Image Inpainting using Wexler and PatchMatch algorithm

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Introduction

The purpose of this project is to

1. Define a mask of arbitrary shape by user. Then use this mask to eliminate any part of the picture.
2. Having an image and a missing part of it, we can then use Wexler's method to fill in the missing region with reference to surrounding background.
3. Use PatchMatch to speed up the process.

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GUI

Using the Matlab function *ginput*, we are able to define any shape by mouse. To generate the mask, an image of certain size is used as a raw material. And we use *ginput* to select part of it.

After selecting the part out of the original image, we have a shape now.

Now we can use the original image to subtract this part then reverse the result. We then get a mask and its binary value is stored in a parameter. This is the user-define mask. Now by multiplying the mask and images, we can eliminate the sections we want out of the pictures.

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Main algorithm

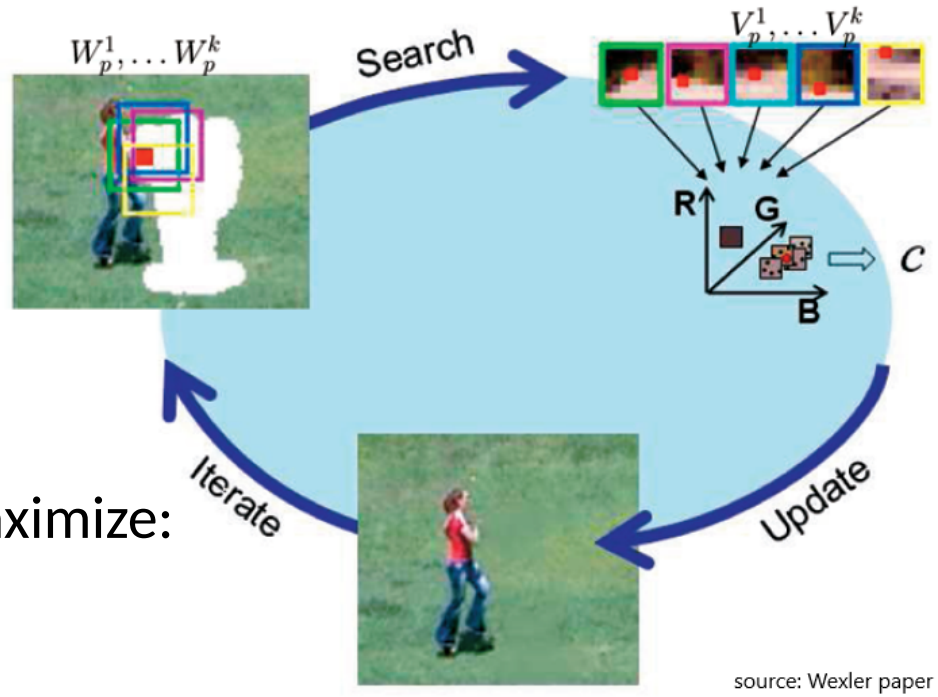
Algorithm 1 Inpainting algorithm

Input: image, binary mask

Output: inpainted image

```
Downscale image to the coarsest level L
Initial reconstruction with Onion-peel at level L
for level of pyramid k = L to 2 do
    while Convergence and max iterations not reached do
        Reconstruction
    end while
    Upscale for next level k
end for
For last level k = 1, apply FinalReconstruction
```

Determine the appropriate color c for a pixel p_i



source: Wexler paper

1. Find windows W_p^i
2. Find windows V_p^i that maximize:

   $sim(W_p, V_q) = e^{-\frac{d(W_p, V_q)}{2\sigma^2}}$
3. Compute $c = \frac{\sum_i \omega_p^i c^i}{\sum_i \omega_p^i}$

   with $\omega_p^i = \alpha_p^i sim(W_p^i, V^i)$

Hole reconstruction

Rather than processing pixel by pixel and finding the set $\{W_p^i\}_{i=1}^N$ and $\{V_p^i\}_{i=1}^N$ for every pixel of the hole, another approach was used to reduce the number of search operations:

1. Slide a window W'.
2. If the windows W' intersect the hole H then find V' that maximizes $sim(W', V')$.
3. The window V' will only contribute in the vote of the pixels contained in W' and H.
4. Redo step 1 until end of the image.

Pyramidal reconstruction: Downscaling

At first, we downscale the occluded image by *L* levels:

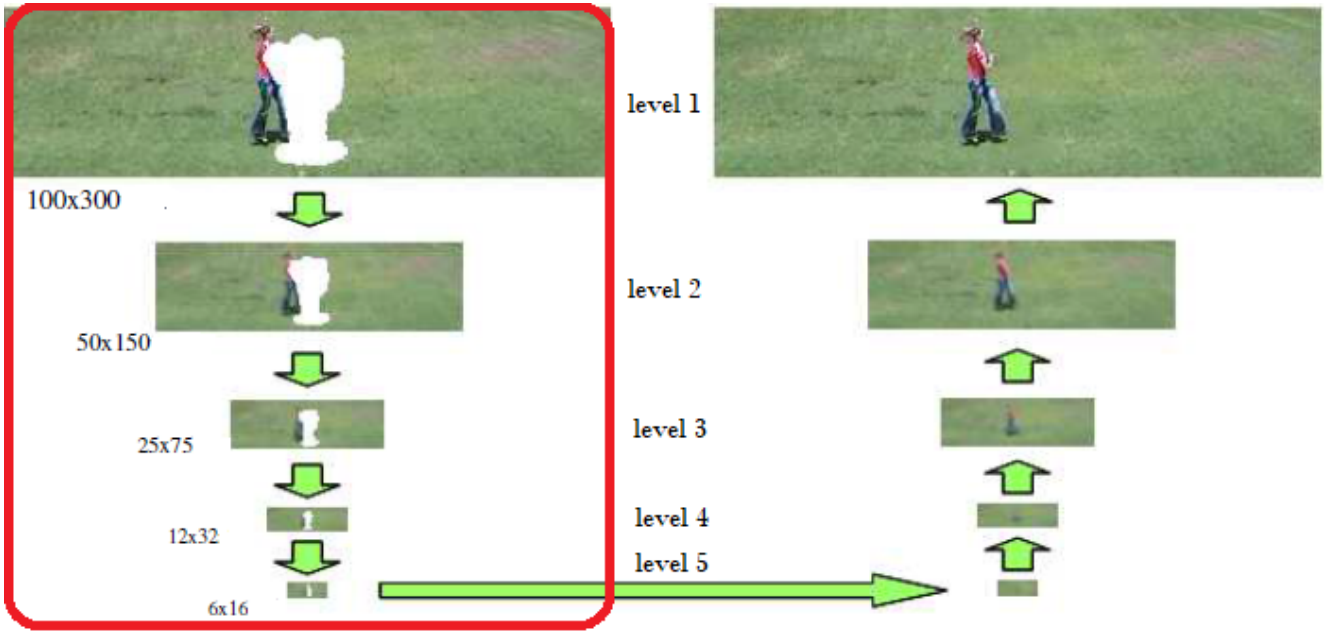


Figure: Pyramidal resolution reconstruction (source: Wexler paper)

Initial Reconstruction: Onion-peel

At the coarsest level L, we fill the hole H layer by layer:

$$W_p^* = \{W_p^i \mid (W_p^i \cap \partial H_k \neq \varnothing) \wedge (W_p^i \cap \partial H_{k+1} = \varnothing)\}$$

For the kth layer, We choose windows W^* containing at least one value k in the distance transform AND no value that is greater than k

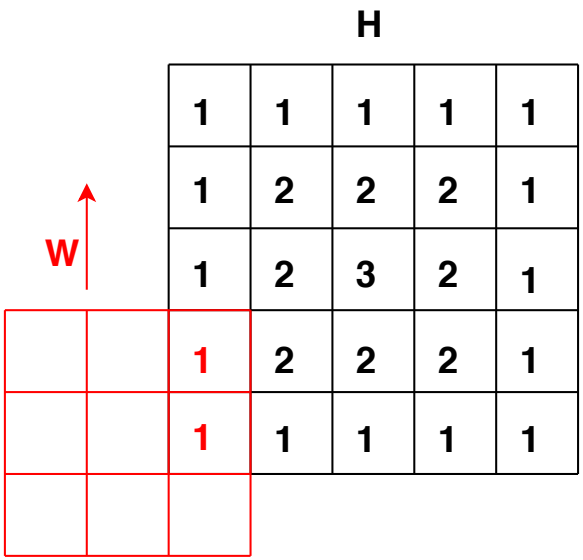


Figure: Distance transform of image

Pyramidal reconstruction: Upscaling

For each pyramid level $l > 1$:

1. Reconstruct downscaled hole H_l as shown before
2. $H_{l-1} \leftarrow upscale(H_l)$

At the finest pyramid level $l = 1$: $c = \arg\min_{q \in S} d(W_p, V_q)$

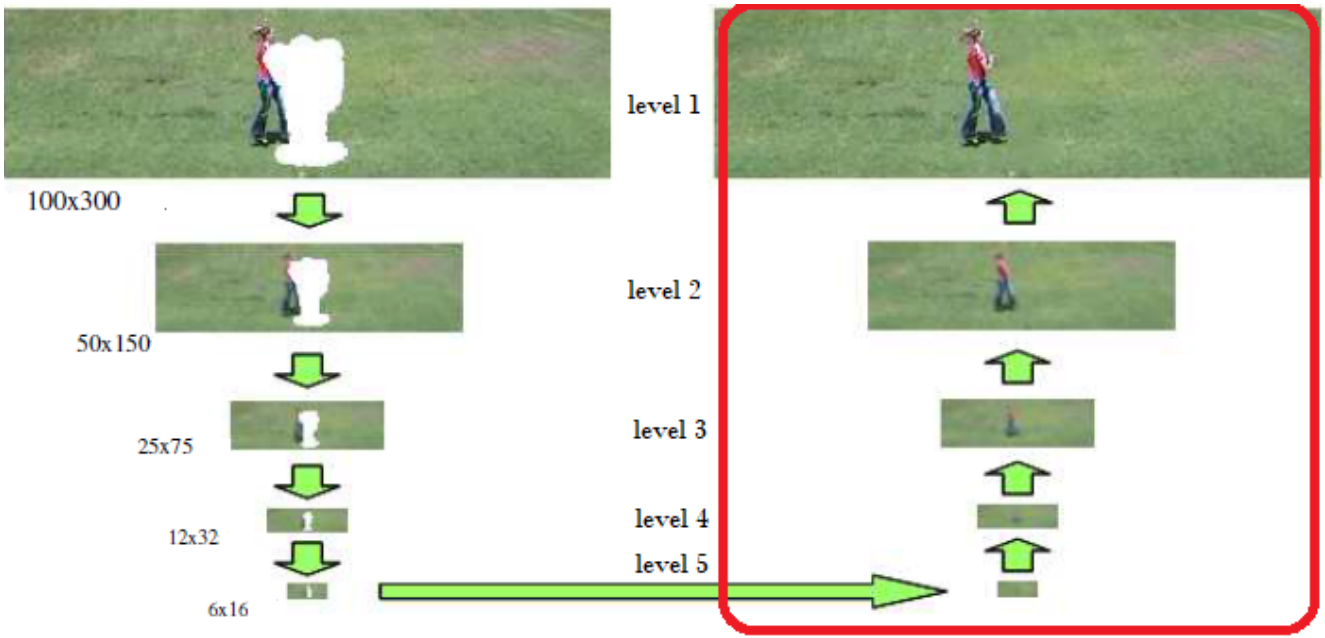


Figure: Pyramidal resolution reconstruction (source: Wexler paper)

Results of reconstruction

(a) Original picture

(b) Our result

Figure: Image completion using PatchMatch (590x591 pixels)

Results of reconstruction

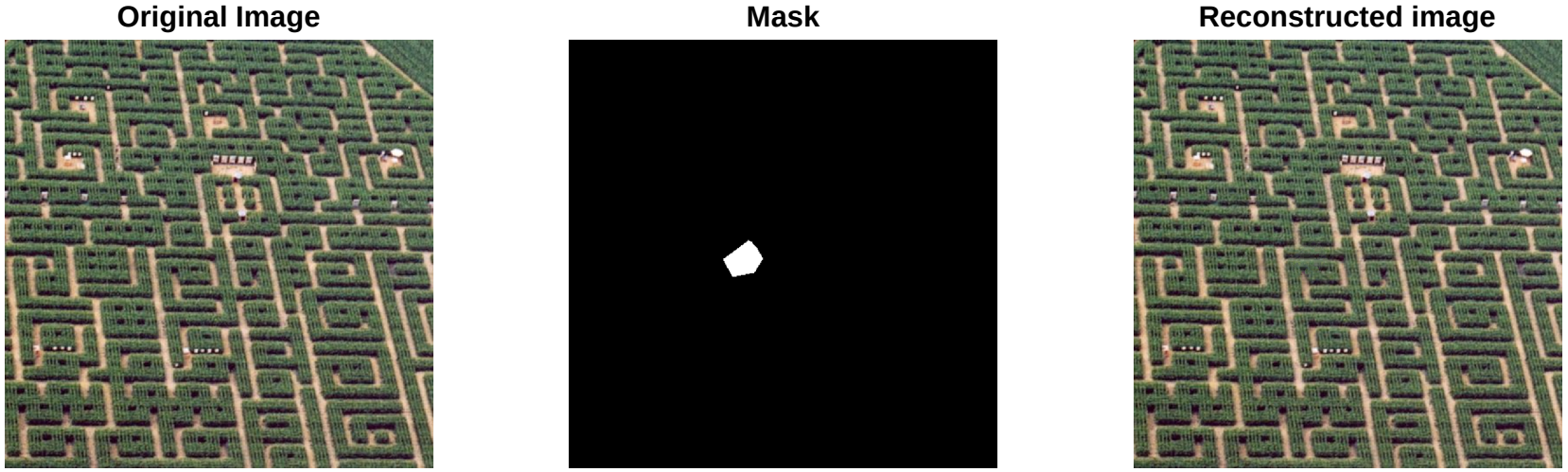


Figure: Completion of a structured image

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Step of PatchMatch

The *nearest-neighbor field* (NNF) is defined as the function $f{:}A \mapsto R^2$ of offset

$$f(x, y) = v$$

Where v is an offset in image B. In the program,

$$(x, y) \mapsto (x, y) + v$$

Step of PatchMatch

The aim of the algorithm is to create a correspondence table between an source image A and destination image B.

1. Initialization of random coordinates in NNF table (same dimension as A)
2. Propagation process: checking the corresponding coordinates in B of pixel (i,j) and its neighbor (i-1,j), (i,j-1). Depending on the similarity of each patch and their corresponding patch in B, the new value of (i,j) is updated with the best matching offset.
3. Search of a random patch which minimize euclidean distance in shrinking window in B

Step of PatchMatch

Propagation:

$$f(x, y) = argmin[D((f(x, y)), D(f(x, y-1)), D(f(x-1, y))]$$

In reverse direction for even iterations.

Random search:

$$u_i = v_0 + w * \alpha^i * R_i$$

u_i : new offset, v_0 : offset after propagation, w: largest dimension of B, α is 0.5 and R_i is a random 2D vector with element between -1 and 1.

Step of PatchMatch

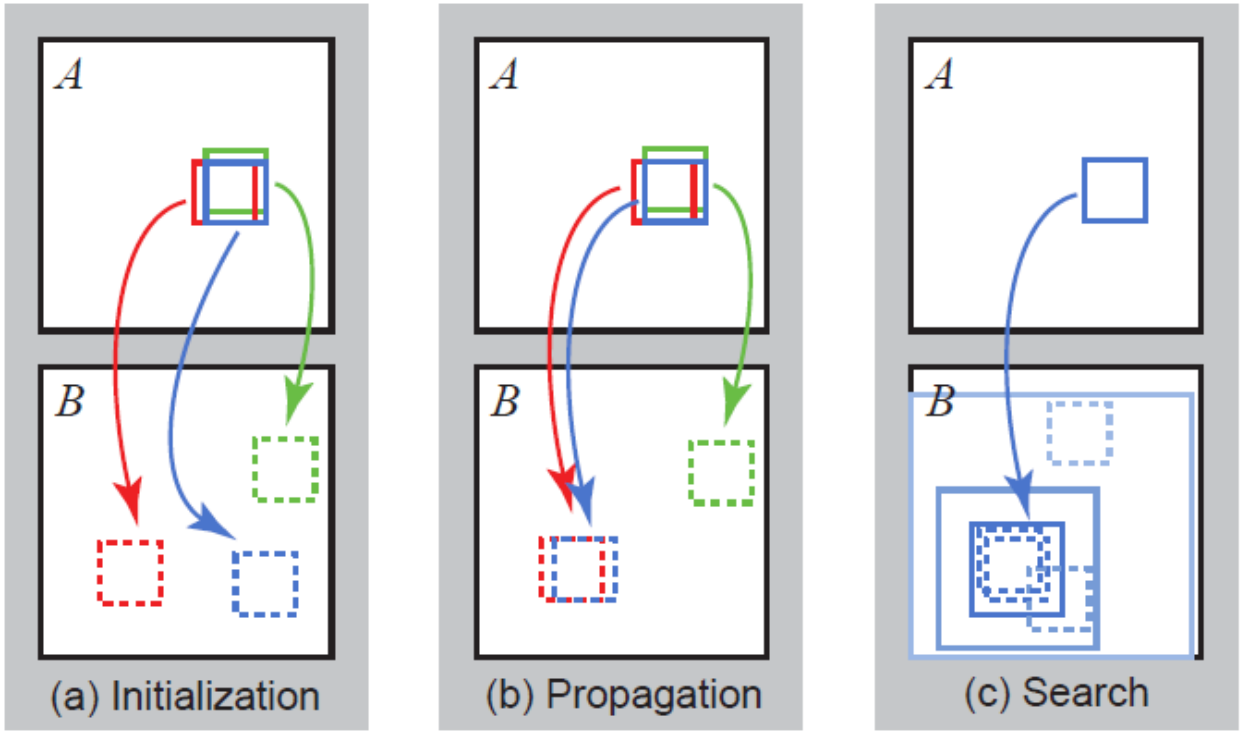

Figure: Step of patchmatch algorithm

Results of algorithm

Figure: Results of PatchMatch algorithm

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Conclusion

- Inpainting algorithm implemented using a patch based multi-scaled reconstruction method
- Brute force research of coherent patches computationally heavy
- PatchMatch algorithm implemented to speed up patch search