Shape Matching and Object Recognition using Low Distortion Correspondences

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Problem Statement
Basic Outline of the Approach
The difficult part
Correspondence points
Constraints-Cues
Geometric Blur
Cost function for Similarity
Correspondence Algorithm
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Introduction

- Recognition is a most important and interesting problem of Computer Vision.
- Any recognition problem is fundamentally a problem of deformable shape matching.
- According to the literature survey, the research on the deformable shape matching is on since 1970’s.

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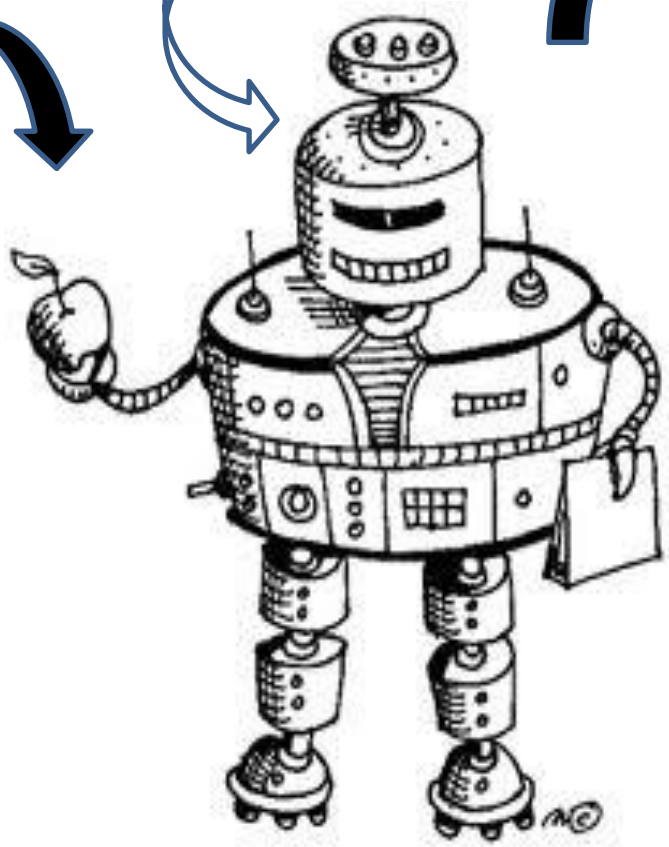
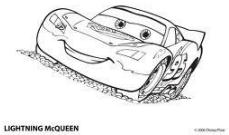
Problem Statement

Query Image

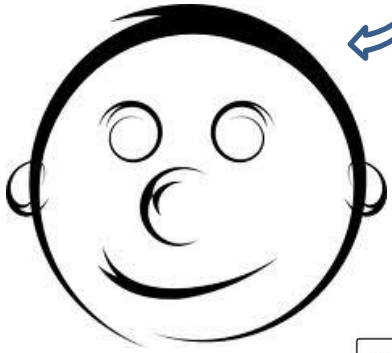
Proposed Algorithm

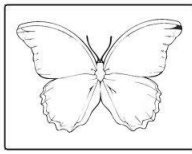


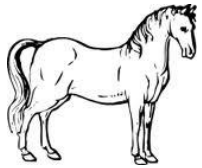
Exemplars of Categories



Corresponding Exemplar







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Basic Outline of the Approach

- The deformable matching takes an unknown input image and compares it to a model by solving the correspondence problem.
- It uses the correspondences to perform an aligning transformation.
- The overall similarity can be estimated by considering Aligning Transformation and Residual difference between both images.

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The difficult part!!

- Solving Correspondence problem itself.
- Interesting challenges are:
  - Position of Correspondence points
  - Intra Category Variation
  - Occlusion and Clutter
  - 3-D pose changes

*We will try to see how the algorithm tackles all these challenges during the course of presentation

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Correspondence Points

- For every image, the algorithm considers 50-100 pixel locations on the edge detector output.
- These points are chosen at random.

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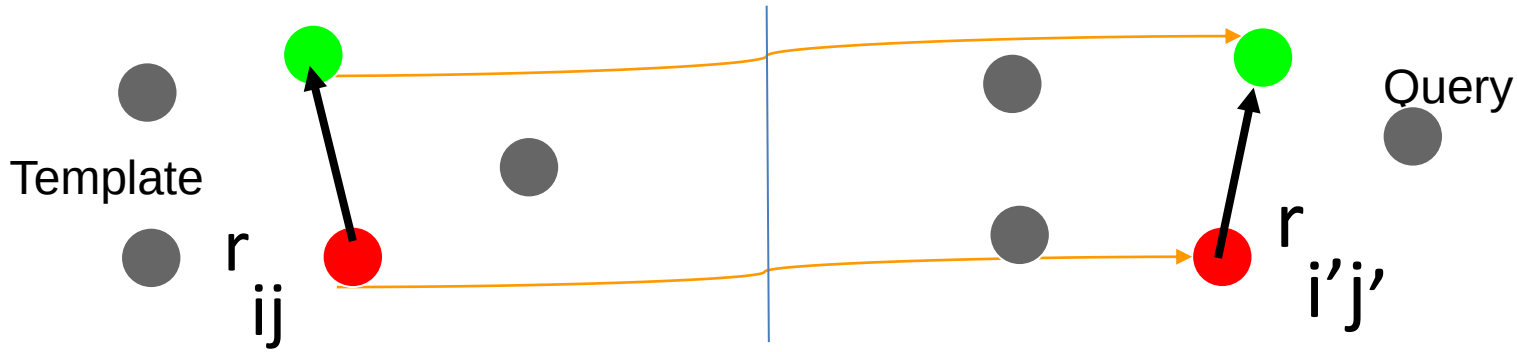
Constraints - Cues

- Similar local descriptors
- Minimizing the geometric distortion:



- Smoothness of the transformation:
  - Regularized thin plate spline

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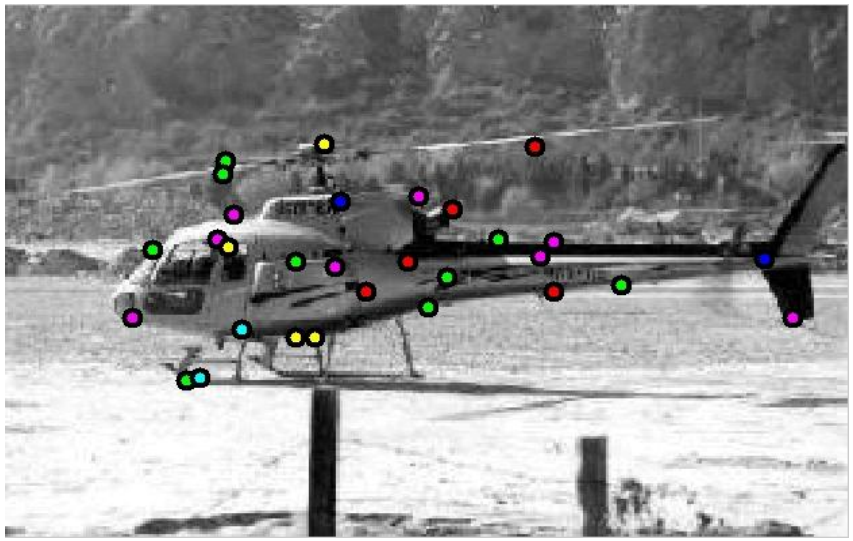
Geometric Blur

- Geometric Blur plays a key role in deciding the Geometric Distortion.
- The two ways a calculating the Geometric Blur are
  - Signal(sparse and indicate the presence of an edge)
  - Blur(should indicate nature and kind of distortion expected.)

…continued

- $S=S*G_d$ (G is the Gaussian Kernel filter)//signal calculation
- $B_{x0}(x)=S_{a|x|+b}(x_0-x)$ //blur calculation
- The feature descriptor is a concatenation of subsampled geometric blurs computed at each point of a correspondence point.
- These values are compared using sqrt(SSD) metric(L_2 distance)
- *Experimentally, it only takes <1 sec for 1 image to calculate geometric blur value.

Correspondence Result



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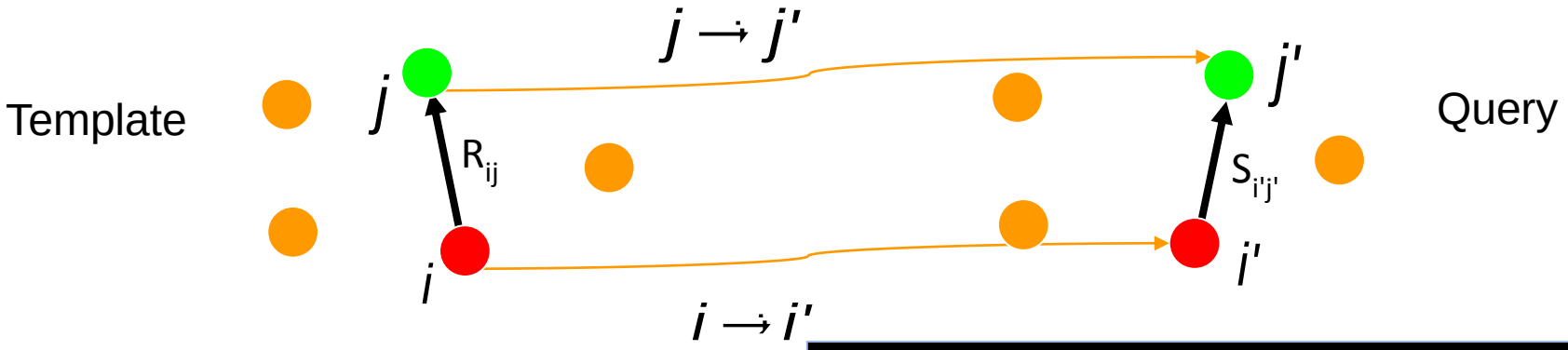
Cost function for similarity

- Quality of correspondence=Similarity of the correspondence points(match) + Change in the spatial arrangement(distortion between a pair of points in each image)

- Outliers: We assign a q_{null} for all the outliers in P when P is being mapped to Q.

Measuring Distortion (Similarity in Configuration)



Measure distortion in vectors between pairs of feature points

- **R** and **S** same length for rotations
- **R** and **S** same direction for scalings

$D_a(sig)=0 \rightarrow$ Translation and pure scale

$D_l(sig)=0 \rightarrow$ Translation and rotation

$$C_{\text{distortion}}(\sigma) = \sum_{ij} \gamma \mathrm{d_a}(\sigma) + (1-\gamma)\mathrm{d_l}(\sigma)$$

$$d_a(\sigma) = \left(\frac{\alpha_d}{|r_{ij}|} + \beta_d\right) \left|\arcsin\left(\frac{s_{i'j'} \times r_{ij}}{|s_{i'j'}||r_{ij}|}\right)\right|$$

$$d_l(\sigma) = \frac{|s_{i'j'}| - |r_{ij}|}{(|r_{ij}| + \mu_d)}$$

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Correspondence Algorithm

- First term for the distortion(R,S in the above example) and second term is match value.

$$\text{cost}(x) = \sum_{a,b} H(a,b)x_a x_b + \sum_{a} c(a)x_a$$

- Integer Quadratic problem reduction of above equation.

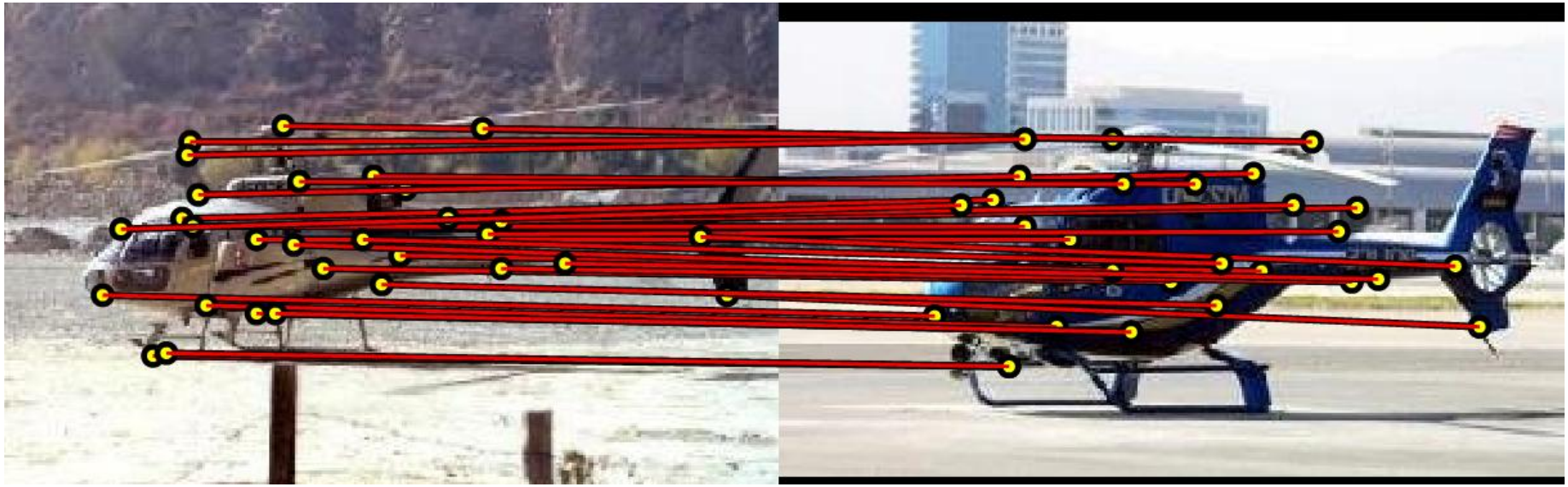
$$\min \text{cost}(x) = x'Hx + c'x \quad \text{subject to,}$$
$$Ax = b, \quad x \in \{0,1\}^n$$

..continued

- IQP is NP hard
- But here the instance the algorithm solves are generated to be easy.
- As an optimization step– The algorithm starts by initializing the bounds by gradient descent.
- Over all it assumes a run time of $O(n^2)$ time for each correspondence(n →the total number of feature descriptors chosen).

- *Math is given less emphasis with comparison to idea explanation

Quadratic Assignment (Using IQP)



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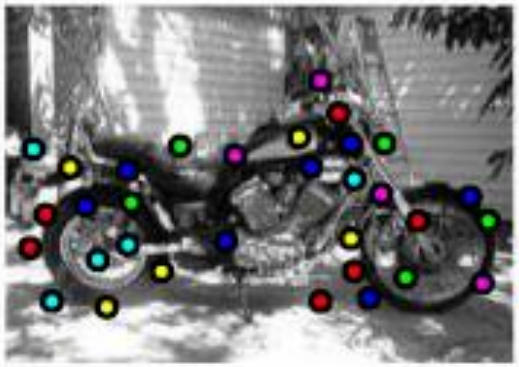
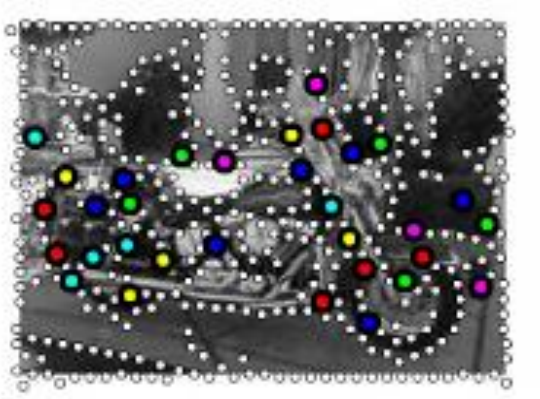
Results

- 2 object recognition problems are answered here.
  - Multi Class Recognition(48%-- previous best 16%)
  - Face Recognition(With only 20 exemplar faces, ROC curve is obtained with better generalizations and slightly worse false detection rate than existing best Face Recognition algorithm)

Correspondence Examples (Shape Matching)





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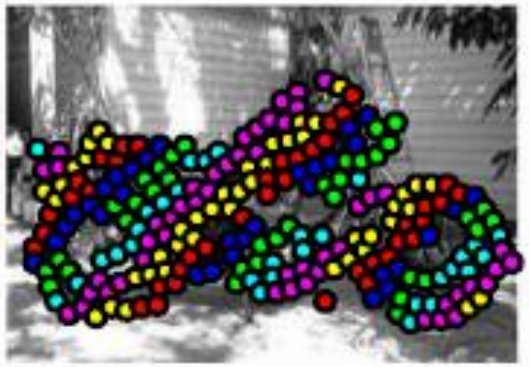

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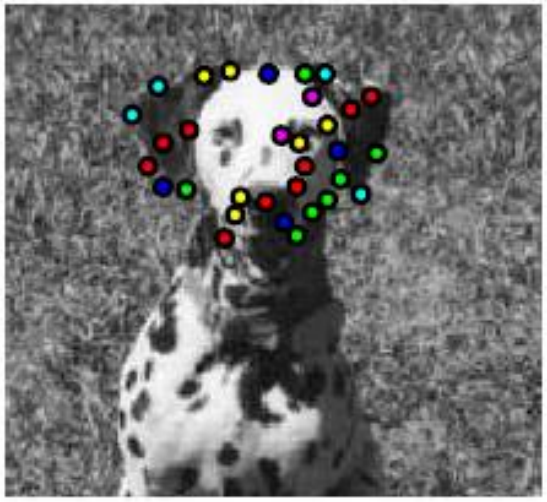

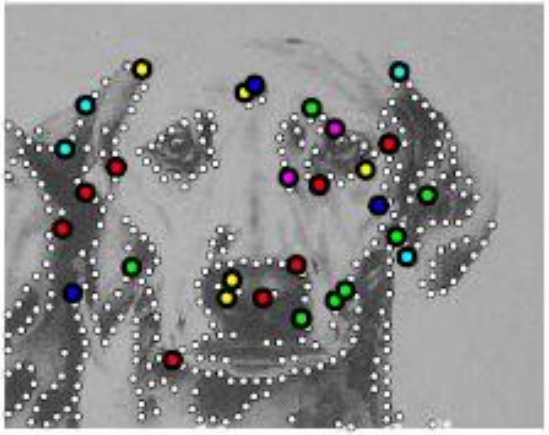

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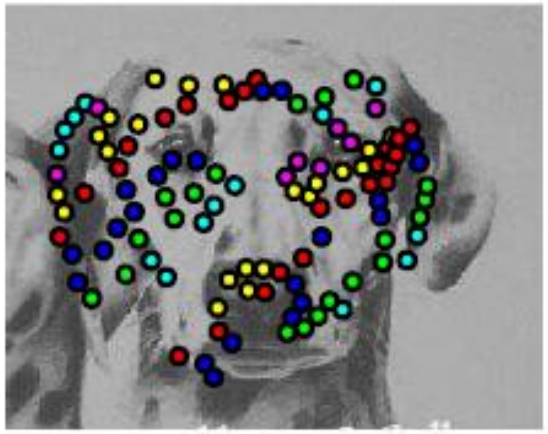

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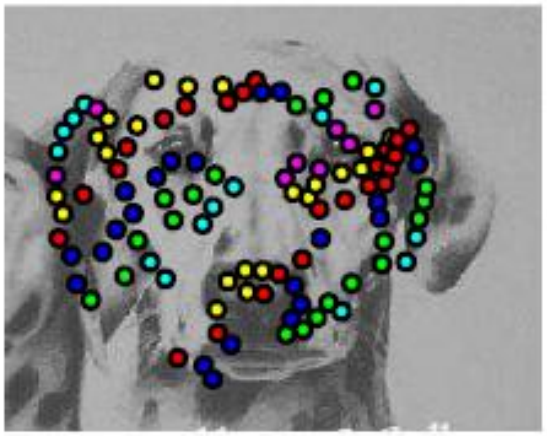

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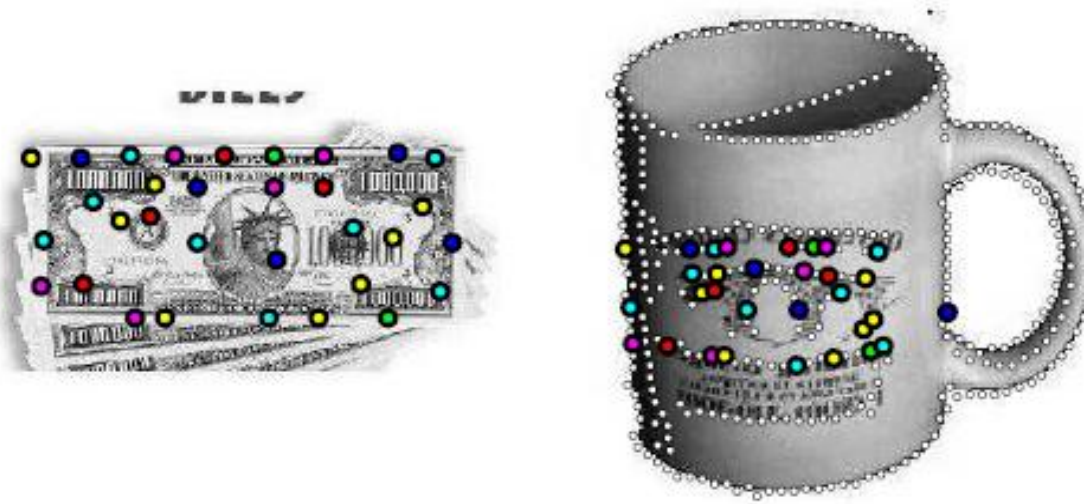

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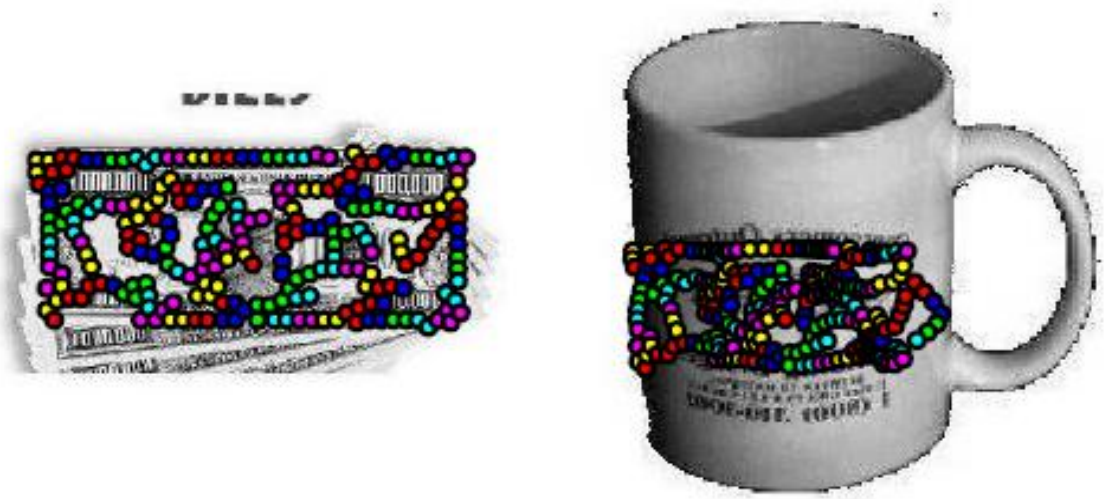

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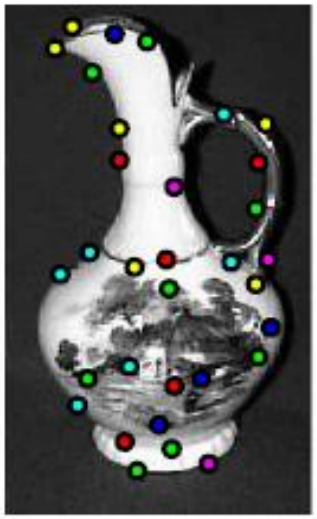

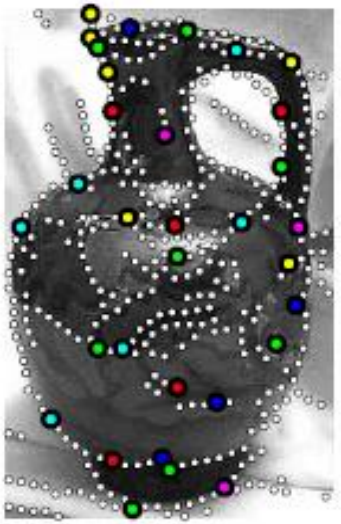

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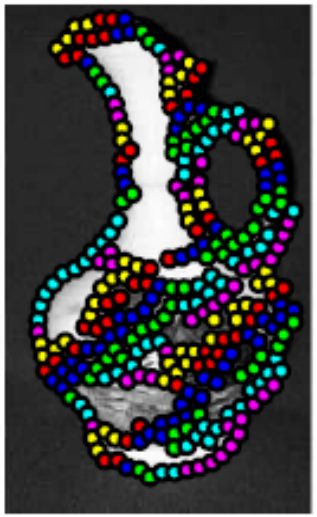

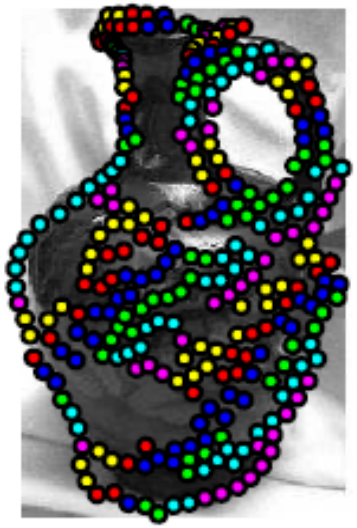

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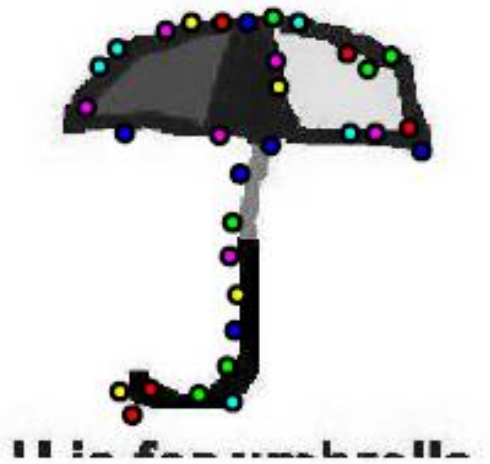

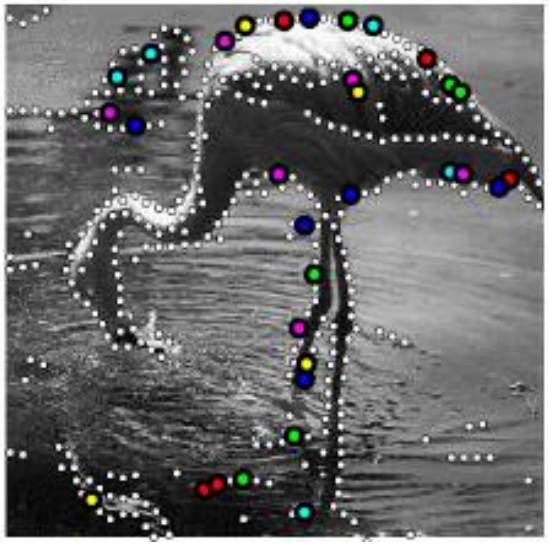

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Idea Applicability

- Applicability to break the distorted image of characters.
- Why and where is used??
  - CAPTCHA analysis.

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Conclusion

- Deformable shape matching.
- Solving Correspondence problem
- Geometric Blur concept
- IQP and fast reduction usage
- 300% improvement in Recognition rate(16% to 48%).

One last interesting point

- Ever had a doubt regarding Rainbow colored representation of feature points on images and why they are marked like that??

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There is a logic of zones of diagonals of colors to place the feature points.

References

- Original paper url: http://acberg.com/papers/berg_correspondence_cvpr.pdf
- Presentation url: acberg.com/papers/berg_cvpr05.ppt

Thank you for the patience.

Any Questions that I could Answer??