

GET OUT OF MY PICTURE! INTERNET-BASED INPAINTING

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DE RECHERCHE
EN INFORMATIQUE
ET EN AUTOMATIQUE



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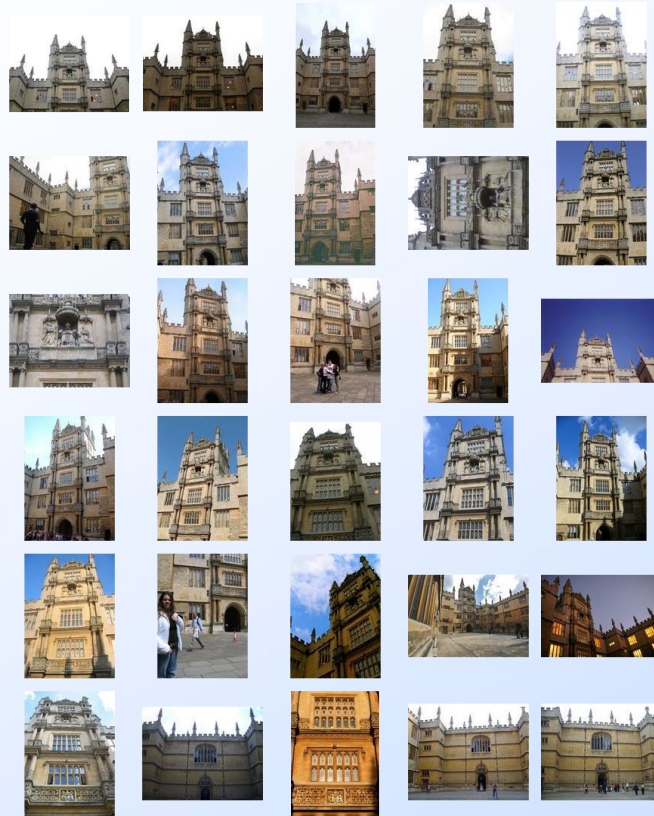
INTRODUCTION

Inpainting using an internet-based image search engine



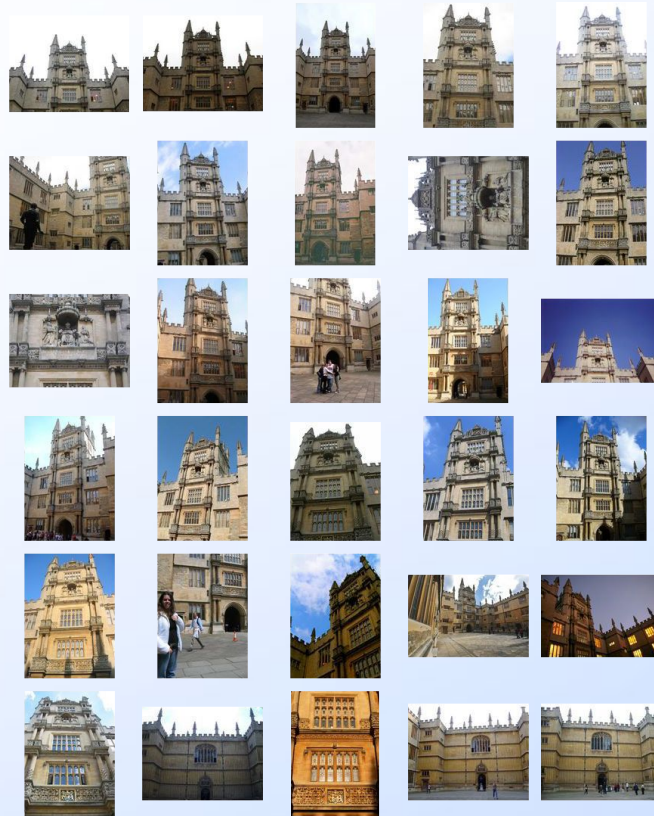
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WHY IS THIS DIFFICULT?

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

Efros & Leung '99

Fill pixels greedily based on local patch comparisons with rest of image. No reasoning about structure.



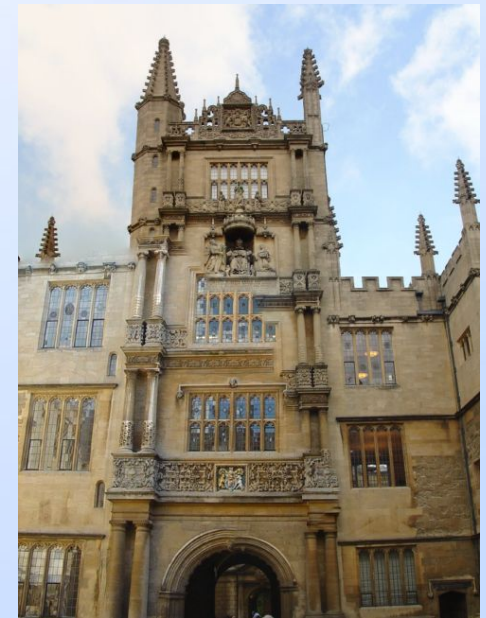
Criminisi *et al.* '03

Modified filling order to continue string edges across region. Structure preservation is still local.



Hays & Efros '06

Images with similar “semantic structure” used to fill region. May even find images of same scene, but no multi-view geometry.



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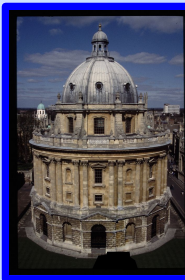
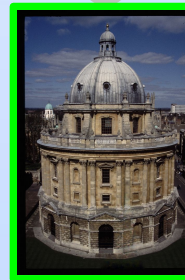
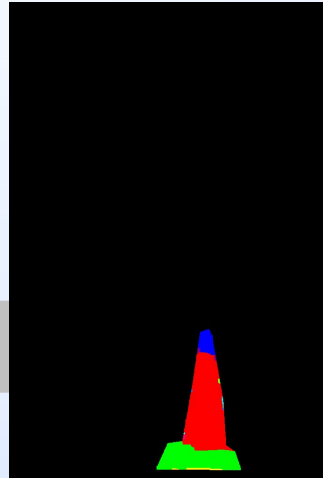
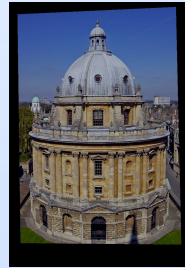
Our Result



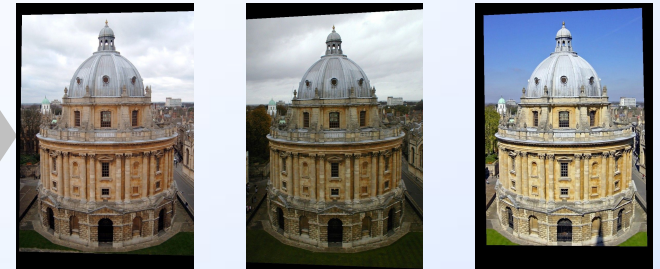
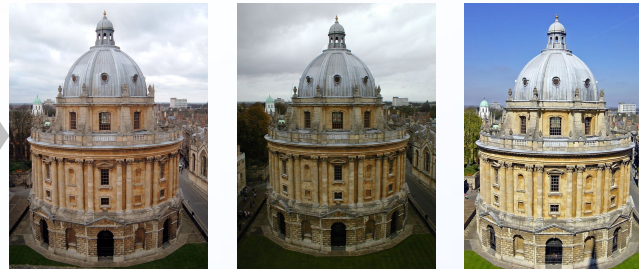
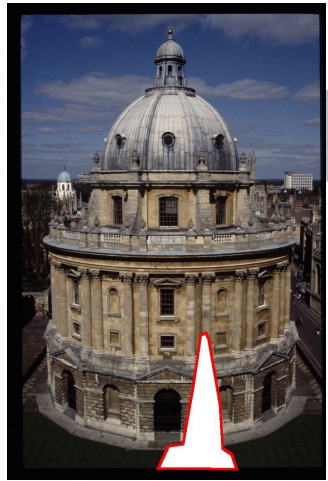
OVERVIEW



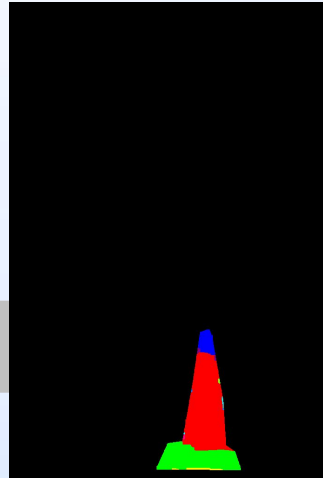
Query image



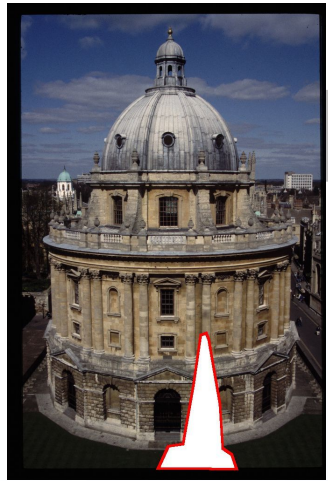
OVERVIEW



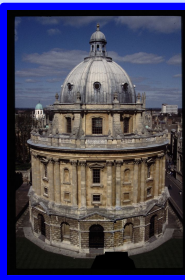
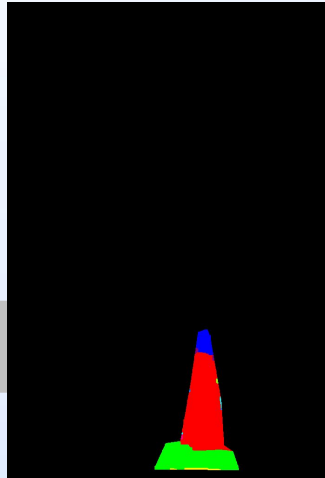
Target region



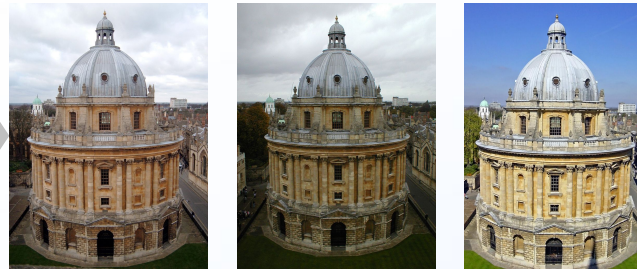
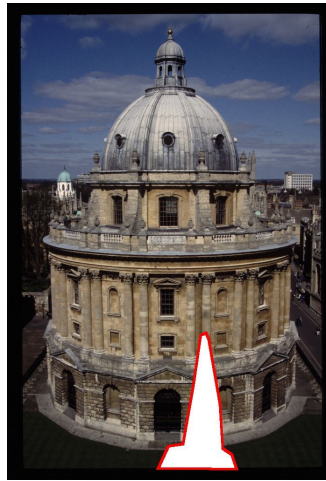
OVERVIEW



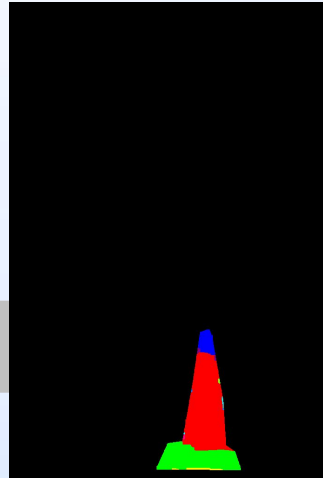
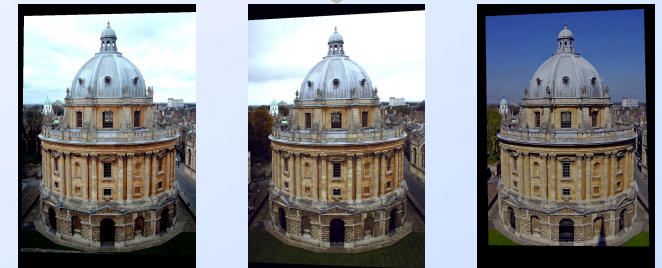
Oracles



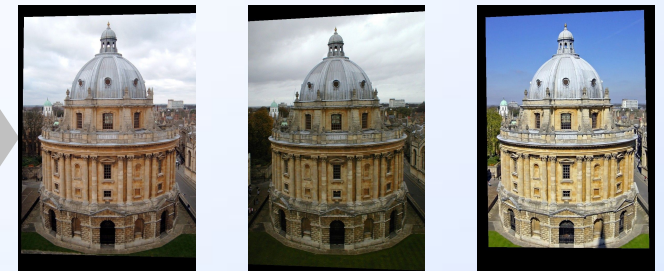
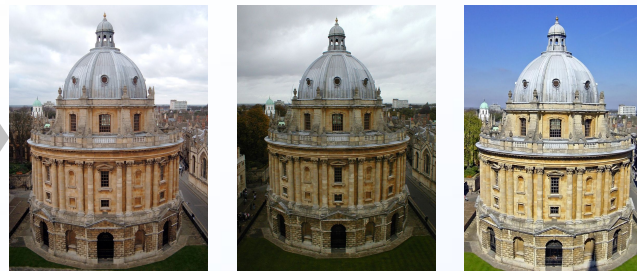
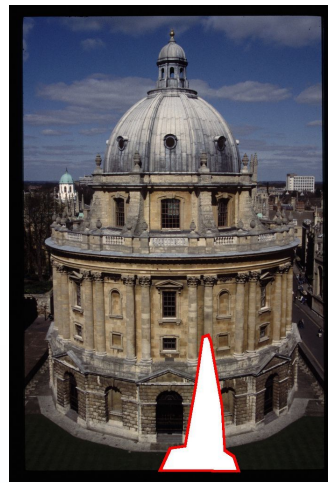
OVERVIEW



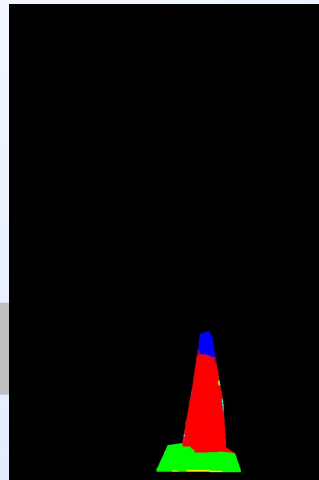
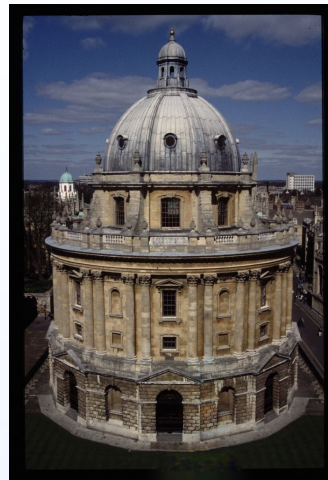
Geometric registration



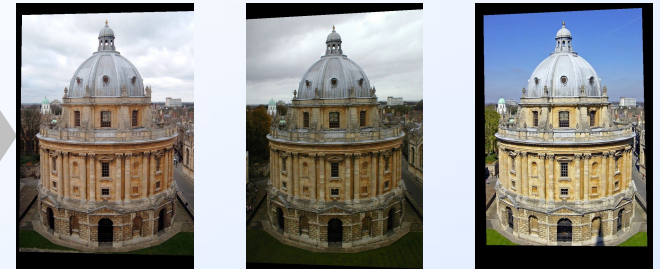
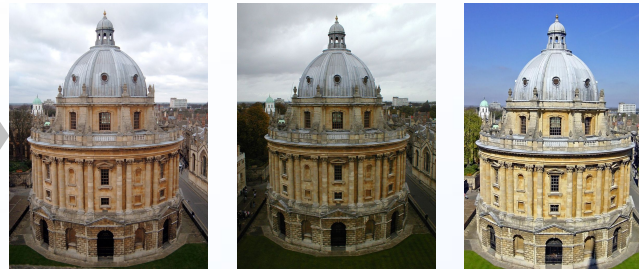
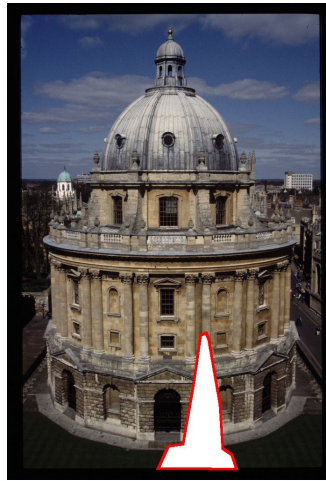
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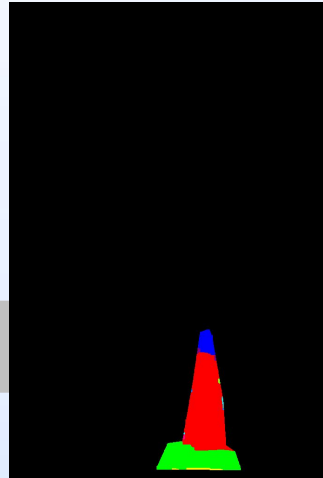
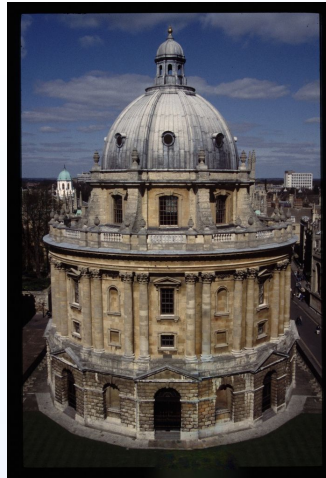
Photometric
registration



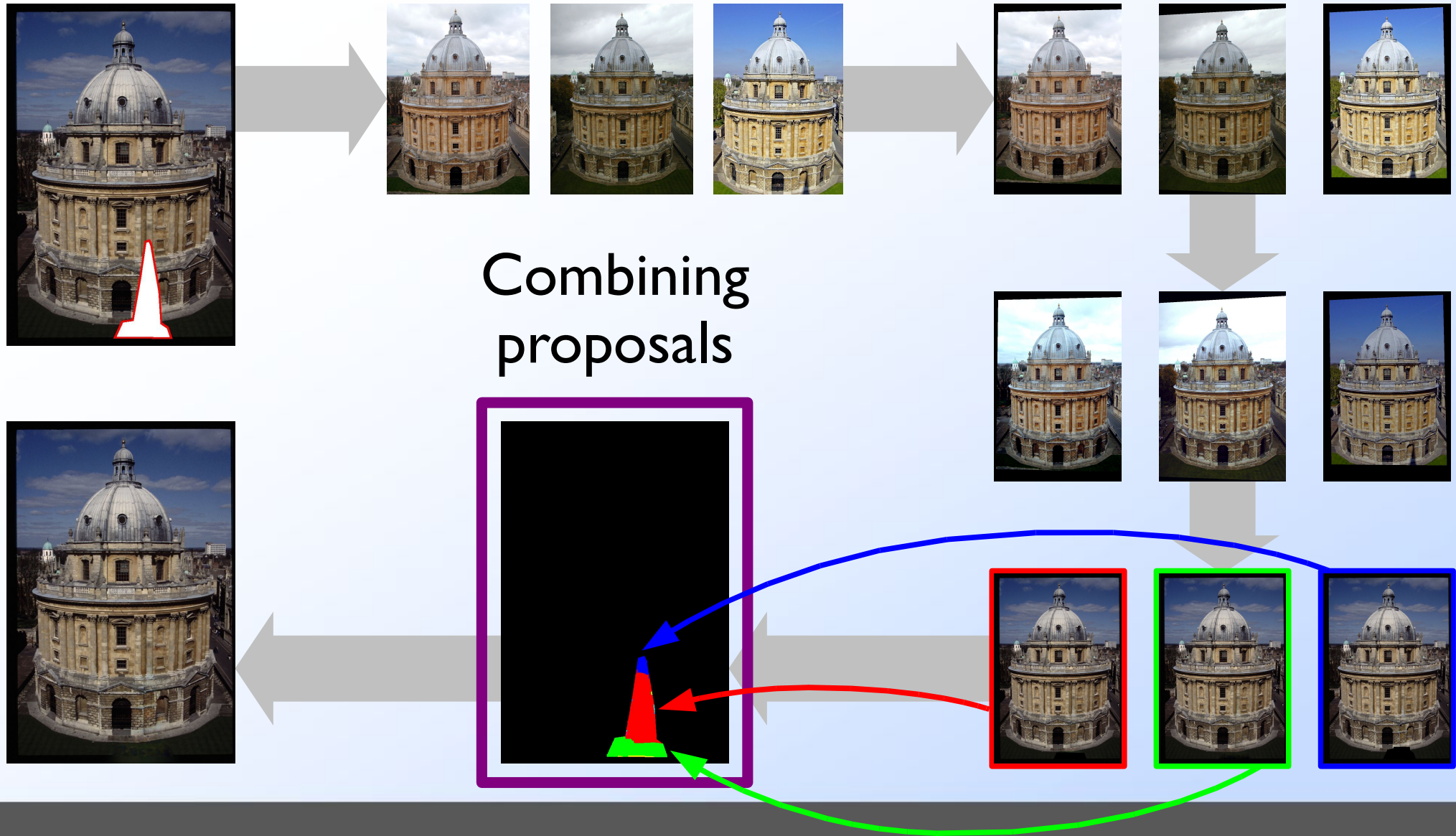
OVERVIEW



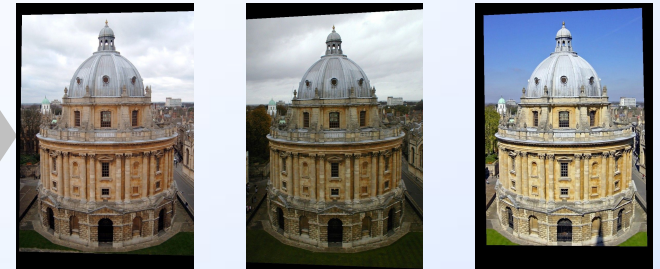
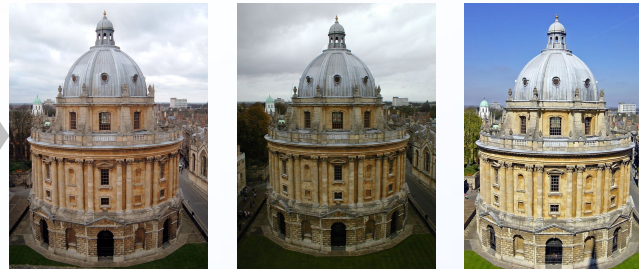
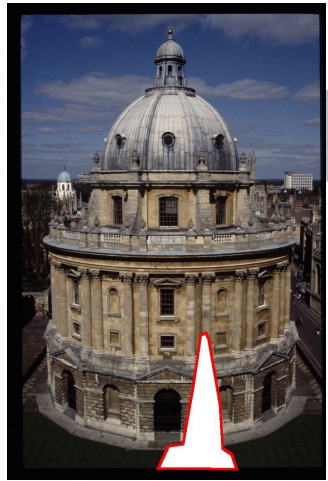
Proposals



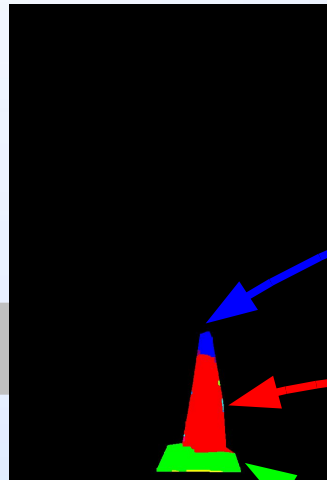
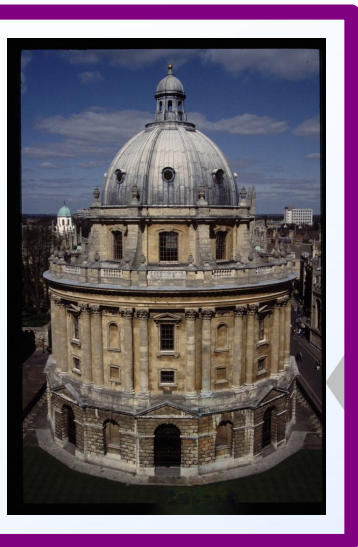
OVERVIEW



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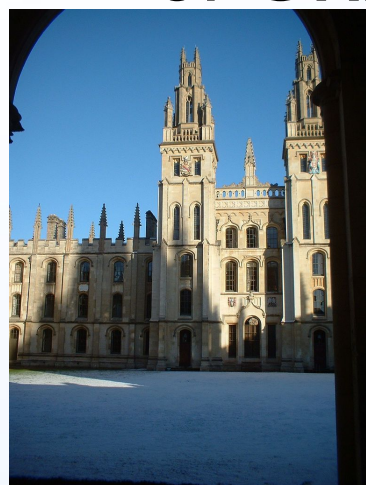


Final result



AUTOMATIC ORACLE RETRIEVAL

- Viewpoint-invariant image search and accompanying image set: “Oxford Buildings Search” [Philbin *et al.* CVPR '07]
- Searches around 100,000 images, of which 5,000 are of Oxford



Query image



First 30 search results, these are our “oracles”

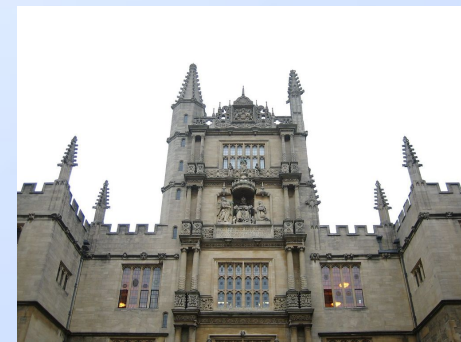
GEOMETRIC REGISTRATION

- 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



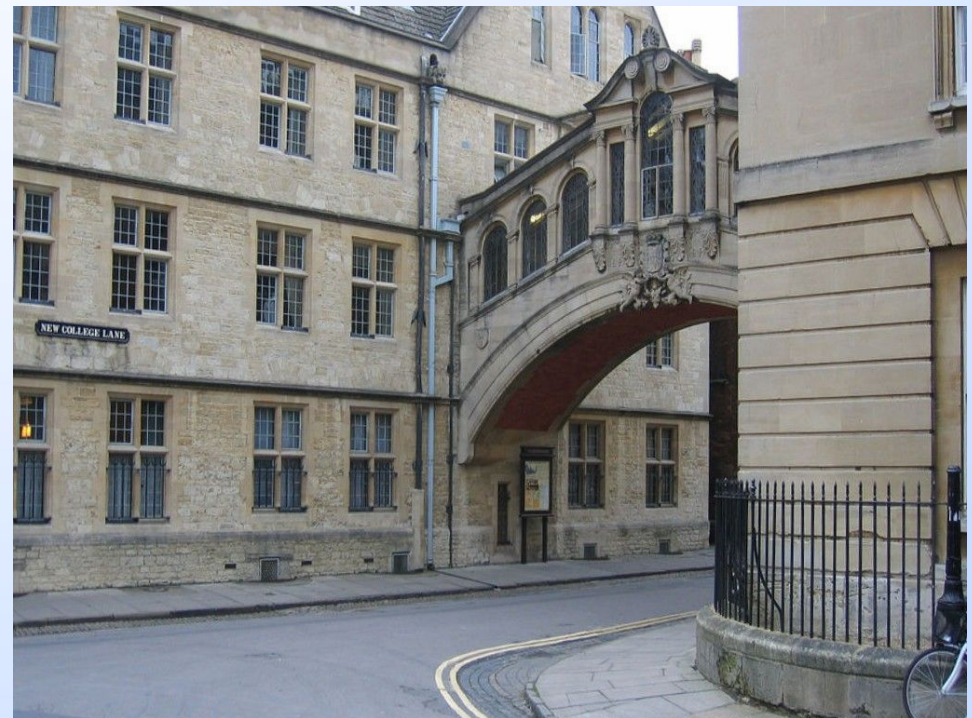
MULTIPLE HOMOGRAPHIES

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



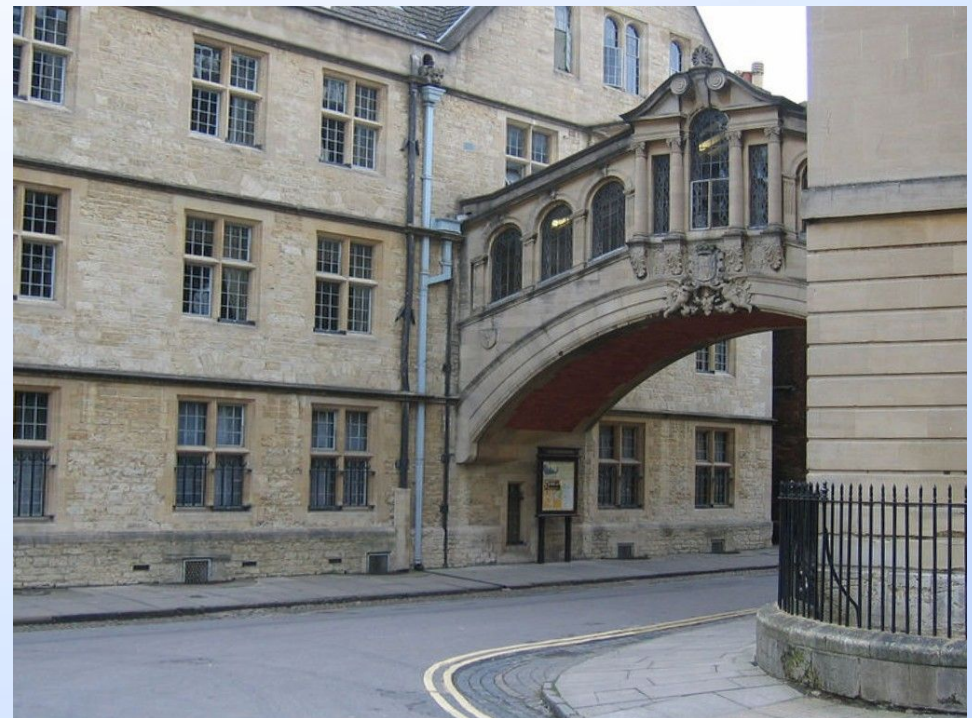
MULTIPLE HOMOGRAPHIES

Multiple homographies for scenes with multiple planes

Query image



2nd homography



MULTIPLE HOMOGRAPHIES

Multiple homographies for scenes with multiple planes

Query image



2nd homography, query overlaid

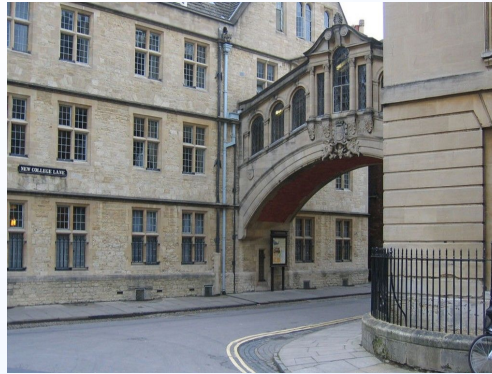


PHOTOMETRIC REGISTRATION

- Find well-registered regions of each oracle



Query image



Registered oracle



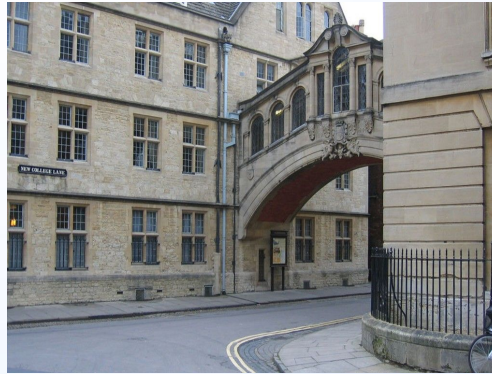
NCC registration map

PHOTOMETRIC REGISTRATION

- Find well-registered regions of each oracle



Query image



Registered oracle



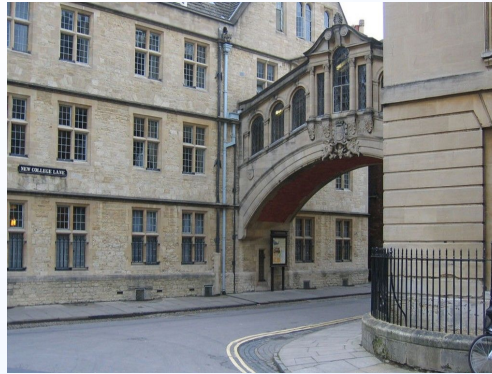
Well-registered regions

PHOTOMETRIC REGISTRATION

- Find well-registered regions of each oracle



Query image

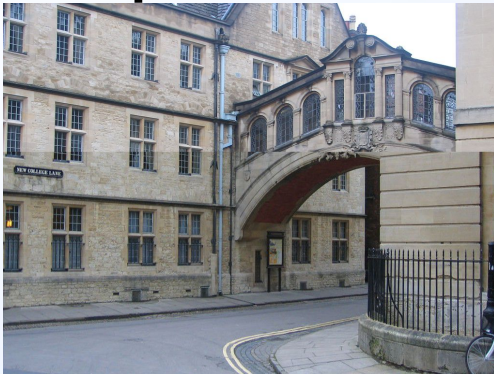


Registered oracle



Well-registered regions

- Compute affine transformation for each colour channel



Split query / registered oracle



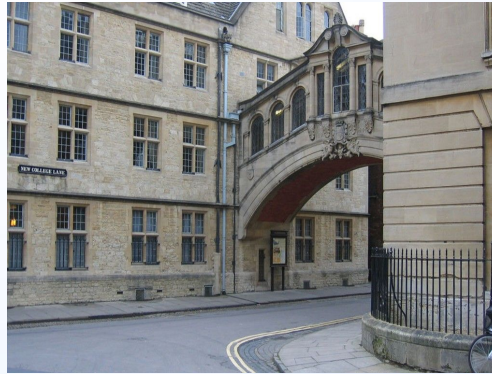
After photometric correction

PHOTOMETRIC REGISTRATION

- Find well-registered regions of each oracle



Query image

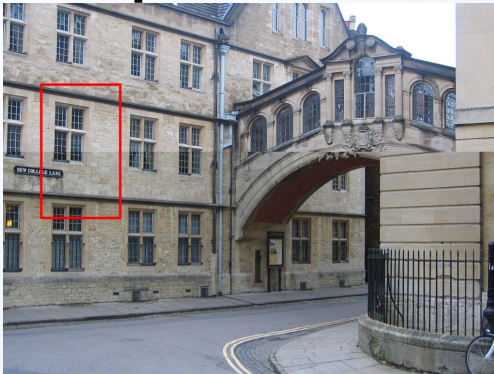


Registered oracle

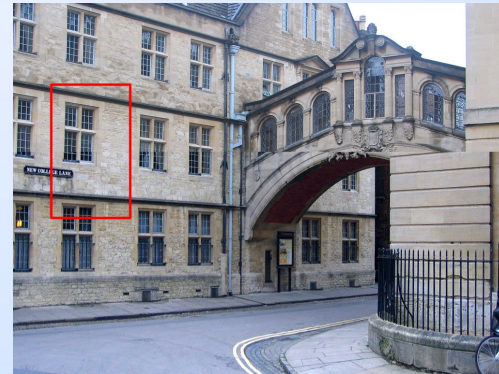


Well-registered regions

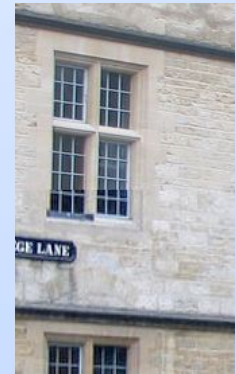
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Split query / registered oracle

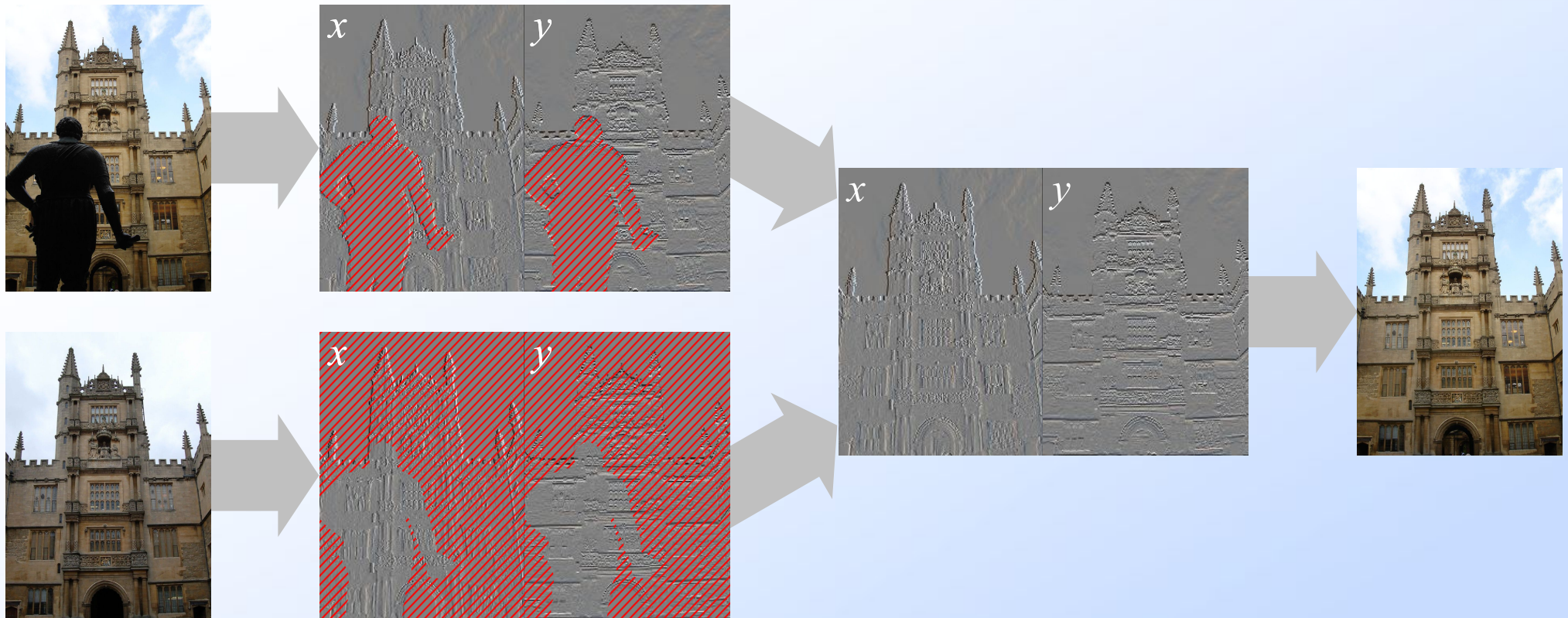


After photometric correction



GENERATING PROPOSALS

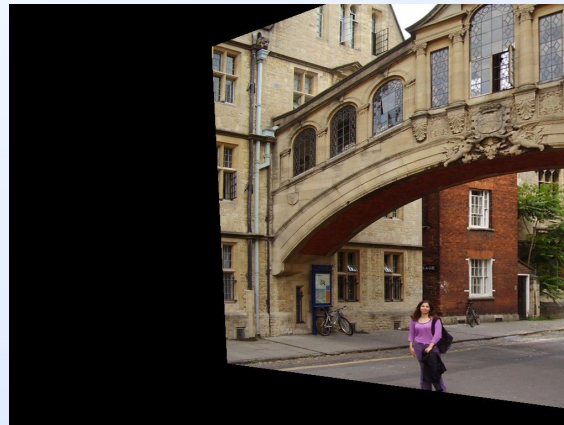
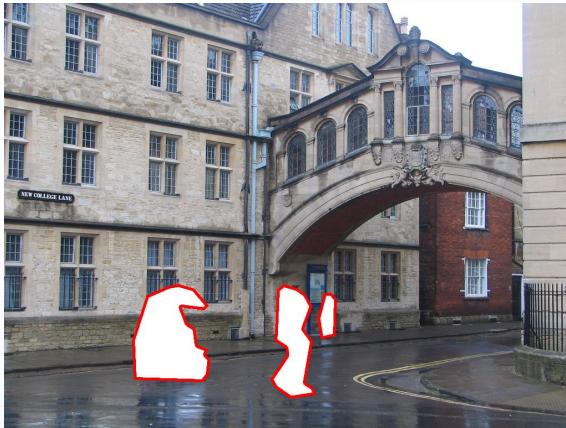
Registered oracles are combined into the target region using Poisson blending



GENERATING PROPOSALS

Geometrically registered oracles

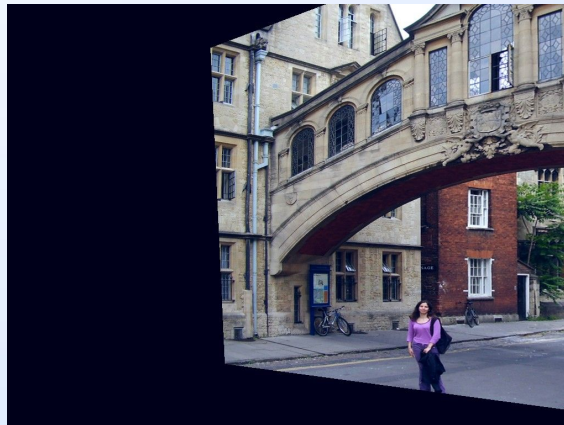
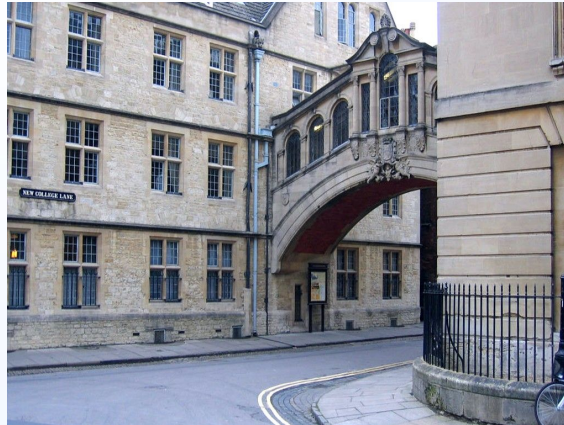
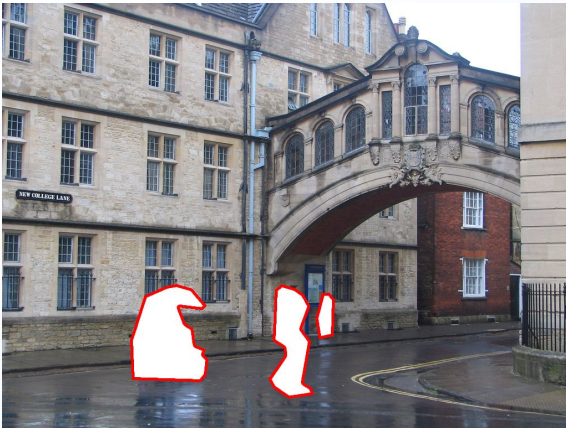
Query Image



GENERATING PROPOSALS

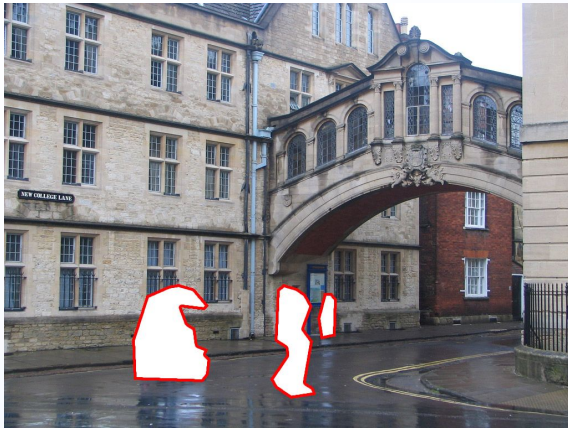
Photometrically registered oracles

Query Image

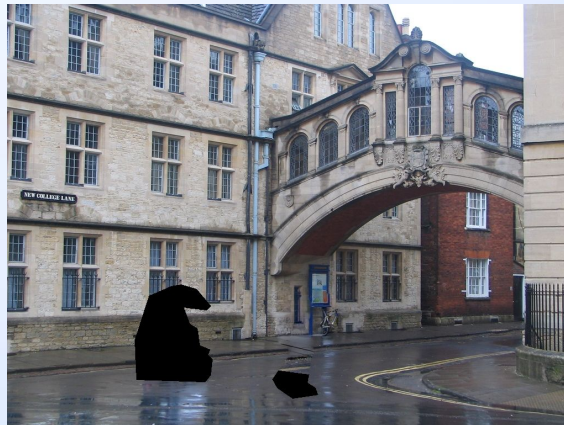


GENERATING PROPOSALS

Query Image

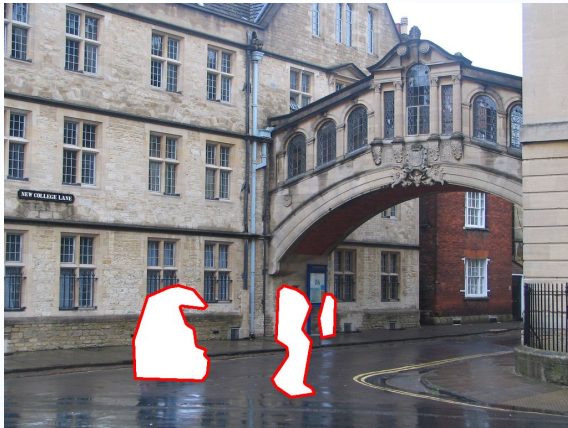


Proposals

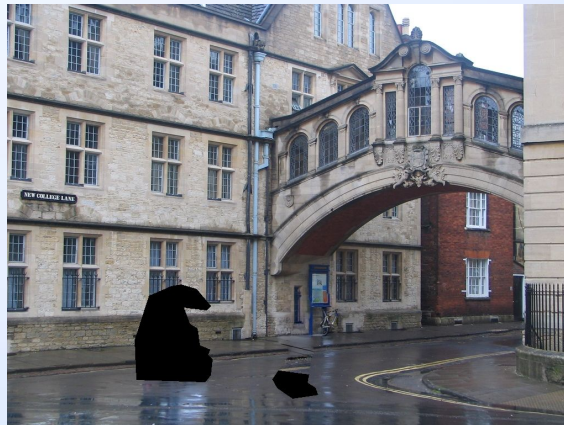


GENERATING PROPOSALS

Query Image

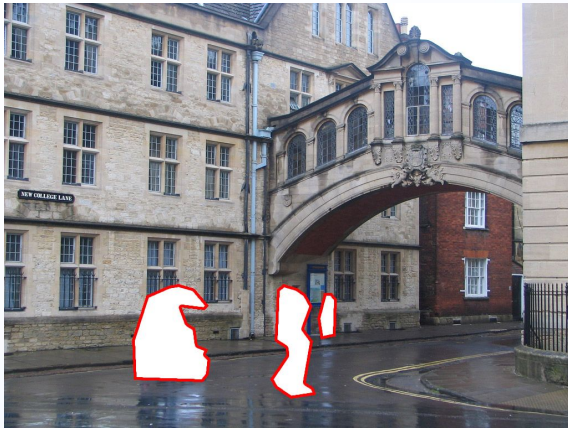


Proposals

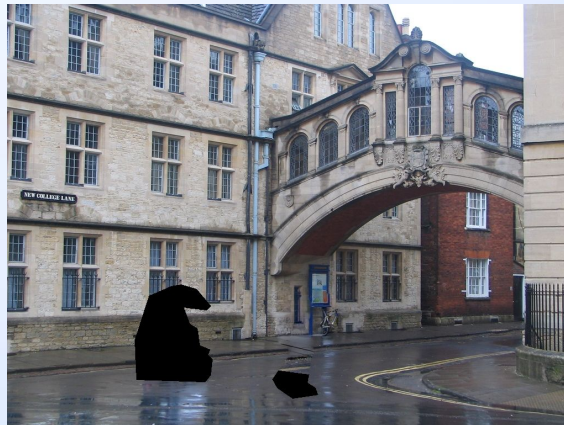


GENERATING PROPOSALS

Query Image

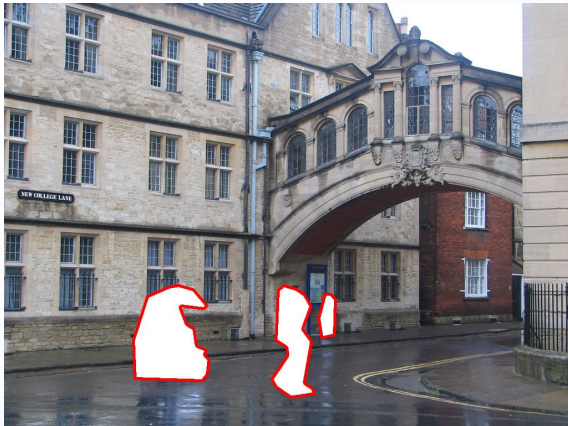


Proposals



GENERATING PROPOSALS

Query Image

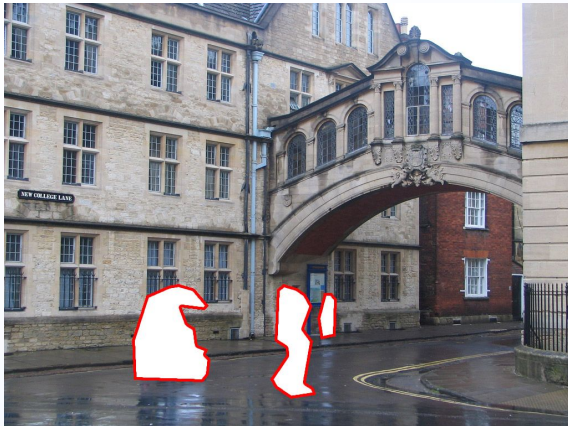


Proposals



GENERATING PROPOSALS

Query Image



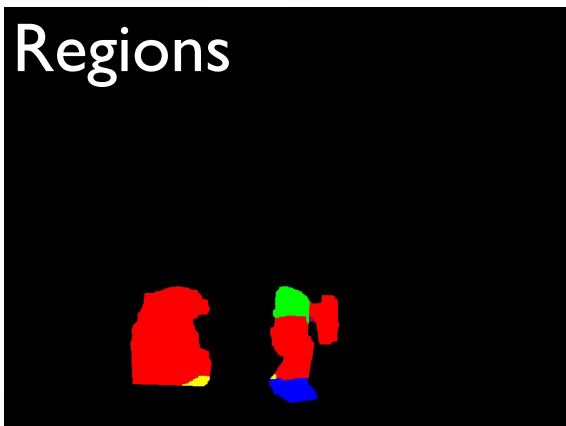
Proposals



COMBINING MULTIPLE PROPOSALS

Combination

Proposals



COMBINING MULTIPLE PROPOSALS

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

$$E(\mathbf{L}) = \underbrace{\sum_{\mathbf{p} \in \mathcal{V}} E_1(\mathbf{p}, L_{\mathbf{p}})}_{\text{unary}} + \underbrace{\sum_{(\mathbf{p}, \mathbf{q}) \in \mathcal{E}} E_2(\mathbf{p}, \mathbf{q}, L_{\mathbf{p}}, L_{\mathbf{q}})}_{\text{pairwise}}$$

\mathbf{p}, \mathbf{q} are pixels

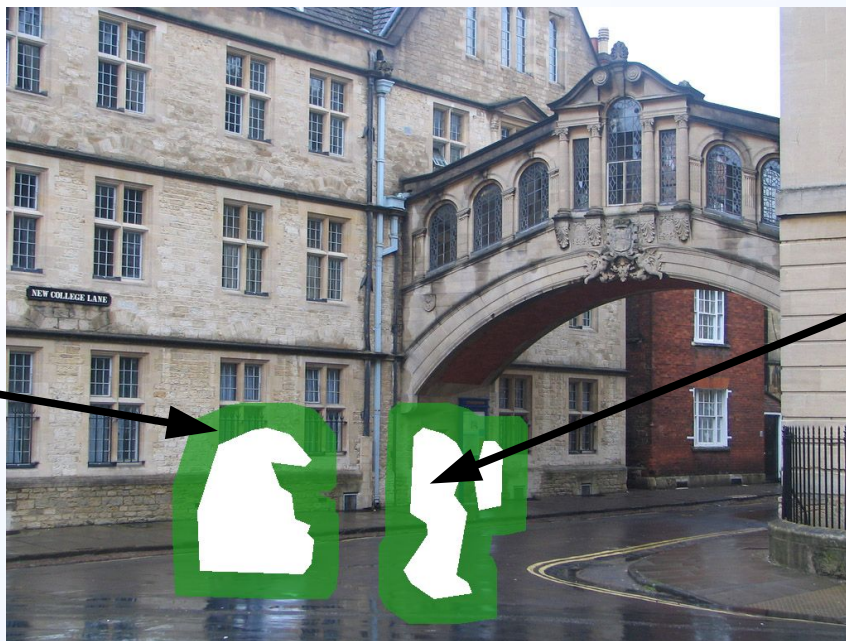
$L_{\mathbf{p}}$ is label (proposal) at pixel \mathbf{p}

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

COMBINING MULTIPLE PROPOSALS

Unary cost

penalise deviation from original query image pixels



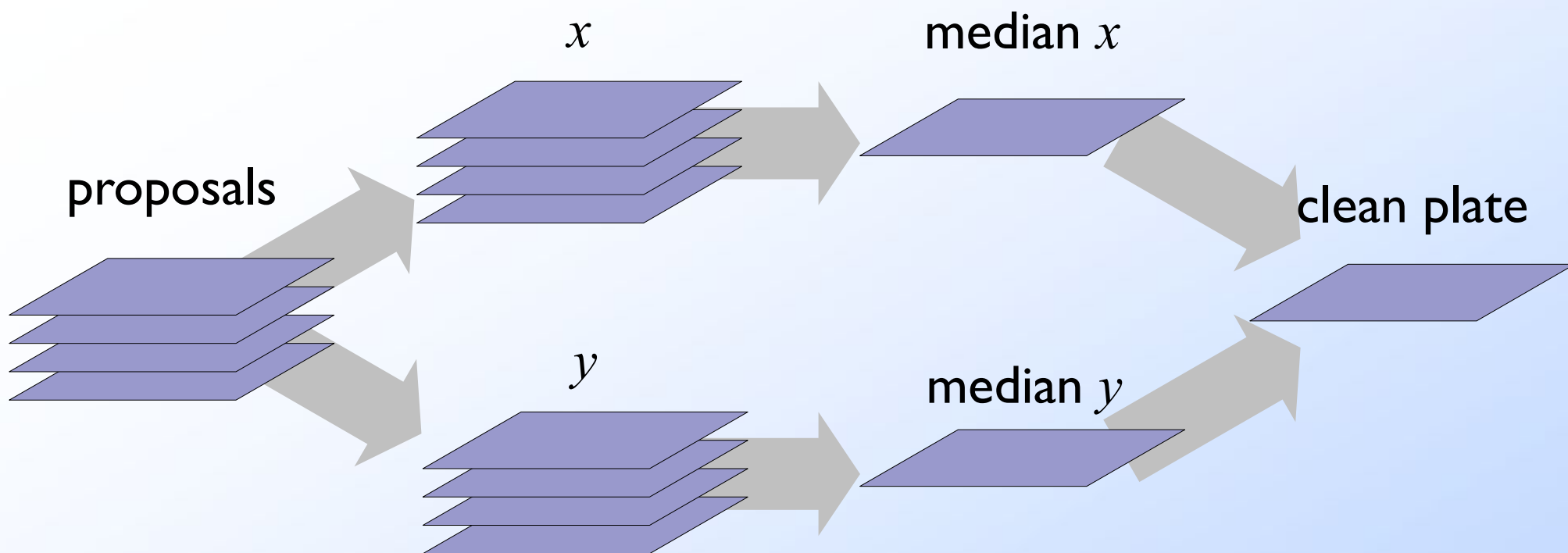
penalise deviation from approximate "clean-plate" image

Pairwise cost

penalise boundaries between regions where gradients of the two proposals are dissimilar

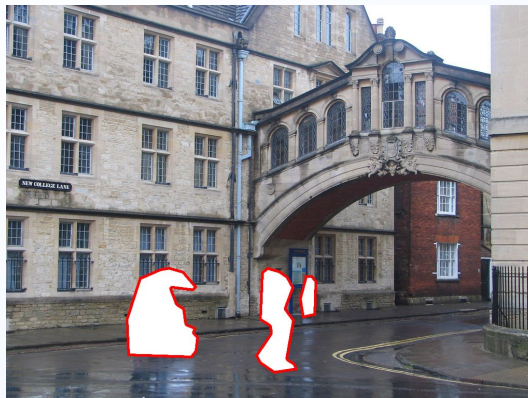
COMPUTING THE “CLEAN PLATE”

For each pixel, take median gradient over all proposals



COMBINING MULTIPLE PROPOSALS

Query / target



Our result

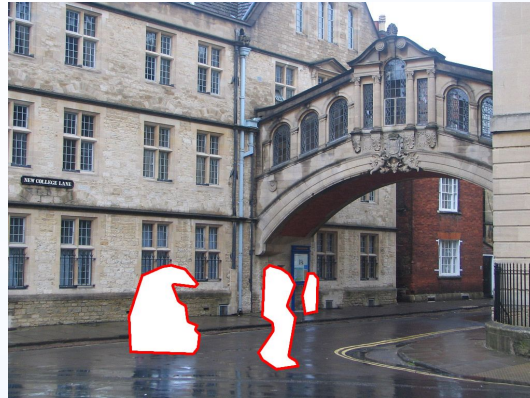


Hays & Efros



COMBINING MULTIPLE PROPOSALS

Query / target



Our result

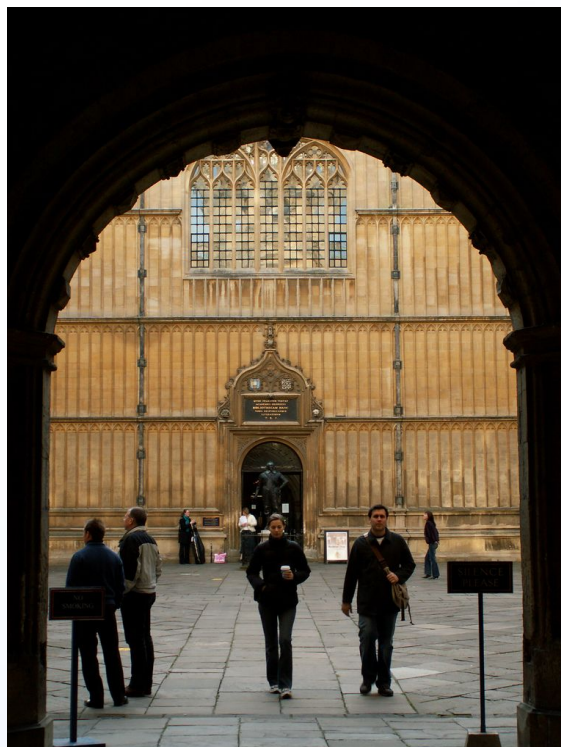


Hays & Efros



EXAMPLE RESULT 1

Query image



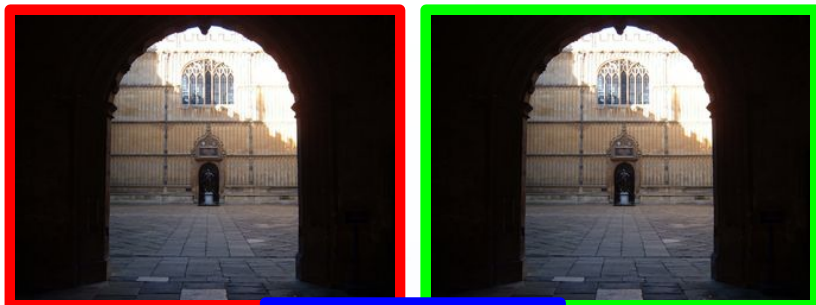
Target region



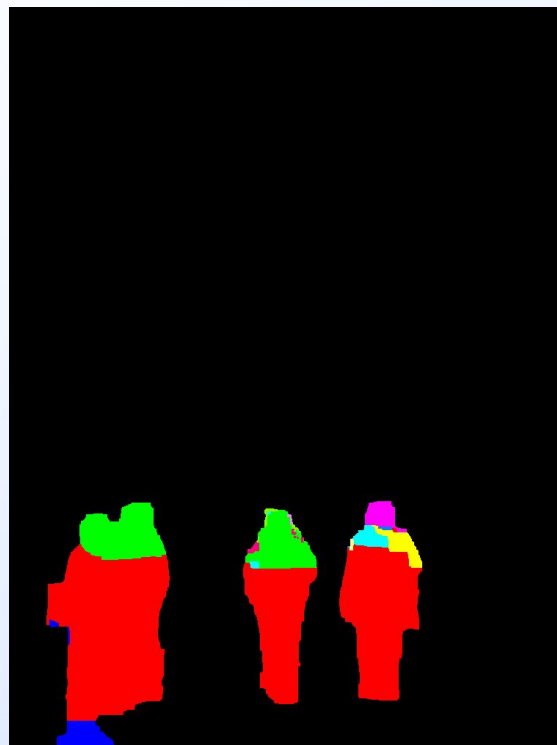
Result



EXAMPLE 1 - ORACLES



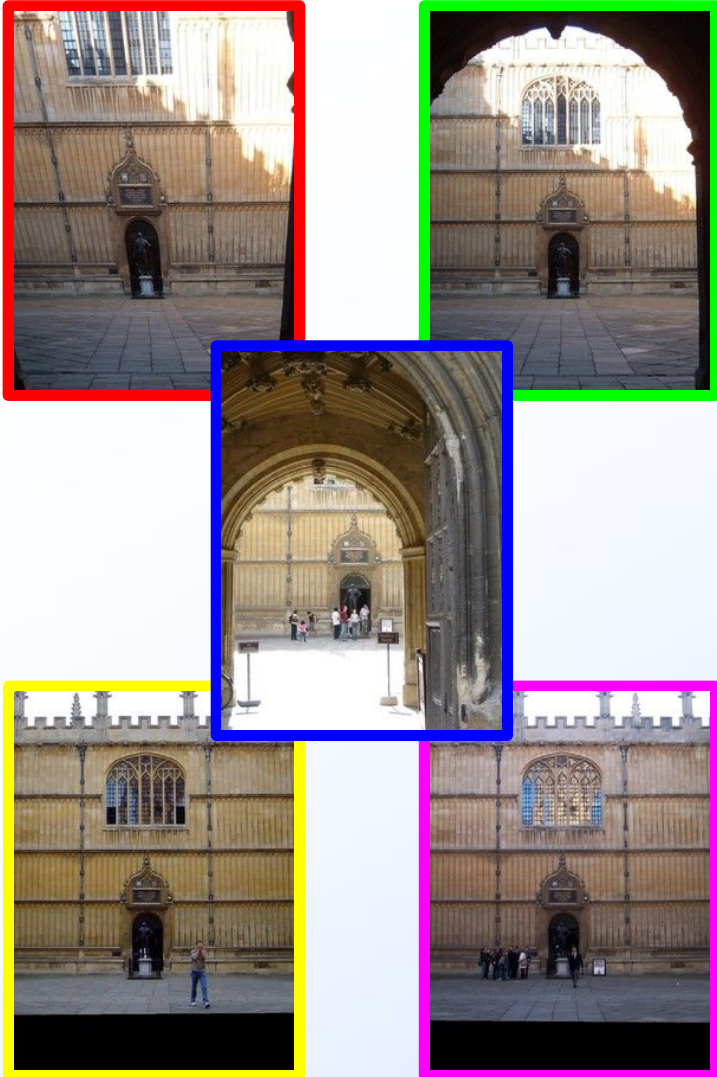
Labels



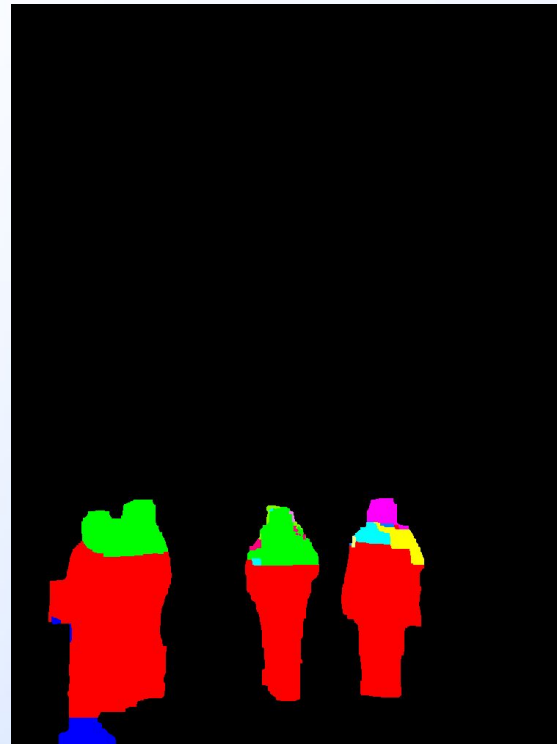
Result



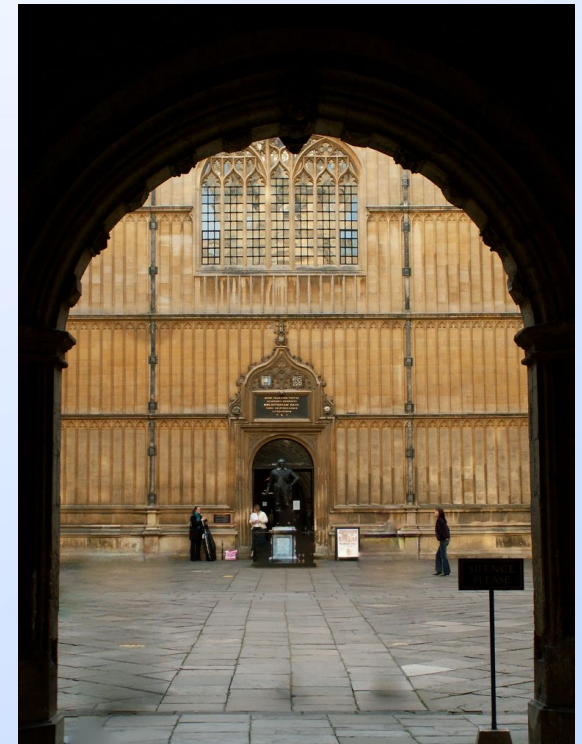
EXAMPLE 1 – REGISTERED ORACLES



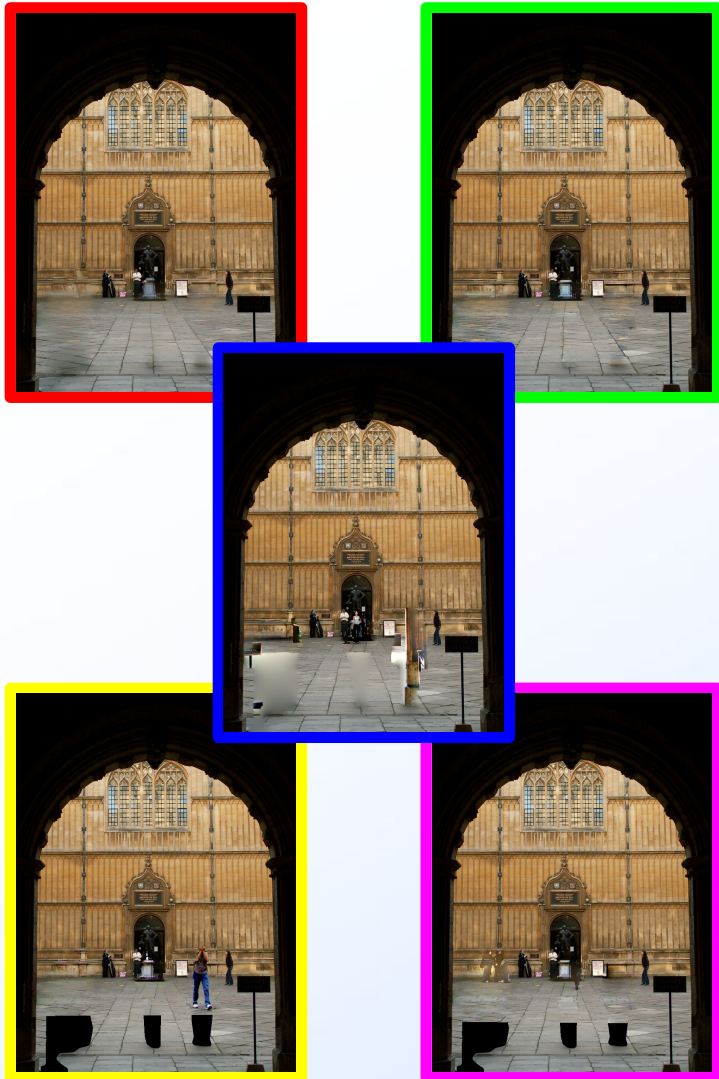
Labels



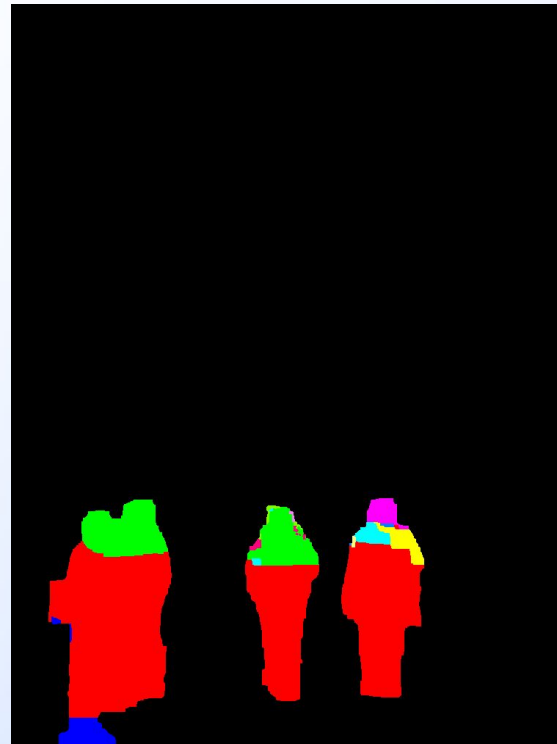
Result



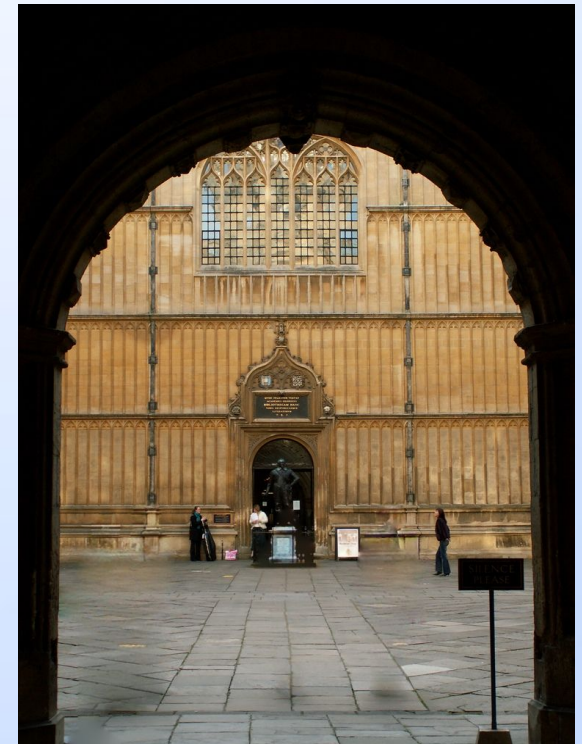
EXAMPLE 1 – PROPOSALS



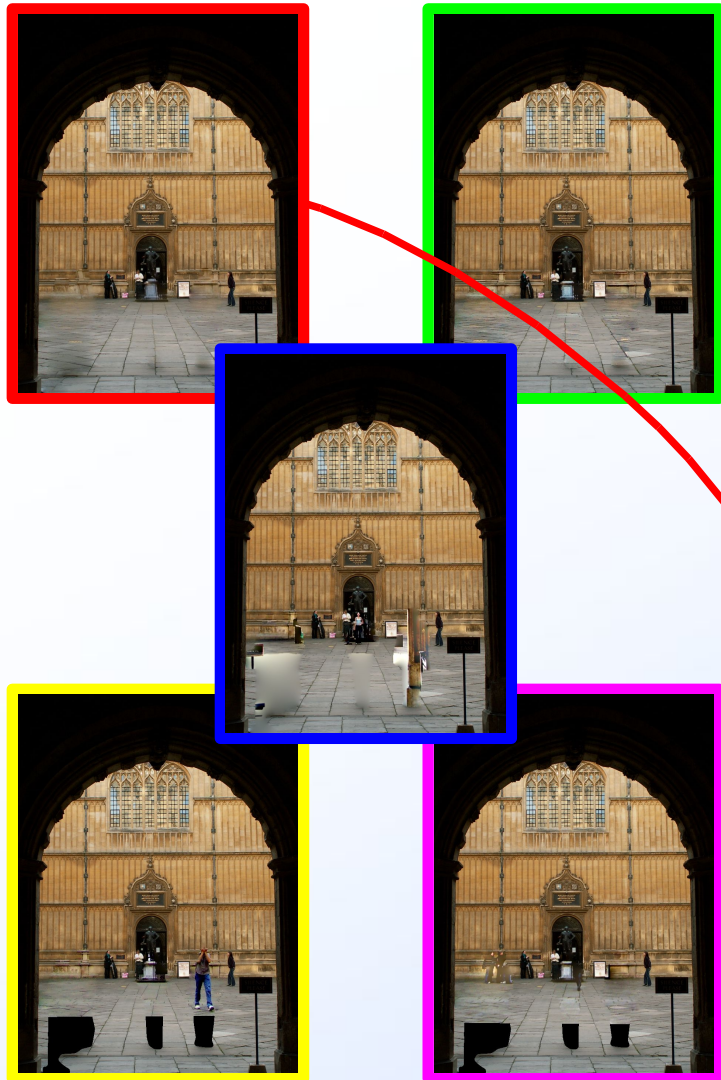
Labels



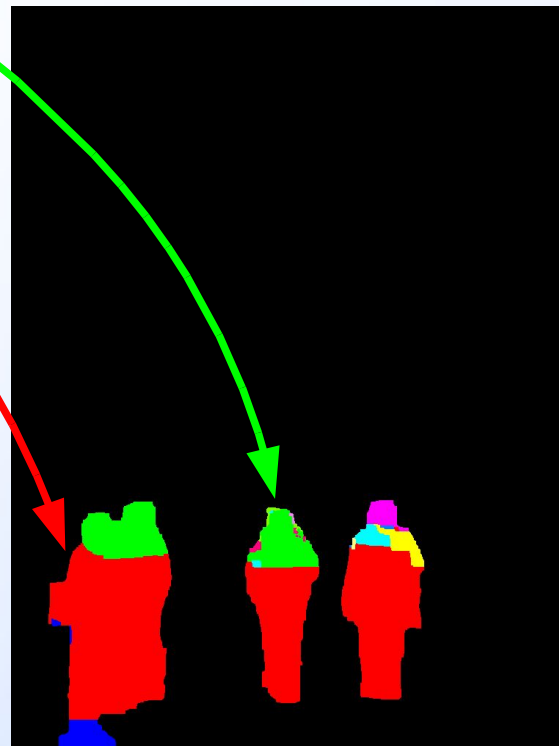
Result



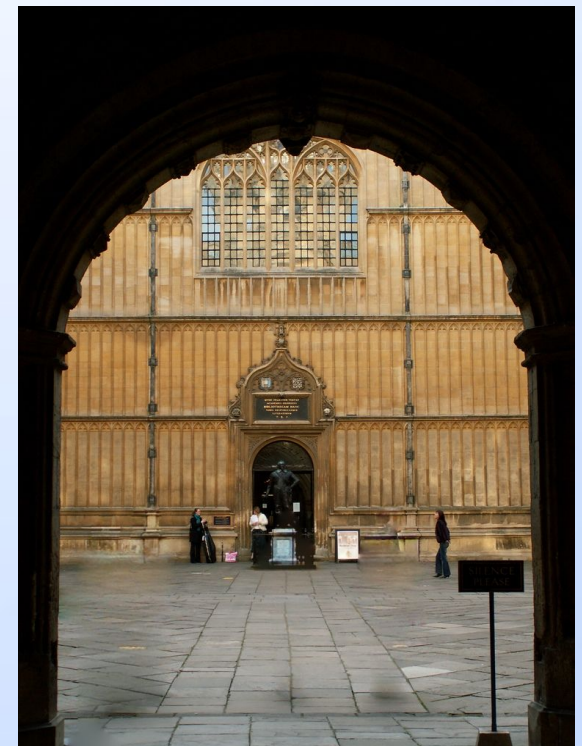
EXAMPLE 1 – PROPOSALS



Labels



Result

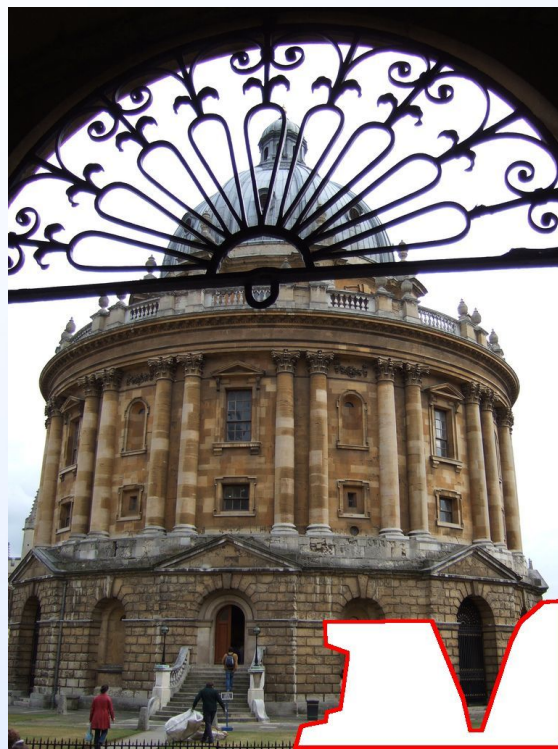


EXAMPLE RESULT 2

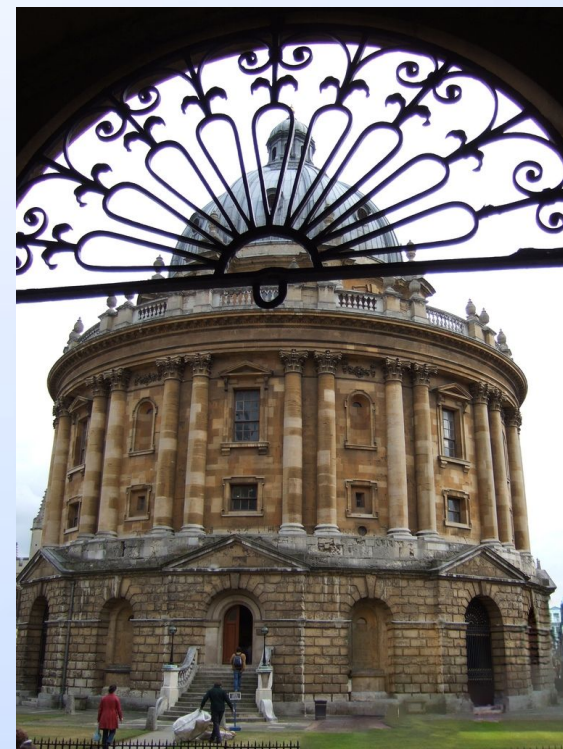
Query image



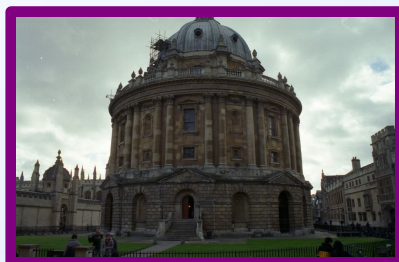
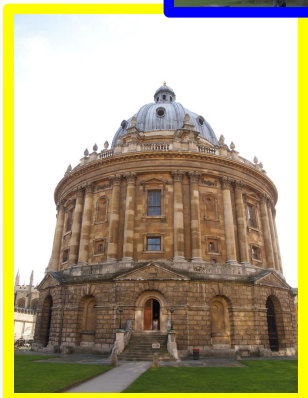
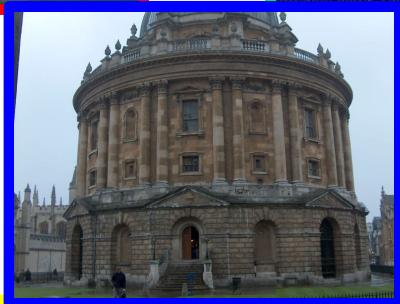
Target region



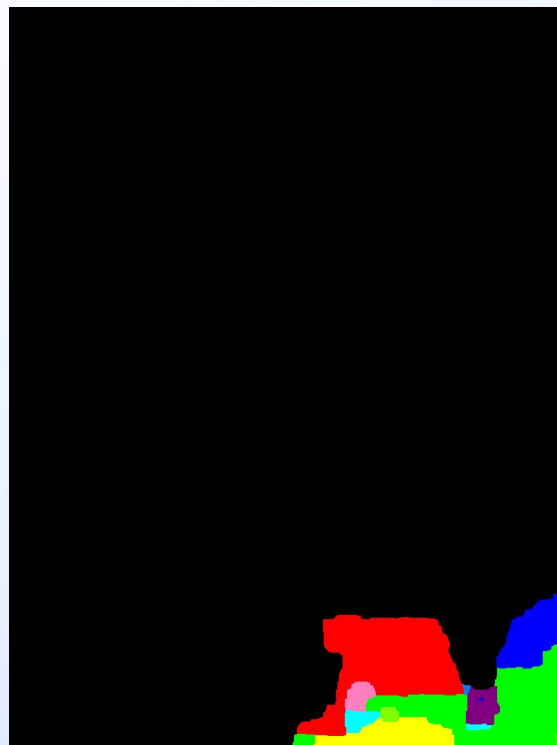
Result



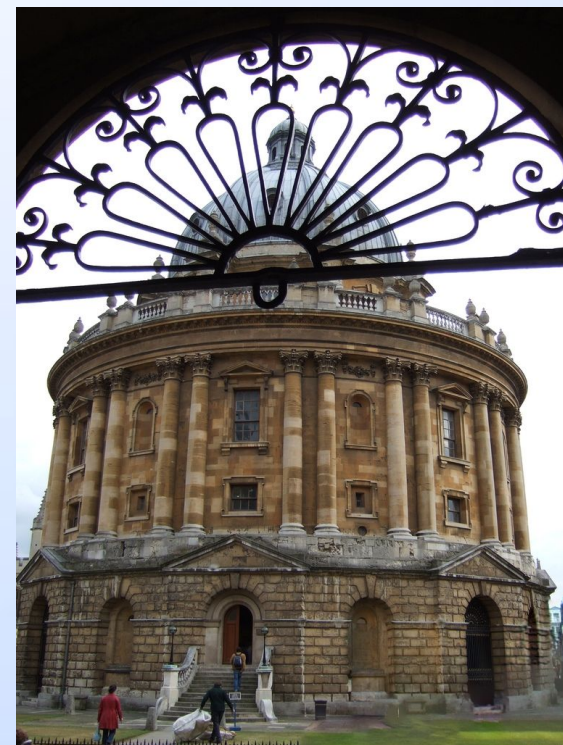
EXAMPLE 2 - ORACLES



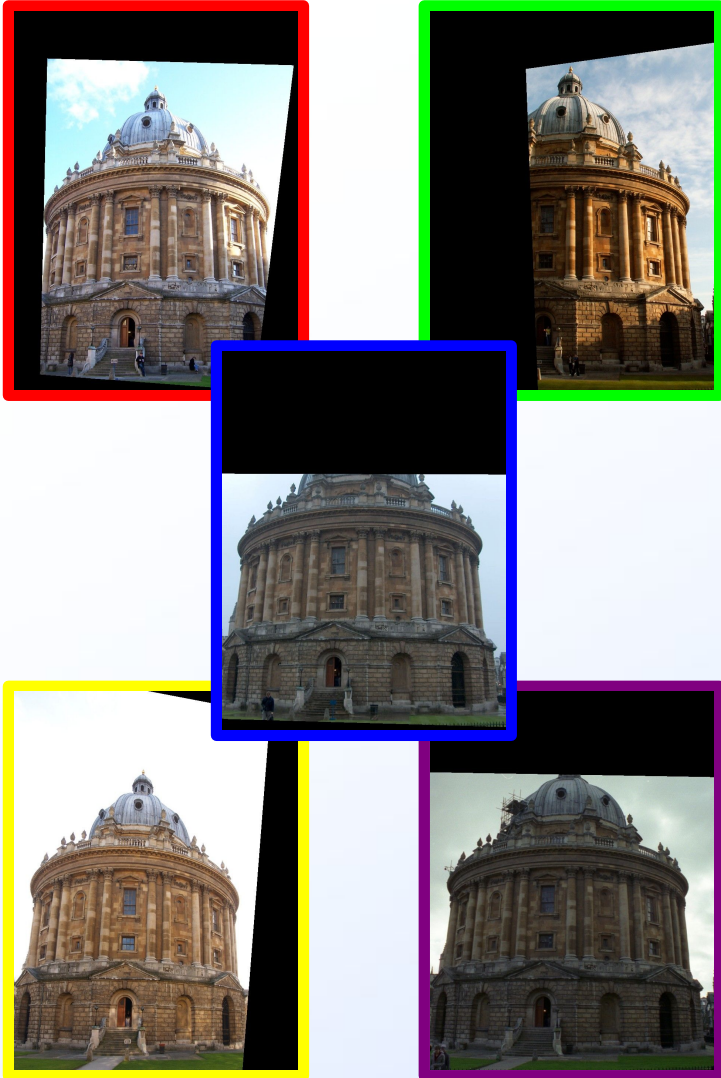
Labels



Result



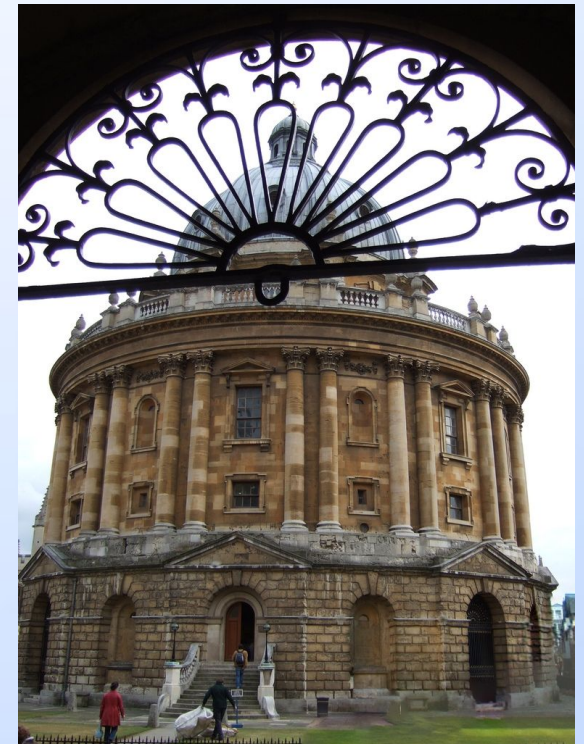
EXAMPLE 2 – REGISTERED ORACLES



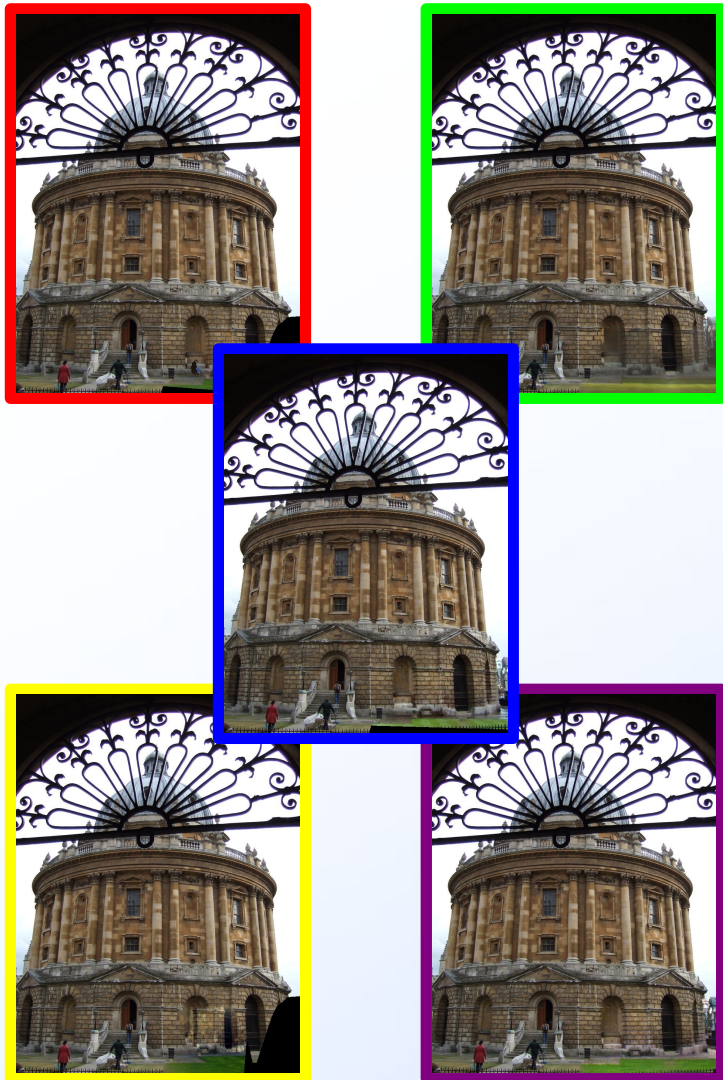
Labels



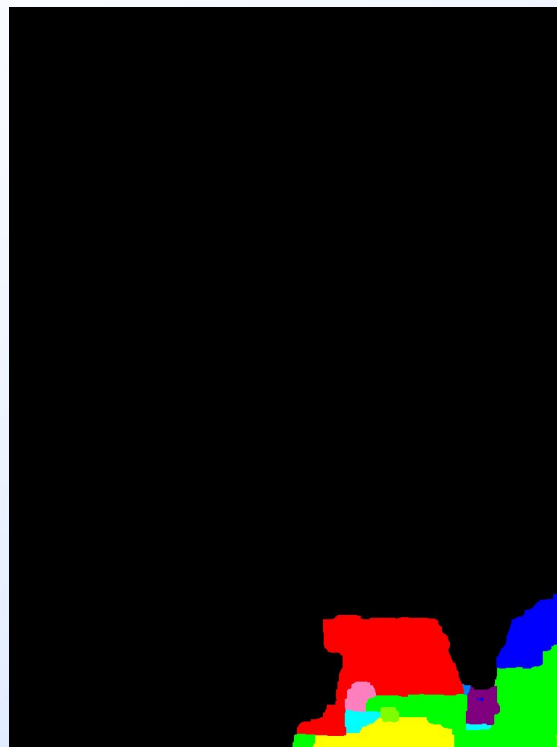
Result



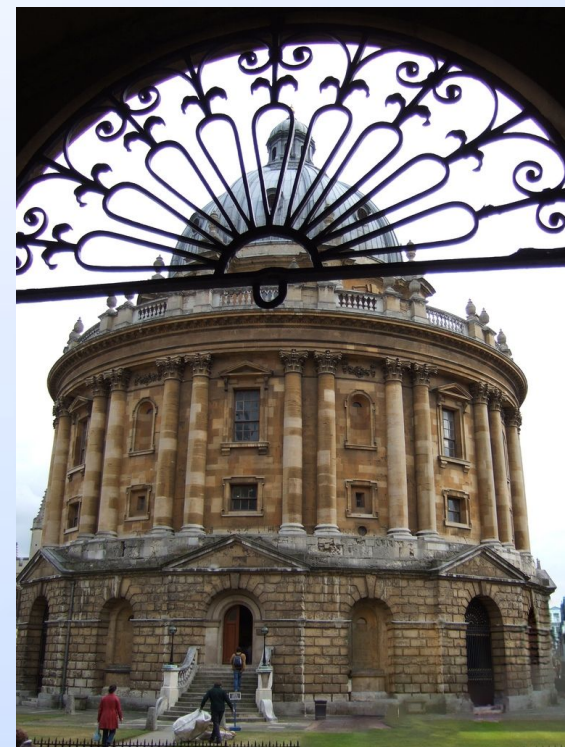
EXAMPLE 2 – PROPOSALS



Labels



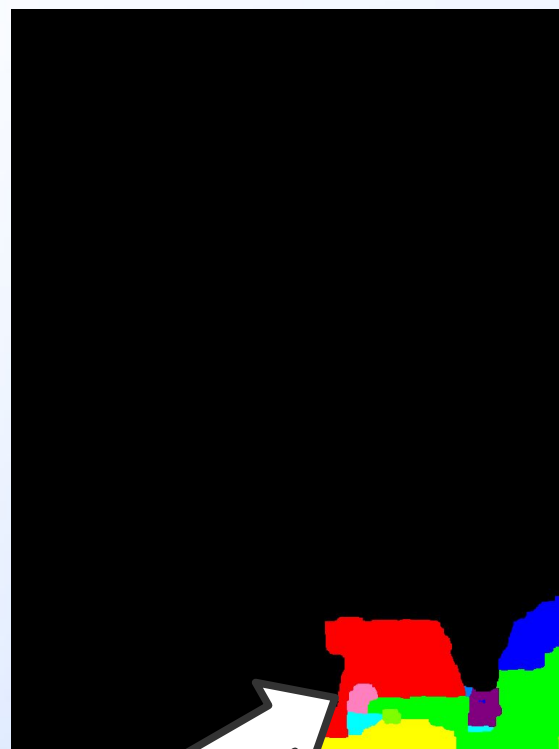
Result



EXAMPLE 2 – EFFECT OF UNARY TERM



Labels



Result



“Clean-plate” unary avoids occlusion

EXAMPLE 2 - EFFECT OF UNARY TERM



Labels



Result



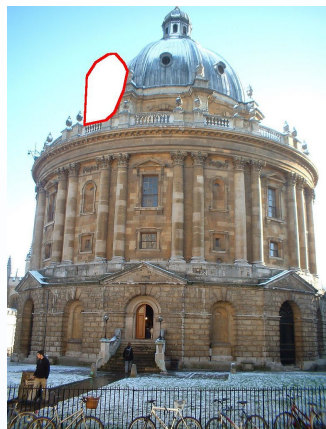
Decreased unary weight

FAILURE CASE – TOO FEW ORACLES

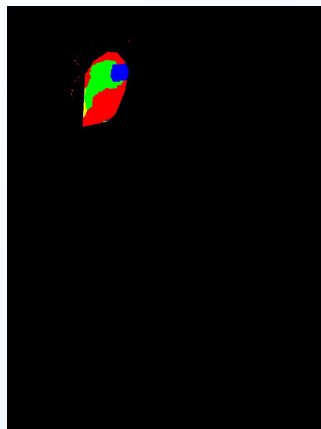
Query



Target region



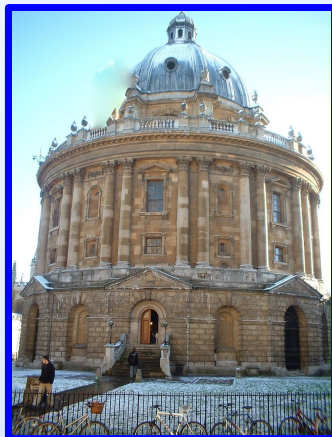
Labels



Final result



Proposals

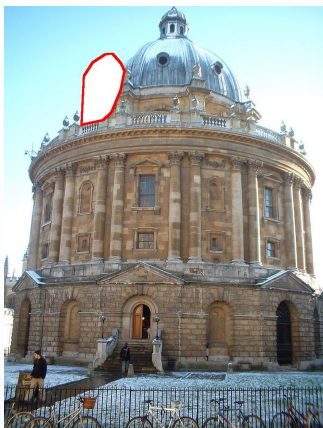


FAILURE CASE – TOO FEW ORACLES

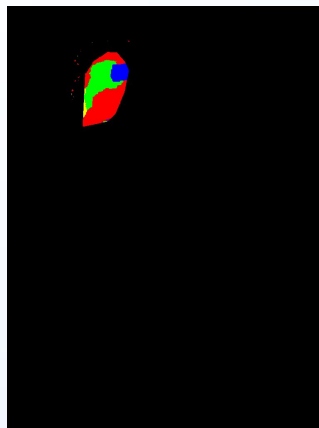
Query



Target region



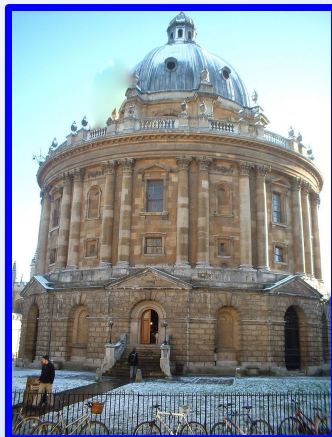
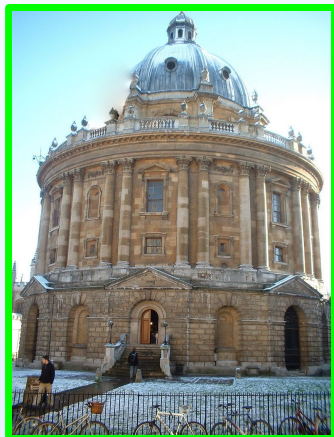
Labels



Final result

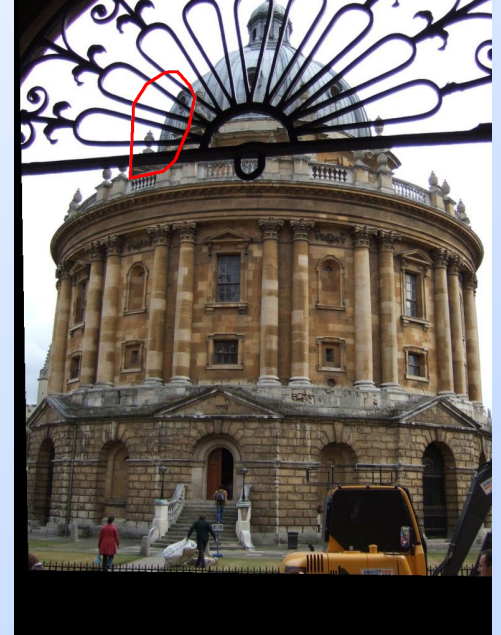
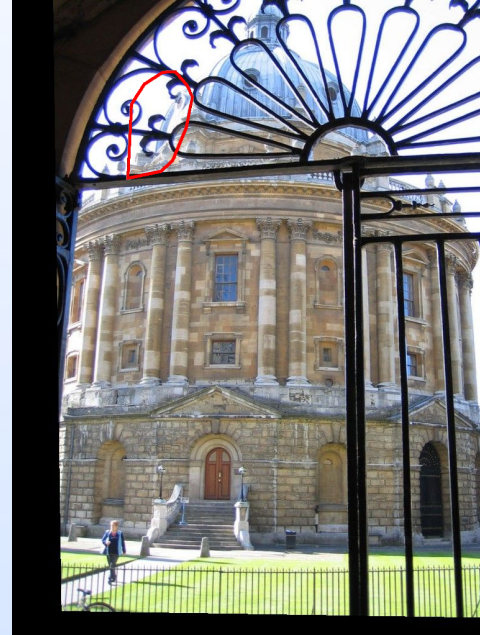
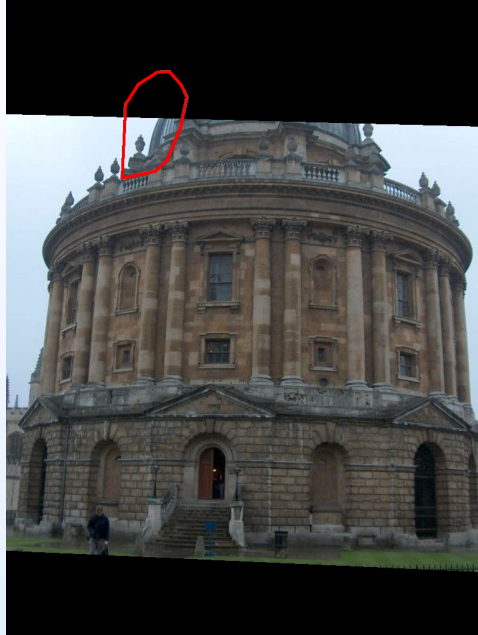
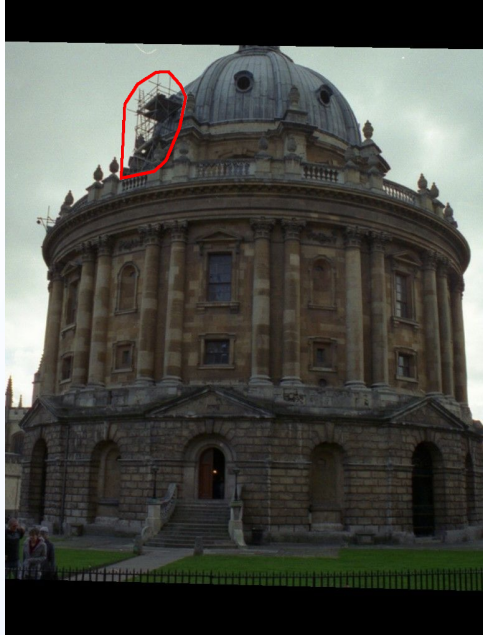


Proposals



FAILURE CASE – TOO FEW ORACLES

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



CONCLUSIONS / FUTURE WORK

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

GET OUT OF MY PICTURE! INTERNET-BASED INPAINTING

Oliver Whyte

Josef Sivic

Andrew Zisserman



INSTITUT NATIONAL
DE RECHERCHE
EN INFORMATIQUE
ET EN AUTOMATIQUE



centre de recherche PARIS - ROCQUENCOURT



COMBINING MULTIPLE PROPOSALS

Unary cost

$$E_1(\mathbf{p}, L_p) = k_{\text{query}} \overline{M}(\mathbf{p}) \|\mathbf{I}_{L_p}(\mathbf{p}) - \mathbf{I}_{\text{query}}(\mathbf{p})\| + k_{\text{median}} M(\mathbf{p}) \|\mathbf{I}_{L_p}(\mathbf{p}) - \mathbf{I}_{\text{median}(G(L_p))}(\mathbf{p})\|$$

penalises deviations from query image outside target region

penalises deviations from clean-plate inside target region

Pairwise cost

$$E_2(\mathbf{p}, \mathbf{q}, L_p, L_q) = k_{\text{grad}} (\|\nabla \mathbf{I}_{L_p}(\mathbf{p}) - \nabla \mathbf{I}_{L_q}(\mathbf{p})\| + \|\nabla \mathbf{I}_{L_p}(\mathbf{q}) - \nabla \mathbf{I}_{L_q}(\mathbf{q})\|)$$

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

$\mathbf{I}_{L_p}(\mathbf{p})$, $\mathbf{I}_{\text{query}}(\mathbf{p})$, $\mathbf{I}_{\text{median}(G(L_p))}(\mathbf{p})$ are colour of pixel \mathbf{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

