Image Inpainting

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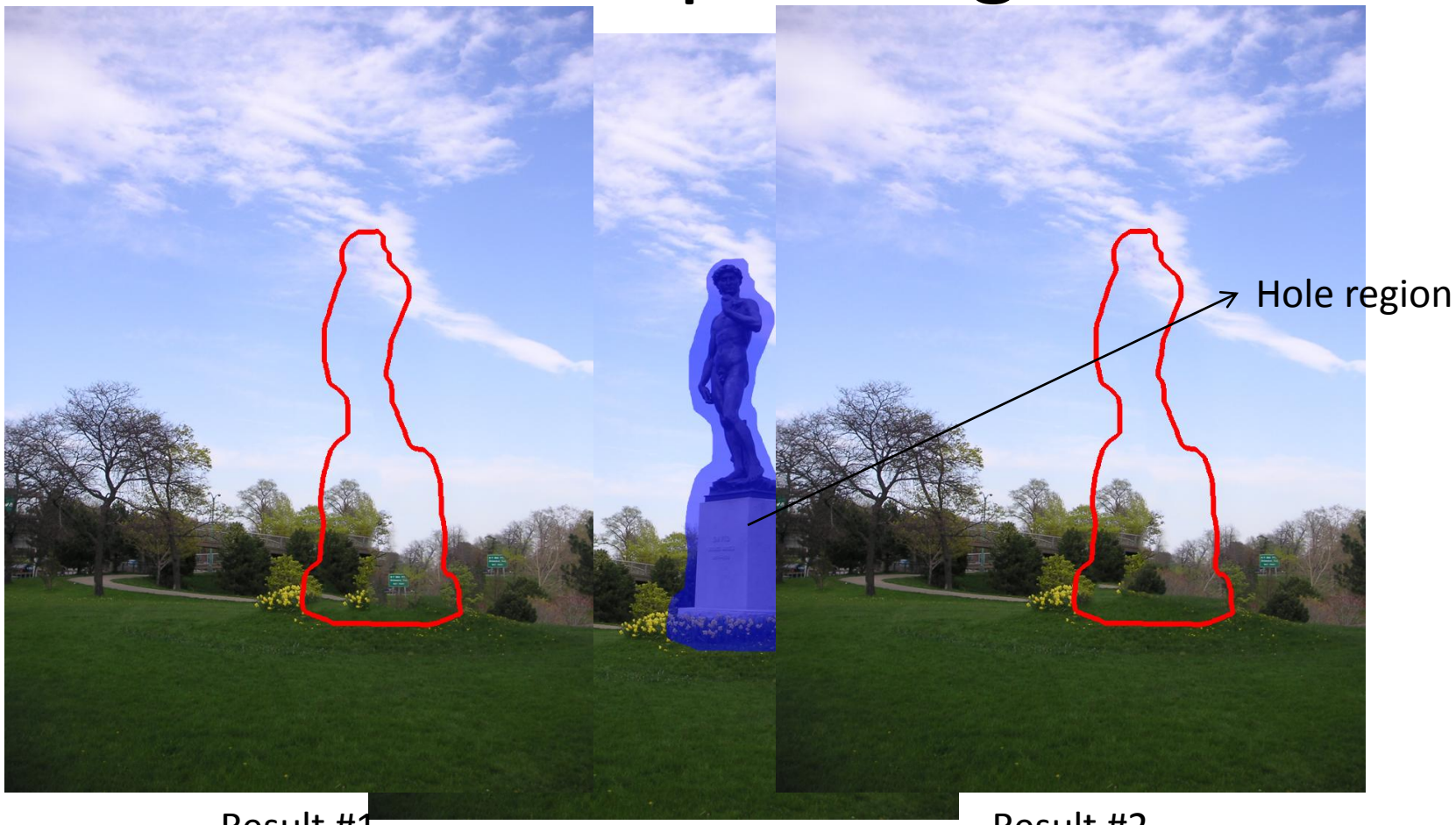
Contents

- Background
- Previous works
- Two papers
  - Space-Time Completion of Video (PAMI'07)[1]
  - PatchMatch: A Randomized Correspondence Algorithm for Structural Image Editing (SIGGRAPH'09)[2]

What is inpainting?

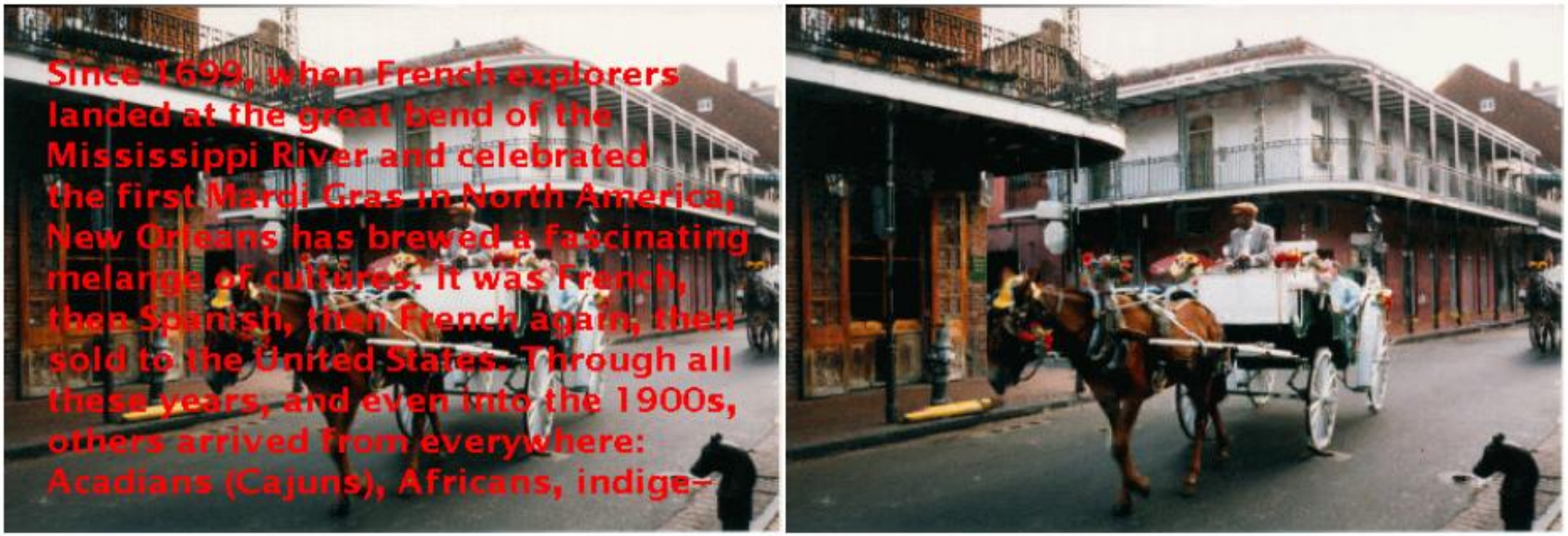


Result #1 Result #2

Goal: Fill in **hole region** in a **'visually plausible'** way

Previous work

- **Partial Differential Equations (PDE) based** (Bertalmio et al.[1])



  - Limited to small gap

Previous work

- **Exempler(or Patch) based**(Criminisi et al.[4])


  - Discontinuity in case of complex structures (e.g. curves or T(or X) conjunctions)

The first paper

- *Space-Time Completion of Video* (PAMI'07)[1]

Input

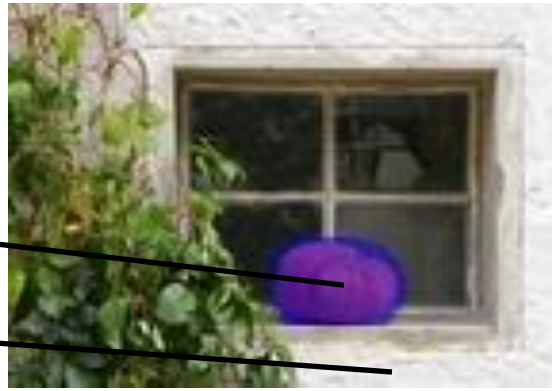
Output




Mask samples

Problem definition

- I : Input image
- $H \subseteq I$: Hole region
- $S = I \setminus H$: Source region
- Fill in H such that the resulting image I^* will have as much ***global visual coherence*** with S



Completion as a global optimazation

- Maximizing a **global objective function**

$$\text{Coherence}(\ I^* \,|\, S\ ) = \prod_{p \in I^*} \max_{q \in S} sim\ (W_p, V_q)$$

I^* : Resulting image

S : Source region

p, q : pixel point (x, y)

W_p, V_q : fixed - sized windows centered around p and q

$$sim\ (W_p, V_q) = e^{-\frac{d(W_p, V_q)}{2\sigma^2}}$$

$$d(W_p, V_q) = \sum_{(x,y)} \left\| W_p(x, y) - V_q(x, y) \right\|^2$$

Coherence maximization

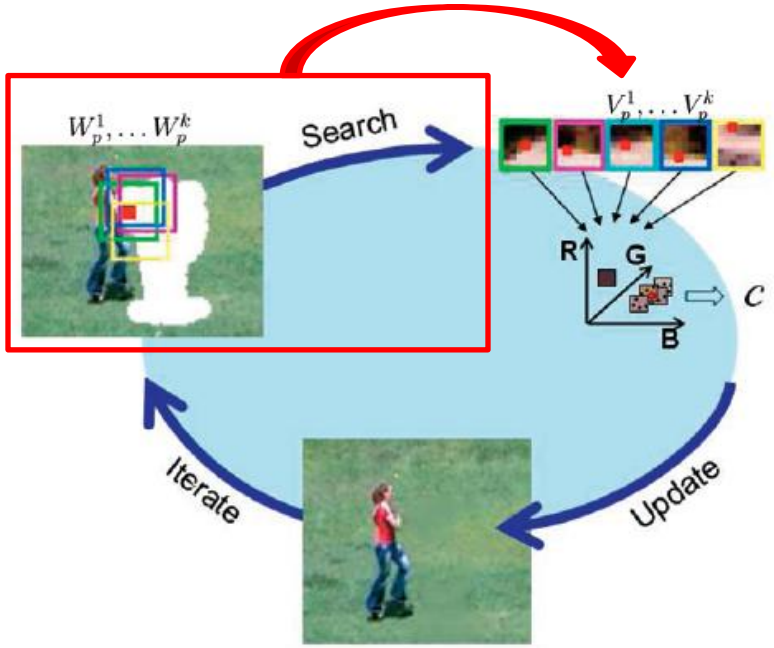
- Two local conditions
  1. All windows $W_p^1 \ldots W_p^k$ containing p appear in the source region S:

$$\exists V^i \subseteq S,\ W_p^i = V^i$$

  2. All those $V^1 \ldots V^k$ agree on the color value c at location p:

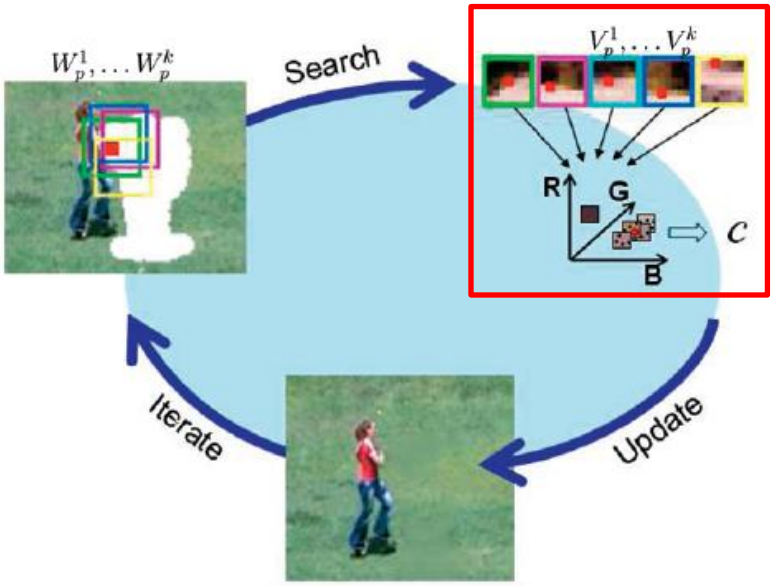
$$c = V^i(p) = V^j(p)$$

Iterative Scheme



- Search
  1. Let $\{W_p^i\}_{i=1}^k$ be all windows such that $p \in W_p^i$
  2. Find $\{V^i\} \subseteq S$ maximizing similarity measure

Iterative Scheme



- Vote
  - Let $c^i \in V^i$ be the appropriate colors

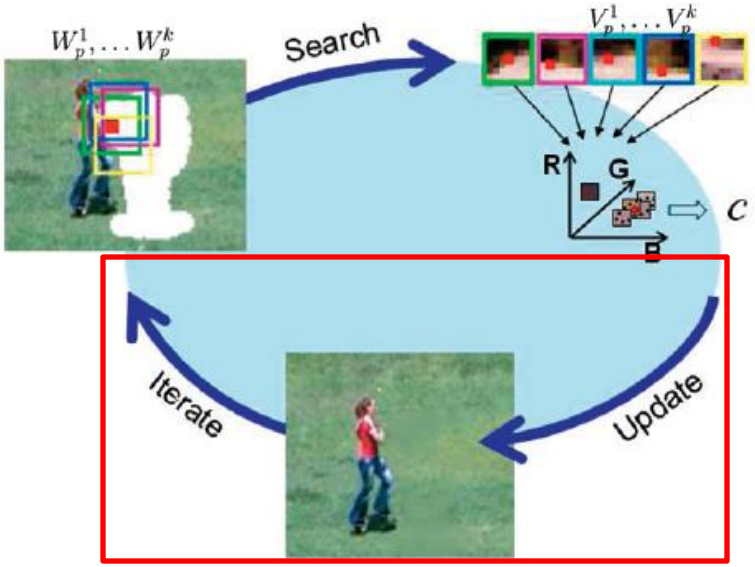
$$c = \frac{\sum_{i \in M} \omega_p^i c^i}{\sum_{i \in M} \omega_p^i}$$

, where $\omega_p^i = \alpha_p^i \cdot sim\left(W_p^i, V^i\right)$

$\alpha^i = \gamma^{-distTransform}$, γ : fixed constant

M is the highest mode from Mean-Shift algorithm

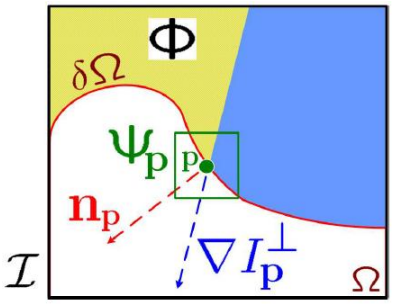
Iterative Scheme

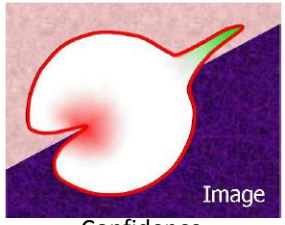


- Update
  - Repeated for every hole pixels
- Multiple iterations until converged

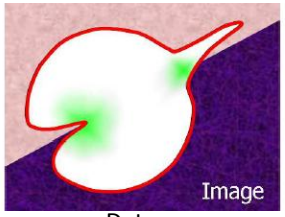
Problems

- **Sensitive to filling order**
  - Which pixels should be filled first?
  - **Priority**(C*D) introduced by Criminisi et al.[4]





Confidence



Data

$$C(\mathbf{p}) = \frac{\sum_{\mathbf{q}\in\Psi_\mathbf{p}\cap(\mathcal{I}-\Omega)} C(\mathbf{q})}{|\Psi_\mathbf{p}|}, \qquad D(\mathbf{p}) = \frac{|\nabla I^\perp_\mathbf{p} \cdot \mathbf{n}_\mathbf{p}|}{\alpha}$$

Only confidence

Only data

Problems

- **Expensive nearest neighbor search**

	NN search	rest	Total
Time[s]	383.95	0.743	384.693
Percentage[%]	99.8	0.2	100

During 1 iteration

  - Use **approximate NN search** to speed up

Results



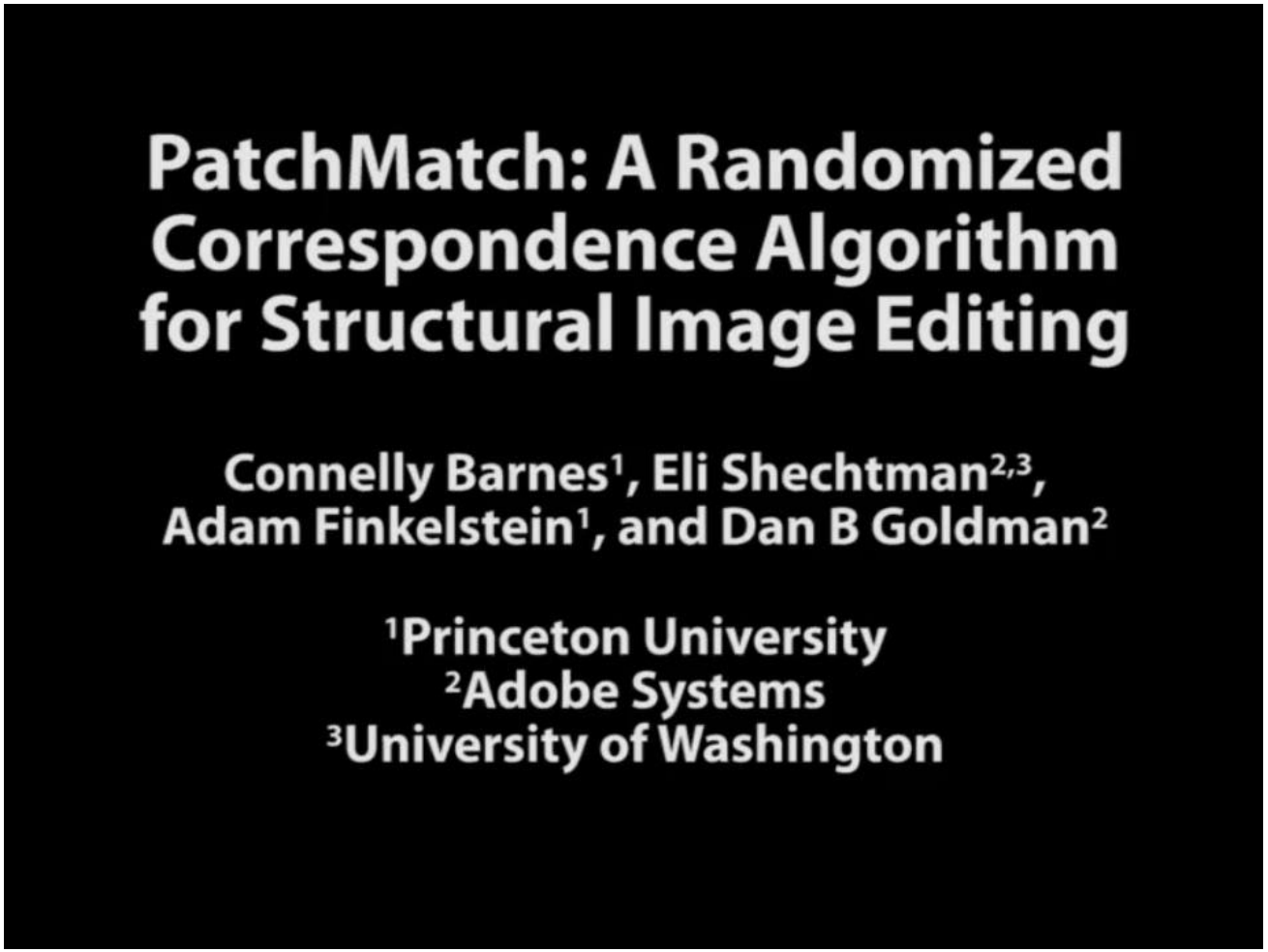



The second paper

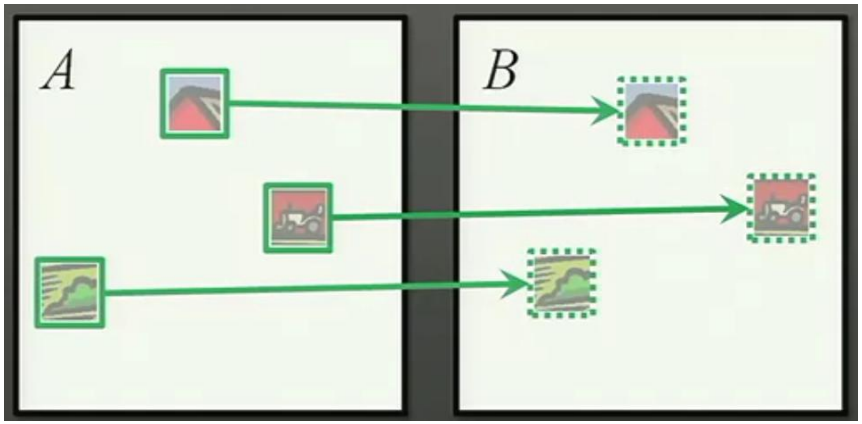
- *PatchMatch: A Randomized Correspondence Algorithm for Structural Image Editing* (SIGGRAPH'09)[2]

(a) original (b) hole+constraints (c) hole filled (d) constraints (e) constrained retarget (f) reshuffle

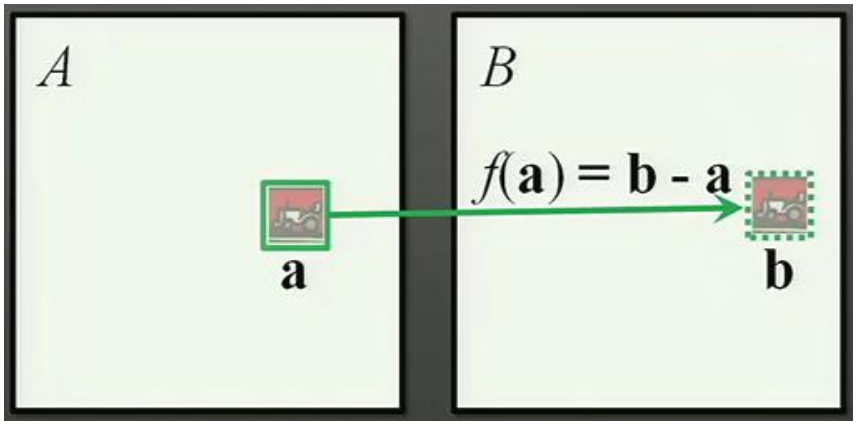
Video


PatchMatch: A Randomized Correspondence Algorithm for Structural Image Editing
Connelly Barnes[1], Eli Shechtman[2,3], Adam Finkelstein[1], and Dan B Goldman[2]
[1]Princeton University
[2]Adobe Systems
[3]University of Washington

Problem definition



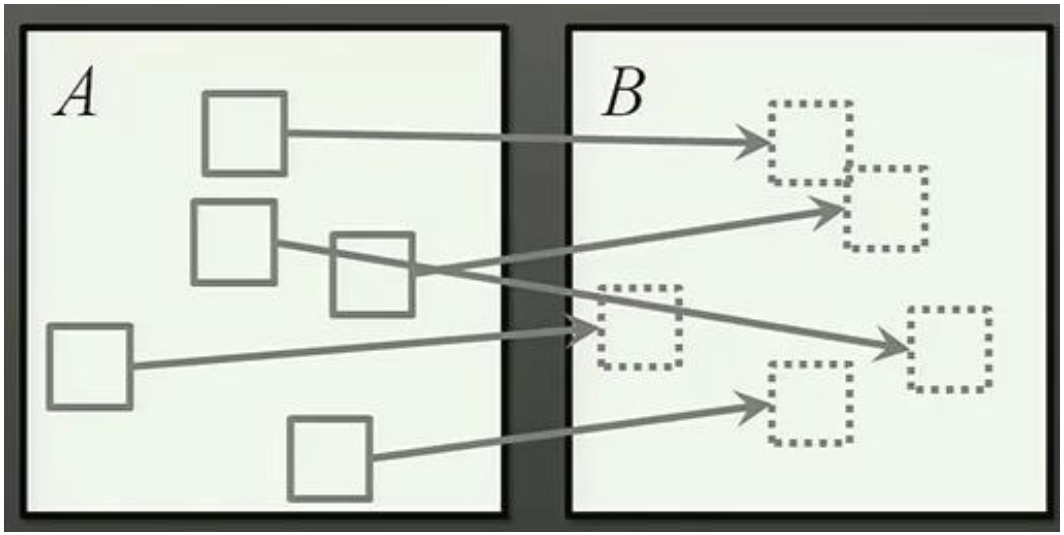
Correspondence



Nearest Neighbor(NN) Field

PatchMatch algorithm

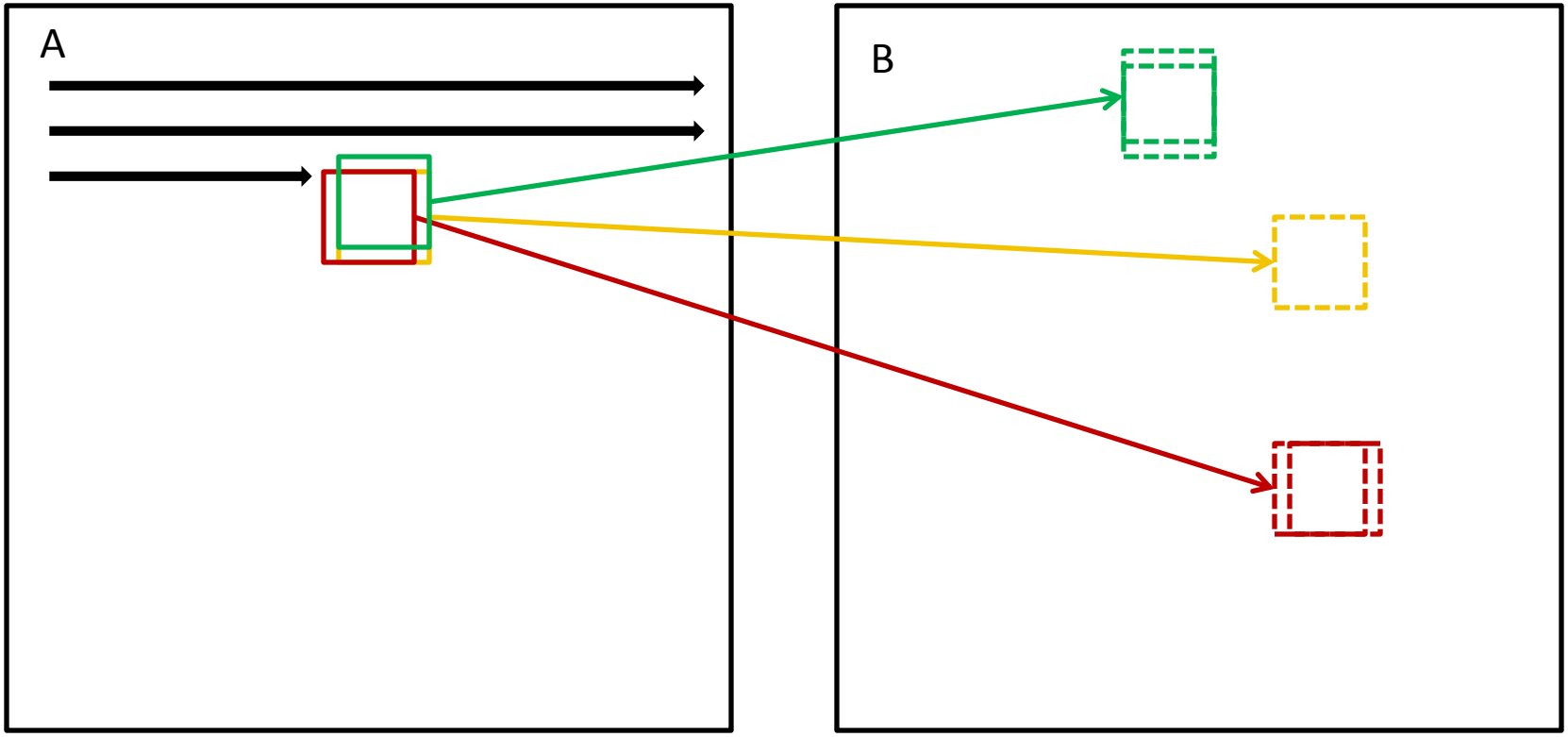
1. Initialization



   – Assign **random values** to the NN-field

PatchMatch algorithm

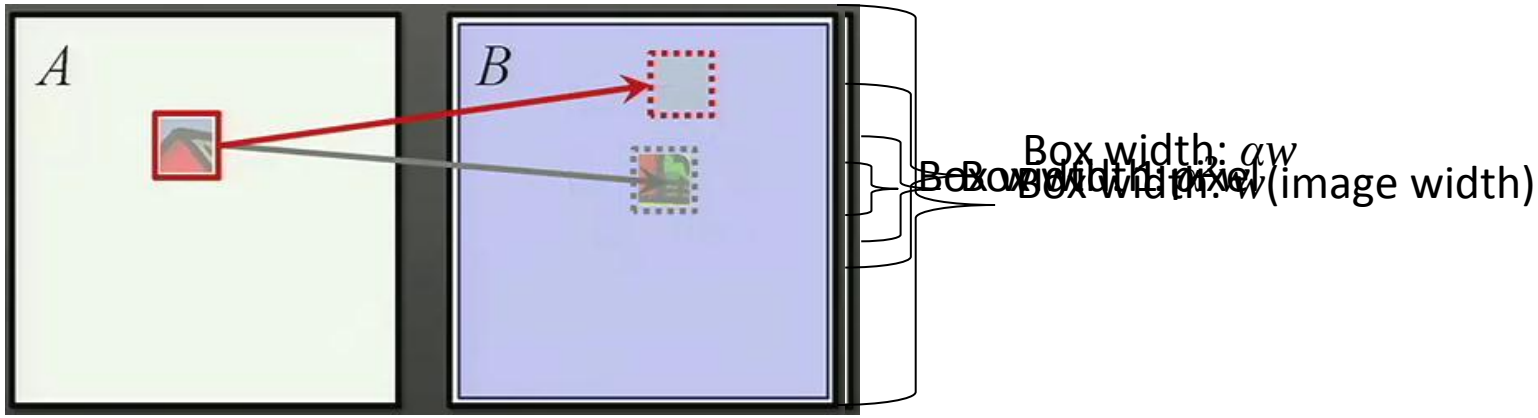
2. Propagation



$$f(x, y) = \arg\min_{D} \{ \text{current}, \quad \text{left}, \quad \text{above} \}$$

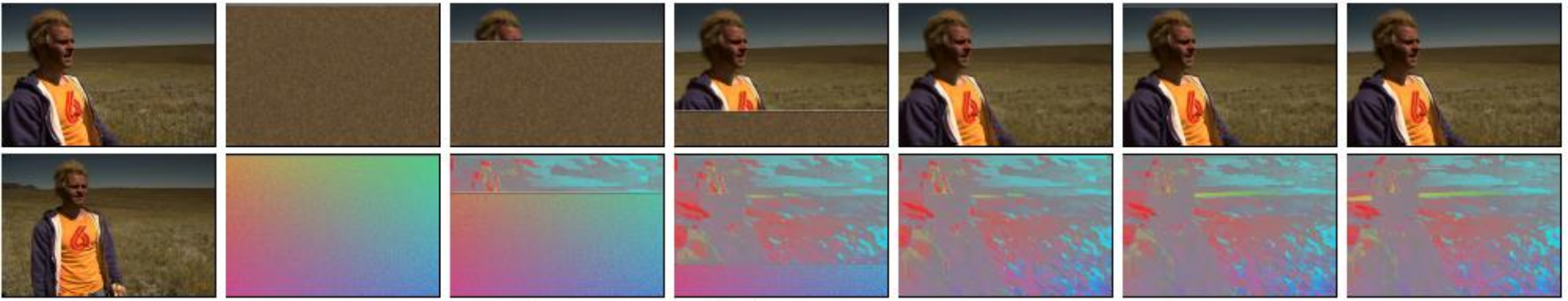
PatchMatch algorithm

3. Random search



Results

- Compare against the most popular method:
  kd-tree with approximate nearest neighbor matching

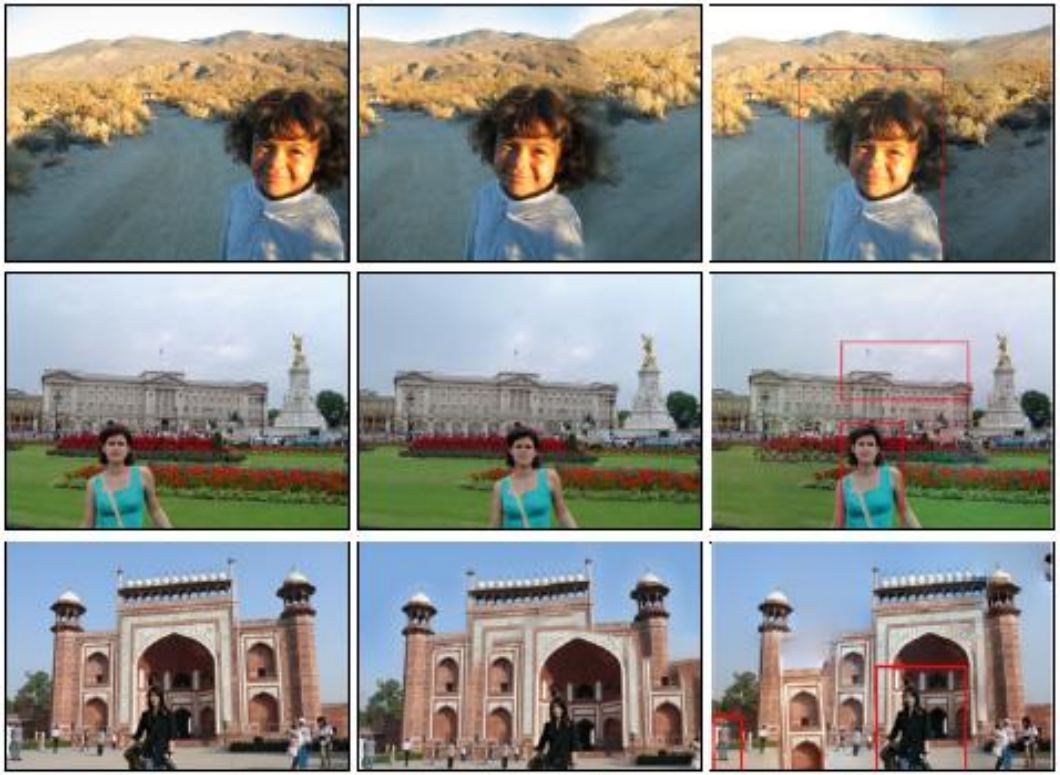


(a) originals (b) random (c) $\frac{1}{4}$ iteration (d) $\frac{3}{4}$ iteration (e) 1 iteration (f) 2 iterations (g) 5 iterations

	Time [s]		Memory [MB]	
Megapixels	PatchMatch	kd-tree	PatchMatch	kd-tree
0.1	0.68	15.2	1.7	33.9
0.2	1.54	37.2	3.4	68.9
0.35	2.65	87.7	5.6	118.3

Results

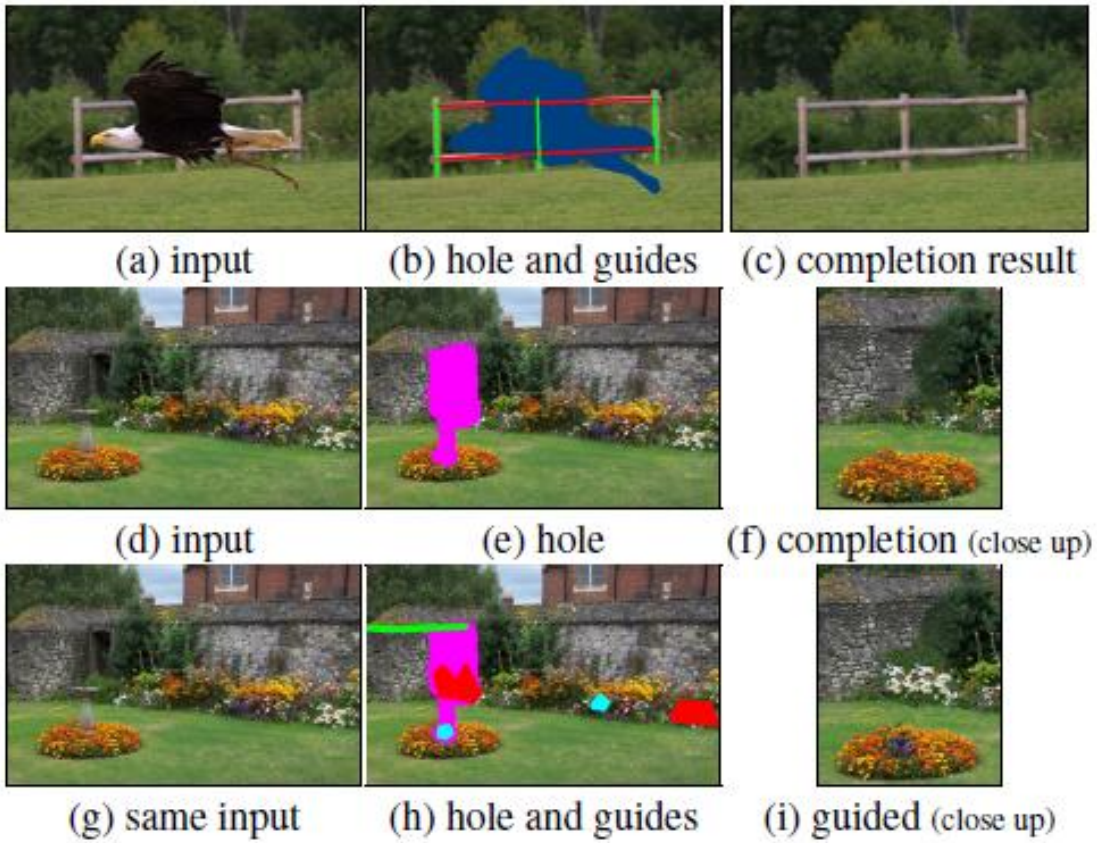
- Application to image reshuffling



(a) input (b) our reshuffling (c) Patch Transform

Results

- Application to image inpainting



Summary

- Global coherence optimization
  - An unified idea used to complete hole regions in both image and video
- Propagation and random search
    - Accelerate the nearest neighbor search based on patches

Q & A

References

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[3] C. Barnes, E. Shechtman, A. Finkelstein and D. B. Goldman,
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[7] C. Barnes, E. Shechtman, D. B. Goldman & A. Finkelstein
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