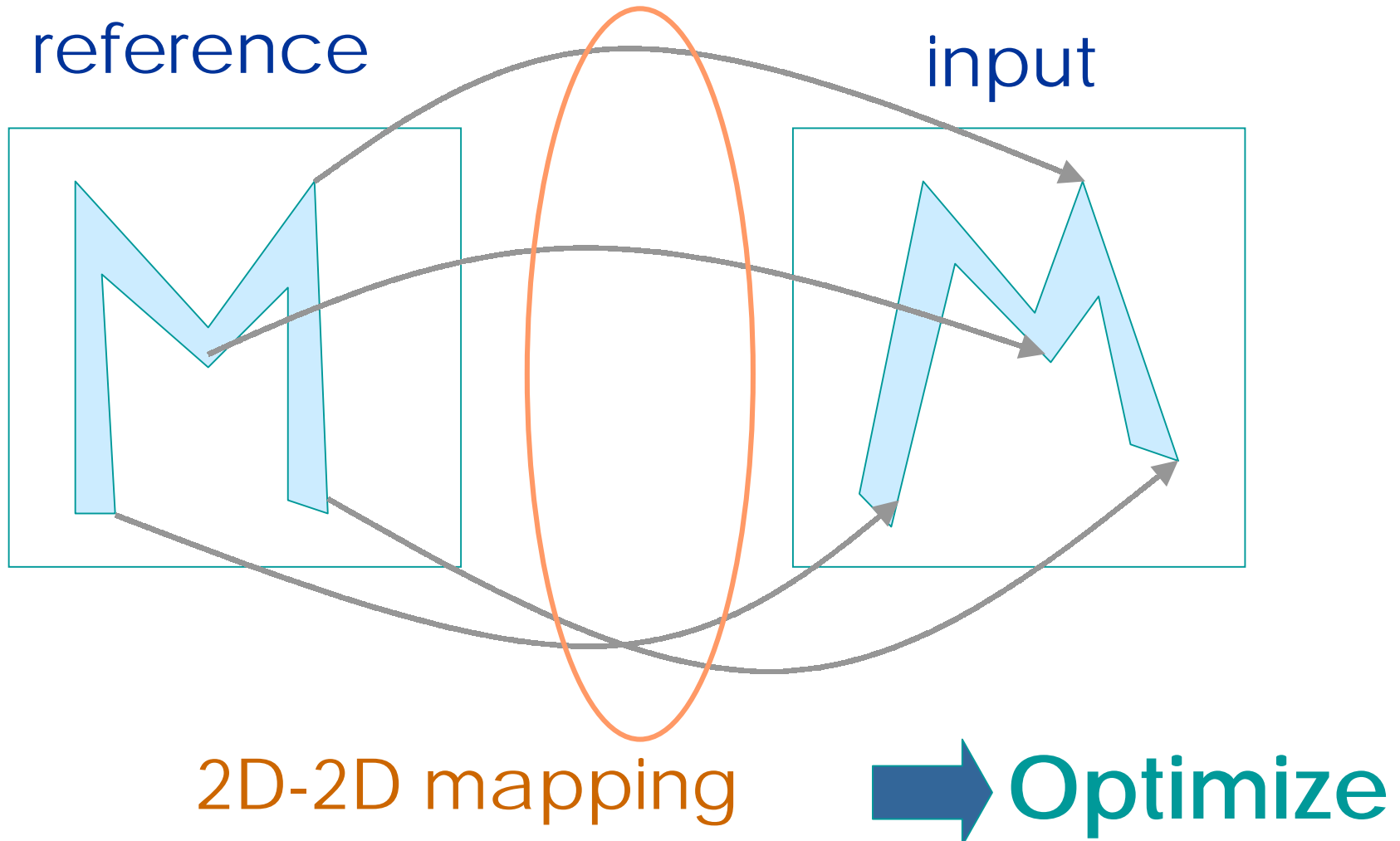


Handwritten Character Recognition Using Piecewise Linear Two-Dimensional Warping

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Elastic matching in character recognition

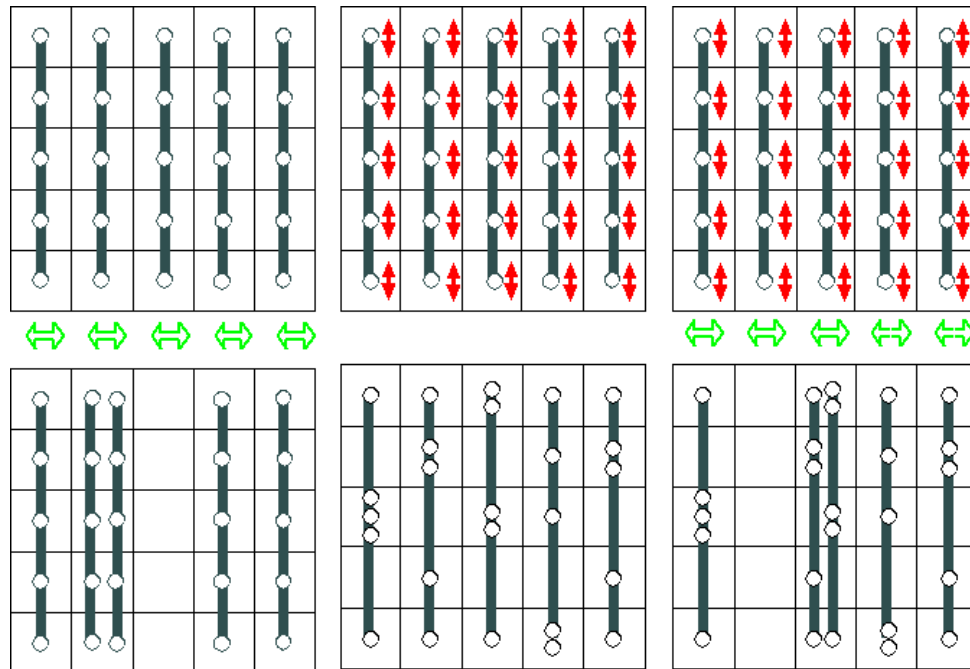


Dynamic programming (DP) as optimization method: advantages

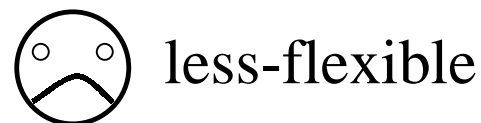
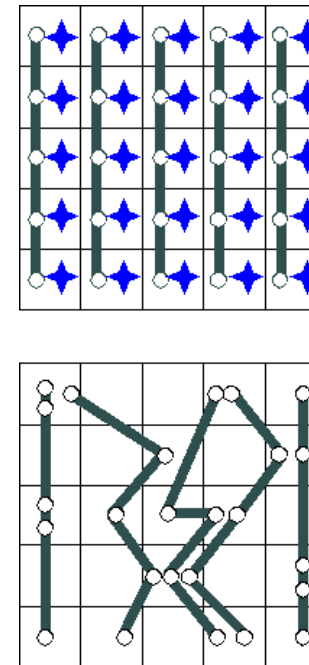
- Global optimality
- Computational stability
- Versatility with constraints and criterion function

DP-based conventional 2DW methods

■ Column restricted 2DWs



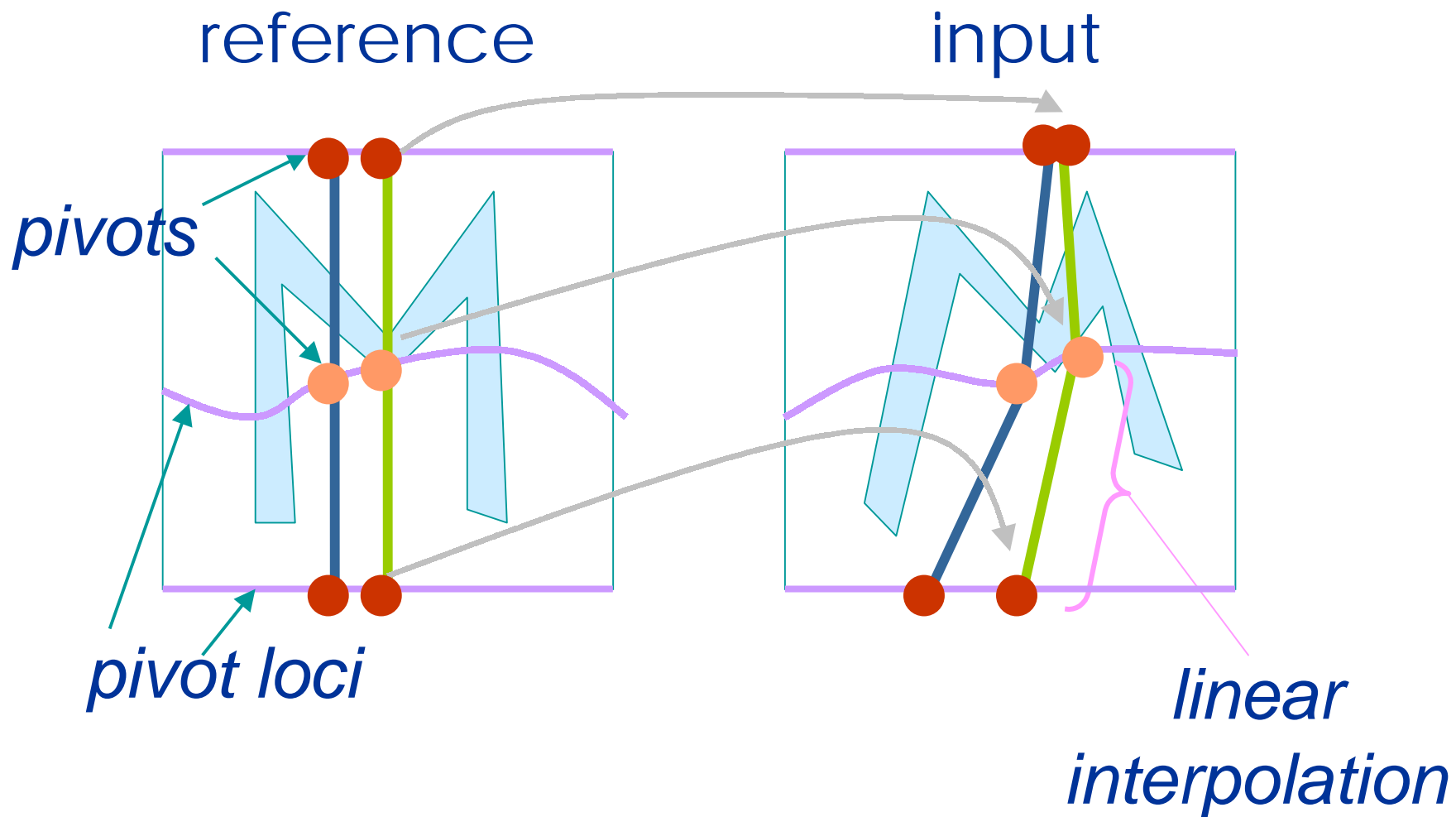
■ Monotonic and continuous 2DW



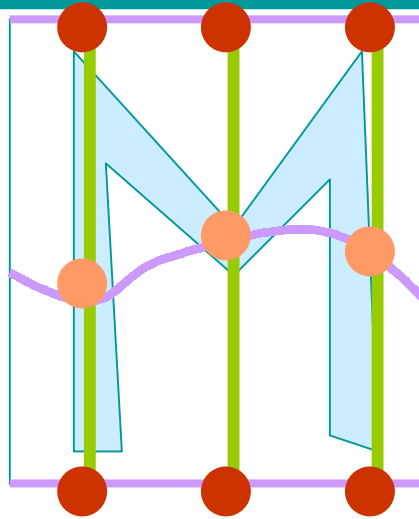
Objective of the present research

- Select a 2DW method by speed-flexibility trade-off
- Compare the performance of that method with that of conventional methods

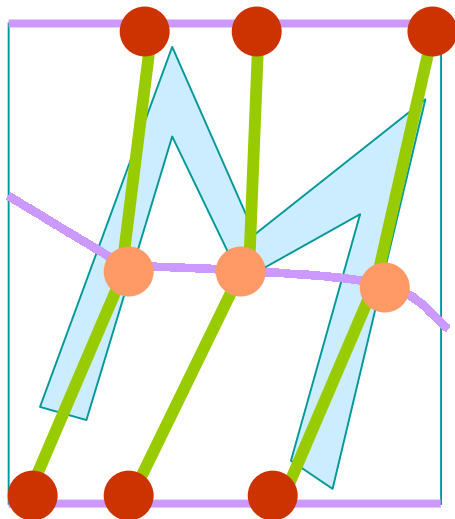
Piecewise linear two-dimensional warping (PL2DW)



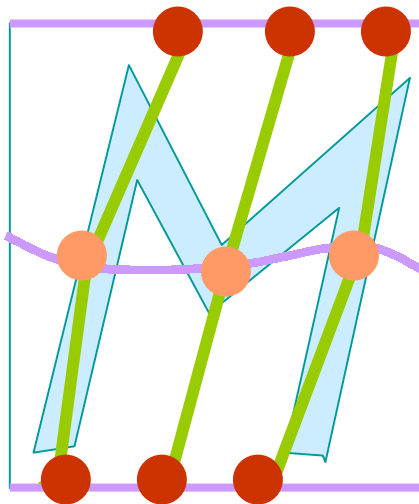
Variation compensation by PL2DW



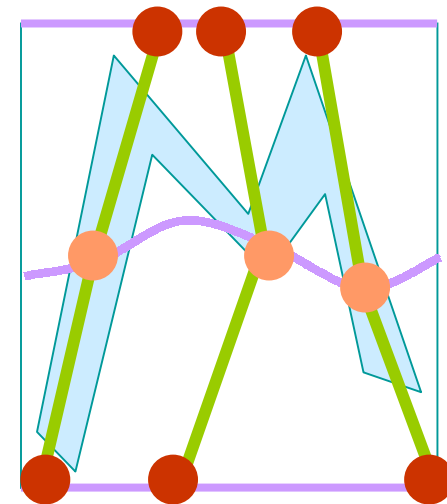
rotation



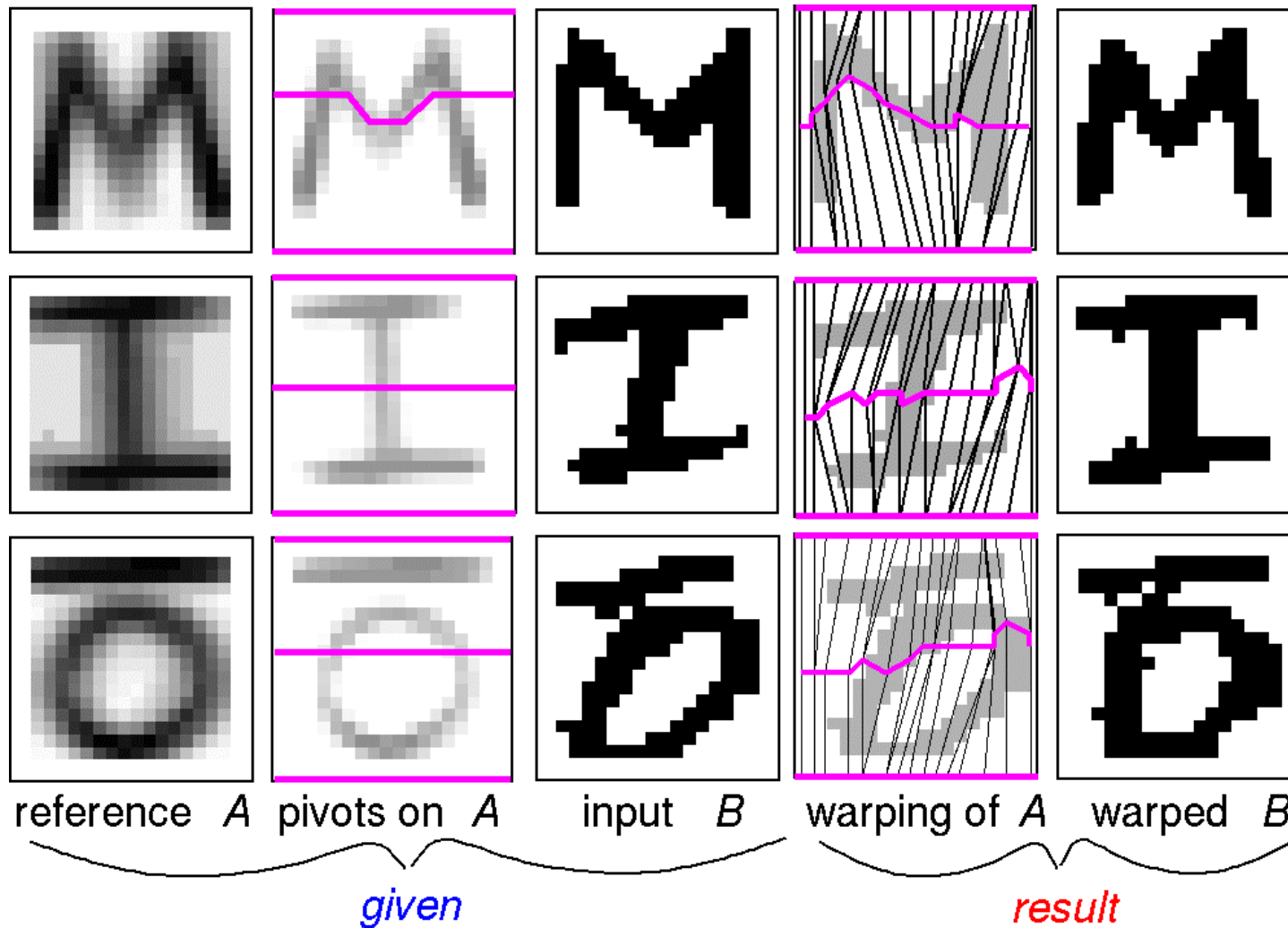
skewness



uneven local variations



Examples of matching using PL2DW



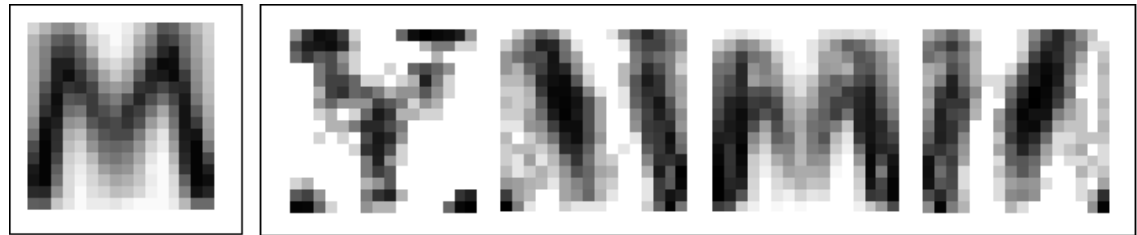
Implementation of PL2DW

- DP-based algorithm under monotonicity and continuity conditions
- Complexity of the DP-algorithm : polynomial order of the image size

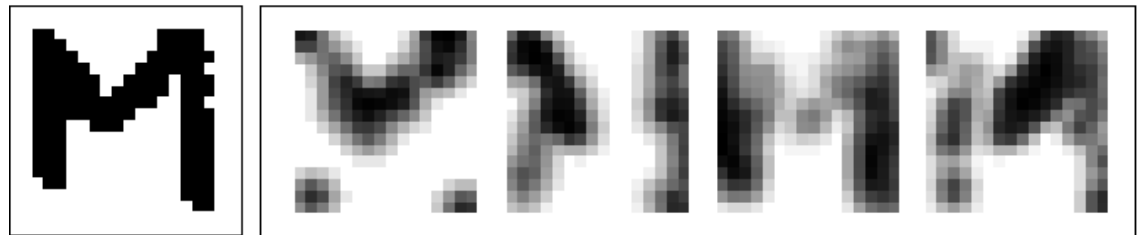
Recognition experiment: setup

- Database: ETL6 (English capital letters)

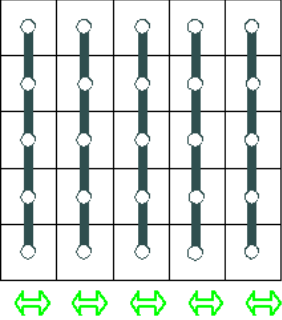
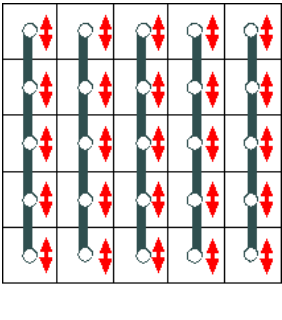
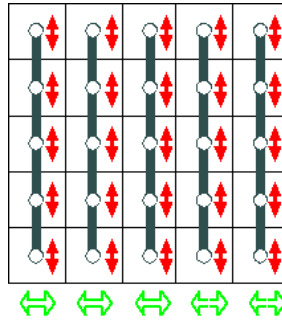
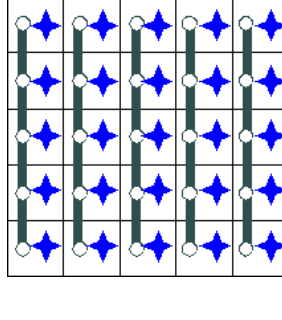
- Reference pattern:
average intensity
of 100 patterns



- # of input patterns:
25895

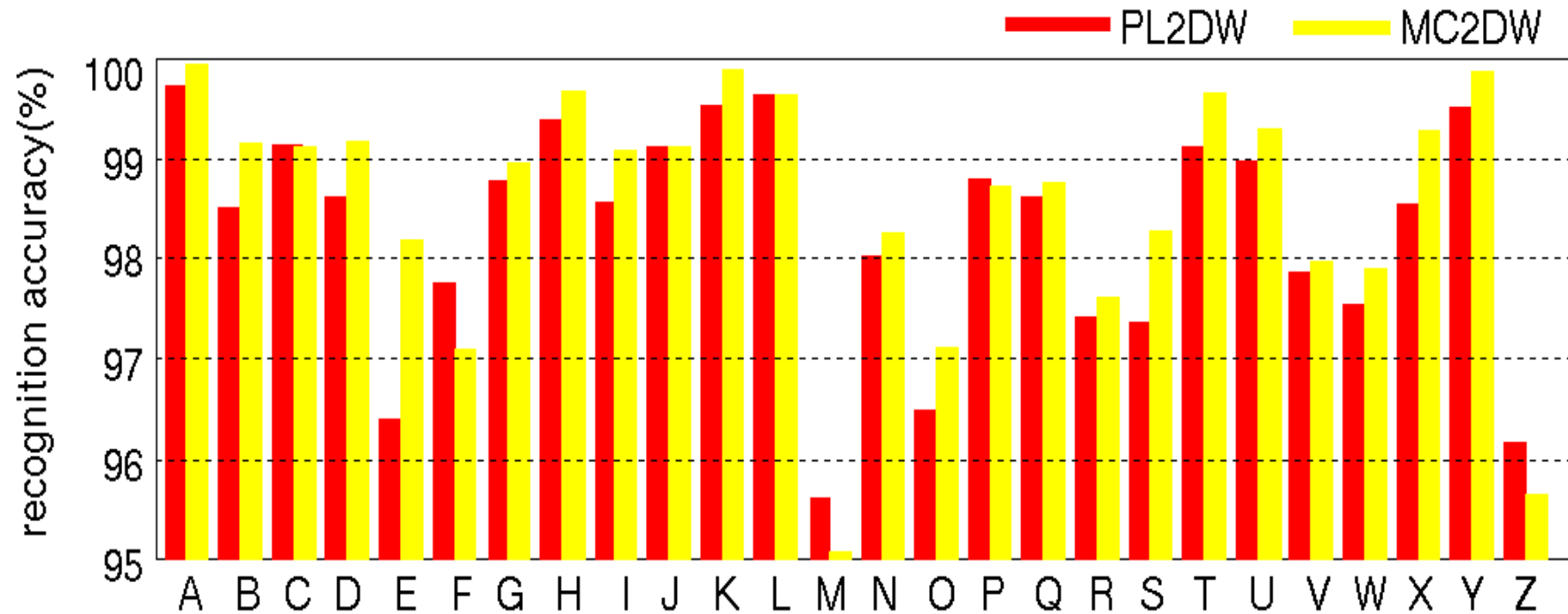


Experimental result (1): recognition accuracy

Column restricted 2DWs			MC2DW	PL2DW
				
97.6	97.5	97.8	<u>98.9</u>	98.6

- PL2DW is superior to column restricted 2DWs
- PL2DW gave slightly inferior accuracy to that of MC2DW, but recognition time is far less (3.4 sec vs 110 sec)

Experimental result (2): Category-wise accuracy



- PL2DW attains close accuracy to MC2DW for most categories

Error analysis of PL2DW results

Insufficient matching	Excessive warping
41%	59%

Conclusion

- The effectiveness of PL2DW in handwritten character recognition is justified experimentally
- Additional local constraints have been applied successfully to control over-deformations.

Arrangement of pivots

