A Keyword Spotting Approach Using Blurred Shape Model-based Descriptors

A. Fornés, V. Frinken, A. Fischer, J. Almazán, G. Jackson, H. Bunke

Computer Vision Center, UAB, Spain
Institute of Computer Science, UB, Switzerland

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- Deformable Blurred Shape Model
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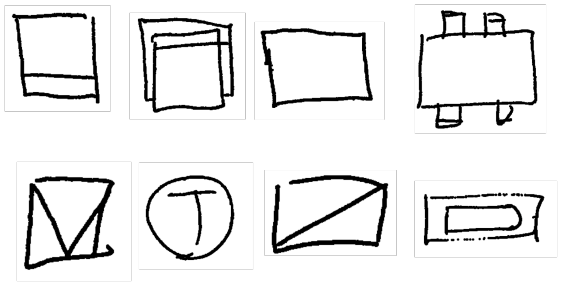
Introduction

- Keyword spotting for historical documents
  - Useful for databases with non-labeled data
    - Query-by-Example
- Two Symbol Recognition methods for hand-drawn symbols
  - Blurred Shape Model
  - Deformable Blurred Shape Model
  - They can cope with variations in handwriting style

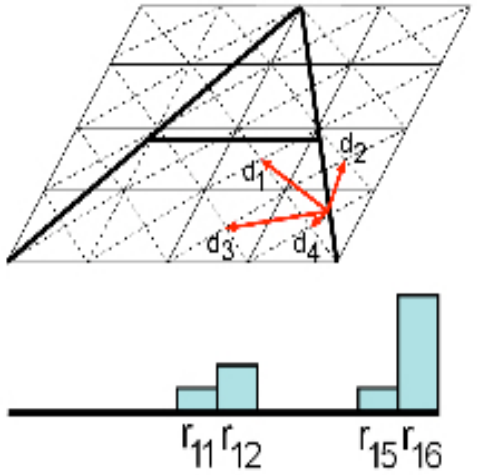


- Idea → Adaptation to word spotting?

Blurred Shape Model

The symbol is divided in *nxn* cells

- Each cell receives votes
  - The value depends on the distance to the centroid of the neighbouring cells
- Normalize the probability density function

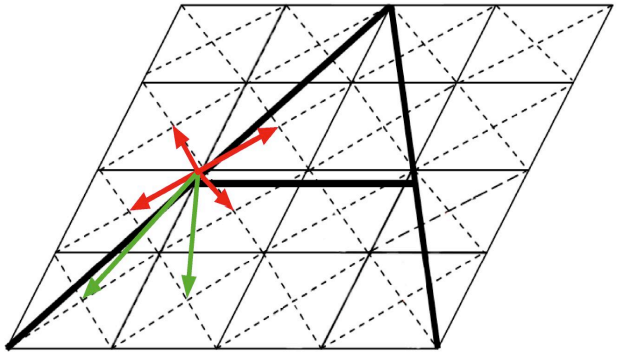


$$d_i = d(\mathbf{x}, r_i) = ||\mathbf{x} - c_i||^2$$

$$v(r_i) = v(r_i) + \frac{1}{d_i D_i}, \quad D_i = \sum_{c_k \in N(r_i)} \frac{1}{||\mathbf{x} - c_k||^2}$$

$$v = \frac{v(i)}{\sum_{i=1}^{n^2} v(j)} \forall i \in [1, ..., n^2]$$

- The number of cells determines the blurred degree allowed



Deformable Blurred Shape Model
Focus representation

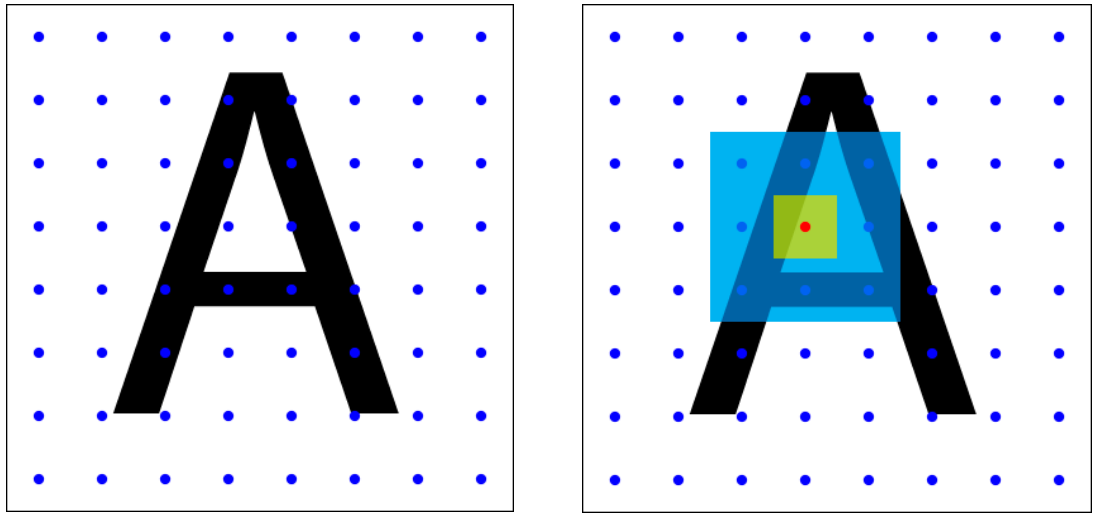
Locate over the image *KxK* points, denoted as focuses

Their position correspond to the BSM cells centroids

Pixels from the shape will *influence nearby* focuses

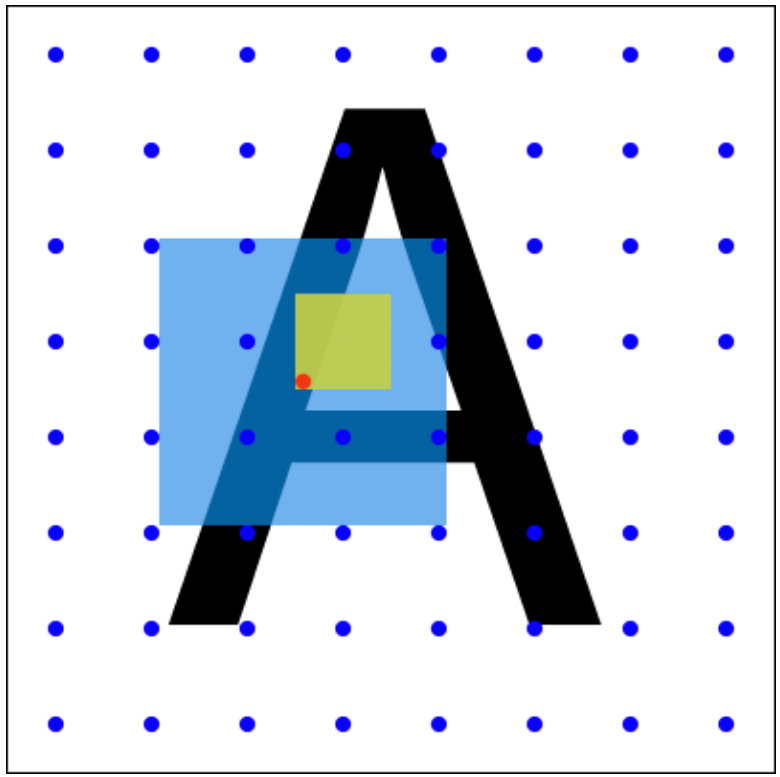
The model used will define:

- *Influence area (blue)*
- *Deformation area (yellow)*



Deformable Blurred Shape Model
Image Distortion Model

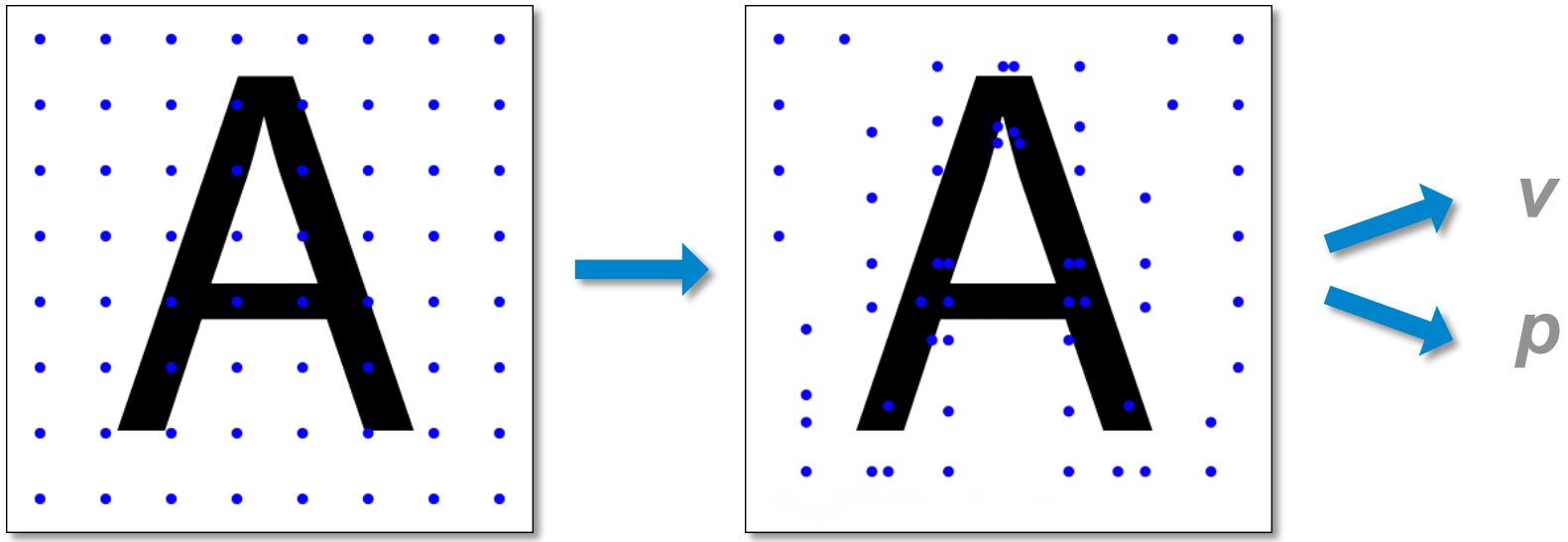
- Defines a *WxW deformation area* and a *NxN influence area* around every focus
- Pixels within the *influence area* will contribute to the density measure
- Focuses are allowed to move inside the *deformation area*
- *Influence area* will move along with the focus
- Two steps for classification: training and matching



Deformable Blurred Shape Model
Training

The training process consists on, for every image, maximize the value of each one of the *KxK* focus

Results a K^2 vector v with the final value of each focus and a $2K^2$ vector p with the focuses coordinates



Deformable Blurred Shape Model
Matching

Given a reference image $\boldsymbol{I}$ and a test image $\boldsymbol{J}$, focuses in $\boldsymbol{J}$ are deformed to optimize a matching criterion:

- *IDMmax: focuses in J will maximize their value*

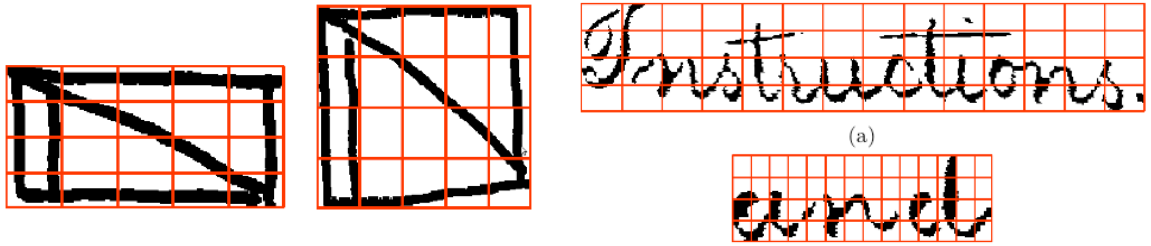
It results in vectors v_J and p_J

- *Similarity measure* is the distance between v_I and v_J
- *Deformation measure* is the distance between p_I and p_J

Final distance between $\boldsymbol{I}$ and $\boldsymbol{J}$ is a weighted combination between *similarity* and *deformation* measures

Adaptation to Word Spotting

- Same number of cells?
  - Symbols → Good!
  - Words → Problem!



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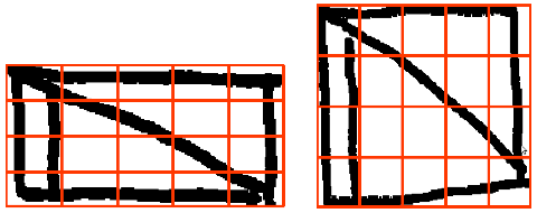
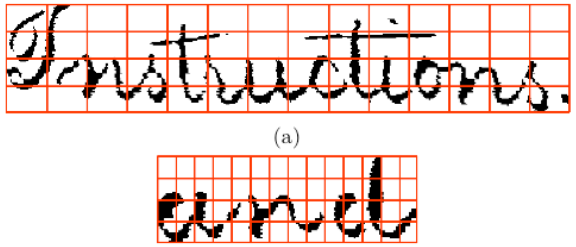
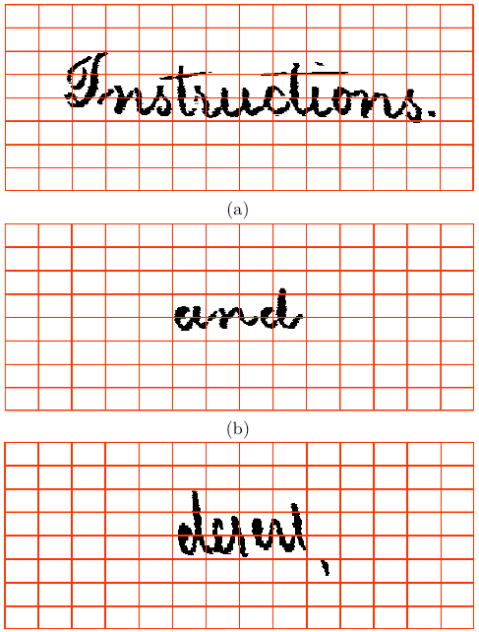


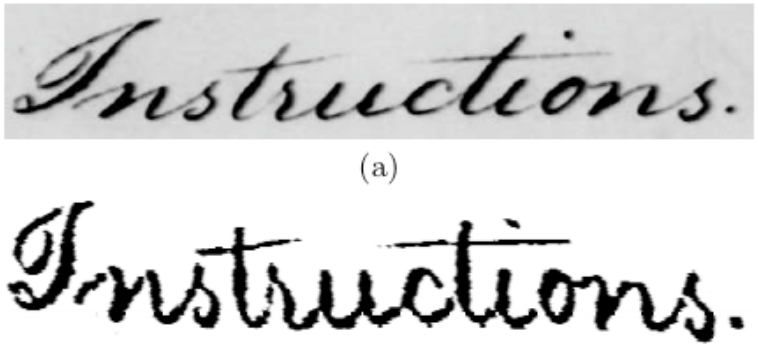


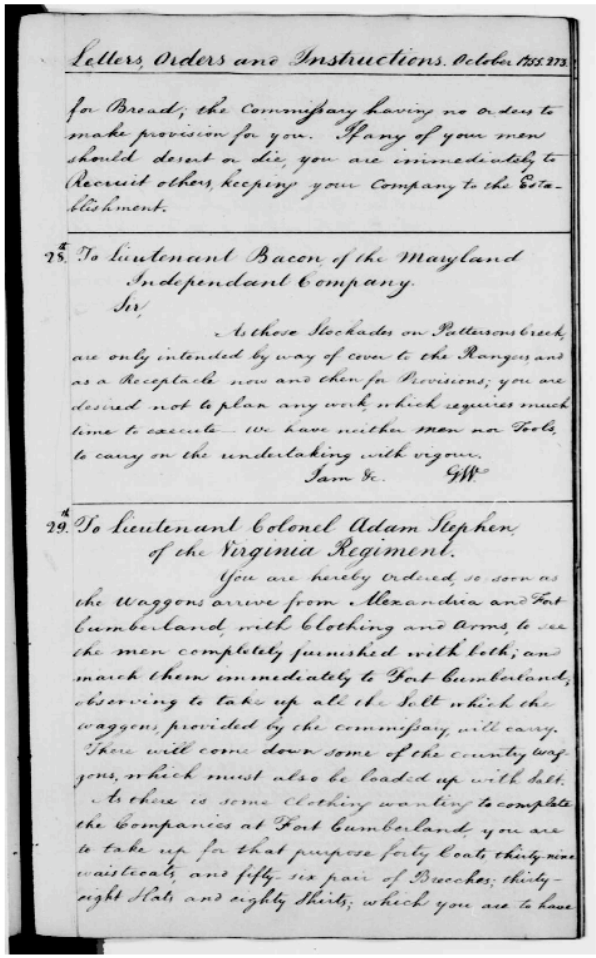
- Proposal
  - Template of fix size
  - Word is located in the center
  - Advantages
    - Same number of cells for each character
    - Feature vector short word ≠ long word
    - Center of gravity is robust to noise



Results

- Database
  - George Washington Dataset
    - 20 pages, already preprocessed




Letters, Orders and Instructions. October 1755 to 1773.

for Bread; the Commissary having no orders to make provision for you. If any of your men should desert or die, you are immediately to Recruit others, keeping your Company to the Establishment.

28. To Lieutenant Bacon of the Maryland Independant Company.

Sr,

As those Stockades on Pattersons Creek, are only intended by way of cover to the Rangers and as a Receptacle now and then for Provisions, you are desired not to plan any work which requires much time to execute — We have neither Men nor Tools, to carry on the undertaking with vigour.

I am &c. GW.

29. To Lieutenant Colonel Adam Stephen of the Virginia Regiment.

You are hereby Ordered, so soon as the Waggons arrive from Alexandria and Fort Cumberland, with Clothing and Arms, to see the men completely furnished with both; and march them immediately to Fort Cumberland, observing to take up at the Salt which the waggons, provided by the commissary will carry. There will come down some of the country Waggons, which must also be loaded up with Salt. As there is some Clothing wanting to compleat the Companies at Fort Cumberland, you are to take up for that purpose forty Coats, thirty nine waistcoats, and fifty six pair of Breeches; thirty eight Hats and eighty Shirts; which you are to have

Results

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    - 20 pages, already preprocessed
- Baseline results
  - Rath and Manmatha
    - Features → 9 dimensional vector (sliding window)
    - Dynamic Time Warping

Results

- Database
  - George Washington Dataset
    - 20 pages, already preprocessed
- Baseline results
  - Rath and Manmatha
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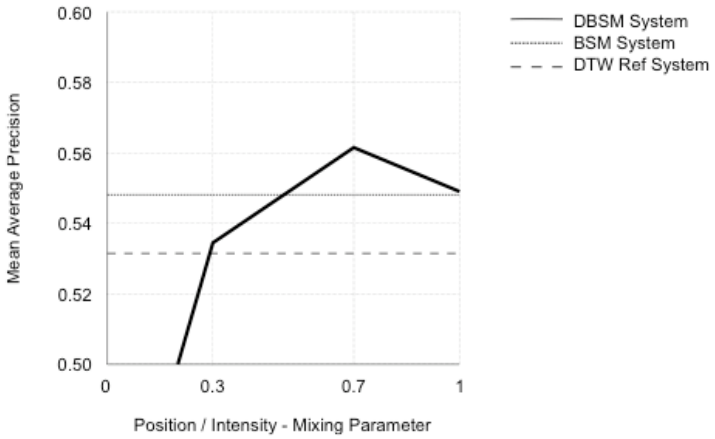
    - Dynamic Time Warping
- Metrics
  - Precision and Recall
  - Average Precision (ap)
    - Average all recall values
  - Mean Average Precision (MaP)
    - Average precision over all queries

$$\text{precision} = \frac{TP}{TP + FP}$$

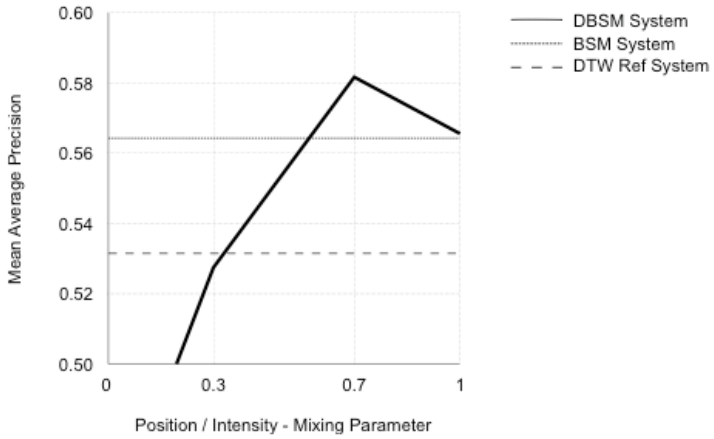
$$\text{recall} = \frac{TP}{TP + FN}$$

Results and Discussion

Cell Size = 5x5 pixels



Cell Size = 4x4 pixels



- Higher resolution → Better performance (on this dataset)
- DBSM → intensity values are more discriminant than positions of focuses
- DBSM obtains slightly better results, but BSM is faster
- BSM and DBSM outperform DTW, with a lower computational cost

Results and Discussion

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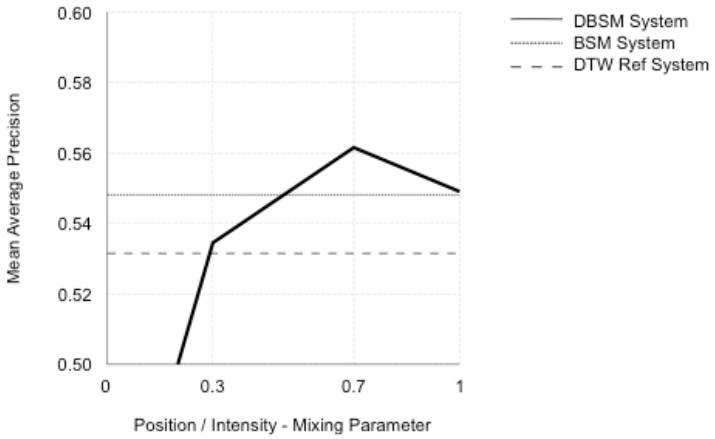

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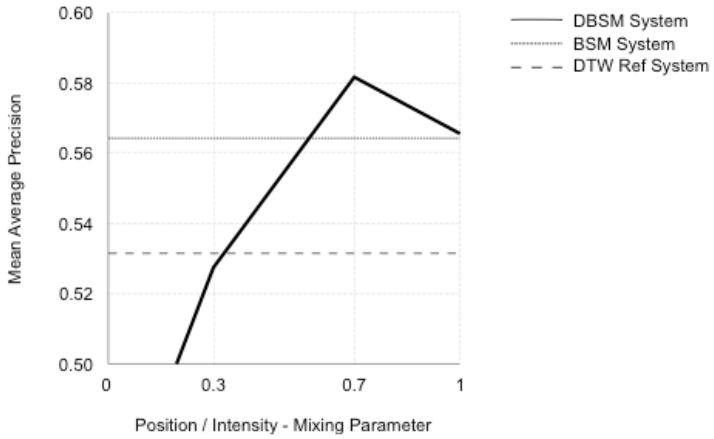

- The mean average precision is below 60%
- Higher performance for training based systems (e.g. HMMs, RNNs)
- BSM, DTW and DBSM proposals do not require training
  - Suitable for searching in databases without ground-truth

Conclusions

- Conclusions
  - Proposal of a Shape-based keyword spotting (BSM and DBSM)
  - Adaptation to words
  - BSM and DBSM outperform DTW with low complexity

- Future Work
  - Other shape descriptors suitable for handwritten text (e.g. Shape Context)

Thank you !!