Mobile Scanner: Document Segmentation and Object Removal by Exemplar-based Image Inpainting and Spectral Regularization

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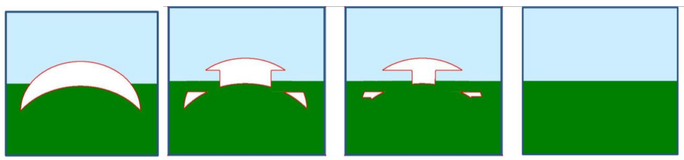
Motivation

Nowadays, people need to process various images in their daily life, such as photos, receipts, written homeworks, printed documents, and name cards; nevertheless, in this digital age, an important method to process and store those paper documents is to capture them with cameras and store them via digital photos. In order to enhance readability, efficiency, and aesthetic feeling, often people needs to crop out the important document part and remove the unnecessary and unaesthetic background. Many mobile apps are made to help users automatically do that such as Evernote Scannable, iScanner, Tiny Scanner, etc. However, we can still include some useful features on top of them, for example, defect/undesirable object removal as well as noise reduction. As a result, in this project, we would like to achieve the scanner functionality of automatic document/photo extraction via edge detection and contour, and properly obtain a top-down, bird eye view image via perspective transform; also we would like to explore techniques for defect/object removal and de-noising.

Filling Process



Related Work

[1] A. Criminisi, P. Perez, and K. Toyama. "Object removal by exemplar-based inpainting." In Computer Vision and Pattern Recognition, 2003. Proceedings. 2003 IEEE Computer Society Conference on, vol. 2, pp. II-II. IEEE, 2003
[2] Mazumder, Rahul, Trevor Hastie, and Robert Tibshirani. "Spectral regularization algorithms for learning large incomplete matrices." Journal of machine learning research 11.Aug (2010): 2287-2322.
[3] M.Ashikhmin.Synthesizing natural textures. InProc. ACM Symposiumon Interactive 3D Graphics, pages 217–226, Research Triangle Park, NC,March 2001.
[4] A. Efros and W.T. Freeman. Image quilting for texture synthesis and transfer. InProc. ACM Conf. Comp. Graphics (SIGGRAPH), pages 341–346,Eugene Fiume, August 2001.

Techniques

Exemplar-Based Image Inpainting
Basic idea: Fill known areas first, encourage linear structures.
(a) given an empty area, first select a patch p on the contour such that:
1 p is surrounded by relatively more known pixels
2 p is on the continuation of a linear structure.
(b) find a similar patch q in the known area, such that the difference between p and q is minimum.
(c) Plug q to p. And update values around p.
And repeat the above steps.

Detailed Steps:
(0) Extract the manually selected initial contour
Repeat:
(a1) Identify the contour, quit if all the area is filled
(a2) Compute priorities P(p)=C(p)D(p) for every p on the contour, to decide which patch to fill first
(a3) Find the p that has the max P(p)
(b) Find exemplar q that minimizes d(p, q)
(c) Copy data from q to p. Update C(p) to C(q)

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

Spectral Regularization
(1) For the original image X, fill in entries of unknown values with 0
(2) Minimize the square errors between X and target Z with L1 regularization
- Perform SVD X = UDV', add regularization to the diagonal of D,
$D_\lambda = diag[|d_1 - \lambda|, \cdots, |d_r - \lambda|]$, initialize target Z = 0
- Select a sequence of regularization coefficient λ1, λ2, ...λk, repeat:

$$Z^{new} \leftarrow U D_\lambda V'(X + Z^{old}_{\Omega^\perp})$$

where we only consider the values of Z in the unknown region
- If the change of Z is less than the threshold,assign Z with the new value.

$$\frac{||Z^{new} - Z^{old}||^2}{||Z^{old}||^2} < \epsilon$$

- Output a sequence of Z for different regularizations and select the most appropriate one

Experimental Results