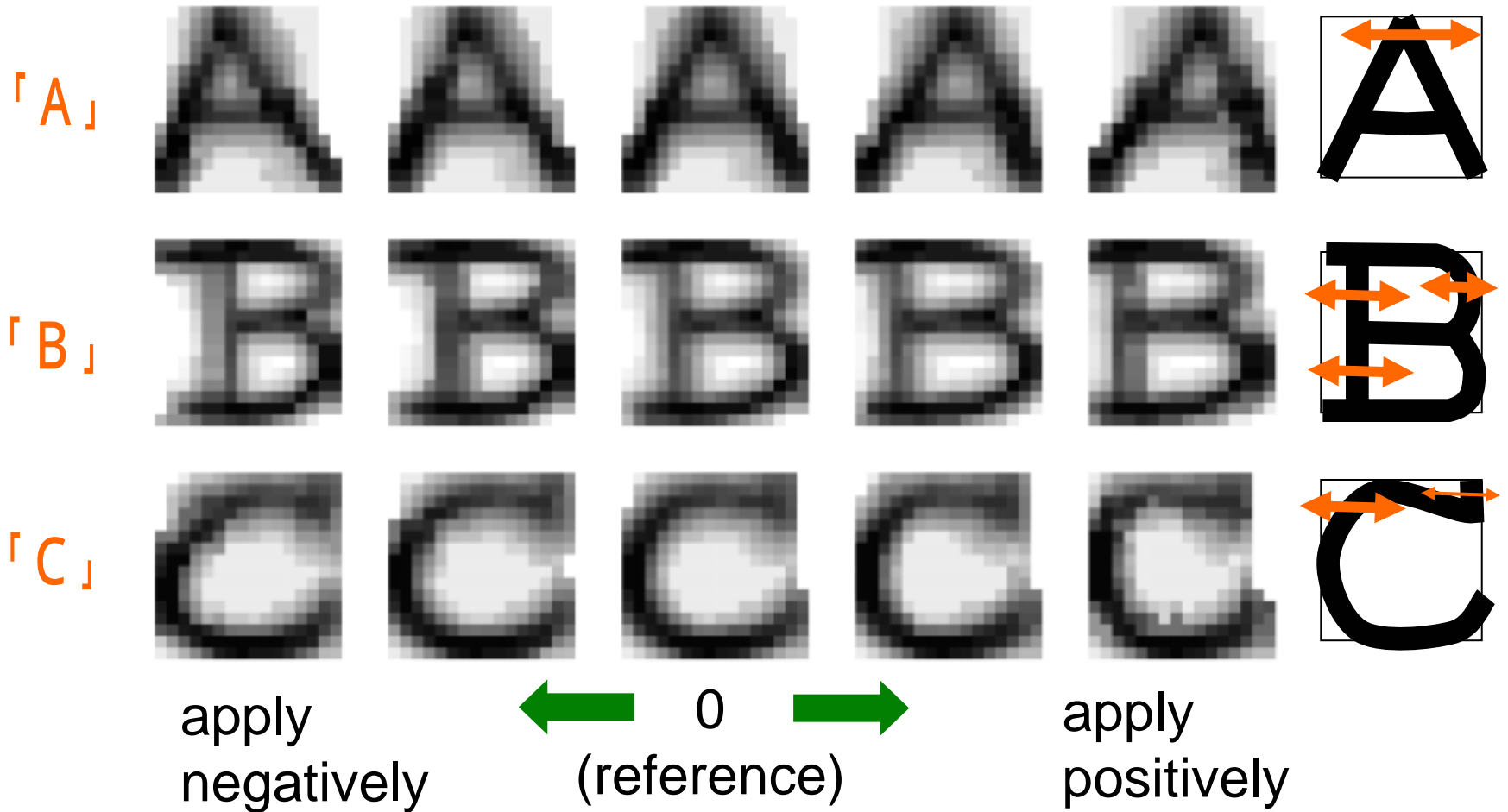


eigen-deformations

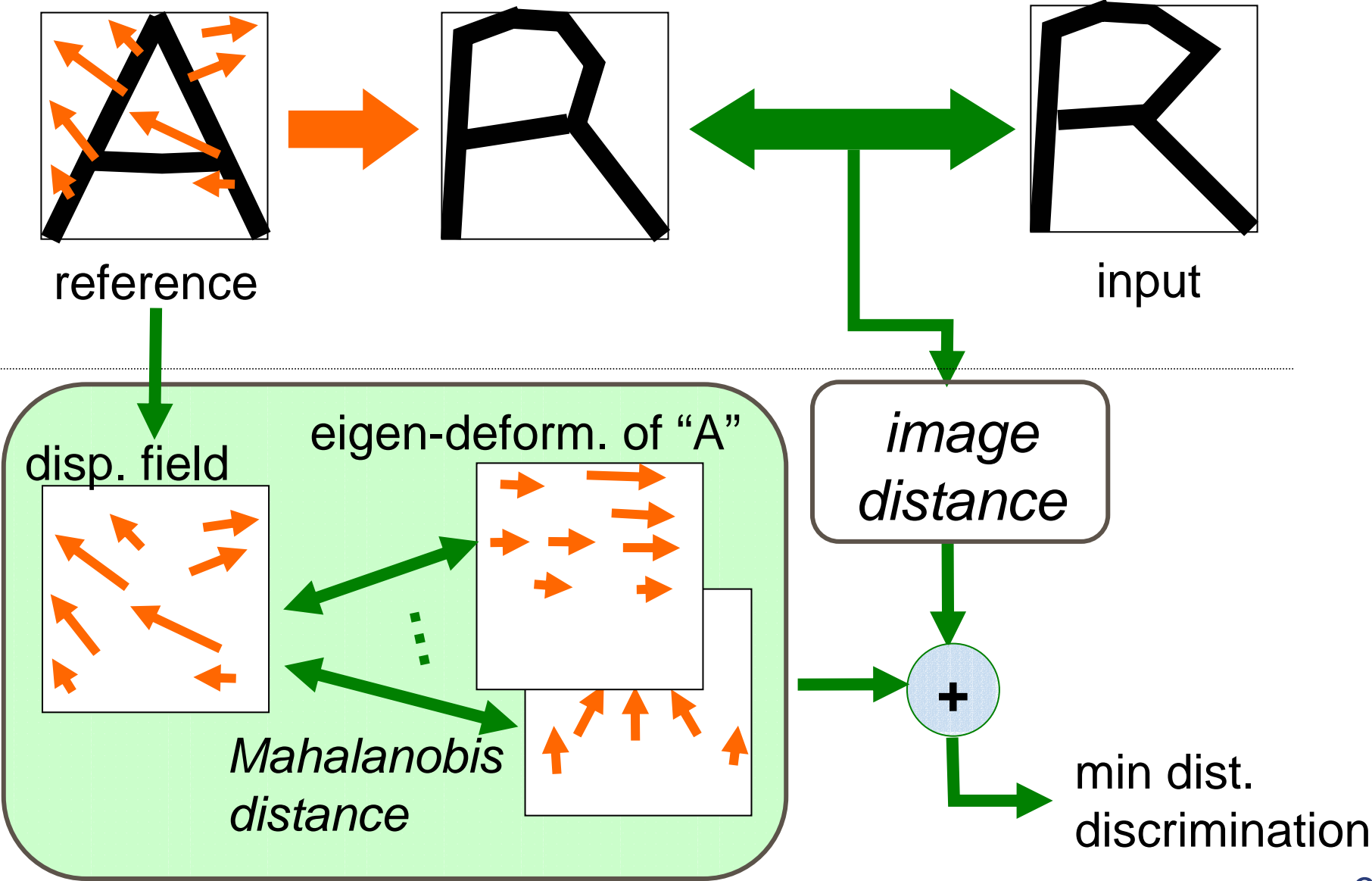
Principal
Component
Analysis



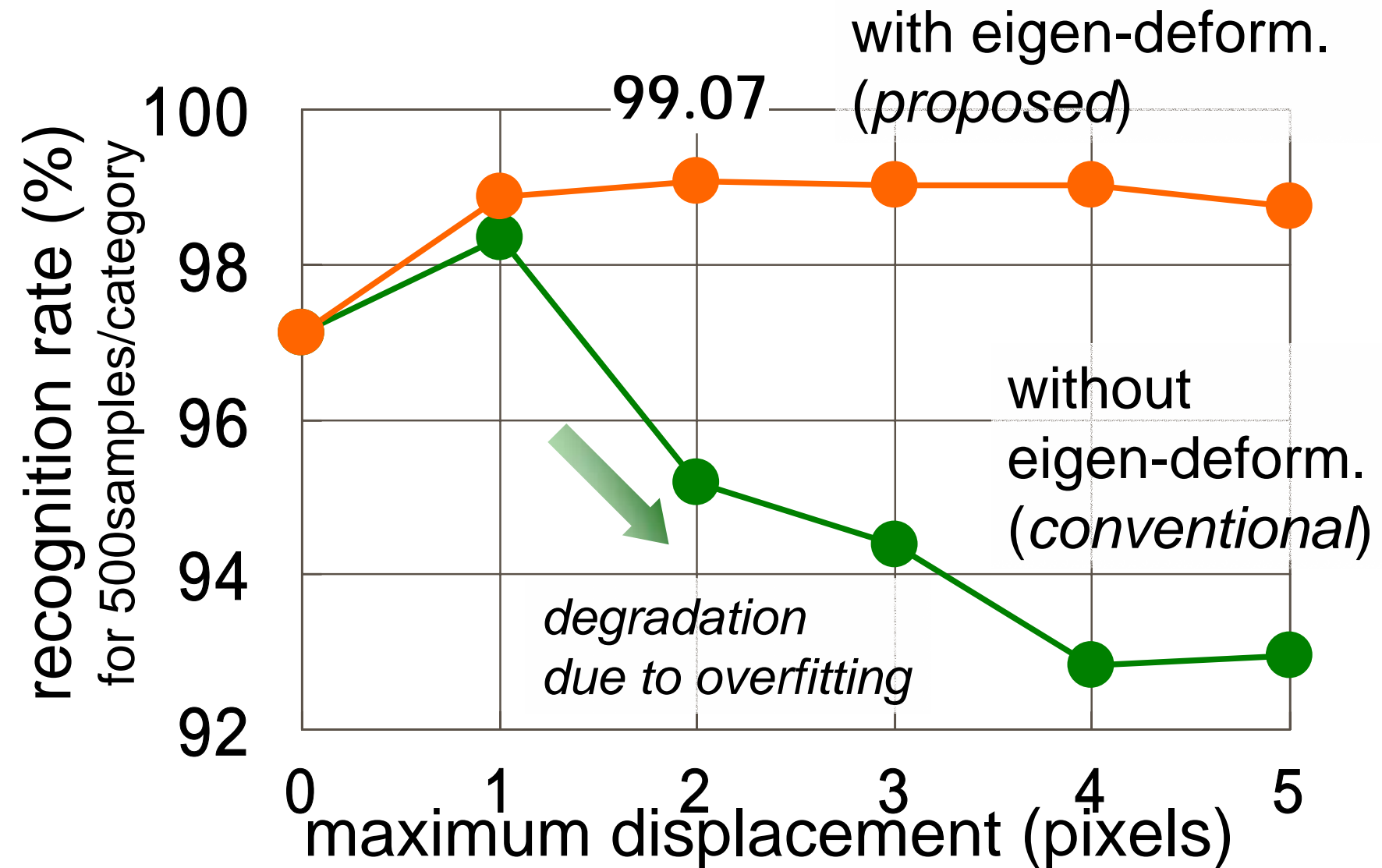
Estimated 1st Eigen-Deformations



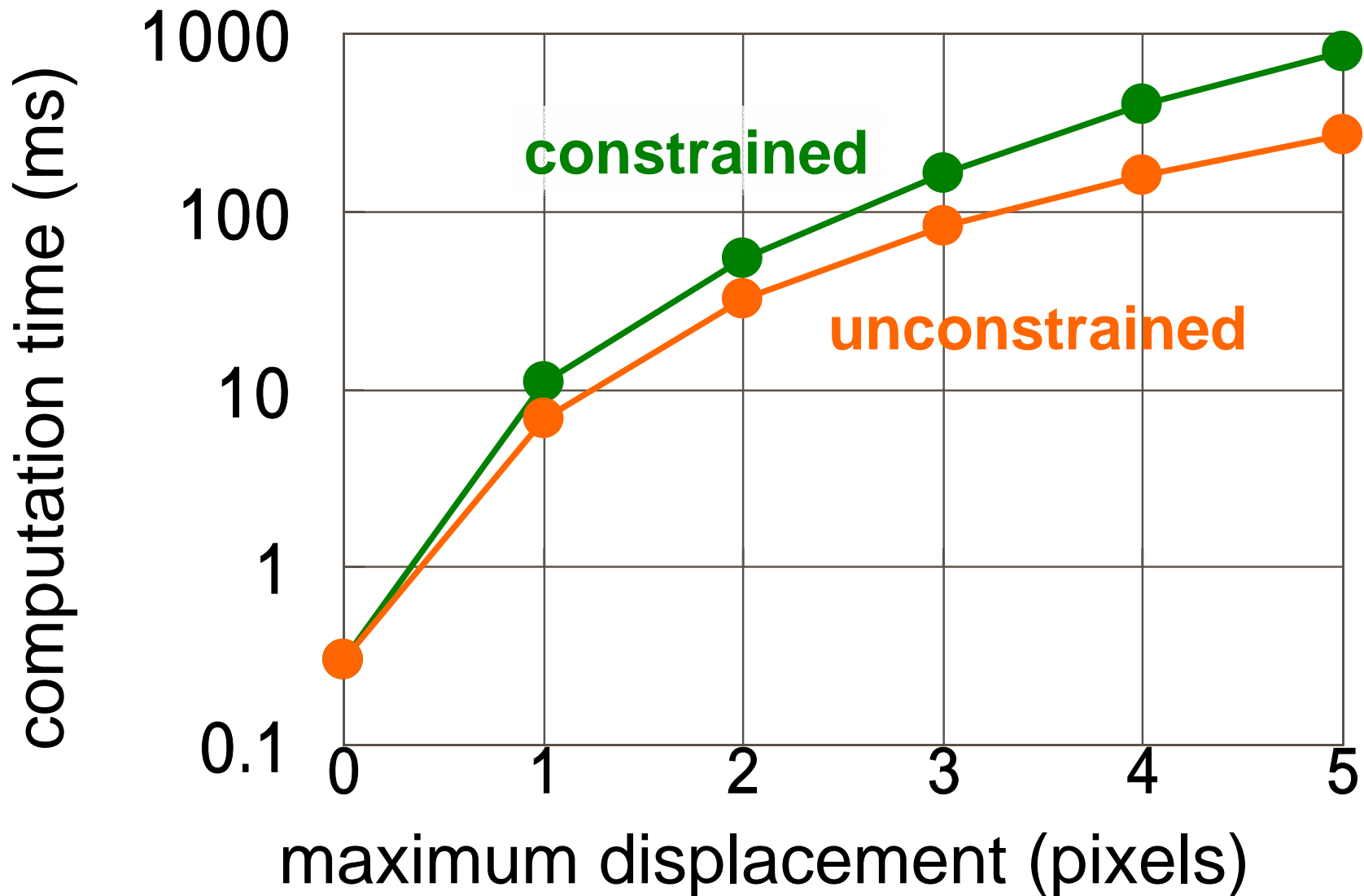
Recognition Using Eigen-Deformations



Recognition Rates

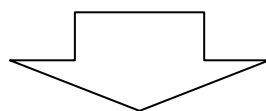


Unconstrained vs. Constrained (1)



Unconstrained vs. Constrained (2)

	without eigen-deform.	with eigen-deform.
unconstrained	98.35%	99.07%
constrained	99.12%	99.43%



Unconstrained EM (fast) is *comparable* to **constrained EM** (slow) in recognition rate when eigen-deformations are used

Conclusion

- Practical recognition method based on **unconstrained EM**
- **Eigen-deformations** to suppress overfitting
- Experimental results enough to encourage the revival of unconstrained EM

Mahalanobis Distance

$$\sum_{m=1}^M \frac{1}{c,m} (\mathbf{v} - \overline{\mathbf{v}}_c, \mathbf{u}_{c,m})$$

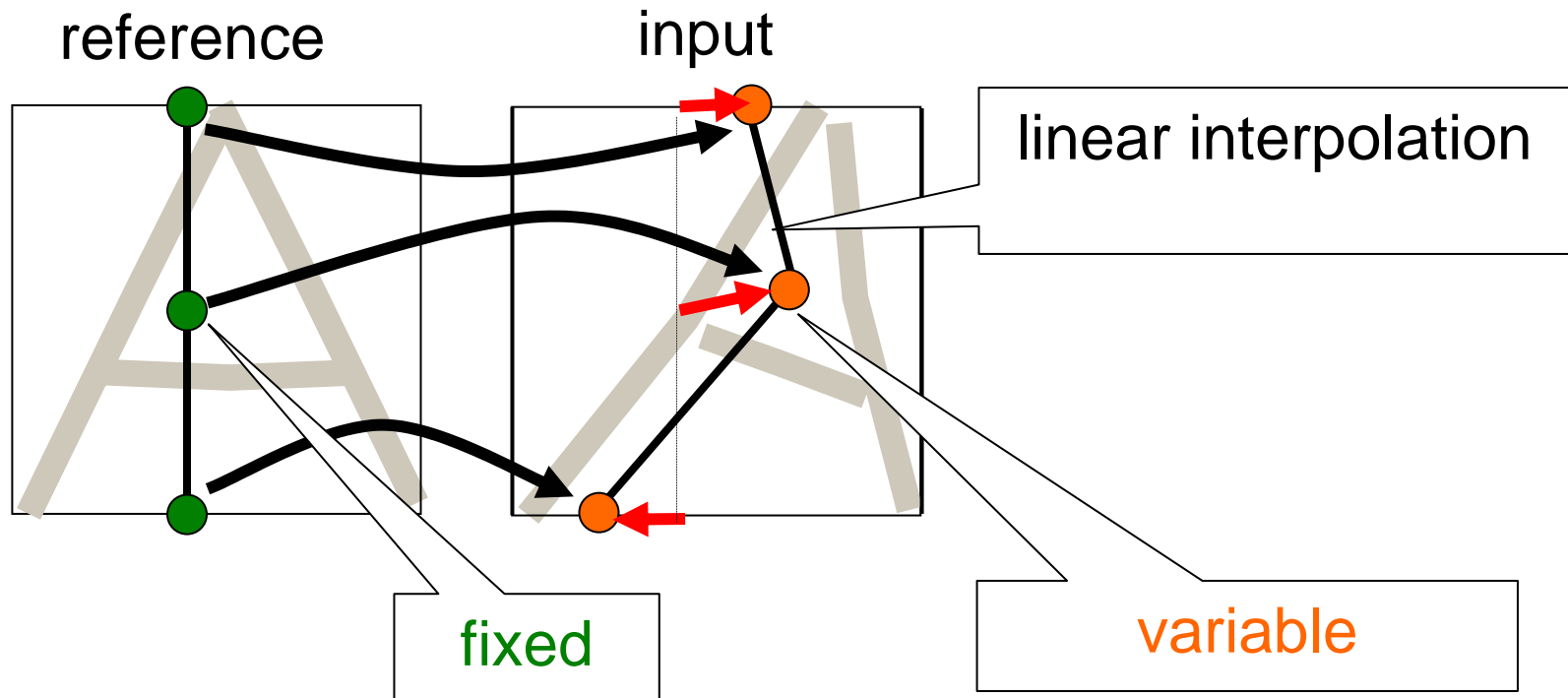
\mathbf{v} : displacement field to be evaluated

c : class ("A", "B", ..) of reference

$\mathbf{u}_{c,m}$: m -th eigen-deformation of class c

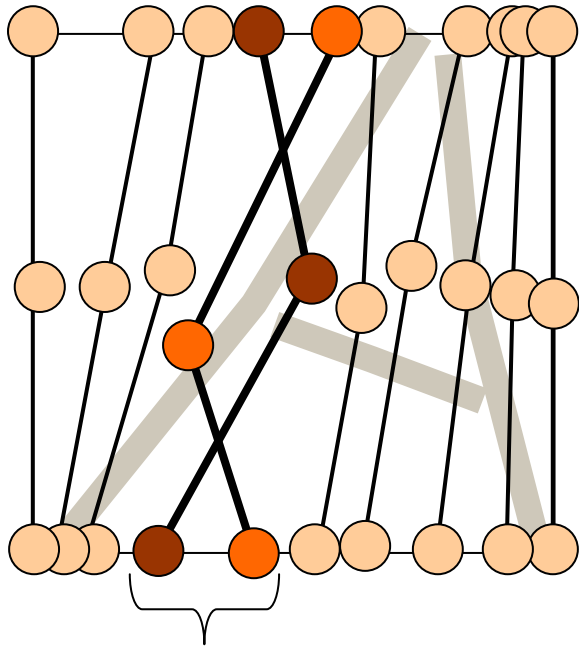
c,m : contribution (eigenvalue) of $\mathbf{u}_{c,m}$

Piecewise Linear Unconstrained EM

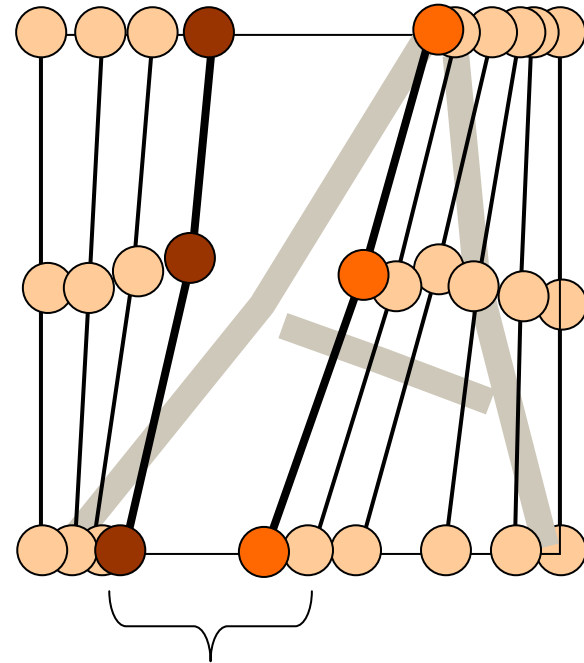


the mapping of each column
is optimized INDEPENDENTLY

Probable Overfitting



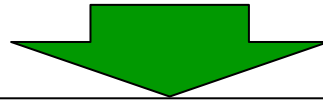
cross (fold over)



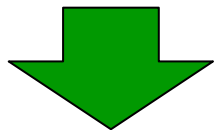
gap (skip)

Data

English capital letters from ETL6
(1100 samples / category)

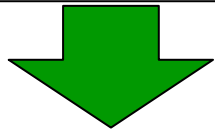


preprocessing
(size normalization, blurring, histogram equalization...)

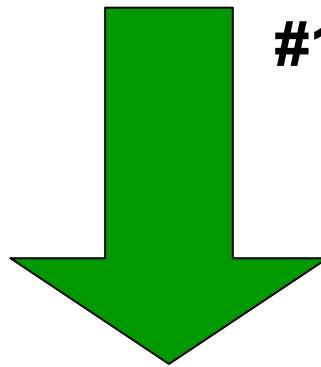


#1-100

average

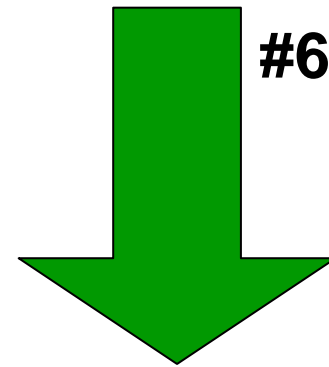


reference



#101-600

training patterns



#601-1100

test patterns

Misrecognitions Reduced by Present Method

“L” ↔ “U”

“F” ↔ “P”

“N” ↔ “M”

misrecognition
due to “gap”