Training Based Descreening

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Description:

Designed an efficient Descreening Algorithm using Resolution Synthesis techniques to remove the halftone noise from scanned documents without degrading edge detail.

Descreening: Objectives

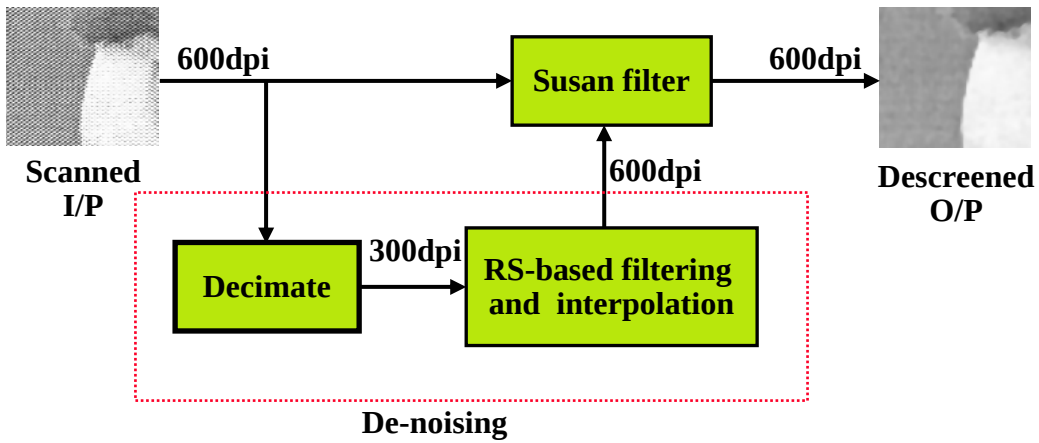
- Motivation
  - High Resolution scanning of printed originals produces screening artifacts in the digital document
  - Moiré patterns tend to appear when scanned image is printed.
- Challenge
  - Design an efficient Descreening Algorithm that removes the halftone noise and moiré without degrading edge detail.
- Proposed Solution
  - Use **Resolution Synthesis (RS)** techniques for descreening.

Printed Original

Scanned Image

Architecture of the Descreening Algorithm

- Use 7x7 MMSE filters for RS-based de-noising and interpolation.
- Apply 7x7 edge preserving Susan filters to the raw scanned image.



Modified Susan Filtering

- Basic Idea:
  - Use only “like” pixels for averaging in the filter window.
  - Preserves edge sharpness
- Implementation:

$y_{m,n}$ = scanned image

$x_{m,n}$ = de-noised image

$z_{m,n}$ = output image

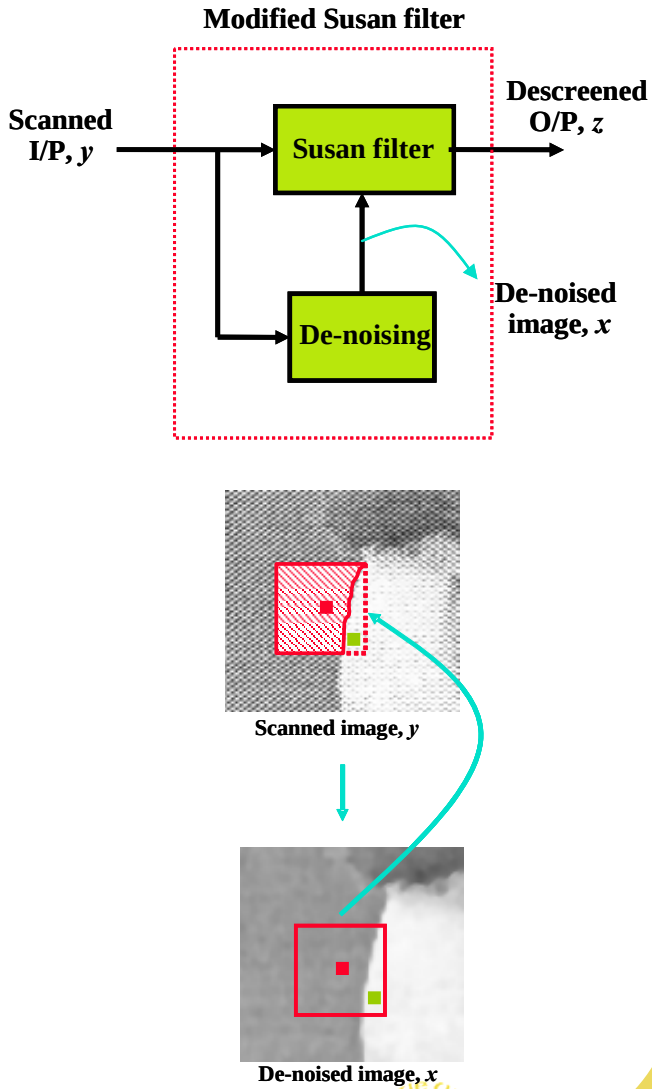
$h_{m,n}$ = NxN gaussian filter

(m_o, n_o) = current pixel

$$g_{m,n,m_o,n_o} = \exp[-(x_{m+m_o,n+n_o} - x_{m_o,n_o})^2 / k], \qquad k=21$$

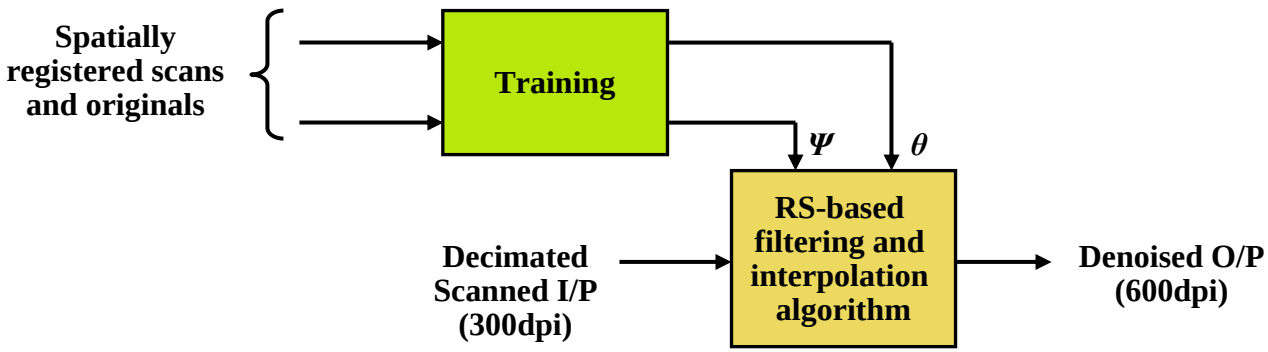
$$c_{m_o,n_o} = \sum_{m=-N}^{N} \sum_{n=-N}^{N} h_{m,n} g_{m,n,m_o,n_o}$$

$$z_{m_o,n_o} = \sum_{m=-N}^{N} \sum_{n=-N}^{N} h_{m,n} g_{m,n,m_o,n_o} y_{m+m_o,n+n_o} \Big/ c_{m_o,n_o}$$



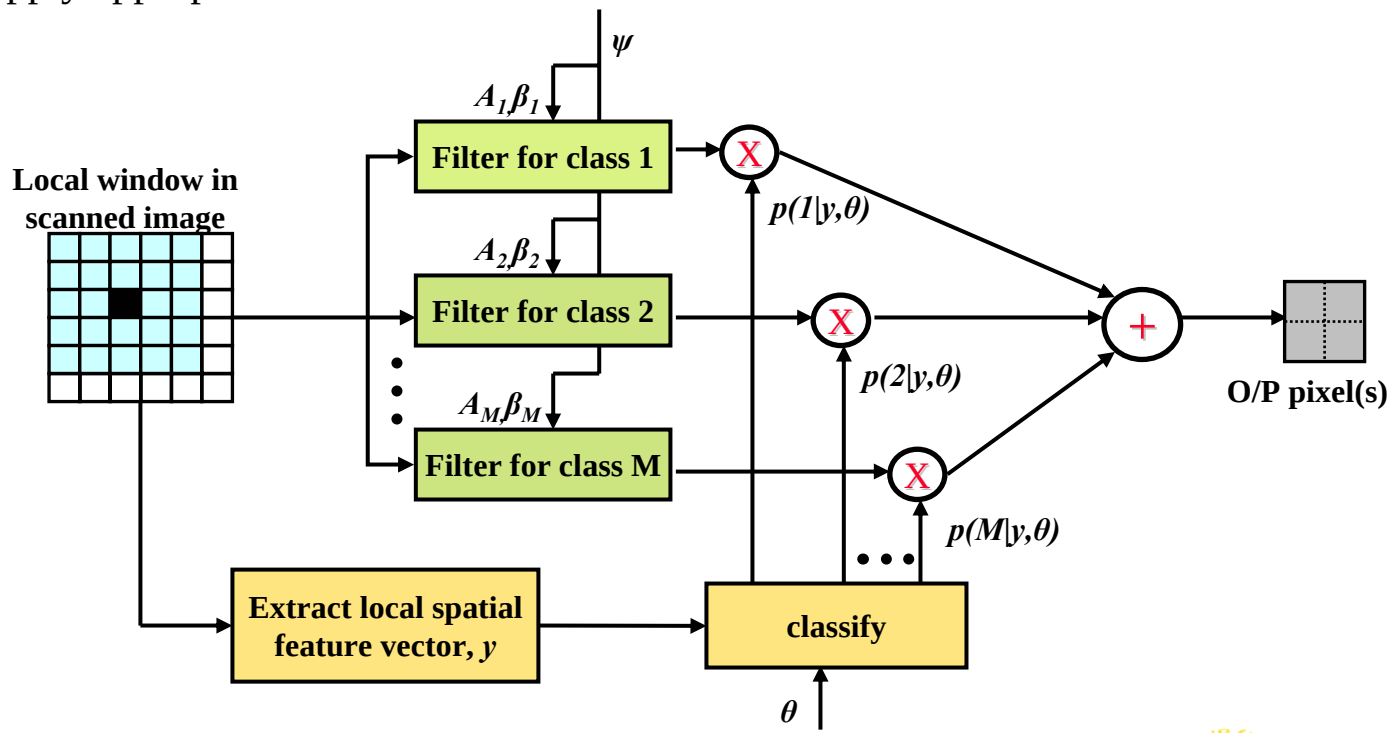
Resolution Synthesis based Filtering and Interpolation

- Resolution Synthesis is training based.
- Training:
  - Use 300dpi scans (Scan Jet 8250)
  - Use spatially registered 600dpi originals
  - Train algorithm to generate classification parameters θ and filters Ψ
- Algorithm
  - Classify pixel based on spatial local feature
  - Apply optimal linear filters Ψ for the selected class θ
  - The filter set Ψ performs both de-noising and interpolation



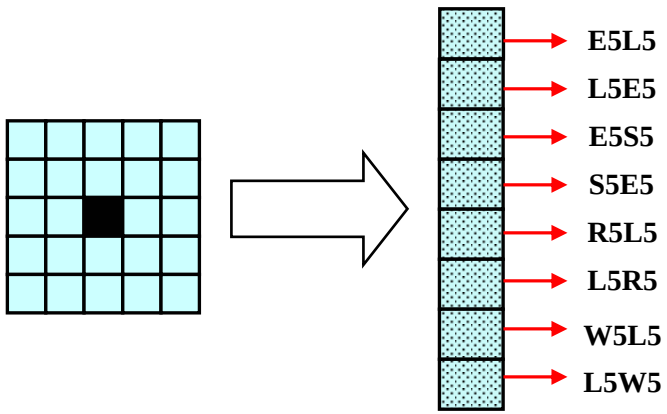
Resolution Synthesis based Filtering and Interpolation Algorithm

- For each input pixel:
  - Extract local spatial feature vector
  - Classify local spatial feature vector
  - Apply appropriate linear filter



Extraction of local feature vector

- Use 5x5 laws texture masks to extract local spatial feature vector
  - 25 possible texture masks
  - Select features that are least sensitive to noise



E5L5

$$\begin{pmatrix} -1 & -4 & -6 & -4 & -1 \\ -2 & -8 & -12 & -8 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 2 & 8 & 12 & 8 & 2 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix}$$

S5L5

$$\begin{pmatrix} 1 & 4 & 6 & 4 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ -2 & -8 & -12 & -8 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix}$$

R5L5

$$\begin{pmatrix} 1 & 4 & 6 & 4 & 1 \\ -4 & -16 & -24 & -16 & -4 \\ 6 & 24 & 36 & 24 & 6 \\ -4 & -16 & -24 & -16 & -4 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix}$$

W5L5

$$\begin{pmatrix} -1 & -4 & -6 & -4 & -1 \\ 2 & 8 & 12 & 8 & 2 \\ 0 & 0 & 0 & 0 & 0 \\ -2 & -8 & -12 & -8 & -2 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix}$$

- L5E5, L5S5, L5R5, L5W5 are the transpose of E5L5, S5L5, R5L5, and W5L5 respectively.

Training Process for Resolution Synthesis based Filtering and Interpolation

- Collection of Training Data:
  - Generate low resolution scans from high resolution originals.
  - Printer: Laser Jet 4050, Scanner: Scan Jet 8250

High Resolution Original

Low Resolution Scan

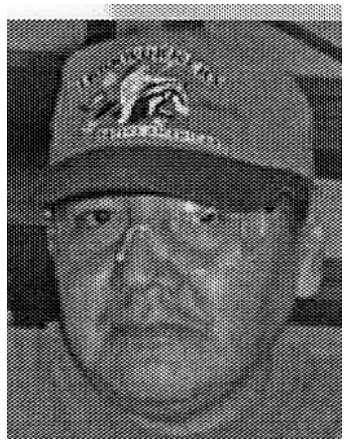
- Image Registration:
  - Register low resolution and high resolution images to **sub-pixel accuracy**!
- Optimize Parameters using Registered Images:
  - Resolution Synthesis: Training phase is implemented using Expectation-Maximization (EM) algorithm

Sub-Pixel Registration Algorithm

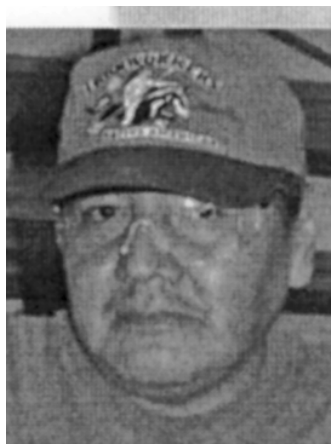
- Purpose:
  - Warp high resolution image to correspond to low resolution pixel coordinates.
- Strategy:
  - Blockwise Affine Transform with Filter (Yeesoo Han).
    - » Separate image into 16x16 block regions to account for spatial variation in warping,
    - » Filter is added to account for sharpness differences.
  - Use Coordinate Descent Algorithm to optimize parameters.
    - » Filter Parameters: Least Square Solution
    - » Spatial Position Parameters: Conjugate Gradient Algorithm

Experimental Results (I)

Original



Scan



Gaussian σ =1.2 (7x7)

RS + Modified Susan Filtering

Experimental Results (II)

Original

Scan

Gaussian σ =1.2 (7x7)

RS + Modified Susan Filtering