Image Matching via Saliency Region Correspondences

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How to match two pictures with small overlap and repeated patterns?

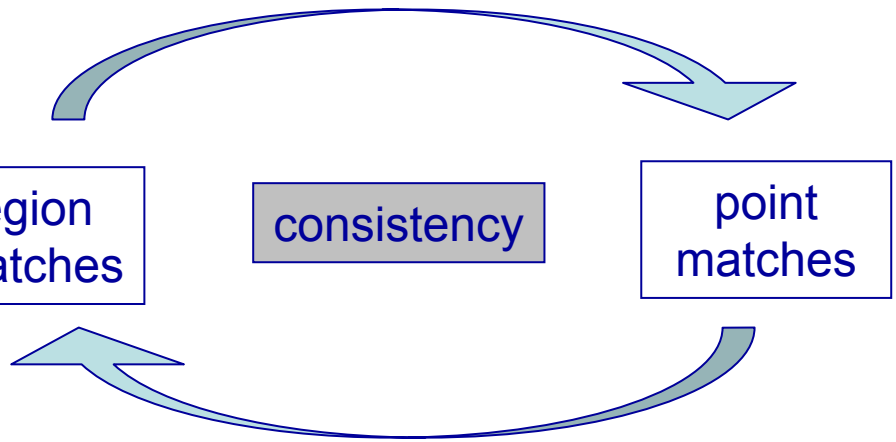
How to match two pictures with small overlap and repeated patterns?

Most approaches assume large dominant overlaps

RANSAC needs **sufficient inlier portion** (> 30%)
and assumes a **model**.

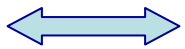
Can we match without a model and still deal with small overlap?

Using Regions in Matching



Interplay Between Region and Feature Matches

Propagation of feature matches to region matches



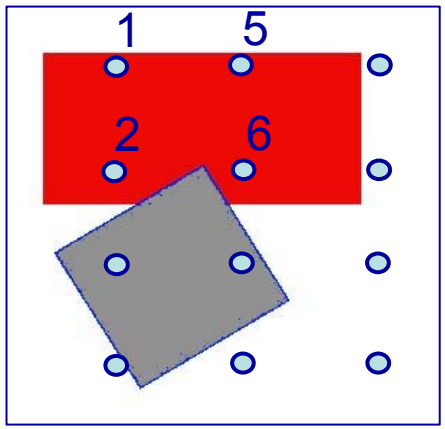
Restriction of feature matches only to ones relating matching regions

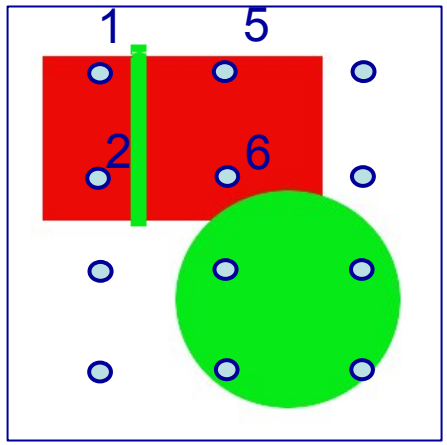
Co-Salient Regions

Goal 1:
Form **coherent image segments**
→ Intra-Image Similarity

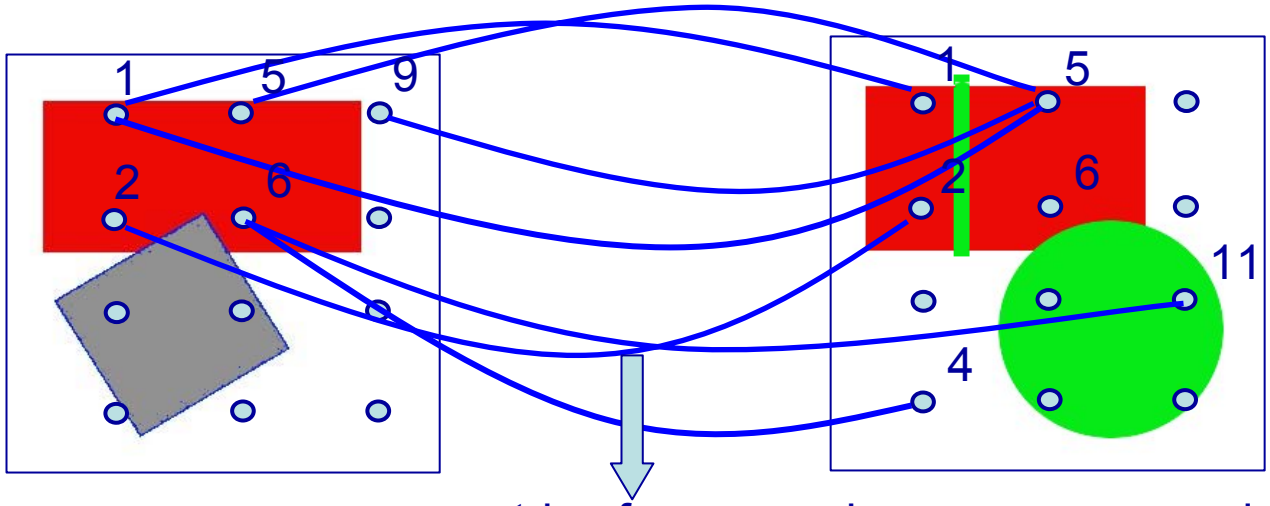
Goal 2:
Exhibit strong feature **similarities between the segments**
→ Inter-Image Similarity

Image as a Graph





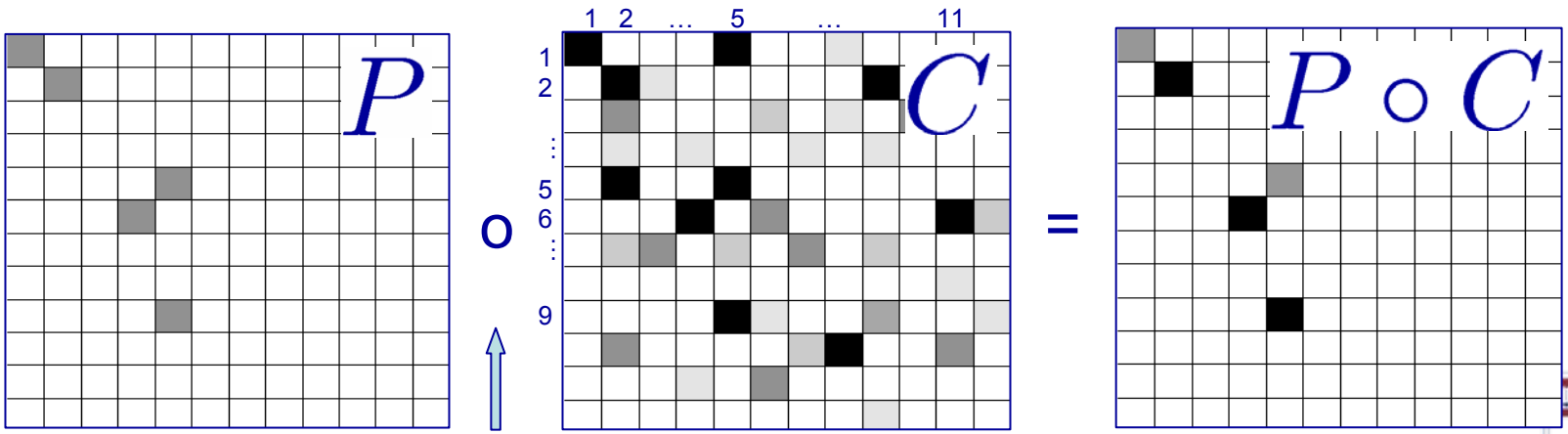
Correspondence Matrix: $P \circ C$



matrix of measured correspondences

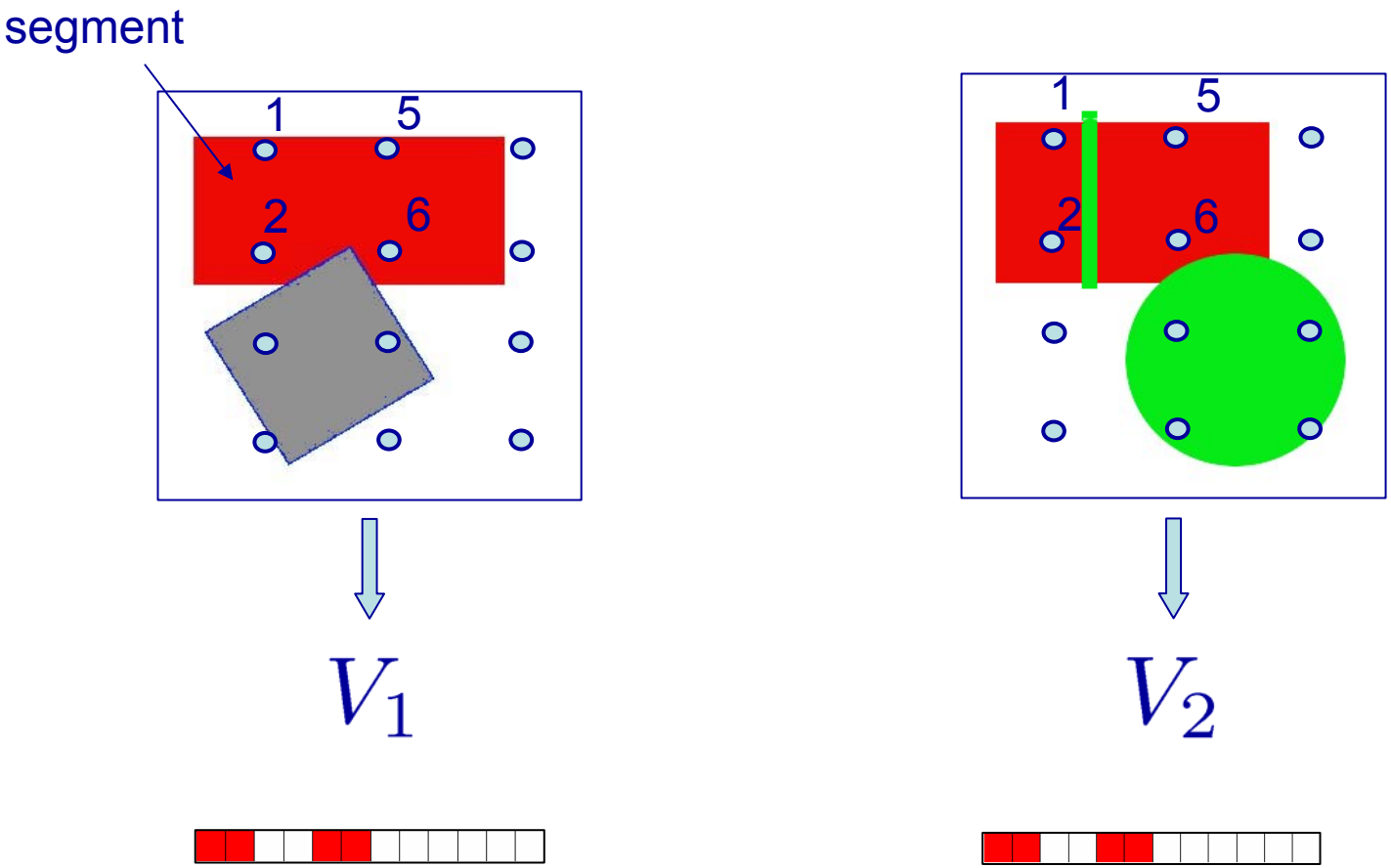
selection matrix

correspondence matrix

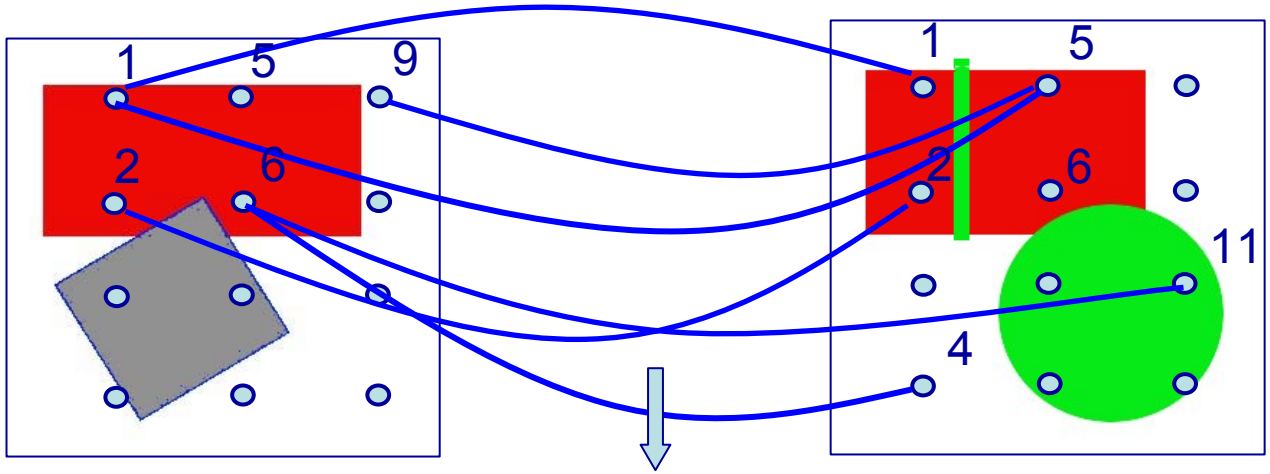


pointwise multiplication

Segment Indicator Vectors



Inter-Image Similarity

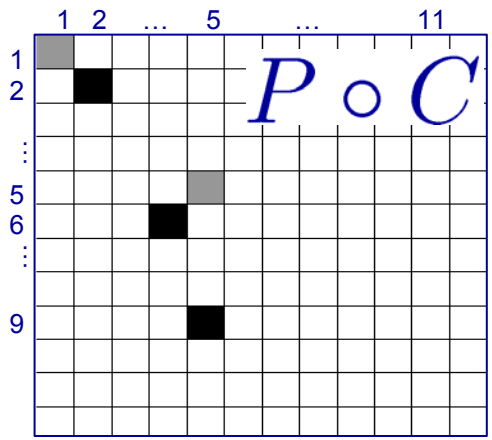


correspondence matrix

segment indicator vector

V_1

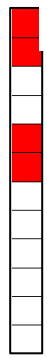
x



$P \circ C$

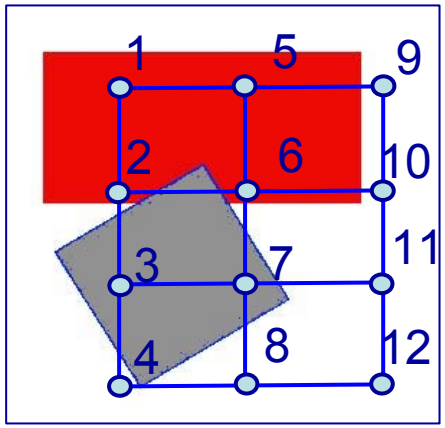
x

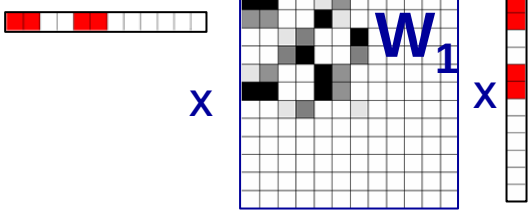
V_2



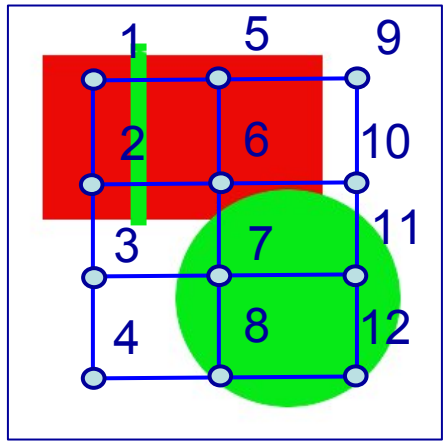
$$= V_1^T (P \circ C) V_2$$

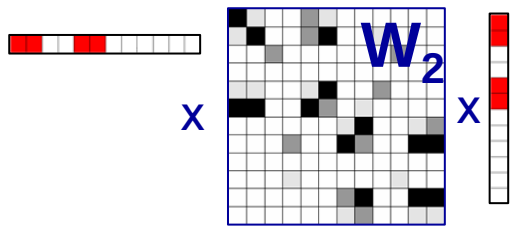
Intra-Image Similarity





$$V_1^T W_1 V_1$$



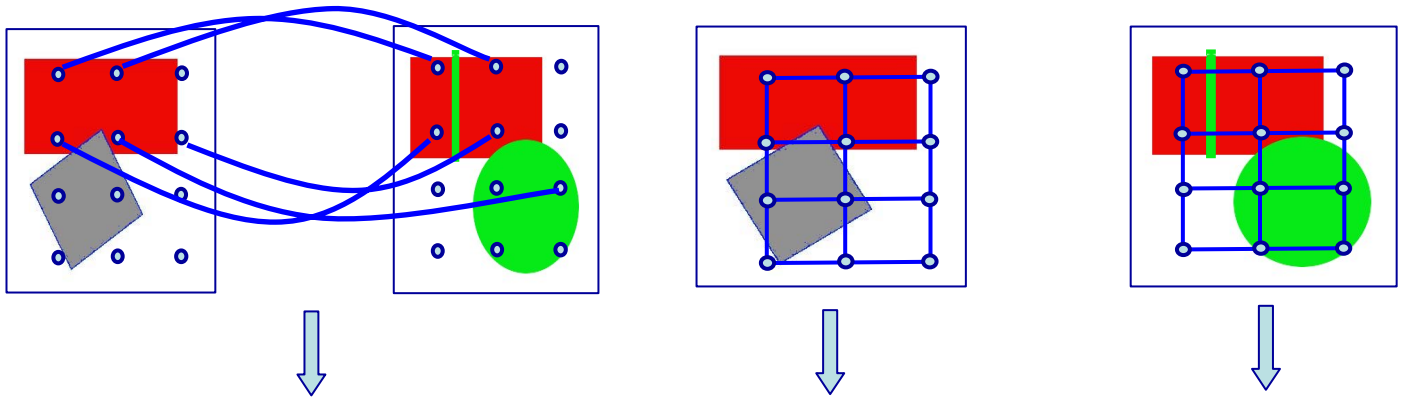


$$V_2^T W_2 V_2$$

Co-Salient Region Matching Score

inter-image similarity

intra-image similarities



$$V_1^T(P \circ C)V_2 \quad + \quad V_1^T W_1 V_1 \quad + \quad V_2^T W_2 V_2 =$$

$$tr\left(V^T \begin{pmatrix} W_1 & (P \circ C) \\ (P \circ C)^T & W_2 \end{pmatrix} V\right) \quad \text{with} \quad V = \begin{pmatrix} V_1 \\ V_2 \end{pmatrix}$$

Co-Salient Region Matching Score

$$\text{Score}(V,P) = tr\left(V^T \begin{pmatrix} W_1 & (P \circ C) \\ (P \circ C)^T & W_2 \end{pmatrix} V\right)$$

Goal 1:

Matching co-salient regions: find optimal **V** for given initial selection **P** of matches from C.

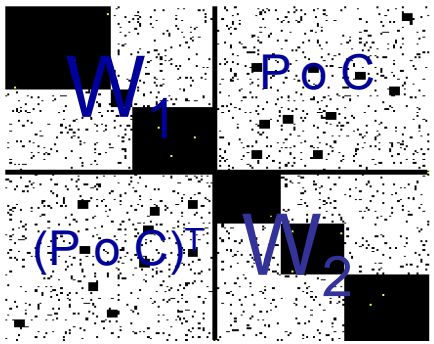
Goal 2:

Inlier selection for point matches: find optimal selection matrix **P** for given co-salient regions **V**.

Matching Co-Salient Regions I

Maximize $tr\left(V^T \begin{pmatrix} W_1 & (P \circ C) \\ (P \circ C)^T & W_2 \end{pmatrix} V\right)$ w.r.t. V

Naïve attempt – optimization with no restrictions on V **fails** !



(P o C) is much sparser than W_1 and W_2

Intra-image similarities dominate score function

$$\text{Score} = V_1^T (P \circ C) V_2 + V_1^T W_1 V_1 + V_2^T W_2 V_2$$

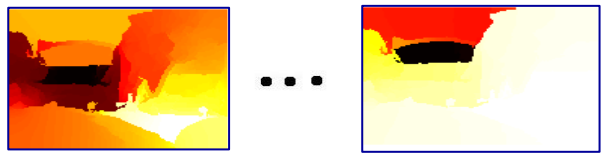
Matching Co-Salient Regions II

Better: restrict co-salient regions to lie in a
space of dominant segmentation modes

input images

spectral basis / dominant segmentation modes

Spectral segmentation



$s_1 \quad \cdots \quad s_k$

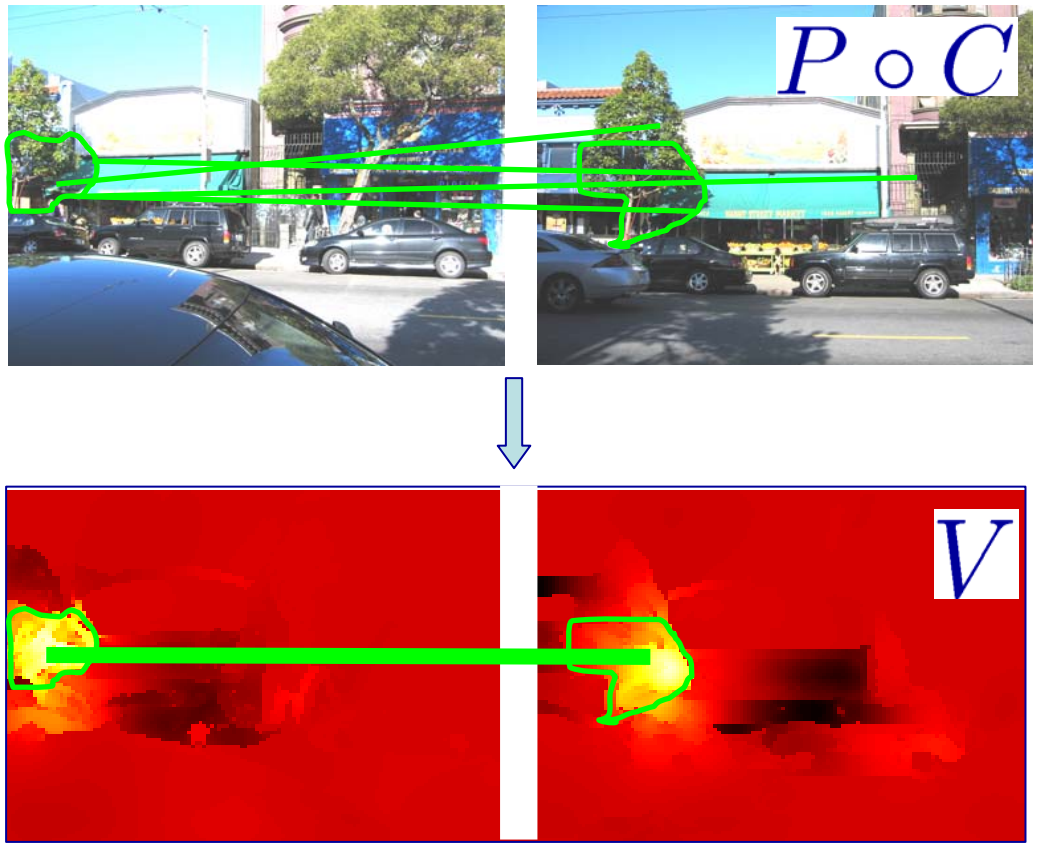
restrict solution space: $V = SA$

co-salient regions

projection in subspaces

Matching Co-Salient Regions III

Maximize $tr\left(V^T \begin{pmatrix} W_1 & (P \circ C) \\ (P \circ C)^T & W_2 \end{pmatrix} V\right)$ for $V = SA$



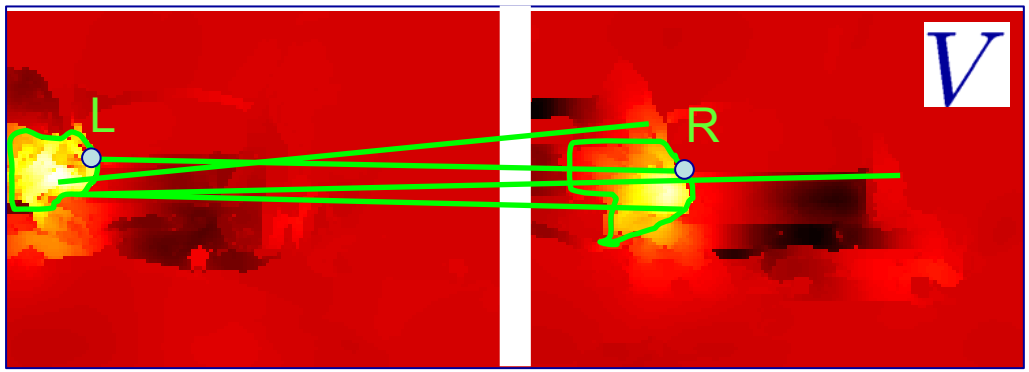
Restrict co-salient regions to a space of dominant segmentation modes

The subspace restriction enables

- **clear matches** of co-salient regions
- **propagation** of feature matches to region matches

Inlier Selection

Maximize $tr\left(V^T \begin{pmatrix} W_1 & P_{inlier} \circ C \\ (P_{inlier} \circ C)^T & W_2 \end{pmatrix} V\right)$ w.r.t. P_{inlier}



Such that:

- $P_{inlier} \subset P$
- Consistency with region matches

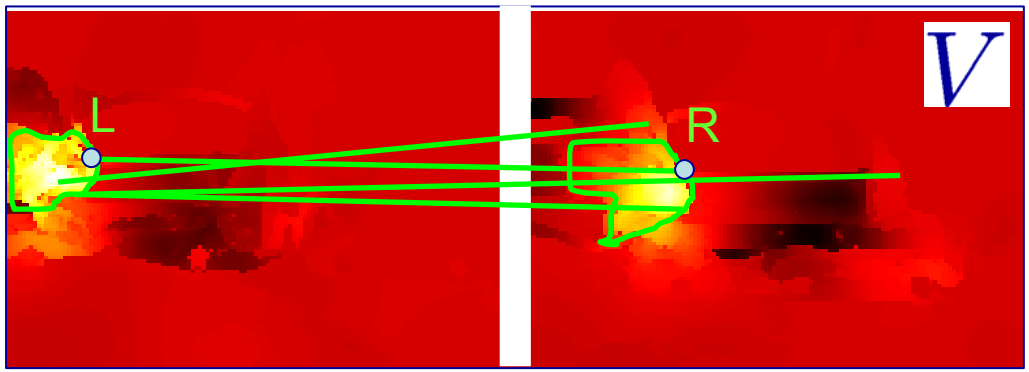
Linear Programming

$$P_{inlier} \circ C \leftarrow (P \circ C) \circ V_1 V_2^T$$

$$\begin{pmatrix} \cdot & \cdot & \cdot \\ \cdot & V_{1,L} \cdot V_{2,R} & \cdot \\ \cdot & \cdot & \cdot \end{pmatrix}$$

Inlier Selection

Maximize $tr\left(V^T \begin{pmatrix} W_1 & P_{inlier} \circ C \\ (P_{inlier} \circ C)^T & W_2 \end{pmatrix} V\right)$ w.r.t. P_{inlier}



Such that:

- $P_{inlier} \subset P$
- Consistency with region matches

Linear Programming

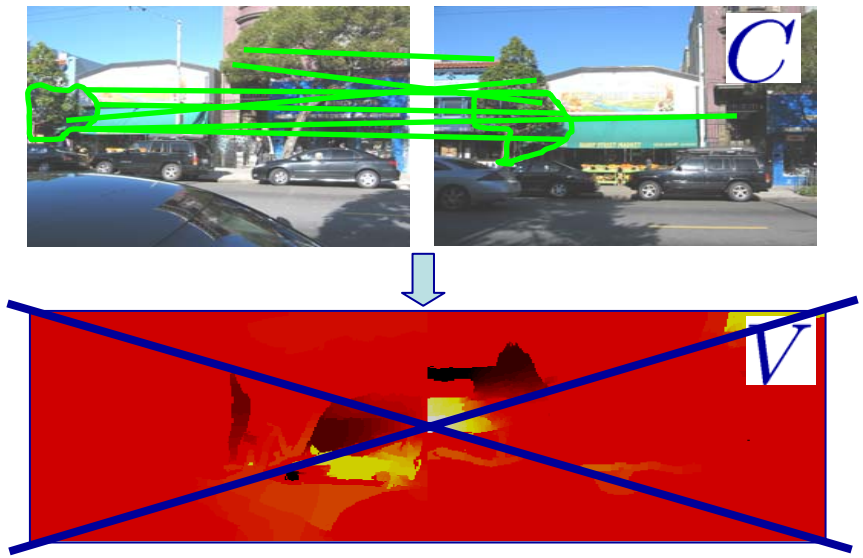
$$P_{inlier} \circ C \leftarrow (P \circ C) \circ V_1 V_2^T$$

P_{inlier} is consistent with co-salient region matches **V**

Inlier Selection – Dense Set of Matches

How can we obtain a dense set of correspondences?

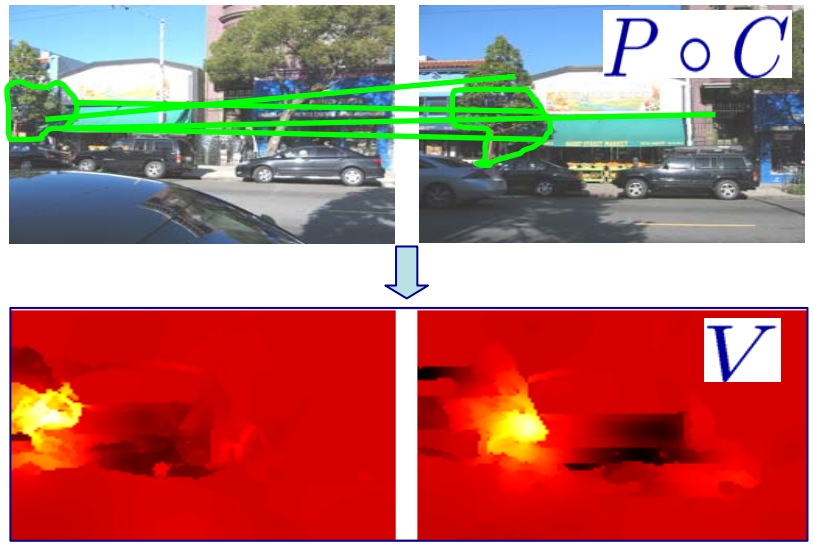
set of **all** matches



Inlier Selection – Dense Set of Matches

How can we obtain a dense set of correspondences?

initial sparse set of matches

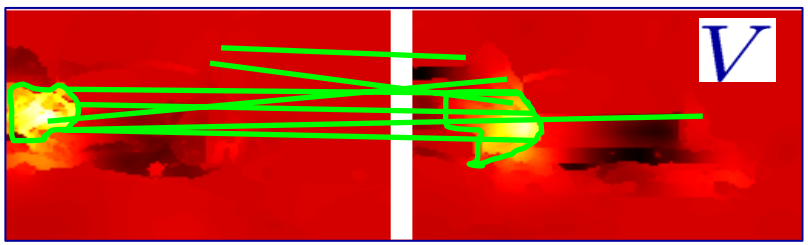


set of **all** matches

Inlier Selection – Dense Set of Matches

How can we obtain a dense set of correspondences?

initial sparse set of matches



set of **all** matches

$C \circ V_1 V_2^T$

Selection of feature matches from **C** based on co-salient region matches **V**.

Algorithm

For given input images

- compute segmentation spaces S

Algorithm

select P

For given input images

- compute segmentation spaces S
- compute feature matches C, P

Algorithm

select P

solve for V

For given input images

- compute segmentation spaces S
- compute feature matches C, P
- detect co-salient region

Algorithm

select P

solve for V

For given input images

- compute segmentation spaces S
- compute feature matches C, P
- detect co-salient region
- select inliers

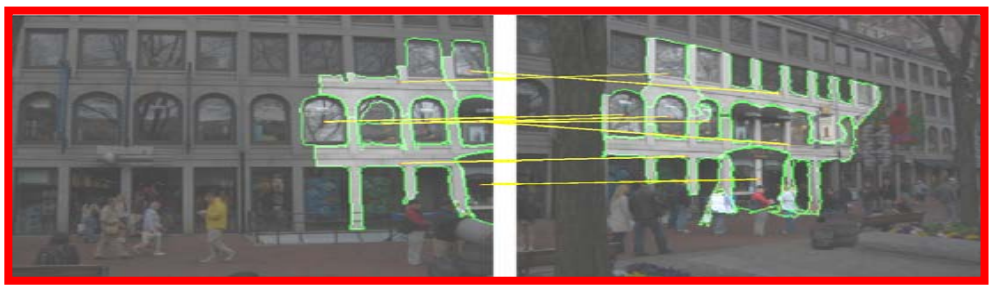
solve for

$$P \circ C$$

Algorithm

select P

solve for V



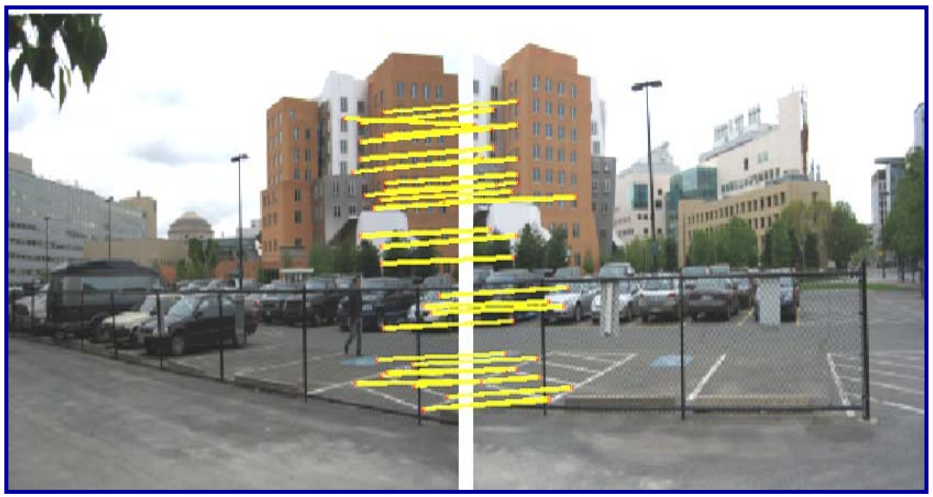
For given input images

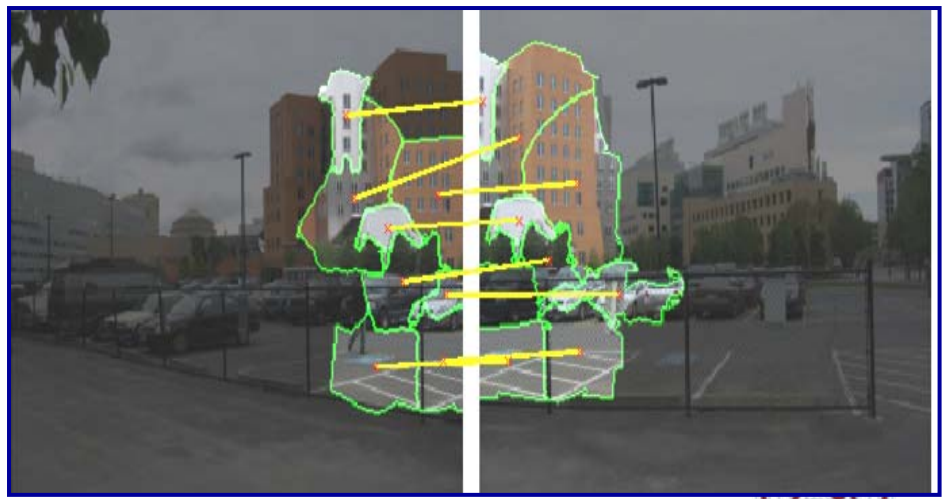
- compute segmentation spaces S
- compute feature matches C, P
- detect co-salient region
- select inliers
- goto step 3

solve for

$P \circ C$

Results





Results

Results


OLD MAIN
FACET
GALLERY


OLD MAIN
FACET
GALLERY


christie's


christie's

Results

Where am I?

query:

[ICCV 2005 CV Contest]

accuracy rate of point matches

matches ranked among	initial P	P_{dense}
1 – 30	19%	75%
31 - 60	12%	52%
60 - 90	15%	44%

accuracy rate of query results

dataset	accuracy of best match	Acccuracy of top 2 matches
Final 5	95%	95%
Test 4	90%	85%

Thank You!

Questions?