Lecture 24 Image inpainting

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Course piazza link：
piazza.com/shanghaitech.edu.cn/spring2021/cs270spring2021

Problem to solve

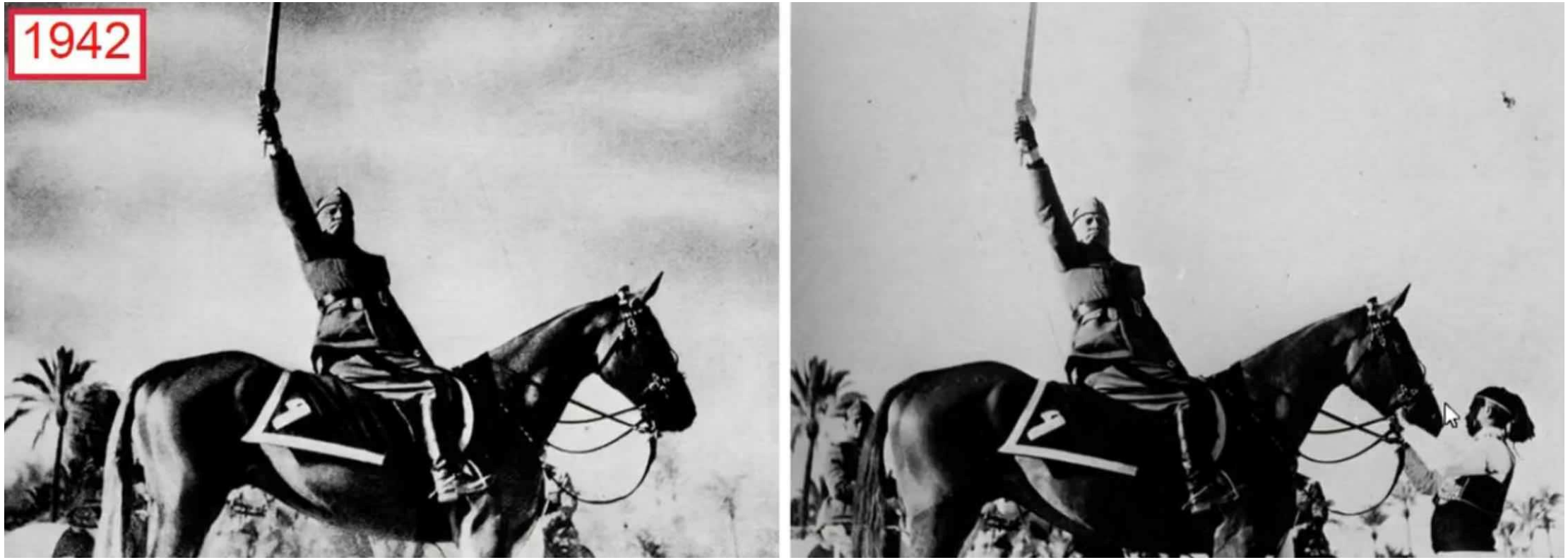

Image inpainting

Outline

- Photomontage
- PDE based image inpainting
- Patch based image inpainting

Image photomontage

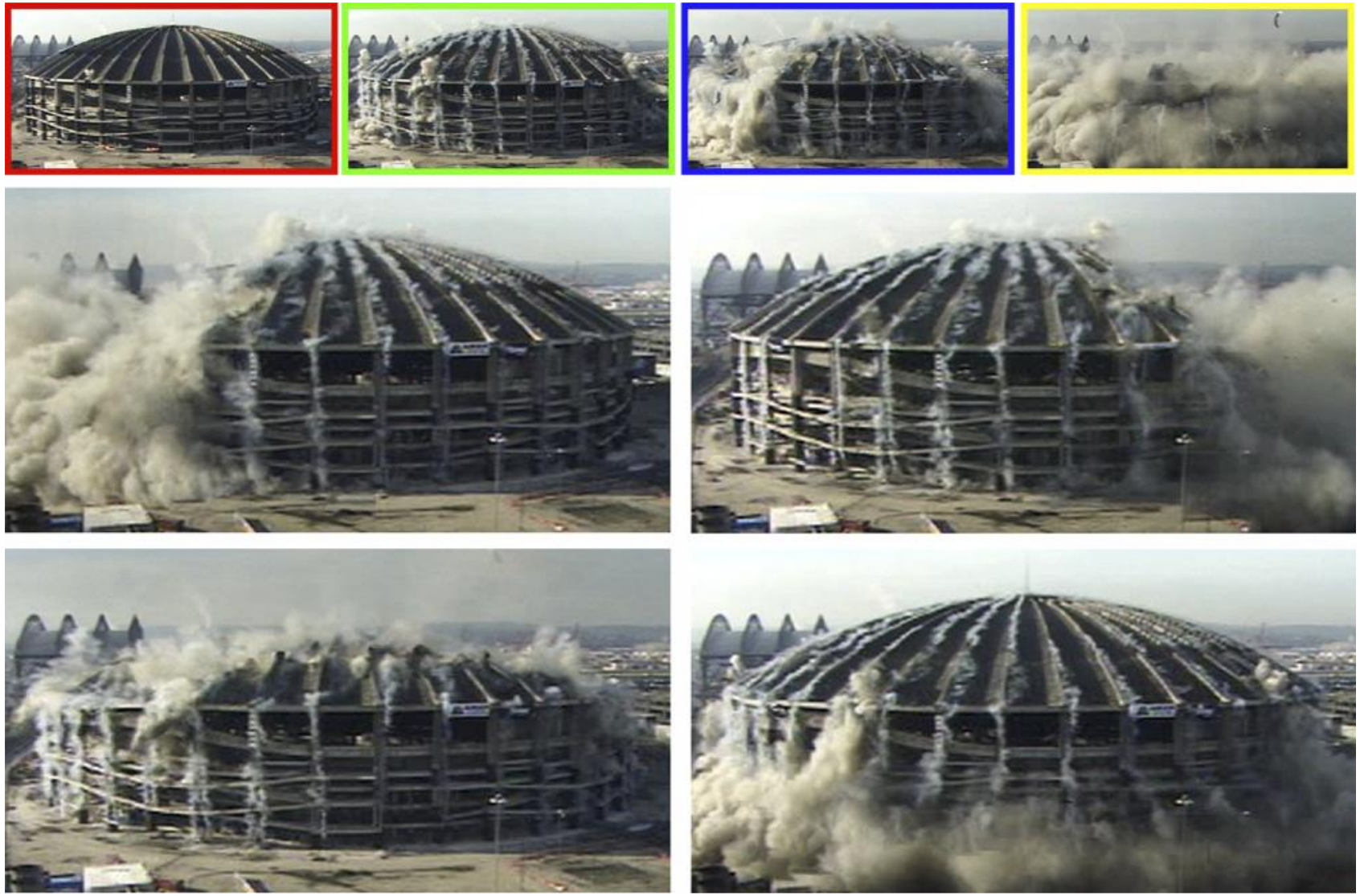

Image photomontage

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Penalty function for image photomontage

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- Idea: “cost” of drawing line between pixels i and j. Where $S(i)$ denote a pixel in the source image; $T(i)$ denote a pixel in the target image

$$C(i,j) = \|S(i) - T(i)\| - \|S(j) - T(j)\|$$

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$$C(i,j) = \|S(i) - T(i)\| + \|S(j) - T(j)\|$$

Find best seam via graph cut

- We could modify this with image gradient:

$$w_{ij} = \frac{\|S(i) - T(i)\| + \|S(j) - T(j)\|}{\left|\vec{d} \cdot \nabla S(i)\right| + \left|\vec{d} \cdot \nabla T(i)\right| + \left|\vec{d} \cdot \nabla S(j)\right| + \left|\vec{d} \cdot \nabla T(j)\right|}$$

Numerator: pixels color should be the same on either side.

Denominator: $\vec{d}$ is the vector pointing from i to j. Weight will be small if seam passed through gradient (parallel to edge). Weight will be large if seam passed along gradient (perpendicular to edge). Smooth areas will be in-between.

- Idea: “scribble” on regions of images that we want to keep in the final composite, let graph cut algorithm decide what to do with pixels.

Find best seam via graph cut

- We could modify this with image gradient:

$$w_{ij} = \frac{\|S(i) - T(i)\| - \|S(j) - T(j)\|}{\left|\vec{d} \cdot \nabla S(i)\right| + \left|\vec{d} \cdot \nabla T(i)\right| + \left|\vec{d} \cdot \nabla S(j)\right| + \left|\vec{d} \cdot \nabla T(j)\right|}$$

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Image in-painting

- E.g. wire removal, removing artifact/creases from old portraits.
- Two easiest approaches:
- Partial Differential Equations (PDE).
- Patch-based methods.

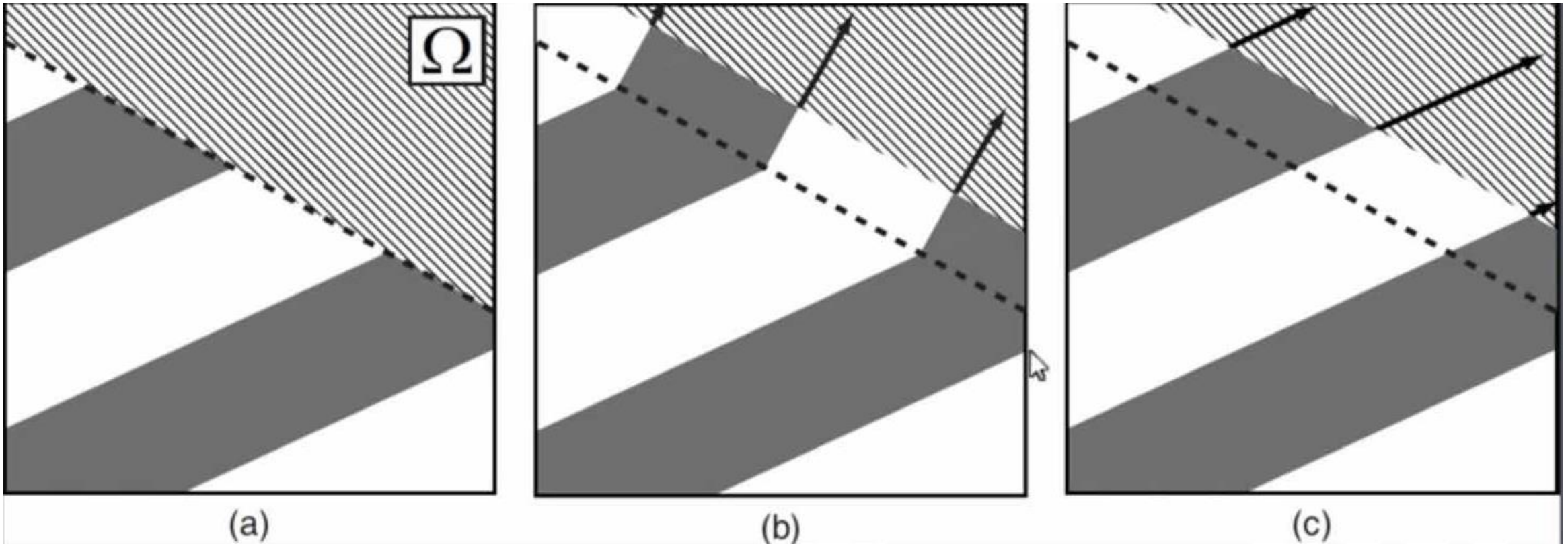
PDE in-painting method

- A differential equation that tries to “punch” good colors from the boundary into the hole.
- The most important thing about image: image edges.
- Edges are particular important; we want to make sure they continue into the hole.
- Key equation:

$$\nabla L \cdot \vec{N} = 0$$

L: information we want to propagate; $\vec{N}$ direction.

PDE inpainting method



PDE inpainting method

- E.G.: We define L=smoothness estimator; $\vec{N}$ = isophote direction:

$$\nabla\left(\nabla^2 I(x,y)\right)\cdot\nabla^P I(x,y) = 0\ ,(x,y\ )\epsilon\Omega$$

- Laplacian edge; the change in the edge; isophote direction (the direction going along the edge).
- Interpretation: change in Laplacian along isophote direction should be zeros. Want to preserve edge of 'arrival'.
- Solution: $\frac{\partial I}{\partial t} = \nabla\left(\nabla^2 I(x,y)\right)\cdot\nabla^P I(x,y)$

General algorithm

$$\frac{\partial I}{\partial t} = \nabla\left(\nabla^2 I(x,y)\right) \cdot \nabla^P I(x,y)$$

➢ **Iteratively**

- Continue edge of surrounding area into hole;
- Continue color of surrounding area into hole;

$$I_i(x,y) = I_{i-1}(x,y) + \nabla\left(\nabla^2 I_{i-1}(x,y)\right) \cdot \nabla^P I_{i-1}(x,y)$$

PDE method performance

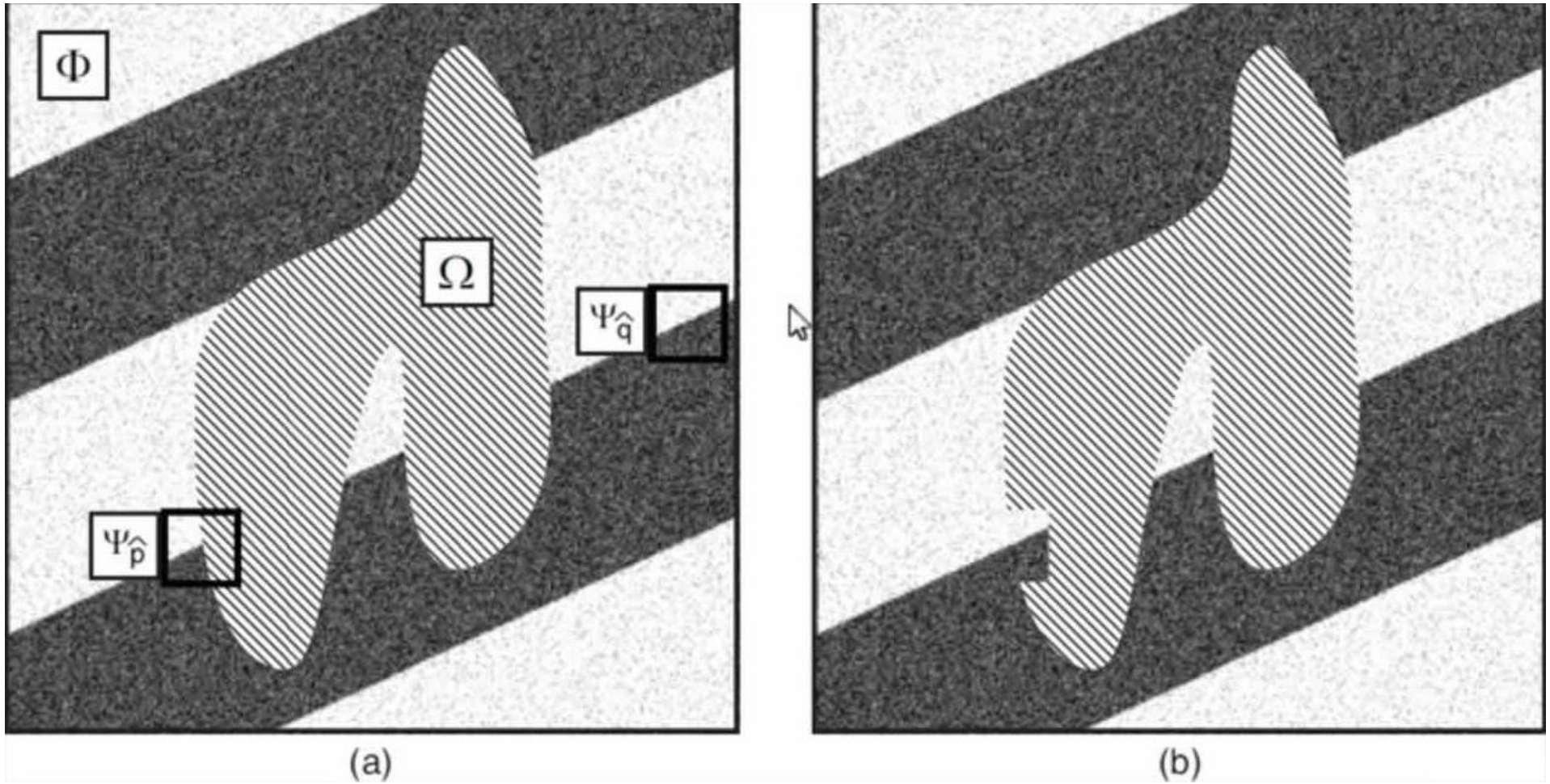
PDE method performance

PDE method performance

An example when PDE doesn't work

- PDE- based method works OK for very thin holes, and low-texture regions. But can't hallucinate high detail.

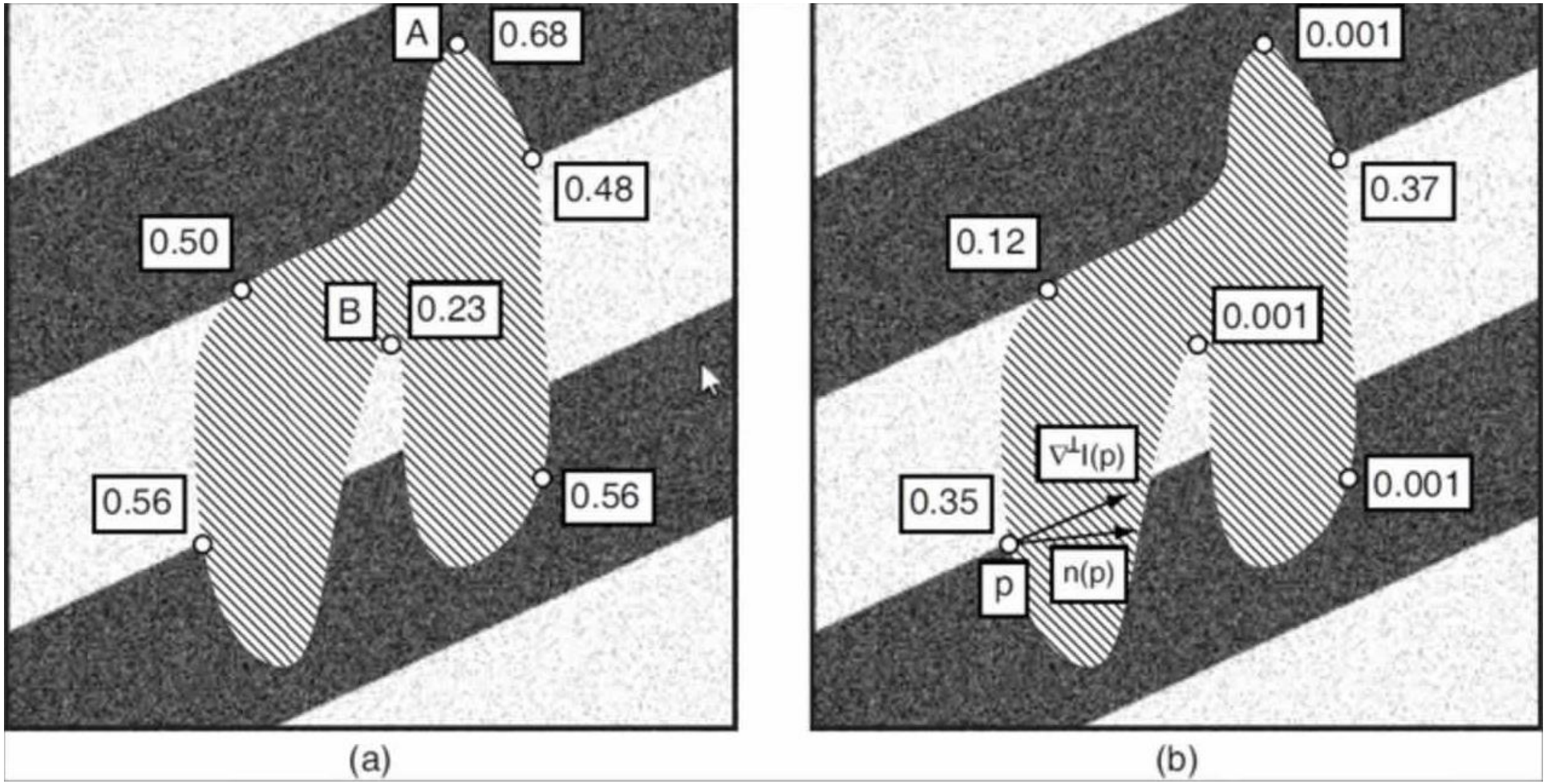
Patch-based method



Patch-based method

- Determine a priority for each pixel on the hole boundary.
- Select patch around pixel p with highest priority, Ψ_p.
- Search remainder of image for the best matting patch Ψ_q.
- Overwrite hole pixels in Ψ_p with corresponding pixel from Ψ_q, shrink the hole, update priority.

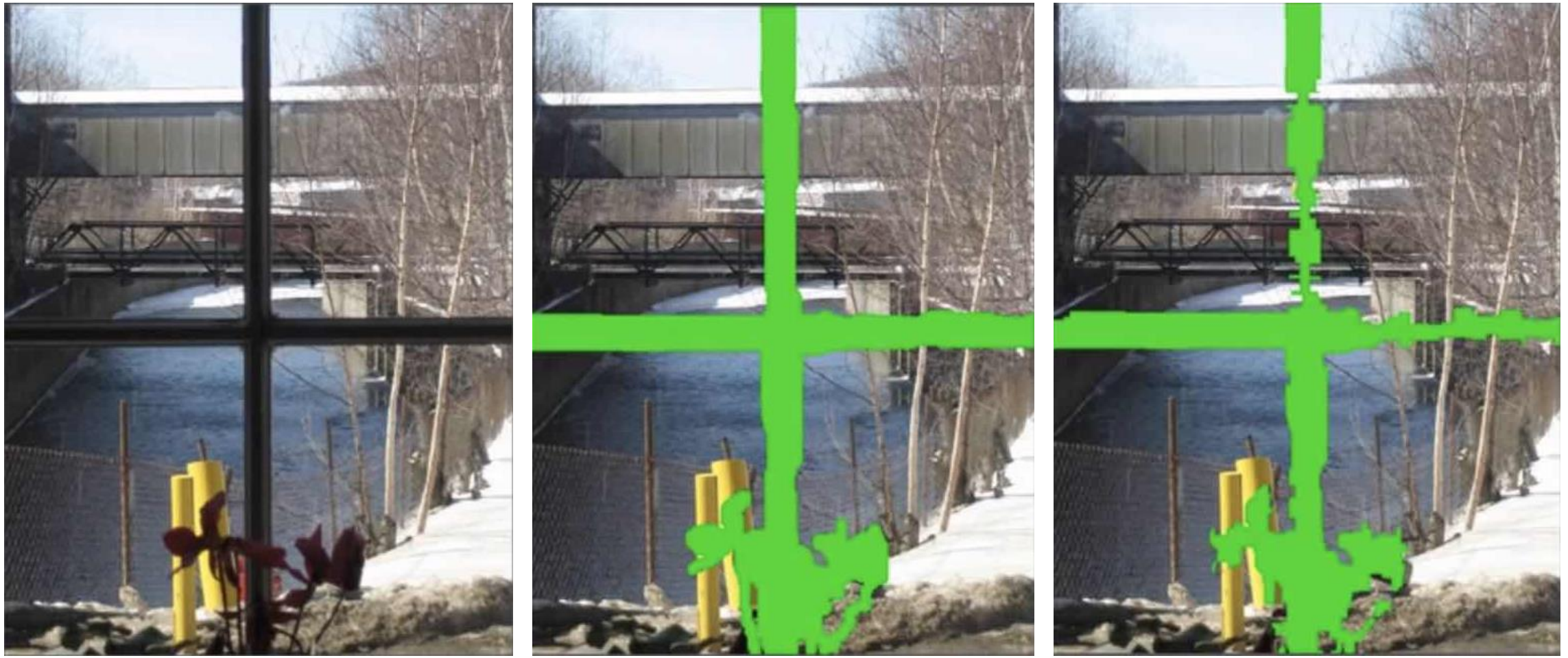
Patch-based method



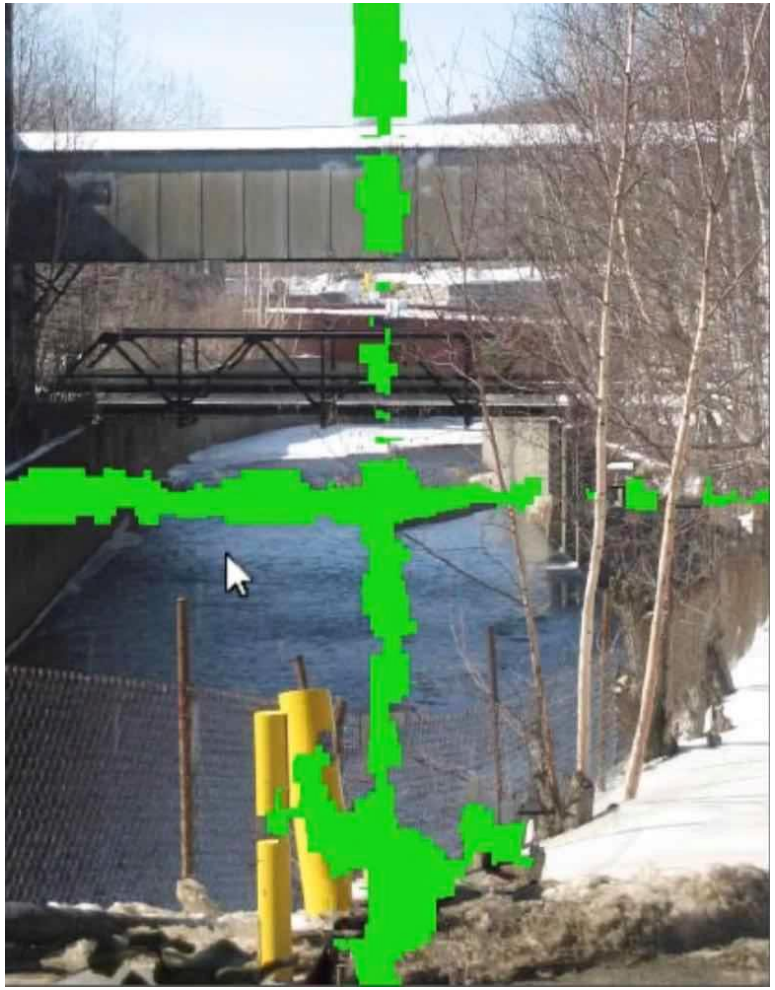
Patch-based method

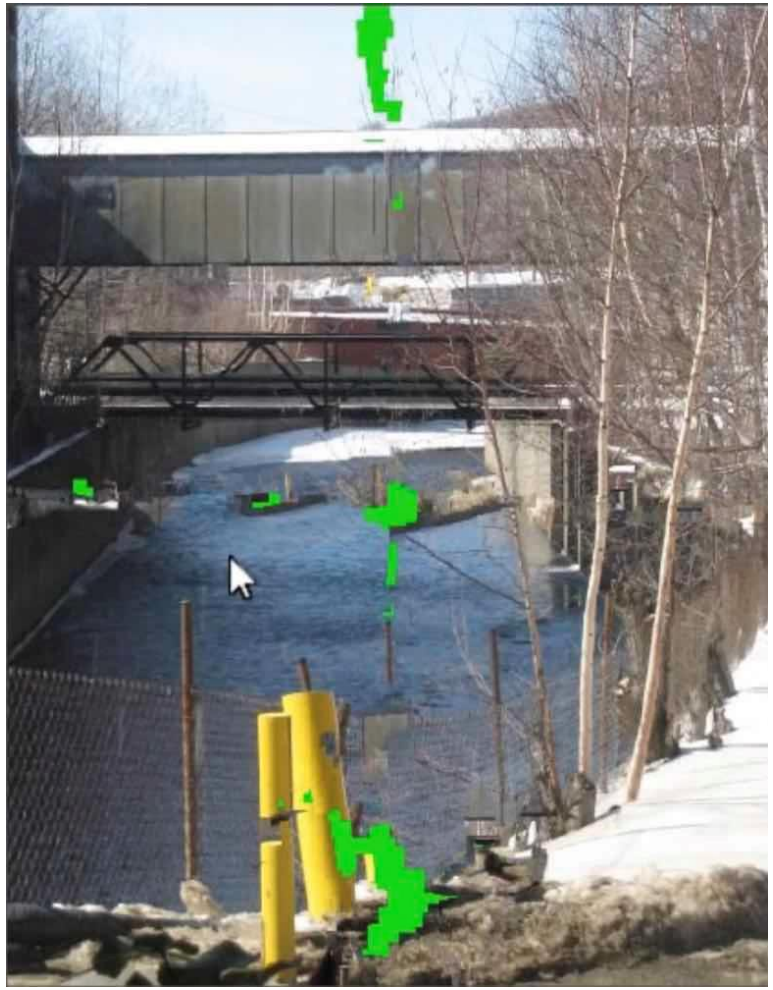
- Which pixel should have highest priority?
- 1) confidence term: high confidence if pixel is surrounded by known pixels $\boldsymbol{C(p)}$.
- Date term: highest strong edges from outside the hole hit the hole at right angles.
- $\boldsymbol{D(p) = \|\nabla I(p)\|(\nabla^{\perp} I(p) \cdot \vec{n}(p))}$

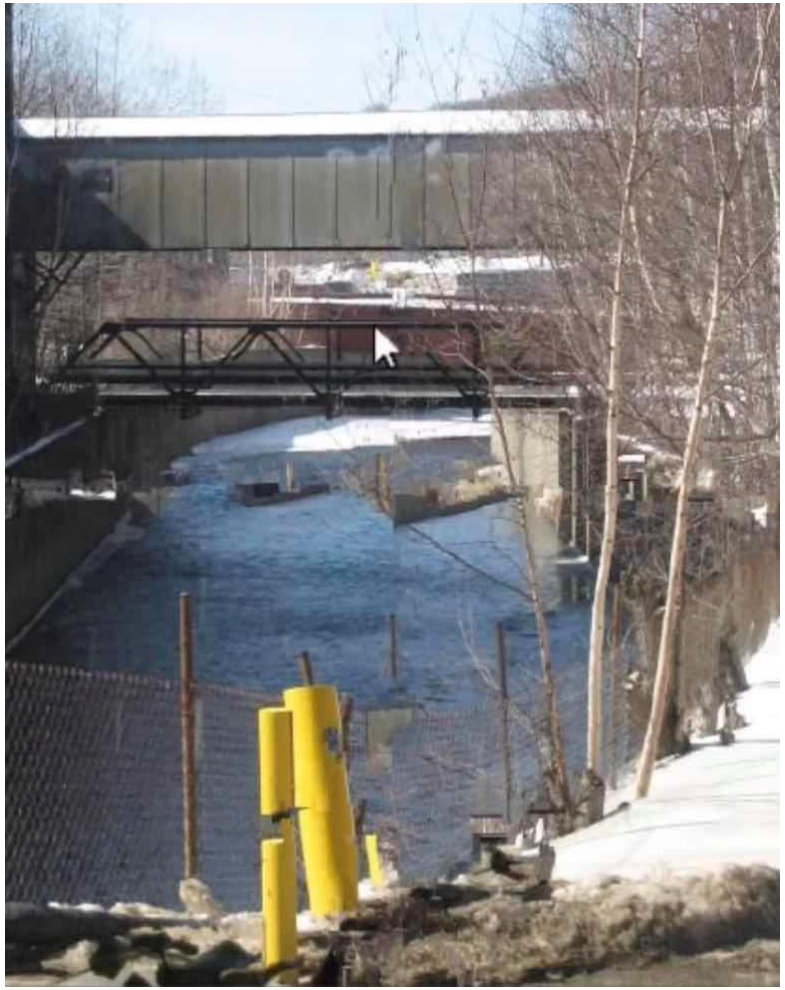
Patch-based method performance



Patch-based method performance







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