Robust Object Removal By Modified Exemplar-based Image Inpainting

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What is Image Inpainting?

- Reconstruction of lost or damaged parts of an image.
- By filling in those regions where the data is lost in a visually plausible way.

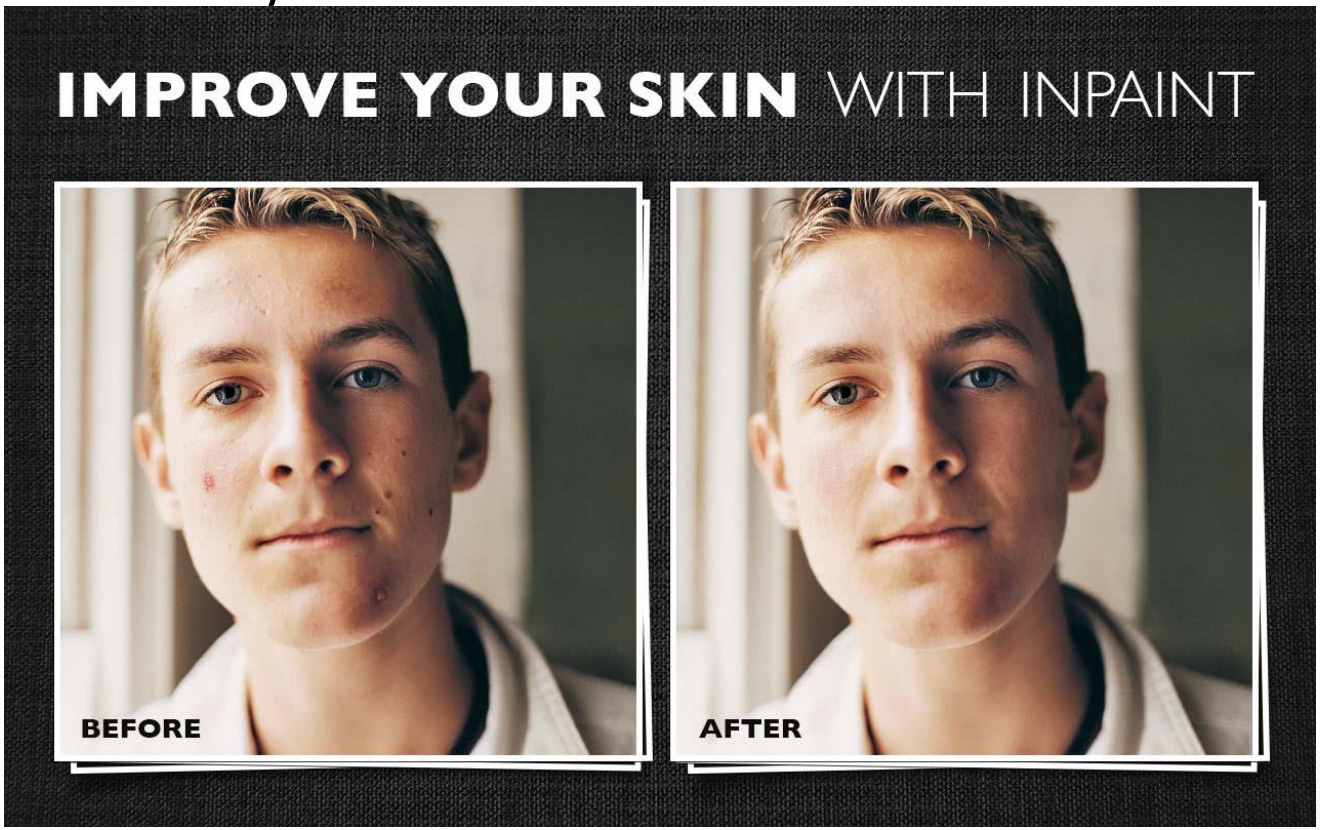
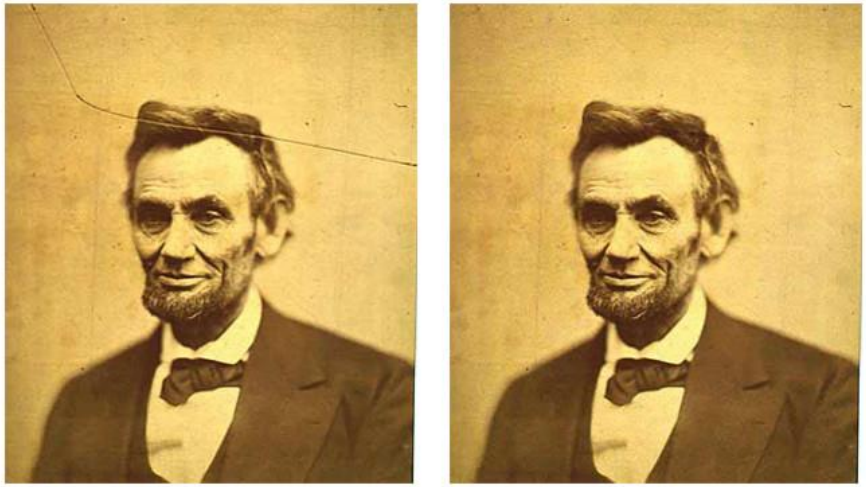


Image Source – theinpaint.com

Applications

- Old damaged images



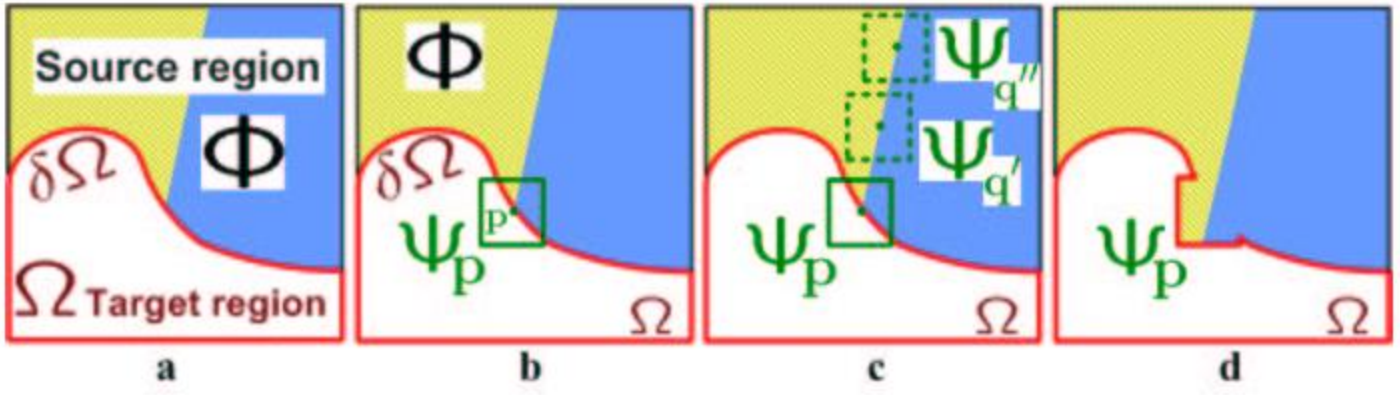
An 1865 Photograph of Abraham Lincoln taken by Alexander Gardner.

- Object Removal

Source - A. Criminisi et al, Paper of 2004.

Criminisi's Approach - 2004

- The advantage with images is that they have redundancies.
- We make use of the same by filling in information from the other 'undamaged' parts of the image into the damaged part and thus, reconstructing it.



Source - A. Criminisi et al, Paper of 2004.

The Algorithm

- To decide the order – Priority term, P(p).

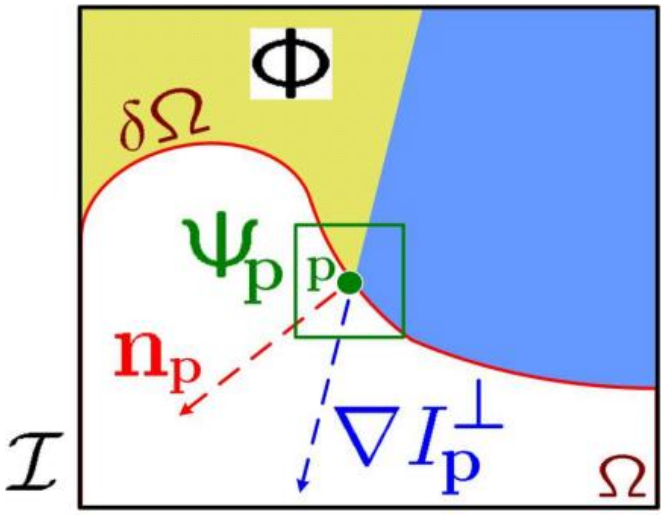
$$P(\mathbf{p}) = C(\mathbf{p})D(\mathbf{p})$$

- Confidence Term – How sure we can be about pixel p.

$$C(\mathbf{p}) = \frac{\sum_{\mathbf{q}\in\Psi_{\mathbf{p}}\cap(\mathcal{I}-\Omega)} C(\mathbf{q})}{|\Psi_{\mathbf{p}}|}$$

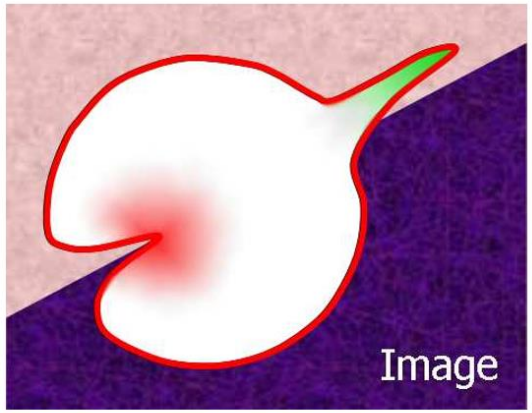
- Data Term – Gives priority to linear structures and edges.

$$D(\mathbf{p}) = \frac{|\nabla I_{\mathbf{p}}^{\perp} \cdot \mathbf{n}_{\mathbf{p}}|}{\alpha}$$

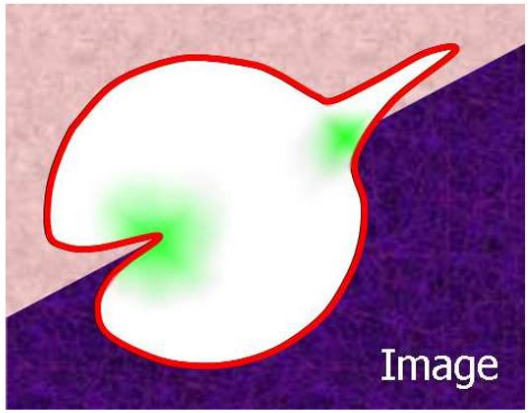


Source - A. Criminisi et al, Paper of 2004.

The Algorithm



(a) Areas preferred (green) and discriminated (red) by the *confidence* term $C(p)$.



(b) Areas preferred (green) by the *data* term $D(p)$.

- To decide the patch with which to fill, we calculate the Sum of Squared Distances (SSD).

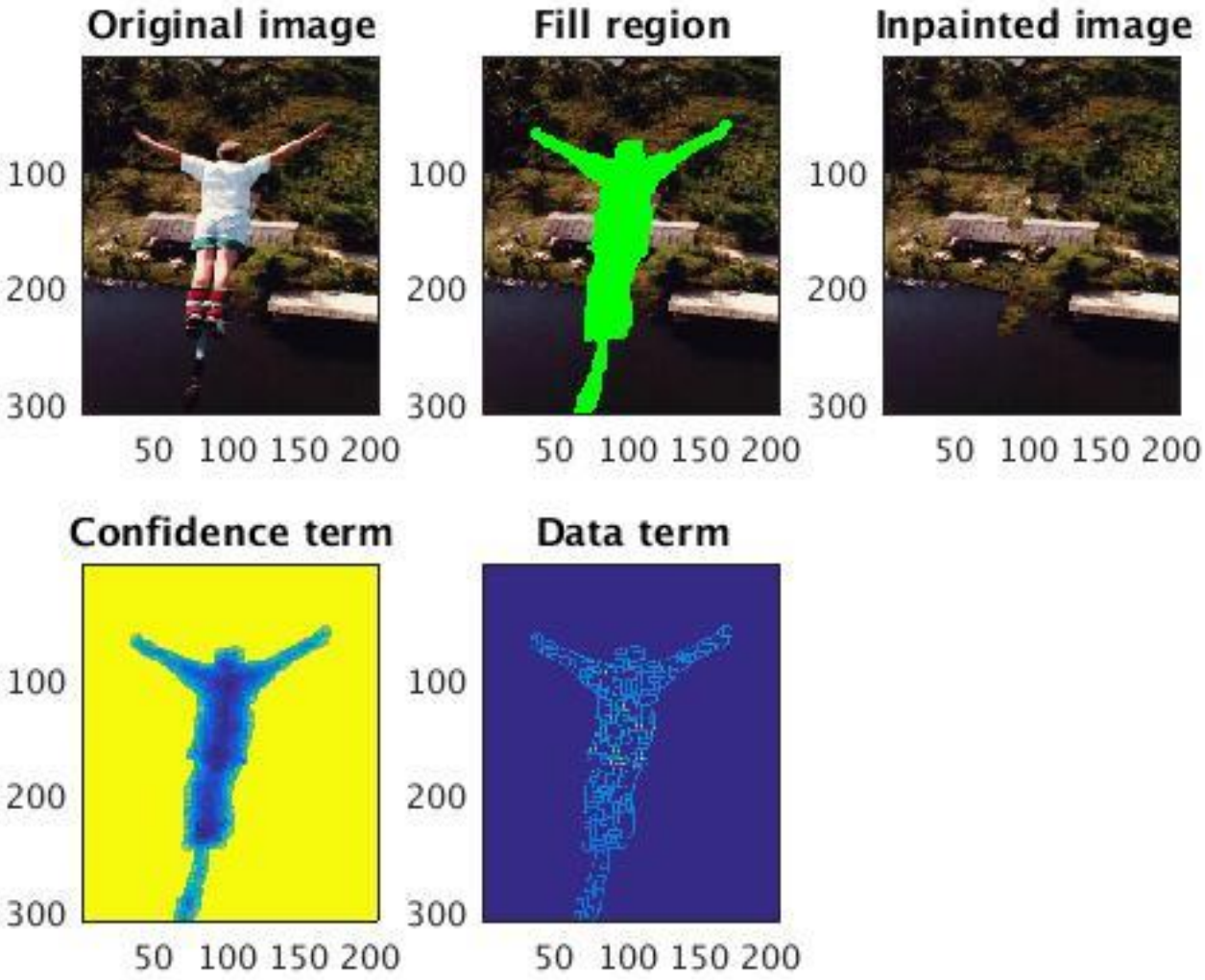
$$\Psi_{\hat{\mathbf{q}}} = \arg \min_{\Psi_{\mathbf{q}} \in \Phi} d(\Psi_{\hat{\mathbf{p}}}, \Psi_{\mathbf{q}})$$

- Fill the target with the patch having the least SSD.
- Update confidence values.

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

Image Source - A. Criminisi et al, Paper of 2004.

Results


Original image
Fill region
Inpainted image
Confidence term
Data term
100
200
300
50 100 150 200

Modifications

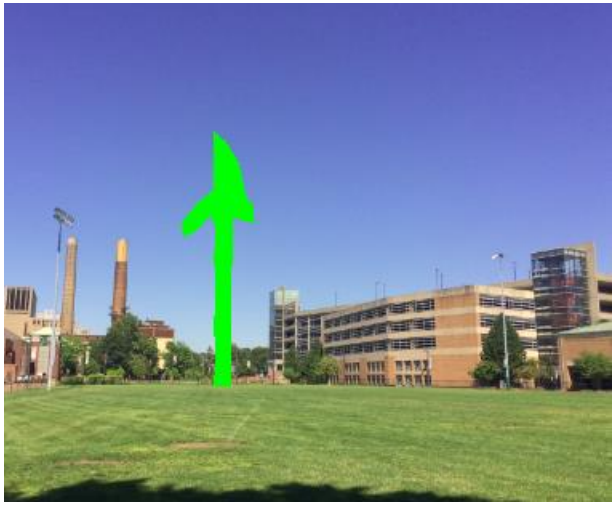
- Confidence values tend to fall rapidly as we fill inwards leading to random selection later.
- To prevent this, a Regularizer term ω, is introduced.

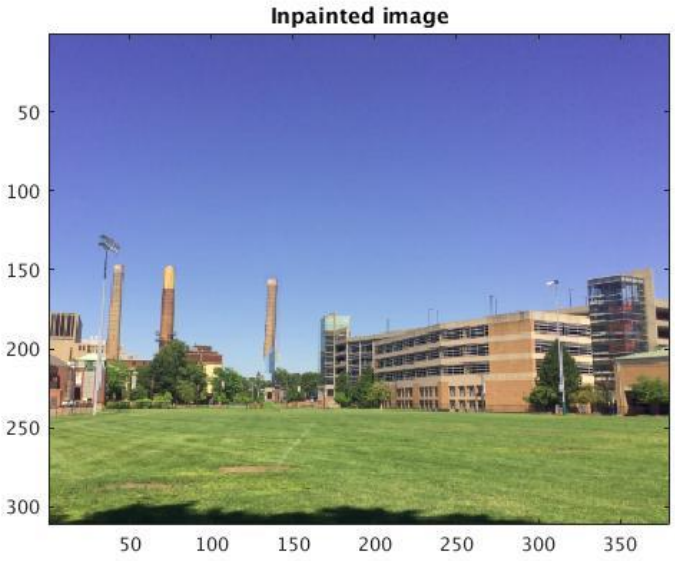
$$R_C(p) = (1-\omega)C(p) + \omega$$
$$P(p) = R_C(p)D(p)$$

Without regularizer

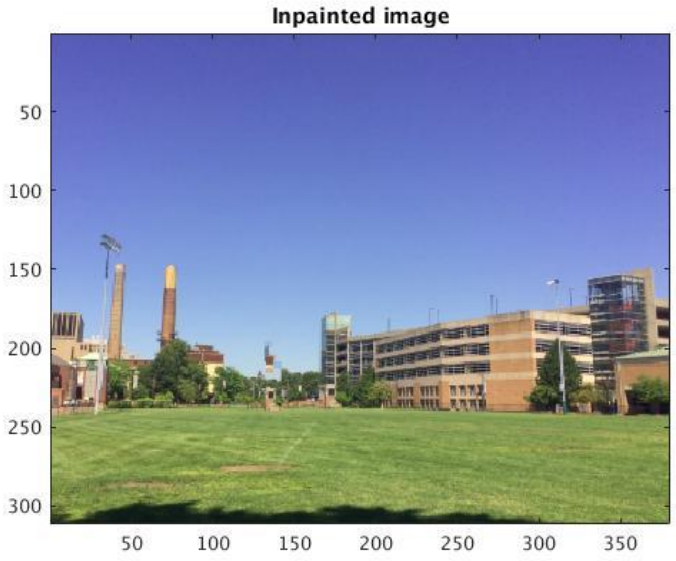
With regularizer

Results





Without Regularizer



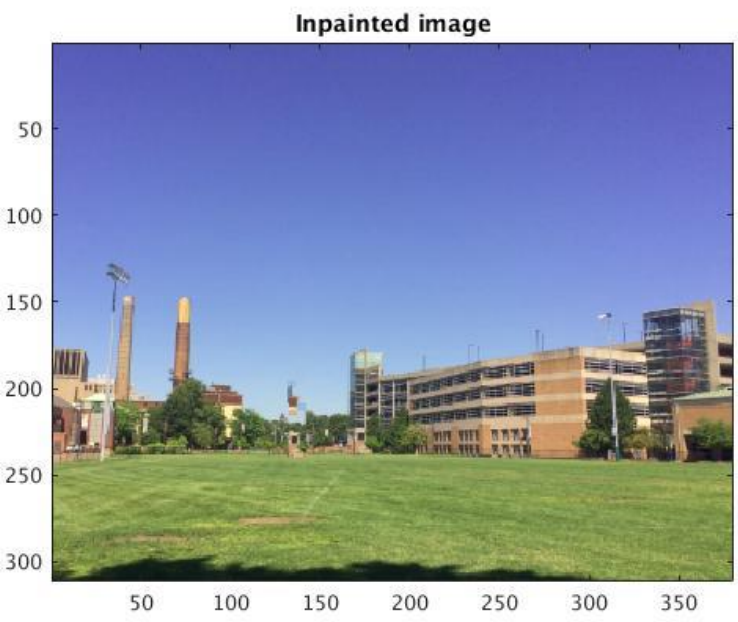
With Regularizer

Modifications

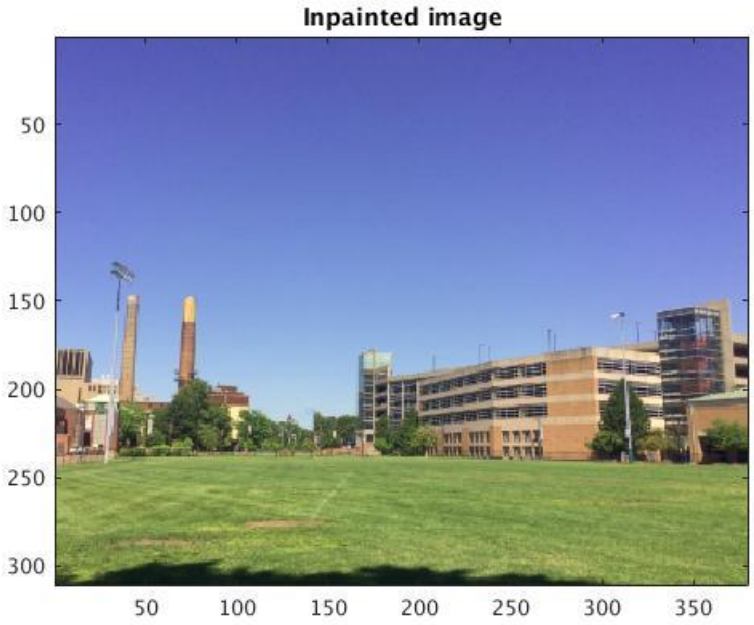
- SSD criteria does not consider similarity of unknown regions.
- For digital images, variance can be used to indicate the stability of the image block pixels.
- Thus, we add the variance on the base of SSD criteria to make a better (stabler) patch selection.

$$\Psi(q) = arg\ min\ (d(\Psi_p, \Psi_q) + \delta \times (v(\Psi_p) - v(\Psi_q)))$$

Results



With Regularizer and SSD criteria



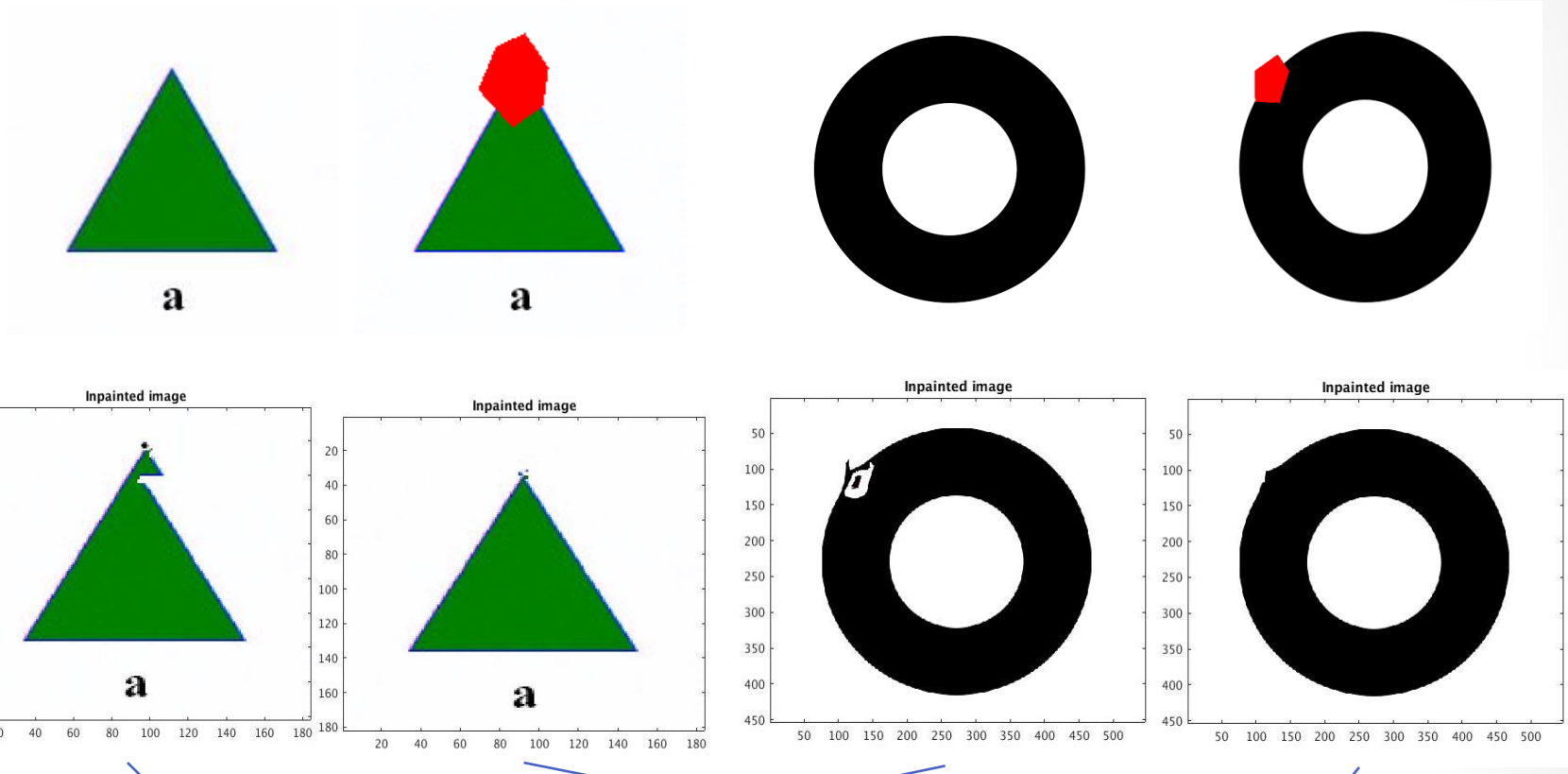
With Regularizer and Variance+SSD Criteria

Modifications

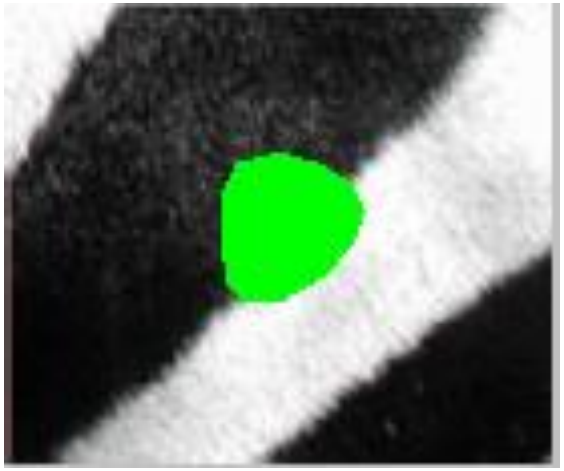
- Up till now gradient-based data term calculation was being carried out.
- It can also be found out by using ‘Edge Map’ technique.

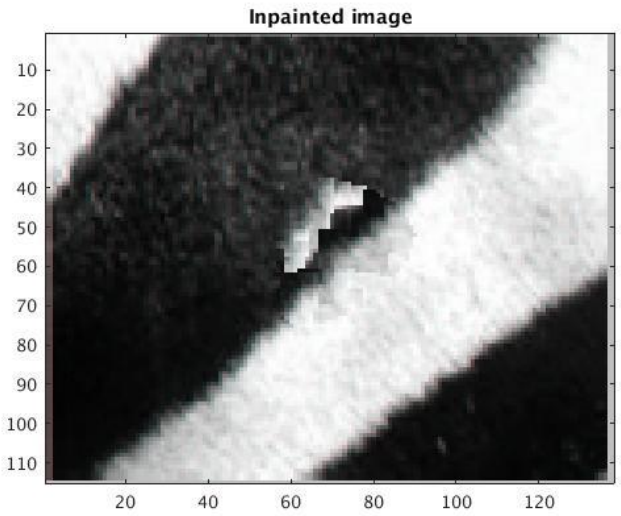
$$D(p) = \max\left(1, \left(\sum_{q \in (\Psi p \cap \Phi \varepsilon)} c\right)\right) * \frac{\mathrm{var}(\Psi p)}{|\Psi p|}$$

Results

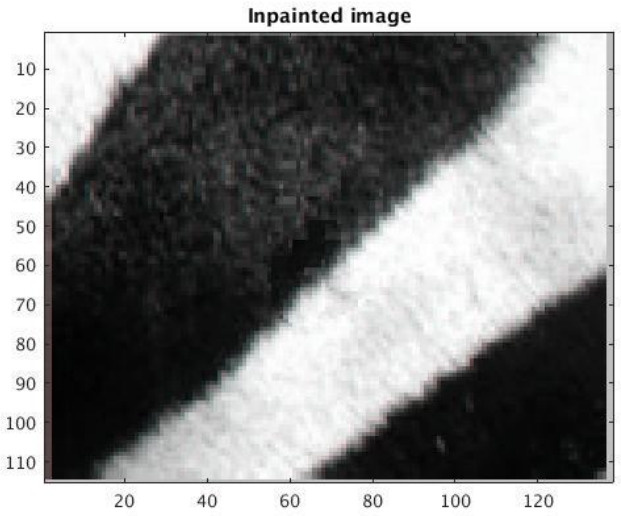

a
a
Inpainted image
Inpainted image
Inpainted image
Inpainted image
With regularizer and gradient-based D(p)
With regularizer and Edge map based D(p)

Results





With regularizer and gradient-based D(p)



With regularizer and Edge map based D(p)

Contribution

We've implemented the Criminisi's algorithm and further built upon it to include –

- A regularizer
- Variance on top of the SSD criteria for patch selection
- Data term using Edge Map technique.

Implementation is done using MATLAB and C.

Future Work

- A constant patch size has been used till now.
- Patch size effects the accuracy, matching probability and the computation time.
- An adaptive patch size can be used to optimize all these.

References

- A. Criminisi, P. Perez, and K. Toyama. Region filling and object removal by exemplarbased image inpainting. In IEEE Transaction of Image Process. IEEE, 2004, vol. 13 (9), pp. 12001212.
- J. Wang, K. Lu, D. Pana, N. Heb and B. Bao. Robust object removal with an exemplarbased image inpainting approach. In Journal of Neurocomputing, Vol. 123, no. 10, pp. 150155, 2014.
- Ye-fei Liu, Fu-Long Wang, Xiang-yan Xi. 2013. Enhanced algorithm for Exemplar based Inpainting. Ninth International Conference on Computational Intelligence and Security, Leshan, 2013, pp. 209-213.
- C. Ralekar, S. Dhondse and M. M. Mushrif, "Image reconstruction by modified exemplar based inpainting," Communications and Signal Processing (ICCSP), 2015 International Conference on, Melmaruvathur, 2015, pp. 1005-1010.