STEREOSCOPIC IMAGE INPAINTING CONSIDERING THE CONSISTENCY OF TEXTURE SIMILARITY

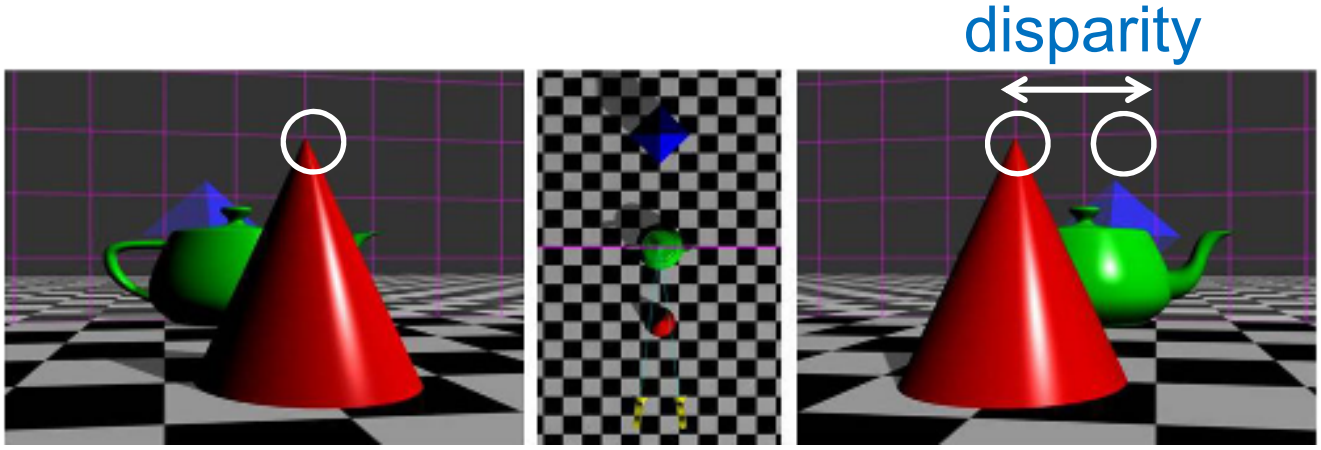
Tokyo University of Agriculture and Technology

Ayako ABE, Ikuko SHIMIZU

BACK GROUND

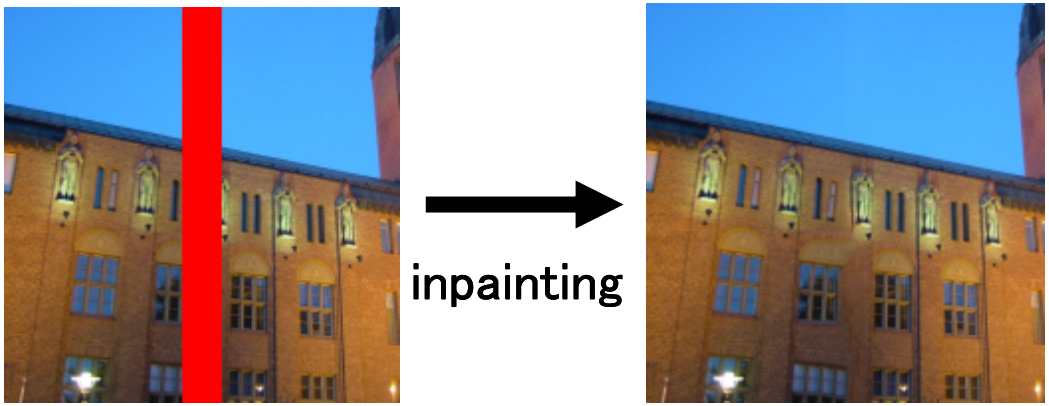
- There has recently been a high demand for the development of techniques for the efficiency editing of stereoscopic images.

- Stereoscopic image is consist of two images for left and right eye.



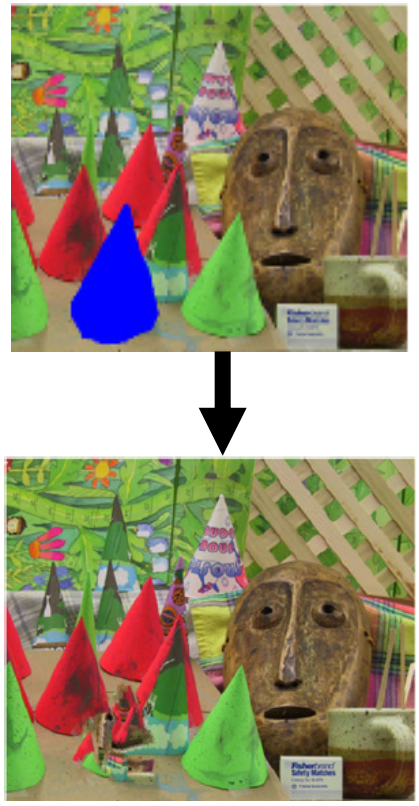
BACK GROUND

- Image inpainting is one of the most important among the many existing editing techniques.
  - It reconstructs an input image that contains "hole(s)", so that it looks natural.
    - To remove the unwanted object
    - Holes are generated by missing color information



The differences between 2D and 3D inpainting

- 2D : only color image is inpainted



Applying to the respective images : there seems to be inconsistent intensity and the unnatural depth in the hole.

- 3D : not only color images but also the depth maps of two images are inpainted

Expected output

CONVENTIONAL 3D INPAINTING METHODS

Wang et al 2008

- does not ensure a convergence (depth map⇄intensity)
- the unnatural artifacts occur.

Harvieu et al 2010

- ensures a convergence (depth map→intensity)
- This can be applied only to images whose depth maps are relatively smooth.

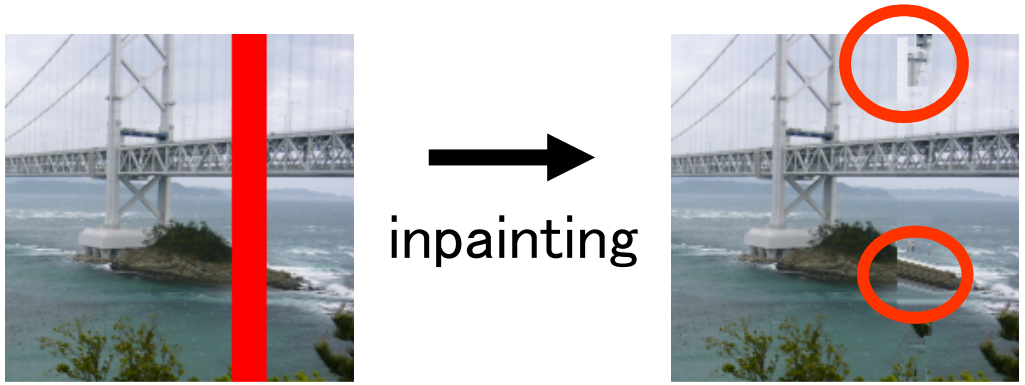
Harvieu et al 2011

- is applicable to an image whose depth maps have various values

Drawbacks of Harvieu et al 2011

- Inpainting of depth map : does not guarantee consistency
  - This leads to an unnatural color image inpainting.

- Inpainting of color image :
  - It tends to induce discontinuous textures when the image contains complex ones
  - It synthesizes texture sequentially from the boundary to the interior

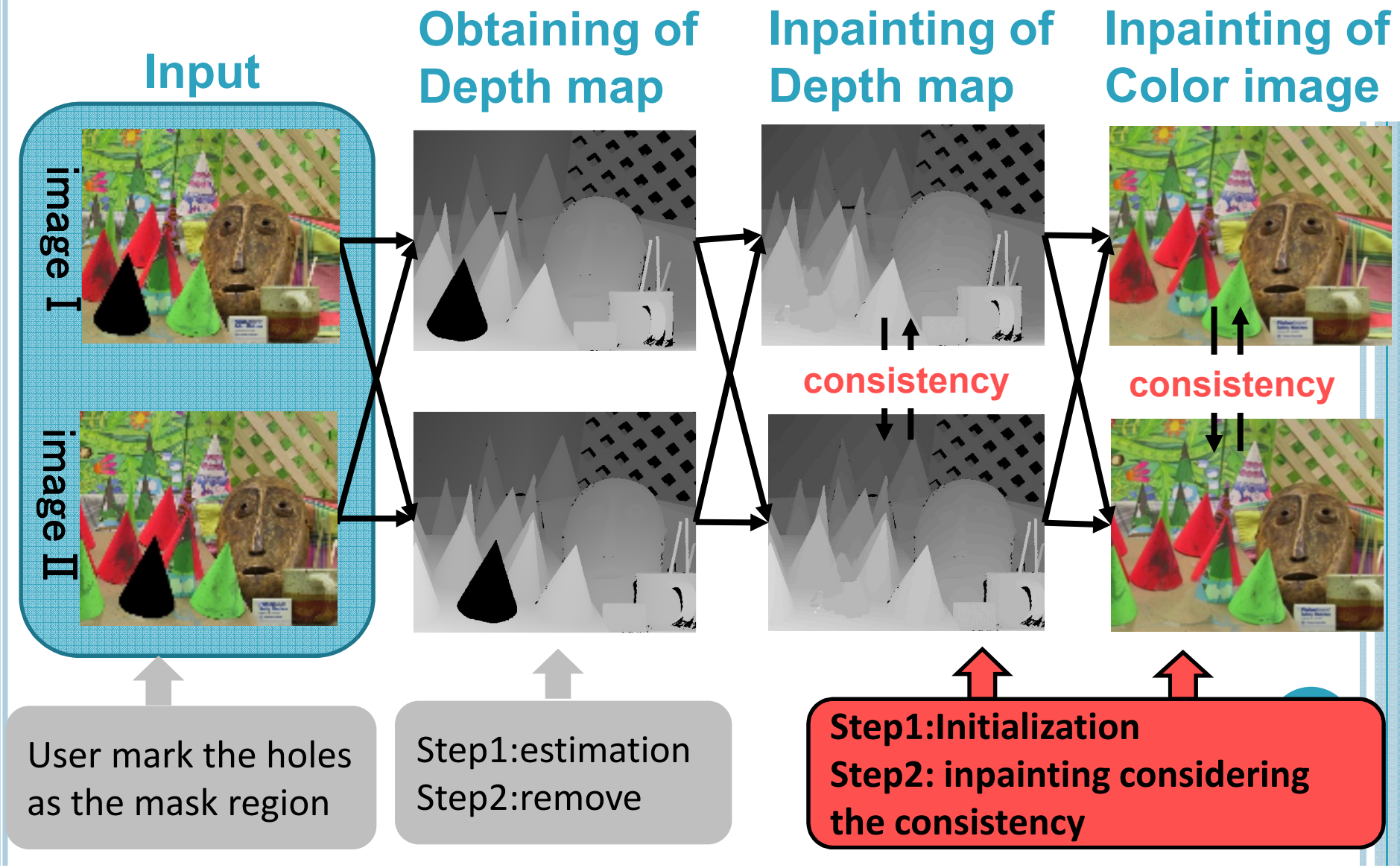


PURPOSE OF OUR METHOD

- A 3D inpainting method is proposed that takes the texture similarity into consideration and guarantee the consistency of depth and intensity .

- Inpainting of depth map :
  - Repeat until the depth of corresponding pixels is consistent.
- Inpainting of color image :
  - Adding the restriction of intensity of corresponding pixels.
  - Previous 2D inpainting method is extended to a 3D one that is applicable to an image with a complex texture

OVERVIEW OF PROPOSED METHOD



ESTIMATION &INITIALIZATION OF THE DEPTH MAP

- Inpainting of depth map in half occluded region
  - The region can be seen by only one view point
  - If there are some candidates, the maximum disparity is chosen

$$D_l(x^l, y) = D_r(x^l - D_l(x^l, y)) \quad , \quad D_r(x^r, y) = D_l(x^r - D_r(x^r, y))$$

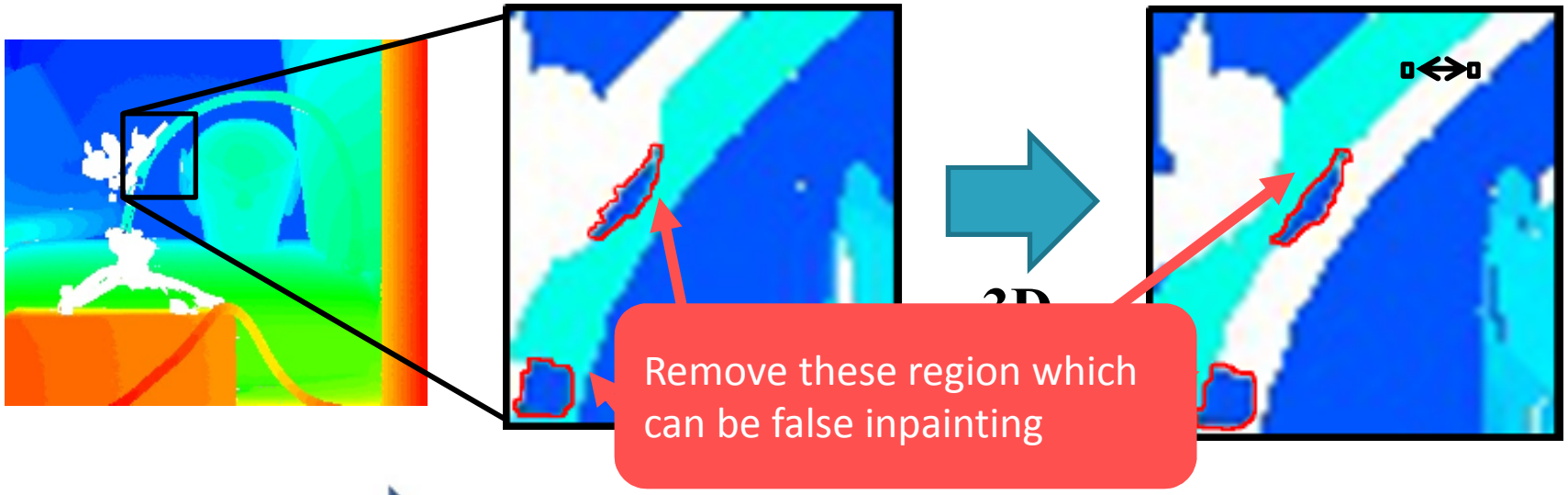
left disparity image

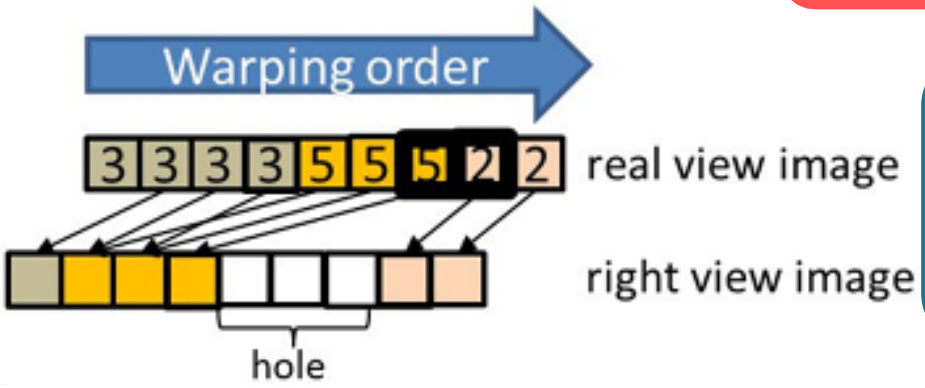
Initialization

left disparity image after Initialization

ELIMINATE THE FALSE INPAINTED DEPTH VALUE

- The object closest to the camera is occluded by the object in the hole

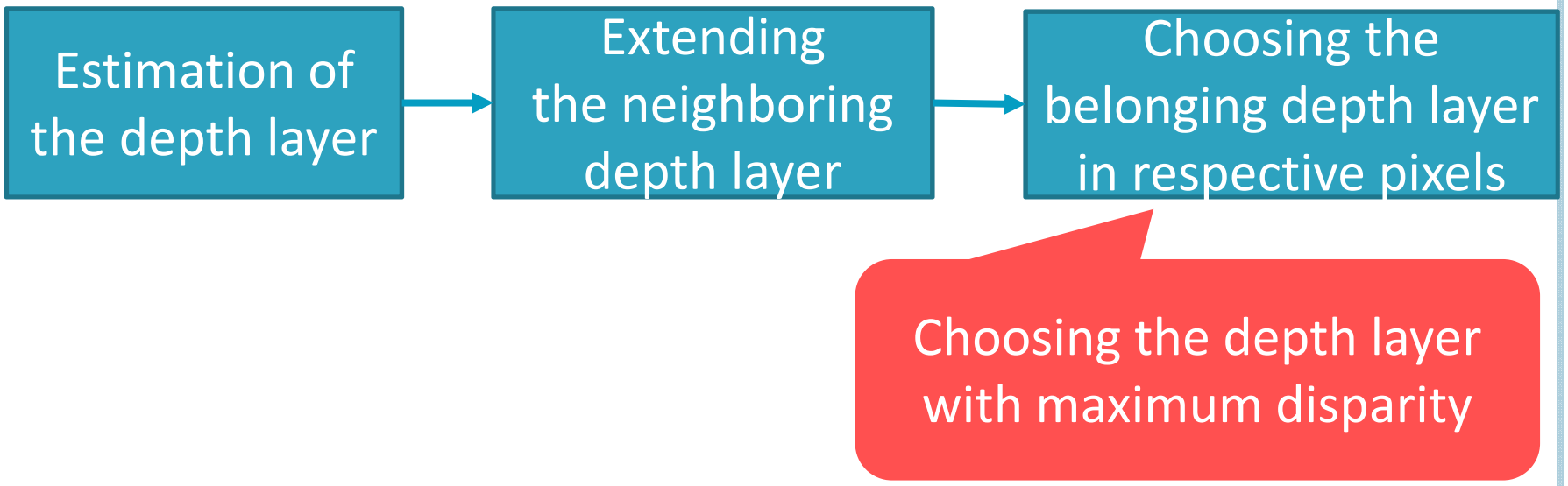




the width of a hole by 3D warping
||
the difference in the depths between the pixels in both sides of the hole

Inpainted by extension of depth layer

- Assumption: the depth map consists of multiple depth planes, called depth layers.



Inpainted by extension of depth layer

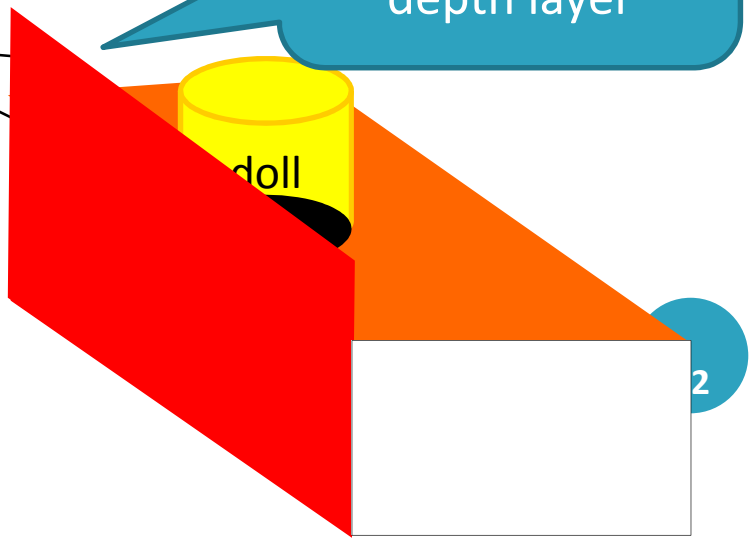
- The smaller disparity must be chosen than the one before missing.

It is unnatural to appear the closer object, not the one included in the hole.

color image before missing

depth map before missing

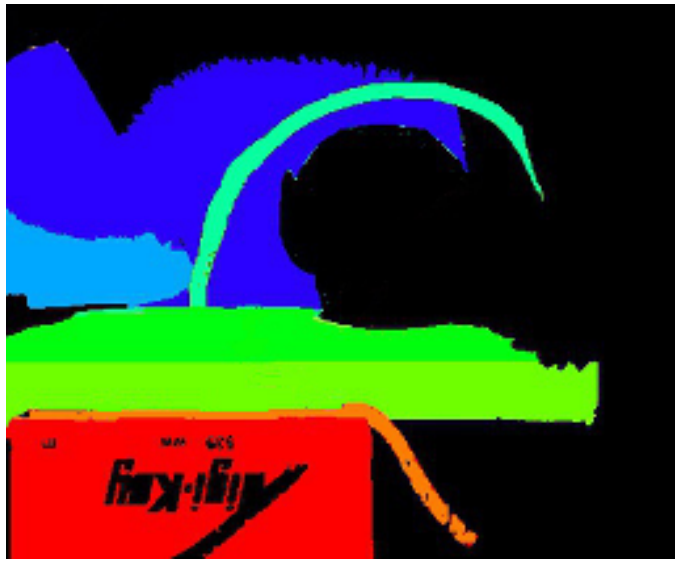
Estimated depth layer



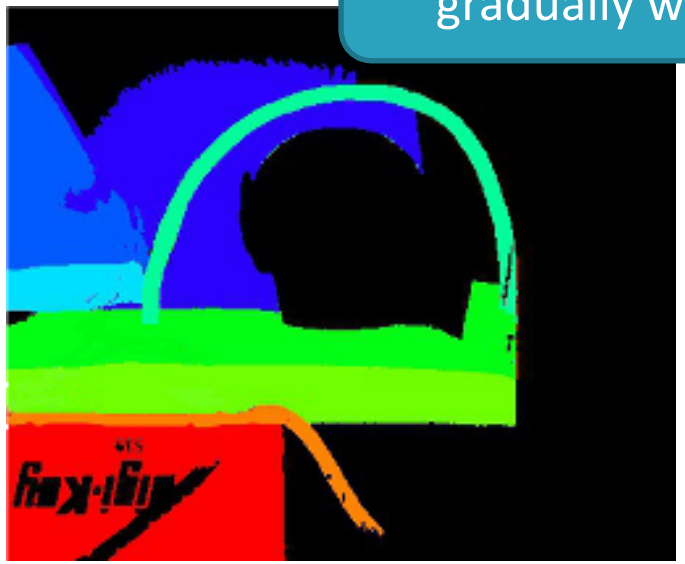
ELIMINATION OF FALSE INPAINTED REGION BY CONSIDERING THE CONSISTENCY OF DEPTH MAP

1. Check the consistency
2. Inconsistent region is considered as missing part
3. Updated depth layer is re-extended to the hole

Inconsistent region gradually will shrink



left image



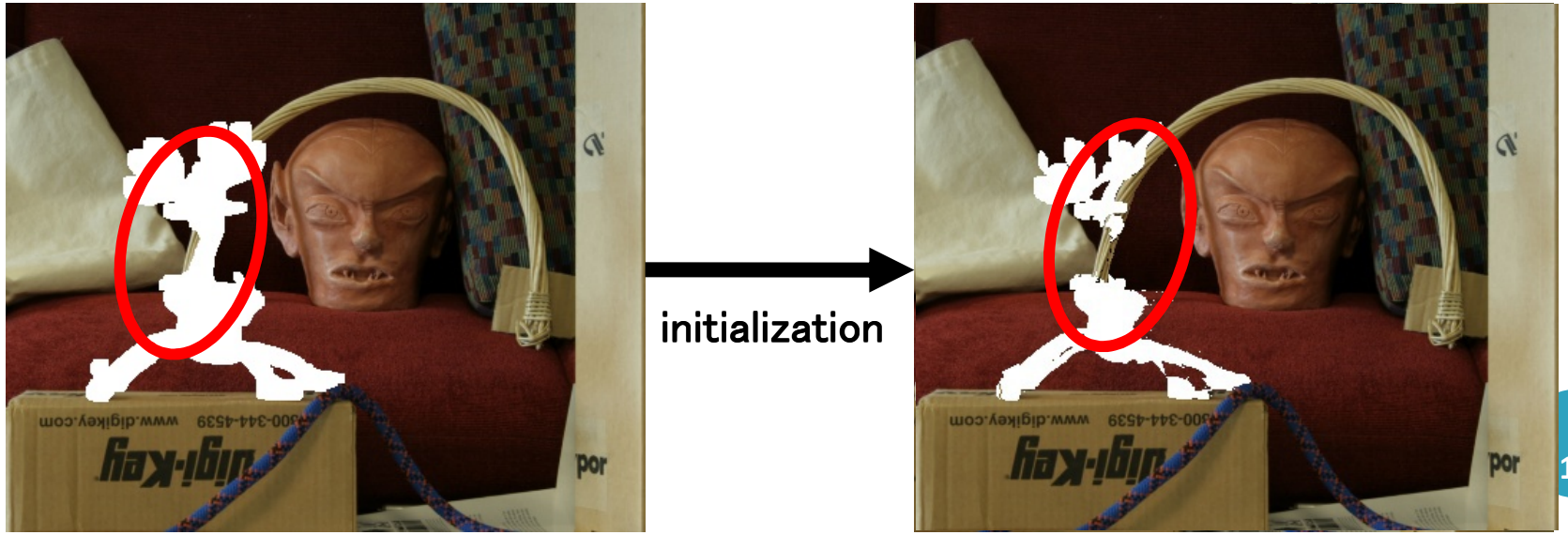
right image

INITIALIZATION OF COLOR IMAGE

- Inpainting of color image in half occluded region

$$I_l(x^l, y) = I_r(x^l - D_l(x^l, y)) \quad , \quad I_r(x^r, y) = I_l(x^r - D_r(x^r, y))$$

However, the region which is confirmed as false-inpainted in the initialization of depth map is eliminated.



left image

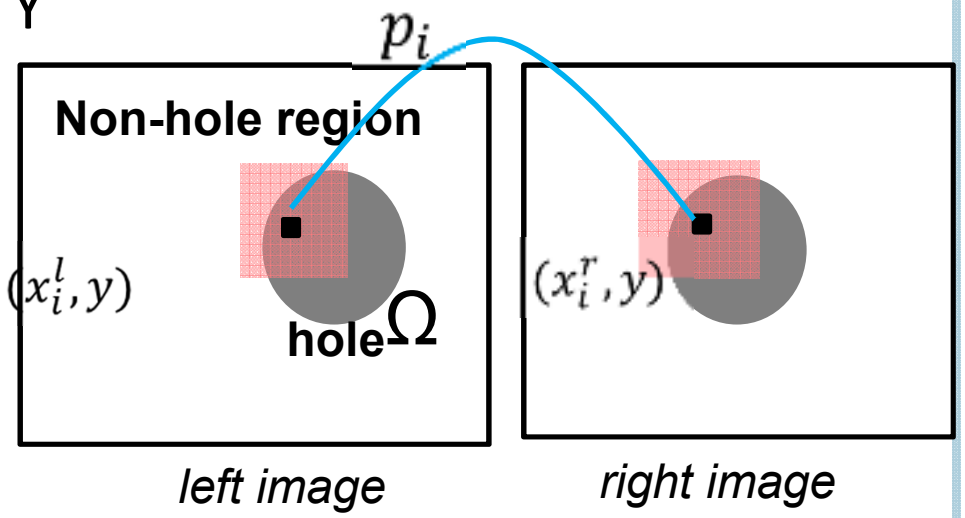
left image after initialization

INPAINTING OF COLOR IMAGE BY CONSIDERING THE CONSISTENCY OF INTENSITY

- Energy function

$$E = E_l + E_r$$

$$s.t.\ \ g = I_l(x_i^l) - I_r(x_i^r) = 0$$



- Two steps are repeated until convergence occurs.

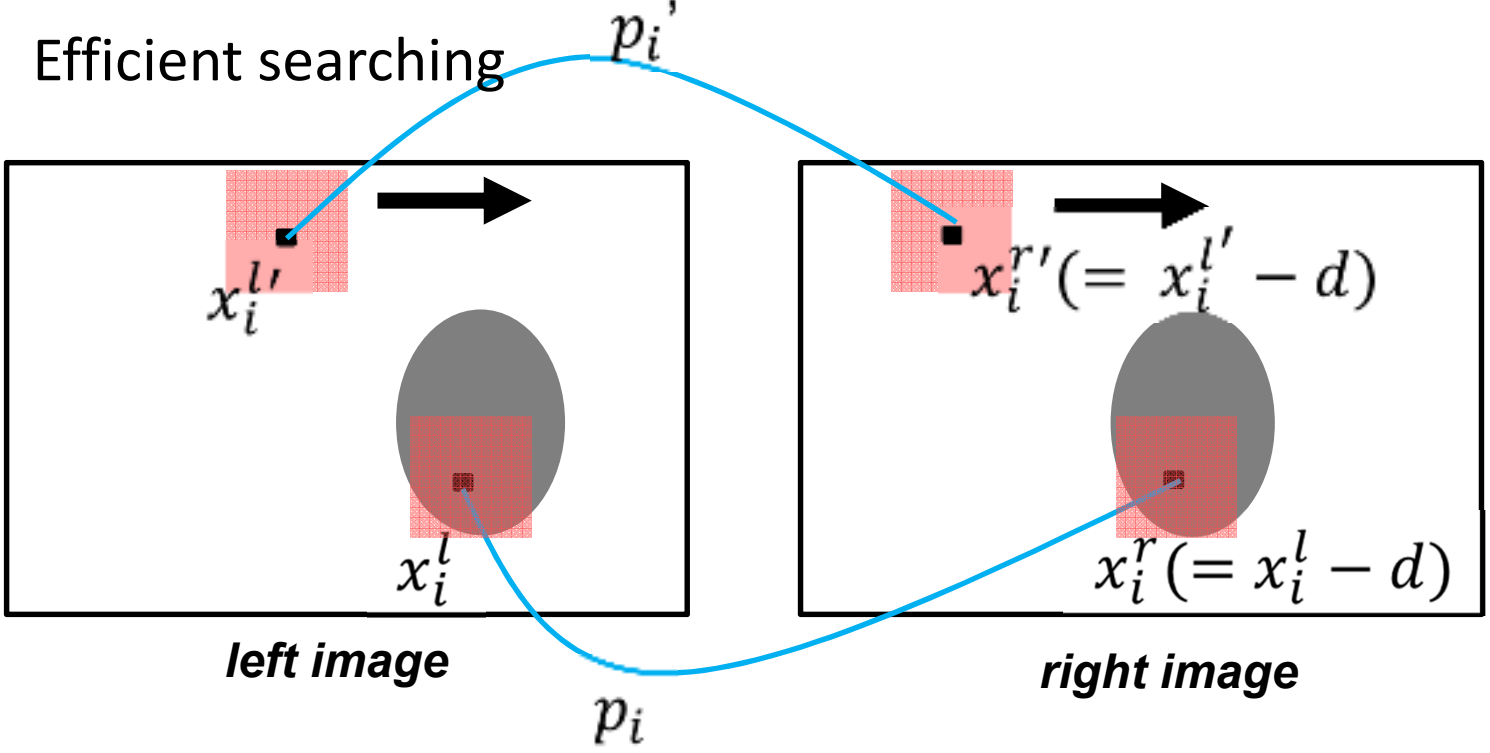
Step1: update the similar texture patterns p_i' for respective pixels p_i: $(x_i^l, y), (x_i^r, y)$

Step2: update the intensity values in the hole

- We create an image pyramid and minimize the energy from coarse to fine.

STEP1: SIMILAR TEXTURE PATTERNS ARE SEARCHED

- Searching pattern $p_i{}'$ by considering the consistency of depth map
  - unnatural inpainting is supposed to prevented
  - Efficient searching



STEP1: SIMILAR TEXTURE PATTERNS ARE SEARCHED

- The search region of a similar pixel to the same depth layer is restricted
  - We assume that the same object belongs the same depth layer
  - Unnatural inpainting by distinctly-different intensity is supposed to prevented

STEP2: UPDATE THE INTENSITY VALUES PARALLELLY

- Minimizing of the energy function ***E***

$$E = \sum_{i=1}^{N_\Omega} \left(E_l(x_i^l) + E_r(x_i^r) \right) + C$$

energy elements of the
respective images' respective pixels

$$\text{s.t. } g = I_l(x_i^l) - I_r(x_i^r) = 0$$

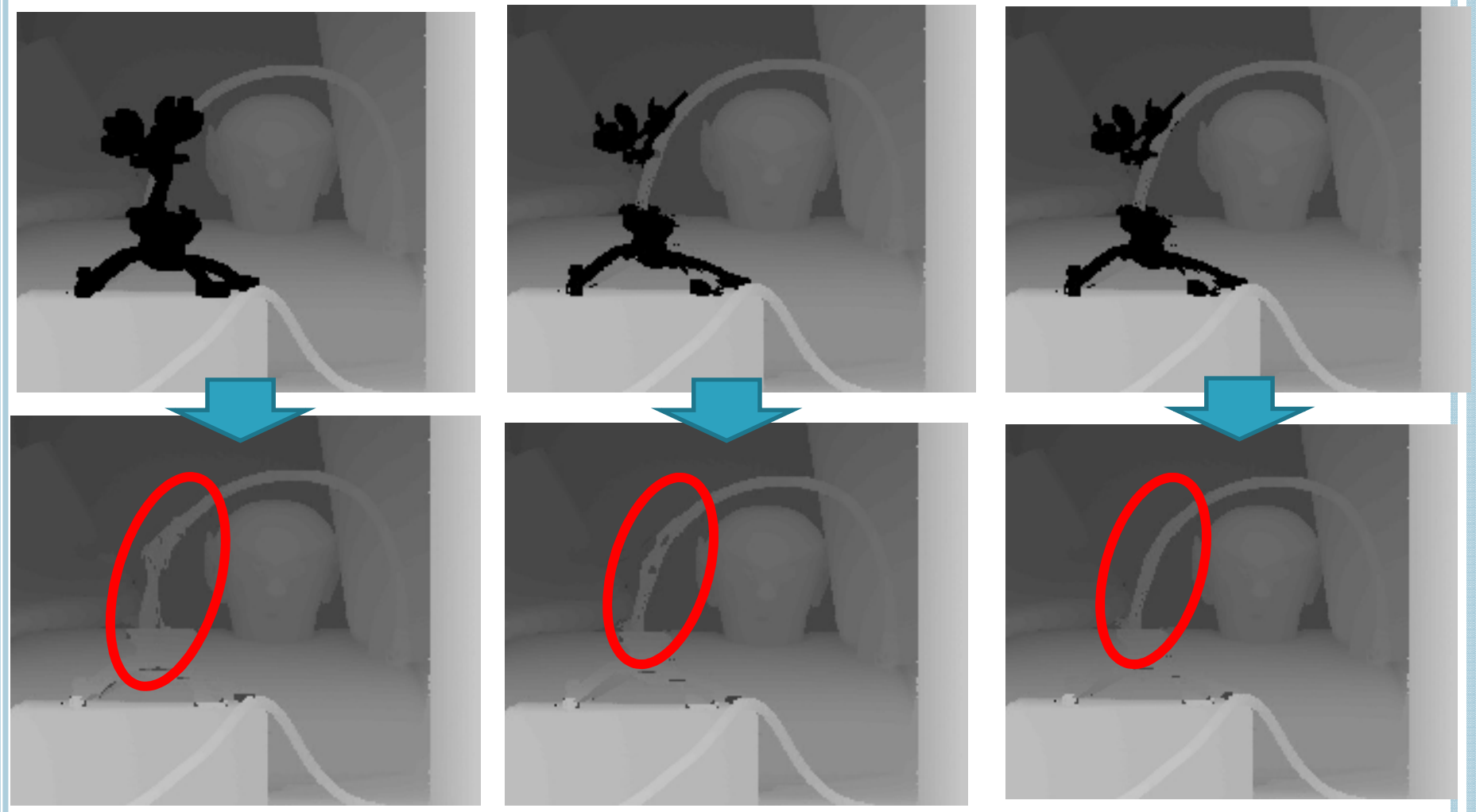
consistency of intensity

C : a constant value in this step, because a similar pattern is fixed

$I_l(x_i^l), I_r(x_i^r)$ is obtained analytically
by the Lagrange multiplier

EXPERIMENT RESULTS –INPAINTING OF DEPTH MAP STEP1–

(i)Initialization ➡ (ii)Elimination of the false inpainting ➡ inpainted by depth layer



without (i)&(ii)

without (ii)

Proposed method

EXPERIMENT RESULTS –INPAINTING OF DEPTH MAP STEP2–

- Inpainted by depth layer considering the consistency of depth map

image I

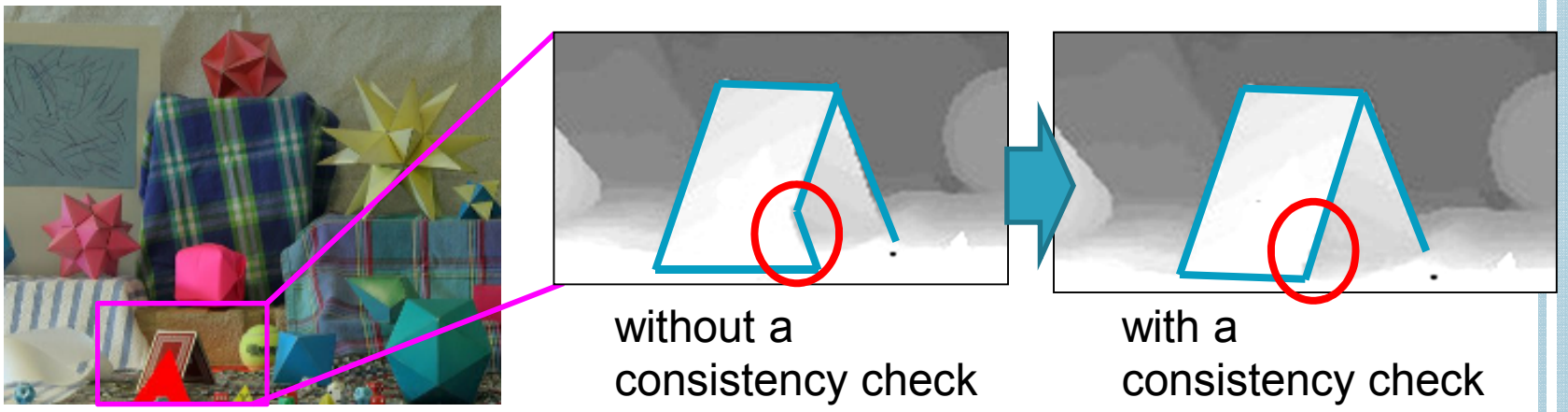
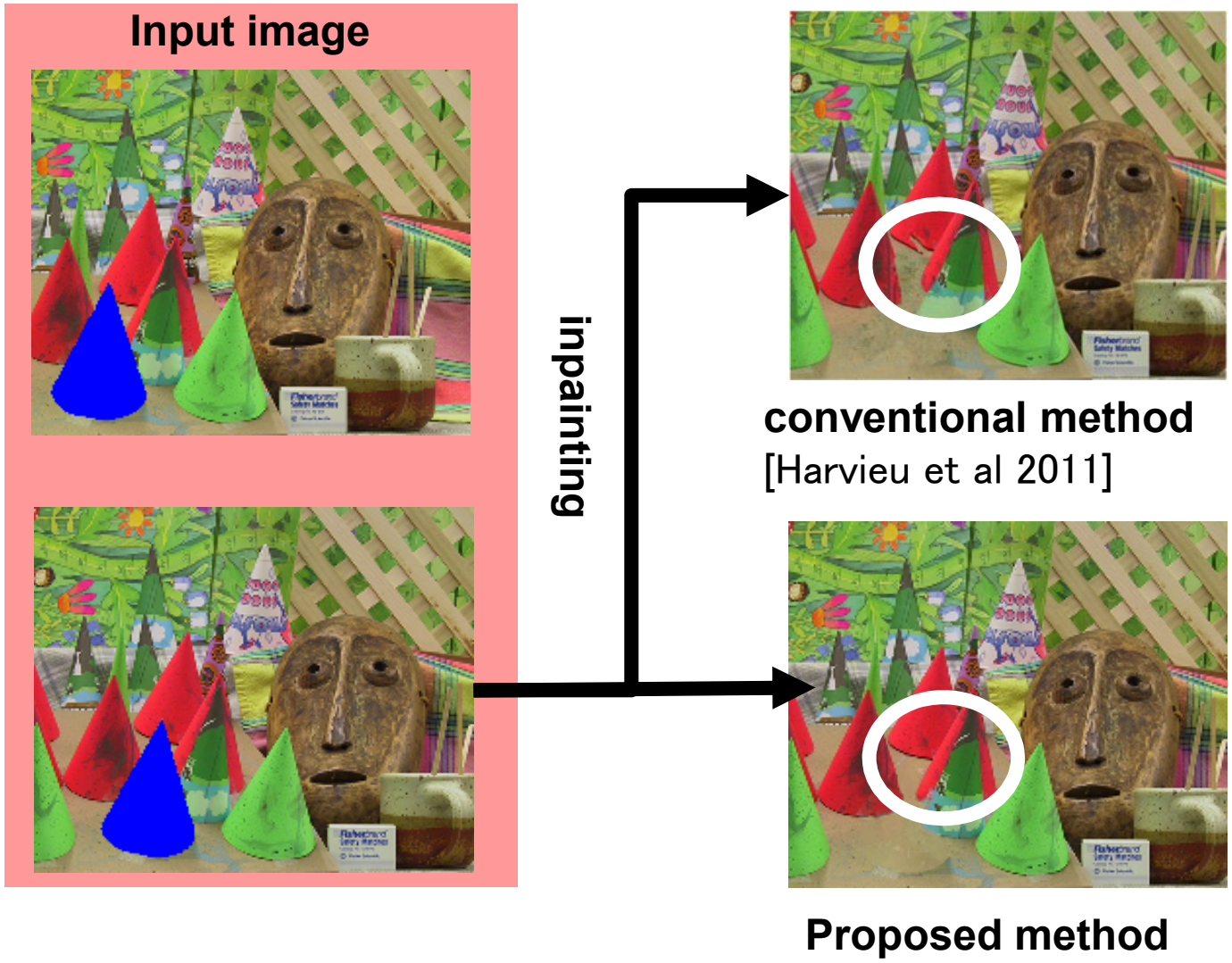


image II

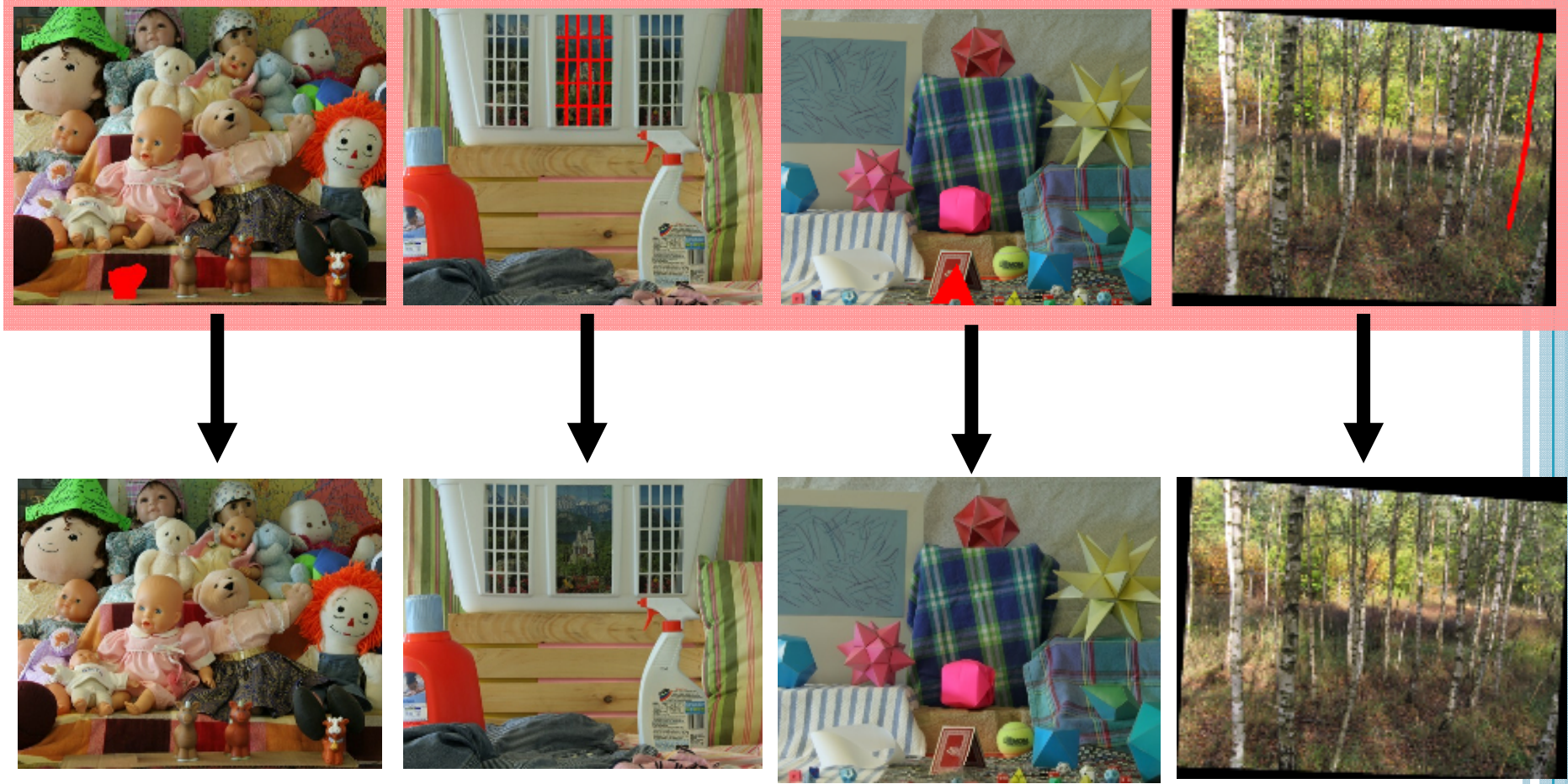
- Because the depth layer is extend in respective image, the false inpainting is sometimes occurred in one image.

EXPERIMENT RESULTS - COMPARISON WITH OUR METHOD AND THE CONVENTIONAL METHOD -



EXPERIMENT RESULTS

Input image



CONCLUSION

- We proposed an inpainting method for a stereoscopic image that takes the texture similarity based on the consistency of the corresponding pixels.

- Future work:

  To extend our method for stereoscopic video

  - by taking into account that the depth varies smoothly along a timeline