Image Interpolation & Superresolution (III)

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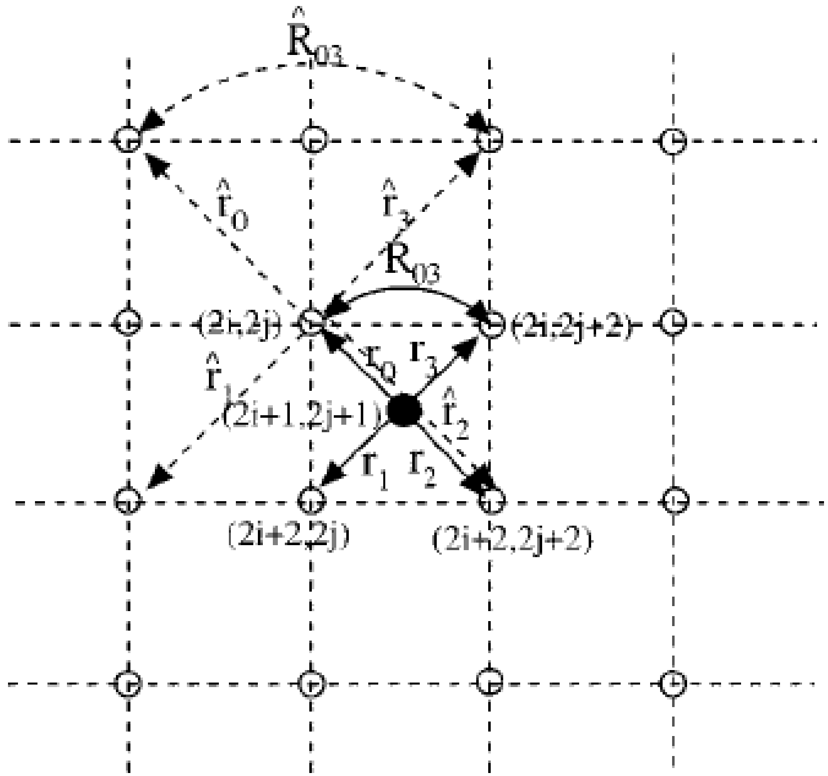
Edge-Directed Interpolation [2]

- The basic idea is to first estimate local covariance coefficients from a low-resolution image and then use these covariance estimates to adapt the interpolation at a higher resolution based on the ***geometric duality*** between the low-resolution covariance and the high-resolution covariance.
  - **Assumption**: natural image can be modeled as a *locally Gaussian process*.

Geometry Duality



$$\vec{\alpha} = R^{-1}\vec{r}$$

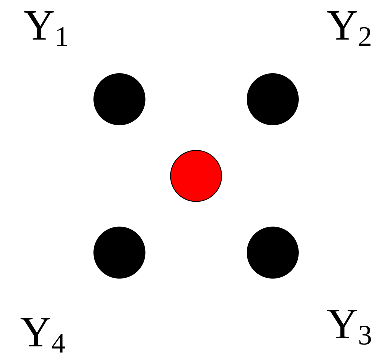
Fig. 1. Geometric duality when interpolating $Y_{2i+1,2j+1}$ from $Y_{2i,2j}$.

$$\hat{Y}_{2i+1,2j+1} = \sum_{k=0}^{1}\sum_{l=0}^{1} \alpha_{2k+l} Y_{2(i+k),2(j+l)}$$

Minimum Mean Square Error (MMSE)

$$E = (\hat{Y} - Y)^2$$

$$= (\sum_{i=1}^{4} \alpha_i Y_i - Y)^2$$



$$\frac{\partial E}{\partial \alpha_i} = (\hat{Y} - Y)\frac{\partial \hat{Y}}{\partial \alpha_i} = (\sum_{k=1}^{4} \alpha_k Y_k - Y)Y_i = 0$$

But the prediction just based on only the 4 neighbors may be unreliable.

$$\alpha_1 \mathrm{Y}_1 Y_i + \alpha_2 Y_2 Y_i + \alpha_3 Y_3 Y_i + \alpha_4 Y_4 Y_i = YY_i$$

$$1 \le i \le 4$$

Implementation

- Natural image can be modeled as **a locally Gaussian process**.
- The low-resolution covariance $\hat{R}_{kl}$, $\hat{r}_k$ can be estimated from *a local window* of the low-resolution image using the classical covariance method:

$$\hat{R} = \frac{1}{M^2} C^T C, \hat{\vec{r}} = \frac{1}{M^2} C^T \vec{y}$$

Where $\vec{y} = \begin{bmatrix} y_1 & y_2 & \cdots & y_{M^2} \end{bmatrix}^T$ is the data vector containing the $M \times M$ pixels inside the ***local*** window and C is a $M^2 \times 4$ data matrix whose kth **row** vector is the four nearest neighbors of y_k.

$$\boxed{\vec{\alpha} = (C^T C)^{-1} (C^T \vec{y})}$$

Interpolated Results

Bicubic Edge-directed interpolation

References

- [2] X. Li and M. T. Orchard, “New edge-directed interpolation,” IEEE Trans. On Image Processing, 10(10): 1521-1527, 2001.

Thank You!

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