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INF FAKULTÄT FÜR INFORMATIK

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

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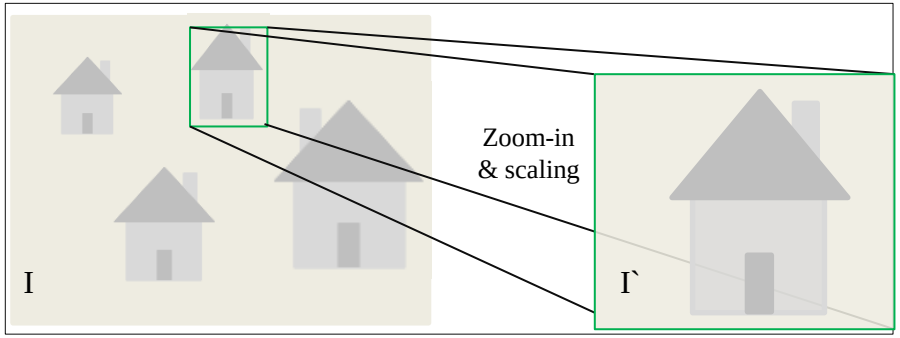
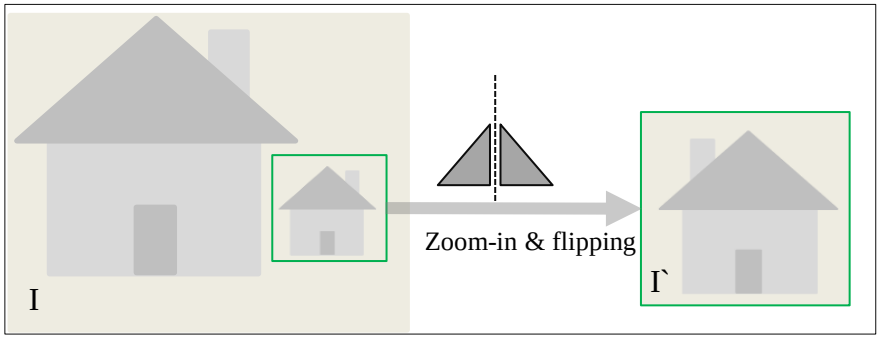
Introduction: Image Near-Duplicates

Near duplicate images in this work:

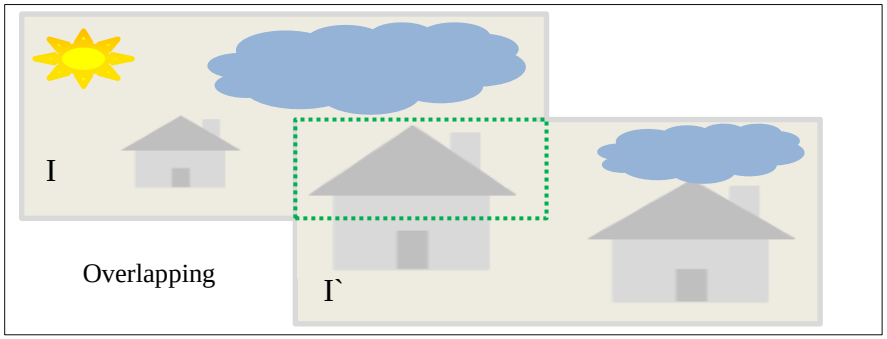
- Zoomed-in panorama with scale change
- Flipped or flipped sub-image
- Shifted image
- Rotated sub-image



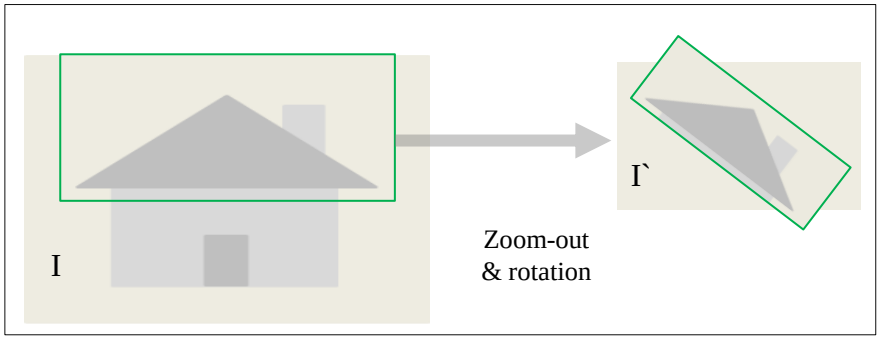
(a)



(b)



(c)



(d)

Related Work:

Approaches to detect the correlation between images

- Non-deterministic approaches: RANSAC, PROSAC, LMEDS
  - Pro: low computing costs
  - Contra: performance decreases when the false feature matches increase

- Deterministic approaches
  - Pro: detect the false feature matches
  - Contra: high computation costs, cannot detect all kinds of transformations

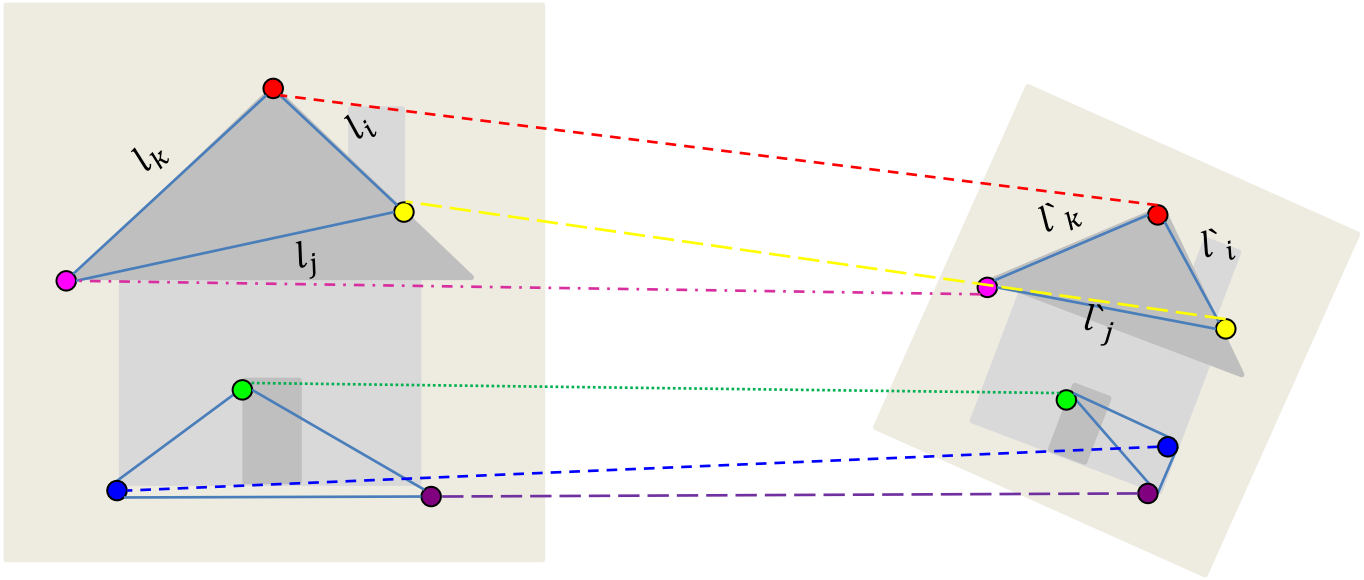
Goal

- Detect the correlation between two image
  - When false feature matches more than 50% of total matches
  - Too few feature matches are detected (lesser than six)
- Reduce the computation costs
- Split the feature matches into inliers and outliers
- Based on the correlated features (inliers) define the kind of transformation between near-duplicate images

Proposed Approach: ECOTA

Extended Congruent Triangles Approach:

Extension of our previous approach COTA

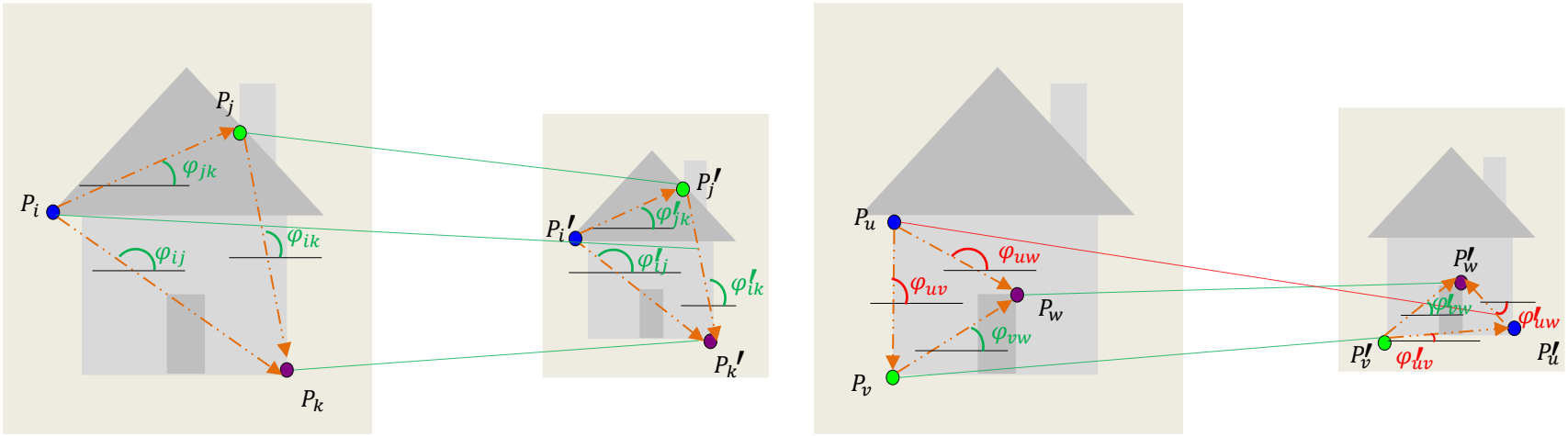


$$\left| \frac{l_i}{\max\{l_i, l_{j,} l_k\}} - \frac{l_i'}{\max\{l_i', l_j', l_k'\}} \right| < \varepsilon$$

Proposed Approach:

Extended Congruent Triangles Approach

In addition to edge in COTA we compute the gradient of edges



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

$$\left|\varphi_{ij} - \varphi'_{ij}\right| < \vartheta$$

Proposed Approach: ECOTA

Extended Congruent Triangles Approach: Estimate rotation & flipping

Rotation:

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

Flipping:

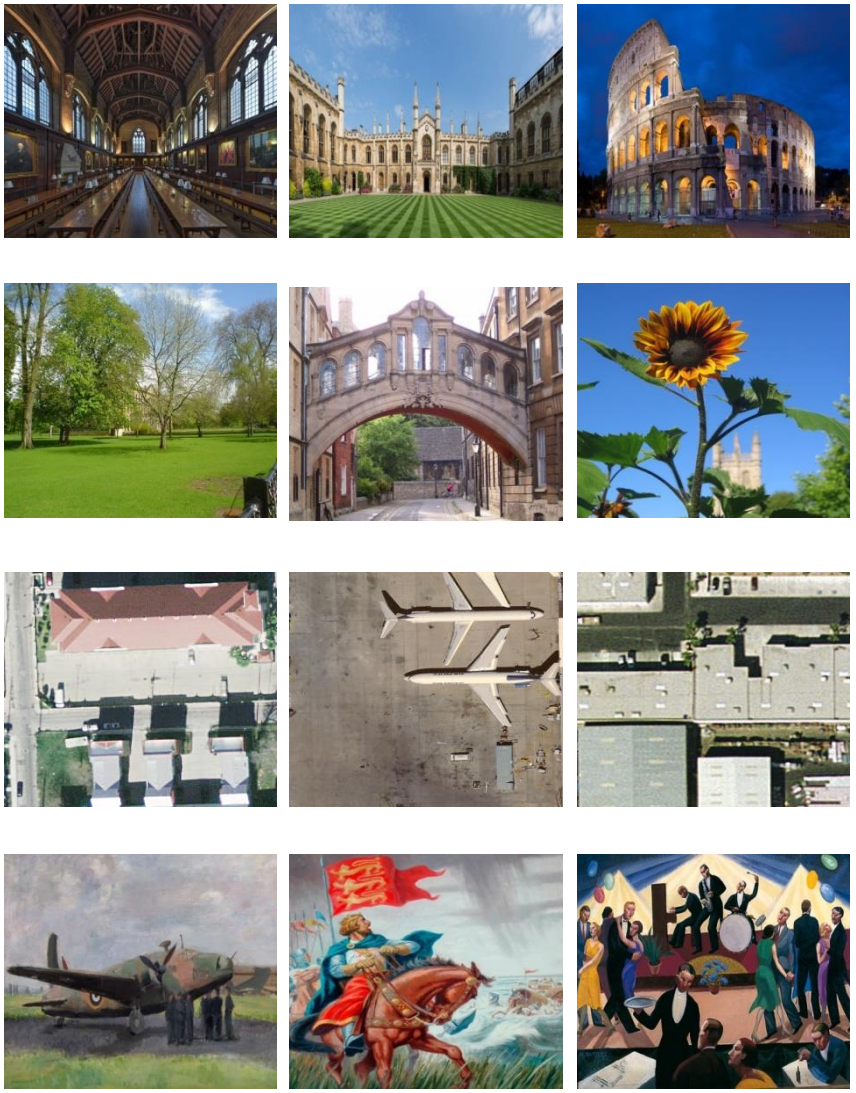
$$\left|\varphi_{ij} - \varphi'_{ij}\right| = 0 \pm \vartheta \quad or \quad \left|\varphi_{ij} - \varphi'_{ij}\right| = \pi \pm \vartheta$$

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

Results/ Benchmarks

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



Results/ Panorama Images

- Panorama benchmark: 20,000 sub-images of different scales and resolutions
- Three kinds of keypoints are utilized: SIFT, SURF and BRISK
- 200 queries (full panoramas)

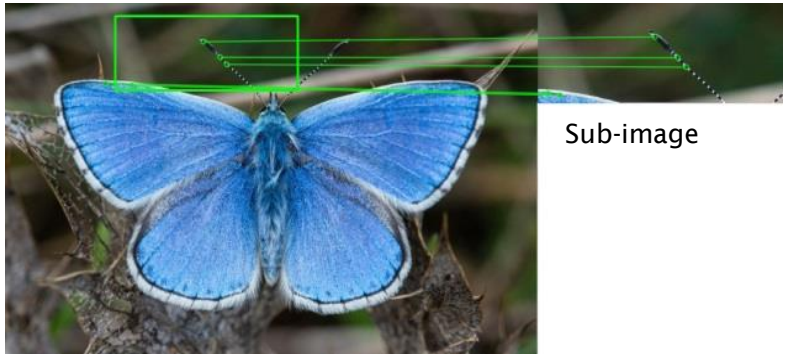
Comparison of RANSAC, PROSAC, LMEDS &ECOTA

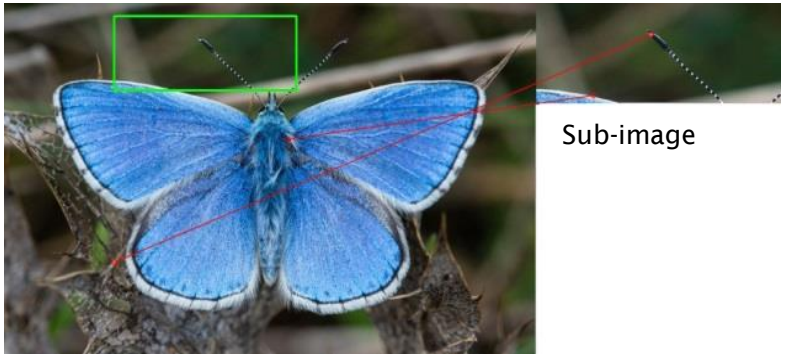
Scale	Method	Detected Correlation				Localization Error			
		RANSAC	PROSAC	LMEDS	ECOTA	RANSAC	PROSAC	LMEDS	ECOTA
100%	SIFT	83.74	83.71	81.91	***99.92***	0.0016	0.0016	0.0016	***0.0013***
	SURF	96.75	95.52	96.67	**98.20**	0.0024	0.0020	0.0020	**0.0018**
	BRISK	85.37	81.65	85.60	**93.16**	0.0028	0.0029	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**

Results: 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)

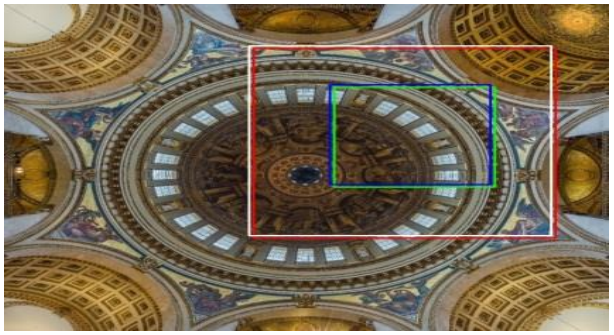
Results: Qualitative Discussion

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

Sub-image

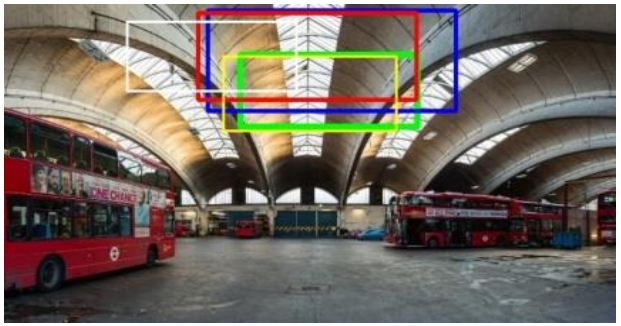
Localization by all methods correct

Sub-image



Correct localization only by ECOTA

Sub-image



Wrong localization by all methods

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 the content
- ECOTA reduces the computational time of correlation detection
- ECOTA outperforms RANSAC, PROSAC, LMEDS and COTA models in estimating and categorization image correlations

THANK YOU