Region Filling and Object Removal by Exemplar-Based Image Inpainting

Source: *IEEE Transactions on image processing*, Vol. 13, No. 9, SEP. 2004.

Authors: A. Criminisi, P. Perez and K. Toyama

Speaker: Hon- Hang Chang

Date: 2011. 07. 22

Outline

1. Introduction
2. Proposed method
3. Experimental results
4. Conclusions

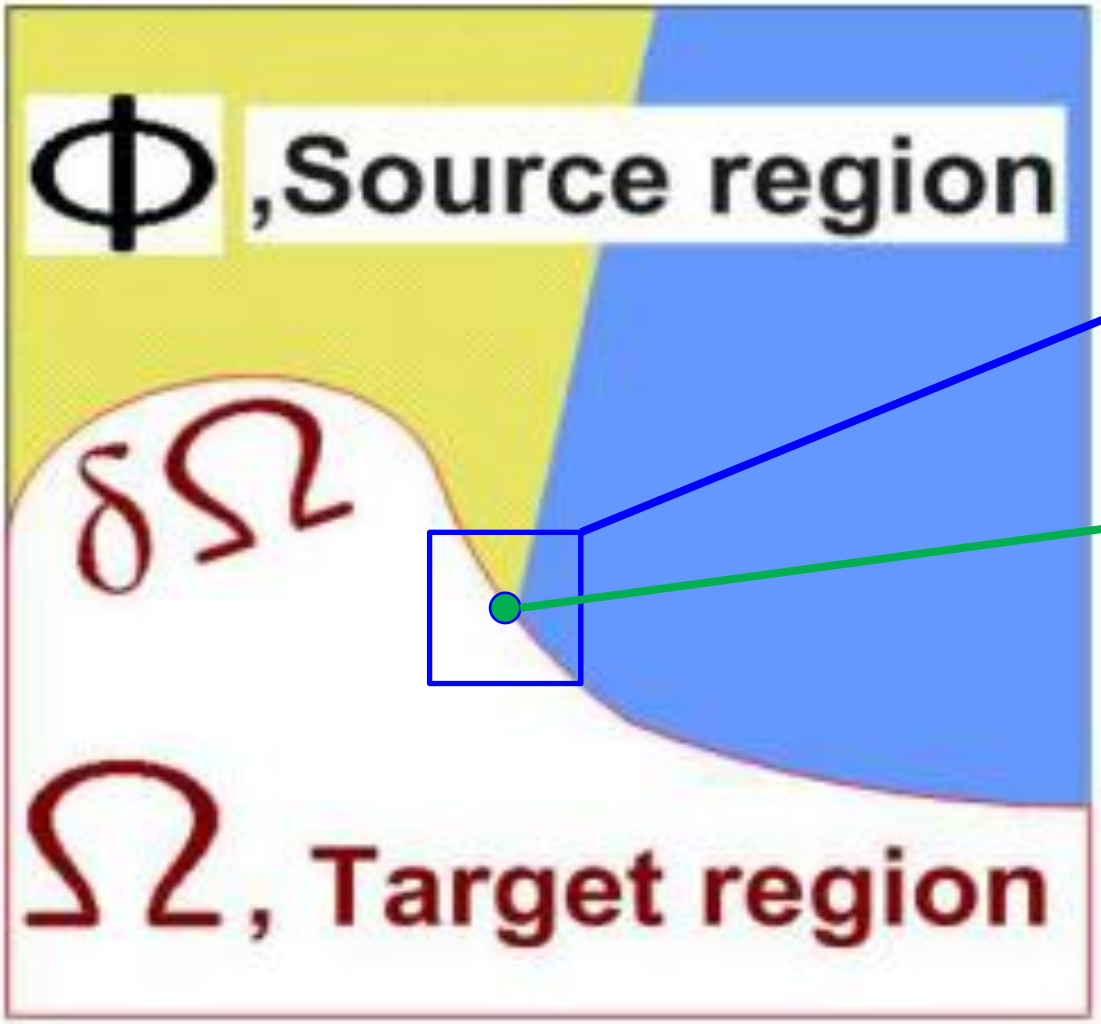
Introduction

- **Idea:**

1. Remove (large) object(s) from digital photographs.
2. Fill the hole with information extracted from the surrounding area.
3. Filled region should look “reasonable” to the human eyes.

Proposed method

- **Proposed region-filling algorithm**

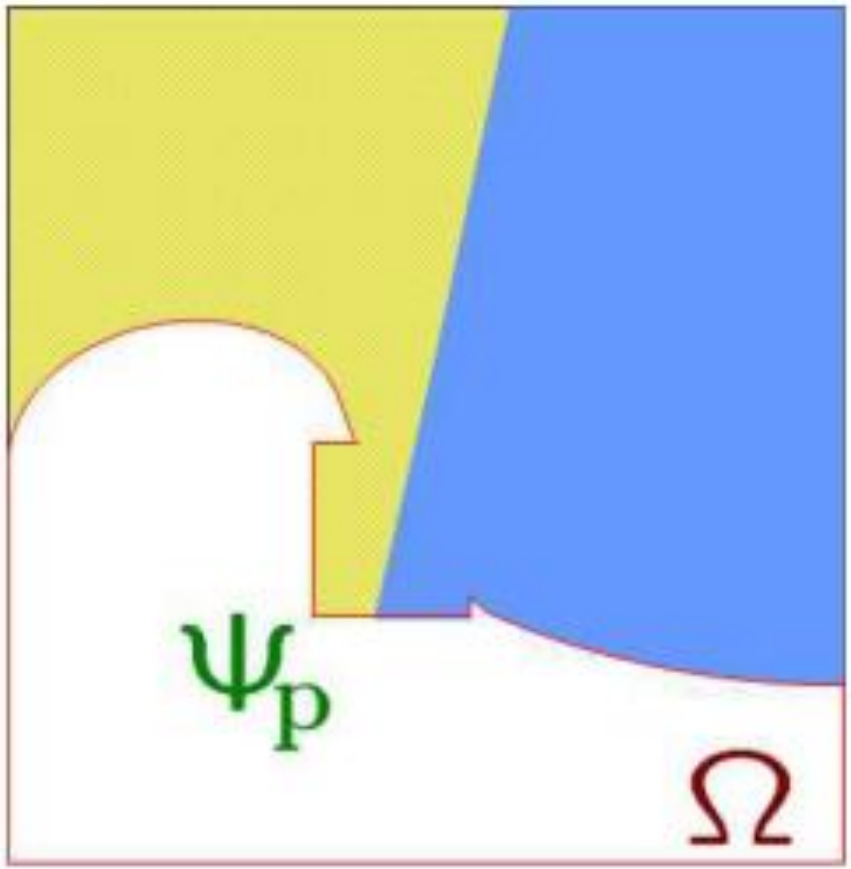


$$p \in \delta\Omega$$

$$\Phi = I - \Omega$$

Proposed method (cont.)

- **Proposed region-filling algorithm**



$$\Psi_q''$$

$$\Psi_q'$$

$$p \in \delta\Omega$$

$$\Phi = I - \Omega$$

Proposed method (cont.)

- **Proposed region-filling algorithm**
  1. **Computing patch priorities**
  2. **Propagating texture and structure information**
  3. **Updating confidence values**

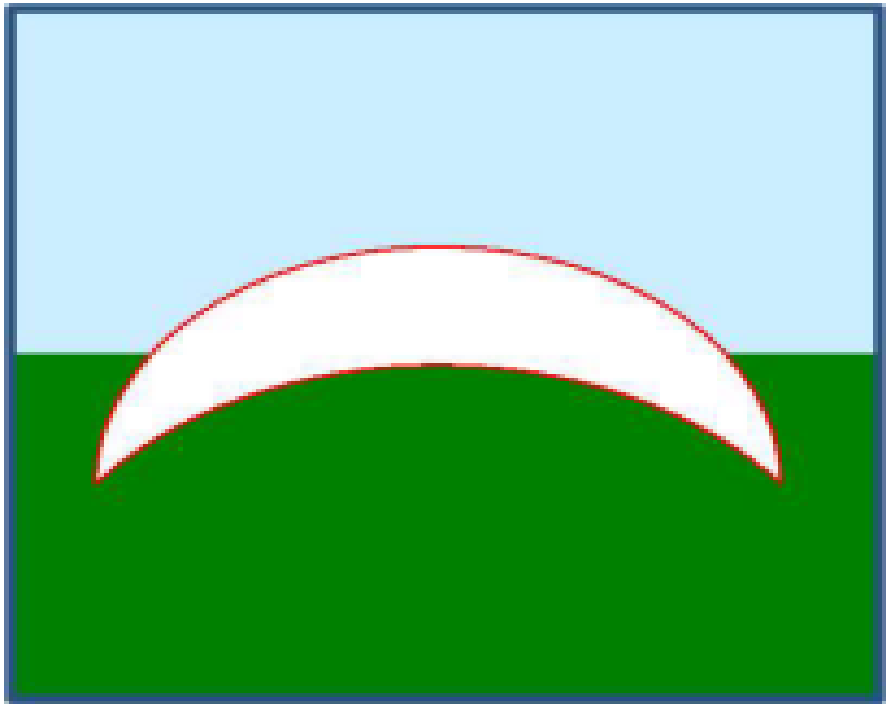
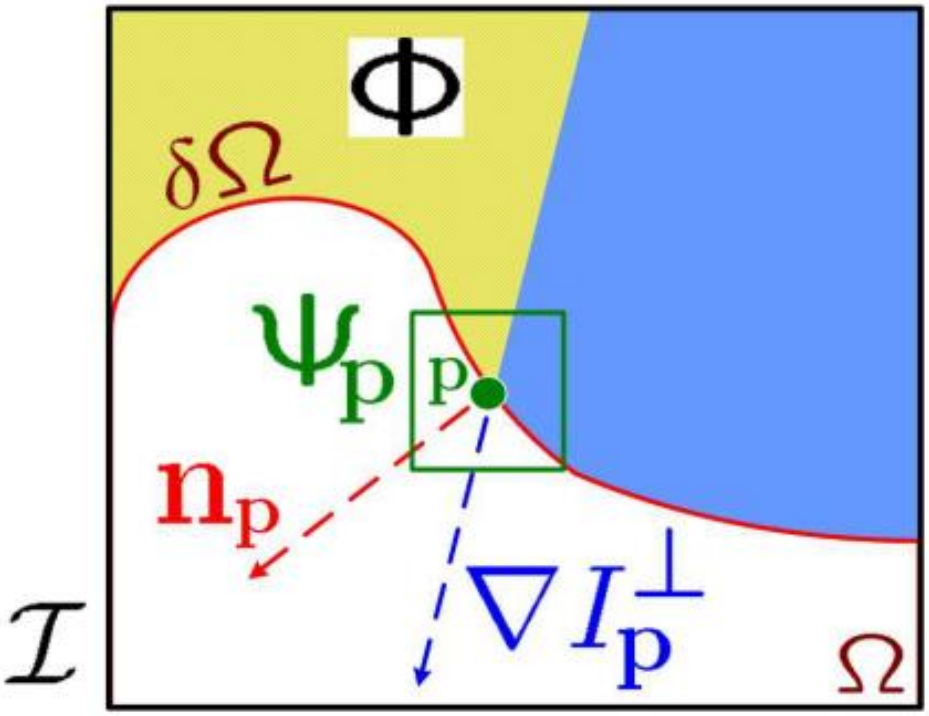


Fig. 1 A diagram showing an image and a selected target region (in white).

Proposed method (cont.)

- **Step 1: Computing patch priorities**



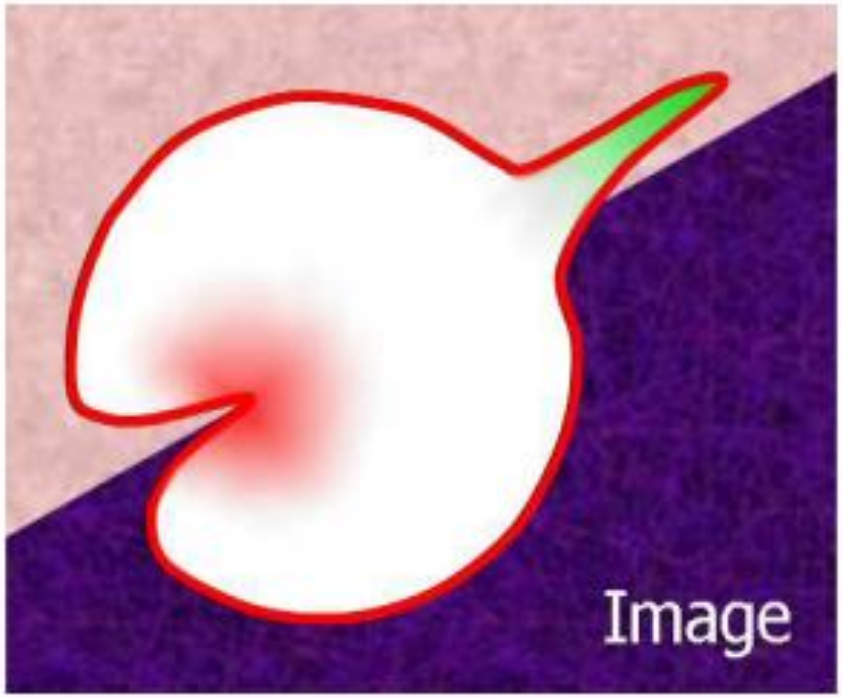
$$P(\mathbf{p}) = C(\mathbf{p})D(\mathbf{p}).$$

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

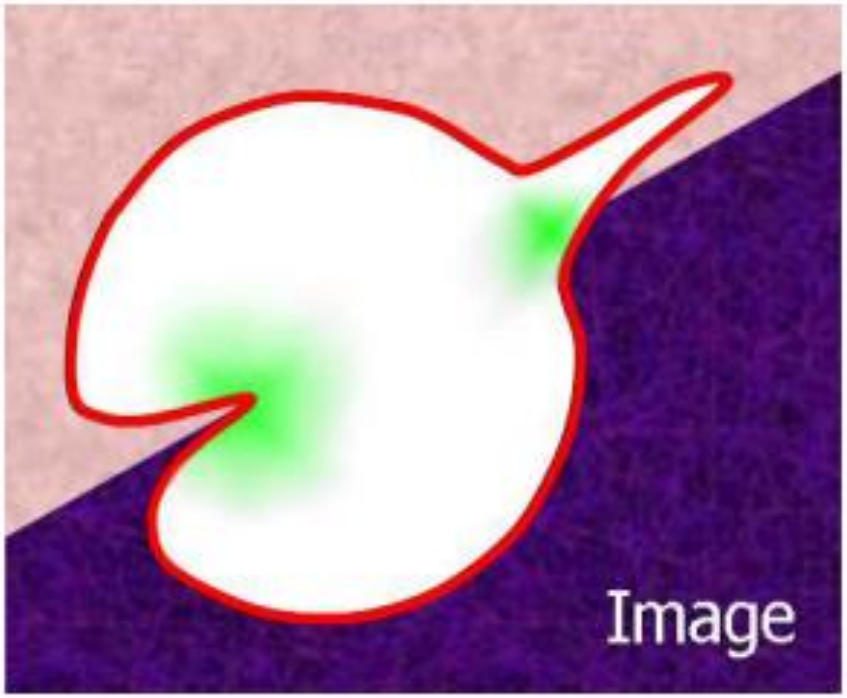
[Note]Initialization: $\begin{cases} C(\mathbf{p}) = 0, \forall \mathbf{p} \in \Omega \\ C(\mathbf{p}) = 1, \forall \mathbf{p} \in I - \Omega \end{cases}$

Proposed method (cont.)

➢ **Step 1: Computing patch priorities (cont.)**



a



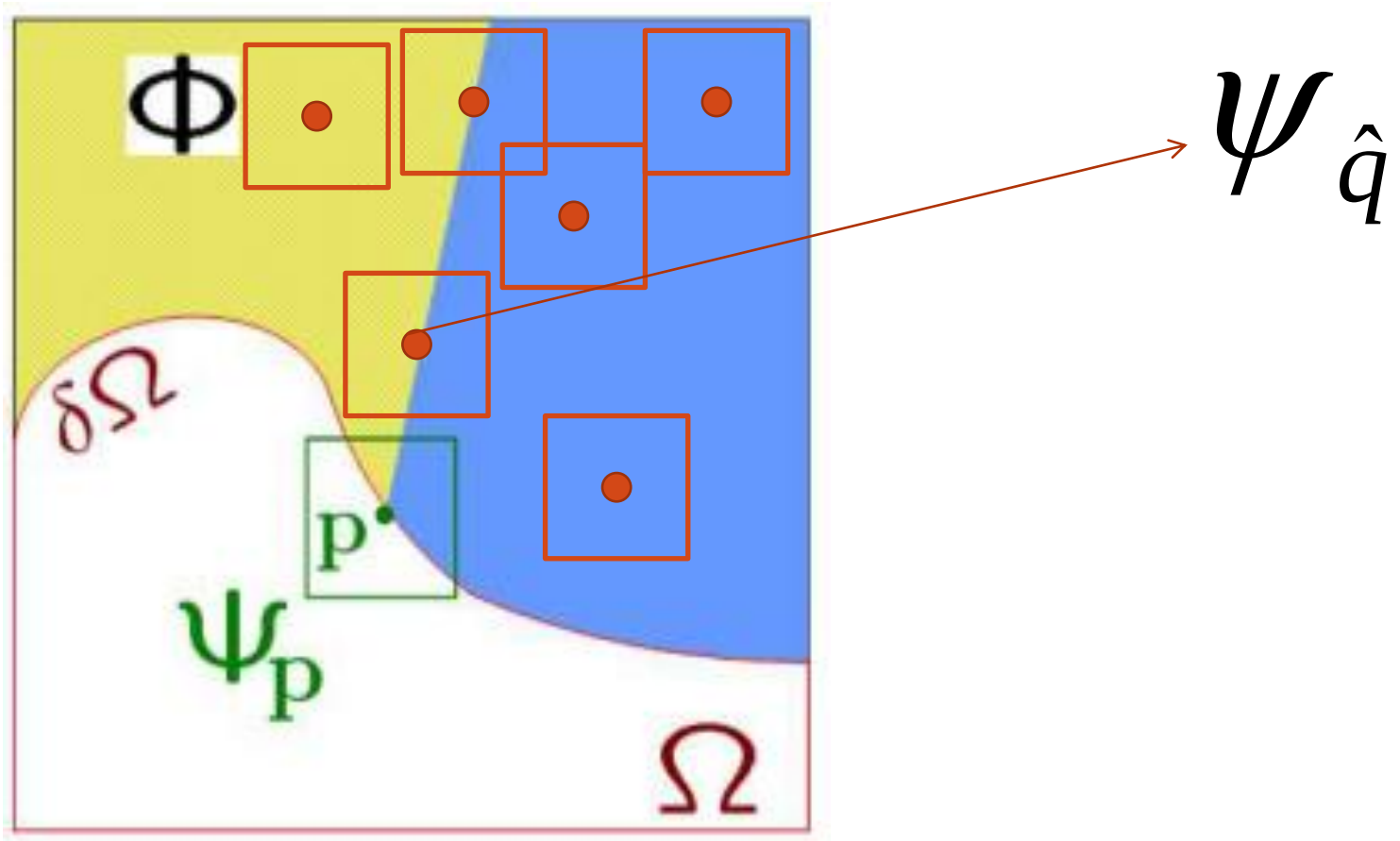
b

Confidence value

Edge

Proposed method (cont.)

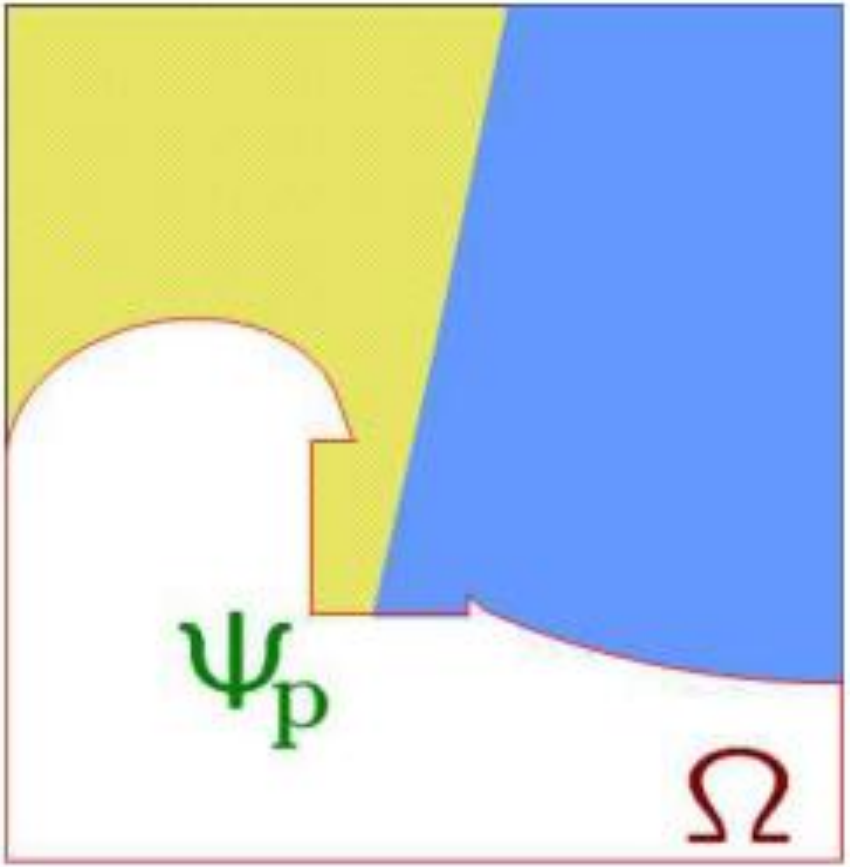
➢ **Step 2: Propagating texture and structure information**



$$\psi_{\hat{q}} = \arg\min_{\Psi_q \in \Phi} d(\psi_{\hat{p}}, \psi_q)$$

Proposed method (cont.)

- **Step 3: Updating confidence values**



$$C(\mathbf{p}) = C(\hat{\mathbf{p}}) \quad \forall \mathbf{p} \in \Psi_{\hat{\mathbf{p}}} \cap \Omega.$$

Proposed method (cont.)

➢ **Algorithm**

- Extract the manually selected initial front $\delta\Omega^0$.
- Repeat until done:

1a. Identify the fill front $\delta\Omega^t$. If $\Omega^t = \emptyset$, exit.

1b. Compute priorities $P(\mathbf{p}) \quad \forall \mathbf{p} \in \delta\Omega^t$.

2a. Find the patch $\Psi_{\hat{\mathbf{p}}}$ with the maximum priority, *i.e.*, $\hat{\mathbf{p}} = \arg\max_{\mathbf{p} \in \delta\Omega^t} P(\mathbf{p})$.

2b. Find the exemplar $\Psi_{\hat{\mathbf{q}}} \in \Phi$ that minimizes $d(\Psi_{\hat{\mathbf{p}}}, \Psi_{\hat{\mathbf{q}}})$.

2c. Copy image data from $\Psi_{\hat{\mathbf{q}}}$ to $\Psi_{\hat{\mathbf{p}}} \; \forall \mathbf{p} \in \Psi_{\hat{\mathbf{p}}} \cap \Omega$.

3. Update $C(\mathbf{p}) \quad \forall \mathbf{p} \in \Psi_{\hat{\mathbf{p}}} \cap \Omega$

Table 1 Region filling algorithm

Experimental results (cont.)

- **Comparing different filling orders**

a b c d

Fig. 1 (a) Original image. (b) The target region has been selected and marked with a red boundary. (c) Results of filling by concentric layers. (d) Results of filling with proposed algorithm. Thanks to the data term in the sign pole is reconstructed correctly by proposedalgorithm.

Experimental results

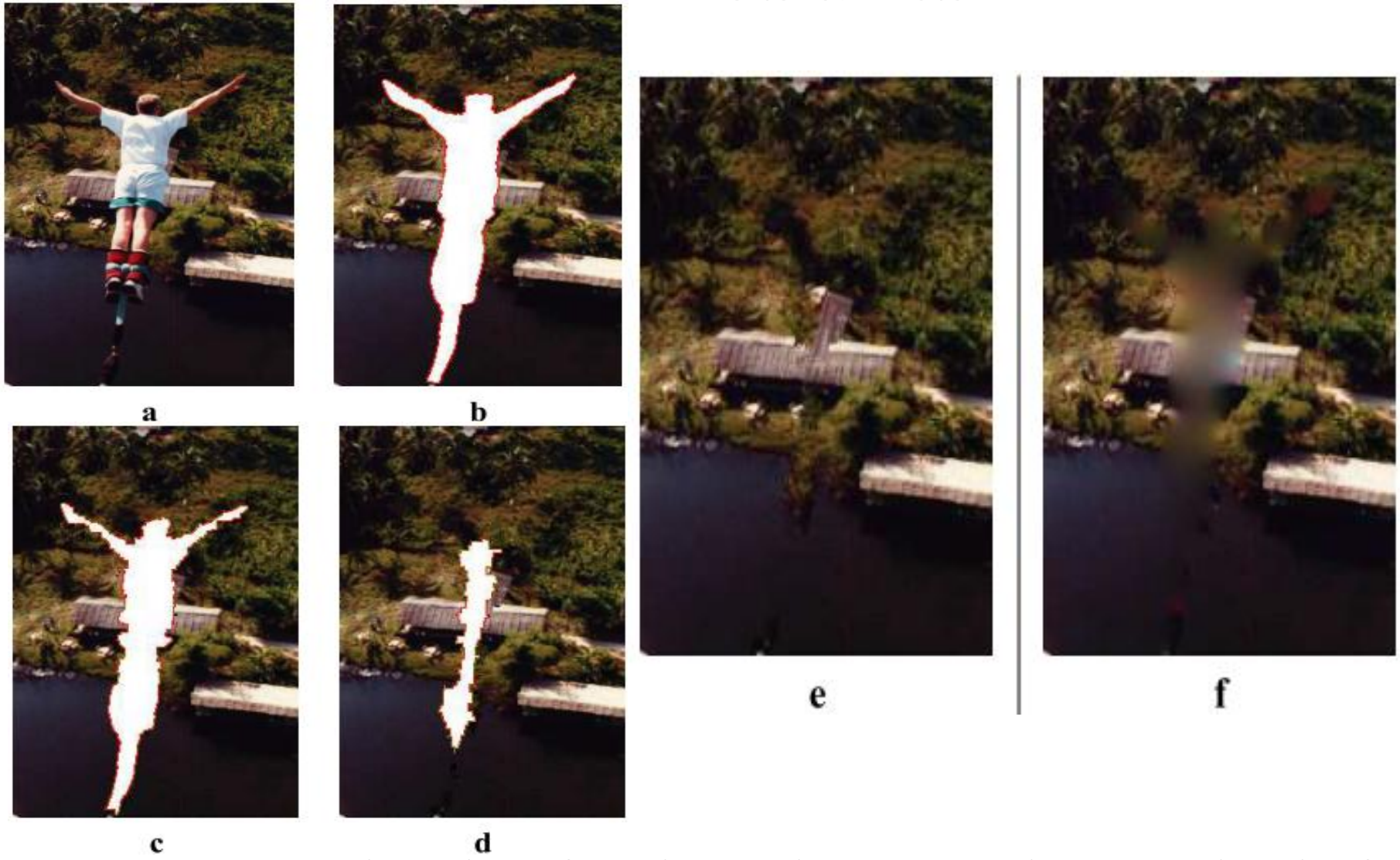


Fig. 2. Removing large objects from photographs. (e) Proposed automatic algorithm(f) filling by traditional image inpainting

Experimental results

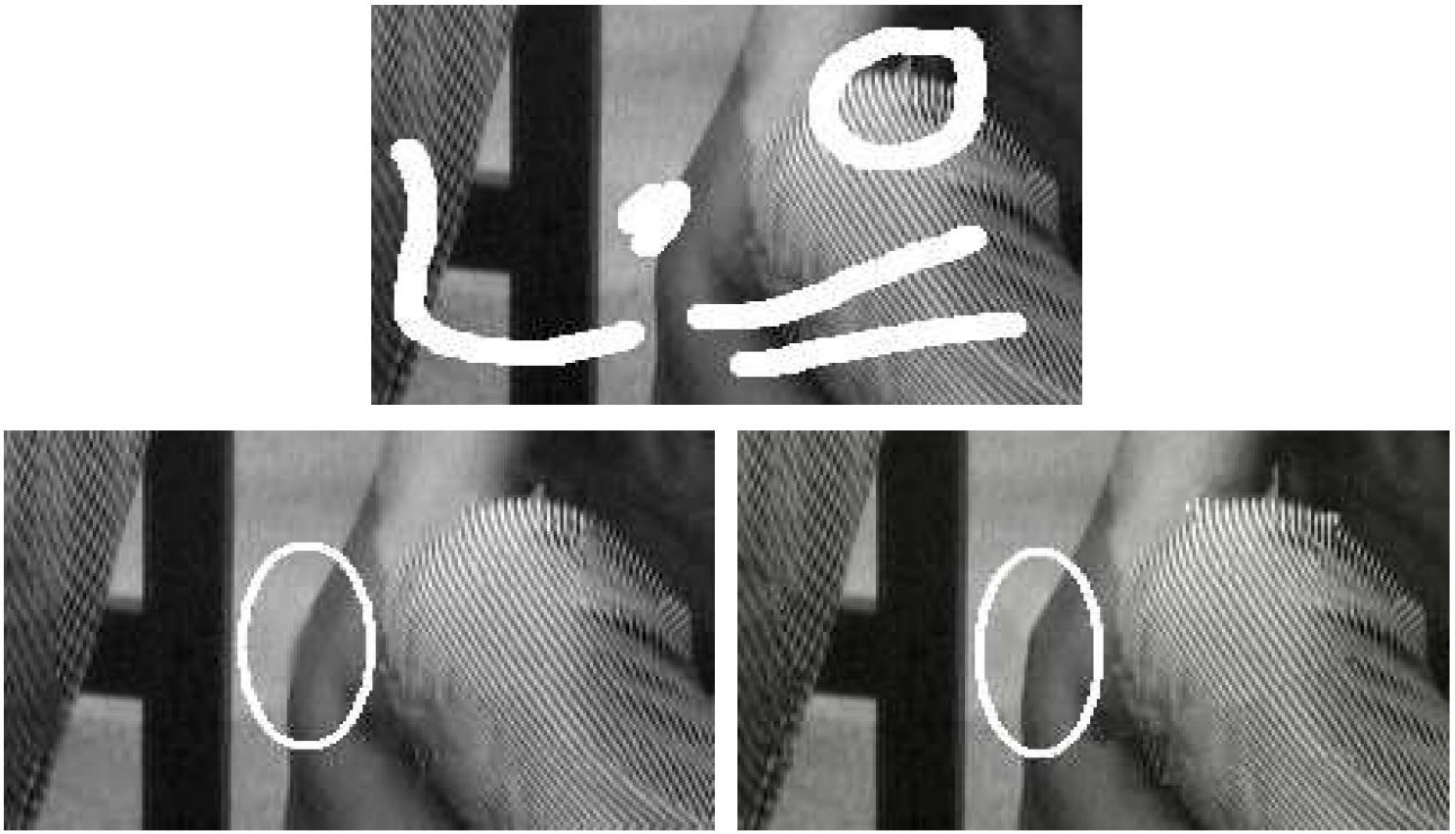


Fig. 3. Comparison with “texture and structure inpainting” [1].

[1] M. Bertalmio, L. Vese, G. Sapiro, and S. Osher. Simultaneous structure and texture image inpainting. In Proc. Conf. Comp. Vision Pattern Rec., Madison, WI, 2003. http://mountains.ece.umn.edu ~guille/inpainting.htm.

Experimental results (cont.)

- Results by proposed method

Fig. 4 Removing an object on a highly textured background. (a) Original photograph. (b) Work correctly on proposed algorithm.

Experimental results (cont.)

- **Results by proposed method**

Fig. 5. Removing several objects from a photograph. (a) Original image, (b) The crowd of people and other objects are gradually removed by proposed algorithm.

Experimental results (cont.)

- **Results by proposed method**

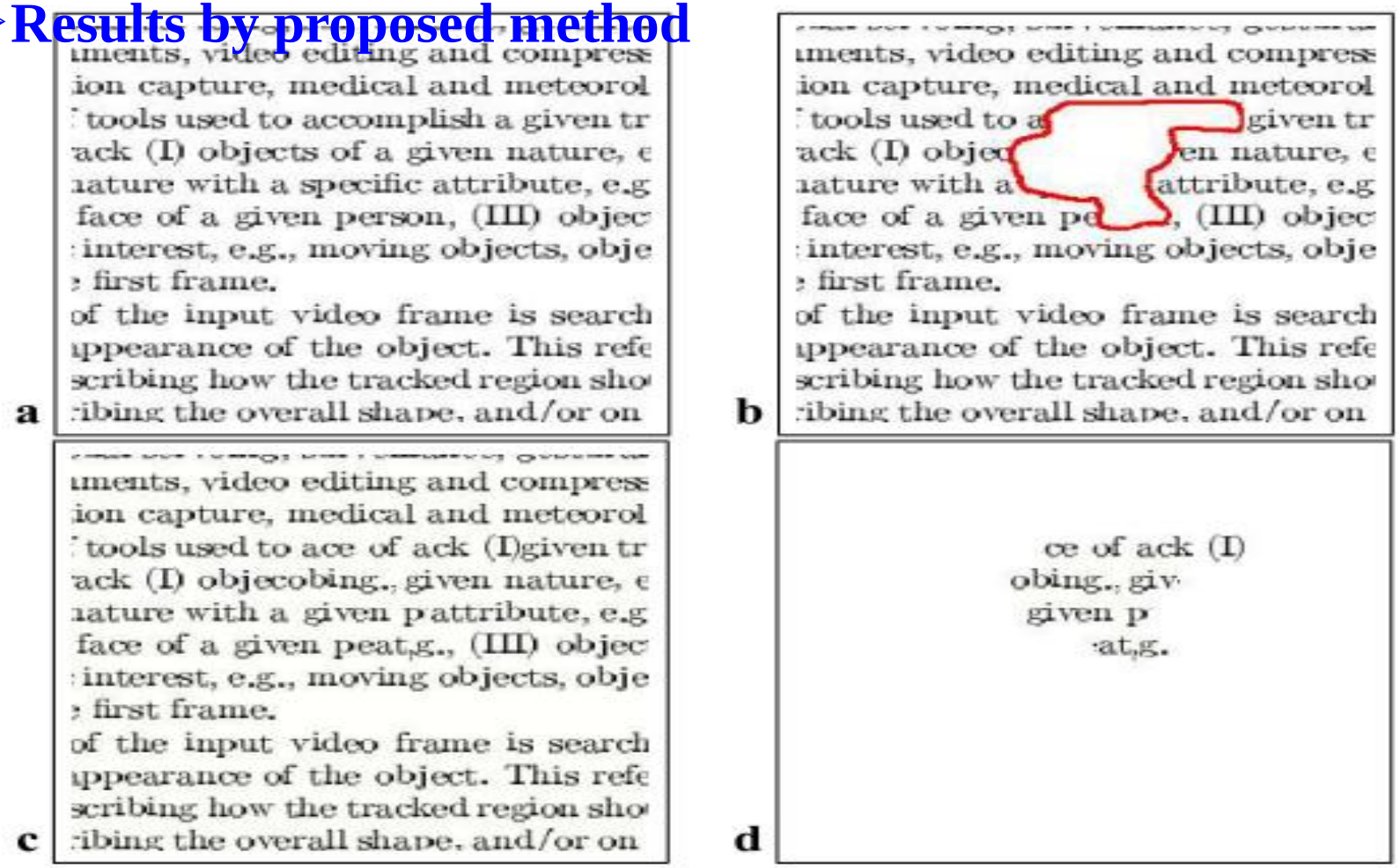
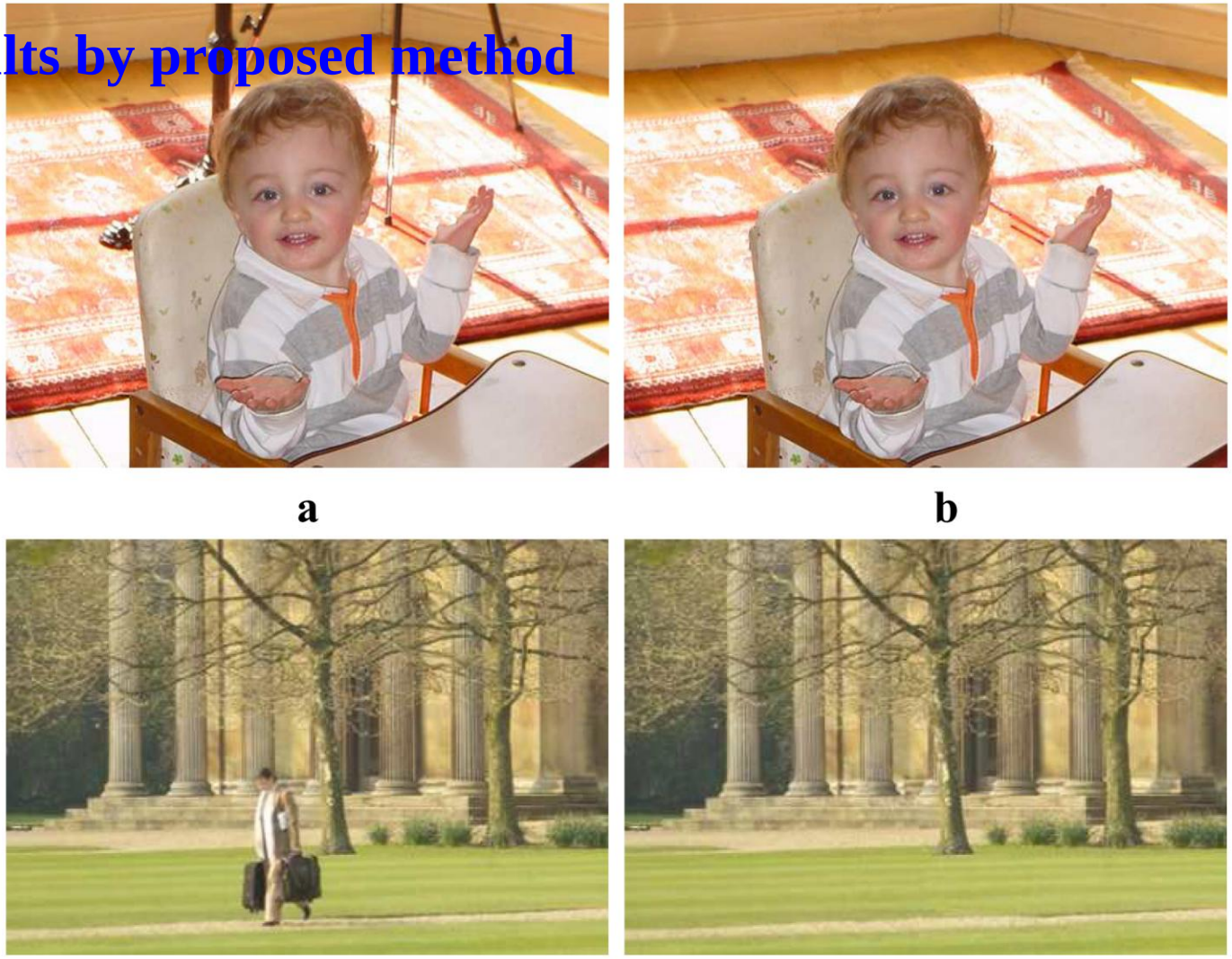


Fig. 6. Region- filling on an image of a text.

Experimental results (cont.)

- **Results by proposed method**



a b c d

Fig. 7. Final examples of object removal from photographs.

Experimental results (cont.)

- **Results by proposed method**

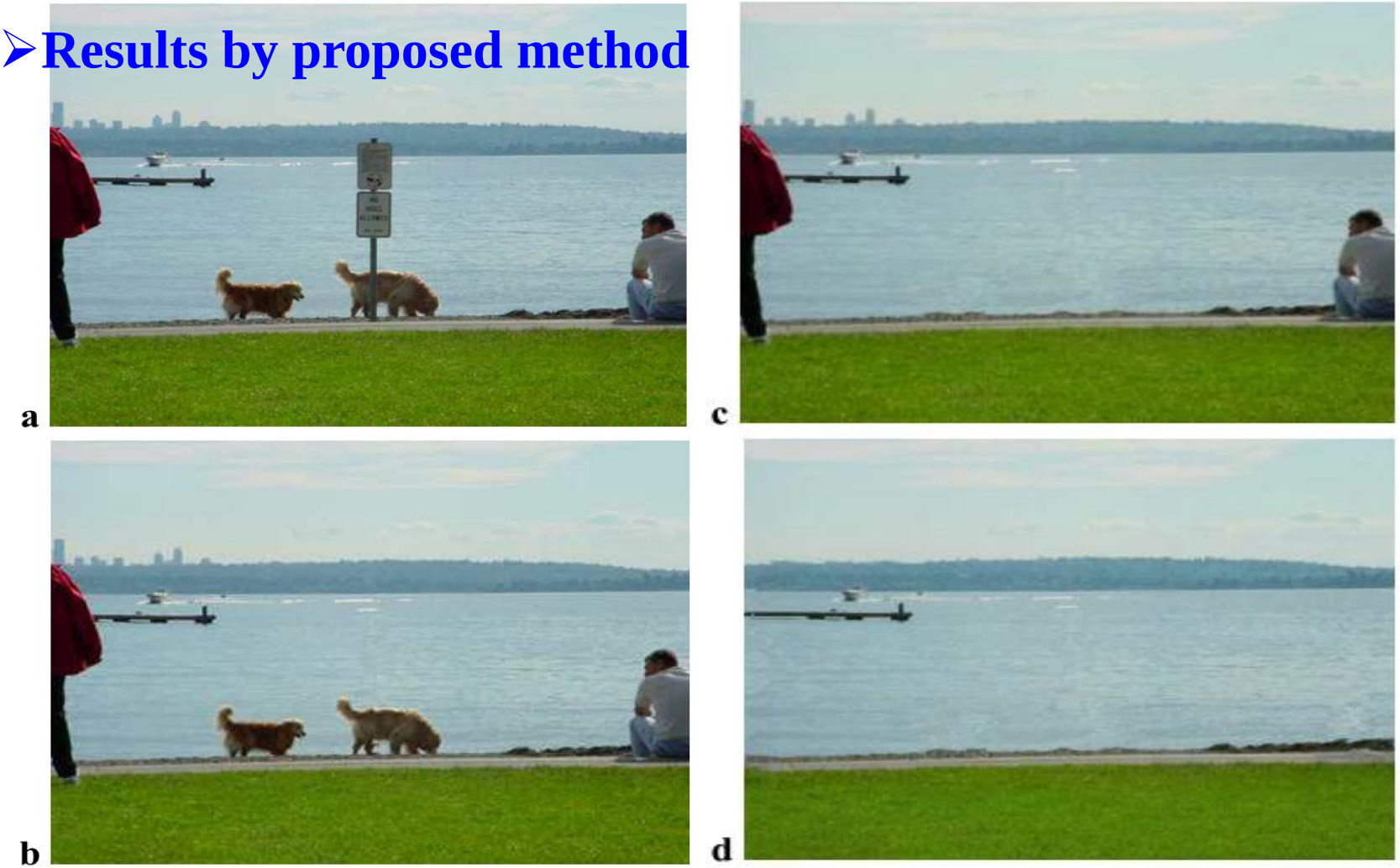


Fig. 8. Removing multiple objects from photographs.

Conclusion

- This paper has presented a novel algorithm for removing large objects from digital photographs.