Localization and Transformation Reconstruction of Image Regions: An Extended Congruent Triangles Approach

Afra'a Ahmad Alyosef, Christian Elias Andreas Nürnberger, {afraa.ahmad-alyosef, andreas.nuernberger}@ovgu.de, Data & Knowledge Engineering Group.

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Motivation

Most of the existing methods to localize (sub) image relations – a subclass of near-duplicate retrieval techniques – rely on the distinctiveness of matched features of the images being compared. These sets of matching features usually include a proportion of outliers, i.e. features linking non matching regions. In approaches that are designed for retrieval purposes only, these false matches usually have a minor impact on the final ranking. However, if also a localization of regions and corresponding image transformations should be computed, these false matches often have a more significant impact. We present a novel outlier filtering approach "ECOTA" to classify outliers and describe the correlation between image regions without any prior knowledge about the content of images. The comparison with the state of the art approaches indicates that our approach is more robust than those approaches and is able to detect correlation even when most matches are outliers. Moreover, ECOTA reduces significantly the pre-processing time to filter the matches.

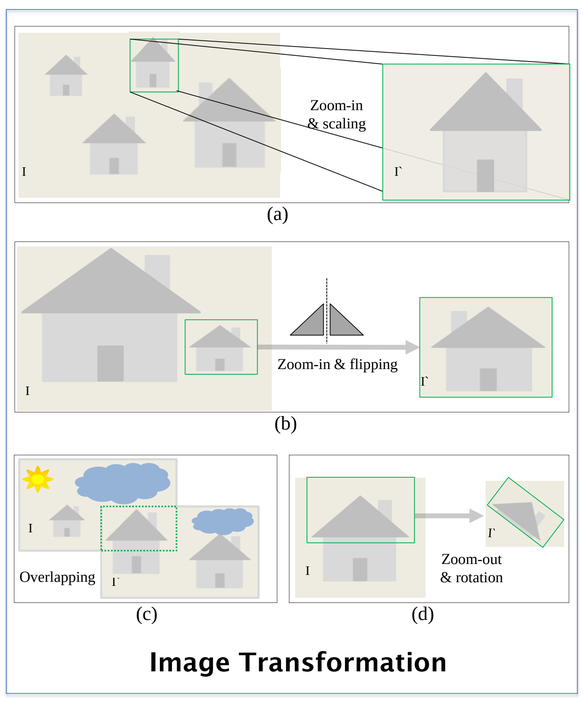
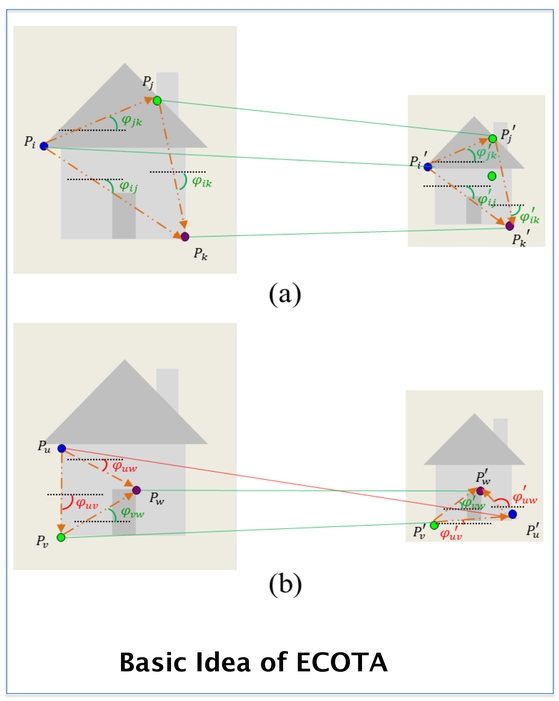


Image Transformation



Basic Idea of ECOTA

Proposed Approach: Extended Congruent Triangles Approach

Correlation Estimation

In the optimal case, the matched features between two near-duplicate images have a specific pattern. However, in practice, sets of false matches may appear and also construct other "false" pattern. To detect the correct pattern, we follow the steps:

- For feature matches P_i, P_j, P_k and P'_i, P'_j, P'_k of images I and I', check whether the corresponding triangles are congruent i.e. they fulfil the following relations:

$$\left| \frac{l_i}{\max\{l_i, l_j, l_k\}} - \frac{l_i'}{\max\{l_i', l_j', l_k'\}} \right| < \varepsilon \qquad (1)$$

  For all of l_i, l_j, l_k and l_i', l_j', l_k', were $L' = \{l_1', l_2', \dots, l_m'\}$, $L = \{l_1, l_2, \dots, l_m\}$ are the edges of triangles
- If condition 1 is justified then compute and check the relation of gradient s:

$$\varphi_{ij} = tan2(m_{ij}) = tan2\left(\frac{y_j - y_i}{x_j - x_i}\right) \quad \varphi'_{ij} = tan2(m'_{ij}) = tan2\left(\frac{y'_j - y'_i}{x'_j - x'_i}\right)$$

$$\left|\varphi_{ij} - \varphi'_{ij}\right| < \vartheta \qquad (2)$$

- If the keypoints P_i, P_j, P_k and P'_i, P'_j, P'_k relations 1 and 2 then they are correct matches.
- If relations 1 and 2 are not fulfilled for all three keypoints then the false keypoint matches is immediately determined through the gradient.

Rotation & Flipping Estimation with ECOTA

- To estimate the rotation instead of condition 2 we check the following condition:

$$\left|\varphi_{ij} - \varphi'_{ij}\right| < \theta \pm \vartheta \qquad (3)$$

- To detect the flipping, we check the condition:

$$\left|\varphi_{ij} - \varphi'_{ij}\right| = 0 \pm \vartheta \quad or \quad \left|\varphi_{ij} - \varphi'_{ij}\right| = \pi \pm \vartheta \qquad (4)$$

We apply 1, 2, 3 and 4, on a set of best feature matches, if they satisfy the same correlation, we employ them to detect the outliers and determine the exact correlation between images without any knowledge about their contents

Evaluation & Results

The performance of ECOTA is evaluated using the following settings:

- Five Datasets are used that contain images of different structures i.e. panoramas, paintings or aerial images (PANO, XOB, Aerial, PAIN, ATRANS)
- Query images are transformed images that are downscaled, rotated, flipped, shifted or cropped from the datasets
- Three kinds of keypoints are utilized: SIFT, SURF and BRISK

Time Complexity Employing various Keypoints

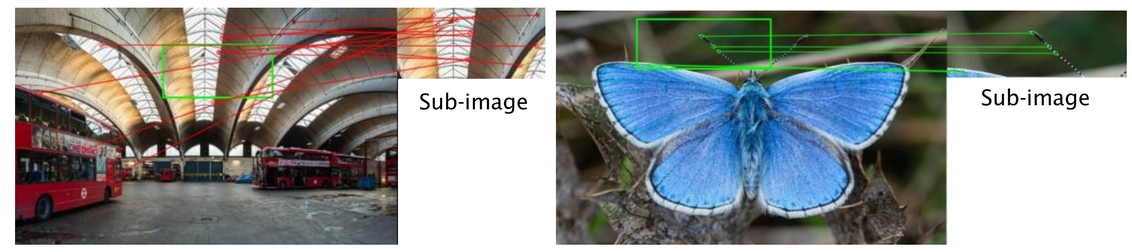
Method	RANSAC	PROSAC	LMEDS	ECOTA
SIFT	1.58 ms	0.72 ms	9.61ms	**0.61 ms**
SURF	1.59 ms	**0.52 ms**	7.94 ms	0.66 ms
BRISK	2.63 ms	**0.62 ms**	8.64 ms	0.69 ms

Comparison of RANSAC, PROSAC, LMEDS &ECOTA

Scale	Method	Detected Correlation				Localization Error			
		RANSAC	PROSAC	LMEDS	ECOTA	RANSAC	PROSAC	LMEDS	ECOTA
100%	SIFT	83.74	83.71	81.91	***99.92***	0.0016	0.0016	0.0016	***0.0013***
	SURF	96.75	95.52	96.67	**98.20**	0.0024	0.0020	0.0020	**0.0018**
	BRISK	85.37	81.65	85.60	**93.16**	0.0028	0.0029	0.0028	**0.0025**
30%	SIFT	78.86	65.98	76.14	***97.10***	0.0033	0.0036	0.0031	***0.0024***
	SURF	81.30	72.28	82.46	**87.02**	0.0040	0.0046	0.0038	**0.0035**
	BRISK	69.75	59.30	67.44	**75.58**	0.0049	0.0057	0.0049	**0.0045**
200%	SIFT	84.55	83.53	80.96	***99.96***	0.0016	0.0016	0.0016	***0.0013***
	SURF	81.30	96.83	97.38	**98.38**	0.0020	0.0019	0.0019	**0.0018**
	BRISK	95.94	90.18	91.72	**96.51**	0.0027	0.0025	0.0024	**0.0021**

Discussion of Outliers Filtering

RANSAC, PROSAC, LMEDS fail in correlation detection, since there are too many outliers or too few feature matches

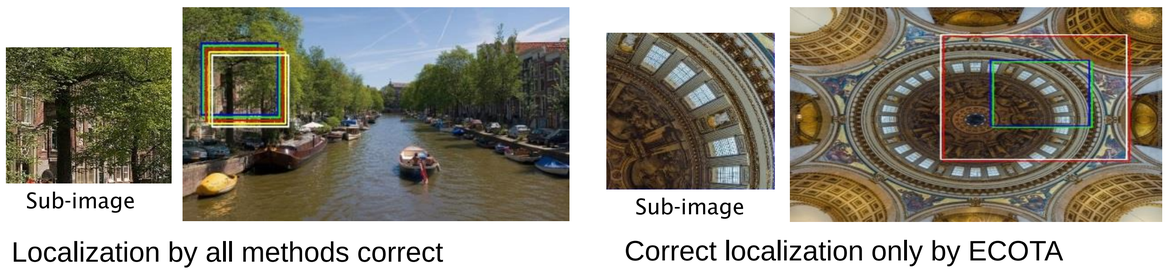


ECOTA detects 50% of features matching as outliers (red lines)

ECOTA detects the correlation even only four matches are correct (green lines)

Qualitative Discussion of Localization & Categorization

Localization of sub-images in whole scene using RANSAC (red), PROSAC (yellow), LMEDS (white) & ECOTA (blue). The ground-truth is the Green box.



Localization by all methods correct

Correct localization only by ECOTA

Summary

- ECOTA applies the property of congruency triangles with gradient to classify features matching into correlating group (inliers) and non-correlating (outliers).
- ECOTA uses the correlating group of matched features to:
  - Exclude the outliers of feature matches
  - Define the non-relevant images in the list of retrieved images
  - Describe the correlation between two images without any previous details about their content
  - Determine the location of one image in the other
- ECOTA reduces the computational time of correlation detection
- ECOTA outperforms RANSAC, PROSAC, LMEDS and COTA models in estimating and categorization image correlations