A Multi-Focus Image Fusion Method based on Fractal Dimension and Guided Filtering

Nikoo Dehghani, Ehsanollah Kabir

Presenter: Nikoo Dehghani, MSc.
Department of Electrical and Computer Engineering,
Tarbiat Modares University

Problem Definition

(a) (b) (a) (b)

Fig. 1. Performance of FD based multi-focus image fusion algorithm, applied on “Flower” image set. (a),(b) Sample multi-focus images from [Nejati, 2015]. (c) Final focus map. (d) Fused fully focused image.

Dataset

- 20 pairs of color images from Lytro dataset [Nejati, 2015]
- 8 pairs of color and grayscale images [Yang, 2008]

Fig. 2. Multi-focus image pairs extracted from Lytro dataset [Nejati, 2015]

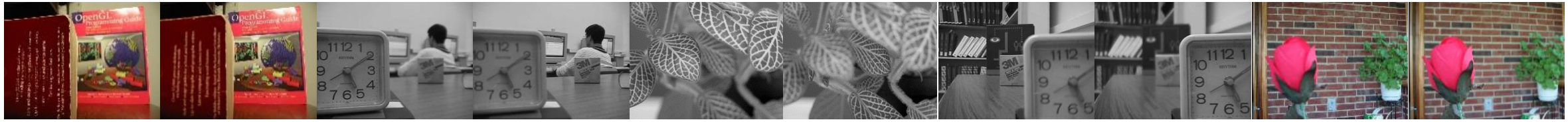


Fig. 3. Multi-focus image pairs widely used in literature [Yang, 2008]

Fractal Dimension

- Fractals geometry
- Successful approach towards quantifying texture information
- Differential box counting (DBC) method

$$FD = \frac{\log(N_r)}{\log\left(\frac{1}{r}\right)}$$

$$n_r(i,j) = \left\lceil \frac{g_{max}}{s'} \right\rceil - \left\lceil \frac{g_{min}}{s'} \right\rceil + 1$$

$$N_r = \sum_{i,j} n_r(i,j)$$

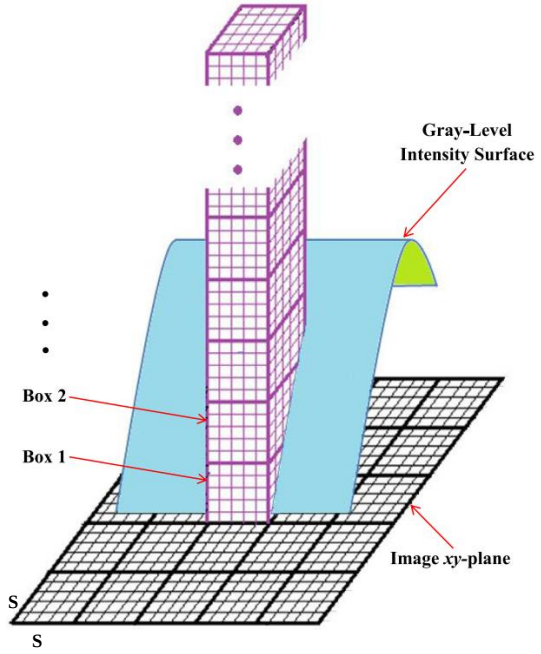


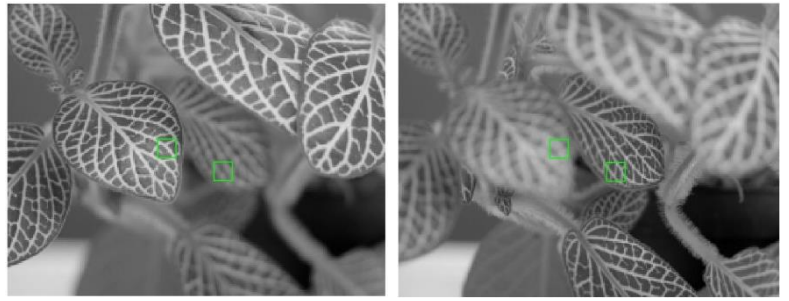
Fig. 4. Sketch for the determination of boxes using the Differential box counting (DBC) method. [Panigrahy, 2019]

Focus Detection Algorithm

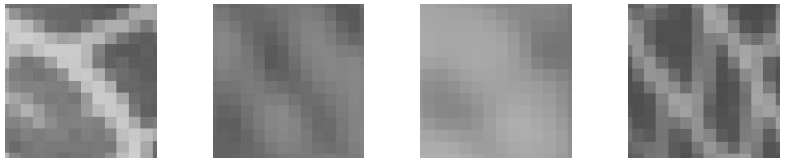
- Building FD representing matrix
  - Importance of window size

Table. 1. FD values for image patches shown in fig. 5.

Image patch	Fig.5 (a.1)	Fig.5 (a.2)	Fig.5 (b.1)	Fig.5 (b.2)
FD value	2.6343	2.5490	2.3245	2.7779



(a) (b)



(a.1) (a.2) (b.1) (b.2)

Fig. 5. (a), (b) Multi-focus image pair with extracted blocks from each two class of regions. (a.1) and (b.2) show extracted blocks from focused regions, (a.2) and (b.1) show extracted blocks from defocused regions.

Focus Detection Algorithm

- Building FD representing matrix
  - Preserving local edges using a guided filter

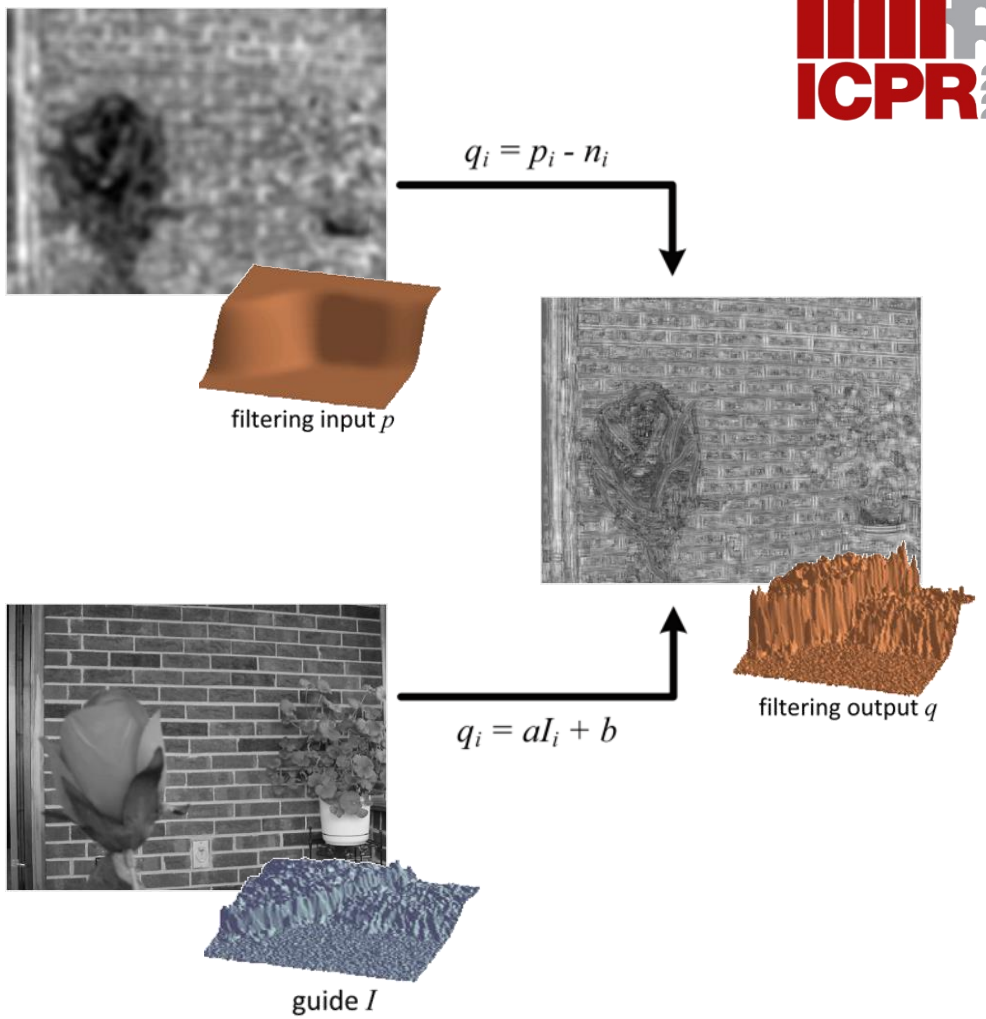


Fig. 6. Use of a guided filter on the obtained matrix of FD values to transfer structure from the respective original image. Original image from [He, 2013] combined with results from the proposed method.

Focus Detection Algorithm

- Building FD representing matrix
- Initial focus map (IFM)

$$\mathrm{IFM}(i,j) = \begin{cases} 1, & if \quad \mathrm{FD}_1(i,j) > \mathrm{FD}_2(i,j) \\ 0, & otherwise \end{cases}$$

- Final focus map (FFM)
- Obtaining fused image (I_F)

$$\mathrm{I_F}(i,j) = \mathrm{FFM}(i,j)\ \mathrm{I}_1(i,j) + \big(1 - \mathrm{FFM}(i,j)\big)\mathrm{I}_2(i,j)$$

Experimental Results

(a) (b) (c) (d) (e)

Fig. 7. Performance of FD based multi-focus image fusion algorithm, applied on “Lytro-10” image set from Lytro dataset. (a),(b) Sample multi-focus image pair. (c) Initial Focus map. (d) Final focus map. (e) Fused fully focused image.

Experimental Results

Fig. 8. Performance of FD based multi-focus image fusion algorithm, applied on “Lytro-11” image set from Lytro dataset. (a),(b) Sample multi-focus images. (c) Initial Focus map. (d) Final focus map. (e) Fused fully focused image. Errors are specified (c) and their related regions in (a),(b).

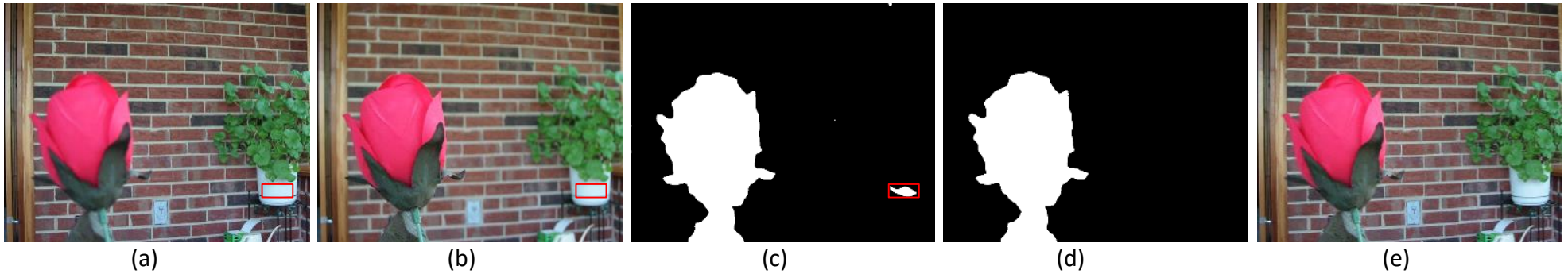


Fig. 9. Performance of FD based multi-focus image fusion algorithm, applied on “Flower” image set. (a),(b) Sample multi-focus images. (c) Initial Focus map. (d) Final focus map. (e) Fused fully focused image. Errors are specified (c) and their related regions in (a),(b).

Evaluations

Table 2. Results of objective quality metrics for the proposed multi-focus image fusion method and the other methods (from [Chen, 2009]).

Image set	Metric	Method						
		GFF	IMF	DSIFT	BFMM	p-CNN	ECNN	Proposed
Lab	Q_{PC}	0.6865	0.6876	0.7014	0.7032	0.7046	0.7935	**0.7972**
	Q_{CB}	0.8344	0.8387	0.8333	0.8321	**0.8398**	0.7489	0.7319
	Q_W	0.5100	0.4683	0.5009	0.4984	0.5018	0.9163	**0.9219**
Book	Q_{PC}	0.6822	0.6827	0.6631	0.6812	0.6835	0.8195	**0.8633**
	Q_{CB}	0.7143	0.7358	0.7355	0.7277	0.7359	**0.7771**	0.7723
	Q_W	0.6272	0.6264	0.5985	0.6361	0.6162	**0.9279**	0.9246
Flower	Q_{PC}	0.7084	0.6964	0.7116	0.7032	0.7090	0.7594	**0.7821**
	Q_{CB}	0.8048	0.8020	0.8014	0.7153	0.8049	**0.8270**	0.8130
	Q_W	0.4781	0.4683	0.5009	0.4123	0.5051	**0.9198**	0.9165
Desk	Q_{PC}	0.7364	0.7246	0.7154	0.7270	0.7360	0.7796	**0.7914**
	Q_{CB}	0.5714	0.5585	0.5619	0.5628	0.5720	0.7602	**0.7852**
	Q_W	0.7038	0.6743	0.6721	0.6745	0.7269	0.9036	**0.9250**
Clock	Q_{PC}	0.7089	0.7110	0.6855	0.7098	0.7130	**0.9060**	0.7852
	Q_{CB}	0.7426	0.7448	0.7497	0.7130	0.7512	**0.7831**	0.7558
	Q_W	0.6123	0.6158	0.5791	0.7016	0.6197	**0.9311**	0.9196
Leaf	Q_{PC}	0.7341	0.7386	0.7363	0.7351	0.7394	N/A	**0.8266**
	Q_{CB}	0.7633	0.7723	0.7699	0.7622	0.7481	N/A	**0.7885**
	Q_W	0.5028	0.4982	0.5007	0.5017	0.5032	N/A	**0.9115**

Thank you for your attention