FlowWeb: Joint Image Set Alignment by Weaving Consistent, Pixel-wise Correspondences

Tinghui Zhou\textsuperscript{1}, Yong Jae Lee\textsuperscript{2}, Stella X. Yu\textsuperscript{1,3}, Alexei A. Efros\textsuperscript{1}

\textsuperscript{1}UC Berkeley, \textsuperscript{2}UC Davis, \textsuperscript{3}ICSI
Match pixels between two chairs
Match pixels between two chairs
Match pixels between two chairs

Appearance Gap
Bridging the appearance gap
Prior Work on Joint Image Alignment

- **Congealing** (*Learned-Miller, PAMI’06*): Minimize pixel entropy with a parametric transformation per image

- **Collection Flow** (*Kemelmacher-Shlizerman et al., CVPR’12*): Low-rank + Optical flow

- **RASL** (*Peng et al., PAMI’12*): Low-rank + parametric transformation

- **Mobahí et al.** (*CVPR’14*): Low rank compositional model + Optical flow
Star vs. Peer-to-Peer

Congealing, Collection Flow, RASL, Mobahi et al.

Canonical Image

Ours
FlowWeb Representation

- A complete, bi-directed graph of $N$ image nodes
- Each edge = flow field relating two images
- \#Correspondences = $O(N^2M)$
FlowWeb could be inconsistent
Cycle consistency

• Composite flows along cycles are zero
• 2-cycle consistency: $T_{ij} \circ T_{ji} = 0$
Cycle consistency

- Composite flows along cycles are zero
- 2-cycle consistency: $T_{ij} \circ T_{ji} = 0$
- 3-cycle consistency: $T_{ik} \circ T_{kj} \circ T_{ji} = 0$
- 2 and 3 cycles are sufficient (Nguyen et al., SGP’11)
Using Cycle Consistency

Shape matching
Huang et al, SGP’13

Co-segmentation
Wang et al, ICCV’13

Structure from Motion
Zach et al, CVPR’10

Our work: using cycle consistency for joint image alignment
Approach Pipeline

Image Collection → Initial Pairwise Flow (e.g. SIFT Flow) → Joint Alignment → Final output
Wisdom of the Crowd

- Good correspondences are consistent
- Cycle-consistency $\approx$ flow quality
- Use consistent flows to guide inconsistent ones

Flow Update Algorithm

Inter-image Phase $\rightarrow$ Intra-image Phase $\rightarrow$ Inter-image Phase
Inter-image Phase

- Update **inconsistent direct** flows with **consistent transitive** flows
- Prioritize by consistency gain
Inter-image Phase

Score_{p\rightarrow q} = 0
Direct

Score_{p\rightarrow s} = 1
Gain = 3

Score_{p\rightarrow t} = 3
Best Transitive
Intra-image Phase

Update flows lacking good transitive flows by **proximity** and **consistency**

\[
T_{ij}^{pq} \leftarrow \frac{1}{Z} \sum_{p' \in I_i} T_{ij}^{p'q'} g_{\sigma_s}(\|x_{p'} - x_p\|) h_{\sigma_c}(C(T_{ij}^{p'q'} - C(T_{ij}^{pq})))
\]
Evaluation: Part and Keypoint Matching

- **PASCAL-Part** (Chen et al., CVPR’14): Part segment annotations for PASCAL objects
- **PASCAL3D+** (Xiang et al., WACV’14): Keypoint annotations for 12 rigid categories
Part segment matching

Source Image

Target Image

Source Mask  Congeal  RASL  Col. Flow  DSP  Ours  Target Mask
Part segment matching

Source Image

Target Image

Source Mask  Congeal  RASL  Col. Flow  DSP  Ours  Target Mask
Keypoint Trajectories

DSP
(Before joint alignment)

Ours
(After joint alignment)
Quantitative Benchmark

Part segment matching

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean IOU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ours</td>
<td>0.38</td>
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<tr>
<td>DSP</td>
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<td>Col. Flow</td>
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<td>RASL</td>
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<td>Congeal</td>
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Keypoint matching

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean PCK</th>
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<td>Congeal</td>
<td>0.16</td>
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</tbody>
</table>
Evaluation: Shape Warping

Source | DSP | Mobahi et al. | Ours | Target
--- | --- | --- | --- | ---
More data $\Rightarrow$ better correspondences

The graphs show the relationship between PCK (left) and Part IOU (right) for different image set sizes. Each line color represents a different object category: red for aeroplane, green for car, and blue for bicycle. The PCK and Part IOU values increase as the image set size increases.
Application: Image Edit Propagation

User Edit

Propagate

...
Take-home Message

• **More Data Wins**: Joint alignment better than Pairwise alignment

• **Consistency as supervision**: All good flows are consistent; each bad flow is bad in its own way.

• **Limitations**:
  • Not globally optimal
  • Slow