GET OUT OF MY PICTURE!
INTERNET-BASED INPAINTING

Oliver Whyte   Josef Sivic   Andrew Zisserman
INTRODUCTION

Inpainting using an internet-based image search engine
Inpainting using an internet-based image search engine
Inpainting using an internet-based image search engine
WHY IS THIS DIFFICULT?

Main problems to overcome:

- Differences in viewpoints
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Main problems to overcome:

- Differences in viewpoints
- Differences in lighting conditions
WHY IS THIS DIFFICULT?

Main problems to overcome:

- Differences in viewpoints
- Differences in lighting conditions
- New occlusions
## Prior Work

<table>
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<tr>
<th>Efros &amp; Leung '99</th>
<th>Criminisi et al. '03</th>
<th>Hays &amp; Efros '06</th>
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<td>Modified filling order to continue string edges across region. Structure preservation is still local.</td>
<td>Images with similar “semantic structure” used to fill region. May even find images of same scene, but no multi-view geometry.</td>
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[Sun et al. '05, Amirshahi et al. '08]
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Our Result
OVERVIEW

Target region
OVERVIEW

Oracles
OVERVIEW

Geometric registration
OVERVIEW

Photometric registration
OVERVIEW

Proposals
OVERVIEW

Combining proposals
OVERVIEW

Final result
AUTOMATIC ORACLE RETRIEVAL


• Searches around 100,000 images, of which 5,000 are of Oxford

Query image

First 30 search results, these are our “oracles”

[Nistér and Stewénius '06, Chum et al. '07, Jegou et al. '08]
GEOMETRIC REGISTRATION

- Planar homographies used for registration
- Valid in two situations:
  - Concurrent camera centres
  - Piecewise planar scenes
MULTIPLE HOMOGRAPHIES

Multiple homographies for scenes with multiple planes

Query image

Oracle image
Multiple homographies for scenes with multiple planes

Query image

1st homography
MULTIPLE HOMOGRAPHIES

Multiple homographies for scenes with multiple planes

Query image

1st homography, query overlaid
MULTIPLE HOMOGRAPHIES

Multiple homographies for scenes with multiple planes

Query image

2nd homography
MULTIPLE HOMOGRAPHIES

Multiple homographies for scenes with multiple planes

Query image

2\text{nd} homography, query overlaid
PHOTOMETRIC REGISTRATION

- Find well-registered regions of each oracle

Query image  Registered oracle  NCC registration map
• Find well-registered regions of each oracle
PHOTOMETRIC REGISTRATION

- Find well-registered regions of each oracle

- Compute affine transformation for each colour channel

Query image

Registered oracle

Well-registered regions

Split query / registered oracle

After photometric correction
PHOTOMETRIC REGISTRATION

• Find well-registered regions of each oracle

Query image  Registered oracle  Well-registered regions

• Compute affine transformation for each colour channel

Split query / registered oracle  After photometric correction
Registered oracles are combined into the target region using Poisson blending

[Pérez et al. '03]
GENERATING PROPOSALS

Geometrically registered oracles

Query Image
GENERATING PROPOSALS

Photometrically registered oracles

Query Image
GENERATING PROPOSALS

Query Image

Proposals
GENERATING PROPOSALS

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Proposals
GENERATING PROPOSALS

Query Image

Proposals
COMBINING MULTIPLE PROPOSALS

Combination

Regions

Proposals

Result
COMBINING MULTIPLE PROPOSALS

- Pixel-labelling problem optimised using belief propagation
- Pixels in target region are nodes, connected to 4-neighbours

\[ E(L) = \sum_{p \in \mathcal{V}} E_1(p, L_p) + \sum_{(p, q) \in \mathcal{E}} E_2(p, q, L_p, L_q) \]

\[ \begin{align*}
\text{unary} & \quad \text{pairwise} \\
E_1(p, L_p) & = \text{unary term at pixel } p \\
E_2(p, q, L_p, L_q) & = \text{pairwise term between pixels } p \text{ and } q \\
p, q & \text{ are pixels} \\
L_p & \text{ is label (proposal) at pixel } p
\end{align*} \]

- Unary – guides individual pixels
- Pairwise – guides boundaries between regions with different labels
COMBINING MULTIPLE PROPOSALS

Unary cost
penalise deviation from original query image pixels

Pairwise cost
penalise boundaries between regions where gradients of the two proposals are dissimilar
For each pixel, take median gradient over all proposals

Similar to “intrinsic images” [Weiss '01]
COMBINING MULTIPLE PROPOSALS

Query / target

Our result

Hays & Efros
COMBINING MULTIPLE PROPOSALS

Query / target

Our result

Hays & Efros
EXAMPLE RESULT 1

Query image | Target region | Result
EXAMPLE 1 – ORACLES

Labels

Result
EXAMPLE 1 – REGISTERED ORACLES
EXAMPLE 1 – PROPOSALS

Labels

Result
EXAMPLE RESULT 2

Query image

Target region

Result
EXAMPLE 2 – ORACLES
EXAMPLE 2 – REGISTERED ORACLES

Labels

Result
EXAMPLE 2 – PROPOSALS

Labels

Result
EXAMPLE 2 – EFFECT OF UNARY TERM

“Clean-plate” unary avoids occlusion
**EXAMPLE 2 - EFFECT OF UNARY TERM**

<table>
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<tr>
<th>Labels</th>
<th>Result</th>
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<tbody>
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<td>Decreased unary weight</td>
<td></td>
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FAILURE CASE – TOO FEW ORACLES

Query | Target region | Labels | Final result

Proposals

[Images of a building and proposed target regions]
FAILURE CASE – TOO FEW ORACLES

Query | Target region | Labels | Final result
--- | --- | --- | ---
![Query Image] | ![Target Region Image] | ![Labels Image] | ![Final Result Image]

Proposals
FAILURE CASE - TOO FEW ORACLES

- Non-planar building – requires same viewpoint
- Several oracles correctly registered, but all occluded in target region
Conclusion

- Framework for using internet photo collections for inpainting
CONCLUSIONS / FUTURE WORK

Conclusion

- Framework for using internet photo collections for inpainting

Future work

- More general geometrical models
- Local lighting transfer
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COMBINING MULTIPLE PROPOSALS

Unary cost

\[ E_1(p, L_p) = k_{\text{query}} \overline{M}(p) \| I_{L_p}(p) - I_{\text{query}}(p) \| + k_{\text{median}} M(p) \| I_{L_p}(p) - I_{\text{median}(G(L_p))}(p) \| \]

penalises deviations from query image outside target region
penalises deviations from clean-plate inside target region

Pairwise cost

\[ E_2(p, q, L_p, L_q) = k_{\text{grad}} \left( \| \nabla I_{L_p}(p) - \nabla I_{L_q}(p) \| + \| \nabla I_{L_p}(q) - \nabla I_{L_q}(q) \| \right) \]

penalises region boundaries where image gradients of the two proposals are dissimilar

\( I_{L_p}(p), I_{\text{query}}(p), I_{\text{median}(G(L_p))}(p) \) are colour of pixel \( p \) in proposal \( L_p \),
query image, and median of proposal \( L_p \)'s group \( G(L_p) \)
COMPUTING THE “CLEAN PLATE”

- Group proposals according to which scene plane is registered

- Compute approximate clean plate for each group from median x / y gradients at each pixel