FEATURES FOR POINT SET MATCHING

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Abstract

Presented here is an optimization of a method for 2D point set matching. The elements of the point sets are pairs of coordinates. The method is based on a description with features invariant to translation, rotation, noise perturbation in coordinates and addition or deletion of points.

1 Introduction

Development of the point set matching method is motivated by the task of physical object identification. There are many professions interested in such a task. For example merchants, transport and logistics services providers, accountants, state institutions, libraries, archives, museums, research institutions, security services, even criminalists, just to name a few.

2 Point Set Matching

The goal was to optimize the method proposed in [1]. The specific aim was to cut down the calculation time. The task is formulated as follows. We have two sets of points, A and B (Figure 1, Figure 2) and we want to evaluate a measure of their similarity.

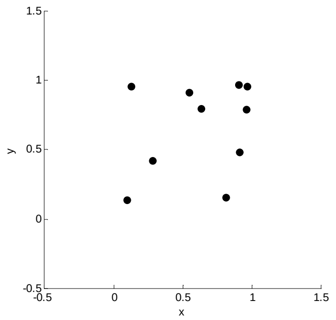

Figure 1: Point set *A*.

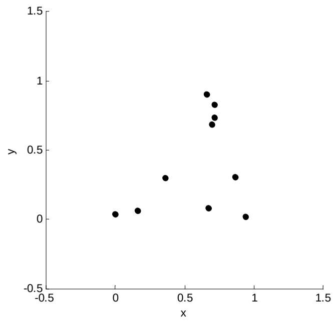

Figure 2: Point set *B*.

The group of points can be translated or rotated (Figure 3), points can be missing (Figure 4) or point coordinates can be perturbed by noise (Figure 5).

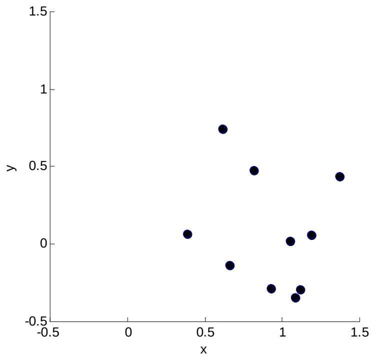

Figure 3: Point set *A*, translated and rotated.

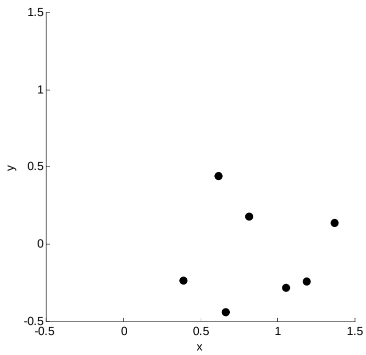

Figure 4: Point set *A*, translated, rotated, three points missing.

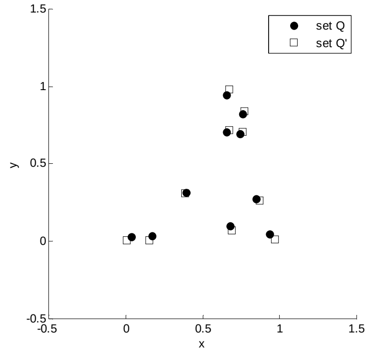

Figure 5: Two embodiments of one point set.
The point coordinates are perturbed by noise.

3 Review of approaches

Some solutions was proposed for example in [2], [3], [4] and [1]. We will resume [1]. The point set is represented as a set of features consisting of pairs: length d of the connecting line between two points and angle φ of the given connecting line and the horizontal axis (Figure 6). Features are analyzed in the feature space (Figure 7). The result is a synthesis of a quantity and its distribution. The distribution is searched for an extreme value, which is an indication of close similarity of the compared point sets (Figure 8 and Figure 9). The analysis of the neighborhood of every feature is time consuming. It takes about seconds for point's sets with 50 points [1].

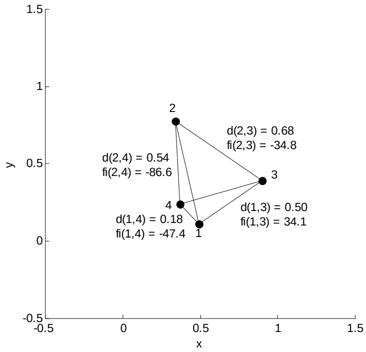

Figure 6: Representation of a point set – the lengths d of the connecting lines and their orientation φ according to horizontal axis.

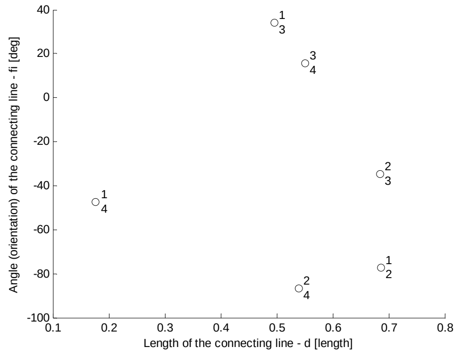

Figure 7: The feature space of d and φ.

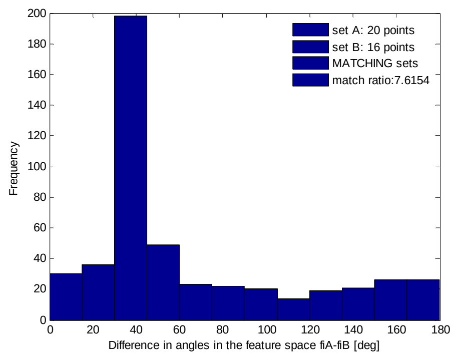

Figure 8: Distribution of angle differences. The presence of a significant maximum indicates a correspondence of the sets.

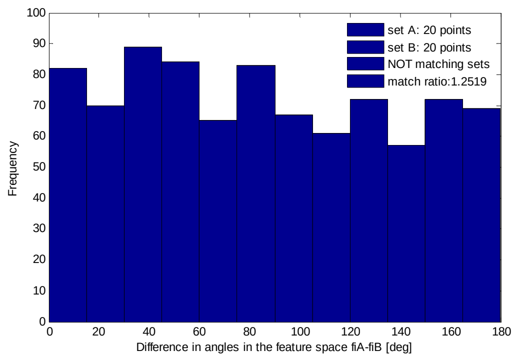

Figure 9: Distribution of angle differences. "Flat" distribution indicates not corresponding sets.

4 Optimized analysis of the feature space

Faster feature space analysis is possible by convolution. Feature spaces of both point sets are transformed into "binary images" with ones in places where are located features and with zeros elsewhere (Figure 10). The image version of one set is doubled as two tiles in a column in the direction of the angle dimension φ (Figure 11). The image of the second set is moved progressively along the (doubled) image of the first set. The sum of products element-wise of the two images is calculated for each position in the angle dimension. The result is a function indicating a measure of the match of the two point sets (Figure 12, Figure 13).

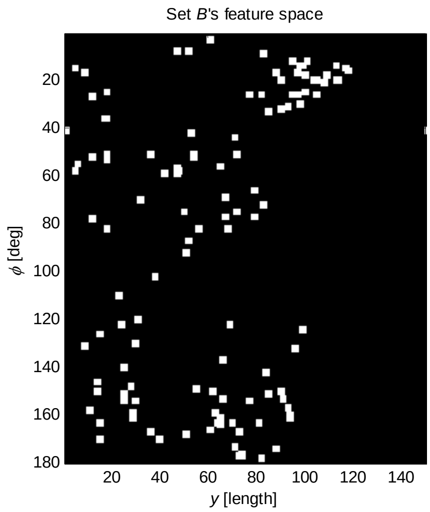

Figure 10: "Binary image" of the feature space.

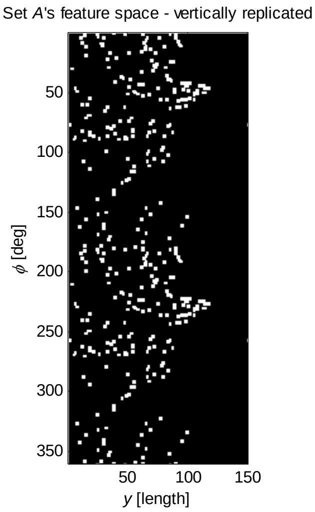

Figure 11: Doubled "binary image" of the feature space.

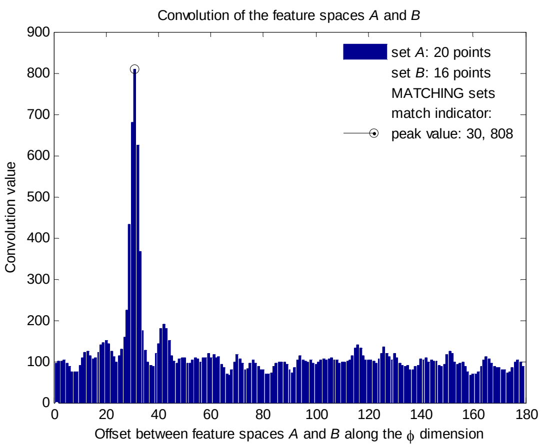

Figure 12: Convolution of feature spaces – the *presence* of a significant *maximum* indicates a *correspondence* of the sets.

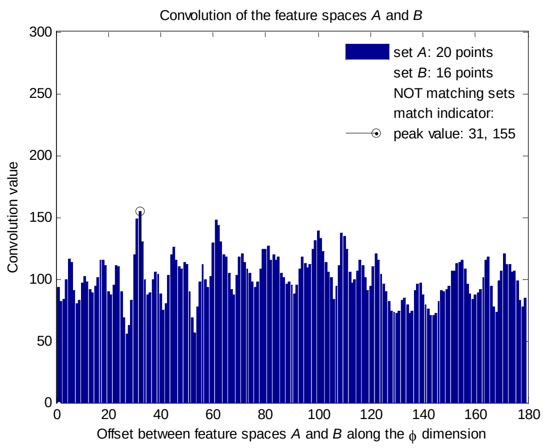

Figure 13: Convolution of feature spaces – *"flat"* distribution indicates *not corresponding* sets.

5 Implementation

The proposed optimization was implemented on a computer system with MATLAB R2011b on an IBM T60 notebook (2 CPU's, 1.8 GHz, 2.5 GB RAM). Analyzing point sets of arbitrary number of points takes approximately 0.05 seconds with a feature space with 150 pixels wide in the length dimension y and 180 pixels high in the angle dimension φ (Figure 10).

The implementation used a few particularly powerful MATLAB functions. The features (distances d, angles φ) were computed by `pdist` function from the *Statistics Toolbox* with custom `distfun = @(u,V) atand((V(:,2)-u(1,2))./(V(:,1)-u(1,1))` for calculating the angles φ. The *Signal Processing Toolbox's* `findpeaks` was used for finding the maximum in the convolution of the feature spaces. Finally `imtool` from *Image Processing Toolbox* was quite handy during elaboration with the images of the feature spaces.

6 Conclusion

The proposed optimization resulted in an approximately constant computing time for comparison of two point sets with arbitrary number of points. The computing time ~ 0.05 seconds is a significant optimization of the original method [1] (10 points → 0.02 seconds, 20 points → 0.1 seconds; 50 points → 2.5 seconds).

The future work will be focused on further optimization. More structured image of the feature space will allow some kind of weighting. This could include areas where the feature *y* approaches extremes and more levels of features instead of the current two-level (0/1 or "binary") approach.

Acknowledgement

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References

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