Handwritten Character Recognition Using Piecewise Linear Two-Dimensional Warping

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1 Pattern matching in handwritten character recognition



2 Optimization of 2DW using dynamic programming (DP)

Advantages of using DP

 Versatility with criterion functions and constraints

- Global optimality
- Computational stability

3 DP-based previous 2DW methods for handwritten character recognition

Column-wise restricted 2DW

Monotonic and continuous 2DW



4 Objective of the present research

Investigation of piecewise linear 2DW(PL2DW) in handwritten character recognition

5 Piecewise linear 2-dimensional warping (PL2DW) B A pivot linear interpolation ***** pivot locus **Optimization of pivot mapping**

6 Examples of matching using PL2DW













7 Constraints on mapping









• Boundary conditions





• Warp range limitation Prevents excessive warping





8 Compensation for variations using PL2DW



skewness



uneven local deformation



rotation



input

9 DP Algorithm for PL2DW



10 Complexity of the DP algorithm for PL2DW

polynomial order of the image size

Computation time: 130 ms/matching (SUN Ultra2, int_95:12.3, fp_95:20.2; 20×20 image size)

MC2DW complexity: exponential order, time: 4.26 sec



12 Arrangement of pivots

- Artificially arranged
- Layout determined by preliminary experiments



13 Recognition result with PL2DW

warp range w					
0 (template matching)	1	2	3	4	
97.4	98.3	98.6	98.3	98.0	

14 Comparison with other DP-based 2DW methods





16 Error analysis of PL2DW results

over def	ormation	59%
insufficien	t matching	41%

17 Additional local constraints to reduce over-deformations



DP allows to incorporate such constraints

18 Recognition result with Additional local constraints

	recognition rate (%)
without a.l.c.	98.6
with a.l.c.	98.8



19 Conclusion

- The effectiveness of PL2DW in handwritten character recognition is justified experimentally upon comparison with several other DP-based 2DW methods.
- Additional local constraints have been applied successfully to control over-deformations.