DIRECTIONAL IMAGE INTERPOLATION WITH ANOVA METHODOLOGY

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Spatial Resolution for Better Visual Perception

Image interpolation

- For many applications, the native resolution of a captured image is not sufficient and should be enhanced by computer software,
- **Image interpolation** is the technique to compensate for the insufficiency of the hardware resolution of an image acquisition device,
- Video deinterlacing, color image demosaicking, medical image registration, subpixel motion estimation are among indirect applications of image interpolation.

Challenges and contributions:

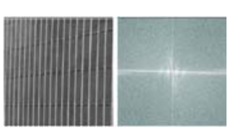
- The technical challenge of image interpolation is to faithfully reconstruct the high-frequency components or fine textures,
- In this work, analysis of variance (ANOVA), a hypothesis testing methodology, is used to decide on the interpolation direction.

Analysis of Variance

- The statistical method of ANOVA tests hypothesis by examining two or more groups of data,
- The null hypothesis is that all groups have equal mean and drawn from the same sampling distribution,
- For image processing applications, ANOVA has measured successes for tasks of edge/object detection, image segmentation, noise removal and image restoration [1],
- The ability of ANOVA to test the statistics of defined features in an image with regard to noises and also complexities of scenes, is the key to success for ANOVA-based image processing applications.

ANOVA for improving edge-directed image interpolation

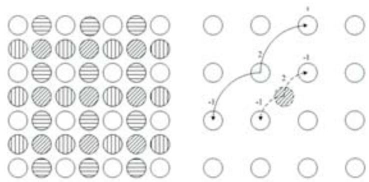
- Edge-directed image interpolation techniques exploit the fact that high-frequency image features are anisotropic in the nature :



- Edge-directed interpolation techniques try to detect the edge orientation and perform the interpolation along the edges,
- Edge-directed rely on edge information which are estimated from the low-resolution input image and are error-prone as insufficient sampling rate causes aliasing,
- In this work, we apply ANOVA to address this issue and improve the interpolation performance.

Proposed ANOVA-based Interpolation Scheme

- We use the absolute value of the directional second derivative as a metric for the smoothness of different directions: $|\nabla_\theta|$



- The value of $|\nabla_\theta|$ at location of a known low resolution sample, in the k^{th} direction can be written as:

$$|\nabla^2{}_k| = \mu + \tau_k + \varepsilon_{kij}$$

level — effect — error

- The above model parameters can be optimally determined as:

$$\min_{\mu,\tau_k}{}^{-1}\{\sum_{(i,j)\in W_{mn}} \sum_{k=1}^{K} (|\nabla^2{}_k| - \mu - \tau_k)^2$$

subject to $\sum_{k=1}^{K} \tau_k = 0$

- The solutions are:

$$\hat{\mu} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} |\nabla^2{}_k(i,j)|}{IJK},$$

$$\hat{\tau}_k = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J} |\nabla^2{}_k(i,j)|}{IJ} - \hat{\mu}$$

- The reason for expressing $|\nabla_\theta|$ in terms of level, effect and error is to infer whether the differences of observed samples of $|\nabla_\theta|$ are caused by error terms or effect terms, by testing the following hypothesis:

$$H_0 : (\forall k)\tau_k = 0$$

- To test the above hypothesis the F-value is computed as:

$$F_a = \frac{[SS(\mu,\tau,0) - SS(\mu,0,e)]/d_a}{SS(\mu,0,e)/d_e}$$

where

$$SS(\mu,\tau,0) = \sum_{(i,j)\in W_{mn}} \sum_{k=1}^{K} (|\nabla^2{}_k(i,j)| - \hat{\mu} - \hat{\tau}_k)^2$$

,

$$SS(\mu,\tau,0) = \sum_{(i,j)\in W_{mn}} \sum_{k=1}^{K} (|\nabla^2{}_k(i,j)| - \hat{\mu})^2$$

and d_a and d_e are corresponding degrees of freedom for nominator and denominator.

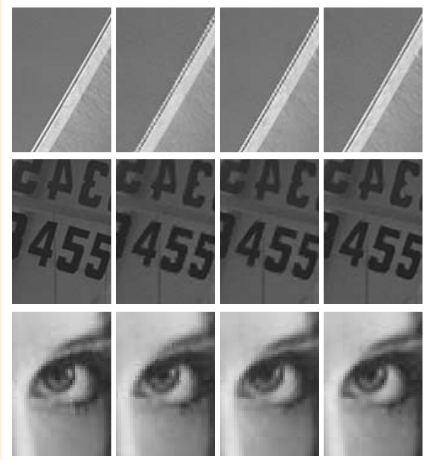
- The above said F-value is computed and compared to the corresponding threshold at a certain level of confidence.
- This technique allows for detecting the cases where there is great amount of uncertainty to decide on the interpolation direction,
- In such cases we can resort to a conservative and isotropic interpolator like bicubic [3].

Experimental Results

Objective comparisons:

Image	Lena	Bike	Window	Fruits
Bicubic	33.83	38.39	34.86	36.98
Method of [2]	33.01	35.94	33.53	36.40
NEDI	33.77	37.53	34.36	37.02
MRF-EDI	33.10	36.06	34.74	35.91
Proposed Method	**34.40**	**39.30**	**35.06**	**37.50**

Visual comparisons:



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

(a) Original ,(b) method of [4], (c) method of [5] and (d) Proposed.

Conclusion

Experimental results show the proposed ANOVA-based image interpolation technique preserves edges and fine structures of an image and suppresses common interpolation artifacts (e.g. ringing, blurring, and jaggies),

Future works:

Although in this study we applied a scalar feature to detect the smooth direction, it is possible to use a vector of features. The extension to multivariate case requires multivariate analysis of variance (MANOVA). Further research on this issue is underway.

References

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